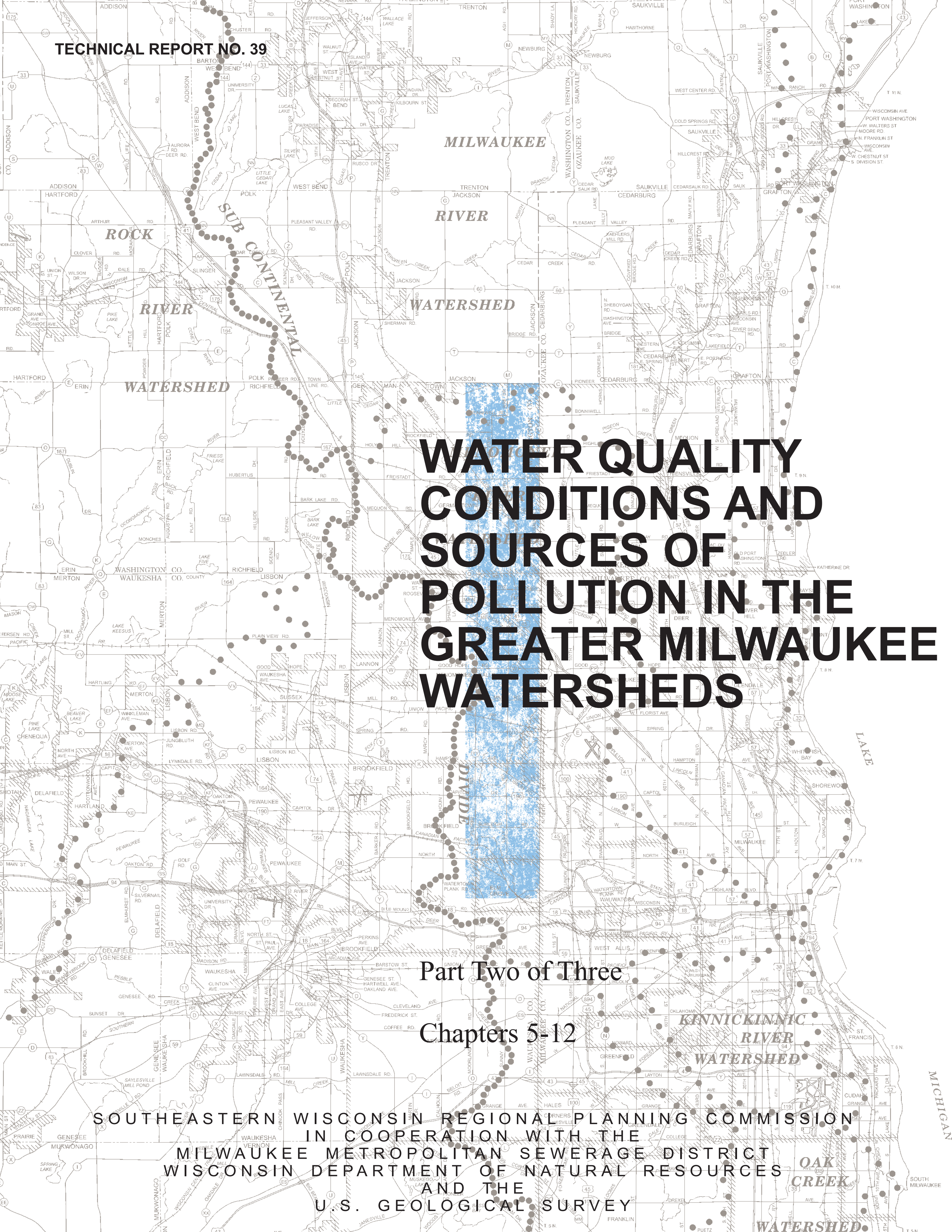
TECHNICAL REPORT NO. 39

WATER QUALITY CONDITIONS AND SOURCES OF POLLUTION IN THE GREATER MILWAUKEE WATERSHEDS

Part Two of Three

Chapters 5-12



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IN COOPERATION WITH THE
MILWAUKEE METROPOLITAN SEWERAGE DISTRICT
WISCONSIN DEPARTMENT OF NATURAL RESOURCES
AND THE
U.S. GEOLOGICAL SURVEY

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Prepared by the

Southeastern Wisconsin Regional Planning Commission
In Cooperation with the
Milwaukee Metropolitan Sewerage District,
Wisconsin Department of Natural Resources,
and the
U.S. Geological Survey

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Chapter V

SURFACE WATER QUALITY CONDITIONS AND SOURCES OF POLLUTION IN THE KINNICKINNIC RIVER WATERSHED

INTRODUCTION AND SETTING WITHIN THE STUDY AREA

A basic premise of the Commission watershed studies is that the human activities within a watershed affect, and are affected by, surface and groundwater quality conditions. This is especially true in the urban and urbanizing areas of the Kinnickinnic River watershed, where the effects of human activities on water quality tend to overshadow natural influences. The hydrologic cycle provides the principal linkage between human activities and the quality of surface and ground waters in that the cycle transports potential pollutants from human activities to the environment and from the environment into the sphere of human activities.

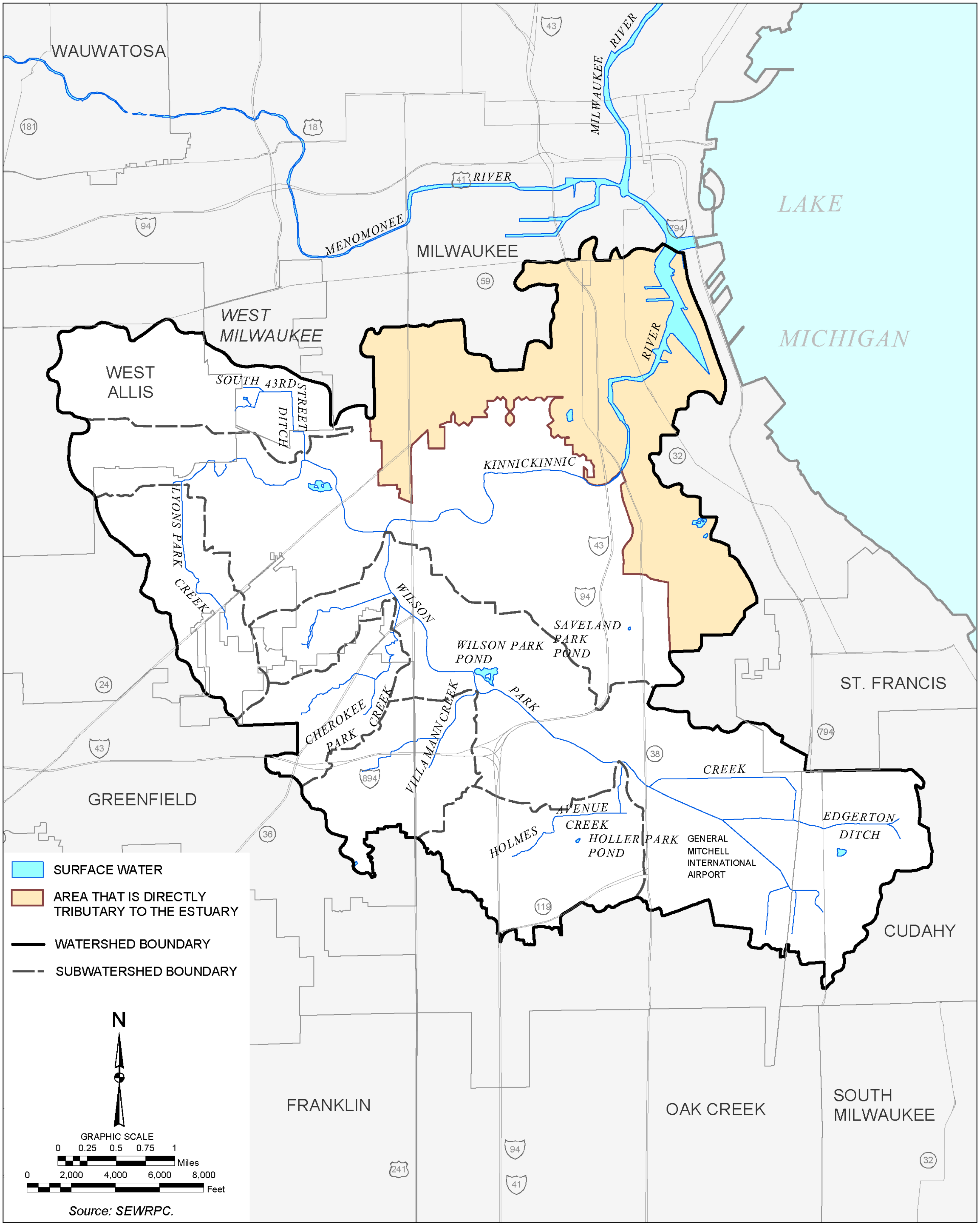
Comprehensive water quality planning efforts such as the regional water quality management plan update, should include an evaluation of historical, present, and anticipated water quality conditions and the relationship of those conditions to existing and probable future land and water uses. The purpose of this chapter is to determine the extent to which surface waters in the Kinnickinnic River watershed have been and are polluted, and to identify the probable causes for, or sources of, that pollution. More specifically, this chapter documents current surface water pollution problems in the watershed utilizing field data from a variety of water quality studies, most of which were conducted during the past 30 years; indicates the location and type of the numerous and varied sources of wastewater, industrial, stormwater runoff, and other potential pollutants discharged to the surface water system of the watershed; describes the characteristics of the discharges from those sources; and, to the extent feasible, quantifies the pollutant contribution of each source. The information presented herein provides an important basis for the development and testing of the alternative water quality control plan elements under the regional water quality management plan update.

DESCRIPTION OF THE WATERSHED

The Kinnickinnic River watershed is located in the east central portion of the Southeastern Wisconsin Region and covers an area of approximately 24 square miles. The Kinnickinnic River originates in central Milwaukee County and flows approximately eight miles in an easterly direction to its confluence with the Milwaukee River. Rivers and streams in the watershed are part of the Lake Michigan drainage system as the watershed lies east of the subcontinental divide. The boundaries of the basin, together with the locations of the main channels of the Kinnickinnic River watershed and its principal tributaries, are shown on Map 13. The Kinnickinnic River watershed contains no lakes with a surface area of 50 acres or more.

Map 13

SURFACE WATER WITHIN THE KINNICKINNIC RIVER WATERSHED: 2000



Source: SEWRPC.

Civil Divisions
Superimposed on the watershed boundary is a pattern of local political boundaries. As shown on Map 14, the watershed lies entirely within Milwaukee County. Six civil divisions lie in part or entirely within the Kinnickinnic River watershed, as also shown on Map 14 and Table 26. Geographic boundaries of the civil divisions are an important factor which must be considered in the regional water quality management plan update since the civil divisions form the basic foundation of the public decision making framework within which intergovernmental, environmental, and developmental problems must be addressed.

LAND USE

This section describes the changes in land use which have occurred within the Kinnickinnic River watershed since 1970, the approximate base year of the initial regional water quality management plan, and indicates the changes in such land uses since 1990, the base year of the initial plan update, as shown in Table 27. Although the watershed is largely urbanized, 7.5 percent of the watershed was still in rural and other open space land uses in 2000. These rural and open space uses included about 5.5 percent of the total area of the watershed in unused and other open lands and about 1 percent in surface water and wetlands.[1] Most of the rural and open spaces remaining in the watershed are located in Milwaukee County near Mitchell International Airport. The remaining approximately 93 percent of the total watershed was devoted to urban uses, as shown on Map 15.

Urban development exists throughout almost all of the Kinnickinnic River watershed. Urban land use in the watershed increased from about 23.3 square miles in 1990 to about 23.5 square miles in 2000, an increase of about 1 percent. As shown in Table 27, residential land represents the largest urban land use in the watershed. Since 1990, most, though not all, of the urban growth in the watershed has occurred in the southern portion of the watershed in the Cities of Cudahy, Greenfield, and Milwaukee. The historic urban growth within the Kinnickinnic River watershed is summarized on Map 16 and Table 28.

The 2020 land use plan discourages scattered, low density urban development.[2] Much of the changes in urban lands within the Kinnickinnic River watershed are due to infill development and redevelopment at compact urban densities.

The changes in land use reflect changes in population and population distribution within the watershed. Several trends are apparent in the data. Over the long term the number of persons living in the watershed has declined. From 1970 through 1990, the population in the watershed decreased by about 23,267, from 172,453 to 149,186; however, during that time period the number of households increased by 3,182, from 56,233 to 59,415. Between 1990 and 2000 the size of the population in the watershed has grown slightly, increasing to 152,137 persons, or an increase of 2,951 persons. During this decade of relatively stable population numbers, the number of households in the watershed remained nearly stable, decreasing by 24 units to 59,391.

QUANTITY OF SURFACE WATER

Since 1975, measurements of discharge have been taken at a number of locations along the Kinnickinnic River and its tributaries. The period of record for most of these stations is rather short, with data collection occurring over periods ranging from about six months to about six years. The station at S. 11th Street has a longer period of record.

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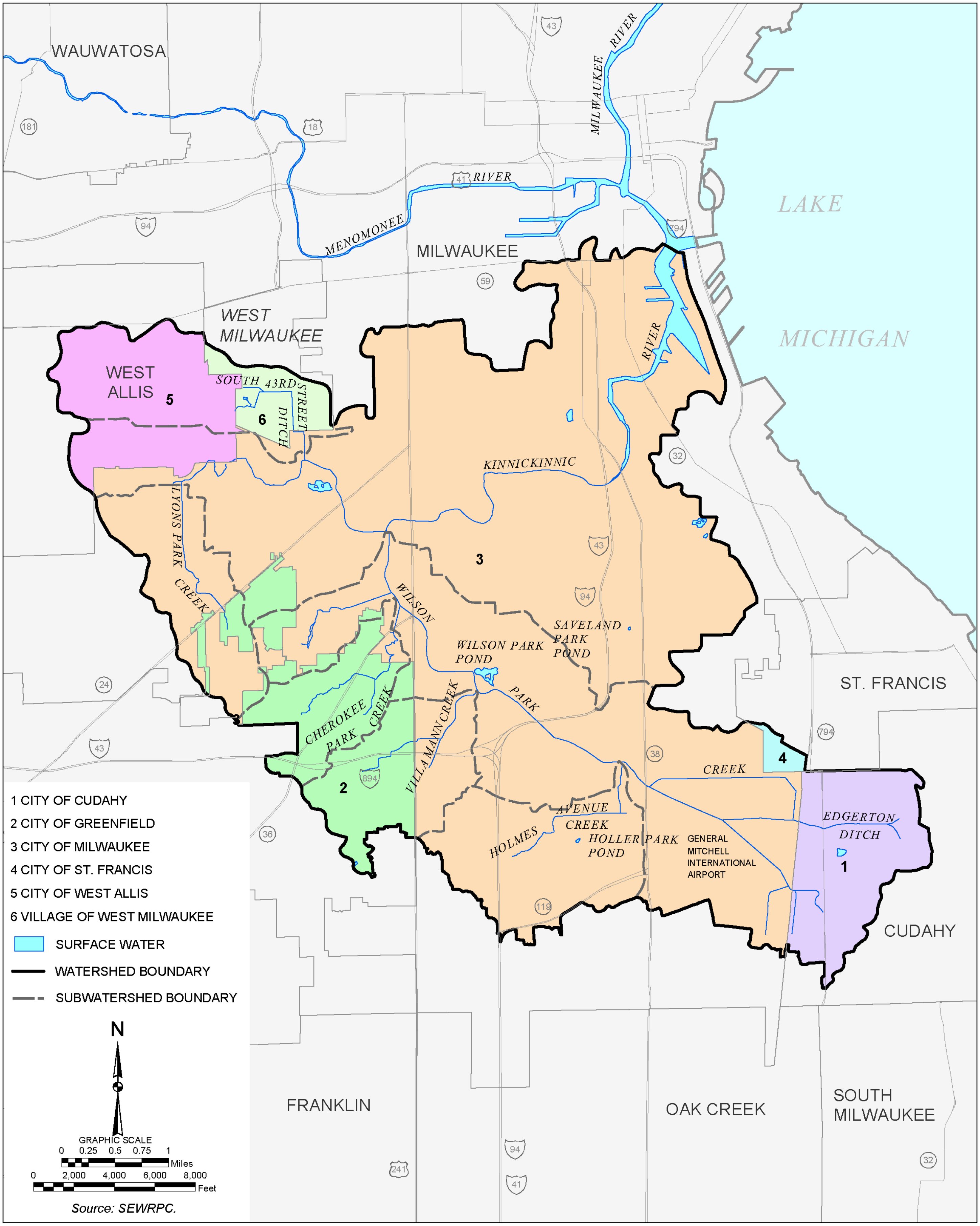
[1]*For inventory purposes and for identifying changes in urban land use over time, unused and other open lands are designated as rural; however, the unused and other open lands in this watershed are predominantly urban in character.*

[2]*SEWRPC Planning Report No. 45,* A Regional Land Use Plan for Southeastern Wisconsin: 2020, *December 1997.*

Map 14

CIVIL DIVISIONS WITHIN THE KINNICKINNIC RIVER WATERSHED: 2000



Source: SEWRPC.

Table 26

AREAL EXTENT OF COUNTIES, CITIES, VILLAGES, AND TOWNS WITHIN THE KINNICKINNIC RIVER WATERSHED

Civil Division	Area (square miles)	Percent of Total
Milwaukee County		
City of Cudahy	1.51	6.18
City of Greenfield	2.22	9.06
City of Milwaukee	18.52	75.50
City of St. Francis	0.11	0.47
City of West Allis	1.67	6.83
Village of West Milwaukee	0.48	1.96
Total	24.51	100.00

Source: SEWRPC.

Table 27

LAND USE IN THE KINNICKINNIC RIVER WATERSHED: 1970-2000[a,b]

Category	1970		1990		2000		Change 1970-2000	
	Square Miles	Percent of Total	Square Miles	Percent of Total	Square Miles	Percent of Total	Square Miles	Percent
Urban								
Residential	8.6	33.9	8.8	34.6	8.8	34.6	0.2	2.3
Commercial	1.1	4.3	1.4	5.5	1.5	5.9	0.4	36.4
Industrial and Extractive	1.8	7.1	1.9	7.5	1.9	7.5	0.1	5.6
Transportation, Communication, and Utilities[c]	7.8	30.7	8.2	32.3	8.3	32.7	0.5	6.4
Governmental and Institutional	2.0	7.9	1.9	7.5	1.9	7.5	-0.1	-5.0
Recreational	1.1	4.3	1.1	4.3	1.1	4.3	0.0	0.0
Subtotal	22.4	88.2	23.3	91.7	23.5	92.5	1.1	4.9
Rural								
Agricultural and Related	0.3	1.1	0.2	0.8	0.1	0.4	-0.2	-66.7
Water	0.2	0.8	0.2	0.8	0.2	0.8	0.0	0.0
Wetlands	0.1	0.4	0.1	0.4	0.1	0.4	0.0	0.0
Woodlands	0.2	0.8	0.1	0.4	0.1	0.4	-0.1	-50.0
Unused and Other Open Lands[d]	2.2	8.7	1.5	5.9	1.4	5.5	-0.8	-36.4
Subtotal	3.0	11.8	2.1	8.3	1.9	7.5	-1.1	-12.1
Total	25.4	100.0	25.4	100.0	25.4	100.0	0.0	- -

[a]*As approximated by whole U.S. Public Land Survey one-quarter sections.*

[b]*As part of the regional land use inventory for the year 2000, the delineation of existing land use was referenced to real property boundary information not available for prior inventories. This change increases the precision of the land use inventory and makes it more usable to public agencies and private interests throughout the Region. As a result of the change, however, year 2000 land use inventory data are not strictly comparable with data from the 1990 and prior inventories. At the county and regional level, the most significant effect of the change is to increase the transportation, communication, and utilities category, the result of the use of narrower estimated right-of-ways in prior inventories. The treatment of streets and highways generally diminishes the area of adjacent land uses traversed by those streets and highways in the 2000 land use inventory relative to prior inventories.*

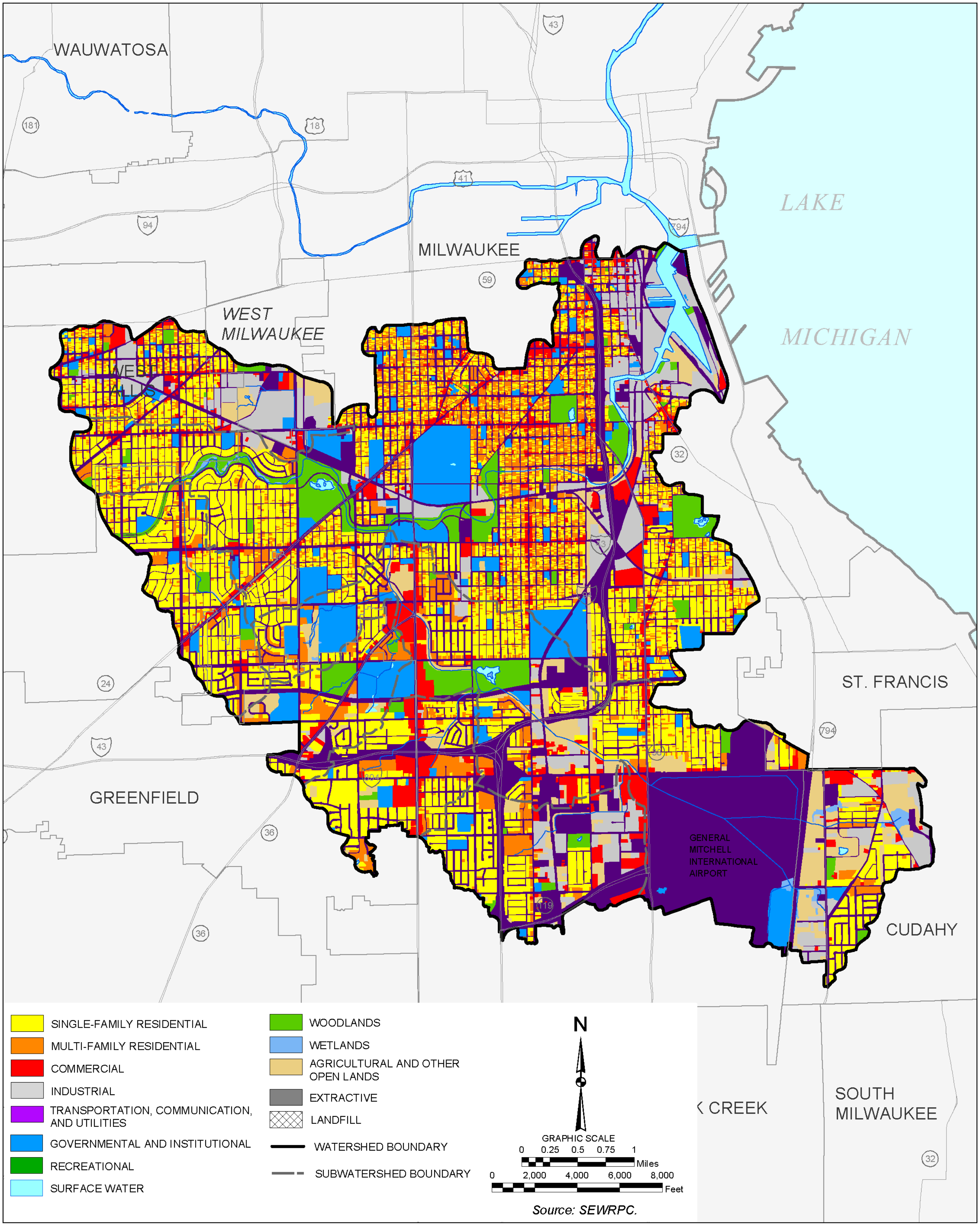
[c]*Off-street parking of more than 10 spaces are included with the associated land use.*

[d]*For inventory purposes and for identifying changes in urban land use over time, this category is designated as rural; however, the unused and other open lands in this watershed are predominantly urban in character.*

Source: SEWRPC.

Map 15

EXISTING LAND USE WITHIN THE KINNICKINNIC RIVER WATERSHED: 2000



Source: SEWRPC.

Map 16

HISTORICAL URBAN GROWTH WITHIN THE KINNICKINNIC RIVER WATERSHED: 1850-2000

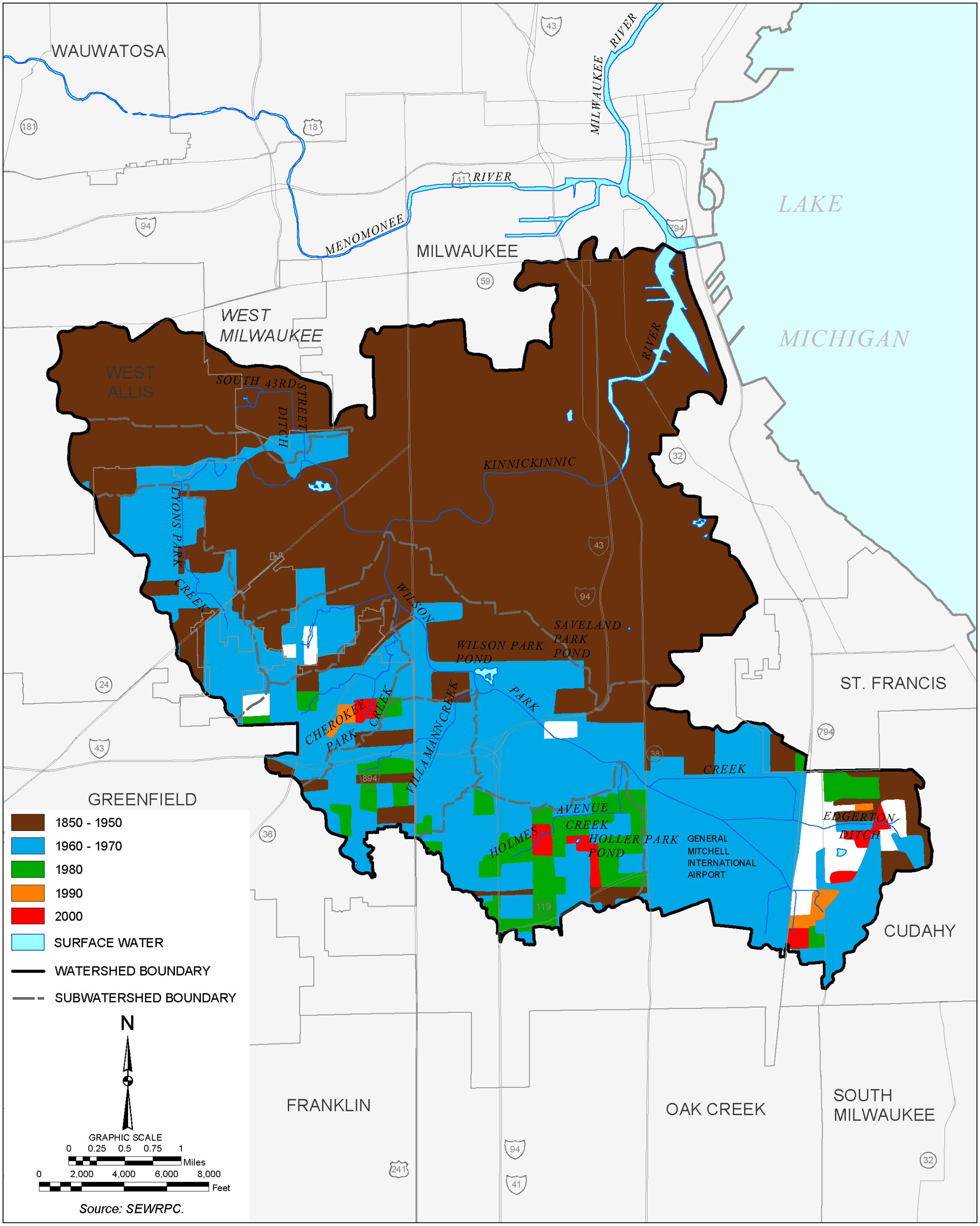


Table 28

EXTENT OF URBAN GROWTH WITHIN THE KINNICKINNIC RIVER WATERSHED: 1850-2000

Year	Extent of New Urban Development Occurring Since Previous Year (acres)[a]	Cumulative Extent of Urban Development (acres)[a]	Cumulative Extent of Urban Development (percent)[a]
1850	567	567	3.6
1880	706	1,273	8.1
1900	667	1,940	12.3
1920	1,311	3,251	20.6
1940	1,775	5,026	31.9
1950	4,215	9,241	58.6
1963	4,292	13,533	85.8
1970	963	14,496	91.9
1975	485	14,981	94.9
1980	210	15,191	96.3
1985	68	15,259	96.7
1990	1	15,260	96.7
1995	31	15,291	96.9
2000	117	15,408	97.6

[a]*Urban development, as defined for the purposes of this discussion, includes those areas within which houses or other buildings have been constructed in relatively compact groups, thereby indicating a concentration of urban land uses. Scattered residential developments were not considered in this analysis.*

Source: U.S. Bureau of the Census and SEWRPC.

Figure 25 shows historical and baseline period discharge for the two stations with long-term records extending into the baseline period. Similar annual patterns are seen in the baseline period mean discharge at both sites. Mean monthly streamflow tends to reach a low point during the winter. The exact timing of this minimum appears to depend on the location of the station in the watershed: It occurs earlier at the upstream stations. Mean monthly discharge rises from this low point to a peak in April associated with spring snowmelt and rains. It then declines slightly through the spring and summer. Following this, it declines more rapidly through the autumn to the winter minimum. Considerable variability is associated with these patterns, but some of this variability is more likely attributed to sampling conditions rather than actual changes in discharge.

For the most part, stream flow from the baseline period is within historical ranges at the S. 11th Street station on the Kinnickinnic River. The ranges of baseline period discharge exceed those of historical discharge at the St. Luke's Hospital station on Wilson Park Creek. This is due to the limited amount of historical discharge data available for this site.

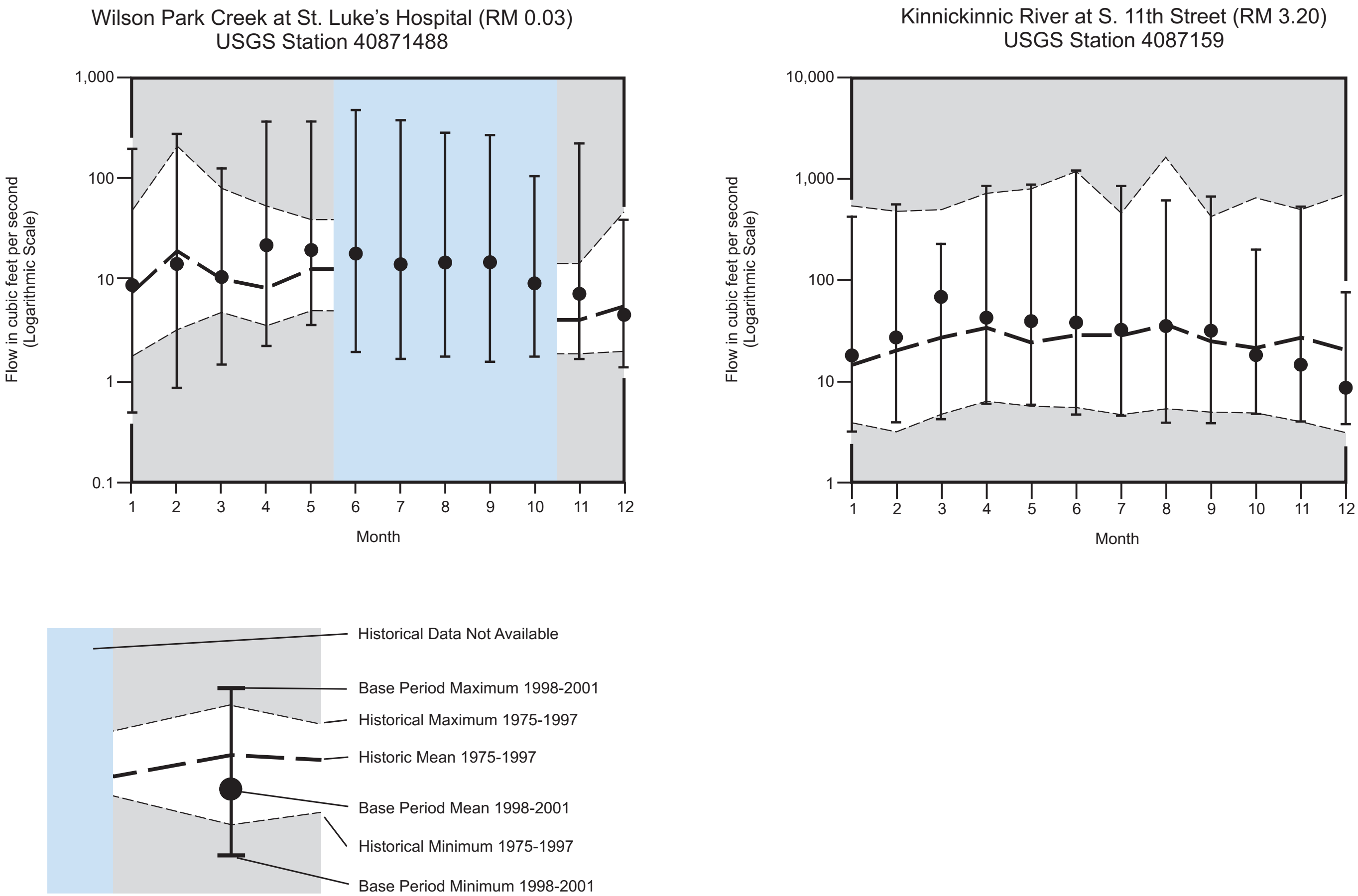
Flow fractions were calculated for all stations relative to the discharge at the S. 11th Street station using the procedure described in Chapter III of this report. These are shown on Map 17. Several generalizations emerge from this analysis:

- The magnitude of average discharge increases rapidly in the headwaters of the River. For example, average discharge roughly doubles between the stations at S. 6th Street and St. Luke's Hospital on Wilson Park Creek. Much of the increase in discharge represents contributions of water from Villa Mann Creek, Cherokee Park Creek, and an unnamed creek that enters Wilson Park Creek downstream from Cherokee Park Creek.

- Much of the discharge at downstream stations can be accounted for by discharge from stations upstream and from tributaries entering the River upstream. For instance, median discharge from the Kinnickinnic River upstream from the confluence with Wilson Park Creek, including contributions from Lyons Park Creek and the S. 43rd Street Ditch represents about 30 percent of the median discharge at S. 11th Street. Similarly, median discharge from Wilson Park Creek represents about 61 percent of median discharge at S. 11th Street. Villa Mann Creek; the sum of discharge from Cherokee Park Creek and the unnamed creek that enters Wilson Park Creek downstream from Cherokee Park Creek; and the sum of the discharge from Edgerton Ditch, Holmes Avenue Creek, and the conduit under General Mitchell International Airport represent 15, 13, and 27 percent of the discharge at S. 11th Street respectively. The remainder of the median discharge is contributed by direct runoff and direct baseflow to the Kinnickinnic River mainstem and runoff and baseflow from smaller tributaries.

Figure 25

HISTORICAL AND BASE PERIOD FLOW AT LONG-TERM STATIONS IN THE KINNICKINNIC RIVER WATERSHED: 1975-2001



Source: U.S. Geological Survey and SEWRPC.

SURFACE WATER QUALITY OF THE KINNICKINNIC RIVER WATERSHED: 1975-2001

The earliest systematic collection of water quality data in the Kinnickinnic River watershed occurred in the mid-1960s.[3] Data collection after that was sporadic until the 1970s. Since then, considerable data have been collected, especially on the mainstem of the River. The major sources of data include the Milwaukee Metropolitan Sewerage District (MMSD), the Wisconsin Department of Natural Resources (WDNR), the U.S. Geological Survey (USGS), and the U.S. Environmental Protection Agency's (EPA) STORET legacy and modern databases (see Map 18). In addition, Commission staff reviewed data collected by citizen monitoring programs including the Testing the Waters Program. These data are presented in Appendix B. The largest portion of data was collected by MMSD. Most of these data were obtained from sampling stations along the mainstem of the River. In addition, sufficient data were available for Wilson Park Creek to assess baseline period water quality for several water quality parameters. The data record for the other tributary streams in the watershed is fragmentary.

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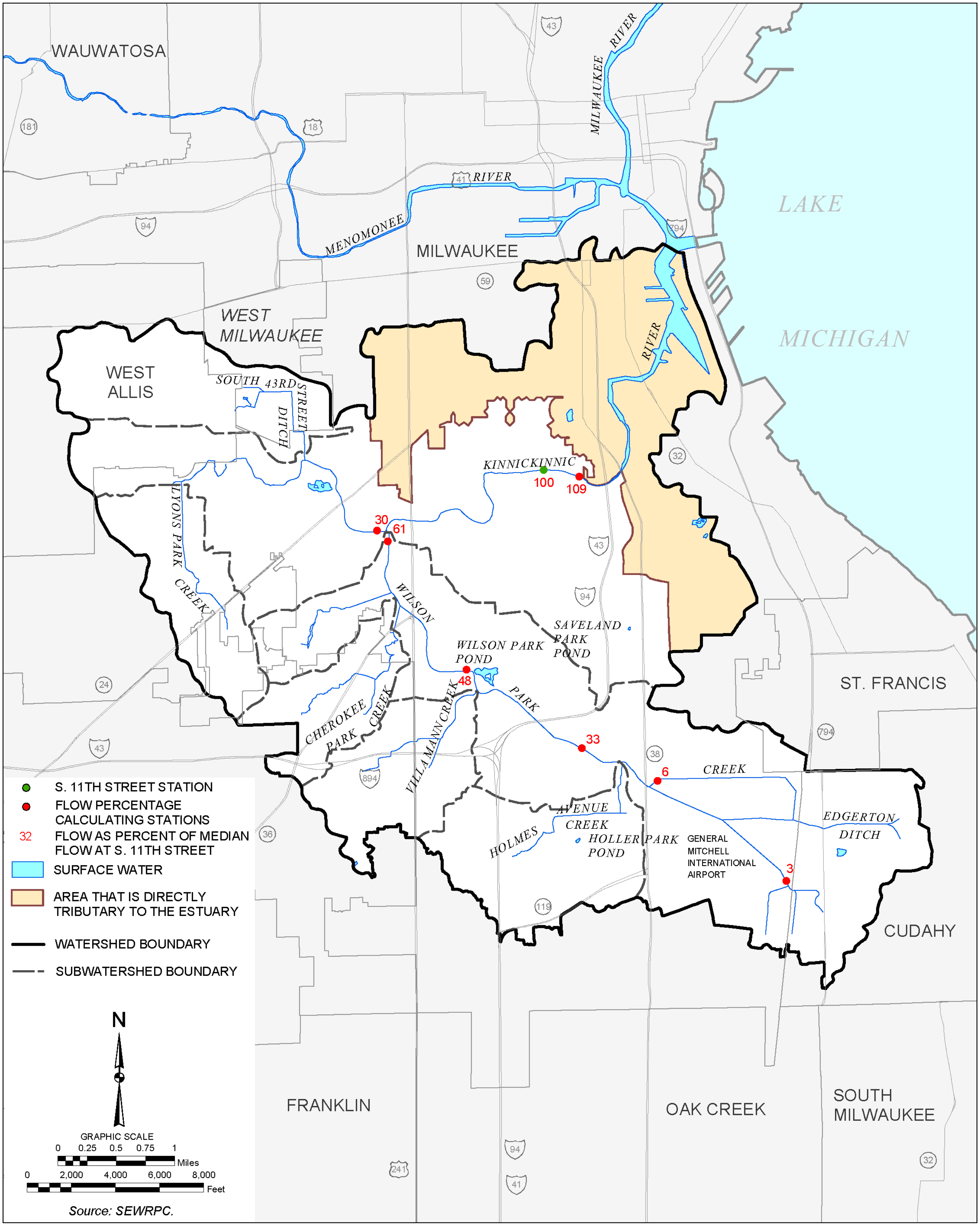
[3]*SEWRPC Technical Report No. 4,* Water Quality and Flow of Streams in Southeastern Wisconsin*, April 1964.*

Map 17

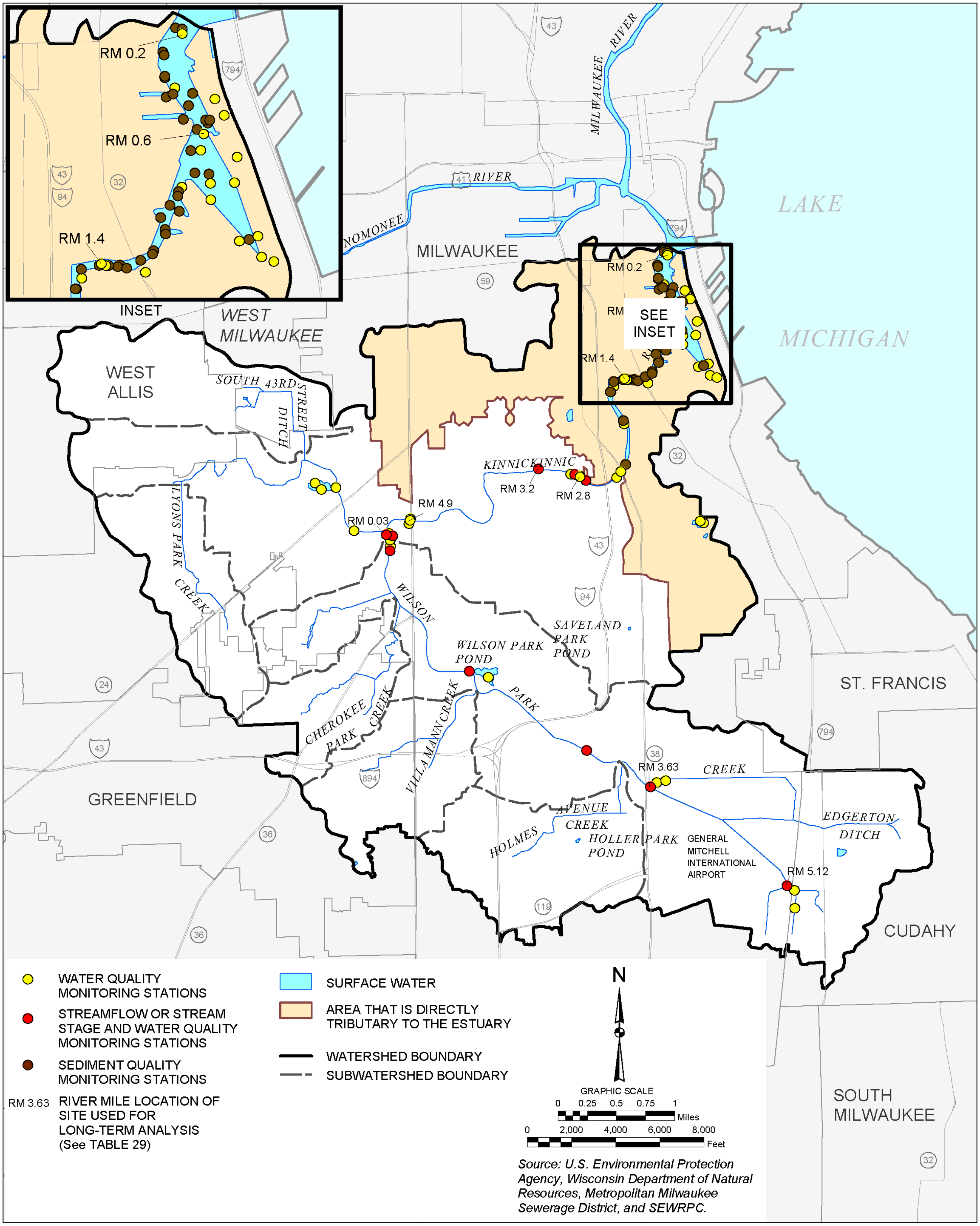
FLOW PERCENTAGES AMONG STATIONS WITHIN THE KINNICKINNIC RIVER WATERSHED: 2000



Source: SEWRPC.

Map 18

WATER AND SEDIMENT QUALITY MONITORING STATIONS WITHIN THE KINNICKINNIC RIVER WATERSHED: 1975-2001



For analytical purposes, data from four time periods were examined: 1975-1986, 1987-1993, 1994-1997, and 1998-2001. Continuous bimonthly data records exist from one of MMSD's long-term monitoring stations beginning in 1975. After 1986, MMSD no longer conducted sampling during the winter months. In 1994, the Inline Storage System, or Deep Tunnel, came online. The remaining period from 1998-2001 defines the baseline water quality conditions of the river system, developed since the Inline Storage System came online.

Under this plan update, baseline water quality conditions were graphically compared to historical conditions on a monthly basis. As shown in the sample graph presented in Figure 23 of Chapter III of this report, for each water quality parameter examined, the background of the graph summarizes the historical conditions. The white area in the graphs shows the range of values observed during the period 1975-1997. The upper and lower boundaries between the white and gray areas show historical maxima and minima, respectively. A blue background indicates months for which no historical data were available. The dashed black line plots the monthly mean value of the parameter for the historical period. Overlaid on this background is a summary of baseline conditions from the period 1998-2001. The black dots show the monthly mean value of the parameter for that period. The black bars show the monthly ranges of parameter for the same period.

In addition to this summarization, water quality parameters from the Kinnickinnic River were examined for the presence of several different types of trends: differences between the average values of parameters from sampling stations located in upstream areas and the average values of parameters from sampling stations located in the Milwaukee River Estuary, changes at individual sampling stations over time, and seasonal changes throughout the year. There was not a sufficient number of long-term sampling stations outside of the estuary to assess changes along the length of the River. Map 18 and Table 29 show the five sampling stations, designated by their River Mile locations, which had sufficiently long periods of sampling to be used for this analysis. All of the sampling stations along the mainstem of the Kinnickinnic River are located at, or downstream from, combined sanitary sewer overflow outfalls. Figures 26 and 27 show photos of selected river sampling stations within the Wilson Park Creek and Kinnickinnic River, respectively. Trends were examined along a section of the Kinnickinnic River from the confluence with the Milwaukee River to a station 4.9 miles upstream. Changes over time were assessed both on an annual and on a seasonal basis as set forth in Appendix C. It is important to note that only limited data were available to assess baseline water quality conditions for tributary streams.

Bacterial and Biological Parameters

Bacteria

As shown in Figure 28, median concentrations of fecal coliform bacteria in the Kinnickinnic River ranged from about 200 to 2,300 cells per 100 milliliters (ml). Fecal coliform counts in the River varied over six orders of magnitude, ranging from as low as one cell per 100 ml to over one million cells per 100 ml. The range of variability appears to be higher during the summer and fall as shown in Figure 29, although it is important to note that this may reflect the larger numbers of samples that were taken during the summer and fall than during the spring and winter. Counts in most samples exceed the standard for full recreational use of 200 cells per 100 ml. In addition, the fecal coliform counts in many samples exceed the standard of 1,000 cells per 100 ml applied by the variance covering the Kinnickinnic River. Table 30 shows that during all periods examined, the mean concentrations of fecal coliform bacteria in the section of the River upstream of the estuary were significantly higher than the mean concentrations of fecal coliform bacteria in the estuary. This suggests that water in the upstream section of the River was receiving more contamination from sources containing these bacteria than water in the estuary. Several factors could account for this difference. First, water in the upstream section of the River may be receiving more contamination from sources containing these bacteria than water in the estuary. Second, larger water volumes coupled with settling of cells might reduce fecal coliform bacteria concentrations in the estuary. By contrast, lower flows coupled with less settling might maintain higher concentrations in the upstream section of the River. Third, dilution effects from the influence of Lake Michigan might act to reduce fecal coliform bacteria concentrations in the estuary. Fourth, in the upstream portion of the River, scour occurring during periods of increased flow could act to resuspend bacteria that had previously settled. During the period 1998-2001, fecal coliform counts at the sampling station at S. 1st Street continued to decline. At the other long-term stations, fecal coliform counts increased. The comparison of baseline period fecal coliform concentrations to

Table 29

SAMPLE SITES USED FOR ANALYSIS OF WATER QUALITY TRENDS IN THE KINNICKINNIC RIVER WATERSHED

Location	River Mile[a]	Position	Period of Record
Tributaries			
Wilson Park Creek Outfall at General Mitchell International Airport	5.12	Upstream	1996-2001
Wilson Park Creek Infall at General Mitchell International Airport near Grange Avenue	3.63	Upstream	1996-2001
Wilson Park Creek at St. Luke's Hospital	0.03	Upstream	1996-2001
Mainstem			
Kinnickinnic River at S. 27th Street	4.9	Upstream	1981-2001
Kinnickinnic River at S. 11th Street	3.2	Upstream	1983-2001
Kinnickinnic River at S. 7th Street	2.8	Upstream	1975-2001
Kinnickinnic River at S. 1st Street	1.4	Estuary	1980-2001
Kinnickinnic River at Greenfield Avenue (extended)	0.6	Estuary	1982-2001
Kinnickinnic River at the Jones Island Ferry	0.2	Estuary	1982-2001

[a]River Mile designations for Wilson Park Creek are measured as distance upstream from the confluence with the Kinnickinnic River. River Mile designations for the Kinnickinnic River are measured as distance upstream from the confluence with the Milwaukee River. The river mile locations corresponding to these samplings sites are shown on Map 18.

Source: SEWRPC.

historical concentrations shown in Figure 29 reveals two additional changes: First, in the estuary mean fecal coliform concentrations during the baseline period were lower than the historical mean concentrations. Analysis of variance shows that this difference is statistically significant. This difference was not seen at the stations upstream of the estuary. Second, at all stations, the minimum concentrations of fecal coliform bacteria detected were consistently lower during the baseline period than during the historical period. This change was seen throughout the year.

As shown in Table C-1 in Appendix C, time-based trends in fecal coliform bacteria concentrations were detected in the Kinnickinnic River. When analyzed on an annual basis, all long-term sampling sites except for one show statistically significant declines in fecal coliform concentrations. No statistically significant trends in fecal coliform bacterial concentrations were detected at the S. 27th Street station. Analysis of these trends by season suggests that the changes have occurred mostly during the spring and fall and have occurred at all estuary sites. At most sites along the River, fecal coliform concentrations tend to be positively correlated with concentrations of both biochemical oxygen demand and total phosphorus. In addition, positive correlations are seen at some sites with concentrations of dissolved phosphorus and inorganic nitrogen compounds. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the River.

The declines in mean fecal coliform concentrations in the estuary, the decreasing trend in fecal coliform concentrations, and the lower minimum fecal coliform concentrations observed at all stations represent improvements in water quality in the Kinnickinnic River.

Regular sampling for *E. coli* in the Kinnickinnic River began at three long-term sampling stations along the mainstem in 2000. During the years 2001 and 2002, the counts ranged from 0.5 cells per 100 ml to 160,000 cells per 100 ml. Statistical analysis detected no differences between the averages of counts at stations in the estuary and the averages of counts at stations upstream from the estuary. Mean concentrations of *E. coli* decrease from upstream to downstream, though it is important to note that no data are available from the stations in the lower estuary and that there are not sufficient data to assess trends through regression analysis. The data are insufficient for assessing whether there are seasonal patterns to the numbers of these bacteria in the River (see Table C-1 in Appendix C of this report).

Figure 26

SAMPLING STATION LOCATIONS IN WILSON PARK CREEK: 2003

WILSON PARK CREEK JUST DOWNSTREAM OF RIVER MILE 3.63 AND THE CONFLUENCE WITH HOLMES AVENUE CREEK

WILSON PARK CREEK AT APPROXIMATELY 1,300 FEET UPSTREAM OF RIVER MILE 0.03

Source: Milwaukee County and Inter-Fluve, Inc.

*Chlorophyll-*a

Over the period of record, the mean concentration of chlorophyll-*a* in the Kinnickinnic River was 8.64 micrograms per liter (μg/l). Individual samples of this parameter ranged from 0.065 μg/l to 358.5 μg/l. In addition, each station had samples with concentrations in excess of 70 μg/l. The results of statistical analyses given in Table 30 show that the relationship between mean concentrations of chlorophyll-*a* between the estuary and the reaches upstream from the estuary is dynamic and has changed over time. Since 1998, the mean concentrations of chlorophyll-*a* in the estuary have been significantly lower than those in the reaches upstream from the estuary. Figure 30 shows that chlorophyll-*a* concentrations at stations in the estuary have declined since 1994. As shown in Table C-1 in Appendix C of this report, this represents a statistically significant declining trend. This change occurred at roughly the time when the Inline Storage System came online and may reflect reductions of nutrient inputs related to the reduction in the number of combined sewer overflows. In contrast to the estuary, few significant time-based trends were detected in chlorophyll-*a* at sampling stations upstream of the estuary (see Table C-1 in Appendix C of this report). At stations in the estuary, chlorophyll-*a* concentrations are moderately positively correlated with water temperatures. Since chlorophyll-*a* in the water strongly reflects algal productivity, this probably reflects the higher growth rates that photosynthetic organisms are able to attain at higher temperature. At some stations, chlorophyll-*a* concentrations are negatively correlated with concentrations of ammonia, nitrate, and dissolved phosphorus. This reflects the role of these compounds as nutrients for algal growth. As algae grow, they remove these compounds from the water and incorporate them into cellular material. The decrease in chlorophyll-*a* concentrations in the estuary represent an improvement in water quality.

Chemical and Physical Parameters

Temperature

As shown in Figure 31, the annual median water temperature in the Kinnickinnic River during the period 1998-2001 ranged from 18.9 degrees Celsius (ºC) at the sampling station at S. 27th Street up to 20.3ºC at the station at S. 7th Street and down to 15.3ºC at the station at the Jones Island Ferry. The lower water temperatures in the estuary may result from the effects of complex mixing regime involving water from the Kinnickinnic River, the Milwaukee River, and the Milwaukee Harbor. Figure 32 shows that while water temperatures from the baseline period tend to be within historical ranges, monthly mean baseline period water temperatures tend to be higher than historical monthly means.

Due to the complexity of these temperature trends, they were further analyzed using a three-factor analysis of variance. This type of analysis tests for statistically significant differences among mean temperatures based upon three different factors which may account for any differences. In addition, it tests for significant effects on mean temperatures of any interactions between the factors. In this instance, the independent factors examined were sampling station, the time periods 1982-1986, 1987-1993, 1994-1997, and 1998-2001, and season. Data from winter months were not included in this analysis because of the small number of samples taken during the winter. The results of this analysis suggest that the estuary and the section of the River upstream from the estuary experience different water temperature regimes. Annual mean water temperatures at the stations upstream from the estuary are four to five degrees Celsius higher than annual mean water temperature at the stations in the estuary. The difference in mean temperatures between estuary and upstream stations are less pronounced in the fall than in the spring or summer. Since the period 1982-1986, mean temperatures in the River have increased.

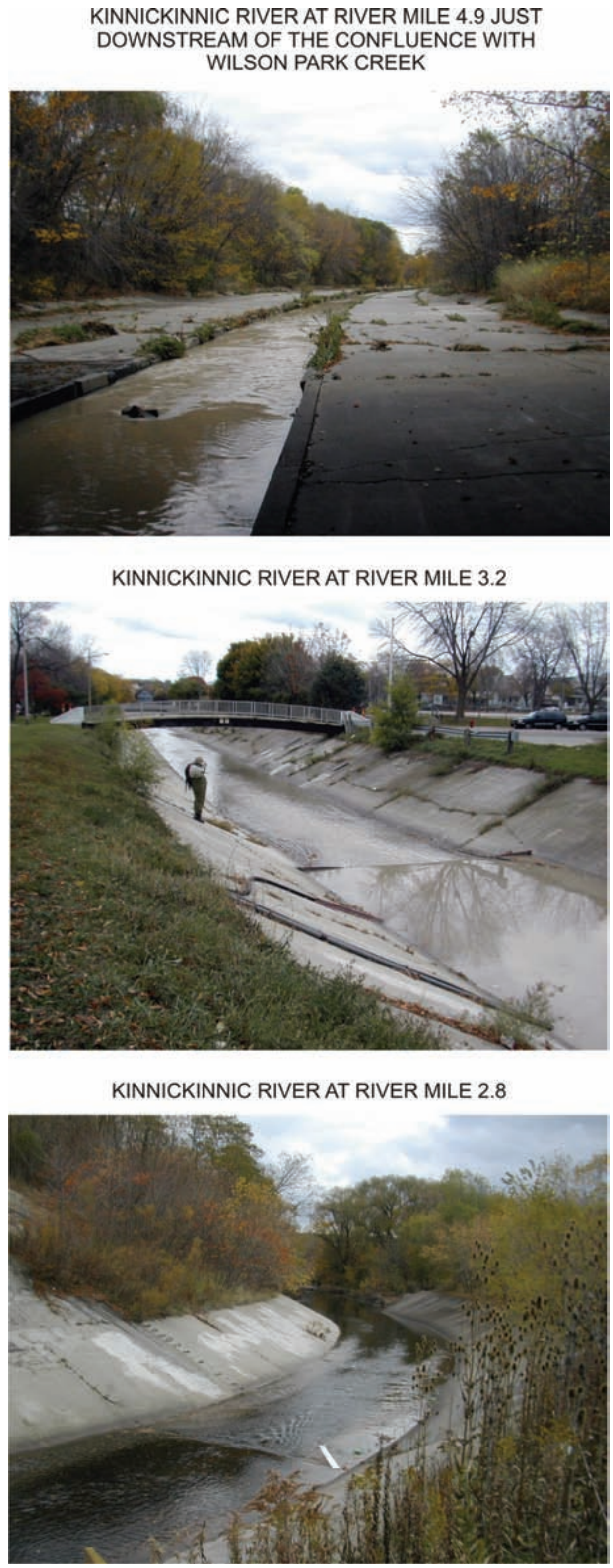
On an annual basis, the data show slight trends toward increasing water temperature at two stations in the estuary, the Jones Island Ferry and Greenfield Avenue (extended) stations. Seasonally, the River exhibits a more complicated pattern of time-based trends. During the spring, the data show slight trends toward increasing water temperature at both stations in the reach upstream from the estuary as well as at the farthest upstream estuary station. During the summer slight increasing trends were detected at all stations in the estuary. During the fall slight increasing trends were detected at the Jones Island Ferry and Greenfield Avenue (extended) stations in the downstream reach of the estuary.

Alkalinity

The mean value of alkalinity in the Kinnickinnic River over the period of record was 176.3 milligrams per liter expressed as the equivalent concentration of calcium carbonate (mg/l as $CaCO_3$). The data show moderate variability, ranging from 11 to 989 mg/l. The analyses in Table 30 show that alkalinity was higher in the section of the river upstream of the estuary than in the estuary in all periods. Few stations showed any evidence of significant changes annually or among seasons, but where there were significant trends, they indicated increasing concentrations (see

Figure 27

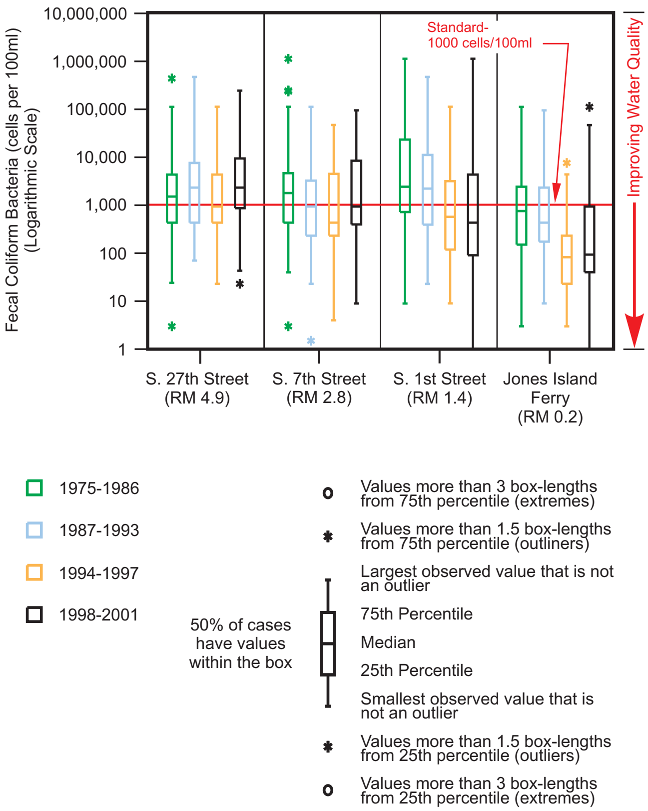
SAMPLING STATION LOCATIONS ALONG THE KINNICKINNIC RIVER: 2003



Source: Milwaukee County and Inter-Fluve, Inc.

Figure 28

FECAL COLIFORM BACTERIA CONCENTRATIONS ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



Source: *U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

Table C-1 in Appendix C). These differences and trends may reflect changes in the relative importance of groundwater and surface runoff on the chemistry of water in the River from upstream to downstream with surface runoff becoming increasingly influential downstream. Alkalinity concentrations in the Kinnickinnic River are strongly positively correlated with hardness, specific conductance, and concentrations of chloride, all parameters which, like alkalinity, measure amounts of dissolved material in water. It is important to note that like hardness, specific conductance, and pH, alkalinity concentrations are greatly influenced by Lake Michigan water dilution in the estuary which probably causes these concentrations to be lower than in the upstream areas.

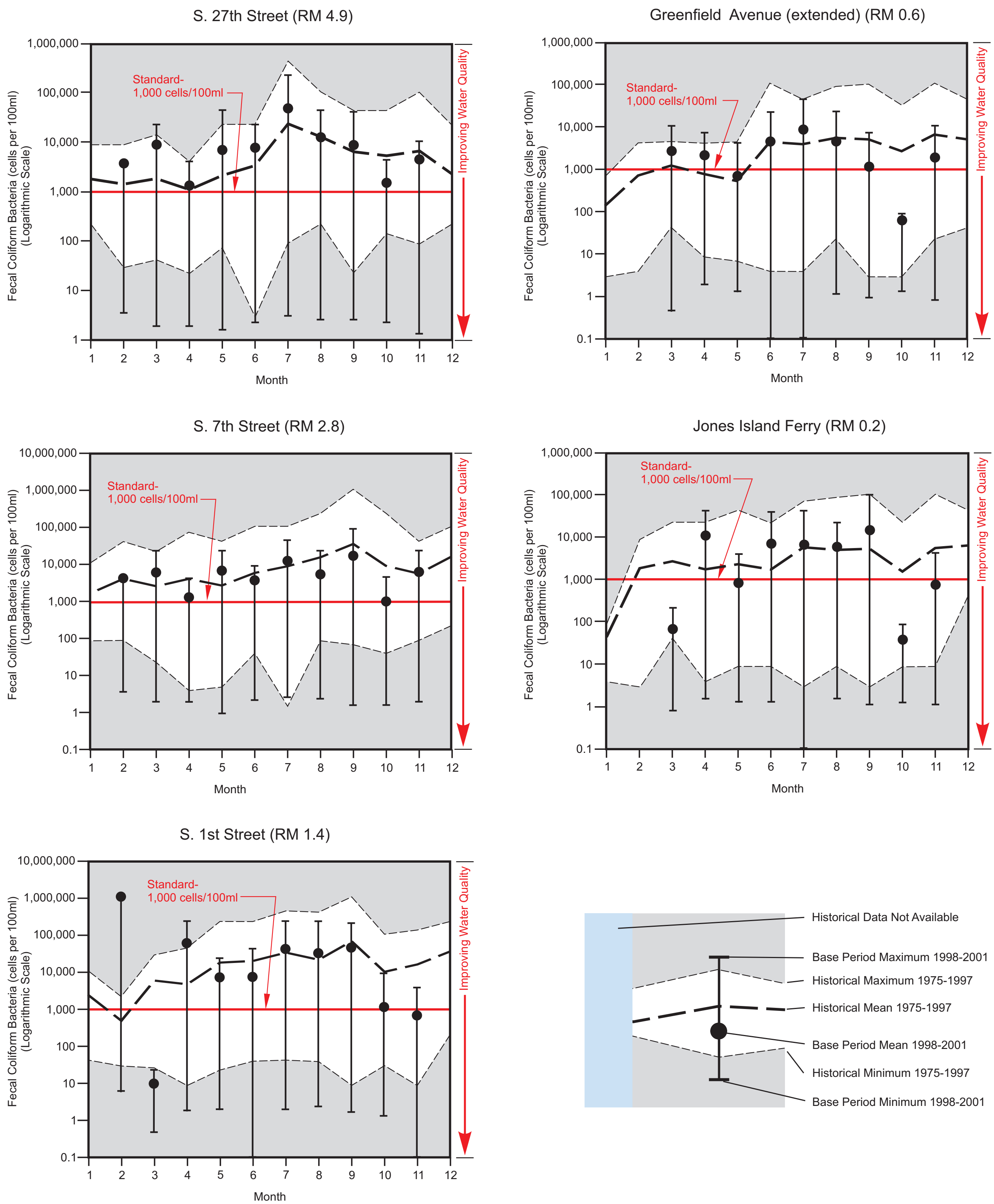
Biochemical Oxygen Demand (BOD)

The mean concentration of BOD in the Kinnickinnic River during the period of record was 3.37 milligrams per liter (mg/l). Individual samples varied from below the limit of detection to 76.5 mg/l. As shown in Figure 33, the concentrations of BOD declined after 1994 at most sampling stations along the River. Figure 34 shows a monthly comparison of baseline and historical concentrations of BOD at two sites along the River, Greenfield Avenue (extended) in the estuary and S. 27th Street in the section of the River upstream from the estuary. At Greenfield Avenue, baseline monthly mean concentrations of BOD are generally below the historical monthly mean concentrations and often near historical minimum concentrations. At S. 27th Street, baseline monthly mean BOD concentrations during the spring and early summer are near historical monthly mean concentrations. In the late summer and fall, baseline period monthly mean BOD concentrations at this station are below historical monthly mean concentrations. At all stations, baseline period minimum monthly mean concentrations are often below the historical monthly minimum concentrations and are often near or below the limit of detection. Similar relationships between baseline and historical concentrations of BOD are seen at the other three long-term sampling stations. All stations show significant declining trends in BOD concentration over time (see Table C-1 in Appendix C of this report). Given that all the sampling stations on the mainstem of the Kinnickinnic River are within the combined sewer overflow area, this suggests that the decline in BOD is being caused, at least in part, by reductions of inputs from combined sewer overflows effected by the operation of the Inline Storage System.

During all periods, the mean value of BOD at stations in the estuary was significantly lower than the mean value of BOD at the stations upstream from the estuary. This indicates that the water in the estuary contained a lower concentration of organic material. Given that all the sampling stations on the mainstem of the Kinnickinnic River are within the combined sewer overflow area, this suggests that considerable organic material in the water is metabolized, oxidized, or settled to the sediment prior to reaching the downstream portions of the estuary. The sharp decrease in dissolved oxygen concentrations between the S. 7th Street and S. 1st Street stations and the decrease in mean BOD concentration from upstream to downstream support this.

Figure 29

HISTORICAL AND BASE PERIOD FECAL COLIFORM BACTERIA CONCENTRATIONS ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Table 30

COMPARISON OF WATER QUALITY BETWEEN THE KINNICKINNIC RIVER AND THE MILWAUKEE RIVER ESTUARY: 1975-2001[a]

Parameters	Years			
	1975-1986[b]	1987-1993[b]	1994-1997[b]	1998-2001[b]
Biological/Bacteria				
Fecal Coliform[c]	River	River	River	River
E. coli [c]	- -	- -	- -	0
Chlorophyll-*a*[c]	0	Estuary	0	River
Chemical/Physical				
Alkalinity	River	River	River	River
Biochemical Oxygen Demand[c]	River	River	River	River
Dissolved Oxygen	River	River	River	River
Hardness	River	River	River	River
pH	River	River	River	River
Specific Conductance	River	River	River	River
Suspended Material				
Total Suspended Solids	River	River	River	River
Nutrients				
Ammonia, Dissolved[c]	Estuary	Estuary	Estuary	Estuary
Kjeldahl Nitrogen[c]	Estuary	Estuary	0	Estuary
Nitrate, Dissolved[c]	Estuary	Estuary	Estuary	Estuary
Nitrite, Dissolved[c]	Estuary	Estuary	River	0
Organic Nitrogen[c]	0	0	River	0
Phosphorus, Dissolved[c]	Estuary	Estuary	0	River
Total Nitrogen[c]	Estuary	Estuary	0	Estuary
Total Phosphorus[c]	0	0	River	River
Metals/Salts				
Arsenic[c]	- -	- -	0	0
Cadmium[c]	Estuary	Estuary	0	0
Chloride[c]	River	River	River	River
Chromium[c]	Estuary	Estuary	0	0
Copper[c]	0	0	0	0
Lead[c]	Estuary	0	Estuary	Estuary
Mercury[c]	- -	- -	0	Estuary
Nickel[c]	- -	0	0	0
Zinc[c]	River	River	River	River

NOTE: The following symbols were used:

"River" indicates that the mean value from the upstream section of the River is statistically significantly higher than the mean value from the estuary.

"Estuary" indicates that the mean value from the upstream section of the River is statistically significantly lower than the mean value from the estuary.

0 indicates that no differences were detected.

- - indicates that the data were insufficient for the analysis.

[a]*The estuary sites used in this analysis were located within the Kinnickinnic River portion of the Milwaukee Harbor estuary.*

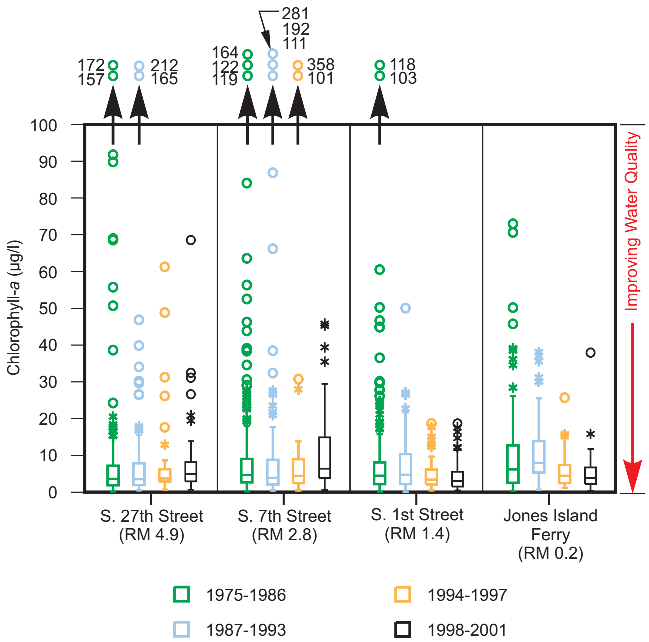
[b]*Differences between means were assessed through analysis of variance (ANOVA). Means were considered significantly different at a probability of P = 0.05 or less.*

[c]*These data were log-transformed before being entered into ANOVA.*

Source: SEWRPC.

Figure 30

CHLOROPHYLL-*a* CONCENTRATIONS ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001

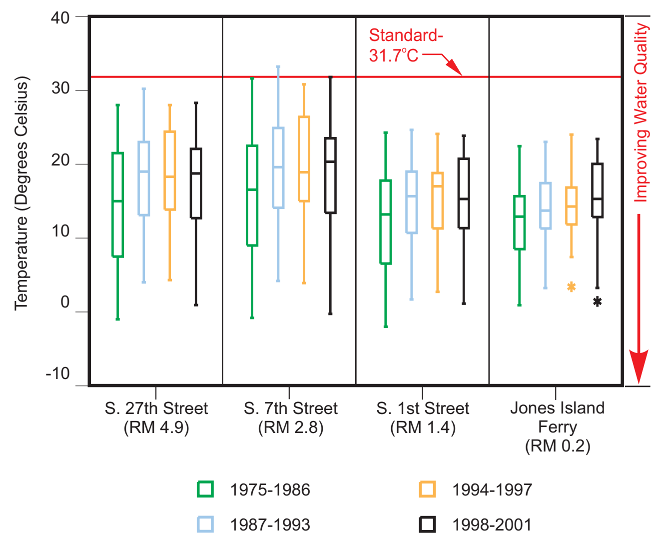


NOTE: See Figure 28 for description of symbols.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 31

WATER TEMPERATURE AT SITES ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



NOTE: See Figure 28 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

As shown on Map 18 and in Figure 35, data for BOD were also available for the years 1996-2001 from three stations along Wilson Park Creek: one station along a tributary near an infall where the tributary enters conduit at General Mitchell International Airport (GMIA), one station along the same tributary at an outfall at GMIA where the tributary leaves conduit, and a third station at St. Luke's Hospital just upstream of the confluence of Wilson Park Creek with the Kinnickinnic River. Figure 35 shows BOD concentrations for these sites. During both the historical and baseline periods BOD concentrations were both high and highly variable at all stations. Mean BOD concentrations were lowest at the GMIA infall station, very high at the GMIA outfall station, and lower but still elevated at the St. Luke's Hospital Station. Analysis of variance shows that mean concentrations of BOD at the GMIA outfall and St. Luke's stations during the period 1998-2001 were significantly lower than mean concentrations during the period 1996-1997. No differences were detected at the GMIA infall station. Deicing compounds used at General Mitchell International Airport represent a major source of BOD to Wilson Park Creek. Ethylene glycol and propylene glycol, two compounds commonly used in airport deicing operations, were often detected in water from the stations at the GMIA outfall and St. Luke's Hospital in sampling conducted during 1999-2000 (see below). While these compounds are known to create high oxygen demands in waters, studies conducted for GMIA found little correlation between glycol deicer usage and periods of dissolved oxygen depletion.[4] The frequency of low dissolved oxygen concentrations in the receiving stream was found to be

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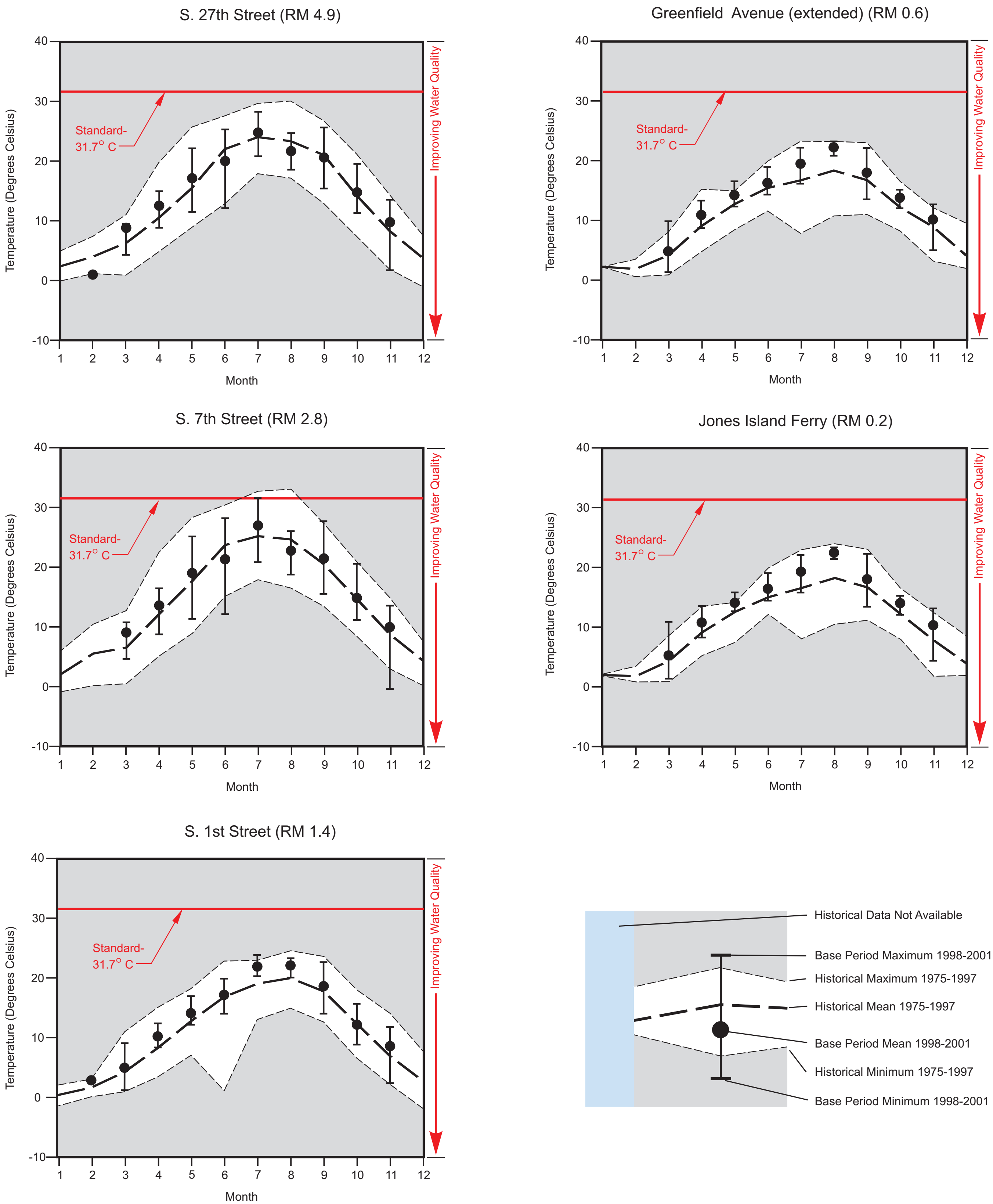
[4]*Camp Dresser & McKee,* Impact of Aircraft Glycol Deicers on the Kinnickinnic River Watershed: Phase II, *February 1998; S.R. Corsi, N.L. Booth, and D.W. Hall, "Aircraft and Runway Deicers at General Mitchell International Airport, Milwaukee, Wisconsin, USA. 1. Biochemical Oxygen Demand and Dissolved Oxygen in Receiving Streams,"* Environmental Toxicology and Chemistry, *Volume 20, 2001.*

Figure 32

HISTORICAL AND BASE PERIOD WATER TEMPERATURE ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

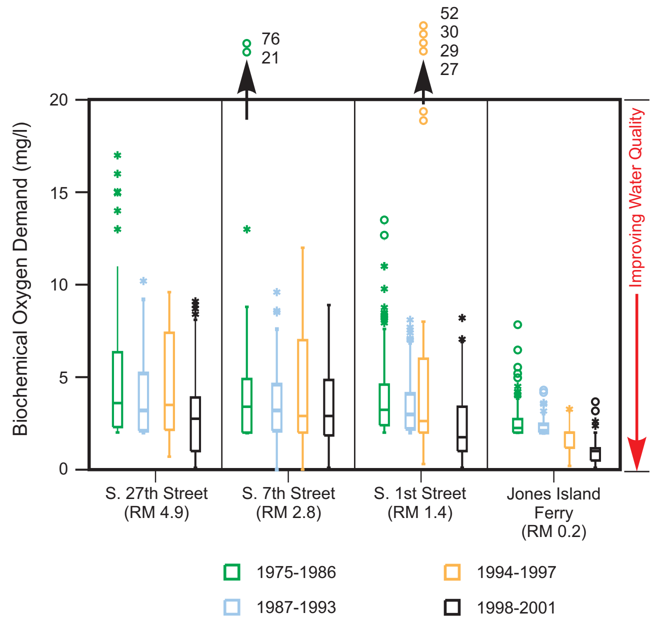
comparable to that at an upstream reference site. This may be due to slowed bacterial metabolism at low water temperatures, short travel times, and dilution from downstream tributaries.[5]

Several other factors may influence BOD concentrations in the Kinnickinnic River. BOD concentrations in the River are positively correlated at most stations with concentrations of fecal coliform bacteria and some nutrients such as ammonia and organic nitrogen. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the River. In some parts of the River, decomposition of organic material in the sediment act as a source of BOD to the overlying water.

The declining trend in BOD concentrations over time detected at stations along the mainstem of the River represent an improvement in water quality.

Figure 33

BIOCHEMICAL OXYGEN DEMAND AT SITES ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



NOTE: See Figure 28 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Chloride

The mean chloride concentration in the Kinnickinnic River for the period of record was 99.0 mg/l. All sites show wide variations between minimum and maximum values. Figure 36 shows that the mean concentrations of chloride in the River dropped at all stations except the Jones Island Ferry station between the periods 1975-1986 and 1987-1993. Following 1993, the mean concentration of chloride at all stations increased. In the period 1998-2001 mean chloride concentration increased at all of the stations in the estuary except for the station at S. 1st Street. At this station and the stations in the section of the River upstream of the estuary, mean chloride concentration decreased. It is important to note, that at all stations except the station at S. 1st Street, mean chloride concentrations during the period 1998-2001 were between 34 percent and 50 percent higher than they were during the period 1975-1986. At the S. 1st Street station, mean chloride concentrations during the period 1998-2001 were similar to mean chloride concentrations during the period 1998-2001.

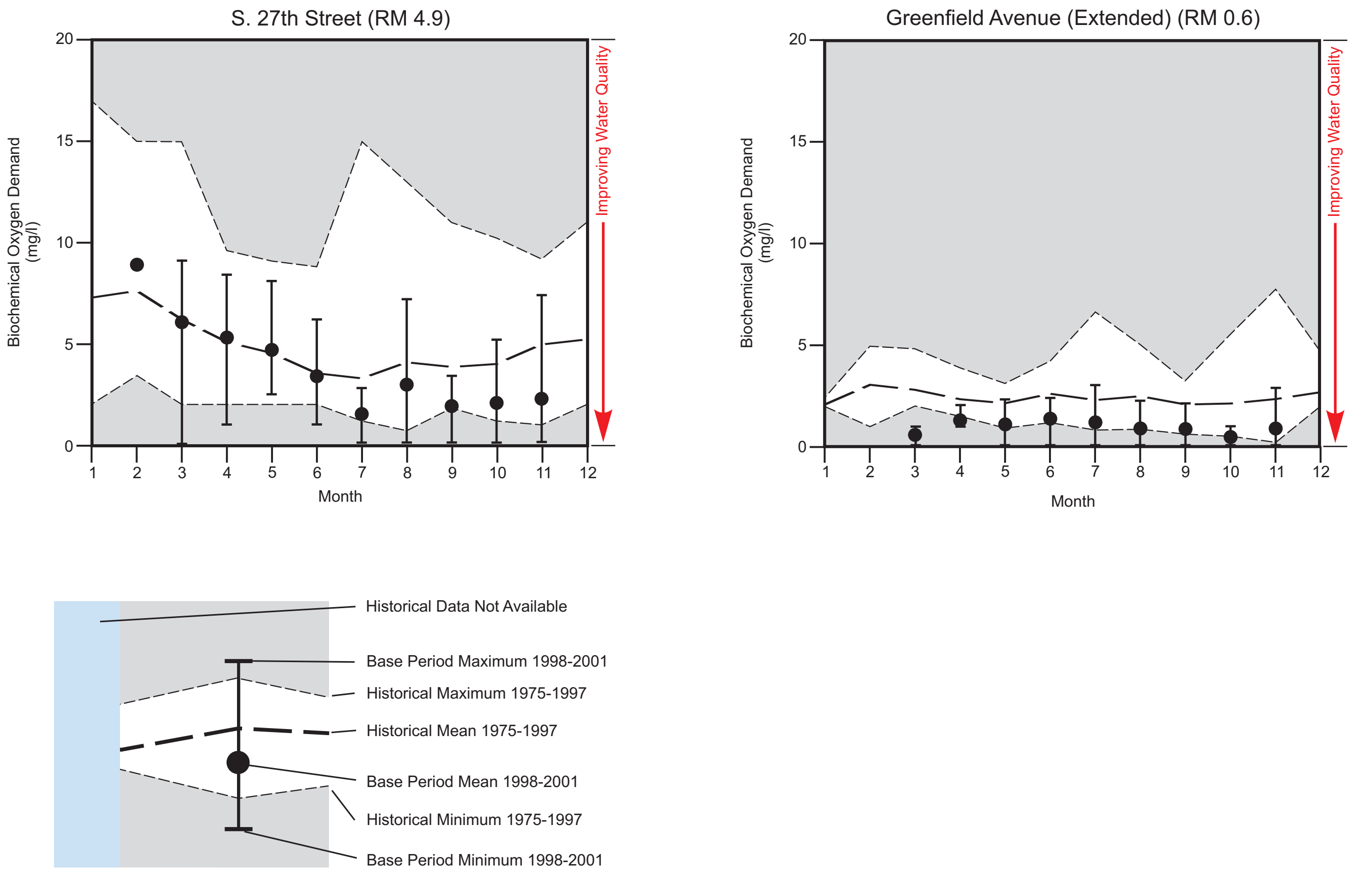
Table C-1 in Appendix C of this report shows that mean chloride concentrations in the River have been increasing over time. On an annual basis, statistically significant increases have been detected at all the sampling stations along the mainstem of the River. Chloride concentrations show a strong seasonal pattern. For the period during which winter data are available, mean chloride concentrations were highest in winter or early spring. This is likely to be related to the use of deicing salts on streets and highways. These concentrations declined through the spring to reach lows during summer and fall.

While observed instream chloride concentrations in the Kinnickinnic River were generally still less than the planning standard of 1,000 milligrams per liter (mg/l) that was adopted under the original regional water quality management plan, they occasionally approached that standard. Observed instream concentrations more frequently

[5]*S.R. Corsi, N.L. Booth, and D.W. Hall,* op. cit.

Figure 34

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF BIOCHEMICAL OXYGEN DEMAND ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

exceeded the 250 mg/l secondary drinking water standard.[6] Instream concentrations occasionally exceeded the chronic toxicity criterion of 395 mg/l or the acute toxicity criterion of 757 mg/l as set forth in Chapter NR 105, "Surface Water Quality Criteria and Secondary Values for Toxic Substances," of the *Wisconsin Administrative Code*.

Chloride concentrations in the Kinnickinnic River show strong positive correlations with alkalinity, hardness, and specific conductance, all parameters which, like chloride, measure amounts of dissolved material in water. In addition, chloride concentrations in the Kinnickinnic River are strongly negatively correlated with temperature, reflecting the use of deicing salts on streets and highways during cold weather. The increase in chloride concentrations in the Kinnickinnic River represents a decline in water quality.

Dissolved Oxygen

Over the period of record, the mean concentration of dissolved oxygen in the Kinnickinnic River was 9.4 mg/l. The data ranged from concentrations that were undetectable to concentrations in excess of saturation. As shown in

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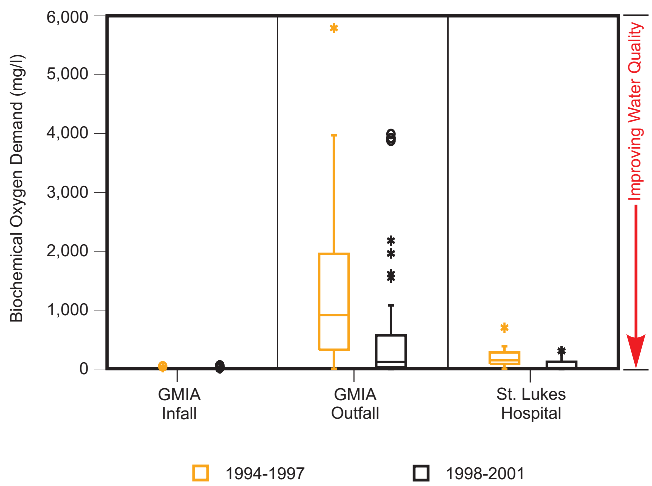
[6]*Section 809.60 of Chapter NR 809, "Safe Drinking Water," of the* Wisconsin Administrative Code, *establishes a secondary standard for chloride of 250 mg/l and notes that, while that concentration is not considered hazardous to health, it may be objectionable to an appreciable number of persons.*

Figure 35

BIOCHEMICAL OXYGEN DEMAND (BOD) AT SITES ALONG WILSON PARK CREEK: 1994-2001

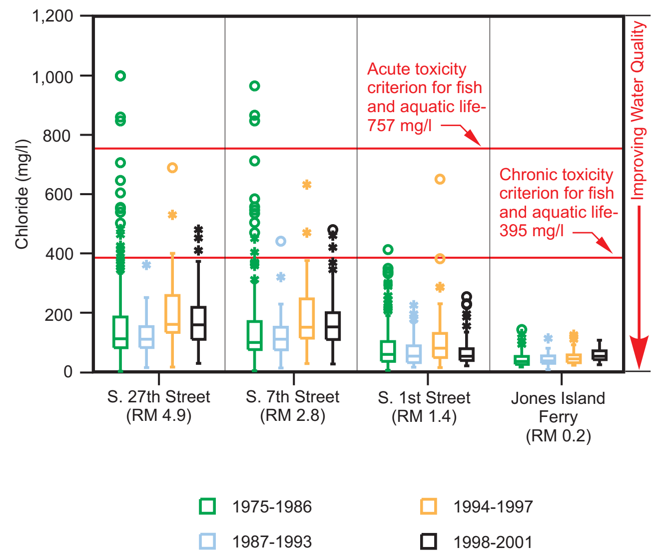


NOTE: See Figure 28 for description of symbols.

Source: U.S. Geological Survey and SEWRPC.

Figure 36

CHLORIDE CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



NOTE: See Figure 28 for description of symbols.

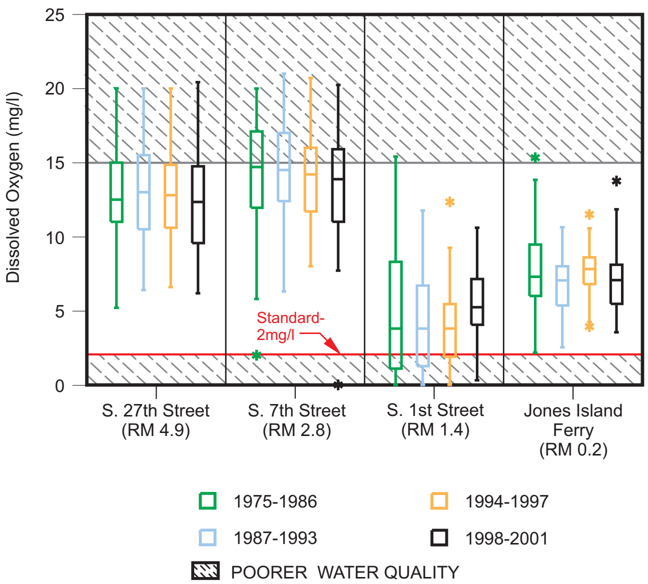
Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 37, this variability is present at individual sample sites. Mean dissolved oxygen concentrations in the estuary are significantly lower than mean concentrations in the section of the River upstream from the estuary (Table 30). In the estuary, dissolved oxygen concentrations are lowest at the S. 1st Street station and increase to slightly higher levels downstream. In the section of the River upstream from the estuary, dissolved oxygen concentrations have declined slightly over time. The pattern in the estuary is more complex. At the station at S. 1st Street, dissolved oxygen concentrations declined slightly until 1998. After 1998, they increased. These changes were accompanied by a reduction in variability. Dissolved oxygen concentrations at the other two stations in the estuary, Greenfield Avenue (extended) and the Jones Island Ferry, declined during the period 1987-1993. Because dissolved oxygen concentration is greatly affected by water temperature, and the data prior to 1987 include samples taken during winter, this change may be more reflective of a change in methodology than any change in the concentration of dissolved oxygen in the River. Dissolved oxygen concentration increased during the period 1994-1997, and declined during the period 1998-2001. Variability did not decrease at these stations. It is important to note that, for the most part, these changes over time were not statistically significant. Statistical analysis detected few time-based trends in dissolved oxygen concentration (see Table C-1 in Appendix C of this report).

Figure 38 compares monthly baseline period concentrations of dissolved oxygen to historical concentrations. At the Jones Island Ferry in the downstream portion of the estuary, baseline period monthly mean dissolved oxygen concentrations are near or below historical monthly mean concentrations. The lowest concentrations detected at this station during the base period tend to be higher than the historical minima. A different pattern is seen at the station at S. 1st Street in the upstream portion of the estuary. Baseline period monthly mean dissolved oxygen concentrations are generally near or above historical means; however, monthly minimum dissolved oxygen concentrations during the baseline period approach historical minima, especially during the summer. At the station at S. 7th Street, in the section of the River upstream from the estuary, baseline period monthly mean dissolved oxygen concentrations are generally below historical mean concentrations, except during the fall. The minimum concentrations of dissolved oxygen are within the historical range.

Figure 37

DISSOLVED OXYGEN CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



NOTES: See Figure 28 for description of symbols.

140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

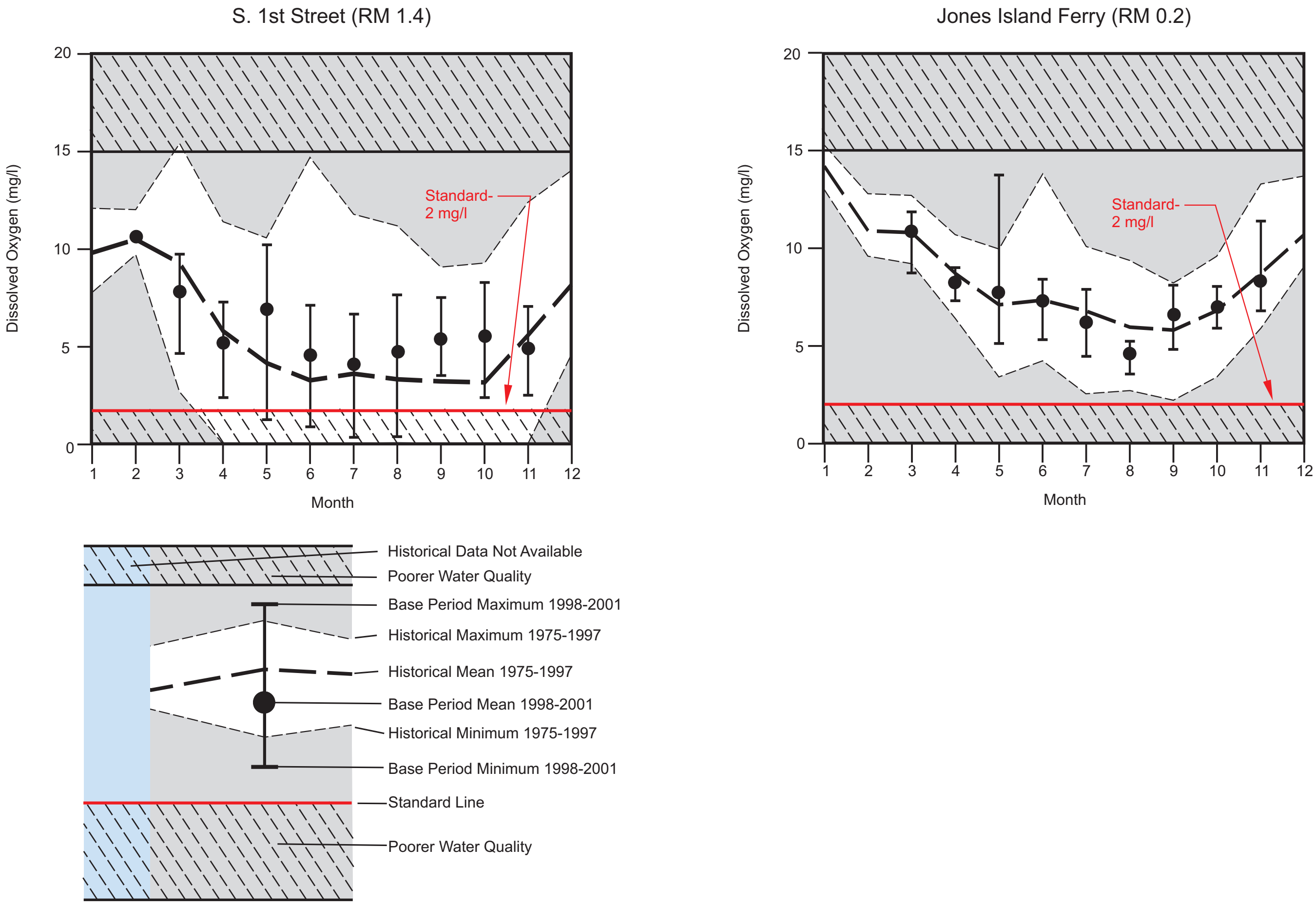
The data show strong seasonal patterns to the mean concentrations of dissolved oxygen (Figure 38). The mean concentration of dissolved oxygen is highest during the winter. It declines through spring to reach a minimum during the summer. It then rises though the fall to reach maximum values in winter. This seasonal pattern is driven by changes in water temperature. The solubility of oxygen in water decreases with increasing temperature. In addition, the metabolic demands and oxygen requirements of most aquatic organisms, including bacteria, tend to increase with increasing temperature. Higher rates of bacterial decomposition when the water is warm may contribute to the declines in the concentration of dissolved oxygen observed during the summer. In addition to the reasons mentioned above, dissolved oxygen concentrations can also be affected by a variety of other factors including the presence of aquatic plants, sunlight, turbulence in the water, and the amount and type of sediment as summarized in the Water Quality Indicators section in Chapter II of this report.

It is important to note that supersaturation of water with dissolved oxygen occasionally occurs at the stations in the portion of the Kinnickinnic River upstream of the estuary. Supersaturation of water with dissolved oxygen occurs when the water contains a higher concentration of dissolved oxygen than is normally soluble at ambient conditions of temperature and pressure. Figure 39 shows the number of samples during the period of record from the five long-term sampling stations on the Kinnickinnic River in which the concentration of dissolved oxygen exceeded 12 mg/l, 16 mg/l, and 18 mg/l respectively. The lowest of these concentrations represents the saturation oxygen concentrations at a water temperature of 6ºC, while the higher two represent concentrations in excess of saturation at all temperatures under normal conditions of atmospheric pressure. While oxygen concentrations in excess of saturation are detected at these stations throughout the year, the highest oxygen concentrations occur mostly during the spring and fall. Oxygen supersaturation in the Kinnickinnic River is probably caused by high intensities of photosynthesis by attached algae growing in concrete-lined channels at and upstream of the sampling stations. This has two implications. First, because dissolved oxygen samples are often collected during the day, the dissolved oxygen concentrations data presented for the Kinnickinnic River may be less representative of average concentrations and more typical of maximum concentrations achieved during diurnal periods. Second, respiration by the same attached algae may cause steep declines in dissolved oxygen concentration at these stations at night when photosynthesis cannot occur due to lack of light.

Several other factors also affect dissolved oxygen concentrations in the Kinnickinnic River, especially in the estuary. First, portions of the estuary act as a settling basin in which material suspended in the water sink and fall out into the sediment. This is indicated by the lower concentrations of total suspended solids (TSS) in the estuary (Table 30 and see below). Decomposition of organic matter contained in this material, through chemical and especially biological processes, removes oxygen from the overlying water, lowering the dissolved oxygen concentration. Second, influxes of water from Lake Michigan and the Menomonee and Milwaukee Rivers may influence dissolved oxygen concentrations in the downstream portions of the estuary. When dissolved oxygen

Figure 38

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF DISSOLVED OXYGEN ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



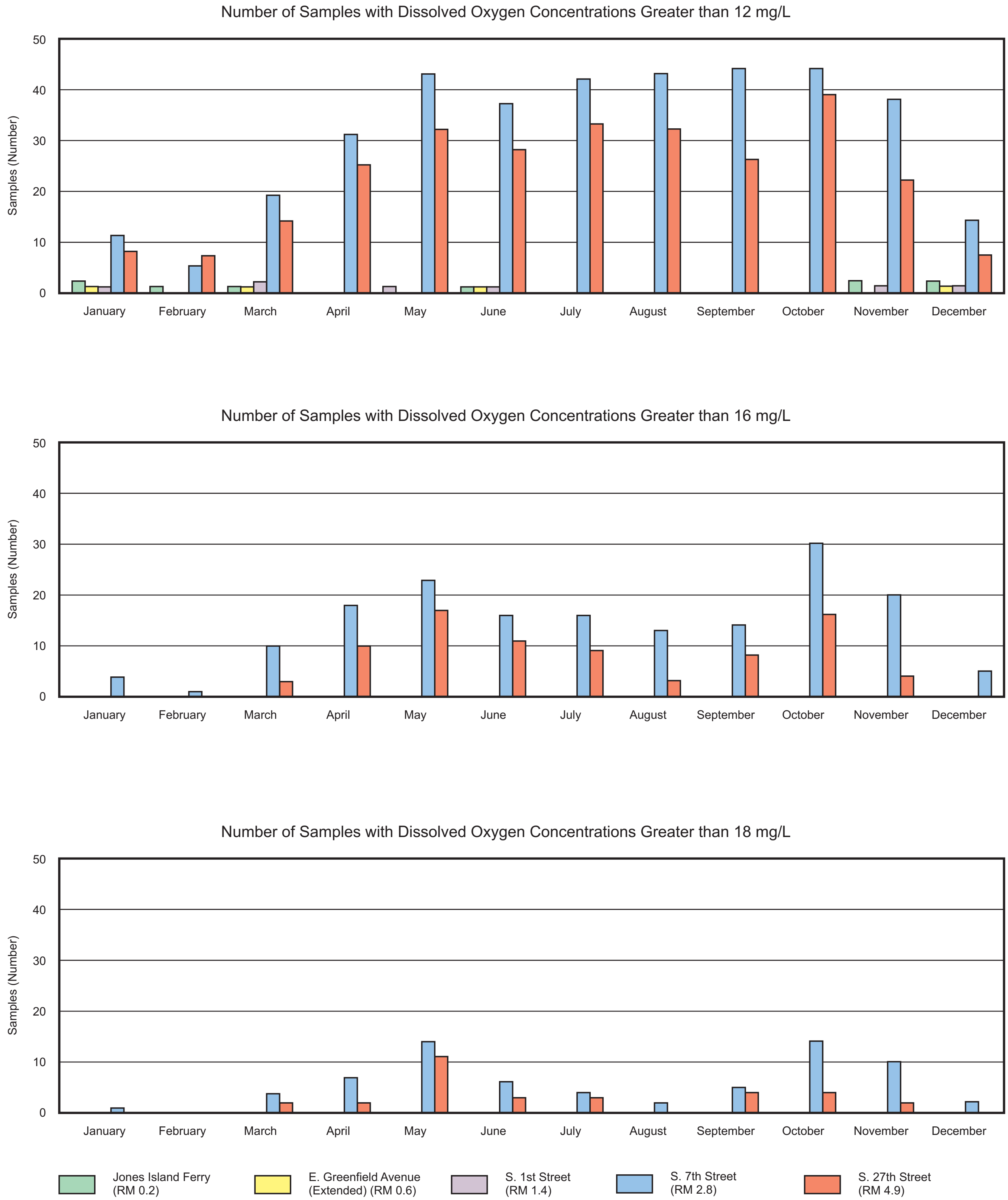
NOTE: 140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

concentrations in these waterbodies are higher than in the estuary, mixing may act to increase dissolved oxygen concentrations in the lower estuary. Third, MMSD operates a flushing tunnel capable of pumping approximately 225 million gallons per day of water from Lake Michigan into the Kinnickinnic River through an outfall near Chase Avenue. Flushing through this tunnel acts to improve water quality in the estuary by increasing flow in the River and flushing stagnant water downstream. MMSD currently operates this tunnel when dissolved oxygen concentrations at the sampling station at S. 1st Street drop below 3.0 mg/l. Typically, flushing occurs six to 12 times per year. Fourth, throughout the mainstem of the Kinnickinnic River, dissolved oxygen concentrations are inversely correlated with ammonia and nitrite concentrations. This suggests that oxidation of ammonia and nitrite to nitrate through biologically mediated nitrification may also be acting to lower dissolved oxygen concentrations when concentrations of these compounds are high. Fifth, dissolved oxygen concentrations are positively correlated with pH. This reflects the effect of photosynthesis on both of these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the water's pH. At the same time, oxygen is released as a byproduct of the photosynthetic reactions.

Figure 39

DISSOLVED OXYGEN EXCEEDING HIGH CONCENTRATIONS ON THE KINNICKINNIC RIVER: 1975-2001



Source: Wisconsin Department of Natural Resources and SEWRPC.

The higher mean concentrations of dissolved oxygen in the upstream section of the estuary and the higher minimum concentrations of dissolved oxygen in the lower section of the estuary suggest that water quality may be improving in the estuary.

Hardness

Over the period of record, the mean hardness in the Kinnickinnic River was 253.0 mg/l as $CaCO_3$. On a commonly used scale, this is considered to be very hard water.[7] The range of the data runs from 30.4 to 923.8 mg/l as $CaCO_3$, showing considerable variability. Some of this variability probably results from inputs of relatively soft water during storm events. Table 30 shows that mean concentrations of hardness were significantly lower in the estuary than at the upstream stations in all periods. Hardness concentrations in the Kinnickinnic River show strong positive correlations with alkalinity, chloride, and specific conductance, all parameters which, like hardness, measure amounts of dissolved material in water. It is important to note that, like alkalinity, specific conductance, and pH, hardness concentrations are greatly influenced by Lake Michigan water dilution in the estuary which probably causes these concentrations to be lower than in the upstream areas. No trends or seasonal patterns in hardness were detected (Table C-1 in Appendix C). In summary, although hardness concentrations are lower in the estuary areas downstream of the S. 7th Street station, hardness concentrations were generally shown to have remained unchanged among stations during the time period examined from 1975 to 2001.

pH

The mean pH in the Kinnickinnic River over the period of record was 7.9 standard units. The mean values at individual sampling stations along the mainstem of the River ranged from 7.5 to 8.5 standard units. At most stations, pH varied only by $\pm$ 1.0 standard unit from the stations' mean values. Variability in pH decreased from upstream to downstream. This higher variability upstream is probably related to the relatively lower discharge at these stations. Because a lower volume of water is flowing past these stations, the effect of fluctuations in inputs from groundwater and runoff from precipitation on pH will be greater than at downstream sites. For all periods for which data were available, mean pH was significantly lower at the stations in the estuary than at the stations in the reaches upstream from the estuary (Table 30). It is important to note that like alkalinity, hardness, and specific conductance; pH concentrations are greatly influenced by Lake Michigan water dilution in the estuary, which probably causes these concentrations to be lower than in the upstream areas. Some positive correlations are seen between pH and alkalinity, chloride concentration, hardness, and specific conductance at some stations, especially in the estuary, but they are neither as common nor as strong as the correlations detected among these other water quality parameters. At all stations, dissolved oxygen concentrations are positively correlated with pH. This reflects the effect of photosynthesis on both of these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the water's pH. At the same time, oxygen is released as a byproduct of the photosynthetic reactions. On an annual basis, a statistically significant decline in pH was detected at the S. 1st Street station (Table C-1 in Appendix C). This was the only time-based trend detected on an annual basis. Summer and fall values of pH in the Kinnickinnic River tend to be lower than spring and winter values. In summary, pH concentrations were generally shown to have decreased at the S. 1st Street station and to have remained unchanged for the rest of the stations during the time period examined from 1975 to 2001.

Specific Conductance

The mean value for specific conductance in the Kinnickinnic River over the period of record was 778.7 microSiemens per centimeter (μS/cm). Considerable variability was associated with this mean. Specific conductance ranged from 0.05 to 8,280.0 μS/cm. Some of this variability may reflect the discontinuous nature of inputs of dissolved material into the River. Runoff associated with storm events can have a major influence on the concentration of dissolved material in the River. The first runoff from a storm event transports a large pulse of salts and other dissolved material from the watershed into the River. This will tend to raise specific conductance in the River. Later runoff associated with the event will be relatively dilute. This will tend to lower specific conductance. Table 30 shows that mean values of specific conductance were lower in the estuary than reaches

[7]*E. Brown, M.W. Skougstad, and M.J. Fishman,* Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, *U.S. Department of Interior, U.S. Geological Survey, 1970.*

upstream from the estuary in all periods examined. This probably results from the greater volume of water passing through the estuary. It is important to note that like, alkalinity, hardness, and pH; specific conductance is greatly influenced by Lake Michigan water dilution in the estuary which causes this to be lower than in the upstream areas. Trend analysis results show that specific conductance has increased over time at two stations, one in the estuary and one in the upstream section of the River (Table C-1 in Appendix C). The data show a seasonal pattern of variation in specific conductance. For those years in which data were available, specific conductance was highest during the winter. It then declined during the spring to reach lower levels in the summer and fall. Specific conductance in the Kinnickinnic River show strong positive correlations with alkalinity, chloride, and hardness, all parameters which, like hardness, measure amounts of dissolved material in water. In summary, specific conductance was shown to have increased at the Greenfield Avenue (extended) and S. 7th Street stations and remained unchanged in the rest of the Kinnickinnic River during the time period examined from 1975 to 2001. The increases in specific conductance at two stations indicates that the concentrations of dissolved materials in water at these stations are increasing and represents a decline in water quality.

Suspended Material

The mean value for total suspended solids (TSS) concentration in the Kinnickinnic River over the period of record was 20.5 mg/l. Considerable variability was associated with this mean, with values ranging from below the limit of detection to 1,400 mg/l. The amount of variability was related to the locations of the sample sites, with variability decreasing from upstream to downstream. Baseline period monthly mean TSS concentrations generally tend to be near historical means. However, during the month of May there is a distinct tendency for monthly mean TSS concentrations from the baseline period to be higher than historical means at upstream sampling stations (see Figure 40). Baseline period monthly maximum TSS concentrations tend to be lower than historical maxima. This difference is less pronounced in the estuary. As shown in Table 30, mean concentrations of TSS were significantly lower at the estuary stations than at stations upstream from the estuary for all periods. This reflects that fact that portions of the estuary act as a settling basin in which material suspended in water sink and fall out into the sediment. Trends toward decreasing concentrations of TSS over time were detected at some sampling stations (Table C-1 in Appendix C). These trends accounted for a small portion of the variation in the data. TSS concentrations showed strong positive correlations with total phosphorus concentrations, reflecting the fact that total phosphorus concentrations include a large particulate fraction. TSS concentrations were also positively correlated with concentrations of fecal coliform bacteria and nutrients.

Nutrients

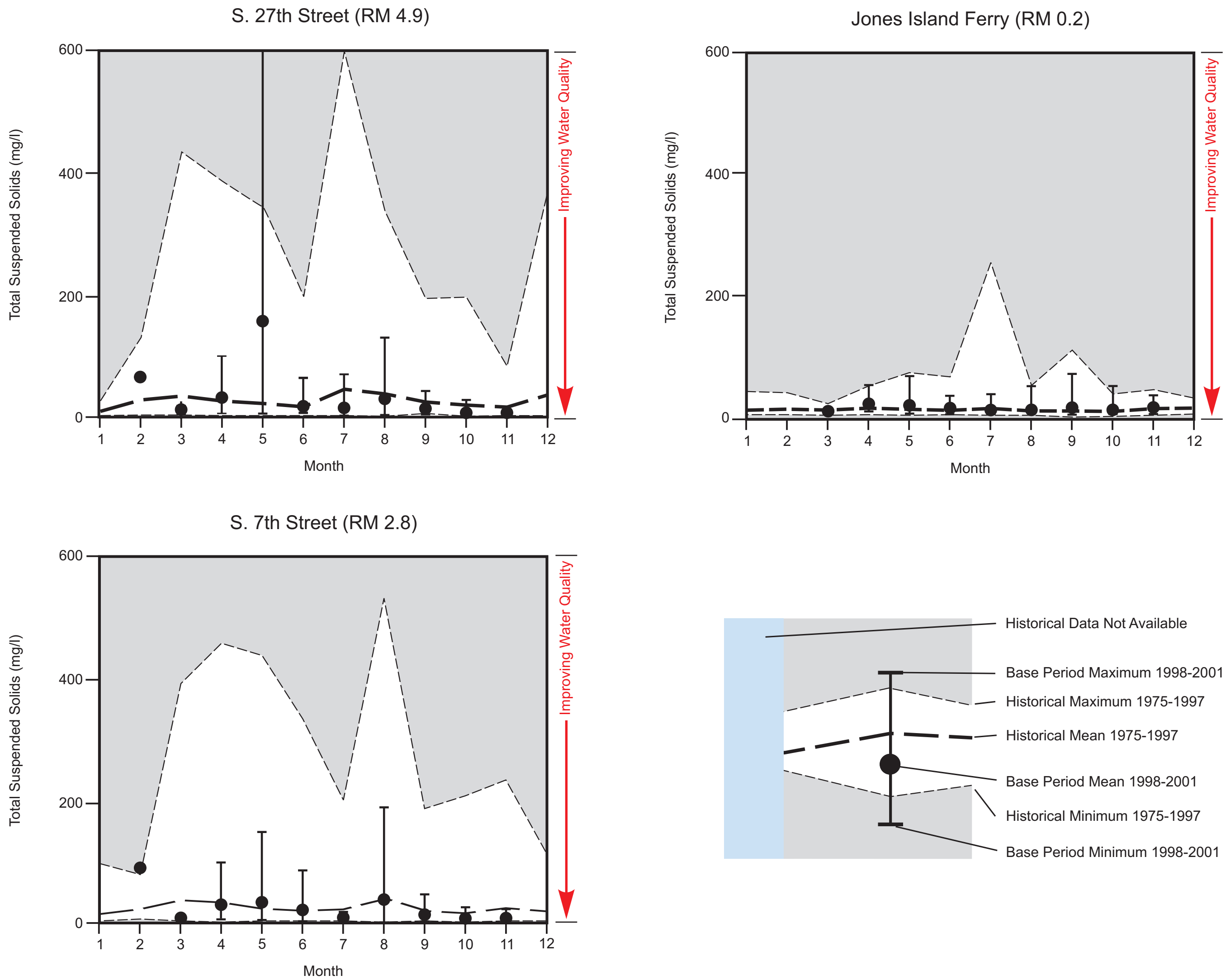
Nitrogen Compounds

The mean concentration of total nitrogen in the Kinnickinnic River over the period of record was 1.52 milligrams per liter measured as nitrogen (mg/l as N). Concentrations varied over three orders of magnitude, ranging from 0.1 to 14.6 mg/l as N. As shown in Figure 41, total nitrogen concentrations declined at all stations after 1986. At most stations, total nitrogen concentrations experienced an increase during the period 1994-1997, followed by a decrease during the period 1998-2001. By contrast, during 1994-1997 total nitrogen concentrations at the Jones Island Ferry station remained similar to those during 1987-1993. This was followed by an increase. The relationship between baseline period and historical monthly mean concentrations of total nitrogen varies along the length of the River. The baseline monthly mean concentrations at stations in the estuary are generally higher than the historical monthly mean concentrations, especially during the summer. In the sections of the River upstream from the estuary monthly mean total nitrogen concentrations are generally near the historical means. Mean concentrations of total nitrogen were significantly higher at stations in the estuary than at the stations along the reaches upstream from the estuary in all periods, except 1994-1997 (Table 30). Table C-1 in Appendix C shows that there is a significant trend in the section of the River upstream from the estuary toward total nitrogen concentrations increasing over time. This trend appears to extend to the upper portions of the estuary. The concentration of total nitrogen in the Kinnickinnic River is moderately positively correlated with the concentration of total phosphorus. This probably reflects the nitrogen and phosphorus contained in particulate organic matter in the water, including live material such as plankton and detritus.

Total nitrogen is a composite measure of several different compounds which vary in their availability to algae and aquatic plants and vary in their toxicity to aquatic organisms. Common constituents of total nitrogen include

Figure 40

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF TOTAL SUSPENDED SOLIDS ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



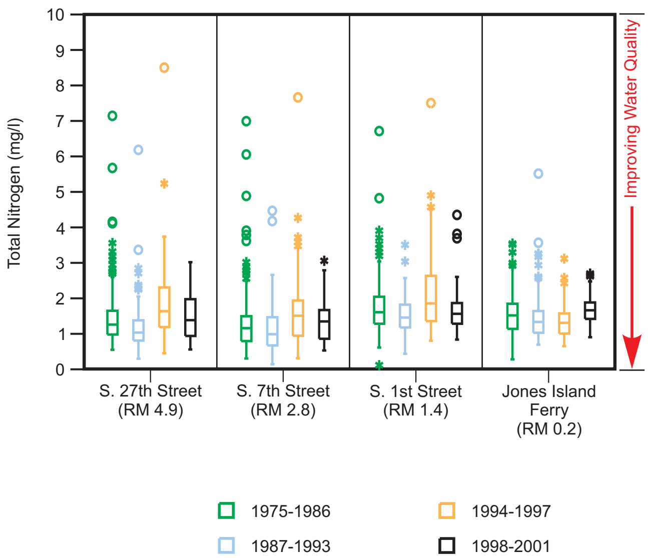
Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

ammonia, nitrate, and nitrite. In addition a large number of nitrogen-containing organic compounds, such as amino acids, nucleic acids, and proteins commonly occur in natural waters. These compounds are usually reported as organic nitrogen.

The mean concentration of ammonia in the Kinnickinnic River was 0.35 mg/l as N. Over the period of record, ammonia concentrations varied between 0.002 and 8.600 mg/l as N. Figure 42 shows that at most stations ammonia concentrations experienced an increase during the period 1994-1997 followed by a decrease during the period 1998-2001. At the station at the Jones Island Ferry, the decrease occurred during 1994-1997. As shown in Table 30, mean ammonia concentrations in the estuary are higher than mean ammonia concentrations in the section of the River upstream of the estuary. For the most part, baseline period monthly mean concentrations of ammonia are generally near or above historical monthly means during the spring and below the historical monthly means during summer and fall. When examined on an annual basis, there is a statistically significant trend toward ammonia concentrations at stations in the estuary declining over time (see Table C-1 in Appendix C of this

Figure 41

TOTAL NITROGEN CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001

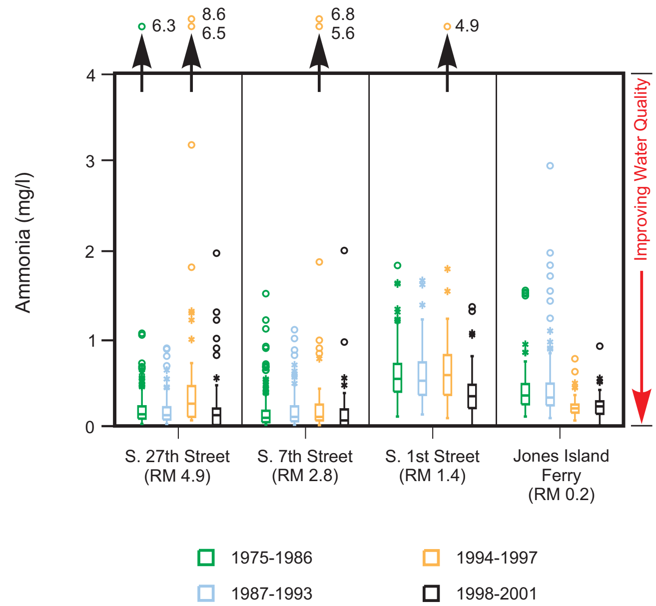


NOTE: See Figure 28 for description of symbols.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 42

AMMONIA CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



NOTES: See Figure 28 for description of symbols.

Standard is dependent on ambient temperature and pH which indicate ammonia concentrations did not exceed those toxicity standards.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

report). Similarly, the stations upstream of the estuary show decreasing trends in ammonia concentrations during the summer and fall. There were no clear patterns of seasonal variation in ammonia concentrations in the Kinnickinnic River. At some stations, ammonia concentrations were negatively correlated with concentrations of, chlorophyll-*a*. This reflects the role of ammonia as a nutrient for algal growth. During periods of high algal productivity, algae remove ammonia from the water and incorporate it into cellular material.

The mean concentration of nitrate in the Kinnickinnic River for the period of record was 0.55 mg/l as N. During this time, concentrations in the River varied between 0.005 and 2.500 mg/l as N. Table 30 indicates that the mean concentration of nitrate at stations in the estuary was higher than the mean concentration of nitrate in the section of the River upstream from the estuary in all periods. Since 1986, nitrate concentrations have been increasing at all stations. These increases represent statistically significant trends only at the stations in the estuary (see Table C-1 in Appendix C of this report). The data show evidence of seasonal variations in nitrate concentration. Nitrate concentration was highest in the early spring and late fall. It declined through spring to reach lower levels in the summer. In the fall, the concentration began to climb again. At all stations, baseline period nitrate monthly mean nitrate concentrations were higher than historical monthly means. At some stations, nitrate concentrations were negatively correlated with concentrations of, chlorophyll-*a*. This reflects the role of nitrate as a nutrient for algal growth. During periods of high algal productivity, algae remove nitrate from the water and incorporate it into cellular material.

The mean concentration of nitrite in the Kinnickinnic River was 0.037 mg/l as N over the period of record. Nitrite concentrations showed more variability than nitrate. This probably reflects the fact that nitrite in oxygenated water tends to oxidize to nitrate fairly quickly. The relationship between mean nitrite concentrations in the estuary and the section of the River upstream from the estuary changed over the period of record. As Table 30 shows, during the period 1975-1993, mean nitrite concentrations were significantly higher in the estuary. During the period 1994-1997, this relationship changed. Mean nitrite concentrations during this period were significantly higher in the section of the River upstream from the estuary. No significant differences were detected between the mean concentration of nitrite at the stations in the estuary and the mean concentration of nitrite at the stations upstream from the estuary during the period 1998-2001. When examined on an annual basis, there is a trend toward increasing nitrite concentrations at the stations in the section of the River upstream from the estuary (see Table C-1 in Appendix C of this report).

During the period of record the mean concentration of organic nitrogen in the Kinnickinnic River was 0.61 mg/l as N. This parameter showed considerable variability with concentrations ranging from undetectable to 7.45 mg/l as N. With one exception, no significant differences were found between the mean concentrations at the stations in the estuary and the stations upstream from the estuary as shown in Table 30. During the period from 1994 to 1997, the mean concentration in the estuary was significantly lower than the mean concentration in the reaches upstream from the estuary. When examined on an annual basis most stations show a trend toward increasing concentrations of organic nitrogen over time. This reflects a trend toward higher organic nitrogen concentrations during the summer (see Table C-1 in Appendix C of this report). There were no clear patterns in seasonal variation of organic nitrogen.

Several processes can influence the concentrations of nitrogen compounds in a waterbody. As noted above, primary production by plants and algae will result in ammonia and nitrate being removed from the water and incorporated into cellular material. This effectively converts the nitrogen to forms which are detected only as total nitrogen. Decomposition of organic material in sediment can release nitrogen compounds to the overlying water. Bacterial action may convert some nitrogen compounds into others.

Several things emerge from this analysis of nitrogen chemistry in the Kinnickinnic River:

- There are distinct differences, with respect to forms of nitrogen, between the estuary and the sections upstream from the estuary. Total nitrogen, nitrate, and ammonia tend to be found in higher concentrations in the estuary.
- The relative proportions of different nitrogen compounds in the River seem to be changing with time.
- Throughout the River ammonia concentrations have been declining over time. This represents an improvement in water quality.
- Where trends exist, the concentrations of organic nitrogen compounds seem to be increasing over time.
- Concentrations of nitrate in the estuary and nitrite in the sections of the River upstream from the estuary seem to be increasing over time. Although for surface waters there are no standards for these constituents, the increases in concentrations may be an indication of declining water quality.

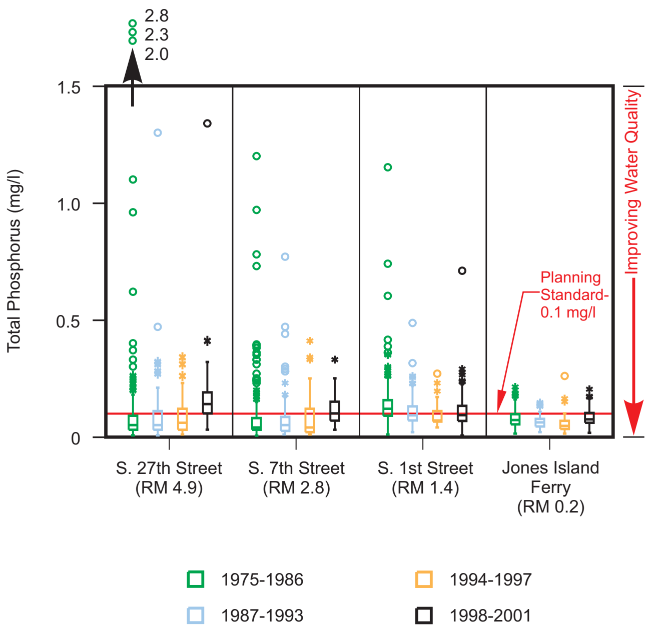
Total and Dissolved Phosphorus

Two forms of phosphorus are commonly sampled in surface waters: dissolved phosphorus and total phosphorus. Dissolved phosphorus represents the form that can be taken up and used for growth by algae and aquatic plants. Total phosphorus represents all the phosphorus contained in material dissolved or suspended within the water, including phosphorus contained in detritus and organisms and attached to soil and sediment.

The mean concentration of total phosphorus in the Kinnickinnic River during the period of record was 0.095 mg/l (see Figure 43), and the mean concentration of dissolved phosphorus in the Kinnickinnic River over the period of record was 0.033 mg/l. Phosphorus concentrations varied over four orders of magnitude, with concentrations of

Figure 43

TOTAL PHOSPHORUS CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



NOTE: See Figure 28 for description of symbols.

Source: *U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

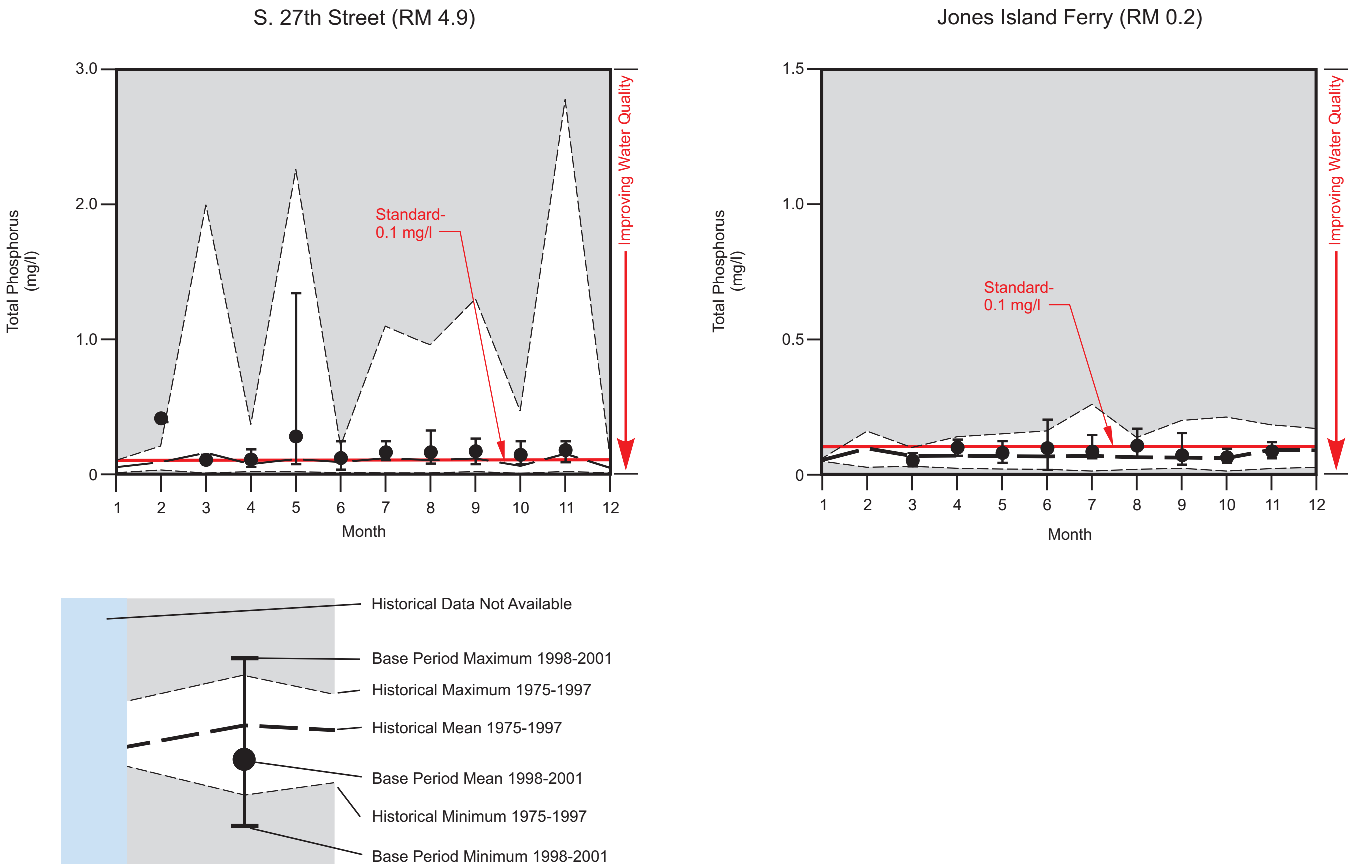
total phosphorus in the River ranging from 0.005 to 2.780 mg/l, and of dissolved phosphorus ranging from 0.003 to 1.010 mg/l. At most sampling sites, the data showed moderate variability. Table 30 shows that the relationship between the mean concentrations of dissolved phosphorus at stations in the estuary and at stations in the section of the River upstream of the estuary has changed over time. During the periods before 1994, Table 30 shows that mean concentrations of dissolved phosphorus were significantly higher at stations in the estuary than at stations in the section of the River upstream of the estuary. During the period 1994-1997, there was no difference between the mean concentrations of dissolved phosphorus at stations in the estuary and at stations in the section of the River upstream of the estuary. During the period 1998-2001, the concentration of dissolved phosphorus at stations in the section upstream of the estuary was higher than at stations in the estuary. At some stations, dissolved phosphorus concentrations were negatively correlated with concentrations of chlorophyll-*a*. This reflects the role of dissolved phosphorus as a nutrient for algal growth. During periods of high algal productivity, algae remove dissolved phosphorus from the water and incorporate it into cellular material.

Figure 44 shows a monthly comparison of the historical and baseline concentrations of total phosphorus at two sampling stations along the length of the mainstem of the Kinnickinnic River, one in the estuary and one in the section upstream from the estuary. At both stations, concentrations of total phosphorus during the period 1998-2001 were generally within the historical ranges. At the estuary stations, monthly mean total phosphorus concentrations from the baseline period are generally near or slightly above historical means except at the station at S. 1st Street. During the fall and early spring at this station, baseline period monthly mean total phosphorus concentrations were below the historical means. At the stations in the section of the River upstream from the estuary, baseline period monthly mean total phosphorus concentrations are generally above the historical means. On an annual basis, trends toward decreasing total phosphorus concentrations over time were detected at two stations in the estuary. Simultaneously, increasing total phosphorus concentrations over time were detected at the stations in the section of the River upstream from the estuary (see Table C-1 in Appendix C of this report). These trends represent an improvement in water quality in the estuary and a decline in water quality in the section of the River upstream from the estuary.

Figure 45 shows the annual mean total phosphorus concentration in the Kinnickinnic River for the years 1985-2001. Mean annual total phosphorus concentration increased sharply after 1996. In addition, researchers at the University of Wisconsin-Milwaukee/University of Wisconsin System Great Lakes WATER Institute have found that phosphorus concentrations have been increasing in the upper reaches of the estuary. One possible cause of these increases is phosphorus loads from facilities discharging noncontact cooling water drawn from municipal water utilities. The City of Milwaukee began treating its municipal water with orthophosphate to inhibit release of copper and lead from pipes in the water system and private residences in 1996. In 2004, for instance, concentrations of orthophosphate in plant finished water from the Milwaukee Water Works ranged between

Figure 44

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF TOTAL PHOSPHORUS ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

1.46 mg/l and 2.24 mg/l,[8] considerably above average concentrations of total phosphorus in the Kinnickinnic River.

Metals

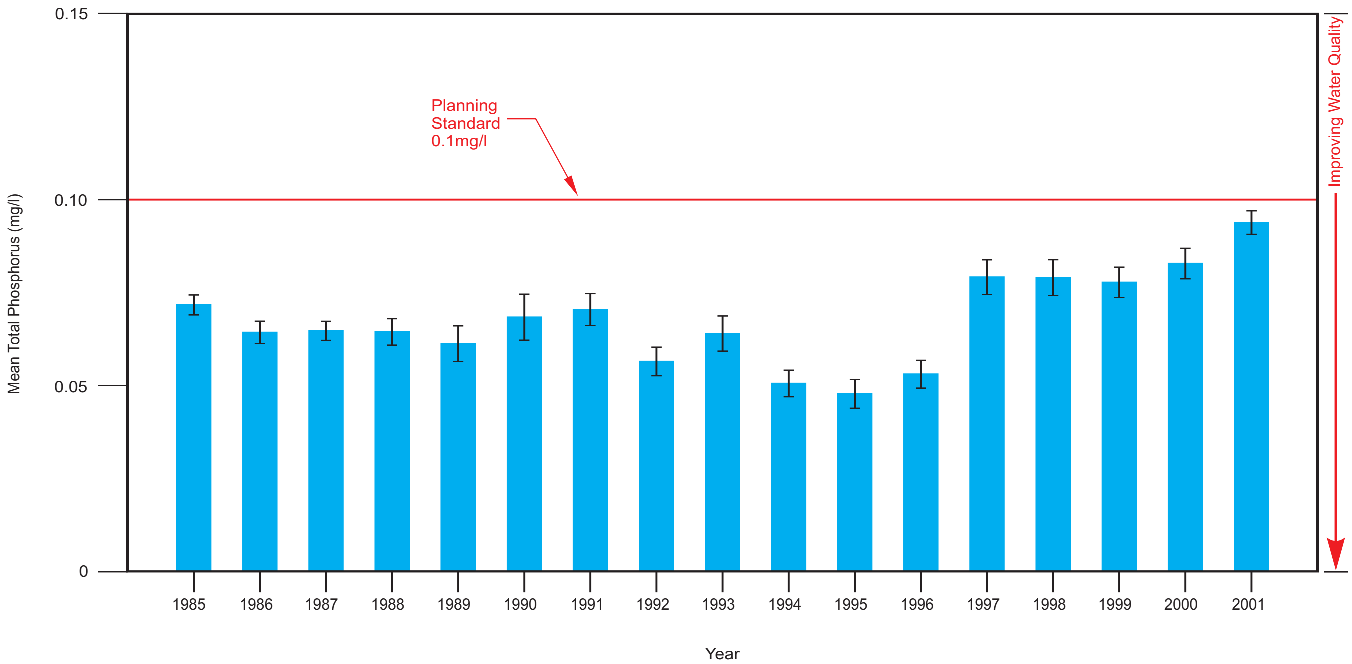
Arsenic

The mean value for the concentration of arsenic in the water of the Kinnickinnic River over the period of record was 1.85 μg/l. The data ranged from 0.95 μg/l to 9.5 μg/l. Table 30 shows that during the periods after 1993, no statistically significant differences were detected between the mean concentrations of arsenic in the estuary and the mean concentrations in the upstream section. Table C-1 in Appendix C reveals a trend at all sampling stations toward arsenic concentrations declining when examined on an annual basis. In addition, when trends in arsenic concentrations were assessed on a seasonal basis, all stations showed declines during the spring and most stations showed declines during the fall. These declines may reflect changes in the amount and types of industry within the Kinnickinnic River watershed, as well as reductions due to treatment of industrial discharges. In addition, sodium arsenate has not been used in herbicides since the 1960s. Arsenic concentrations in the Kinnickinnic River show no evidence of seasonal variation. The reductions in arsenic concentration in the Kinnickinnic River represent an improvement in water quality.

[8]*Milwaukee Water Works,* Annual Water Quality Report, 2004, *February 2005.*

Figure 45

MEAN ANNUAL CONCENTRATION OF TOTAL PHOSPHORUS IN THE KINNICKINNIC RIVER: 1985-2001



NOTE: Error bars (I) represent one standard error of the mean.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Cadmium

The mean concentration of cadmium in the Kinnickinnic River over the period of record was 1.7 μg/l. A moderate amount of variability was associated with this mean. Individual samples ranged from 0.05 to 27.0 μg/l. There were few differences among the stations in the amount of variability. In the periods before 1994, the mean concentration of cadmium was significantly higher at stations in the estuary than at stations in the section of the River upstream of the estuary as shown in Table 30. In the periods since 1994, the mean concentration of cadmium in the estuary did not differ from the mean concentration in the section of the River upstream of the estuary. Table C-1 in Appendix C also shows the presence of a strong decreasing trend in cadmium concentrations at nearly all stations on an annual and seasonal basis. These declines in cadmium concentration may reflect changes in the number and types of industry present in the watershed, reductions due to treatment of industrial discharges, and reductions in airborne deposition of cadmium to the Great Lakes region. Cadmium concentrations in the River showed no evidence of seasonal variation. Cadmium concentrations in the Kinnickinnic River showed strong correlations with lead concentrations. The reduction in cadmium concentrations in the Kinnickinnic River represents an improvement in water quality.

Chromium

The mean concentration of chromium in the Kinnickinnic River over the period of record was 9.81 μg/l. Chromium concentration showed moderate variability, with individual sample concentrations ranging from 0.1 to 280.0 μg/l. As shown in Table C-1 in Appendix C, analysis of time-based trends suggests that chromium concentrations are declining within much of the estuary. The increasing trend shown at the station at S. 7th Street is strongly influenced by a single sample from May 2001 with unusually high concentration. The decline in chromium concentration and the reduction in the amount of variability in chromium concentration may reflect the loss of industry in some parts of the watershed and the decreasing importance of the metal plating industry in particular, as well as the establishment of mandatory treatment and pretreatment of discharges instituted for the remaining and new industries since the late 1970s. The treatment/pretreatment requirements instituted did result in many discharges which previously went to the River being removed and connected to the public system. There is no evidence of seasonal variation in chromium concentrations in the Kinnickinnic River. The decline in chromium concentrations in the estuary represents an improvement in water quality.

Copper

The mean concentration of copper in the Kinnickinnic River during the period of record was 10.8 μg/l. Moderate variability was associated with this mean. Figure 46 shows that prior to 1998, the mean concentrations of copper increased over time at all stations. During the period 1998-2001, the mean concentration of copper declined at all sampling stations along the River. Nearly all stations showed that monthly mean copper concentrations are generally near or below the historical monthly means. Despite this recent decline, all stations show significant increasing trends in copper concentrations (see Table C-1 in Appendix C of this report). Table 30 shows that mean concentrations of copper did not differ between stations in the estuary and stations in the section of the River upstream from the estuary during all periods that were examined. The increasing trend over time may be caused by increased amounts of vehicle traffic. Wear and tear of brake pads and other metal components of vehicles is a major source of copper to the environment. Once deposited on impervious surfaces, stormwater may carry this metal into the River. While copper compounds are also used in lake management for algae control, the Kinnickinnic River watershed contains no major lakes and few ponds. This makes it unlikely that algicides constitute a major source of copper to the Kinnickinnic River. There is no evidence of seasonal variation in copper concentrations in the Kinnickinnic River. At most stations, copper showed moderately strong positive correlations with zinc concentrations in the Kinnickinnic River. This reflects the fact that many of the same sources release these two metals to the environment. The trend toward increasing copper concentration in the Kinnickinnic River represents a decline of water quality.

Lead

The mean concentration of lead in the Kinnickinnic River over the period of record was 33.1 μg/l. This mean is not representative of current conditions because lead concentrations in the water of the River have been declining since the late 1980s, as shown in Figure 47. At all sampling stations, the baseline ranges of lead concentrations are below the historical mean concentrations. Baseline monthly mean lead concentrations are quite low when compared to the historical means and ranges. This pattern is seen at all of the sampling stations. A major factor causing the decline in lead concentrations has been the phasing out of use of lead as a gasoline additive. From 1983-1986, the amount of lead in gasoline in the United States was reduced from 1.26 g/gal to 0.1 g/gal. In addition lead was completely banned for use in fuel for on-road vehicles in 1995. The major drop in lead in water in the Kinnickinnic River followed this reduction in use. In freshwater, lead has a strong tendency to adsorb to particulates suspended in the water.[9] As these particles are deposited, they will carry the adsorbed lead into residence in the sediment. Because of this, the lower concentrations of lead in the water probably reflect the actions of three processes: reduction of lead entering the environment, washing out of lead in the water into the estuary and Lake Michigan, and deposition of adsorbed lead in the sediment. Lead concentrations in the Kinnickinnic River show no evidence of patterns of seasonal variation. The reductions in lead concentration in the Kinnickinnic River represent an improvement in water quality.

Mercury

Few historical data on the concentration of mercury in the water of the Kinnickinnic River exist. Though a few samples were taken during the mid-1970s, most sampling for mercury in water in the River was taken during or after 1995. The mean concentration of mercury in the River over the period of record was 0.060 μg/l. Mercury concentrations showed moderate variability, with a range from 0.02 to 0.44 μg/l. For the period 1998-2001, the mean concentration of mercury in the River was 0.031 μg/l. The means at individual stations during this period ranged from 0.022 μg/l at S. 7th Street to 0.052 μg/l at S. 1st Street. Table 30 shows that the mean mercury

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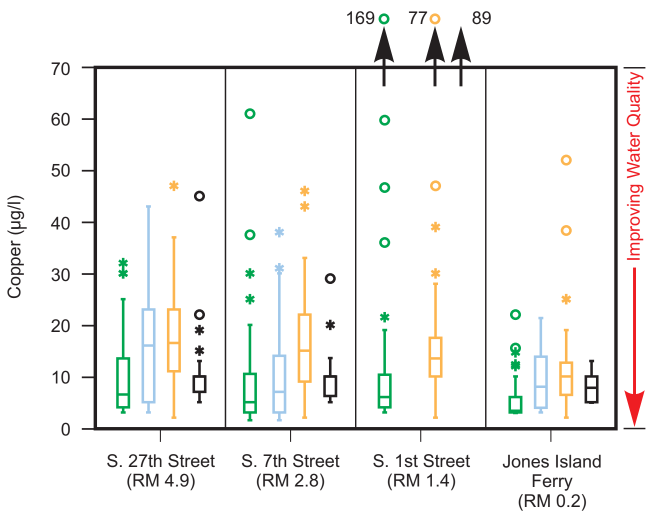
[9] *H.L. Windom, T. Byrd, R.G. Smith, and F. Huan, "Inadequacy of NASQUAN Data for Assessing Metal Trends in the Nation's Rivers,"* Environmental Science and Technology *Volume 25, 1991, pp. 1137-1142.*

Figure 46

COPPER CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



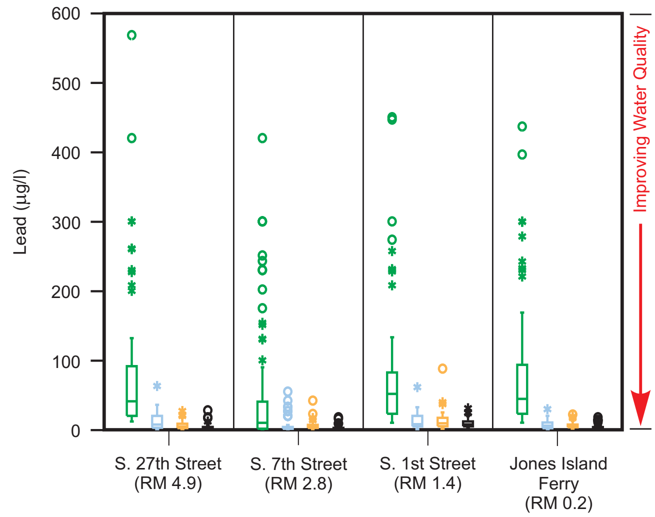
NOTES: See Figure 28 for description of symbols.

Copper acute and chronic toxicity standards depend on ambient hardness which indicates that copper concentrations exceeded these standards in 2 percent and up to 23 percent of samples in the estuary and upstream of the estuary, respectively.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 47

LEAD CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



NOTES: See Figure 28 for description of symbols.

The human threshold criteria for public health and welfare for lead is 140 µg/l.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

concentrations at stations in the estuary were significantly higher than the mean mercury concentration in the section of the River upstream from the estuary during the period 1998-2001. In the period prior to this, there was no difference between the mean mercury concentrations in these two sections of the River. When examined on an annual basis, all stations show significant trends toward decreasing mercury concentration over time (Table C-1 in Appendix C). There is no evidence of seasonal variation of mercury concentrations in the Kinnickinnic River. The reduction in mercury concentrations in the Kinnickinnic represents an improvement in water quality.

Nickel

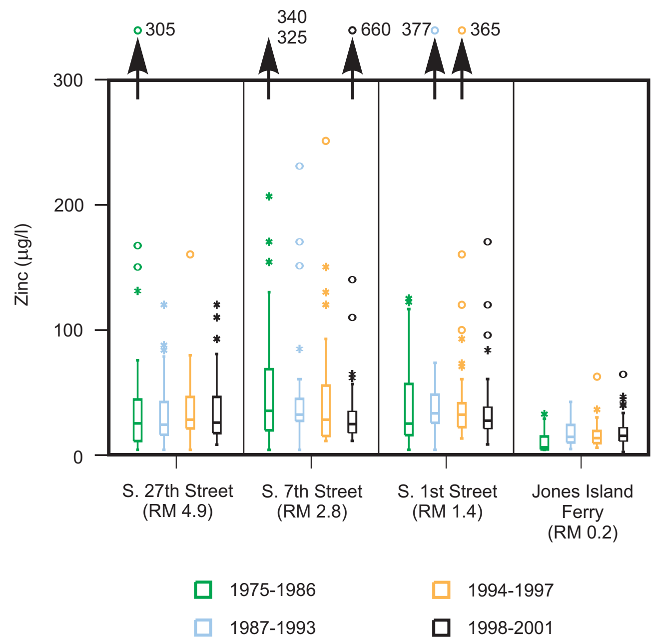
The mean concentration of nickel in the Kinnickinnic River over the period of record was 11.8 μg/l. While some sites had outliers, variability was generally low. No differences were detected between the mean concentrations of nickel in the estuary and in the section of the River upstream from the estuary in any period for which data existed (Table 30). When examined on an annual basis, a significant decline was observed at the Greenfield Avenue (extended) sampling station. No significant trends were detected at any other sampling stations. There was no evidence of seasonal variation in nickel concentration in the Kinnickinnic River (Table C-1 in Appendix C).

Zinc

The mean concentration of zinc in the Kinnickinnic River during the period of record was 34.4 μg/l. Zinc concentrations showed moderate variability. Concentrations in individual samples ranged from 4.3 to 660 μg/l. Variability tended to be greater at stations upstream from the estuary than at stations within the estuary as shown in Figure 48. As shown in Table 30, mean concentrations of zinc at stations upstream from the estuary tended to be greater than mean concentrations in the estuary. At the stations in the estuary near the confluence with the Milwaukee River, concentrations of zinc during the baseline period often exceed the historical maxima as shown in Figure 49. Farther upstream, this occurs mostly during the spring and early summer. This may reflect high amounts of zinc washing into the River during snowmelt and spring rains. These increases in zinc may be caused by an increased amount of vehicle traffic in the watershed. Zinc can be released to stormwater by corrosion of galvanized gutters and roofing materials. In addition, wear and tear on automobile brake pads and tires are major sources of zinc to the environment. Stormwater can carry zinc from these sources into the River. Table C-1 in Appendix C of this report shows a statistically significant trend toward increasing mean concentrations of zinc over time in the estuary, especially at the two stations nearest the confluence with the Milwaukee River. In spring and fall, a decreasing trend was detected at the station at S. 7th Street. There is no evidence of seasonal variation in the concentration of zinc in the Kinnickinnic River. The trend toward increasing zinc concentrations in the estuary represents a reduction in water quality.

Figure 48

ZINC CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



NOTES: See Figure 28 for description of symbols.

Acute and chronic toxicity standards for zinc depend on ambient hardness which indicates that zinc concentrations did not exceed these toxicity standards.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Organic Compounds

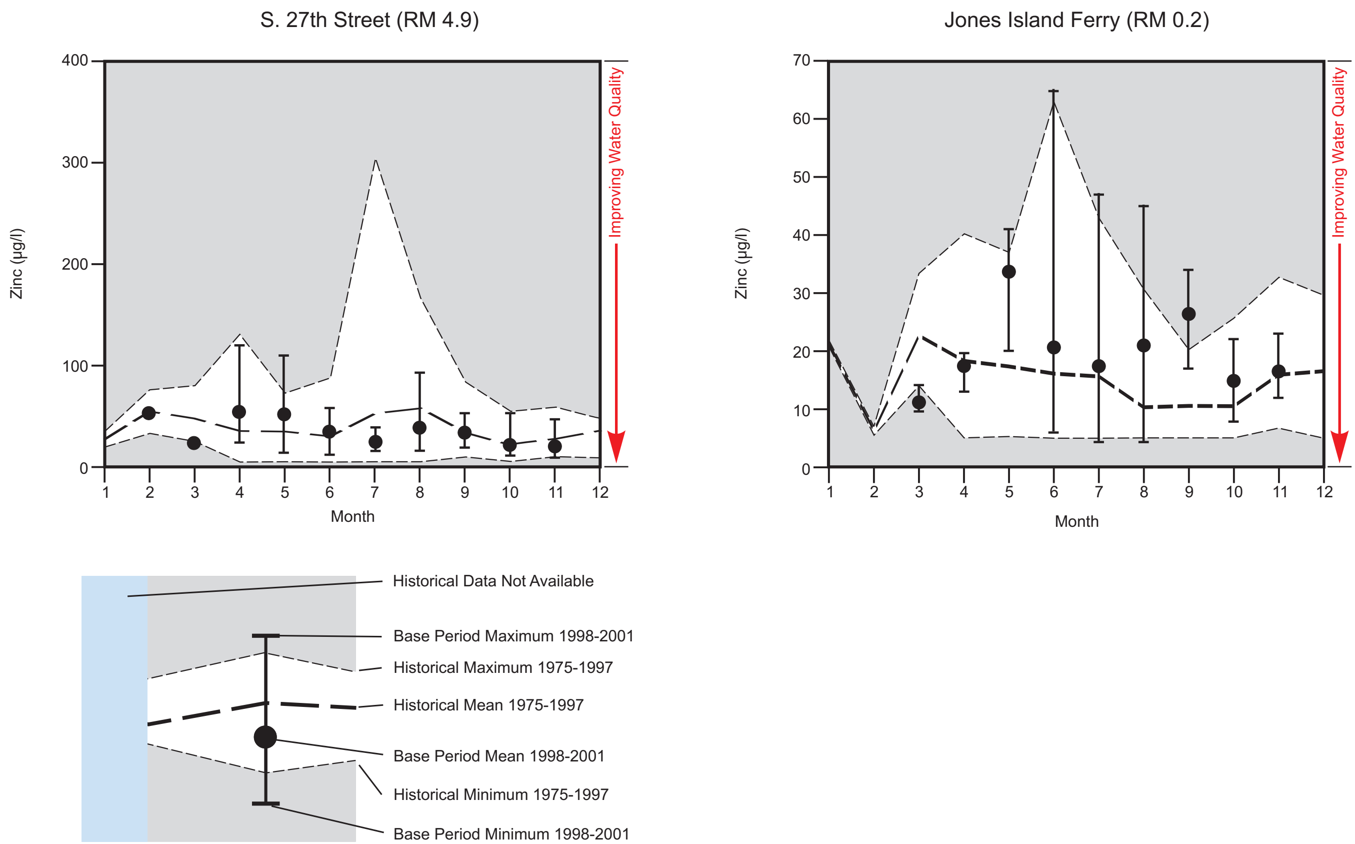
Between February and June 2004, samples were collected on three dates from the Kinnickinnic River at S. 11th Street and examined for the presence and concentrations of two organic compounds dissolved in water. Concentrations of dissolved bromoform were below the limit of detection in all samples. Dissolved isophorone was detected in one sample at a concentration of 0.1 μg/l. As shown in Table 18 in Chapter IV of this report, this concentration is below Wisconsin's human threshold criterion for public heath and welfare for fish and aquatic life waters.

During 1999 and 2000, three sites on Wilson Park Creek were sampled for ethylene glycol and propylene glycol, two compounds used in airport deicing operations. These compounds can create high oxygen demands in waters and are toxic to some organisms. During this period, 19 samples were collected at the GMIA infall near Grange Avenue. Concentrations of ethylene glycol were below the limit of detection in all samples. Propylene glycol was detected in one sample at a concentration of 20 mg/l. Over the same period, samples were collected at the GMIA outfall 7. Ethylene glycol was detected in six out of 19 samples with concentrations at this site ranging from below the limit of detection to 605 mg/l. Propylene glycol was detected in 11 out of 20 samples with concentrations at this site ranging from below the limit of detection to 4,150 mg/l. Samples were also collected during this period at St. Luke's Hospital near the confluence with the Kinnickinnic River. Ethylene glycol was detected in one out of 20 samples at a concentration of 35 mg/l. Propylene glycol was detected in seven out of 21 samples from this site with concentrations ranging from below the limit of detection to 250 mg/l. Wisconsin currently has no surface water quality standard or criteria for ethylene glycol or propylene glycol.

General Mitchell International Airport has discontinued the use of ethylene glycol as a deicing fluid. In addition, the airport has taken several measures to reduce the amount of deicing fluids entering the Wilson Park Creek, including placing pads under aircraft to capture deicing fluids during deicing operations, reducing the amount of deicing fluids used, and redesigning its storm sewers to seal while deicing operations are in progress.

Figure 49

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF ZINC ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Pharmaceuticals and Personal Care Products

In February, March, and May 2004, the USGS sampled water from the Kinnickinnic River at S. 11th Street for the presence of triclosan, an antibacterial agent commonly found in such personal care products as toothpaste, mouthwash, hand soaps, deodorants, and cosmetics and for caffeine, a stimulant found in beverages and analgesics. The concentration of triclosan was below the limit of detection in all of the samples. Caffeine was detected at concentrations ranging between 0.3 μg/l and 0.7 μg/l with a mean concentration of 0.47 μg/l. The source of caffeine entering the Kinnickinnic River is unknown. No other data were available regarding the presence or concentrations of pharmaceuticals and personal care products in the Kinnickinnic River or any of its tributaries.

TOXICITY CONDITIONS OF THE KINNICKINNIC RIVER

Toxic Substances in Water

Pesticides

Since the 1970s, the Kinnickinnic River watershed has been sampled for the presence of pesticides in water on several occasions. There have been four sampling years: 1975, 1984, 1993 and 2004. It is important to note that the results from the samples taken in 2004 are not directly comparable to those from the early periods. The data from the earlier periods were derived from unfiltered samples which included both pesticides dissolved in water and pesticides contained in and adsorbed to particulates suspended in the water. The data from 2004 were derived from filtered samples and measure only the fraction of pesticides dissolved in water. Since most pesticides are poorly soluble in water, the data from 2004 may underestimate ambient pesticide concentrations relative to the earlier data. Sampling during 1975 focused heavily on the insecticides dieldrin, lindane, and DDT and on the metabolites of DDT. In general, the concentrations of these substances were below the limits of detection. In 1984 samples were tested for chlordane, dieldrin, DDT and its metabolites, endosulfan, lindane, and toxaphene. While the concentrations of most of these were below the limit of detection, lindane and toxaphene were each detected in one sample. In 1993, four sites in the estuary were sampled for chlordane isomers. In one sample, measurable concentrations of γ-chlordane were detected. During the 2004 sampling, the insecticides carbaryl and diazinon were occasionally detected as were the herbicide atrazine and its metabolite deethylatrazine. Where detectable concentrations of diazinon and atrazine were reported, they were found to be below the U.S. Environmental Protection Agency's (USEPA) draft aquatic life criteria.

Polycyclic Aromatic Hydrocarbons (PAHs)
Extensive sampling for 16 PAH compounds in unfiltered water was conducted at the MMSD long-term stations along the mainstem of the Kinnickinnic River between 1995 and 2001. Measurable concentrations of PAHs were detected in most of the samples. Mean PAH concentration in the water samples from the estuary for the period 1995 to 1997 was 0.98 μg/l. This increased to 1.15 μg/l during the period 1998 to 2001. By contrast, the mean concentration of PAHs in water samples from the reaches upstream from the estuary declined from 1.70 μg/l during the period 1995-1997 to 1.04 μg/l during the period 1998-2001. It is important to note that there was considerable variation in the concentrations detected among different sites within these sections of the River and among samples taken at individual sites on different dates. In 2004, one site along the mainstem of the River was sampled on three dates for six PAH compounds dissolved in water. The mean concentration from these samples was 0.5 μg/l. It is important to note that the results from this last sampling are not directly comparable to the results from the earlier sampling for the reasons discussed in the previous paragraph. The increase in PAH concentration in water of the estuary represents a decline in water quality. The decrease in PAH concentration in the section of the River upstream of the estuary represents an improvement in water quality.

Polychlorinated Biphenyls (PCBs)
Between 1995 and 2001 the MMSD long-term sampling sites along the mainstem of the Kinnickinnic River were sampled for the presence and concentrations of 14 PCB congeners in water. Since concentrations of only 14 out of 209 congeners from this family of compounds were examined, the results from the mainstem should be considered minimum values. While in the majority of samples, the concentrations of these PCB congeners were below the limit of detection, when PCBs were detected they exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 nanograms per liter (ng/l). Detections of PCBs generally increased from upstream to downstream along the mainstem of the River.

Toxic Contaminants in Aquatic Organisms
The WDNR periodically surveys tissue from fish and other aquatic organisms for the presence of toxic and hazardous contaminants. Several surveys were conducted at sites within the Kinnickinnic River watershed between 1977 and 1996. These surveys screened for the presence and concentrations of several contaminants including metals, PCBs, and organochloride pesticides. Because of potential risks posed to humans by consumption of fish containing high levels of contaminants, the WDNR has issued fish consumption advisories for several species of fish taken from the Kinnickinnic River. The statewide fish consumption advisory for mercury applies to fish in the Kinnickinnic River watershed. In addition, a special consumption advisory has been issued for several species due to tissue concentrations of PCBs (Table 31).

It is important to note that the samples collected from the Kinnickinnic River all consisted of whole organism homogenates. By contrast, samples collected from three ponds in the watershed consisted of fillets of skin and muscle tissue. These types of samples are not directly comparable. Consumption advisory determinations are based upon fillet samples. In both types of samples, a single sample may represent tissue from several fish of the same species.

Table 31

FISH CONSUMPTION ADVISORIES FOR THE KINNICKINNIC RIVER WATERSHED[a]

Species	Consumption Advisory Level			
	One Meal per Week	One Meal per Month	One Meal per Two Months	Do Not Eat
Jackson Park Pond				
Black Crappie	- -	- -	All sizes	- -
Bluegill	- -	- -	All sizes	- -
Carp	- -	- -	All sizes	- -
Largemouth Bass	- -	- -	All sizes	- -
Pumpkinseed	- -	- -	All sizes	- -
Kinnickinnic River Up to First Dam				
Chubs	- -	All sizes	- -	- -
Chinook Salmon	- -	Less than 32 inches	Larger than 32 inches	- -
Coho Salmon	- -	All sizes	- -	- -
Brown Trout	- -	Less than 22 inches	Larger than 22 inches	- -
Lake Trout	- -	Less than 23 inches	23-27 inches	Larger than 27 inches
Rainbow Trout	Less than 22 inches	Larger than 22 inches	- -	- -
Smelt	All sizes	- -	- -	- -
Whitefish	- -	All sizes	- -	- -
Yellow Perch	All sizes	- -	- -	- -
Kinnickinnic River				
Black Crappie	- -	- -	All sizes	- -
Carp	- -	- -	- -	All sizes
Northern Pike	- -	- -	All sizes	- -
Redhorse	- -	- -	All sizes	- -
Rock Bass	- -	All sizes	- -	- -
Smallmouth Bass	- -	- -	All sizes	- -
Walleyed Pike	- -	Less than 18 inches	Larger than 18 inches	- -
White Sucker	- -	- -	All sizes	- -
Yellow Perch	All sizes	- -	- -	- -

[a]*The statewide general fish consumption advisory applies to other fish species not listed in this table.*

Source: Wisconsin Department of Natural Resources.

Mercury

Between 1977 and 1984 the WDNR sampled tissue from fish collected from the mainstem of the Kinnickinnic River for mercury contamination. As shown in Figure 50, the concentrations detected in whole fish samples ranged from below the limit of detection to 0.21 micrograms per gram tissue (μg per g tissue). It is important to recognize that the number of individual organisms and the range of species taken from this watershed that have been screened for the presence of mercury contamination are quite small. In addition, no recent data were available. Because of this, these data may not be completely representative of current body burdens of mercury carried by aquatic organisms in the River and its tributaries.

PCBs

In 1986 and 1996 the WDNR examined fillet samples from several species of fish collected from the Jackson Park Pond for PCB contamination. As shown in Figure 51, the concentrations of PCBs ranged from below the limit of detection to 0.67 μg per g tissue. A wider range of tissue concentrations was detected in the 1996 sampling than in the 1986 sampling. This may simply reflect the larger number of fish sampled in 1996. Special fish consumption advisories for PCBs have been issued by the WDNR for fish in Jackson Park Pond (Table 31).

Between 1977 and 1984 the WDNR examined whole fish samples from several species of fish collected from the mainstem of the Kinnickinnic River for PCB contamination. As shown in Figure 51, tissue concentrations of PCBs ranged between 2.7 μg per g tissue and 52.0 μg per g tissue.

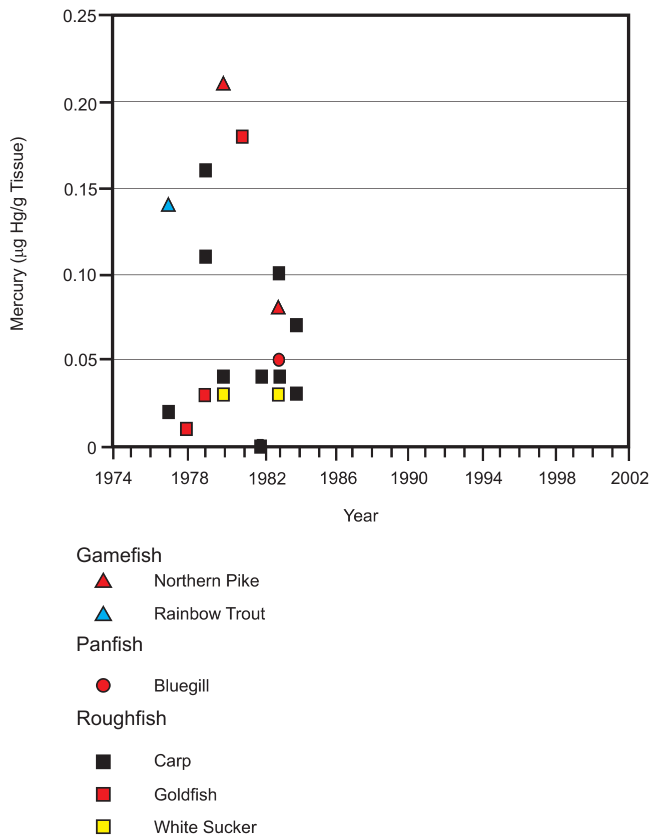
The number of individual organisms and the range of species taken from this watershed that have been screened for the presence of PCB contamination are quite small. Because of this, these data may not be completely representative of current body burdens of PCBs carried by aquatic organisms in the River and its tributaries.

Pesticides

Between 1977 and 1986 the WDNR sampled several species of aquatic organisms from the Kinnickinnic River watershed for contamination by historically used, bioaccumulative pesticides and their breakdown products. Many of these compounds are no longer in use. For example, crop uses of most of these compounds were banned in the United States between 1972 and 1983. While limited uses were allowed after this for some of these substances, by 1988 the uses of most had been phased out. During the 1970s and 1980s, measurable concentrations of o,p'-DDT and p,p'-DDT were rarely detected in tissue of fish collected from the Kinnickinnic River. During the same period, measurable concentrations of the DDT breakdown products of o,p'-DDD, p,p'-DDD, o,p'-DDE, and p,p'-DDE were detected in the tissue of fish from several species including bluegill, carp, goldfish, northern pike, and white sucker. Measurable concentrations of the DDT breakdown product p,p'-DDE were also detected in fillets of bluegill and largemouth bass collected from Jackson Park Pond in 1988.

Figure 50

TISSUE CONCENTRATIONS OF MERCURY IN WHOLE FISH SAMPLES COLLECTED FROM THE KINNICKINNIC RIVER: 1975-2001



Source: Wisconsin Department of Natural Resources.

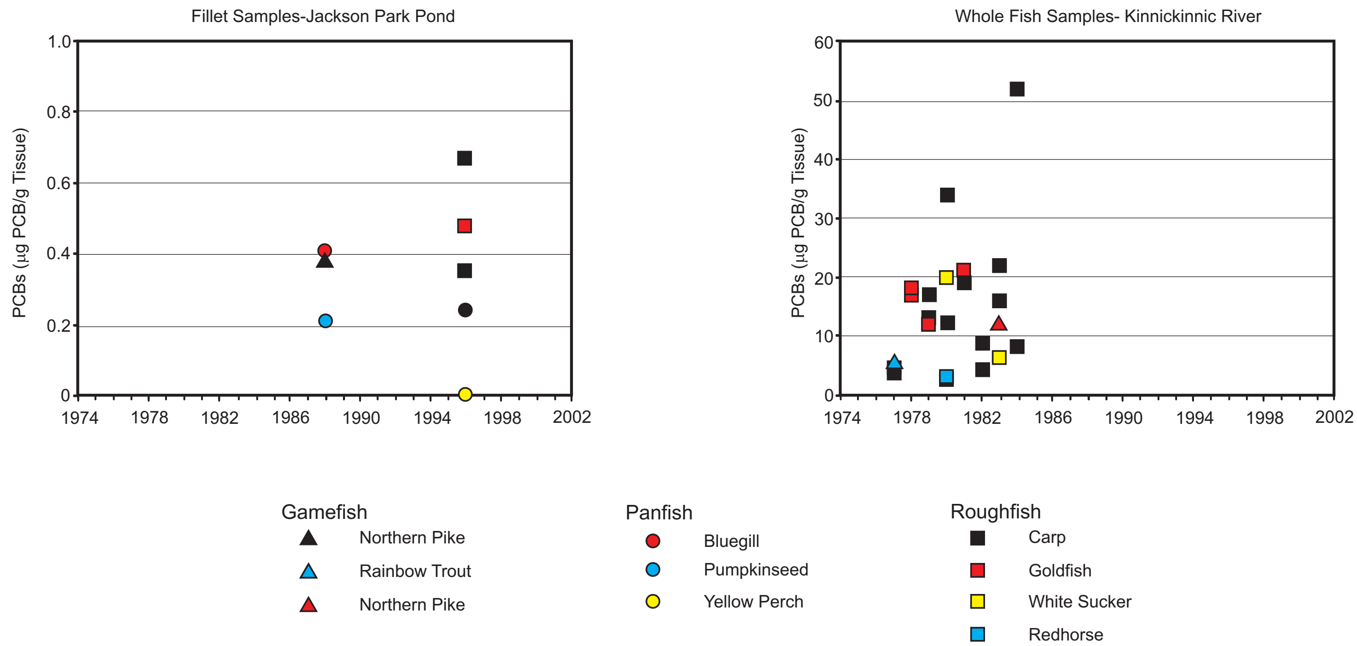
Also between 1977 and 1986, tissue from fish collected in the Kinnickinnic River watershed was analyzed for the presence of several other pesticides. Measurable concentrations of the chlordane isomers α-chlordane and γ-chlordane were detected in the tissue of several carp and goldfish and measurable concentrations of trans-nonachlor were detected in the tissue of several carp. Except for these samples, concentrations of chlordane isomers and derivatives in tissue samples from the River were generally at or below the limit of detection. Chlordane isomers were not detected in fillets from fish collected from Humboldt Park Pond, Jackson Park Pond, and Wilson Park Pond between 1986 and 1996.

Measurable concentrations of aldrin were detected in tissue from carp and white sucker collected from the Kinnickinnic River in the late 1970s and early 1980s. Measurable concentrations of α-BHC and hexachlorobenzene were detected in tissue from carp collected from the River during the same period. Tissue from two goldfish samples collected in 1978 contained measurable concentrations of the insecticide methoxychlor. Measurable amounts of the pesticides, γ-BHC, endrin, 2,4,5-trichlorophenol, 2,4,6-trichlorophenol, and toxaphene were not detected in the tissue of aquatic organisms collected from the Kinnickinnic River during the period 1977-1986. Measurable concentrations of 2,4,5-trichlorophenol and 2,4,6-trichlorophenol were detected in fillets from largemouth bass collected from Jackson Park Pond and Wilson Park Pond in 1988 and bluegill collected from Wilson Park Pond in 1988.

The number of individual organisms and the range of species taken from this watershed that have been screened for the presence of pesticide contamination are quite small. Because of this, these data may not be completely representative of pesticide body burdens of pesticides carried by aquatic organisms in the River and its tributaries.

Figure 51

**TISSUE CONCENTRATIONS OF PCB IN FISH SAMPLES
COLLECTED FROM THE KINNICKINNIC RIVER WATERSHED: 1975-2001**



Source: Wisconsin Department of Natural Resources.

Toxic Contaminants in Sediment

Most of the data on contaminants in sediments of the Kinnickinnic River watershed are from the mainstem of the Kinnickinnic River within the estuary. Toxicants that have been sampled for include metals, PAHs, PCBs, and pesticides. While recent data on toxic metals are not available, sediment samples taken from the Kinnickinnic River during the period 1984 to 1993 show detectable concentrations of arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, and zinc (Table 32). The mean concentrations of chromium, lead, and zinc in these samples exceed the respective Probable Effect Concentrations (PEC) above which toxicity to benthic organisms is considered highly probable (Table 13 in Chapter III of this report). Mean concentrations of cadmium, copper, iron, mercury, and nickel in these samples were between the Threshold Effect Concentrations (TEC) and the PECs, indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms.

The amount of organic carbon in sediment can exert considerable influence on the toxicity of nonpolar organic compounds such as PAHs, PCBs, and certain pesticides to benthic organisms. While the biological responses of benthic organisms to nonionic organic compounds has been found to differ across sediments when the concentrations are expressed on a dry weight basis, they have been found to be similar when the concentrations have been normalized to a standard percentage of organic carbon.[10] Because of this, the concentrations of PAHs, PCBs, and pesticides were normalized to 1 percent organic carbon prior to analysis.

Concentrations of PAHs in 27 sediment samples collected between 1989 and 1994 ranged between about 6,800 micrograms PAH per kilogram sediment (μg PAH/kg sediment) and about 589,000 μg PAH/kg sediment with a mean value of 139,000 μg PAH/kg sediment. Total organic carbon data was not available for seven of the

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[10]*U.S. Environmental Protection Agency,* Technical Basis for the Derivation of Equilibrium Partitioning Sediment Guidelines (ESGs) for the Protection of Benthic Organisms: Nonionic Organics, *USEPA Office of Science and Technology, Washington, D.C., 2000.*

Table 32

CONCENTRATIONS OF TOXIC METALS IN SEDIMENT SAMPLES FROM THE KINNICKINNIC RIVER: 1984-1993[a]

Statistic	Metals							
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Mean	7.03	4.41	392	87.4	298	0.68	29.9	528
Standard Deviation	3.95	1.94	320	27.3	106	0.98	5.3	102
Minimum	3.50	1.80	69	60.0	170	0.00	22.0	340
Maximum	14.00	9.50	1,320	143.0	530	3.15	41.5	677
Number of Samples	13	14	14	14	14	16	13	13

[a]*All concentrations in mg/kg based on dry weight.*

Source: Wisconsin Department of Natural Resources.

samples. For 15 of the 20 samples that had associated total organic carbon data, the concentrations of PAHs found in the sediments the Kinnickinnic River exceed the PEC for total PAHs and are high enough to pose substantial risk of toxicity to benthic organisms. Concentrations of PCBs in 39 sediment samples collected between 1984 and 1994 ranged between about 100 micrograms PCB per kilogram sediment (μg PCB/kg sediment) and about 20,000 μg PCB/kg sediment with a mean value of 4,344 μg PCB/kg sediment. Total organic carbon data was not available for 13 of the samples. For 20 of the 26 samples that had associated total organic carbon data, the concentrations of PCBs found in the sediments of the Kinnickinnic River exceed the PEC for total PCBs and are high enough to pose substantial risk of toxicity to benthic organisms. In addition, the concentration of PCBs in one sample was between the Threshold Effect Concentration (TEC) and the PEC, indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms.

Sediment from the Kinnickinnic River was examined for the presence of up to 12 pesticides on a number of occasions between 1984 and 1994. Chlordane was detected in 10 of 30 samples at concentrations ranging between 5.0 and 32.5 μg chlordane/kg sediment. In two of these samples, the concentrations of chlordane found in the sediments of the Kinnickinnic River exceeded the PEC for chlordane and are high enough to pose substantial risk of toxicity to benthic organisms. In addition, the concentration of chlordane in one sample was between the TEC and the PEC, indicating that this pesticide is likely to be producing some level of toxic effect in benthic organisms. In addition, DDT was found in one sample collected in 1993 at a concentration of 65.3 μg DDT/kg sediment, a concentration exceeding the PEC for DDT. The concentrations of all other pesticides were below the limit of detection.

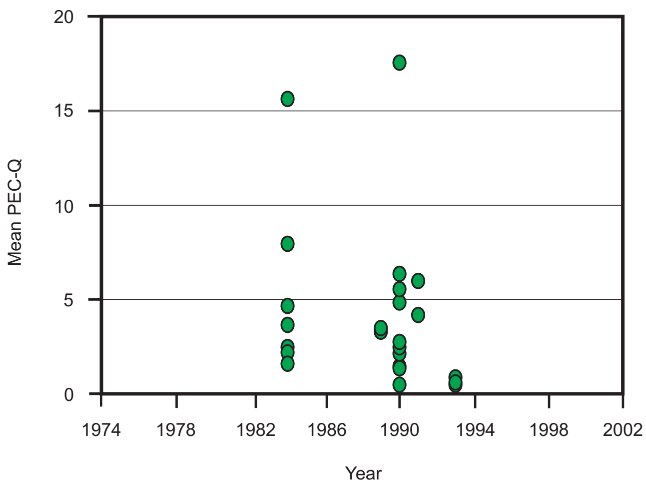
The combined effects of several toxicants in sediment of the Kinnickinnic River were estimated using the methodology described in Chapter III of this report. Figure 52 shows that overall mean PEC-Q values, a measure that integrates the effects of multiple toxicants on benthic organisms, from sediments in the Kinnickinnic River are high. These high PEC-Q levels suggest that benthic organisms in the Kinnickinnic River are experiencing substantial incidences of toxic effects, as indicated in Figure 53. In most of the samples, the estimated incidence of toxicity is 100 percent. It is important to note that because the sediment samples were collected at different sites in the River, the lower estimated incidences from 1994 may be less representative of any time-based trends and more representative of spatial variation in toxicant concentrations.

BIOLOGICAL CONDITIONS OF THE KINNICKINNIC RIVER AND ITS TRIBUTARIES

Aquatic and terrestrial wildlife communities have educational and aesthetic values, perform important functions in the ecological system, and are the basis for certain recreational activities. The location, extent, and quality of fishery and wildlife areas and the type of fish and wildlife characteristic of those areas are, therefore, important determinants of the overall quality of the environment in the Kinnickinnic River watershed area.

Figure 52

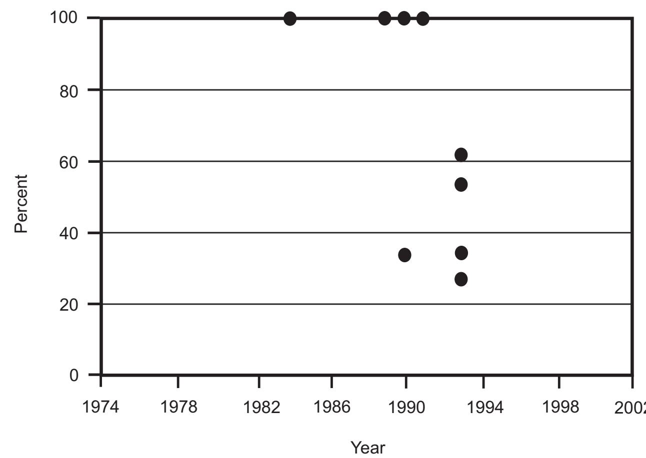
MEAN PROBABLE EFFECT CONCENTRATION QUOTIENTS (PEC-Q) FOR SEDIMENT ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



Source: Wisconsin Department of Natural Resources.

Figure 53

ESTIMATED INCIDENCE OF TOXICITY TO BENTHIC ORGANISMS ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



Source: Wisconsin Department of Natural Resources.

Fisheries

Creeks and Rivers

Review of the fishery data collected in the Kinnickinnic River basin between 1902 and 2004 indicates an apparent loss of multiple species throughout the watershed during this time period. This apparent decrease seems to be due, in part, to decreased sampling effort, with only one sample taken in the most recent time period as shown in Table 33. Table 33 also shows that the historical and current numbers of species have been, and continue to be, very low. The most recent fishery survey in 2000 indicated an apparent loss of all species but goldfish, which is a tolerant warmwater species. With additional sampling it is likely that more species would be observed, as were during the period 1994 through 1997. Nonetheless, species that have not been observed since 1986 were the northern pike; brook stickleback; rainbow trout; banded killifish, a species of special concern in the State of Wisconsin; and striped shiner, which is an endangered species in the State of Wisconsin.

In Wisconsin, high-quality warmwater streams are characterized by many native species, darters, suckers, sunfish, and intolerant species (species that are particularly sensitive to water pollution and habitat degradation). Within such environments, tolerant fish species also occur that are capable of persisting under a wide range of degraded conditions and are also typically present within high-quality warmwater streams, but they do not dominate. Insectivores (fish that feed primarily on small invertebrates) and top carnivores (fish that feed on other fish, vertebrates, or large invertebrates) are generally common. Omnivores (fish that feed on both plant and animal material) are also generally common, but do not dominate. Simple lithophilous spawners which are species that lay their eggs directly on large substrate, such as clean gravel or cobble, without building a nest or providing parental care for the eggs are also generally common.

The Kinnickinnic River watershed fishery has been and continues to be largely dominated by a high proportion of low dissolved oxygen tolerant fishes and low numbers of native fish species, which are indicative of a poor fishery (see Table 33 and Figure 54). The proportions of such tolerant fish species have all increased as shown in Table 33. Most notable is the exotic invasive common carp and goldfish species. Carp are likely to be having a negative effect on the overall fishery in this watershed by destroying habitat and competing for food and spawning areas of native fish species.

Table 33

FISH SPECIES COMPOSITION IN THE KINNICKINNIC RIVER WATERSHED: 1902-2000

Species According to Their Relative Tolerance to Pollution	Percent Occurrence[a]				
	1902-1974	1975-1986	1987-1993	1994-1997	1998-2004
Intolerant					
Greater Redhorse[b]	0.0	0.0	- -	25.0	0.0
Redhorse Species	0.0	0.0	- -	25.0	0.0
Tolerant					
Banded Killifish[c]	33.3	0.0	- -	0.0	0.0
Common Carp[d]	0.0	40.0	- -	50.0	0.0
Creek Chub	33.3	20.0	- -	0.0	0.0
Fathead Minnow	33.3	20.0	- -	50.0	0.0
Golden Shiner	0.0	0.0	- -	25.0	0.0
Goldfish[d]	0.0	20.0	- -	50.0	100.0
Green Sunfish	0.0	20.0	- -	0.0	0.0
White Sucker	0.0	40.0	- -	50.0	0.0
Intermediate Tolerance Classification					
Alewife	0.0	0.0	- -	50.0	0.0
Black Bullhead	0.0	0.0	- -	25.0	0.0
Brassy Minnow	33.3	0.0	- -	0.0	0.0
Brook Stickleback	33.3	0.0	- -	0.0	0.0
Chinook Salmon	0.0	20.0	- -	0.0	0.0
Coho Salmon	0.0	20.0	- -	0.0	0.0
Gizzard Shad	0.0	0.0	- -	50.0	0.0
Johnny Darter	33.3	0.0	- -	0.0	0.0
Northern Pike	0.0	20.0	- -	0.0	0.0
Orangespotted Sunfish	0.0	20.0	- -	0.0	0.0
Pumpkinseed	0.0	0.0	- -	25.0	0.0
Rainbow Trout	0.0	40.0	- -	0.0	0.0
Striped Shiner[e]	33.3	0.0	- -	0.0	0.0
Threespine Stickleback	0.0	0.0	- -	25.0	0.0
Total Number of Samples	3	5	- -	4	1
Total Number of Samples per Year	<1.0	<1.0	- -	<1.0	<1.0
Total Number of Species	7	11	- -	12	1

[a]*Values represent percent occurrence, which equals the number of sites where each species was found divided by the total number of sites within a given time period.*

[b]*Designated threatened species.*

[c]*Designated species of special concern.*

[d]*Nine Common Carp x Goldfish hybrids were found in 1994-1997 samplings.*

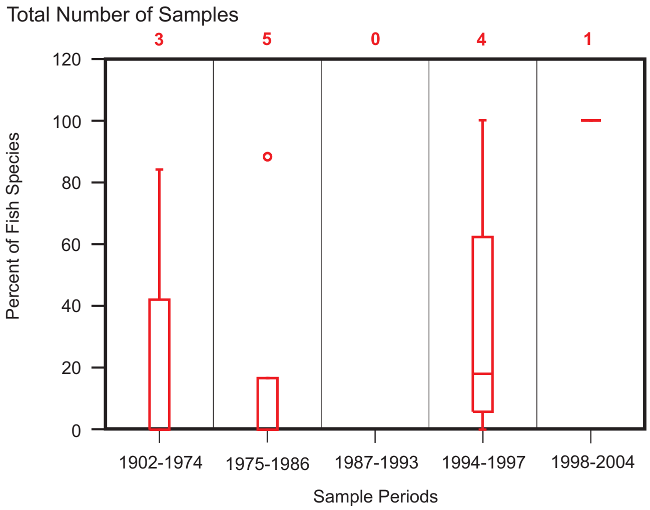
[e]*Designated endangered species.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Index of Biotic Integrity (IBI) results indicate that there has not been any significant change in the quality of the fishery of the Kinnickinnic River watershed compared to the historical conditions (Figure 55 and Map 19). Although some of the samples over time achieved a poor community IBI rating score of 20 to 30, in the majority of the sites over all years, samples have generally remained in the very poor (IBI score 0-20) classification. Although the data are limited, Figure 56 indicates that both the Kinnickinnic River watershed and the Wilson Park Creek subwatershed have historically contained a low abundance and diversity of fishes. It is very likely that these subwatersheds continue to sustain a limited fishery, however, additional data would have to be collected in order to verify this condition.

Figure 54

PROPORTIONS OF DISSOLVED OXYGEN TOLERANT FISHES WITHIN THE KINNICKINNIC RIVER WATERSHED: 1902-2004

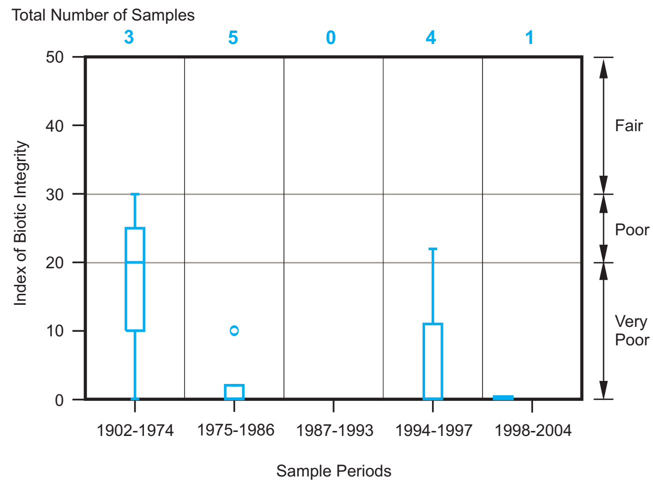


NOTE: See Figure 28 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 55

FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION IN THE KINNICKINNIC RIVER WATERSHED: 1902-2004



NOTE: See Figure 28 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Urbanization can cause numerous changes to streams that have the potential to alter aquatic biodiversity that include but are not limited to the following factors which have been observed to varying degrees in the Kinnickinnic River watershed:[11]

- Increased flow volumes and channel-forming storms—These alter habitat complexity, change availability of food organisms related to timing of emergence and recovery after disturbance, reduce prey availability, increase scour related mortality, deplete large woody debris for cover in the channel, and accelerate streambank erosion;
- Decreased base flows—These lead to increased crowding and competition for food and space, increased vulnerability to predation, and increased sediment deposition;
- Increased sediment transport—This leads to reduced survival of eggs, loss of habitat due to deposition, siltation of pool areas, and reduced macroinvertebrate reproduction;
- Loss of pools and riffles—This leads to a loss of deep water cover and feeding areas causing a shift in balance of species due to habitat changes;
- Changed substrate composition—This leads to reduced survival of eggs, loss of inter-gravel cover refuges for early life stages for fishes, and reduced macroinvertebrate production;
- Loss of large woody debris—This leads to loss of cover from large predators and high flows, reduced sediment and organic matter storage, reduced pool formation, and reduced organic substrate for macroinvertebrates;

[11]*Center for Watershed Protection, "Impacts of Impervious Cover on Aquatic Systems,"* Watershed Protection Research Monograph No. 1*, March 2003.*

Map 19

FISHERIES (1902-2000) AND MACROINVERTEBRATE (1987-2002) SAMPLE LOCATIONS AND CONDITIONS WITHIN THE KINNICKINNIC RIVER WATERSHED

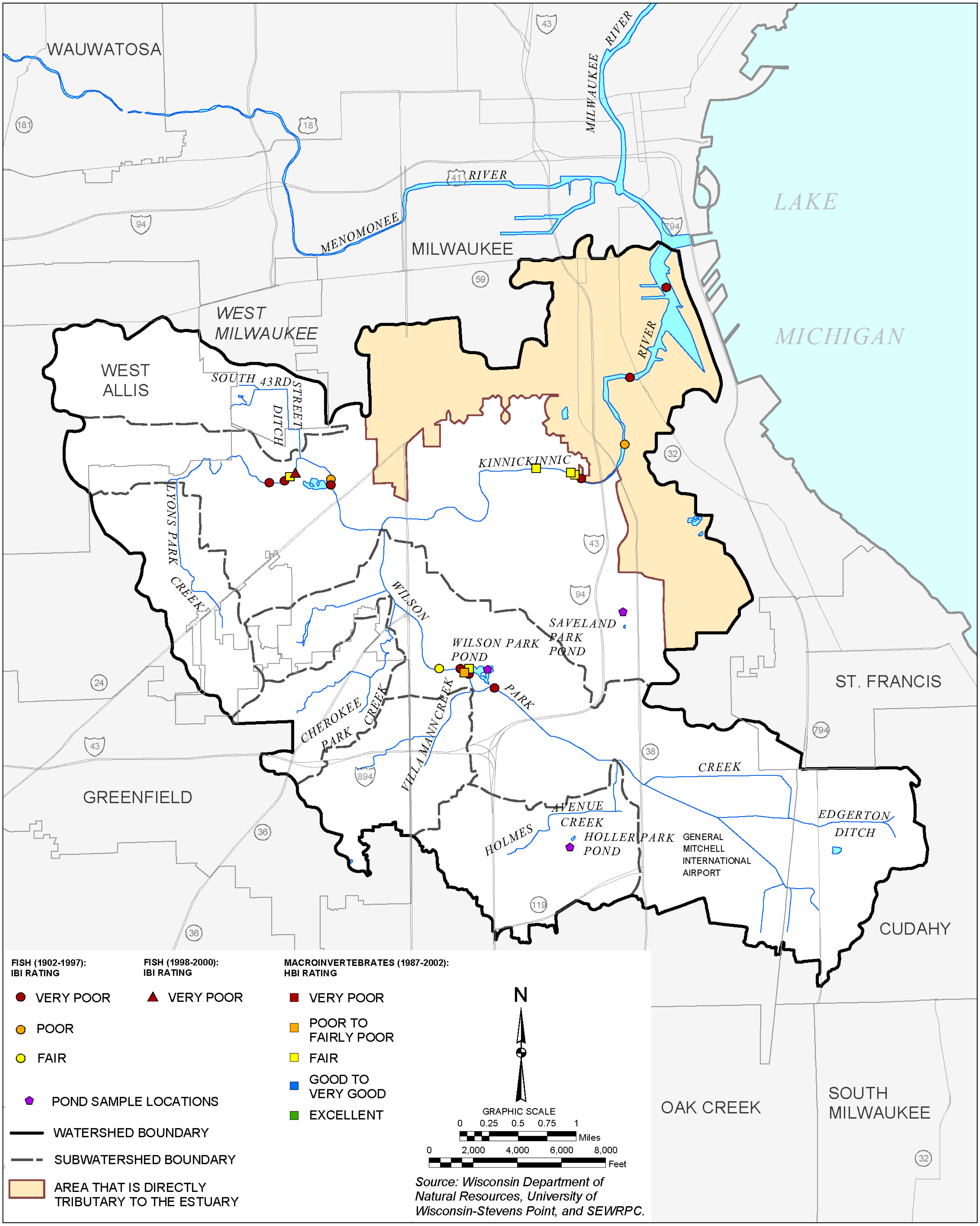
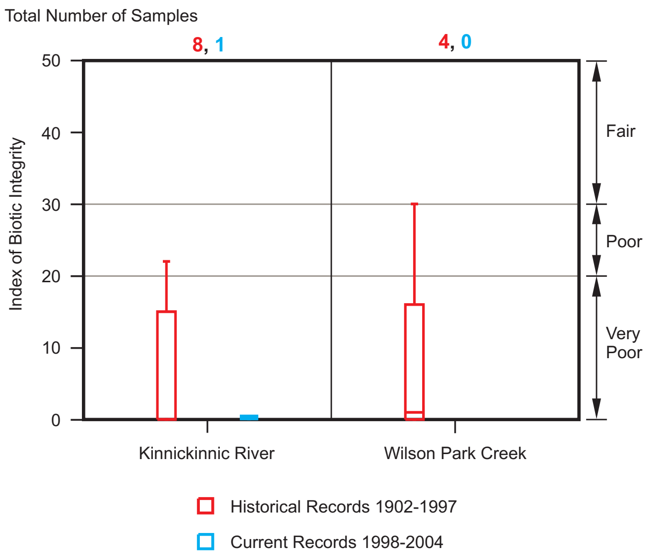


Figure 56

HISTORICAL AND BASE PERIOD FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION AMONG STREAMS IN THE KINNICKINNIC RIVER WATERSHED: 1902-2004



NOTE: See Figure 28 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

- Increased temperatures due to runoff from pavement versus natural landscapes—This leads to changes in migration patterns, increased metabolic activity, increased disease and parasite susceptibility, and increased mortality of sensitive fishes and macroinvertebrates;
- Creation of fish blockages by road crossings, culverts, drop structures, and dams—This leads to loss of spawning habitat, inability to reach feeding areas and/or overwintering sites, loss of summer rearing habitat, and increased vulnerability to predation;
- Loss of vegetative rooting systems—This leads to decreased channel stability, loss of undercut banks, and reduced streambank integrity;
- Channel straightening or hardening—This leads to increased stream scour and loss of habitat complexity through disruption of sediment transport ability;
- Reduced water quality—This leads to reduced survival of eggs and juvenile fishes, acute and chronic toxicity to juveniles and adult fishes, and increased physiological stress;
- Increased turbidity—This leads to reduced survival of eggs, reduced plant productivity, and increased physiological stress on aquatic organisms; and
- Increased algae blooms—These lead to oxygen depletion causing fish kills due to chronic algae blooms and increased eutrophication rate of standing waters.

The apparent stagnation of the fishery community within the Kinnickinnic River watershed can be attributed to habitat loss and degradation as a consequence of human activities primarily related to the historic and current development that has occurred within the watershed.

Chapter II of this report includes a description of the correlation between urbanization in a watershed and the quality of the aquatic biological resources. The amount of imperviousness in a watershed that is directly connected to the stormwater drainage system can be used as a surrogate for the combined impacts of urbanization in the absence of mitigation. The Kinnickinnic River watershed included about 30 percent urban land use in 1940, which approximately corresponds to about 10 percent directly connected imperviousness in the watershed; about 90 percent urban land use in 1970, corresponding to about 30 percent directly connected imperviousness, and it currently has about 93 percent urban land overall. Thus, since about 1940, the amount of directly connected impervious land cover in the watershed has been beyond the threshold level of 10 percent at which previously cited studies indicate that negative biological impacts have been observed. Based upon the amount of urban lands in the watershed and, in the past, a lack of measures to mitigate the adverse effects of those land uses, the resultant poor to very poor IBI scores observed throughout this watershed are not surprising. The standards and requirements of Chapter NR 151 "Runoff Management," and Chapter NR 216, "Storm Water Discharge Permits," of the *Wisconsin Administrative Code* are intended to mitigate the impacts of existing and new urban development and agricultural activities on surface water resources through control of peak flows in the channel-forming range, promotion of increased baseflow through infiltration of stormwater runoff, and reduction in sediment loads to streams and lakes. The implementation of those rules is intended to mitigate, or improve, water quality and instream/inlake habitat conditions.

Limited habitat data have been collected in the Kinnickinnic River watershed. In general, habitat conditions have generally been described as being degraded due, in large part, to more than 60 percent of the entire river network either being comprised of enclosed conduit or concrete lined channel (see Channel Condition and Structures section below).[12] Within the natural channel sections substrate diversity, large and small woody debris, and pool and riffle structure were reported to have the potential to sustain a diverse aquatic community of fishes and macroinvertebrates.[13] However, these natural channel reaches are interrupted by the enclosed conduits and concrete lined sections making passage difficult for aquatic organisms and causing these areas to be largely isolated from the rest of the river system. In addition, some areas are reported to be polluted by high amounts of urban and industrial trash along the banks and in the stream.[14]

Lakes and Ponds
There are no major lakes (i.e. lakes greater than 50 acres in size) within the Kinnickinnic River watershed, but there are several ponds within the watershed that include Holler Park Pond, Humboldt Park Pond, Jackson Park Pond, Kosciuszko Park Pond, Saveland Park Pond, and Wilson Park Pond.

The only recorded fisheries surveys were completed for Holler Park, Saveland Park, and Wilson Park Ponds in 1981. These surveys indicated that these ponds all contained a typical urban fish species mixture of largemouth bass, pumpkinseed, green sunfish, and yellow perch. No other surveys have been completed on these or any other ponds within the Kinnickinnic River watershed to date.

It is important to note that, except for Jackson Park Pond, all of the aforementioned ponds are enrolled in the Wisconsin Department of Natural Resources' Urban Fishing Program in partnership with Milwaukee County that was initiated in 1983 for the metropolitan Milwaukee area. This program, still active today, provides fishing in these urban ponds for anglers who don't have opportunities to leave the urban environment. The program stocks rainbow trout and other species to provide seasonal and year-round fishing. In some ponds illegal stocking of goldfish and management of Eurasian Water Milfoil and Curly Leaf Pondweed macrophytes is an issue. Shoreline erosion is also a general problem around many of the ponds.

Macroinvertebrates
The Hilsenhoff Biotic Index[15] (HBI) and percent EPT (percent of families comprised of Ephemeroptera, Plecoptera, and Trichoptera) were used to classify the historic and existing macroinvertebrate and environmental quality in this stream system using survey data from various sampling locations in the Kinnickinnic River watershed.

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[12] *Inter-Fluve, Inc.,* Milwaukee County Stream Assessment, Final Report*, September 2004.*

[13] *U.S. Army Corps of Engineers,* Environmental Assessment, "*Section 14, Streambank Protection, Kinnickinnic River, Milwaukee, Milwaukee County, Wisconsin," March 2000; Hey and Associates, Inc., Prepared for Harza Engineering Company and Milwaukee Metropolitan Sewerage District,* Habitat Survey of the 43rd Street Channel, Kinnickinnic River in Milwaukee, Wisconsin, *January 2000; and Inter-Fluve, Inc.,* op. cit.

[14] *Inter-Fluve, Inc.,* op. cit.

[15] *William L. Hilsenhoff,* Rapid Field Assessment of Organic Pollution with Family-Level Biotic Index*, University of Wisconsin- Madison, 1988.*

Macroinvertebrate surveys conducted from 1987 through 2004 by the WDNR show that HBI scores generally range from poor to fair in the Kinnickinnic River watershed and Wilson Park Creek, which are the only two streams for which data are available (Figure 57 and Map 19). Figure 57 also shows that there has not been any substantial change in the macroinvertebrate community quality over time. Results generally indicate that current macroinvertebrate diversity and abundances are indicative of fair water quality in the Kinnickinnic River watershed; however, this was based only upon one sample collected during the 1998 through 2004 time period. It is important to note that macroinvertebrate abundances in two of the nine samples taken during the 1994 through 1997 period were too low to calculate an HBI value. In more than half of the samples taken within this watershed, more than 50 percent of the total number of organisms were within one family of organisms, the chironomidae (i.e. flies and midges). This high dominance by a single taxon is associated with low abundance and diversity of macroinvertebrates at these sample sites and is indicative of disturbed and/or degraded conditions within a stream.[16]

Macroinvertebrate community conditions seem to be equally poor in both the Kinnickinnic River and Wilson Park Creek, as demonstrated by both HBI and percent EPT as shown in Figure 58. Due to the lack of recent data, current macroinvertebrate community quality conditions are not available, but they are not likely to be different from the historical conditions because of the degraded habitat within this watershed.

Wisconsin researchers have generally found that as the amount of urban lands increase, such as in the Kinnickinnic River watershed, the subsequent macroinvertebrate community diversity and abundance decreases, which is supported by the data for this watershed.[17]

Synthesis

The Kinnickinnic River watershed contains a very poor fishery and macroinvertebrate communities at present. The fish community contains relatively few species of fishes, is trophically unbalanced, contains few or no top carnivores, and is dominated by tolerant fishes. The macroinvertebrate community is equally depauperate and dominated by tolerant taxa. Since water quality has generally been improving in the watershed for some constituents, habitat seems to potentially be the most important factor limiting both the fishery and macroinvertebrate community. It is also important to note there are several other factors that are likely limiting the aquatic community, including but not limited to 1) periodic stormwater loads; 2) decreased base flows; 3) continued fragmentation due to culverts and concrete lined channels, enclosed conduits, and drop structures; 4) past channelization; and/or 5) increased water temperatures due to urbanization.

Other Wildlife

Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of this study, it is possible, by polling naturalists and wildlife managers familiar with the area, to compile lists of amphibians, reptiles, birds, and mammals which may be expected to be found in the area under existing conditions. The technique used in compiling the wildlife data involved obtaining lists of those amphibians, reptiles, birds, and mammals known to exist, or known to have existed, in the Kinnickinnic River watershed area, associating these lists with the historic and remaining habitat areas in the area as inventoried, and projecting the appropriate amphibian, reptile, bird, and mammal species into the watershed area. The net result of the application of this technique is a listing of those species which were probably once present in the drainage area, those species which may be expected to still be present under currently prevailing conditions, and those species which may be expected to be lost or gained as a result of urbanization within the area. It is important to note that this inventory was conducted on a countywide basis for Milwaukee County for each of the aforementioned major groups of

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[16]*M.T. Barbour, J. Gerritsen, B.D. Snyder, and J.B. Stribling,* Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish*, Second Edition, EPA 841-B-99-002, U.S. Environmental Protection Agency, Office of Water, Washington, D.C., 1999.*

[17]*J. Masterson and R. Bannerman, "Impact of Stormwater Runoff on Urban Streams in Milwaukee County, Wisconsin," Wisconsin Department of Natural Resources, Madison, Wisconsin, 1994.*

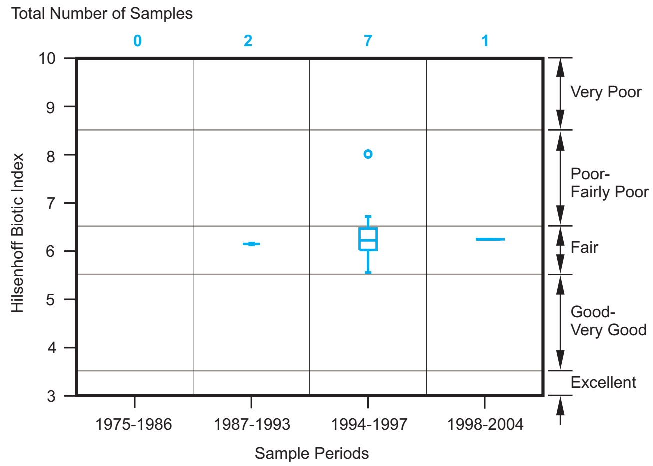
organisms. Some of the organisms listed as occurring in Milwaukee County may only infrequently occur within the Kinnickinnic River watershed.

A variety of mammals, ranging in size from large animals like the white-tailed deer, to small animals like the meadow vole, are likely to be found in the Kinnickinnic River watershed. Muskrat, white-tailed deer, gray squirrel, and cottontail rabbit are mammals reported to occur in the area. Appendix D lists the mammals whose ranges historically extended into the watershed.

A large number of birds, ranging in size from large game birds to small songbirds, are found in the Kinnickinnic River watershed. Appendix E lists those birds that normally occur in the watershed. Each bird is classified as to whether it breeds within the area, visits the area only during the annual migration periods, or visits the area only on rare occasions. The watershed also supports a significant population of waterfowl, including mallards and Canada geese. Larger numbers of various waterfowl likely move through the watershed during the annual migrations when most of the regional species may also be present. Many game birds, songbirds, waders, and raptors also reside or visit the watershed.

Figure 57

HILSENHOFF BIOTIC INDEX MACROINVERTEBRATE SCORES WITHIN THE KINNICKINNIC RIVER: 1975-2004



NOTES: See Figure 28 for description of symbols.

Macroinvertebrate abundances in two samples taken during the 1994-1997 period were too low to calculate an HBI value.

Source: Wisconsin Department of Natural Resources and SEWRPC.

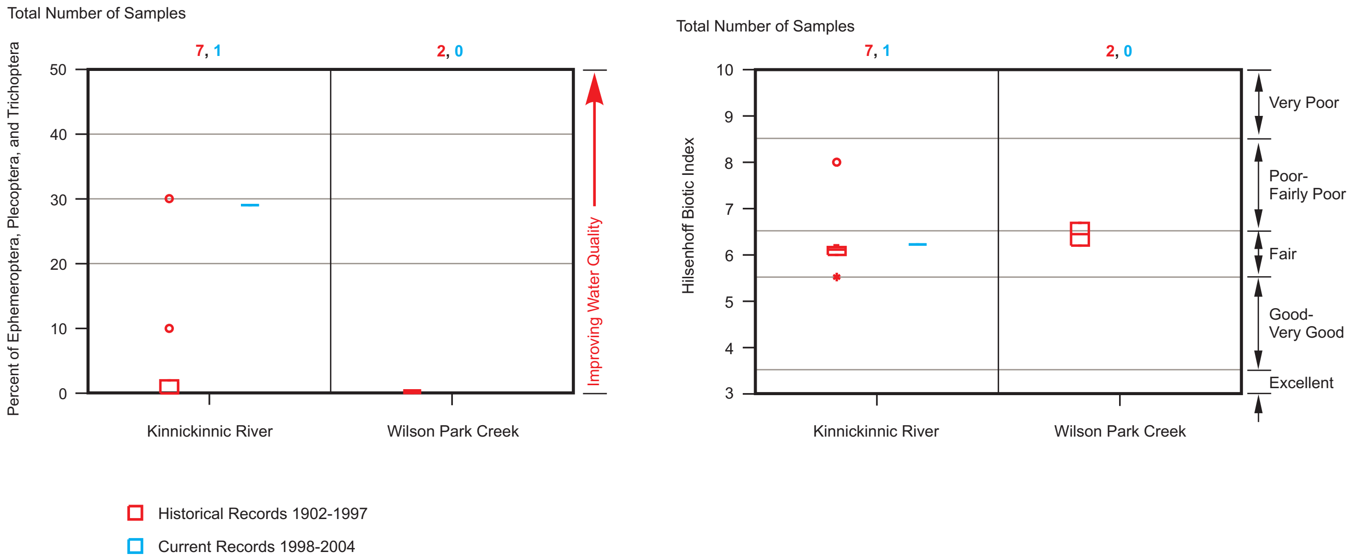
Amphibians and reptiles are vital components of the ecosystem within an environmental unit like that of the Kinnickinnic River watershed. Examples of amphibians native to the area include frogs, toads, and salamanders. Turtles and snakes are examples of reptiles common to the Kinnickinnic River area. Appendix F lists the amphibian and reptile species normally expected to be present in the Kinnickinnic River area under present conditions. Most amphibians and reptiles have specific habitat requirements that are adversely affected by advancing urban development. The major detrimental factors affecting the maintenance of amphibians in a changing environment is the destruction of breeding ponds, urban development occurring in migration routes, and changes in food sources brought about by urbanization.

Endangered and threatened species and species of special concern present within the Kinnickinnic River drainage area include 22 species of plants, one species of birds, six species of fish, one species of herptiles, and one species of invertebrates from Wisconsin Department of Natural Resources records dating back to the late 1800s (see Table 34). Since 1975, there have only been observed nine species of plants, one species of fish, one species of herptiles, and one species of invertebrates totaling to an apparent loss of 19 species.

The complete spectrum of wildlife species originally native to the watershed, along with their habitat, has undergone significant change in terms of diversity and population size since the European settlement of the area. This change is a direct result of the conversion of land by the settlers from its natural state to agricultural and urban uses, beginning with the clearing of the forest and prairies, the draining of wetlands, and ending with the development of extensive urban areas. Successive cultural uses and attendant management practices, primarily urban, have been superimposed on the land use changes and have also affected the wildlife and wildlife habitat. In urban areas, cultural management practices that affect wildlife and their habitat include the use of fertilizers, herbicides, and pesticides; road salting for snow and ice control; heavy motor vehicle traffic that produces disruptive noise levels and air pollution and nonpoint source water pollution; and the introduction of domestic pets.

Figure 58

HISTORICAL AND BASE PERIOD PERCENT EPHEMEROPTERA, PLECOPTERA, AND TRICHOPTERA (EPT) MACROINVERTEBRATE GENERA AND HILSENHOFF BIOTIC INDEX (HBI) SCORES IN STREAMS IN THE KINNICKINNIC RIVER WATERSHED: 1975-2004



NOTES: See Figure 28 for description of symbols.

Macroinvertebrate abundances in two samples taken during the 1994-1997 period were too low to calculate an HBI value.

Source: Wisconsin Department of Natural Resources and SEWRPC.

CHANNEL CONDITIONS AND STRUCTURES

The conditions of the bed and bank of a stream are greatly affected by the flow of water through the channel. The great amount of energy possessed by flowing water in a stream channel is dissipated along the stream length by turbulence, streambank and streambed erosion, and sediment resuspension. Sediments and associated substances delivered to a stream may be stored, at least temporarily, on the streambed, particularly where obstructions or irregularities in the channel decrease the flow velocity or act as particle traps or filters. On an annual basis or a long-term basis, streams may exhibit net deposition, net erosion, or no net change in internal sediment transport, depending on tributary land uses, watershed hydrology, precipitation, and geology. From 3 to 11 percent of the annual sediment yield in a watershed in southeastern Wisconsin may by contributed by streambank erosion.[18] In the absence of mitigative measures, increased urbanization in a watershed may be expected to result in increased streamflow rates and volumes, with potential increases in streambank erosion and bottom scour, and flooding problems. In the communities in the Kinnickinnic River watershed, the requirements of MMSD Chapter 13, "Surface Water and Storm Water," are applied to mitigate instream increases in peak rates of flow that could occur due to new urban development without runoff controls. Also, where soil conditions allow, the infiltration standards of Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* are applied to limit increases in runoff volume from new development.

[18] *SEWRPC Technical Report No. 21,* Sources of Water Pollution in Southeastern Wisconsin: 1975, *September 1978.*

Table 34

ENDANGERED AND THREATENED SPECIES AND SPECIES OF SPECIAL CONCERN IN THE KINNICKINNIC RIVER WATERSHED: 2004

Common Name	Scientific Name	Status under the U.S. Endangered Species Act	Wisconsin Status
Crustacea			
Prairie Crayfish	*Procambarus gracilis*	Not listed	Special concern
Fish			
American Eel[a]	*Anguilla rostrata*	Not listed	Special concern
Banded Killifish[a]	*Fundulus diaphanus*	Not listed	Special concern
Greater Redhorse	*Moxostoma valenciennesi*	Not listed	Threatened
Longear Sunfish[a]	*Lepomis magalotis*	Not listed	Threatened
Redfin Shiner[a]	*Lythrurus umbratilis*	Not listed	Threatened
Striped Shiner[a]	*Luxilus chrysocephalus*	Not listed	Endangered
Reptiles and Amphibians			
Butler's Garter Snake	*Thamnophis butleri*	Not listed	Threatened
Birds			
Black Crowned Night Heron[a]	*Nycticorax nycticorax*	Not listed	Special concern
Plants			
American Sea Rocket	*Cakile edentula*	Not listed	Special concern
American Gromwell	*Lithospermum latifolium*	Not listed	Special concern
Bluestem Goldenrod	*Solidago caesia*	Not listed	Endangered
False Hop Sedge[a]	*Carex lupuliformis*	Not listed	Endangered
Great Indian-Plantain[a]	*Cacalia muehlenbergii*	Not listed	Special concern
Hairy Beardtongue[a]	*Penstemon hirsutus*	Not listed	Special concern
Harbinger-of-Spring[a]	*Erigenia bulbosa*	Not listed	Endangered
Hooker Orchis[a]	*Platanthera hookeri*	Not listed	Special concern
Indian Cucumber Root[a]	*Medeola virginiana*	Not listed	Special concern
Lesser Fringed Gentain	*Gentianopsis procera*	Not listed	Special concern
Marsh Blazing Star[a]	*Liatris spicata*	Not listed	Special concern
Ohio Goldenrod	*Solidago ohioensis*	Not listed	Special concern
Purple False Oats[a]	*Trisetum melicoides*	Not listed	Endangered
Reflexed Trillium	*Trillium recurvatum*	Not listed	Special concern
Seaside Spurge[a]	*Euphorbia polygonifolia*	Not listed	Special concern
Showy Lady's Slipper[a]	*Cypripedium reginae*	Not listed	Special concern
Slender Bog Arrow Grass	*Triglochin palustris*	Not listed	Special concern
Small White Lady's Slipper[a]	*Cypripedium candidum*	Not listed	Threatened
Small Yellow Lady's-Slipper[a]	*Cypripedium calceolus*	Not listed	Special concern
Sticky False Asphodel	*Tofieldia glutinosa*	Not listed	Threatened
Variegated Horsetail	*Equisetum variegatum*	Not listed	Special concern
Wild Licorice[a]	*Glycyrrhiza lepidota*	Not listed	Special concern

[a]*Species observed prior to year 1975.*

Source: Wisconsin Department of Natural Resources, Wisconsin State Herbarium, Wisconsin Society of Ornithology, and SEWRPC.

Milwaukee County commissioned an assessment of stability and fluvial geomorphic character of streams within four watersheds in the County including the Kinnickinnic River watershed.[19] This study, conducted in fall 2003, examined channel stability in about six miles of stream channel along the mainstem of the Kinnickinnic River and several of its tributaries. In addition, a major goal of the study was to create a prioritized list of potential project sites related to mitigation of streambank erosion and channel incision, responses to channelization, and maintenance of infrastructure integrity. The impacts of development on streamflow rates and volumes can be mitigated to some degree by properly installed and maintained stormwater management practices. Some level of control is

[19]*Inter-Fluve, Inc.,* op. cit.

required by current regulations. The effectiveness of such regulations is, in part, dependent upon the level of compliance with, and enforcement of, the regulations.

Map 20 shows the types of channel bed lining in streams within the Kinnickinnic River watershed. Outside the estuary, a large portion of the mainstem of the Kinnickinnic River is concrete-lined. The bed of the upper two-mile reach is not lined with concrete. This reach is laterally unstable and severely incised (see Bed and Bank Stability section below). Comparisons of current longitudinal bed profiles with historical profiles indicate that four to five feet of incision have occurred in this section since the 1970s.[20] Cherokee Park Creek, Edgerton Ditch, Holmes Avenue Creek, Lyons Park Creek, S. 43rd Street Ditch, and Wilson Park Creek all have significant portions that are either concrete-lined or that are enclosed in underground conduit.

The stream network has been substantially modified over much of the watershed. Of the 29 miles of channel examined, about 8.7 miles, or 30 percent, are lined with concrete and about 8.1 miles, or 28 percent, are enclosed in conduit, with the remaining 42 percent consisting of natural channel bottom material (Map 20). In many reaches, portions of the concrete lining are failing. In addition, these areas offer minimal ecological and aesthetic benefit.[21]

Bed and Bank Stability

Alluvial streams within urbanizing watersheds often experience rapid channel enlargement. As urbanization occurs, the fraction of the watershed covered by impervious materials increases. This can result in profound changes in the hydrology in the watershed. As a result of runoff being conveyed over impervious surfaces to storm sewers which discharge directly to streams, peak flows become higher and more frequent and streams become "flashier" with flows increasing rapidly in response to rainfall events. The amount of sediment reaching the channel often declines. Under these circumstances and in the absence of armoring, the channel may respond by incising. This leads to an increase in the height of the streambank, which continues until a critical threshold for stability is exceeded. When that condition is reached, mass failure of the bank occurs, leading to channel widening. Typically, incision in an urbanizing watershed proceeds from the mouth to the headwaters.[22] Lowering of the channel bed downstream increases the energy gradient upstream and in the tributaries. This contributes to further destabilization. Once it begins, incision typically follows a sequence of channel bed lowering, channel widening, and deposition of sediment within the widened channel. Eventually, the channel returns to a stable condition characteristic of the altered channel geometry.

Map 21 summarizes bank stability for the Kinnickinnic River and several of its tributaries.[23] Since a large portion of the watershed contains channels which are enclosed in conduit or concrete-lined, only about six miles of channel were inventoried for stability as shown on Map 21. Most alluvial reaches that were examined appeared to be degrading and actively eroding (see Figure 59). Less than 5 percent of the total 6.1 miles assessed were observed to be stable. That stable reach is located on the Lower Kinnickinnic River as shown on Map 21 and Figure 59. All of the rest of the reaches assessed within the upper portions of the Kinnickinnic River, S. 43rd Street Ditch, Lyons Park Creek, Cherokee Park Creek, Villa Mann Creek, and Wilson Park Creek were observed to be eroding (Figure 59).

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[20]Ibid.

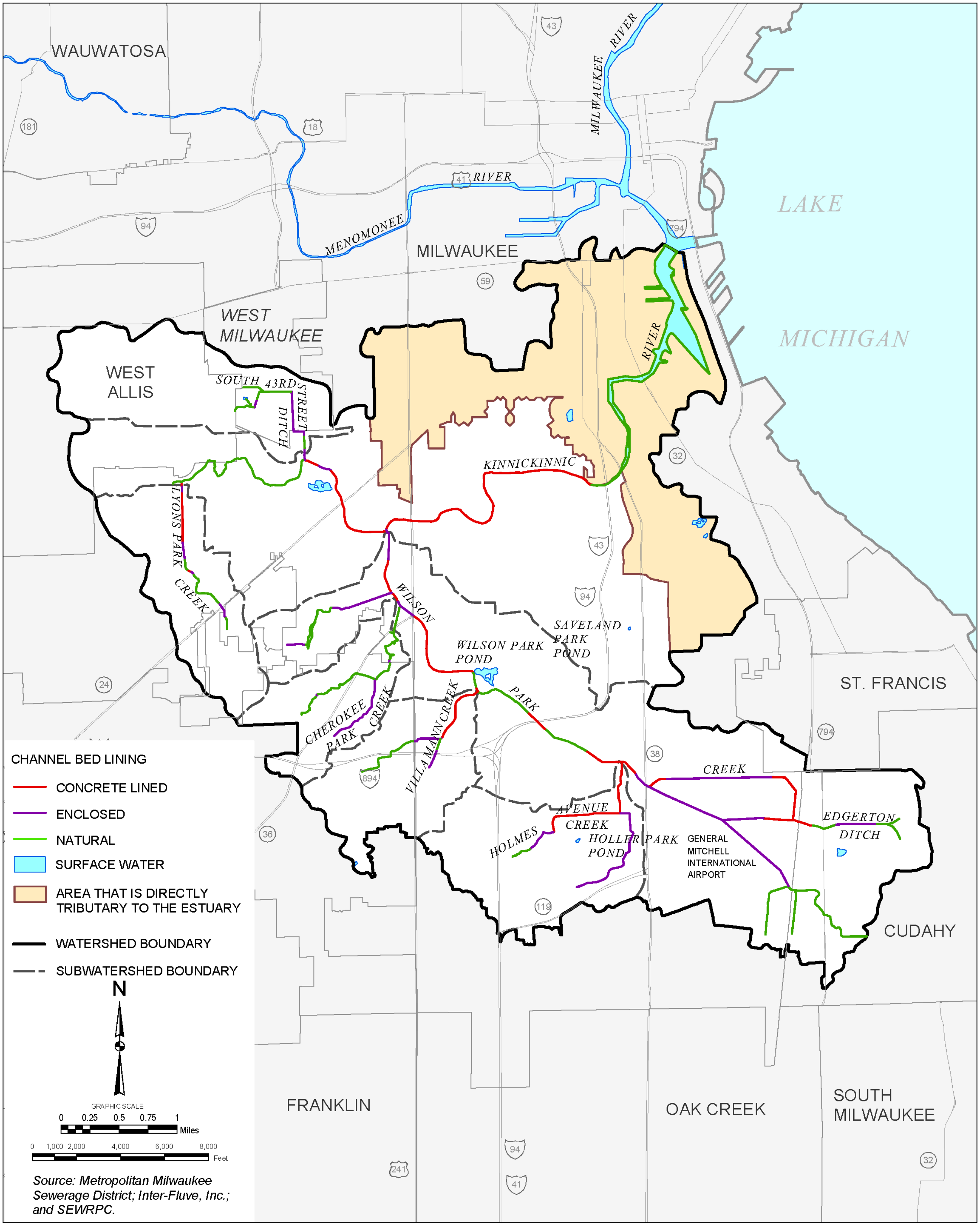
[21]*Inter-Fluve, Inc.,* op. cit.

[22]*S.A. Schumm, "Causes and Controls of Channel Incision," In: S. E. Darby and A. Simon (eds.),* Incised River Channels: Processes, Forms, Engineering and Management, *John Wiley & Sons, New York, 1999.*

[23]*Inter-Fluve, Inc.,* op. cit.

Map 20

CHANNEL BED CONDITIONS WITHIN THE KINNICKINNIC RIVER WATERSHED: 2000



Source: Metropolitan Milwaukee Sewerage District; Inter-Fluve, Inc.; and SEWRPC.

Map 21

STREAMBANK STABILITY CONDITIONS WITHIN THE KINNICKINNIC RIVER WATERSHED: 2000

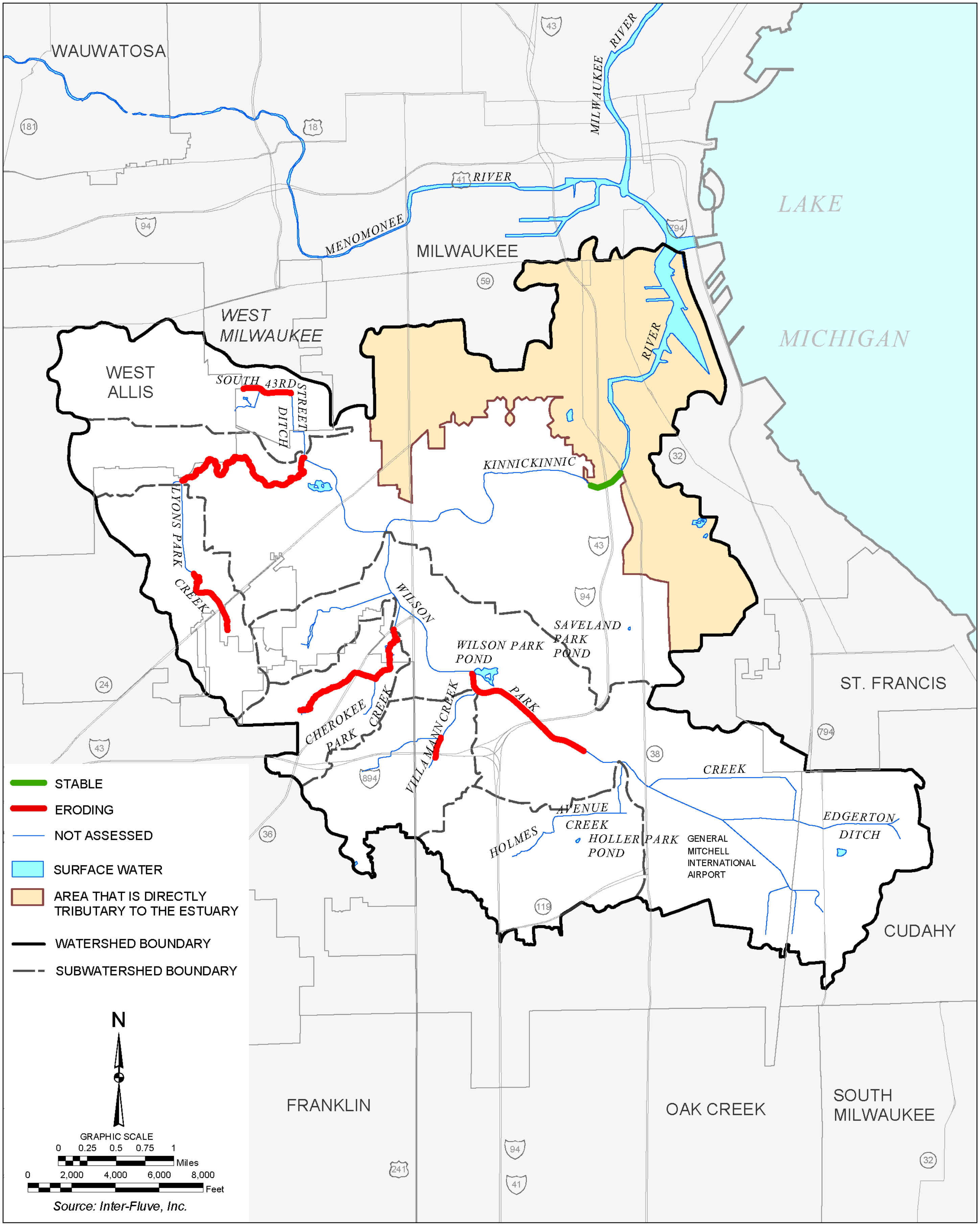


Figure 59

STREAMBANK STABILITY CONDITIONS AMONG REACHES WITHIN THE KINNICKINNIC RIVER WATERSHED: 2003

WILSON PARK CREEK (RM 2.02)

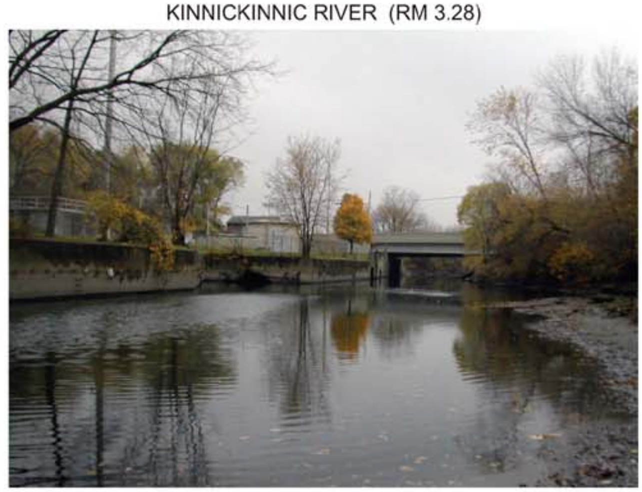
SOUTH 43RD STREET DITCH (RM 0.85)

CHEROKEE PARK CREEK (RM 0.34)

KINNICKINNIC RIVER (RM 6.95)

LYONS PARK CREEK (RM 0.96)

KINNICKINNIC RIVER (RM 3.28)



Source: Milwaukee County and Inter-Fluve, Inc.

Work Progress Administration (WPA) Walls

The WPA walls were constructed as flood management structures in the 1920s and 1930s along several streams in the Milwaukee metropolitan area. Depending on location, these walls either form the active channel margin or are located within the active floodplain. They serve as channel boundaries and act to inhibit lateral channel migration and associated erosion. They are made from mortared limestone blocks and are generally about two feet thick. They vary in height from five to 12 feet depending on local channel bed, bank, and floodplain elevations. These walls are about 70 years old. As they degrade over time, increases in lateral bank instability and flooding are likely results. Relatively stable WPA walls are present in the upper portion of the Kinnickinnic River.

Dams

There is currently one dam within the Kinnickinnic River watershed. It is a low sill located on Cherokee Park Creek as shown on Map 22. In addition, numerous drop structures are located in Lyons Park Creek and Villa Mann Creek. These structures can disrupt sediment transport and limit aquatic organism passage in these systems, which serves to fragment these populations reducing overall abundance and diversity.

HABITAT AND RIPARIAN CORRIDOR CONDITIONS

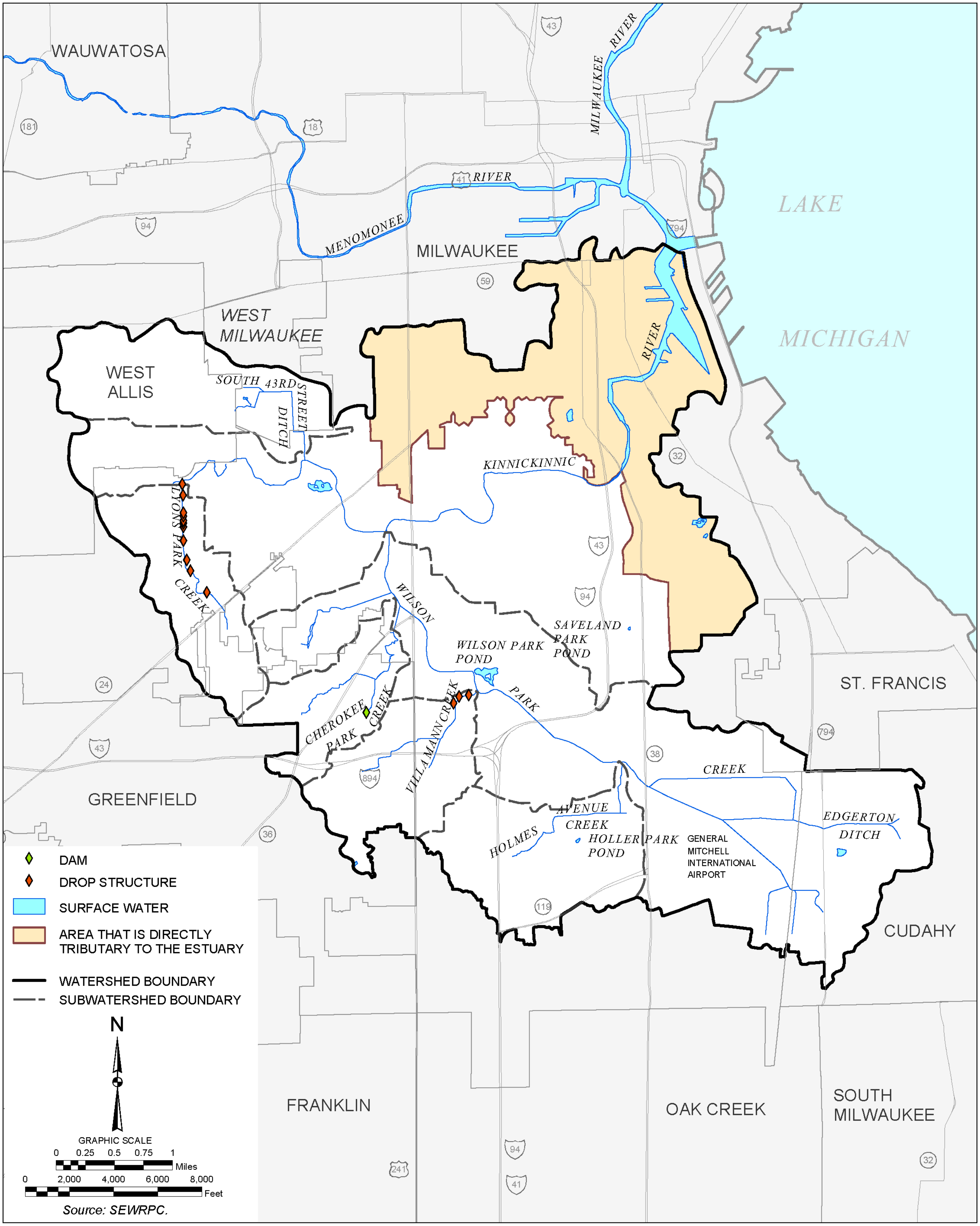
One of the most important tasks undertaken by the Commission as part of its regional planning effort was the identification and delineation of those areas of the Region having high concentrations of natural, recreational, historic, aesthetic, and scenic resources and which, therefore, should be preserved and protected in order to maintain the overall quality of the environment. Such areas normally include one or more of the following seven elements of the natural resource base which are essential to the maintenance of both the ecological balance and the natural beauty of the Region: 1) lakes, rivers, and streams and the associated undeveloped shorelands and floodlands; 2) wetlands; 3) woodlands; 4) prairies; 5) wildlife habitat areas; 6) wet, poorly drained, and organic soils; and 7) rugged terrain and high-relief topography. While the foregoing seven elements constitute integral parts of the natural resource base, there are five additional elements which, although not a part of the natural resource base per se, are closely related to or centered on that base and therefore are important considerations in identifying and delineating areas with scenic, recreational, and educational value. These additional elements are: 1) existing outdoor recreation sites; 2) potential outdoor recreation and related open space sites; 3) historic, archaeological, and other cultural sites; 4) significant scenic areas and vistas; and 5) natural and scientific areas.

The delineation of these 12 natural resource and natural resource-related elements on a map results in an essentially linear pattern of relatively narrow, elongated areas which have been termed "environmental corridors" by the Commission. Primary environmental corridors include a wide variety of the abovementioned important resource and resource-related elements and are at least 400 acres in size, two miles in length, and 200 feet in width. Secondary environmental corridors generally connect with the primary environmental corridors and are at the least 100 acres in size and one mile long. In addition, smaller concentrations of natural resource features that have been separated physically from the environmental corridors by intensive urban or agricultural land uses have also been identified. These areas, which are at least five acres in size, are referred to as isolated natural resource areas.

It is important to point out that, because of the many interlocking and interacting relationships between living organisms and their environment, the destruction or deterioration of any one element of the total environment may lead to a chain reaction of deterioration and destruction among the others. The drainage of wetlands, for example, may have far-reaching effects, since such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas of interconnecting lake and stream systems. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater. Groundwater serves as a source of domestic, municipal, and industrial water supply and provides a basis for low flows in rivers and streams. Similarly, the destruction of woodland cover, which may have taken a century or more to develop, may result in soil erosion and stream siltation and in more rapid runoff and increased flooding, as well as destruction of wildlife habitat. Although the effects of any one of these environmental changes may not in and of itself be overwhelming, the combined effects may lead eventually to the

Map 22

DAM AND DROP STRUCTURES WITHIN THE KINNICKINNIC RIVER WATERSHED: 2005



Source: SEWRPC.

deterioration of the underlying and supporting natural resource base, and of the overall quality of the environment for life. The need to protect and preserve the remaining environmental corridors within the drainage area directly tributary to Kinnickinnic River system thus becomes apparent.

Primary Environmental Corridors

The primary environmental corridors in Southeastern Wisconsin generally lie along major stream valleys and around major lakes, and contain almost all of the remaining high-value woodlands, wetlands, and wildlife habitat areas, and all of the major bodies of surface water and related undeveloped floodlands and shorelands. As shown on Map 23, in the year 2000 primary environmental corridors in the Kinnickinnic River drainage area encompassed about 15 acres, or less than one-half of one percent of the drainage area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of primary environmental corridors within the watershed. Primary environmental corridors may be subject to urban encroachment because of their desirable natural resource amenities. Unplanned or poorly planned intrusion of urban development into these corridors, however, not only tends to destroy the very resources and related amenities sought by the development, but tends to create severe environmental and development problems as well. These problems include, among others, water pollution, flooding, wet basements, failing foundations for roads and other structures, and excessive infiltration of clear water into sanitary sewerage systems.

Secondary Environmental Corridors

Secondary environmental corridors are located generally along intermittent streams or serve as links between segments of primary environmental corridors. As shown on Map 23, secondary environmental corridors in the Kinnickinnic River drainage area encompassed about 182 acres, or about 1 percent of the drainage area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of secondary environmental corridors within the watershed. Secondary environmental corridors contain a variety of resource elements, often remnant resources from primary environmental corridors which have been developed for intensive agricultural purposes or urban land uses, and facilitate surface water drainage, maintain “pockets” of natural resource features, and provide for the movement of wildlife, as well as for the movement and dispersal of seeds for a variety of plant species.

Isolated Natural Resource Areas

In addition to primary and secondary environmental corridors, other small concentrations of natural resource base elements exist within the drainage area. These concentrations are isolated from the environmental corridors by urban development or agricultural lands and, although separated from the environmental corridor network, have important natural values. These isolated natural resource areas may provide the only available wildlife habitat in a localized area, provide good locations for local parks and nature study areas, and lend a desirable aesthetic character and diversity to the area. Important isolated natural resource area features include a variety of isolated wetlands, woodlands, and wildlife habitat. These isolated natural resource area features should also be protected and preserved in a natural state whenever possible. Such isolated areas five or more acres in size within the Kinnickinnic River drainage area also are shown on Map 23 and total about 100 acres, or less than 1 percent of the drainage area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of isolated natural resource areas within the watershed.

Natural Areas and Critical Species Habitat

The regional natural areas and critical species habitat protection and management plan[24] ranked natural resource features based upon a system that considered areas to be of statewide or greater significance, NA-1; countywide or regional significance, NA-2; or local significance, NA-3. In addition, certain other areas were identified as critical species habitat sites. Within the Kinnickinnic River drainage area there were no sites identified as natural areas or critical species habitat sites.

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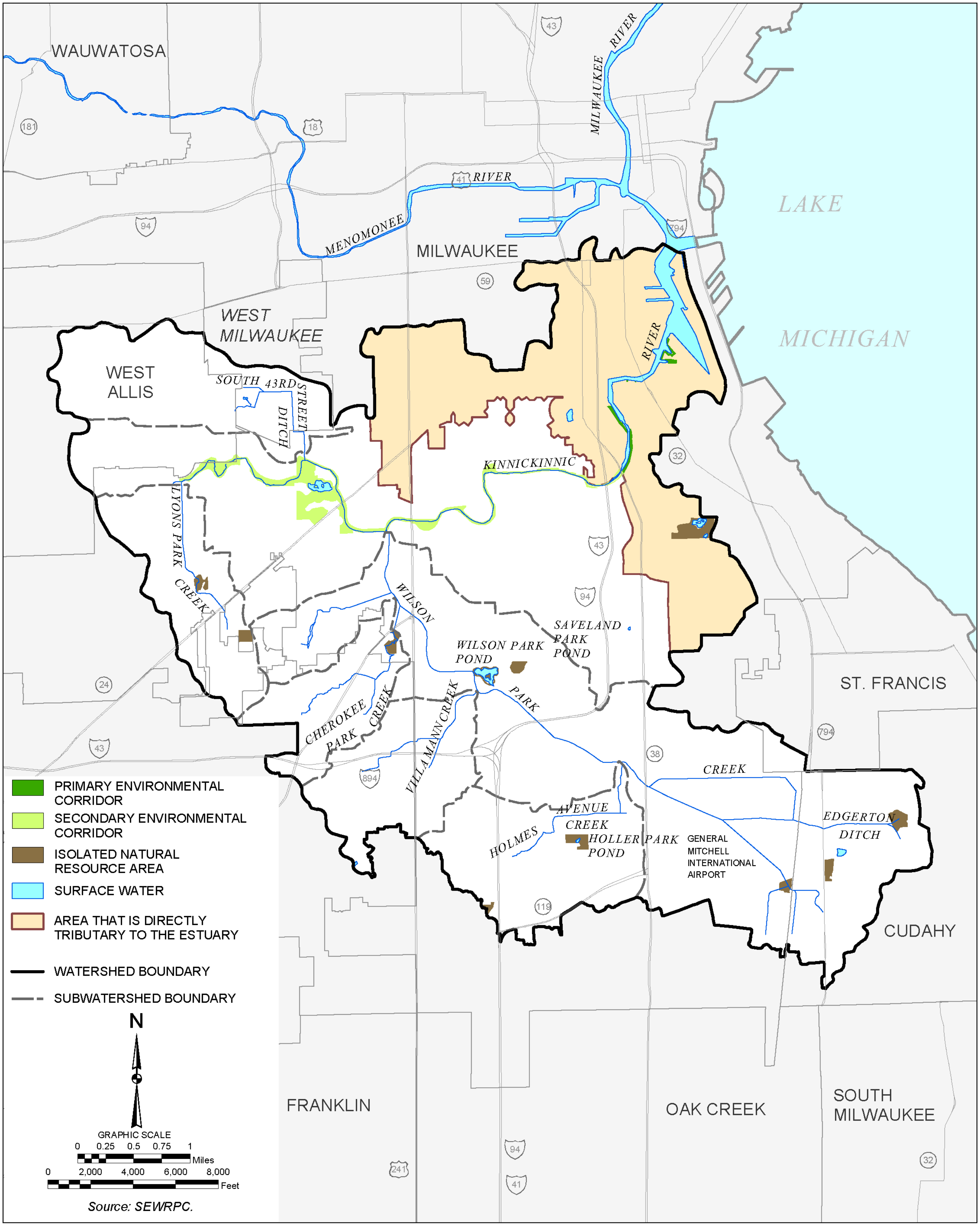
[24]*SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*, September 1997.*

Map 23

ENVIRONMENTAL CORRIDORS WITHIN THE KINNICKINNIC RIVER WATERSHED: 2000



Source: SEWRPC.

Measures for Habitat Protection
Within the Kinnickinnic River basin, as in the rest of Milwaukee County, stream corridor protection has been focused on public acquisition of the lands adjacent to the stream banks and their preservation as river parkways. These lands are frequently incorporated into public parks and other natural areas.

The provision of buffer strips around waterways, in every case, represents an important intervention that addresses anthropogenic sources of contaminants, with even the smallest buffer strip providing environmental benefit.[25] Map 24 shows the current status of riparian buffers along the Kinnickinnic River and its major tributary streams. Approximately 12.4 miles of the Kinnickinnic River systems, concentrated within the Wilson Park Creek and S. 43rd Street Ditch subbasins, are enclosed conduits, and offer limited opportunity for installation of such buffers as shown on Map 24. In general, buffers greater than 75 feet in width are largely associated with adjacent recreational and park lands within the Kinnickinnic River watershed.

Figure 60 shows the current status of buffer widths ranging from less than 25 feet, 25 to 50 feet, 50 to 75 feet, and greater than 75 feet among each of the major Kinnickinnic River subwatersheds. All of the subwatersheds are dominated by buffers less than 25 feet in width, which generally account for about 55 to 80 percent of the buffer widths in the subwatersheds. The subwatersheds contained an average of about 4 percent and 5 percent of the buffer categories that ranged from 25 to 50 feet in width and 50 to 75 feet in width, respectively. The subwatersheds with the greatest proportion of the buffers greater than 75 feet in width include the Kinnickinnic River, Cherokee Park Creek, and Lyons Park Creek.

SUMMARY AND STATUS OF IMPLEMENTATION OF ELEMENTS OF THE REGIONAL WATER QUALITY MANAGEMENT PLAN IN THE KINNICKINNIC RIVER WATERSHED

The initial regional water quality management plan for the Southeastern Wisconsin Region which was adopted in 1979, had five elements: a land use element, a point source pollution abatement element, a nonpoint source pollution abatement element, a sludge management element, and a water quality monitoring element.[26] For the purposes of documenting current conditions and trends in water quality and pollution sources, it is deemed important to redocument the point source and nonpoint source pollution abatement elements of the regional water quality management plan as amended. This section provides that redocumentation and describes the action taken to implement that plan. Those two specific elements of the plan as they relate to the Kinnickinnic River watershed and actions taken to implement them are described below for those components of the plan elements most directly related to water quality conditions.

Point Source Pollution Abatement Plan Element
A preliminary recommendation to abate separate sanitary sewer overflows and combined sewer overflows through the provision of large subterranean conveyance and storage facilities to contain separate and combined sewer peak flows in excess of sewage system capacity was originally made in the comprehensive plan for the Milwaukee River watershed.[27] The initial regional water quality management plan deferred recommendation on adoption of this alternative pending completion of the facility planning related to MMSD's Water Pollution

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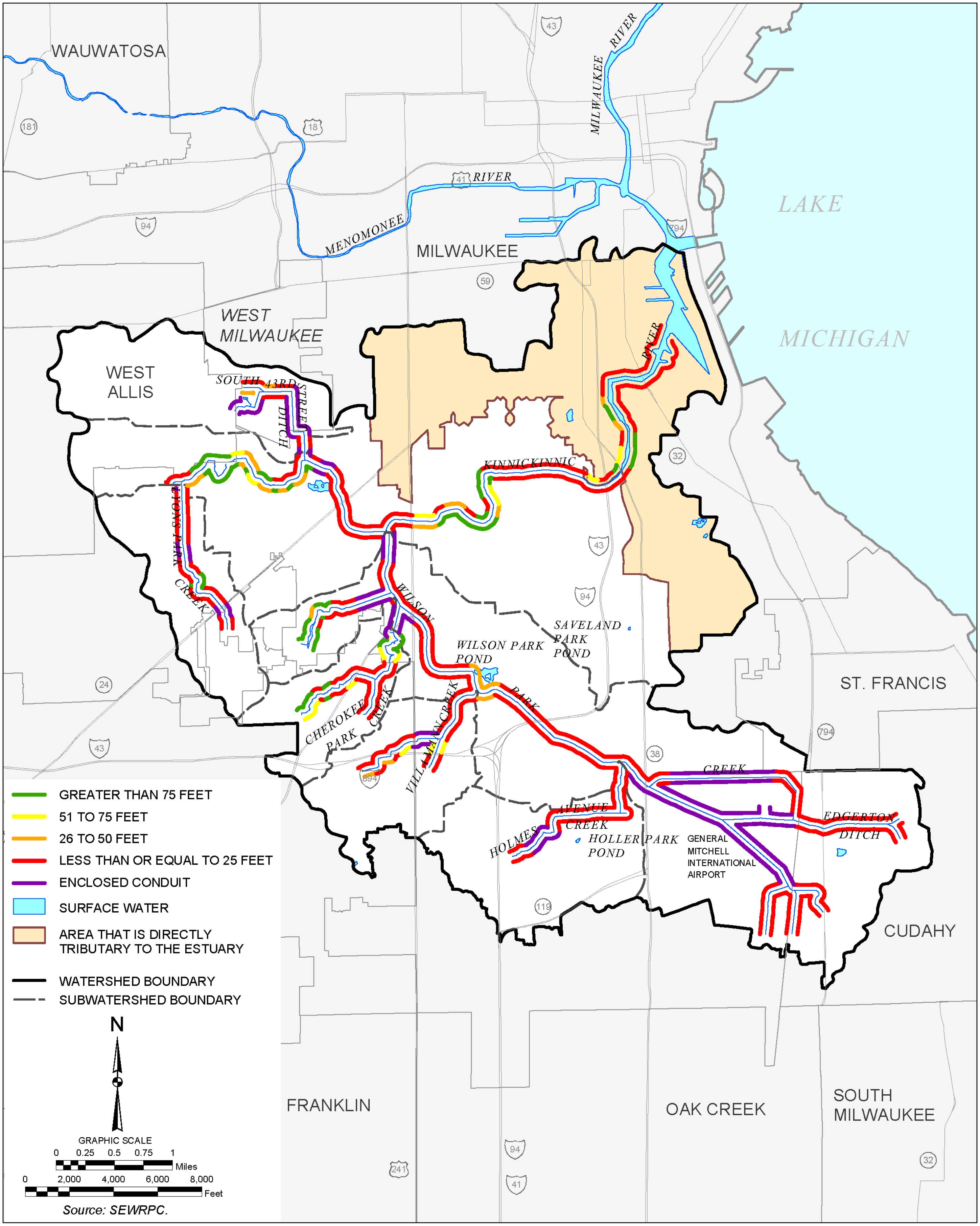
[25]*A. Desbonnet, P. Pogue, V. Lee, and N. Wolff, "Vegetated Buffers in the Coastal Zone - a summary review and bibliography,"* CRC Technical Report No. 2064*. Coastal Resources Center, University of Rhode Island, 1994.*

[26]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume One,* Inventory Findings, *September 1978; Volume Two,* Alternative Plans, *February 1979; Volume Three,* Recommended Plan*, June 1979.*

[27]*SEWRPC Planning Report No. 13,* A Comprehensive Plan for the Milwaukee River Watershed, *Volume One,* Inventory Findings and Forecasts, *December 1970; Volume Two,* Alternative Plans and Recommended Plan, *October 1971.*

Map 24

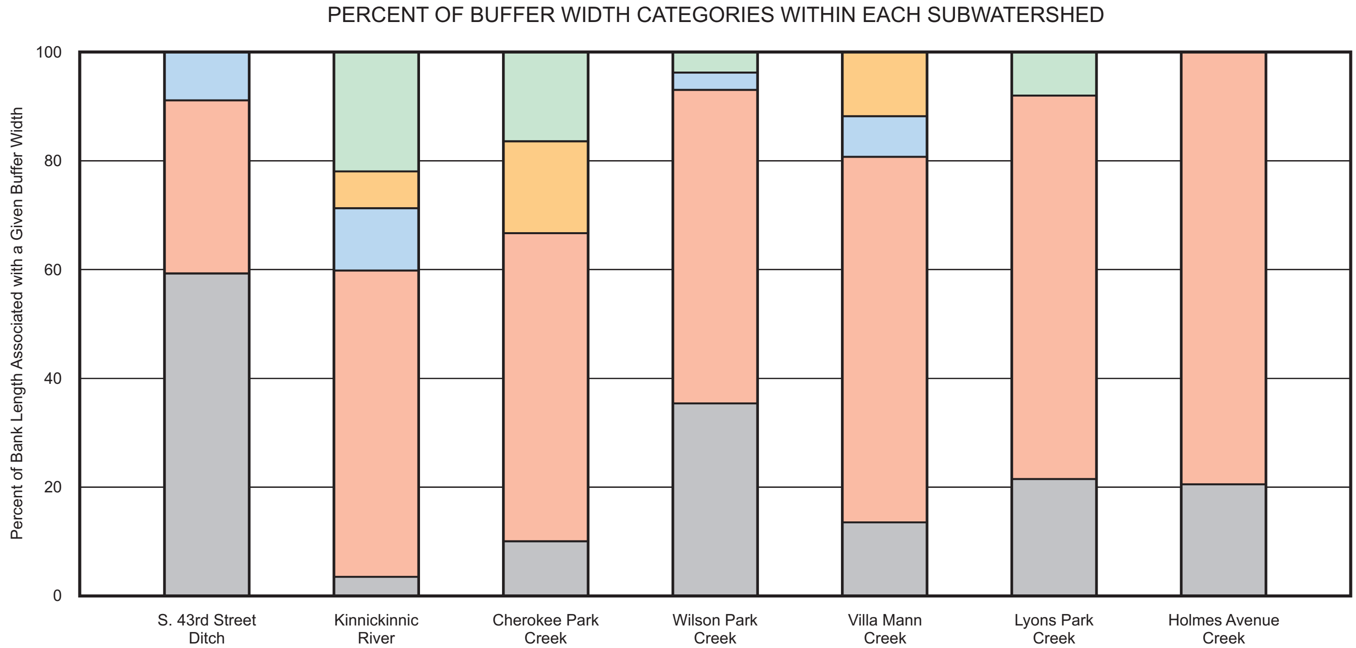
RIPARIAN CORRIDOR WIDTHS WITHIN THE KINNICKINNIC RIVER WATERSHED : 2000

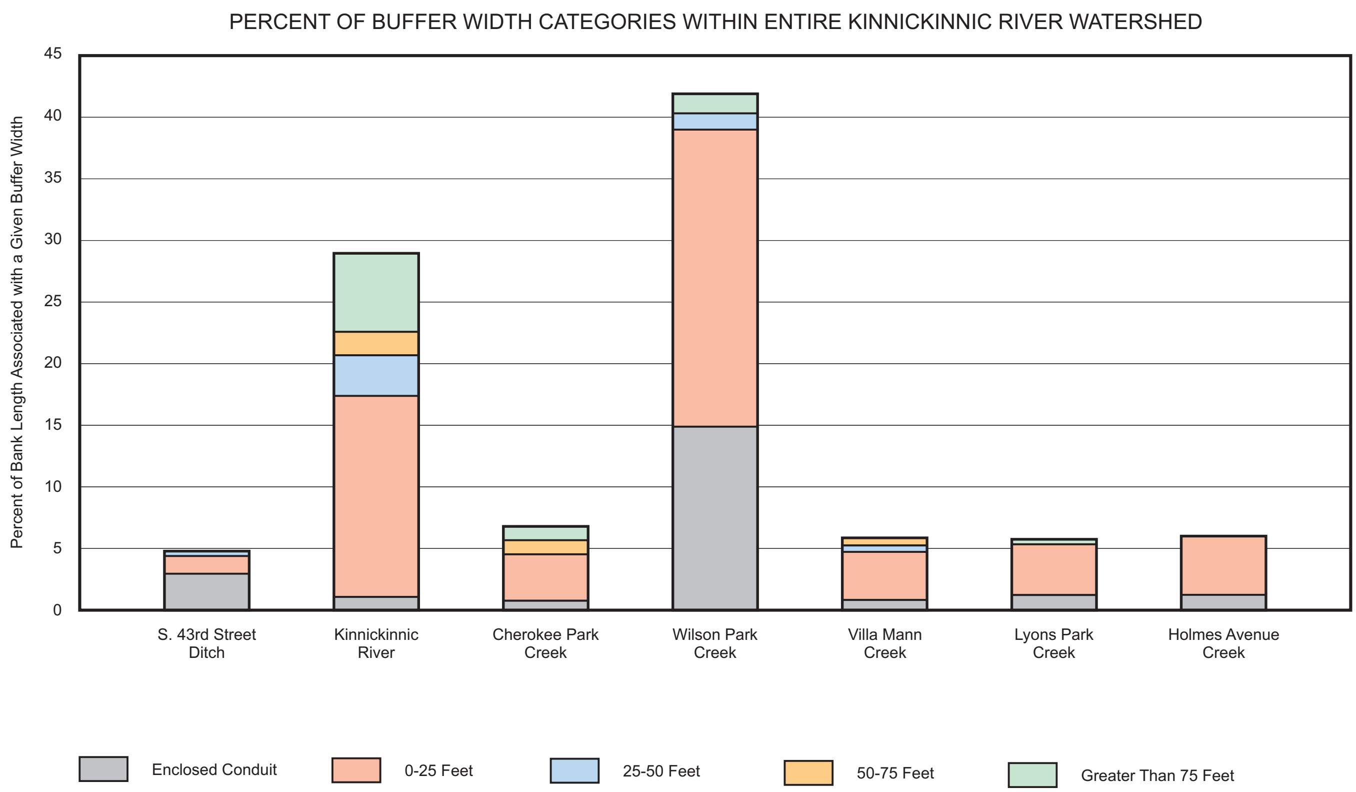


Source: SEWRPC.

Figure 60

RIPARIAN CORRIDOR BUFFER WIDTHS WITHIN THE KINNICKINNIC RIVER WATERSHED: 2000





Source: SEWRPC.

Abatement Program. This planning effort, documented in a series of reports by MMSD,[28] recommended construction of a deep tunnel inline storage system in conjunction with construction of a shallow relief sewer system. These recommendations were adopted as an amendment to the regional water quality management plan as part of the water resources management plan for the Milwaukee Harbor estuary.[29] This system was subsequently constructed and began operation in 1994.

In 1975, there were 23 combined sewer outfalls and 29 known separate sewer overflow relief devices located in the Kinnickinnic River watershed. Combined sewer overflows typically occurred over 50 times per year. Currently combined sewer overflows have been reduced to less than three per year. Likewise, the number of separate sanitary sewer overflows has been markedly reduced from the 1975 conditions.

In 1975, there were 30 point sources of wastewater other than public and private sewage treatment plants. These sources discharged industrial cooling, process, rinse, and wash waters through 60 outfalls directly, or indirectly, to the surface water system. The initial regional water quality management plan included a recommendation that these industrial point sources of wastewater be monitored, and discharges limited to levels determined on a case-by-case basis under the Wisconsin Pollutant Discharge Elimination System (WPDES) permit process. Currently, this recommendation has been nearly fully implemented for the point sources that currently exist in the watershed, the only exception being an unplanned discharge or spill.

Due to the dynamic nature of permitted point sources, it is recognized that the number of wastewater sources changes as industries and other facilities change locations or processes and as decisions are made with regard to the connection of such sources to public separate sanitary sewer systems. Many of the historical dischargers are now connected to the public separate sanitary sewer system.

Nonpoint Source Pollution Abatement Plan Element

The nonpoint source element of the original plan described a variety of methods and practices for abatement of nonpoint source pollution in urban and rural areas and estimated the percent reduction of released pollutants that could be achieved through implementation of these methods and practices. It identified phosphorus and fecal coliform bacteria as pollutants requiring nonpoint source control in the Kinnickinnic River watershed. For urban areas, it recommended construction site erosion control and implementation of urban land practices sufficient to produce a 25 percent reduction in pollutants released to the streams of the watershed. For rural areas, it recommended conservation practices sufficient to produce a 25 percent reduction in pollutants released to the streams of the watershed. In addition, it noted that excessive levels of toxic and hazardous materials had previously been documented to exist in the Kinnickinnic River and its tributaries.[30] Studies are currently being conducted to address remediation of this issue.

In 1990, the Kinnickinnic River Watershed was designated a priority watershed under the Wisconsin Nonpoint Source Priority Watershed Pollution Abatement Program.[31] This plan identified the need for reductions in total

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[28]*Milwaukee Metropolitan Sewerage District,* Combined Sewer Overflows, *June 1980; Milwaukee Metropolitan Sewerage District,* Inline Storage Facilities Plan, *February 1982; Milwaukee Metropolitan Sewerage District,* Combined Sewer Overflows Advanced Facilities Plan, *December 1983.*

[29]*SEWRPC Planning Report No. 37,* A Water Resources Management Plan for the Milwaukee Harbor Estuary, *Volume One,* Inventory Findings, *March 1987; Volume Two,* Alternative and Recommended Plans, *December 1987.*

[30]*SEWRPC Planning Report No. 32,* A Comprehensive Plan for the Kinnickinnic River Watershed, *December 1978.*

[31]*Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the Kinnickinnic River Priority Watershed Project, *Publication WR-378-94, October 1994.*

pollutant loadings, including heavy metal loadings, phosphorus loadings, and sediment loadings to the streams of the watershed in order to meet water quality objectives. In addition, it recommended a number of management actions and practices to be implemented over the period 1994 to 2001 for both urban and rural lands and provided funding for a variety of activities related to abatement of nonpoint source pollution. The plan recommendations for nonpoint source pollution control were partially implemented as of 2005.

Several additional measures to abate nonpoint source pollution have been instituted since adoption of the initial plan. Facilities engaged in certain industrial activities have been required to apply for and obtain stormwater discharge permits under the WPDES and to develop and follow storm water pollution prevention plans. All the communities in the watershed have applied for WPDES discharge permits, and have adopted construction site erosion control ordinances. All of the communities except the Village of West Milwaukee have adopted stormwater management plans or ordinances. These communities will be required to develop new or update existing stormwater management ordinances to be consistent with the standards of Chapter NR 151 of the *Wisconsin Administrative Code.* Stormwater management measures are described more fully in the section on nonpoint source pollution in this chapter.

SOURCES OF WATER POLLUTION

An evaluation of water quality conditions in the Kinnickinnic River watershed must include an identification, characterization, and where feasible, quantification of known pollution sources. This identification, characterization, and quantification is intended to aid in determining the probable causes of water pollution problems.

Point Source Pollution

Point source pollution is defined as pollutants that are discharged to surface waters at discrete locations. Examples of such discrete discharge points include separate sanitary sewerage system flow relief devices, sewage treatment plant discharges, and industrial discharges.

Sewage Treatment Plants

In 1975, there were no public sewage treatment facilities located in or discharging to the Kinnickinnic River watershed. Currently, the Milwaukee Metropolitan Sewerage District Jones Island and South Shore treatment plants serve the existing sewered portions of the Kinnickinnic River watershed. It should be noted that in 1975, the base year of the initial plan, and in 1990, there were no privately owned sewage treatment plants discharging to the stream system of the Kinnickinnic River watershed. There are currently no privately owned sewage treatment plants in the Kinnickinnic River watershed.

The initial regional water quality management plan recommended that all of the sanitary sewer service areas identified in the plan be refined and detailed in cooperation with the local units of government concerned. The entire Kinnickinnic River watershed is part of the Milwaukee Metropolitan Sewerage District which is currently unrefined. The planned sewer service area includes the entire 24.5-square-mile watershed.

Sanitary Sewer Overflow (SSO) Sites in the Watershed

By 1993, work was completed by the Milwaukee Metropolitan Sewerage District on its Water Pollution Abatement Program, including construction of the Inline Storage System and major relief sewers. As a result of this project, many of the flow relief devices within the watershed have recently been eliminated. Those which remain include combined sewer overflows and sanitary sewer overflows. During the period from August 1995 to August 2002, overflows were reported at eight SSO locations. Table 35 gives the locations of sanitary sewer overflow locations in the Kinnickinnic River watershed for MMSD and the City of West Allis. Table 35 indicates the number of days during which overflow occurred at each location during the period from August 1995 to August 2002. The SSO sites which are being incorporated into the water quality model are indicated on Map 25.

Table 35

SEPARATE SANITARY SEWER OVERFLOW LOCATIONS IN THE KINNICKINNIC RIVER WATERSHED

Identification Number	Location	Community or Agency	Number of Days with Overflow: August 1995 to August 2002
220	S. Howell Avenue and E. Grange Avenue	MMSD	5
225	S. 35th Street and Manitoba Avenue	MMSD	4
243	W. Lincoln Avenue 565 feet west of S. 43rd Street	MMSD	4
260	S. 6th Street at W. Oklahoma Avenue	MMSD	21
CU6	5749 S. New York Avenue	Cudahy	1
MI05	E. Ohio Street and S. Quincy Avenue	Milwaukee	2
MI40	S. 46th Street and W. Cleveland Avenue	Milwaukee	2
MI41	S. 57th Street and W. Euclid Avenue	Milwaukee	1
MI45	S. Burrell Street and E. Van Norman Avenue	Milwaukee	1
MI50	S. 36th Street and W. Lincoln Avenue	Milwaukee	2
WA10	S. 68th Street and W. Burnham Street	West Allis	3
WA12	S. 69th Street and W. Lincoln Avenue	West Allis	2
WA13	S. 57th Street and W. Grant Street	West Allis	1
WA14	S. 56th Street and W. Grant Street	West Allis	1
WA18	6400 W. Becher Place	West Allis	1
WA20	6200 Block of W. Beloit Road	West Allis	1

NOTE: For the MMSD Sanitary Sewer Overflow locations, the Identification Number corresponds to the WPDES permit number.

Source: Wisconsin Department of Natural Resources; Milwaukee Metropolitan Sewerage District; Triad Engineering, Inc.; and SEWRPC.

Combined Sewer Overflows (CSOs)

Combined sewer overflows are potential sources of pollution within the watershed. MMSD has 26 combined sewer overflow outfalls that discharge to the Kinnickinnic River watershed. These outfalls can convey diluted sewage from the combined sewer system to the surface water system of the watershed as a result of high water volume from stormwater, meltwater, and excessive infiltration and inflow of clear water during wet weather conditions. This conveyance occurs in order to prevent damage to residential dwellings or the mechanical elements of the conveyance system during such events. The locations of these outfalls are shown on Map 25. Associated with these CSO outfalls is a set of sample collectors which obtain samples of the effluent discharged during overflow events for chemical and bacteriological analysis. The assignment of collectors to outfalls is shown in Table 36. Over the period August 1995 to August 2002, the mean number of days during which individual outfalls discharged to the watershed was 12.6. Associated with this mean was high variability among outfalls. There were no known discharges from several of these outfalls during this period. Other outfalls discharged over as many as 45 days. There was also variation in the number of outfalls involved in particular discharge events. Some CSO events were quite localized, consisting of discharge from only one outfall. Others occurred over a large portion of the CSO area, involving discharge from as many as 17 outfalls into the watershed. The mean number of outfalls discharging on any day that discharge occurred was 7.6.

Other Known Point Sources

Industrial Discharges

The number of known industrial wastewater permitted dischargers in the Kinnickinnic River watershed has increased over time. In 1975, there were a total of 30 known industrial wastewater permitted dischargers identified in the watershed. These permitted facilities discharged industrial cooling, process, rinse, and wash waters to surface waters.[32] In 1990, 50 permitted facilities discharged wastewater to the Kinnickinnic River, its tributaries, or the groundwater system.[33]

[32]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *September 1978.*

[33]*SEWRPC Memorandum Report No. 93,* op. cit.

Map 25

POINT SOURCES OF POLLUTION WITHIN THE KINNICKINNIC RIVER WATERSHED: 2003

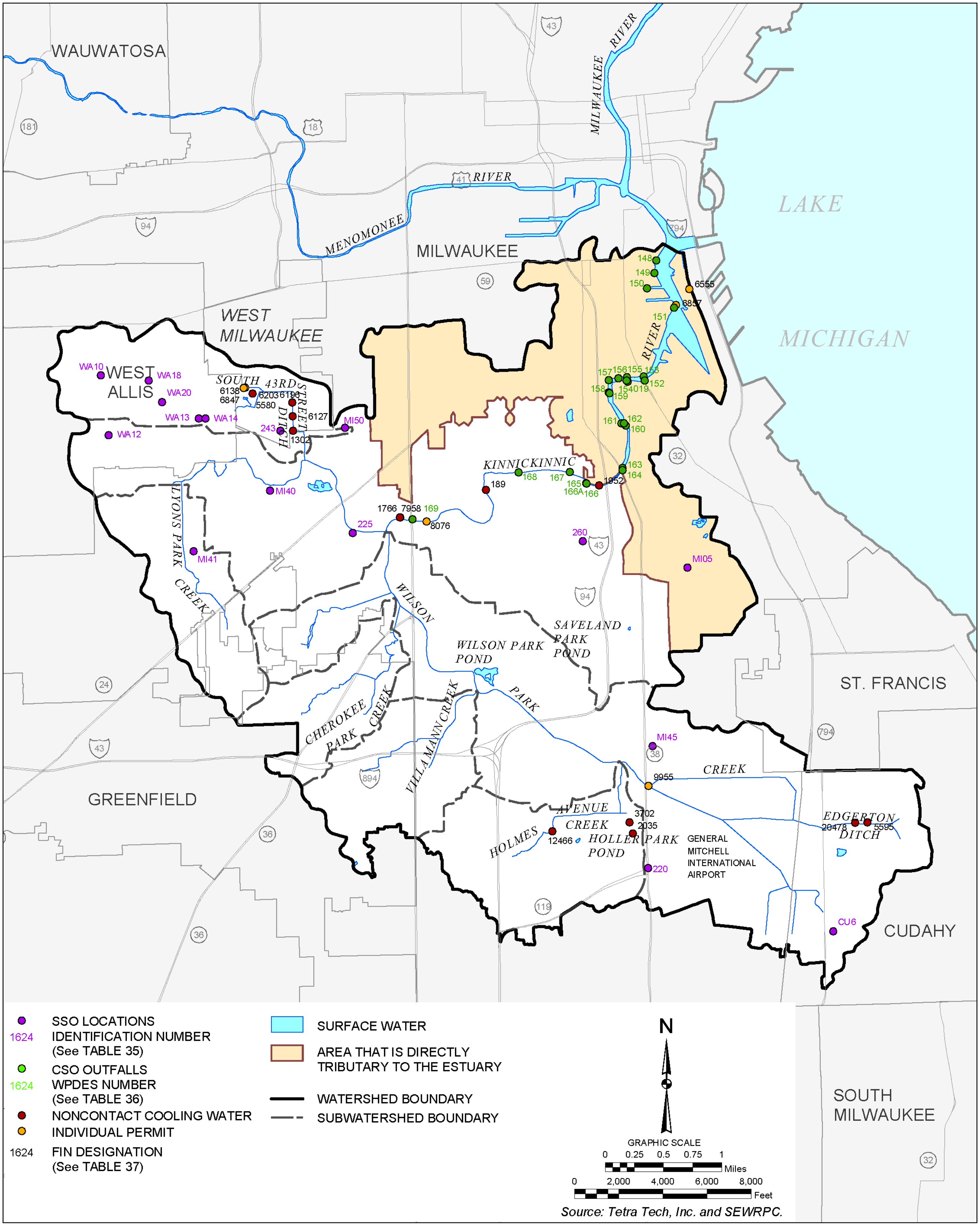


Table 36

COMBINED SEWER OVERFLOW OUTFALL LOCATIONS IN THE KINNICKINNIC RIVER WATERSHED

WPDES Number	Location	Collector[a]	Outfall Size (inches)	Number of Days with Overflow August 1995 to August 2002
18	S. Water Street and E. Bruce Street	Unknown	36	0
19	S. 1st Street at the Kinnickinnic River	Unknown	48	3
148	E. National Avenue	CT 8[a]	48	18
149	South of E. Walker Street	CT 8	78 x 60[b]	19
149A	South of E. Walker Street	CT 8	- -[c]	0
150	South of E. Washington Street	CT 8	36	5
151	E. Greenfield Avenue	CT 8	66 x 36	5
152	S. Kinnickinnic Avenue	KK 3[d]	30	0
153	S. Kinnickinnic Avenue	KK 3	60	0
154	S. 1st Street	KK 3	42	11
155	S. 1st Street	KK 3	42	18
156	S. 2nd Street	KK 3	78	26
157	W. Rogers Street	KK 3	72	26
158	W. Becher Street	KK 3	144 x 72	1
159	W. Becher Street	KK 3	96	0
160	E. Lincoln Avenue	KK 4	54	20
161	W. Lincoln Avenue	KK 4	30	4
162	W. Lincoln Avenue	KK 4	48	16
163	S. Chase Avenue	KK 2	18	11
164	S. Chase Avenue	KK 2	120 x 60	14
165	W. Cleveland Avenue	KK 1	72	26
166	W. Cleveland Avenue	KK 1	84	39
166A	S. 6th Street and W. Cleveland Avenue	KK 1	84	45
167	S. 8th Street	KK 1	84 x 60	20
168	S. 14th Street	KK 1	120 x 60	0
169	S. 27th Street	KK 1	72	0

[a]*CT Stands for Cross Town Tunnel Location.*

[b]*Double outfall.*

[c]*Data not available.*

[d]*KK stands for Kinnickinnic Tunnel Location.*

Source: Milwaukee Metropolitan Sewerage District; Triad Engineering, Inc.; and SEWRPC.

Table 37 lists the industrial discharge permits in effect through the Wisconsin Pollution Discharge Elimination System (WPDES) during February 2003 in the Kinnickinnic River watershed. At that time, 33 WPDES industrial permits were in effect in the watershed. Individual permits represent five of these permits, the rest are spread among seven categories of general permits. The most common category of general permit issued in this watershed was for the discharge of noncontact cooling water. There were 16 facilities in the watershed covered by permits in this category which regulates the discharge noncontact cooling water, boiler blowdown, and air conditioning condensate. The other general permit categories were each represented by five or fewer facilities. Data from discharge monitoring reports for several facilities covered by individual permits or general permits for noncontact cooling water are being included in water quality modeling for the regional water quality management plan update and the MMSD 2020 Facility Plan. These sites are shown on Map 25.

Table 37

PERMITTED WASTEWATER DISCHARGERS UNDER THE WPDES GENERAL PERMIT AND INDIVIDUAL PERMIT PROGRAMS IN THE KINNICKINNIC RIVER WATERSHED: FEBRUARY 2003

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Carriage/Interstitial Water from Dredging[a]	- -	- -	- -	- -	- -	- -
Concrete Products Operations	Central Ready Mixed LP	4350 S. 13th Street	Milwaukee	0046507	241096020	8220
Contaminated Groundwater Remedial Actions	General Electric Corporation - Medical Systems Group	4855 Electric Avenue	West Milwaukee	0046566	241014180	6203
	General Electric Corporation	2205 S. 43rd Street	West Milwaukee	0046566	241013410	14519
	Miller Processing Corporation	1000 E. Bay Street	Milwaukee	0046566	241096570	14472
Hydrostatic Test Water and Water Supply System	Milwaukee Waterworks	725 W. Howard Avenue	Milwaukee	0057681	241009890	5653
Land Applying Liquid Industrial Wastes[b]	- -	- -	- -	- -	- -	- -
Noncontact Cooling Water	Acme Galvanizing, Inc.	2730 S. 19th Street	Milwaukee	0044938	241036950	189
	Associated Spring	434 W. Edgerton Avenue	Milwaukee	0044938	241054880	3702
	Elite Finishing	3270 S. 3rd Street	Milwaukee	0044938	241243310	1952
	Froedtert Malt	2100 S. 43rd Street	Milwaukee	0044938	241013960	6196
	Froedtert Malt	3830 W. Grant Street	Milwaukee	0044938	241011100	6127
	General Electric Corporation – Medical Systems Group	4855 Electric Avenue	West Milwaukee	0044938	241014180	6203
	Grebes Bakery	5132 Lincoln Avenue	West Allis	0044938	241063240	1302
	Joy Mark, Inc.	2121 E. Norse Avenue	Cudahy	0044938	241879550	11727
	Ladish Corporation, Inc.	5481 S. Packard Avenue	Cudahy	0044938	241006920	5595
	Milwaukee Malleable & Grey Iron Works	2776 S. 29th Street	Milwaukee	0044938	241031780	7958
	Patrick Cudahy, Inc.	4801 S. Kingan Avenue	Cudahy	0044938	241009670	5646
	Reliable Plating Works, Inc.	5230 S. 13th Street	Milwaukee	0044938	241288520	12466
	Rexnord/Stearns Division	5151 S. International Drive	Cudahy	0044938	341047740	20478
	Southeastern Wisconsin Products Company	500 W. Edgerton Avenue	Milwaukee	0044938	241052680	2035
	Spinweld, Inc.	6623 W. Mitchell Street	West Allis	0044938	241989990	3391
	St. Luke's Medical Center	2900 W. Oklahoma Avenue	Milwaukee	0044938	241024300	1766
	Unit Drop Forge Company, Inc.	1903 S. 62nd Street	West Allis	0044938	241011760	6138
Nonmetallic Mining Operations[c]	- -	- -	- -	- -	- -	- -
Petroleum Contaminated Water	Wisconsin Air National Guard 128th Air Refueling Group	1919 East Grange Avenue	Milwaukee	0046531	241862390	3412
Pit/Trench Dredging[d]	- -	- -	- -	- -	- -	- -
Potable Water Treatment and Conditioning	Milwaukee Waterworks	725 W. Howard Avenue	Milwaukee	0046540	241009890	5653

Table 37 (continued)

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Swimming Pool Facilities	Four Points Sheraton	4747 S. Howell Avenue	Milwaukee	0046523	241522270	13724
	Milwaukee County Parks and Recreation - Holler Park Pool	5151 S. 6th Street	Milwaukee	0046523	241520180	14056
	Milwaukee County Parks and Recreation - Jackson Park Pool	3500 W. Forest Home Avenue	Milwaukee	0046523	241520400	14058
	Milwaukee County Parks and Recreation - Pulaski Pool	2701 S. 16th Street	Milwaukee	0046523	341043450	19531
	Milwaukee County Parks and Recreation - Wilson Park Pool	4001 S. 20th Street	Milwaukee	0046523	241521170	14072
Individual Permits	General Mitchell International Airport	5300 S. Howell Avenue	Milwaukee	0046477	241280270	9955
	Great Lakes Water Institute	600 E. Greenfield Avenue	Milwaukee	0045942	241107350	6857
	Maynard Steel Casting Company	2856 S. 27th Avenue	Milwaukee	0000272	241005710	8076
	Milwaukee Ductile Iron, Inc.	1706 S. 68th Street	West Allis	0000493	241006260	5580
	Pressed Steel Tank Company, Inc.	1445 S. 66th Street	West Allis	0045705	241037940	6847

[a] *There were no active WPDES general permits for Carriage/Interstitial Water from Dredging in the Kinnickinnic River watershed during February 2003.*

[b] *There were no active WPDES general permits for Land Applying Industrial Wastes in the Kinnickinnic River watershed during February 2003.*

[c] *There were no active WPDES general permits for Nonmetallic Mining Operations in the Kinnickinnic River watershed during February 2003.*

[d] *There were no active WPDES general permits for Pit/Trench Dredging in the Kinnickinnic River watershed during February 2003.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Due to the dynamic nature of permitted point sources, it is recognized that the number of wastewater sources in the watershed will change as industries and other facilities change locations or processes and as decisions are made with regard to the connection of such sources to public sanitary sewer systems.

Nonpoint Source Pollution

Urban Stormwater Runoff

As shown in Table 27, as of the year 2000, the Kinnickinnic River watershed was predominantly in urban uses (92.5 percent, with an additional 5.5 percent consisting of generally urban unused and open lands). Urban land uses within the watershed were primarily residential (34.6 percent), followed by transportation, communication, and utilities (32.7 percent); industrial (7.5 percent); governmental and institutional (7.5 percent), commercial (5.9 percent), and recreational (4.3 percent). Chapter II of this report includes descriptions of the types of pollutants associated with specific urban nonpoint sources.

Regulation of Urban Nonpoint Source Pollution through the Wisconsin Pollutant Discharge Elimination System Permit Program

Facilities engaged in industrial activities listed in Section NR 216.21(2)(b) of Chapter NR 216 of the *Wisconsin Administrative Code* must apply for and obtain a stormwater discharge permit. The WDNR originally developed a three-tier system of industrial storm water permits. Tier 1 permits apply to facilities involved in heavy industry and manufacturing, including facilities involved in lumber and wood product manufacturing, leather tanning, and primary metal industries. Tier 2 permits apply to facilities involved in light industry and manufacturing and transportation facilities, including facilities involved in printing, warehousing, and food processing. Tier 3 permits used to be issued to facilities which have certified, with WDNR concurrence, that they have no discharges of contaminated stormwater. WDNR authority for Tier 3 permits no longer exists and the Tier 3 permits have been terminated. Facilities now submit a certificate of no exposure. In addition, the WDNR also issues separate permits for automobile parts recycling facilities and scrap recycling facilities. Associated with each category of permit are specific requirements for monitoring and inspection. For all categories of permits except Tier 3 industrial permits, the permit requires the facility to develop and follow a storm water pollution prevention plan (SWPPP). Specific requirements for the SWPPP are listed in Chapter NR 216.27 of the *Wisconsin Administrative Code*. They include provisions related to site mapping, implementation scheduling, conducting annual plan assessments, and monitoring of discharge.

As shown in Appendix G, "WPDES Permitted Stormwater Facilities," 81 industrial stormwater permits were in effect in the Kinnickinnic River watershed in February 2003. Most of these were Tier 2 permits. With 45 of these permits in effect, this category represented slightly over half of the permitted facilities in the watershed. Tier 3 permits were the next most common in the watershed. In February 2003, 11 of these were in effect. There were 10 or fewer each of Tier 1, Automobile Parts Recycling, and Scrap Recycling permits in effect in the watershed at this time.

The WDNR also issues and administers construction site stormwater permits through the WPDES General Permits program. All construction sites that disturb one acre of land or more are required to obtain coverage under the General Permit. Permitted construction sites are required to implement a construction erosion control plan, and a post-construction stormwater management plan as required in Chapter NR 216.46 and Chapter NR 216.47 of the *Wisconsin Administrative Code*. Owners of permitted construction sites are also required to conduct inspections of their construction erosion control measures on a weekly basis and within 24 hours of a precipitation event of 0.5 inch or more. Due to the dynamic nature of construction activities, it is recognized that the number of sites requiring Construction Site Storm Water permits in the watershed will change as construction projects are completed and new projects are initiated.

The WPDES stormwater permits for municipalities within the watershed are described below.

Chapter NR 151 of the Wisconsin Administrative Code

Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*, which was promulgated in September 2002, establishes performance standards for the control of nonpoint source pollution from agricultural lands, nonagricultural (urban) lands, and transportation facilities. The standards for urban lands apply to areas of existing development, redevelopment, infill, and construction sites. In general, the construction erosion control, post-construction nonpoint source pollution control, and stormwater infiltration requirements of Chapter NR 151 apply to projects associated with construction activities that disturb at least one acre of land.

The urban standards are applied to activities covered under the WPDES program for stormwater discharges. As noted below, communities with WPDES stormwater discharge permits must adopt stormwater management ordinances that have requirements at least as stringent as the standards of Chapter NR 151. Those communities must also achieve levels of control of nonpoint source pollution from areas of existing development (as of October 1, 2004) that are specified under Chapter NR 151.

Stormwater Management Systems
Stormwater management facilities are defined, for purposes of this report, as conveyance, infiltration, or storage facilities, including, but not limited to, subsurface pipes and appurtenant inlets and outlets, ditches, streams and engineered open channels, detention and retention basins, pumping facilities, infiltration facilities, constructed wetlands for treatment of runoff, and proprietary treatment devices based on settling processes and control of oil and grease. Such facilities are generally located in urbanized areas and constructed or improved and operated for purposes of collecting stormwater runoff from tributary drainage areas and conveying, storing, and treating such runoff prior to discharge to natural watercourses. In the larger and more intensively developed urban communities, these facilities consist either of complete, largely piped, stormwater drainage systems which have been planned, designed, and constructed as systems in a manner similar to sanitary sewer and water utility systems, or of fragmented or partially piped systems incorporating open surface channels to as great a degree as possible. In the Kinnickinnic River watershed, the stormwater drainage systems have historically provided the means by which a significant portion of the nonpoint sources pollutants reach the surface water system. However, about 17 percent of the watershed area is served by combined sanitary and storm sewers, with most of the runoff from that area being conveyed to MMSD sewage treatment facilities. That results in a high level of nonpoint source pollution control of runoff from the combined sewer service area.

With the relatively recent application of the WPDES permitting program to stormwater discharges and the adoption of local stormwater management ordinances, controls on the quality of stormwater runoff prior to discharge to receiving streams have become more common. Table 38 indicates the status of stormwater management activities in each of the communities in the watershed.

Table G-1 in Appendix G indicates that Milwaukee County; the Cities of Cudahy, Greenfield, Milwaukee, St. Francis, and West Allis; and the Village of West Milwaukee have WPDES stormwater discharge permits. Thus, all of the communities in the watershed have been issued WPDES stormwater discharge permits. In addition to specific nonpoint source pollution control activities recommended under their WPDES permits, these communities will also all be required to develop new, or update existing, stormwater management ordinances to be consistent with the standards of Chapter NR 151 of the *Wisconsin Administrative Code*. As part of their permit application, each community prepared maps of the stormwater outfalls that are part of the municipal separate stormwater system.

Urban Enclaves Outside Planned Sewer Service Areas
There are no enclaves of urban development located outside the planned sewer service area. Thus, failure of onsite disposal systems is not an issue in the Kinnickinnic River watershed.

Solid Waste Disposal Sites
Solid waste disposal sites are a potential source of surface water, as well as groundwater, pollution. It is important to recognize, however, the distinction between a properly designed and constructed solid waste landfill and the variety of operations that are referred to as refuse dumps, especially with respect to potential effects on water quality. A solid waste disposal site may be defined as any land area used for the deposit of solid wastes regardless of the method of operation, or whether a subsurface excavation is involved. A solid waste landfill may be defined as a solid waste disposal site which is carefully located, designed, and operated to avoid hazards to public health

Table 38

STORMWATER MANAGEMENT INFORMATION FOR CITIES, VILLAGES, AND TOWNS WITHIN THE KINNICKINNIC RIVER WATERSHED

Civil Division	Stormwater Management Ordinance and/or Plan	Construction Erosion Control Ordinance	Stormwater Utility, General Fund, and/or Established Stormwater Fee Program
Milwaukee County			
City of Cudahy	X	X	X
City of Greenfield	X	X	- -
City of Milwaukee	X	X	X
City of St. Francis	X	X	X
City of West Allis	X	X	X
Village of West Milwaukee	- -[a]	X	- -

[a]*It is anticipated that the Village of West Milwaukee will adopt a stormwater management ordinance to fulfill the conditions of its WPDES stormwater discharge permit.*

Source: SEWRPC.

or safety, or contamination of groundwaters or surface waters. The proper design of solid waste landfills requires careful engineering to confine the refuse to the smallest practicable area, to reduce the refuse mass to the smallest practicable volume, to avoid surface water runoff, to minimize leachate production and percolation into the groundwater and surface waters, and to seal the surface with a layer of earth at the conclusion of each day's operation or at more frequent intervals as necessary.

In order for a landfill to produce leachate, there must be some source of water moving through the fill material. Possible sources included precipitation, the moisture content of the refuse itself, surface water infiltration, groundwater migrating into the fill from adjacent land areas, or groundwater rising from below to come in contact with the fill. In any event, leachate is not released from a landfill until a significant portion of the fill material exceeds its saturation capacity. If external sources of water are excluded from the solid waste landfill, the production of leachates in a well-designed and managed landfill can be effectively minimized if not entirely avoided. The quantity of leachate produced will depend upon the quantity of water that enters the solid waste fill site minus the quantity that is removed by evapotranspiration. Studies have estimated that for a typical landfill, from 20 to 50 percent of the rainfall infiltrated into the solid waste may be expected to become leachate. Accordingly, a total annual rainfall of about 35 inches, which is typical of the Kinnickinnic River watershed, could produce from 190,000 to 480,000 gallons of leachates per year per acre of landfill if the facility is not properly located, designed, and operated.

As of 2005, there were no active solid waste landfills within the watershed. As set forth in Table 39 and shown on Map 26, there is one inactive landfill in the Wilson Park Creek subwatershed in the City of Milwaukee.

Rural Stormwater Runoff

There are no significant rural lands within the Kinnickinnic River watershed.

Pollution Loadings

Annual Loadings

Annual average point and/or nonpoint pollution loads to the Kinnickinnic River watershed are set forth in Tables 40 through 46. Average annual per acre nonpoint source loads are set forth in Table 47. The nonpoint source load estimates represent loads delivered to the modeled stream reaches after accounting for any trapping factors that would retain pollutants on the surface of the land. They include loads from groundwater. It is important to note that the stream channel pollutant loads may be expected to be different from the actual transport

Table 39

SOLID WASTE DISPOSAL SITE IN THE KINNICKINNIC RIVER WATERSHED: 2004

Facility Name	Address	Municipality	Classification	Subwatershed	License Number	Status
Wisconsin Department of Transportation Lake Arterial-CTY Milwaukee-Layton Landfill	Layton Avenue and Pennsylvania Avenue	Milwaukee	Landfill, unclassified	Wilson Park Creek	- -	Inactive

Source: Wisconsin Department of Natural Resources and SEWRPC.

from the watershed, because physical, chemical, and/or biological processes may retain or remove pollutants or change their form during transport within the stream system. These processes include particle deposition or entrapment in floodplains, stream channel deposition or aggradation, biological uptake, and chemical transformation and precipitation. The total nonpoint source pollution loads set forth in Table 40 are representative of the total annual quantities of potential pollutants moved from the Kinnickinnic River watershed into stream channels, but are not intended to reflect the total amount of the pollutants moving from those sources through the entire hydrologic-hydraulic system.

Tables 41 through 46 indicate that nonpoint source pollution loads comprise from 69 to 98 percent of the total pollution load, while point sources only account for 2 to 31 percent of the total load, depending on the pollutant.

Point Source Loadings

Annual average total point source pollutant loads of six pollutants in the Kinnickinnic River watershed are set forth in Tables 41 through 46. Contributions of these pollutants by point sources represent from 2 percent of the total average annual load of total suspended solids to 31 percent of the total average annual loads of fecal coliform bacteria.

Average annual point source loads of total phosphorus in the Kinnickinnic River watershed are shown in Table 41. The total average annual point source load of total phosphorus is about 2,820 pounds. Most of this is contributed by the Kinnickinnic River subwatershed. Industrial dischargers represent about 51 percent of the point source contributions of total phosphorus, separate sanitary sewer overflows represent approximately 32 percent, and combined sewer overflows represent about 17 percent.

Average annual point source loads of total suspended solids in the Kinnickinnic River watershed are shown in Table 42. The total average annual point source load of total suspended solids is about 106,490 pounds. About 90 percent of that load is contributed by the Kinnickinnic River subwatershed. Separate sanitary sewer overflows represent about 48 percent of the point source contributions of total suspended solids, combined sewer overflows represent about 40 percent, and industrial discharges represent about 12 percent.

Average annual point source loads of fecal coliform bacteria in the Kinnickinnic River watershed are shown in Table 43. The total average annual point source loads of fecal coliform bacteria is about 1,532.85 trillion cells per year, which is contributed by separate sanitary sewer overflows in the Kinnickinnic River, Wilson Park Creek, Lyons Park Creek, and S. 43rd Street Ditch subwatersheds (64 percent of the point source total) and combined sewer overflows in the Kinnickinnic River subwatershed (36 percent of the point source total).

Average annual point source loads of total nitrogen in the Kinnickinnic River watershed are shown in Table 44. The total average annual point source load of total nitrogen is about 10,890 pounds. Most of this is contributed by the Kinnickinnic River subwatershed. Industrial discharges represent about 62 percent of the point source contributions of total nitrogen, combined sewer overflows represent about 21 percent, and separate sanitary sewer overflows represent about 17 percent.

Map 26

LOCATION OF THE INACTIVE SOLID WASTE DISPOSAL SITE WITHIN THE KINNICKINNIC RIVER WATERSHED: 2000

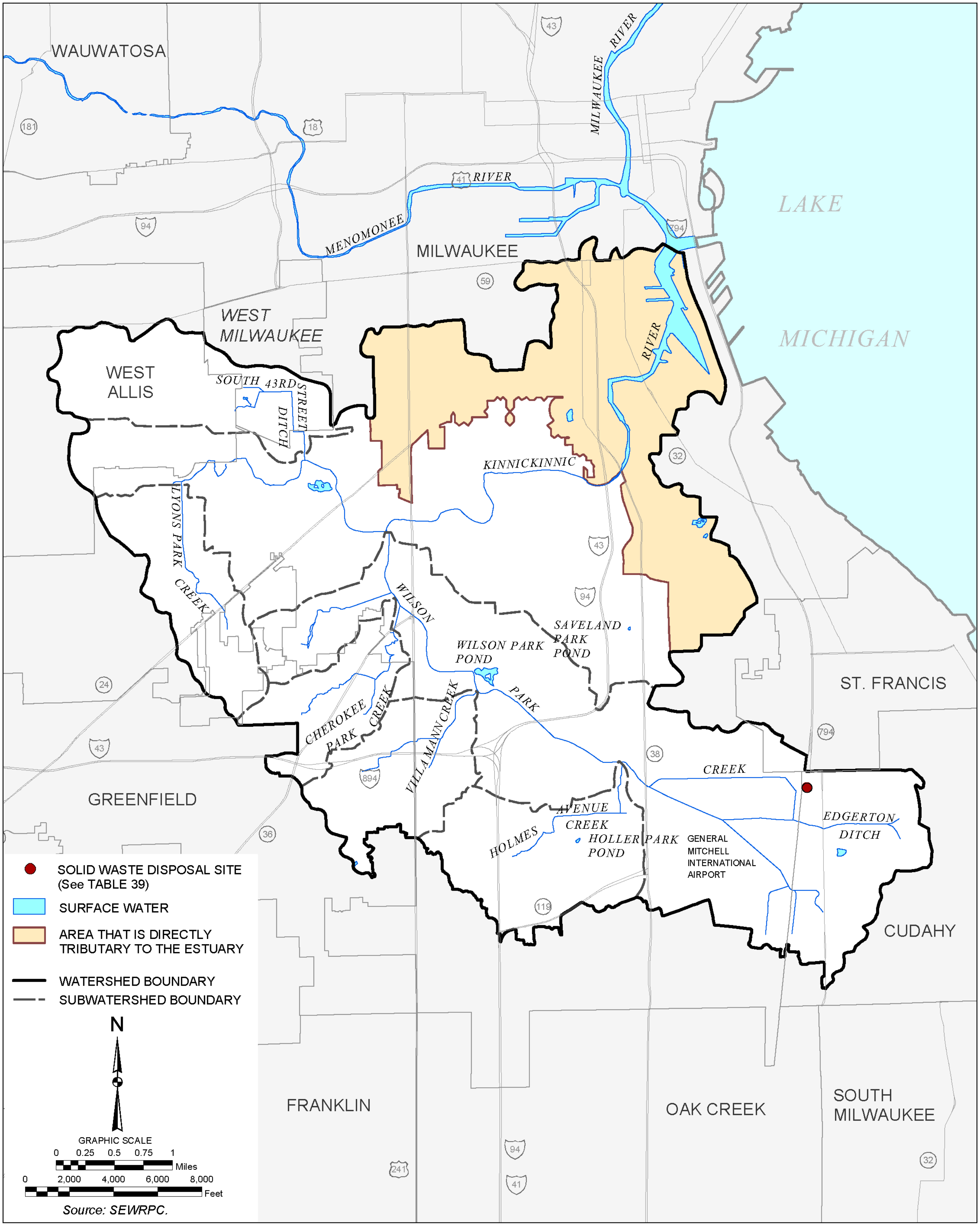


Table 40

AVERAGE ANNUAL TOTAL NONPOINT SOURCE POLLUTANT LOADS IN THE KINNICKINNIC RIVER WATERSHED[a]

Subwatershed	Total Phosphorus (pounds)	Total Suspended Solids (pounds)	Fecal Coliform Bacteria (trillions of cells)	Total Nitrogen (pounds)	Biochemical Oxygen Demand (pounds)	Copper (pounds)
Kinnickinnic River	2,810	1,403,480	1,032.00	17,950	80,790	146
Wilson Park Creek	3,440	1,706,110	996.59	22,250	167,560	175
Holmes Avenue Creek	1,000	643,540	361.86	6,140	44,480	59
Villa Mann Creek	730	380,440	247.98	4,500	20,400	37
Cherokee Park Creek	440	217,010	145.03	2,800	12,120	22
Lyons Park Creek	620	283,870	247.10	4,000	16,940	30
S. 43rd Street Ditch	890	557,830	327.95	5,600	30,860	57
Total	9,930	5,192,280	3,358.51	63,240	373,150	526

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Table 41

AVERAGE ANNUAL LOADS OF TOTAL PHOSPHORUS IN THE KINNICKINNIC RIVER WATERSHED[a]

	Point Sources				Nonpoint Sources			
Subwatershed	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	Total (pounds)
Kinnickinnic River	220	880	490	1,590	2,790	20	2,810	4,400
Wilson Park Creek	320	10	0	330	3,390	50	3,440	3,770
Holmes Avenue Creek	440	0	0	440	1,000	<10	1,000	1,440
Villa Mann Creek	0	0	0	0	730	<10	730	730
Cherokee Park Creek	0	0	0	0	440	<10	440	440
Lyons Park Creek	0	<10	0	<10	620	<10	620	620
S. 43rd Street Ditch	460	<10	0	460	890	<10	890	1,350
Total	1,440	890	490	2,820	9,860	70	9,930	12,750
Percent of Total	11.3	7.0	3.8	22.1	77.3	0.6	77.9	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Average annual point source loads of BOD in the Kinnickinnic River watershed are shown in Table 45. The total average annual point source load of BOD is about 35,350 pounds. Most of this is contributed by the Kinnickinnic River subwatershed. Industrial discharges represent about 45 percent of the point source contributions of BOD, separate sanitary sewer overflows represent about 36 percent, and combined sewer overflows represent about 19 percent.

Average annual point source loads of copper in the Kinnickinnic River watershed are shown in Table 46. The total average annual point source load of copper is 30 pounds per year, almost all of which is contributed by the Kinnickinnic River subwatershed. Combined sewer overflows represent about 50 percent of the point source contributions of total suspended solids, separate sanitary sewer overflows represent about 27 percent, and industrial discharges represent about 23 percent.

Table 42

AVERAGE ANNUAL LOADS OF TOTAL SUSPENDED SOLIDS IN THE KINNICKINNIC RIVER WATERSHED[a]

Subwatershed	Point Sources				Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Kinnickinnic River	2,230	50,280	42,810	95,320	1,400,580	2,900	1,403,480	1,498,800
Wilson Park Creek	6,300	850	0	7,150	1,681,280	24,830	1,706,110	1,713,260
Holmes Avenue Creek	800	0	0	800	643,010	530	643,540	644,340
Villa Mann Creek	0	0	0	0	380,220	220	380,440	380,440
Cherokee Park Creek	0	0	0	0	216,410	600	217,010	217,010
Lyons Park Creek	0	30	0	30	283,620	250	283,870	283,900
S. 43rd Street Ditch	3,080	110	0	3,190	557,400	430	557,830	561,020
Total	12,410	51,270	42,810	106,490	5,162,520	29,760	5,192,280	5,298,770
Percent of Total	0.2	1.0	0.8	2.0	97.4	0.6	98.0	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

Table 43

AVERAGE ANNUAL LOADS OF FECAL COLIFORM BACTERIA IN THE KINNICKINNIC RIVER WATERSHED[a]

Subwatershed	Point Sources				Nonpoint Sources			Total (trillions of cells)
	Industrial Point Sources (trillions of cells)	SSOs (trillions of cells)	CSOs (trillions of cells)	Subtotal (trillions of cells)	Urban (trillions of cells)	Rural (trillions of cells)	Subtotal (trillions of cells)	
Kinnickinnic River	0	959.33	554.79	1,514.12	1,031.94	0.06	1,032.00	2,546.12
Wilson Park Creek	0	16.14	0.00	16.14	996.39	0.20	996.59	1,012.73
Holmes Avenue Creek	0	0.00	0.00	0.00	361.85	0.01	361.86	361.86
Villa Mann Creek	0	0.00	0.00	0.00	247.97	0.01	247.98	247.98
Cherokee Park Creek	0	0.00	0.00	0.00	145.02	0.01	145.03	145.03
Lyons Park Creek	0	0.52	0.00	0.52	247.09	0.01	247.10	247.62
S. 43rd Street Ditch	0	2.07	0.00	2.07	327.94	0.01	327.95	330.02
Total	0	978.06	554.79	1,532.85	3,358.20	0.31	3,358.51	4,891.36
Percent of Total	0.0	20.0	11.3	31.3	68.7	0.0	68.7	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

Nonpoint Source Loads

Because nonpoint source pollution is delivered to streams in the watershed through many diffuse sources, including direct overland flow, numerous storm sewer and culvert outfalls, and swales and engineered channels, it would be prohibitively expensive and time-consuming to directly measure nonpoint source pollution loads to streams. Thus, the calibrated water quality model was applied to estimate average annual nonpoint source pollutant loads delivered to the streams in the watershed. The results of that analysis are set forth in Tables 40 through 46 and depicted graphically on Maps H-1 through H-12 in Appendix H. General water quality modeling procedures are described in Chapter V of SEWRPC Planning Report No. 50, *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds.*

Table 44

AVERAGE ANNUAL LOADS OF TOTAL NITROGEN IN THE KINNICKINNIC RIVER WATERSHED[a]

Subwatershed	Point Sources				Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Kinnickinnic River	3,800	1,840	2,290	7,930	17,730	220	17,950	25,880
Wilson Park Creek	980	30	0	1,010	21,270	980	22,250	23,260
Holmes Avenue Creek	1,460	0	0	1,460	6,090	50	6,140	7,600
Villa Mann Creek	0	0	0	0	4,480	20	4,500	4,500
Cherokee Park Creek	0	0	0	0	2,750	50	2,800	2,800
Lyons Park Creek	0	<10	0	<10	3,980	20	4,000	4,000
S. 43rd Street Ditch	490	<10	0	490	5,570	30	5,600	6,090
Total	6,730	1,870	2,290	10,890	61,870	1,370	63,240	74,130
Percent of Total	9.1	2.5	3.1	14.7	83.5	1.8	85.3	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Table 45

AVERAGE ANNUAL LOADS OF BIOCHEMICAL OXYGEN DEMAND IN THE KINNICKINNIC RIVER WATERSHED[a]

Subwatershed	Point Sources				Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Kinnickinnic River	3,680	12,370	6,880	22,930	80,050	740	80,790	103,720
Wilson Park Creek	5,630	210	0	5,840	165,660	1,900	167,560	173,400
Holmes Avenue Creek	1,120	0	0	1,120	44,320	160	44,480	45,600
Villa Mann Creek	0	0	0	0	20,320	80	20,400	20,400
Cherokee Park Creek	0	0	0	0	11,980	140	12,120	12,120
Lyons Park Creek	0	10	0	10	16,880	60	16,940	16,950
S. 43rd Street Ditch	5,420	30	0	5,450	30,730	130	30,860	36,310
Total	15,850	12,620	6,880	35,350	369,940	3,210	373,150	408,500
Percent of Total	3.9	3.1	1.7	8.7	90.5	0.8	91.3	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Table 40 shows the average annual total nonpoint source pollutant loads in the Kinnickinnic River watershed. These estimates represent loads delivered to the modeled stream reaches, after accounting for any trapping factors that would retain pollutants on the surface of the land. They include loads from groundwater. Loads from point sources are not included in the totals. It is important to note that the stream channel pollutant loads may be expected to be different from the actual transport from the watershed, because physical, chemical, and/or biological processes may retain or remove pollutants or change their form during transport over the land surface or within the stream system. These processes include particle deposition or entrapment on the land surface or in floodplains, stream channel deposition or aggradation, biological uptake, and chemical transformation and

Table 46

AVERAGE ANNUAL LOADS OF COPPER IN THE KINNICKINNIC RIVER WATERSHED[a]

Subwatershed	Point Sources				Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Kinnickinnic River	7	8	15	30	146	<1	146	176
Wilson Park Creek	0	<1	0	<1	174	1	175	175
Holmes Avenue Creek	0	0	0	0	59	<1	59	59
Villa Mann Creek	0	0	0	0	37	<1	37	37
Cherokee Park Creek	0	0	0	0	22	<1	22	22
Lyons Park Creek	0	<1	0	<1	30	<1	30	30
S. 43rd Street Ditch	0	<1	0	<1	57	<1	57	57
Total	7	8	15	30	525	1	526	556
Percent of Total	1.3	1.4	2.7	5.4	94.4	0.2	94.6	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Table 47

AVERAGE ANNUAL PER ACRE NONPOINT SOURCE POLLUTANT LOADS IN THE KINNICKINNIC RIVER WATERSHED[a]

Subwatershed	Total Phosphorus (pounds per acre)	Total Suspended Solids (pounds per acre)	Fecal Coliform Bacteria (trillions of cells per acre)	Total Nitrogen (pounds per acre)	Biochemical Oxygen Demand (pounds per acre)	Copper (pounds per acre)
Kinnickinnic River	0.73	367	0.27	4.69	21.11	0.038
Wilson Park Creek	0.77	380	0.22	4.95	37.27	0.039
Holmes Avenue Creek	0.93	600	0.34	5.72	41.45	0.055
Villa Mann Creek	0.86	451	0.29	5.33	24.16	0.044
Cherokee Park Creek	0.72	353	0.24	4.55	19.71	0.036
Lyons Park Creek	0.73	333	0.29	4.69	19.85	0.035
S. 43rd Street Ditch	0.81	508	0.30	5.10	28.12	0.052

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

precipitation. The total pollutant loads set forth in Table 40 are representative of the annual quantities of potential pollutants moved from the Kinnickinnic River watershed into stream channels, but are not intended to reflect the total amount of the pollutants moving from those sources through the entire hydrologic-hydraulic system to the estuary. Because the land area that is classified as rural in this watershed is small, rural nonpoint source loads are a very small component of the total nonpoint source load.

Average annual per acre nonpoint source pollution loads for subwatersheds of the Kinnickinnic River watershed are shown in Table 47.

For each of the pollutants listed in Tables 41 through 46, the highest nonpoint source loads are generally contributed by the Wilson Park Creek and Kinnickinnic River subwatersheds, reflecting the relatively large areas of those subwatersheds. For all pollutants listed in the tables, the highest unit area loads occur in the Holmes Avenue Creek subwatershed.

The average annual nonpoint load of total phosphorus is estimated to be 9,930 pounds per year. The distribution of the total load among the subwatersheds is shown on Map H-1 in Appendix H. Map H-2 shows the annual per acre loads of total phosphorus for the subwatersheds. Contributions of total phosphorus vary among the subwatersheds (Table 40) from a low of 440 pounds per year from the Cherokee Park Creek subwatershed to 3,440 pounds per year from the Wilson Park Creek subwatershed.

The average annual nonpoint load of total suspended solids is estimated to be 5,192,280 pounds per year. The distribution of this load among the subwatersheds is shown on Map H-3 in Appendix H. Map H-4 shows the annual per acre loads of total suspended solids for the subwatersheds. Contributions of total suspended solids vary among the subwatersheds (Table 40) from a low of 217,010 pounds per year from the Cherokee Park Creek subwatershed to 1,706,110 pounds per year from the Wilson Park Creek subwatershed.

The average annual nonpoint load of fecal coliform bacteria is estimated to be 3,358.51 trillion cells per year. The distribution of this load among the subwatersheds is shown on Map H-5 in Appendix H. Map H-6 shows the annual per acre loads of fecal coliform bacteria for the subwatersheds. Contributions of fecal coliform bacteria vary among the subwatersheds (Table 40) from a low of 145.03 trillion cells per year from the Cherokee Park Creek subwatershed to 1,032.0 trillion cells per year from the Kinnickinnic River subwatershed.

The average annual nonpoint load of total nitrogen in the watershed is estimated to be 63,240 pounds per year. The distribution of this load among the subwatersheds is shown on Map H-7 in Appendix H. Map H-8 shows the annual per acre loads of total nitrogen for the subwatersheds. Contributions of total nitrogen vary among the subwatersheds (Table 40) from a low of 2,800 pounds per year from the Cherokee Park Creek subwatershed to 22,250 pounds per year from the Wilson Park Creek subwatershed.

The average annual nonpoint load of BOD in the watershed is estimated to be 373,150 pounds per year. The distribution of this load among the subwatersheds is shown on Map H-9 in Appendix H. Map H-10 shows the annual per acre loads of BOD for the subwatersheds. Contributions of BOD vary among the subwatersheds (Table 40) from a low of 12,120 pounds per year from the Cherokee Park Creek subwatershed to 167,560 pounds per year from the Wilson Park Creek subwatershed.

The average annual nonpoint load of copper in the watershed is estimated to be 526 pounds per year. The distribution of this load among the subwatersheds is shown on Map H-11 in Appendix H. Map H-12 in Appendix H shows the annual per acre loads of copper for the subwatersheds. Contributions of copper vary among the subwatersheds (Table 40) from a low of 22 pounds per year from the Cherokee Park Creek subwatershed to 175 pounds per year from the Wilson Park Creek subwatershed.

Wet-Weather and Dry-Weather Loads

It is important to distinguish between instream water quality during dry weather conditions and during wet weather conditions. Differences between wet-weather and dry-weather instream water quality reflect differences between the dominant sources and loadings of pollutants associated with each condition. Dry-weather instream water quality reflects the quality of groundwater discharge to the stream plus the continuous or intermittent discharge of various point sources, for example industrial cooling or process waters, and leakage or other unplanned dry-weather discharges from sanitary sewers or private process water systems. While instream water quality during wet weather conditions includes the above discharges, and in extreme instances discharges from separate and/or combined sanitary sewer overflows, the dominant influence, particularly during major rainfall or snowmelt runoff events, is likely to be the soluble or insoluble substances carried into streams by direct land surface runoff. That direct runoff moves from the land surface to the surface waters by overland routes, such as drainage swales, street and highway ditches, and gutters, or by underground storm sewer systems.

Daily average loads of six pollutants—total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, biochemical oxygen demand, and copper, were estimated for both wet-weather and dry-weather conditions for one site along the Kinnickinnic River—S. 7th Street station (River Mile 2.80)—based upon flow and water quality data. A water quality sample was assumed to represent wet-weather conditions when daily mean flow was in the upper 20th percentile of the flow duration curve for the relevant flow gauge. This includes flows that are high due to rainfall events, runoff from snowmelt, or a combination of rainfall and snowmelt.

The flow duration curve for the Kinnickinnic River at S. 11th Street in Milwaukee is shown in Figure 61. This stream flow gauge began operation in October 1982. Prior to October 1982 flow data was collected from the Kinnickinnic River at a stream flow gauge located at S. 7th Street. Figure 61 includes data from both gauges. To adjust for the fact that the stream flow gauge at S. 11th Street is about 0.4 mile upstream from the stream flow gauge at S. 7th Street, the data from the S. 11th Street gauge were multiplied by the ratio of the drainage area above the S. 7th Street gauge and the drainage area above the S. 11th Street gauge. Water quality samples were considered to reflect wet-weather conditions when daily mean flow for the corresponding date equaled or exceeded 23.73 cubic feet per second (cfs). On dates when daily mean flow was less than this threshold, the corresponding water quality samples were considered to reflect dry-weather conditions. Daily average pollutant loads were estimated by appropriately combining daily average flow and pollutant ambient concentration.

Figure 62 shows the daily average pollutant loads for total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, and biochemical oxygen demand from the Kinnickinnic River at the S. 7th Street sampling station. In all cases, the estimated loads occurring during wet-weather periods were considerably higher than the estimated loads occurring during dry-weather periods. For the 1998 through 2001 baseline period, the mean estimated daily average wet-weather load of total phosphorus was about 159 pounds, which is almost 30 times the mean estimated daily average dry-weather load of about 5.4 pounds. For the baseline period, the mean estimated daily average wet-weather load of total suspended solids was about 85,060 pounds, about 214 times the mean estimated daily average dry-weather load of about 398 pounds. For the baseline period, the mean estimated daily average wet-weather load of fecal coliform bacteria was about 60 trillion cells, over 50 times the mean estimated daily average dry-weather load of 1.14 trillion cells. For the baseline period, the mean estimated daily average wet-weather load of total nitrogen was 1,525 pounds, about 22 times the mean estimated daily average dry-weather load of 69 pounds. For the baseline period, the mean estimated daily average wet-weather load of BOD was about 4,280 pounds, about 26 times the mean estimated daily average dry-weather load of about 167 pounds. For the baseline period, the mean estimated daily average wet-weather load of copper was about 12 pounds, about 27 times the mean estimated daily average dry-weather load of about 0.45 pound.

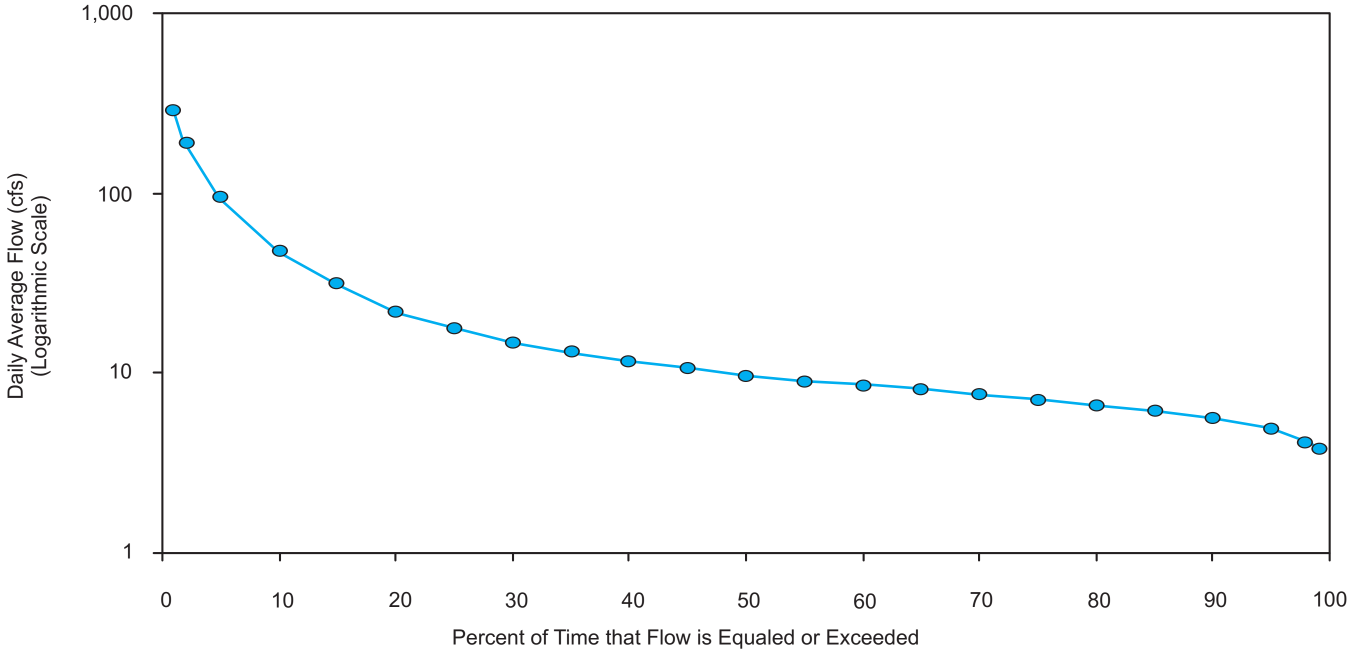
Figure 62 also shows the occurrence of individual wet-weather events during which the estimated daily average pollutant load was many times higher than typical wet-weather loads. The presence of these outliers indicates that individual wet-weather events can contribute a substantial fraction of the annual pollutant load to the stream. For example, Figure 62 shows that the maximum estimated daily average wet-weather load of total suspended solids detected at the S. 7th Street station during the baseline period of 1998-2001 was about 765,000 pounds. Comparing this to Table 42 shows that this single day's load represents about 14 percent of the estimated average annual load of total suspended solids in the entire watershed. Similarly, Figure 61 shows that the maximum estimated daily average wet-weather load of total nitrogen detected during the baseline period of 1998-2001 was about 15,550 pounds. Comparing this to Table 44 shows that this single day's load represents about 21 percent of the estimated average annual load of total nitrogen in the entire watershed. While these two examples may represent extreme cases, they do indicate that a large fraction of the annual pollutant load to the watershed is contributed by a small number of wet-weather events.

ACHIEVEMENT OF WATER USE OBJECTIVES IN THE KINNICKINNIC RIVER AND ITS TRIBUTARIES

The water use objectives and the supporting water quality standards and criteria for the Kinnickinnic River watershed are discussed in Chapter IV of this report. Most of the stream reaches in the Kinnickinnic River watershed are recommended for fish and aquatic life and full recreational uses. The exceptions to this are all subject to special variances under Chapter NR 104 of the *Wisconsin Administrative Code*. The mainstem of the Kinnickinnic River is subject to a special variance under which dissolved oxygen is not to be less than 2.0 mg/l and counts of fecal coliform bacteria are not to exceed 1,000 per 100 ml.

Figure 61

FLOW DURATION CURVE FOR USGS STREAM GAUGE ON THE KINNICKINNIC RIVER AT S. 11TH STREET (USGS GAUGE 04087159): 1976-2004



NOTE: The stream gauge at S. 11th Street came online in 1982. Data from 1976-1982 are from the stream gauge at S. 7th Street (USGS Gauge 04087160).

Source: U.S. Geological Survey and SEWRPC.

Based upon the available data for sampling stations in the watershed, the mainstem of the Kinnickinnic River and its major tributaries did not fully meet the water quality standards associated with the recommended water use objectives during and prior to 1975, the base year of the initial plan. Review of subsequent data indicated that as of 1995, the recommended water use objectives were only being partially achieved in the majority of the streams in the watershed.[34]

During the 1998-2001 baseline period, the recommended water use objectives were only being partially achieved in much of the Kinnickinnic River Watershed. Table 48 shows the results of comparisons of water quality data from the baseline period to supporting water quality standards. Review of data from 1998 to 2001 shows the following:

- Ammonia concentrations in all samples taken along the mainstem and in most samples along Wilson Park Creek were under the acute toxicity criterion for fish and aquatic life for ammonia, indicating compliance with the standard.
- Dissolved oxygen concentrations from the mainstem were at or above the relevant standard in the vast majority of samples, indicating substantial compliance with the standard.
- Except for two stations, water temperatures in all samples taken from the mainstem were at or below the relevant standard, indicating substantial compliance with the standard. During the summer, surface water temperature at the S. 7th Street and S. 1st Street stations occasionally exceeds the standard.

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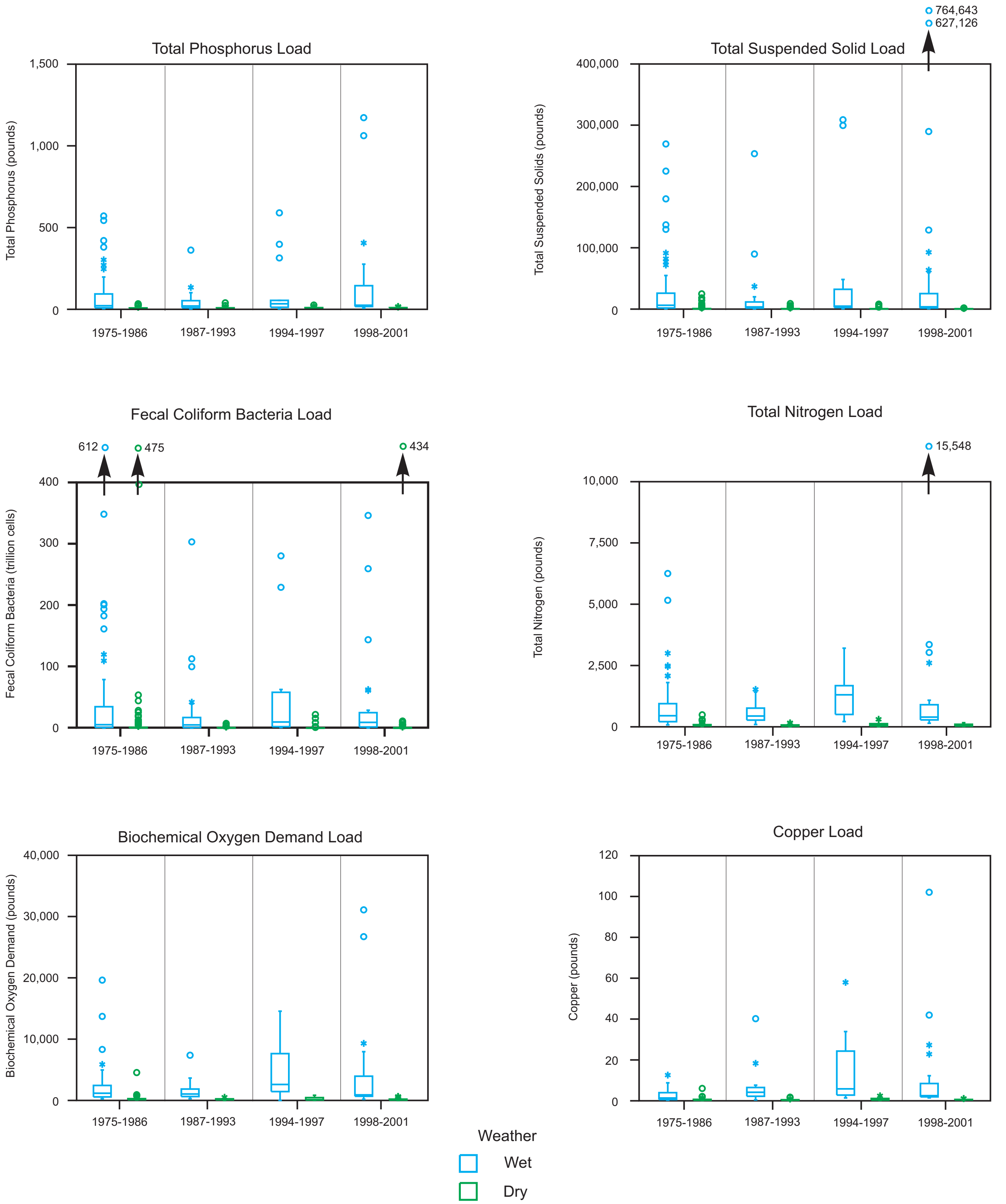
[34]*SEWRPC Memorandum Report No. 93,* op. cit.

Figure 62

DAILY AVERAGE POLLUTION LOADS IN THE KINNICKINNIC RIVER AT S. 7TH STREET (RIVER MILE 3.2): 1975-2001



NOTE: See Figure 28 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Table 48

CHARACTERISTICS OF STREAMS IN THE KINNICKINNIC RIVER WATERSHED: 1998-2001[a]

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[b]					Fish Biotic Index Rating[b,c]	Macroinvertebrate Biotic Index Rating (HBI)[b,c]	303(d)[d] Impairments
		Dissolved Oxygen	Temperature	NH_3[e]	Total Phosphorus[f]	Fecal Coliform Bacteria			
Lyons Park Creek	1.5	- -	- -	- -	- -	- -	- -	- -	- -
South 43rd Street Ditch	1.1	- -	- -	- -	- -	- -	- -	- -	- -
Edgerton Ditch	1.4	- -	- -	- -	- -	- -	- -	- -	- -
Holmes Avenue Creek	1.8	- -	- -	- -	- -	- -	- -	- -	- -
Villa Mann Creek	1.3	- -	- -	- -	- -	- -	- -	- -	- -
Cherokee Park Creek	1.6	- -	- -	- -	- -	- -	- -	- -	- -
Wilson Park Creek Tributary Upstream of conduit		- -	- -	100.0 (22)	78.6 (42)	- -	- -	- -	- -
Wilson Park Creek Tributary downstream of conduit		- -	- -	96.0 (25)	70.5 (44)	- -	- -	- -	- -
Wilson Park Creek	5.5	- -	- -	100.0 (22)	70.5 (44)	- -	- -	- -	- -
Kinnickinnic River above S. 27th Street	3.1	100.0 (67)[g]	100.0 (67)	100.0 (55)	29.9 (67)	30.3 (66)[h]	Very poor (1)	- -	- -
Kinnickinnic River between S. 7th Street and S. 27th Street	2.1	98.4 (63)[g]	98.4 (63)	100.0 (46)	56.2 (64)	50.8 (63)[h]	- -	Fair (1)	- -
Kinnickinnic River between S. 1st Street and S. 7th Street[i]	1.4	94.1 (68)[g]	100.0 (68)	100.0 (64)	58.8 (68)	58.2 (67)[h]	- -	- -	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory[i]
Kinnickinnic River between Greenfield Avenue (extended) and S. 1st Street	0.8	100.0 (58)[g]	100.0 (58)	100.0 (56)	74.1 (58)	75.4 (57)[h]	- -	- -	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory
Kinnickinnic River between Jones Island Ferry and Greenfield Avenue (extended)	0.4	100.0 (58)[g]	100.0 (58)	100.0 (57)	74.1 (58)	77.2 (57)[h]	- -	- -	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory

Table 48 Footnotes

[a]*Except as noted, evaluations of dissolved oxygen, temperature, ammonia, total phosphorus, and fecal coliform bacteria are based on data from 1998-2001.*

[b]*Number in parentheses shows number of samples.*

[c]*The State of Wisconsin has not promulgated water quality standards or criteria for biotic indices.*

[d]*As listed in the Approved Wisconsin 303(d) Impaired Waters List.*

[e]*Based upon the acute toxicity criterion for ammonia.*

[f]*Total phosphorus is compared to the concentration recommended in the regional water quality management plan.*

[g]*A special variance dissolved oxygen standard of 2.0 milligrams per liter applies to the Kinnickinnic River.*

[h]*A special variance standard for fecal coliform bacteria concentration applies to the Kinnickinnic River. Membrane filter fecal coliform counts shall not exceed 1,000 per 100 ml as a monthly geometric mean based on not less than five samples per month nor exceed 2,000 per 100 ml in more than 10 percent of all samples in any month.*

[i]*The upstream limit of the 303(d) impairments only extends to Chase Avenue.*

Source: SEWRPC.

- Fecal coliform bacteria standards are commonly exceeded at stations along the mainstem of the Kinnickinnic River, indicating frequent violation of the standard.

- Concentrations of total phosphorus in the mainstem of the Kinnickinnic River and Wilson Park Creek commonly exceeded the recommended levels in the regional water quality management plan.

Thus, during the baseline period the stream reaches for which data are available only partially achieved the recommended water use objectives.

An additional issue to consider when examining whether stream reaches are achieving water use objectives is whether toxic substances are present in water, sediment, or tissue of aquatic organisms in concentrations sufficient to impair beneficial uses. Table 49 summarizes the data from 1998 to 2004 regarding toxic substances in water, sediment, and tissue from aquatic organisms for the Kinnickinnic River watershed. For toxicants, the baseline period was extended to 2004 in order to take advantage of results from phase III of the MMSD Corridor Study Project conducted by the USGS. Pesticides were detected in water from one station along the mainstem of the River. The concentrations detected did not exceed water quality standards. No samples were available for concentrations of pesticides in tissue from aquatic organisms during the baseline period. Examination of water samples from the five long-term stations on the mainstem for 12 (out of 209) PCB congeners revealed concentrations that exceeded the human cancer criterion for public health and welfare at the three stations in the estuary. The 12 PCB congeners were not detected in samples from the reaches upstream of the estuary. No samples were available for concentration of PCBs in tissue from aquatic organisms during the baseline period. PCBs were detected in this sample. No data were available from the period 1998 to 2004 on the concentration of PCBs in sediment. Water samples from all five stations along the mainstem of the Kinnickinnic River showed detectable concentrations of PAHs. Limited sampling for other organic compounds showed detectable concentrations of the solvent isophorone and the stimulant caffeine in water from the mainstem of the River. The concentrations of this substance detected were below the human threshold criterion for public health and welfare. In addition, the aircraft deicing compounds ethylene glycol and propylene glycol were detected in water samples from three stations on Wilson Park Creek. Finally, water samples from the five long-term stations along the mainstem of the River were examined for concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. While the sample sizes given in Table 49 are representative of sampling for most of these metals, it is important to note that mercury was sampled less intensively. The number of samples analyzed for mercury was about two-thirds the number analyzed for other metals. Detectable concentrations of each of these metals were present in samples from each of the stations tested. Two of these metals were present at times in concentrations that exceeded water quality standards. Concentrations of mercury in water commonly exceeded both the human threshold concentration for public health and welfare and the wildlife criterion for surface water quality. The percent of samples exceeding the lower of these two concentrations is given in Table 49. In addition, concentrations of copper in water samples occasionally exceeded the EPA's criterion maximum concentration (CMC) for copper. About zero to 23 percent of samples, depending on the station, had copper concentrations exceeding this standard. At the S. 1st Street station, over 23 percent of samples had copper concentrations exceeding this standard. There were fewer exceedences of the CMC at the two stations in the lower portion of the estuary. At the Jones Island Ferry station and Greenfield Avenue (extended) station, the percentages of samples in which copper concentrations exceeded the CMC were zero and two, respectively.

The summary above suggests that some beneficial uses are being impaired by the presence of contaminants, especially PCBs and mercury. The fish consumption advisories in effect for the Kinnickinnic River shown in Table 31 reflect this.

Section 303(d) of the Clean Water Act requires that the states periodically submit a list of impaired waters to the USEPA for approval. Wisconsin most recently submitted this list in 2004.[35] This list was subsequently approved

[35] *Wisconsin Department of Natural Resources,* Approved 2004 Wisconsin 303(d) Impaired Waters List, *August 2004.*

Table 49

TOXICITY CHARACTERISTICS OF STREAMS IN THE KINNICKINNIC RIVER WATERSHED: 1998-2001[a]

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
Lyons Park Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
South 43rd Street Ditch	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Edgerton Ditch	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Holmes Avenue Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Villa Mann Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Cherokee Park Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Wilson Park Creek Tributary Upstream of Conduit	- -	- -	- -	- -	- -	- -	- -	- -	- -	D (19)	- -	- -	E-8 (15)	- -	- -
Wilson Park Creek Tributary Downstream of Conduit	- -	- -	- -	- -	- -	- -	- -	- -	- -	D (20)	- -	- -	E-18 (17)	- -	- -
Wilson Park Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	D (21)	- -	- -	E-19 (16)	- -	- -
Kinnickinnic River between Jones Island Ferry and Greenfield Avenue (extended)	- -	- -	- -	E-38 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-5 (43)	- -	- -
Kinnickinnic River between Greenfield Avenue (extended) and S. 1st Street	- -	- -	- -	E-31 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-4 (45)	- -	- -
Kinnickinnic River between S. 1st Street and S. 7th Street	- -	N (9)	- -	E-31 (13)	D (18)	- -	D (13)	D (18)	- -	- -	N (18)	- -	E-37 (43)	N (18)	- -
Kinnickinnic River between S. 7th Street and S. 27th Street	D (3)[c]	- -	- -	N (13)	- -	- -	D (13)	- -	- -	D (3)[c]	- -	- -	E-9 (43)	- -	- -
Kinnickinnic River above S. 27th Street	- -	- -	- -	N (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-16 (44)	- -	- -

NOTE: E-X denotes exceedence of a water quality standard in X percent of the samples, D denotes detection of a substance in this class in at least one sample, N denotes that no substances in this class were detected in any sample.

[a] *Number in parentheses indicates sample size.*

[b] *Metals sampled were arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. Sample sizes are shown for most metals. Mercury was sampled less frequently.*

[c] *These samples were taken at S. 11th Street.*

Source: SEWRPC.

by the USEPA. Table 48 and Map 27 indicate stream reaches in the Kinnickinnic River watershed that are classified as being impaired waters. The estuary portion of the mainstem of the Kinnickinnic River from S. Chase Avenue downstream to the confluence with the Milwaukee River portion of the estuary, all of which is classified as a variance water, is listed as impaired due to aquatic toxicity, bacteria, dissolved oxygen, and fish consumption advisories necessitated by high concentrations of PCBs and mercury in the tissue of fish collected from this reach. Metals, PCBs, bacteria, and phosphorus from a combination of nonpoint and point source pollution and contaminated sediment are cited as factors contributing to the impairment of this reach.

The Jackson Park Pond is also listed as impaired due to fish consumption advisories necessitated by high concentrations of PCBs in the tissue of fish collected from the pond. PCBs from contaminated sediment are cited as contributing to the impairment of the Pond.

SUMMARY

The water quality and pollution sources inventory for the Kinnickinnic River system have been summarized by answering five basic questions. The chapter provided detailed information needed to answer the questions. The information is summarized below.

How Have Water Quality Conditions Changed Since 1975?

Water quality conditions in the Kinnickinnic River watershed have both improved in some respects and declined in other respects since 1975.

Improvements in Water Quality

Concentrations in the Kinnickinnic River of several pollutants associated with combined sewer overflows, such as BOD, fecal coliform bacteria, and ammonia, have decreased. In addition, total phosphorus concentrations in the estuary have also decreased. These reductions in nutrients and oxygen-demanding wastes have produced some improvements in dissolved oxygen concentration and in lower chlorophyll-*a* concentrations in the estuary portion of the River. One important, though not the only, factor responsible for these decreases is the reduction in combined and separate sewer overflows resulting from construction and operation of MMSD’s inline storage system. These improvements also likely reflect both changes in the types of industries present in the watershed, the connection of most process wastewaters to the MMSD sewerage system, and the implementation of treatment requirements for all industrial discharges. Concentrations of lead have also declined, due largely to the phasing out of the use of lead as an additive to gasoline. Concentrations of mercury in the water have declined.

Some improvement has also occurred in the concentrations of BOD in Wilson Park Creek. While BOD concentrations downstream of General Mitchell International Airport were often very high during the period 1998 to 2001, they were lower than during the period from 1996 to 1997. Deicing compounds from General Mitchell International Airport are likely to constitute a major source of BOD to this stream.

No Change or Reductions in Water Quality

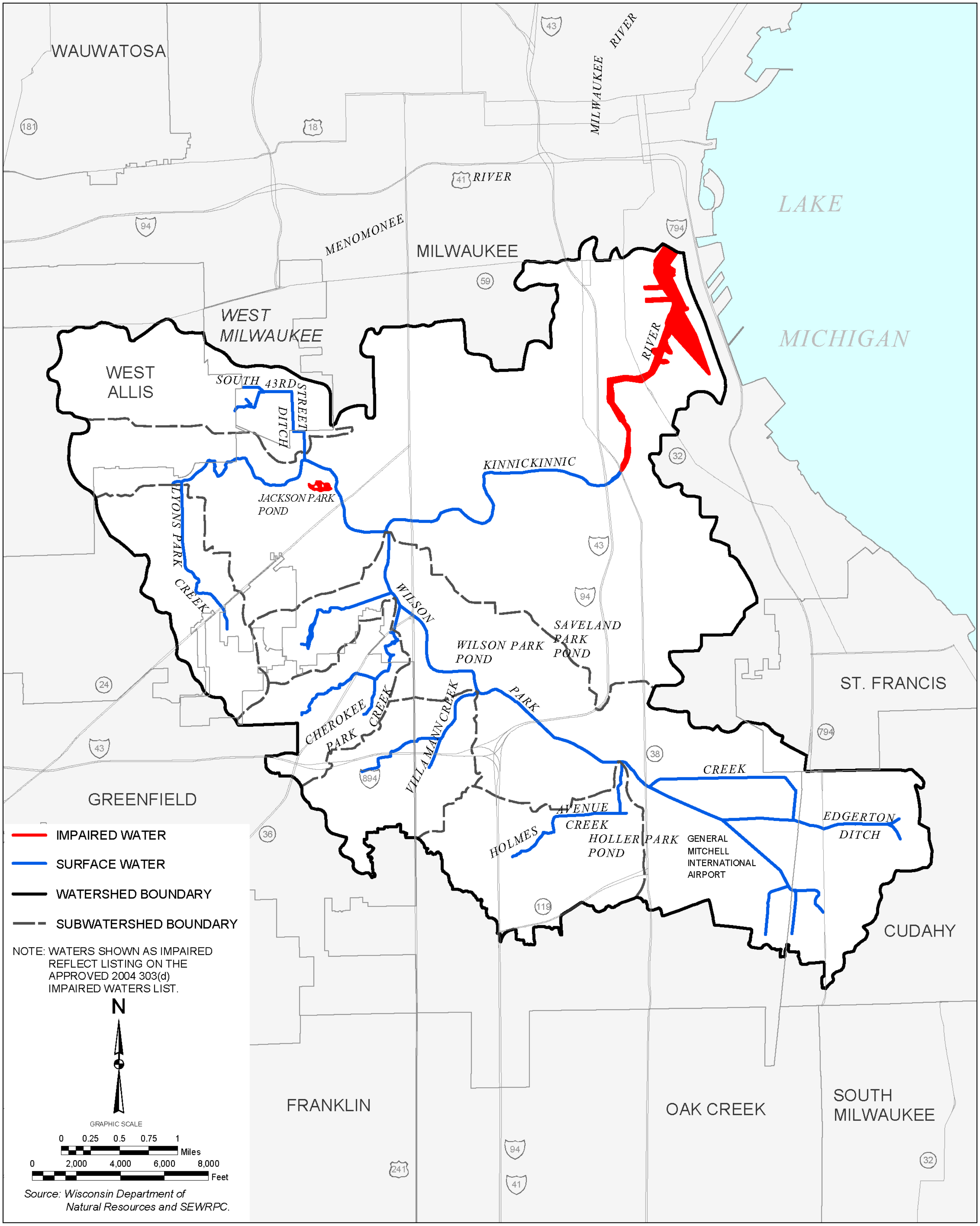
Concentrations of suspended and dissolved pollutants typically associated with stormwater runoff and other nonpoint source pollution, such as chloride, copper, total suspended solids, and zinc have remained unchanged or increased. For some of these pollutants, such as copper, increases in concentration have occurred in all reaches sampled along the Kinnickinnic River. For others, such as chloride and zinc, concentrations have increased in some reaches while remaining unchanged in others. In addition, specific conductance has increased in at least two reaches of the River, suggesting that the total concentration of dissolved material in the water has increased. In other reaches, the concentration of dissolved material, as indicated by specific conductance, has remained unchanged.

How Have Toxicity Conditions Changed Since 1975?

In some respects, toxicity conditions in the Kinnickinnic River have improved since 1975; in other respects, they have declined or not changed.

Map 27

IMPAIRED WATERS WITHIN THE KINNICKINNIC RIVER WATERSHED: 2004



Improvements in Toxicity Conditions

The concentrations of PAHs in water in the section of the Kinnickinnic River upstream from the estuary have declined. In addition, as described above, there have been reductions in concentrations of some toxic metals in the water column.

Worsened Toxicity Conditions

Other toxicity conditions in the Kinnickinnic River have gotten worse. The concentrations of PAHs detected in water in the estuary portion of the River have increased. Also, concentrations of zinc in the water column have increased in the estuary and concentrations of copper in water have increased along the entire Kinnickinnic River mainstem.

Inconclusive Toxicity Data

In some cases the available data are not adequate to assess changes. For example, the concentrations of PCBs detected in water during the period 1998 to 2001 were lower than the concentrations detected in previous samplings; however, the most recent samplings may underestimate PCB concentrations both because of methodological differences in sample collection and because they only screened for a subset of PCB congeners. Various pesticides have been detected in water in the Kinnickinnic River, but different compounds were screened for in recent samplings than were examined in historical samplings. Few recent data are available on tissue concentrations of mercury, PCBs, and pesticides in aquatic organisms in the watershed and consumption advisories remain in effect for several species of fish from portions of the watershed.

Sediment Conditions

In the most recent available data on sediment toxicity, the expected incidence of toxicity to benthic organisms shows a decline from 100 percent to 27 to 62 percent. The overall quality of sediment, as measured by mean PEC-Q, remains poor. Sediment in the Kinnickinnic River contains concentrations of chromium, lead, PCBs, PAHs, zinc, and some pesticides high enough to pose substantial risks of toxicity to benthic organisms, and contains concentrations of cadmium, copper, iron, mercury, nickel, and other pesticides high enough to likely produce some toxic effects in benthic organisms.

What Are the Sources of Water Pollution?

The Kinnickinnic River watershed contains several potential sources of water pollution. These fall into two broad categories: point sources and nonpoint sources.

Point Sources

There are no public or private sewage treatment plants discharging into the Kinnickinnic River watershed. MMSD has 26 combined sewer overflow outfalls that discharge to the streams in the Kinnickinnic River watershed. These outfalls convey a combination of stormwater runoff and sanitary sewage from the combined sewer system to the surface water system of the watershed as a result of high water volume from stormwater, meltwater, and excessive infiltration and inflow of clear water during wet weather conditions. Prior to 1994, overflows from these sites typically occurred around 50 times per year. Since MMSD's inline storage system came online in 1994, the number of combined sewer overflows per year has declined to about three. Since 1995, separate sewer overflows have been reported at eight locations: four within MMSD's SSO area and four within local communities. The number of SSO events occurring per year has shown a decline similar to that of CSO events. As of February 2003, 33 industrial dischargers and other point sources were permitted through the WPDES program to discharge wastewater to streams in the Kinnickinnic River watershed. About half of the permitted facilities discharged noncontact cooling water. The remaining discharges are of several types as indicated in Table 37. All of the permitted discharges are of a nature which typically complies with the WPDES permit levels which are designed to meet water quality standards.

Nonpoint Sources

The Kinnickinnic River watershed is dominated by urban land uses and contains no significant rural lands. The entire watershed is contained within MMSD's planned sewer service area. Because there are no urban enclaves outside of the planned sewer service area, failure of onsite sewage treatment systems is not an issue in this watershed. About 17 percent of the watershed is served by combined sanitary and storm sewers which convey sewage and stormwater to MMSD's sewage treatment facilities, resulting in a high degree of nonpoint source pollution control from the combined sewer service area. All communities in the watershed have adopted construction erosion control ordinances. All communities in the watershed except for the Village of West Milwaukee have adopted stormwater management ordinances or plans. It is anticipated that the Village of West Milwaukee will adopt a stormwater management ordinance in order to fulfill the conditions of the WPDES stormwater discharge permit that they have applied for. As of February 2003, 81 facilities engaged in industrial activities in the watershed had applied for and obtained WPDES stormwater discharge permits. As a condition of these permits, these facilities are required to develop and follow a stormwater pollution prevention plan. There are currently no active solid waste landfills in the watershed. The watershed contains one inactive solid waste landfill, located in the Wilson Park Creek subwatershed.

Quantification of Pollutant Loads

The annual average load of BOD to streams of the Kinnickinnic River watershed is estimated to be 408,500 pounds per year. Combined sewer overflows and separate sewer overflows contribute about 1.7 percent and 3.1 percent, respectively, of this load. Industrial discharges contribute about 3.9 percent of this load. The rest of BOD loadings to streams in the Kinnickinnic River watershed, about 91.3 percent, are contributed by nonpoint sources.

The annual average load of TSS to streams of the Kinnickinnic River watershed is estimated to be 5,298,770 pounds per year. Combined sewer overflows and separate sewer overflows contribute about 0.8 percent and 1.0 percent, respectively, of this load. Industrial discharges contribute about 0.2 percent of this load. The rest of TSS loadings to streams in the Kinnickinnic River watershed, about 98.0 percent, are contributed by nonpoint sources.

The annual average load of fecal coliform bacteria to streams of the Kinnickinnic River watershed is estimated to be 4,891.36 trillion cells per year. Combined sewer overflows and separate sewer overflows contribute about 11.3 percent and 20.0 percent, respectively, of this load. The rest of fecal coliform bacteria loadings to streams in the Kinnickinnic River watershed, about 68.7 percent, are contributed by nonpoint sources.

The annual average load of total phosphorus to streams of the Kinnickinnic River watershed is estimated to be 12,750 pounds per year. Combined sewer overflows and separate sewer overflows contribute about 3.8 percent and 7.0 percent, respectively, of this load. Industrial discharges contribute about 11.3 percent of this load. The rest of total phosphorus loadings to streams in the Kinnickinnic River watershed, about 77.9 percent, are contributed by urban nonpoint sources.

What is the Current Condition of the Fishery?

The Kinnickinnic River watershed seems to have very poor fishery and macroinvertebrate communities at present. The fish community contains relatively few species of fishes, is trophically unbalanced, contains few or no top carnivores, and is dominated by tolerant fishes. The macroinvertebrate community is equally depauperate and dominated by tolerant taxa. Since water quality has generally been improving in the watershed for some constituents, habitat seems to potentially be the most important factor limiting both the fishery and macro-invertebrate community.

To What Extent Are Water Use Objectives and Water Quality Standards Being Met?

During the 1998 to 2001 study baseline period, the Kinnickinnic River only partially met the water quality criteria supporting its recommended water use classification. In the vast majority of the samples taken from the mainstem of the River temperatures and concentrations of dissolved oxygen and ammonia were in compliance with the relevant water quality standards. Only in occasional samples in the reaches between S. 27th Street and S. 1st Street were temperatures above the standard of 89ºF or were dissolved oxygen concentrations below the special variance standard of 2.0 mg/l that applies to the Kinnickinnic River. Concentrations of fecal coliform bacteria in the Kinnickinnic River often exceed the special variance standard of 1,000 cells per 100 ml which applies to the River. The rate of compliance with this standard increased from upstream to downstream. At the S. 27th Street station, fecal coliform counts were below the standard in only about 30 percent of samples. This increased to about 77 percent at the Jones Island Ferry station. Compliance with the standard for total phosphorus recommended in the regional water quality management plan followed the same pattern: the number of samples showing total phosphorus below the 0.1 mg/l standard increased from upstream to downstream from a low of about 30 percent at the S. 27th Street station to a high of about 74 percent at the Jones Island Ferry station.

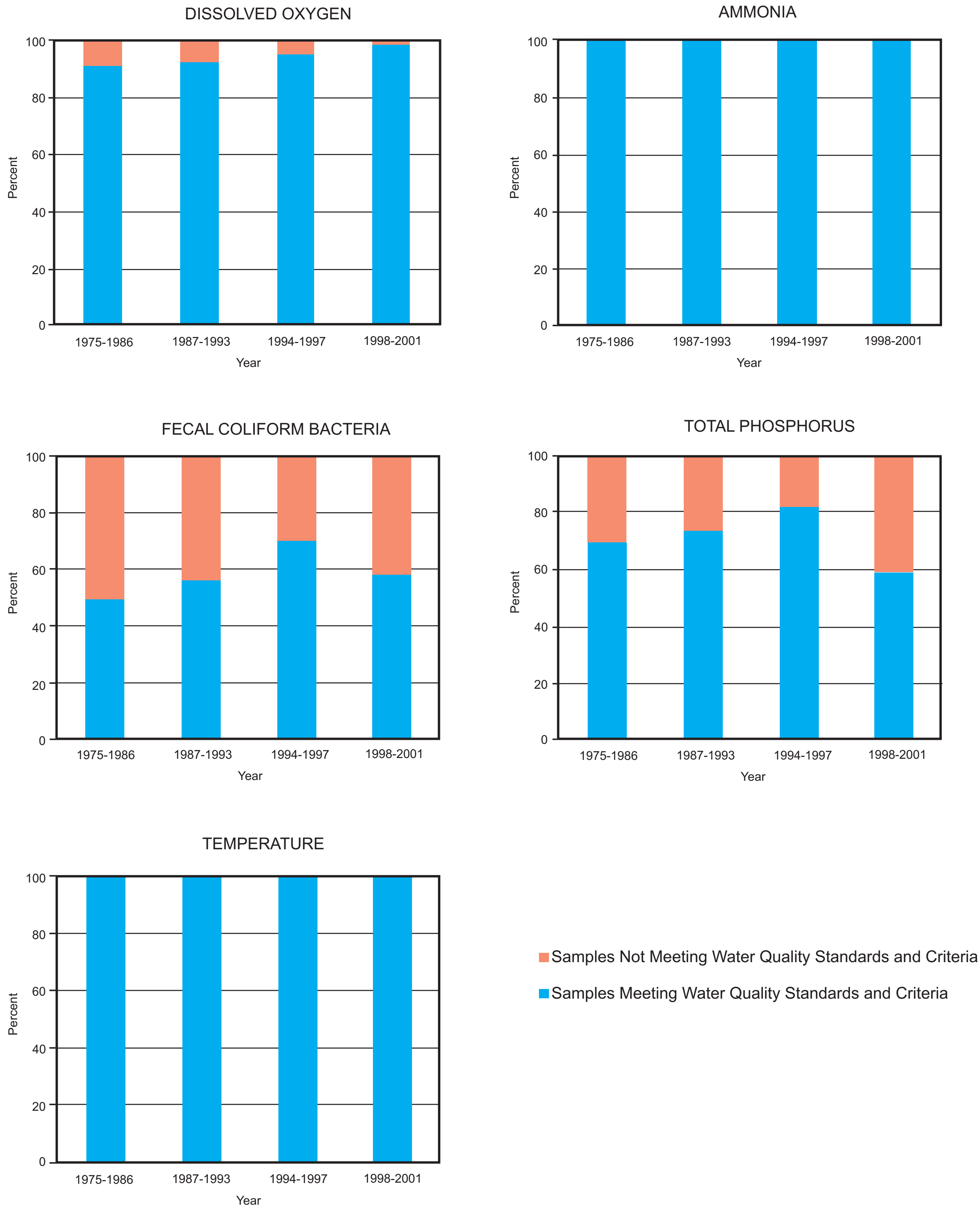
Figure 63 shows changes over time in the proportions of samples showing compliance with applicable water quality standards for the Kinnickinnic River. Over the entire study period of 1975-2001, water temperatures and concentrations of ammonia were in compliance with the applicable water quality standards in all samples, and dissolved oxygen concentrations were in compliance approximately 90 percent or more of the time, with the proportion of samples in compliance increasing over time. By contrast, significant percentages of samples collected in each period had concentrations of fecal coliform bacteria and total phosphorus that were not in compliance with the applicable water quality standard. In about 50 percent of the samples collected during the period 1975-1986, fecal coliform bacteria concentrations were in compliance with the standard. This rate of compliance increased to close to 70 percent of the samples collected during the period 1994-1997, and then decreased somewhat to just below 60 percent of the samples in the period from 1998-2001. The rate of compliance with the standard recommended for total phosphorus in the regional water quality management plan increased from about 70 percent of samples collected being in compliance during the period 1975-1986 to just over 80 percent of all samples being in compliance during the period 1994-1997. During the period 1998-2001 the percentage of samples collected in compliance with the standard decreased to just below 60 percent.

Relatively few data are available for assessing whether streams tributary to the Kinnickinnic River are meeting water use objectives and water quality standards. Based on available data, Wilson Park Creek is only partially meeting its water use objectives. While ammonia concentrations in this stream were below the acute toxicity standard for fish and aquatic life in almost all samples, total phosphorus concentrations exceeded the recommended concentration in about 30 percent of the samples.

Some toxic substances have been detected in the Kinnickinnic River watershed at concentrations that may impede beneficial uses. In 31 to 38 percent of the water samples taken at the three sampling stations in the estuary section of the Kinnickinnic River, PCBs were present in concentrations that exceeded the human cancer criterion for public health and welfare. In addition, concentrations of mercury in water samples taken from the Kinnickinnic River and Wilson Park Creek often exceeded both the human threshold concentration for public health and welfare and the wildlife criterion for surface water quality. Also, concentrations of copper in water samples occasionally exceeded the EPA's criterion maximum concentration.

Figure 63

PROPORTION OF SAMPLES FOR SEVERAL CONSTITUENTS MEETING WATER QUALITY STANDARDS AND CRITERIA ALONG THE MAINSTEM OF THE KINNICKINNIC RIVER: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, and Milwaukee Metropolitan Sewerage District.

Chapter VI

SURFACE WATER QUALITY CONDITIONS AND SOURCES OF POLLUTION IN THE MENOMONEE RIVER WATERSHED

INTRODUCTION AND SETTING WITHIN THE STUDY AREA

A basic premise of the Commission watershed studies is that the human activities within a watershed affect, and are affected by, surface and groundwater quality conditions. This is especially true in the urban and urbanizing areas of the Menomonee River watershed, where the effects of human activities on water quality tend to overshadow natural influences. The hydrologic cycle provides the principal linkage between human activities and the quality of surface and ground waters in that the cycle transports potential pollutants from human activities to the environment and from the environment into the sphere of human activities.

Comprehensive water quality planning efforts such as the regional water quality management plan update, should include an evaluation of historic, present, and anticipated water quality conditions and the relationship of those conditions to existing and probable future land and water uses. The purpose of this chapter is to determine the extent to which surface waters in the Menomonee River watershed have been and are polluted, and to identify the probable causes for, or sources of, that pollution. More specifically, this chapter documents current surface water pollution problems in the watershed utilizing field data from a variety of water quality studies, most of which were conducted during the past 30 years; indicates the location and type of the numerous and varied sources of wastewater, industrial, stormwater runoff, and other potential pollutants discharged to the surface water system of the watershed; describes the characteristics of the discharges from those sources; and, to the extent feasible, quantifies the pollutant contribution of each source. The information presented herein provides an important basis for the development and testing of the alternative water quality control plan elements under the regional water quality management plan update.

DESCRIPTION OF THE WATERSHED

The Menomonee River watershed is located in the east-central portion of the Southeastern Wisconsin Region and covers an area of approximately 136 square miles. The Menomonee River originates in southeastern Washington County, and flows approximately 28 miles through the northeastern corner of Waukesha County and through western and central Milwaukee County to its confluence with the Milwaukee River. The Little Menomonee River originates in southwestern Ozaukee County and from there flows approximately 11 miles through the northwestern part of Milwaukee County to its confluence with the Menomonee River. Rivers and streams in the watershed are part of the Lake Michigan drainage system as the watershed lies east of the subcontinental divide. The boundaries of the basin, together with the locations of the main channels of the Menomonee River watershed and its principal tributaries, are shown on Map 28. The Menomonee River watershed contains no lakes with a surface area of 50 acres or more.

Civil Divisions

Superimposed on the watershed boundary is a pattern of local political boundaries. As shown on Map 29, the watershed lies within Milwaukee, Ozaukee, Washington, and Waukesha Counties. Seventeen civil divisions lie in part or entirely within the Menomonee River watershed, as also shown on Map 29 and Table 50. Geographic boundaries of the civil divisions are an important factor which must be considered in the regional water quality management plan update since the civil divisions form the basic foundation of the public decision making framework within which intergovernmental, environmental, and developmental problems must be addressed.

LAND USE

This section describes the changes in land use which have occurred within the Menomonee River watershed since 1970, the approximate base year of the initial regional water quality management plan, and indicates the changes in such land uses since 1990, the base year of the initial plan update, as shown in Table 51. Although the watershed is largely urbanized, 36 percent of the watershed was still in rural and other open space land uses in 2000. These rural and open space uses included about 17 percent of the total area of the watershed in agricultural and related rural uses, about 2 percent in woodlands, about 8 percent in surface water and wetlands, and about 8 percent in other open lands. Most of the rural and open spaces remaining in the watershed are located in Ozaukee and Washington Counties. The remaining approximately 63 percent of the total watershed was devoted to urban uses, as shown on Map 30.

Urban development exists in much of the Menomonee River watershed, with concentrated development generally occurring in portions of Milwaukee, Washington, and Waukesha Counties. Concentrations of urban-related land use are located in and around the Village of Menomonee Falls, particularly along the STH 175 corridor, in the Villages of Elm Grove, Greendale, Germantown, and West Milwaukee, and in the Cities of Brookfield, Greenfield, Wauwatosa, West Allis, and Milwaukee. Urban land use in the watershed continued to increase, from about 80 square miles in 1990, to about 87 square miles in 2000, or by about 9 percent. As shown in Table 51, residential land represents the largest urban land use in the watershed. Since 1990, most, though not all, of the urban growth in the watershed has occurred in the northwestern portion of the watershed in the Villages of Germantown and Menomonee Falls. The historic urban growth within the Menomonee River watershed is summarized on Map 31 and Table 52.

These changes in land use reflect changes in population and population distribution within the watershed. Several trends are apparent in the data. Over the long term the number of persons living in the watershed has declined. From 1970 through 1990, the population in the watershed decreased by about 23,969, from 346,412 to 322,443; however, during that time period the number of households increased by 18,076, from 107,155 to 125,231. Between 1990 and 2000 the size of the population in the watershed has remained nearly stable, declining to 321,999 persons, or a decrease of only 444 persons. During this decade of relatively stable population numbers, the number of households in the watershed continued to rise, reaching 129,736, an increase of 4,505 units.

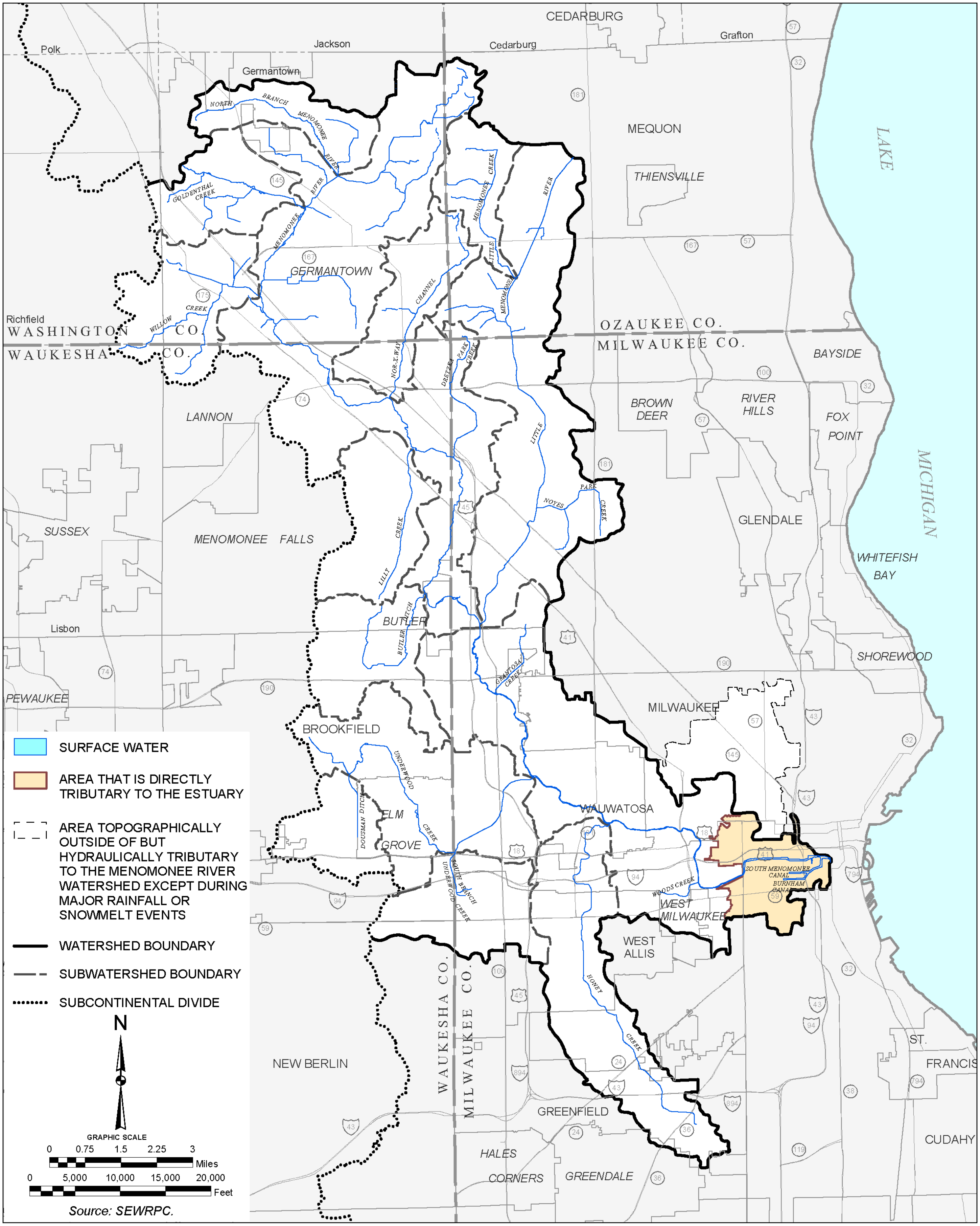
QUANTITY OF SURFACE WATER

Since 1975, measurements of discharge have been taken at a number of locations along the Menomonee River and its tributaries. The period of record for most of these stations is rather short, with data collection occurring over periods ranging from about six months to about eight years. A few stations have longer periods of record.

Figure 64 shows historic and baseline period discharge for the three stations with long-term records extending into the baseline period. Similar annual patterns are seen in the historic mean discharge at all three sites. Mean monthly streamflow tends to reach a low point during the late summer or early fall. The exact timing of this minimum appears to depend on the location of the station in the watershed: It occurs earlier at the upstream stations. Mean monthly discharge rises from this low point to a peak in December. It then declines to a second

Map 28

SURFACE WATER WITHIN THE MENOMONEE RIVER WATERSHED: 2000



Source: SEWRPC.

Map 29

CIVIL DIVISIONS WITHIN THE MENOMONEE RIVER WATERSHED: 2000

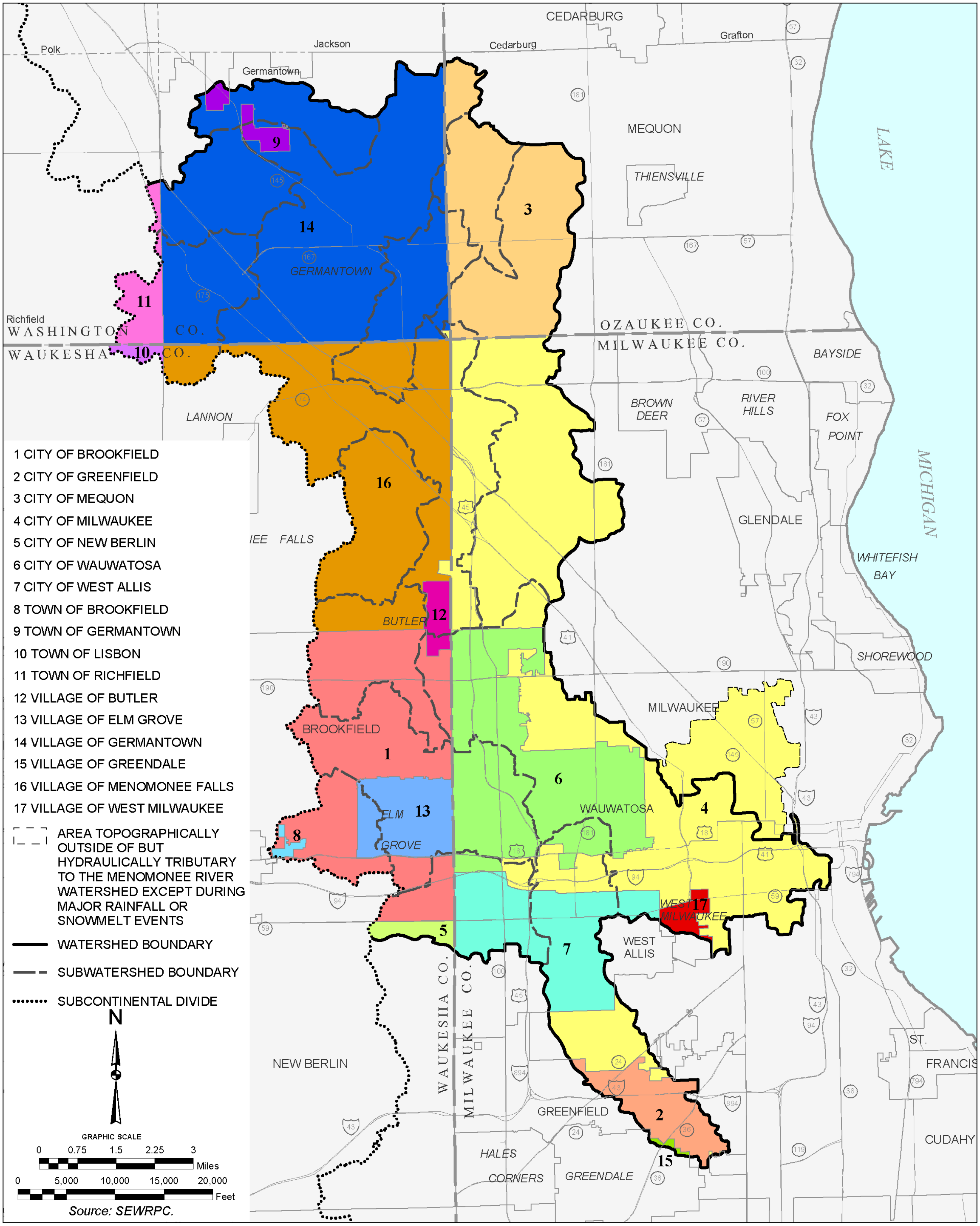


Table 50

AREAL EXTENT OF COUNTIES, CITIES, VILLAGES, AND TOWNS WITHIN THE MENOMONEE RIVER WATERSHED

Civil Division	Area (square miles)	Percent of Total
Ozaukee County		
City of Mequon	11.69	8.59
Milwaukee County		
City of Greenfield	2.90	2.13
City of Milwaukee	31.60	23.23
City of Wauwatosa	13.23	9.72
City of West Allis	6.77	4.97
Village of Greendale	0.12	0.09
Village of West Milwaukee	0.64	0.47
Subtotal	55.26	40.61
Washington County		
City of Milwaukee	0.02	0.02
Town of Germantown	0.76	0.56
Town of Richfield	1.55	1.14
Village of Germantown	29.37	21.59
Subtotal	31.70	23.31
Waukesha County		
City of Brookfield	13.54	9.95
City of New Berlin	0.67	0.49
City of Milwaukee	0.08	0.06
Town of Brookfield	0.21	0.15
Town of Lisbon	0.29	0.21
Village of Butler	0.79	0.58
Village of Elm Grove	3.29	2.42
Village of Menomonee Falls	18.54	13.63
Subtotal	37.41	27.49
Total	136.06	100.00

Source: SEWRPC.

minimum that occurs in January. Following this, it rises to high levels associated with spring snowmelt and rains. It remains high through March and April. Following this, it declines to the low levels of late summer and early fall. Considerable variability is associated with these patterns, but some of this variability is more likely attributed to sampling conditions rather than actual changes in discharge. For example, during January and February of some years, no discharge was detected in Underwood Creek; however, this may be related to freeze-up conditions when measurements cannot be made.

For the most part, stream flow from the baseline period is within historic ranges at all three long-term stations.

Flow fractions were calculated for all stations relative to the discharge at the 70th Street station using the procedure described in Chapter III of this report. These are shown on Map 32. Several generalizations emerge from this analysis:

- The magnitude of average discharge increases rapidly in the headwaters of the River. For example, average discharge roughly doubles between the station near Highway 167 in Germantown and the station at Pilgrim Road in Menomonee Falls. Some of the increase in discharge represents contributions of water from Willow Creek.

Table 51

LAND USE IN THE MENOMONEE RIVER WATERSHED: 1970-2000[a,b]

Category	1970		1990		2000		Change 1970-2000	
	Square Miles	Percent of Total	Square Miles	Percent of Total	Square Miles	Percent of Total	Square Miles	Percent
Urban								
Residential	33.4	24.6	38.6	28.4	40.5	29.8	7.1	21.3
Commercial	2.8	2.1	4.5	3.3	5.5	4.0	2.7	96.4
Industrial and Extractive	4.4	3.2	6.0	4.4	6.9	5.1	2.5	56.8
Transportation, Communication, and Utilities[c]	18.8	13.9	19.8	14.6	22.7	16.8	3.9	20.7
Governmental and Institutional	5.3	3.9	5.8	4.3	5.7	4.2	0.4	7.5
Recreational	4.3	3.2	5.0	3.7	5.3	3.9	1.0	23.3
Subtotal	69.0	50.9	79.7	58.7	86.7	63.8	17.7	25.7
Rural								
Agricultural and Related	40.6	29.9	30.0	22.1	23.4	17.2	-17.2	-42.4
Water	0.5	0.4	0.8	0.6	0.8	0.5	0.3	60.0
Wetlands	9.7	7.1	10.3	7.6	10.6	7.8	0.9	9.3
Woodlands	3.8	2.8	3.4	2.5	3.3	2.4	-0.5	-13.2
Unused and Other Open Lands	12.1	8.9	11.5	8.5	11.0	8.1	-1.1	-9.1
Subtotal	66.7	49.1	56.0	41.3	49.1	36.2	-17.6	-26.4
Total	135.7	100.0	135.7	100.0	135.8	100.0	0.1	0.0

[a]*As approximated by whole U.S. Public Land Survey one-quarter sections.*

[b]*As part of the regional land use inventory for the year 2000, the delineation of existing land use was referenced to real property boundary information not available for prior inventories. This change increases the precision of the land use inventory and makes it more usable to public agencies and private interests throughout the Region. As a result of the change, however, year 2000 land use inventory data are not strictly comparable with data from the 1990 and prior inventories. At the county and regional level, the most significant effect of the change is to increase the transportation, communication, and utilities category, the result of the use of narrower estimated right-of-ways in prior inventories. The treatment of streets and highways generally diminishes the area of adjacent land uses traversed by those streets and highways in the 2000 land use inventory relative to prior inventories.*

[c]*Off-street parking of more than 10 spaces are included with the associated land use.*

Source: SEWRPC.

- Much of the discharge at downstream stations can be accounted for by discharge from stations upstream and from tributaries entering the River upstream. For instance, median discharge from the Menomonee River at N. 124th Street, the Little Menomonee River, Underwood Creek, and Honey Creek, represent about 46 percent, 10 percent, 14 percent, and 6 percent, respectively, of the median discharge at 70th Street. Together, median discharge from these four sources represents about 76 percent of the median discharge in the Menomonee River at 70th Street. The remainder of the median discharge is contributed by direct runoff and direct baseflow to the Menomonee River mainstem and runoff and baseflow from smaller tributaries.

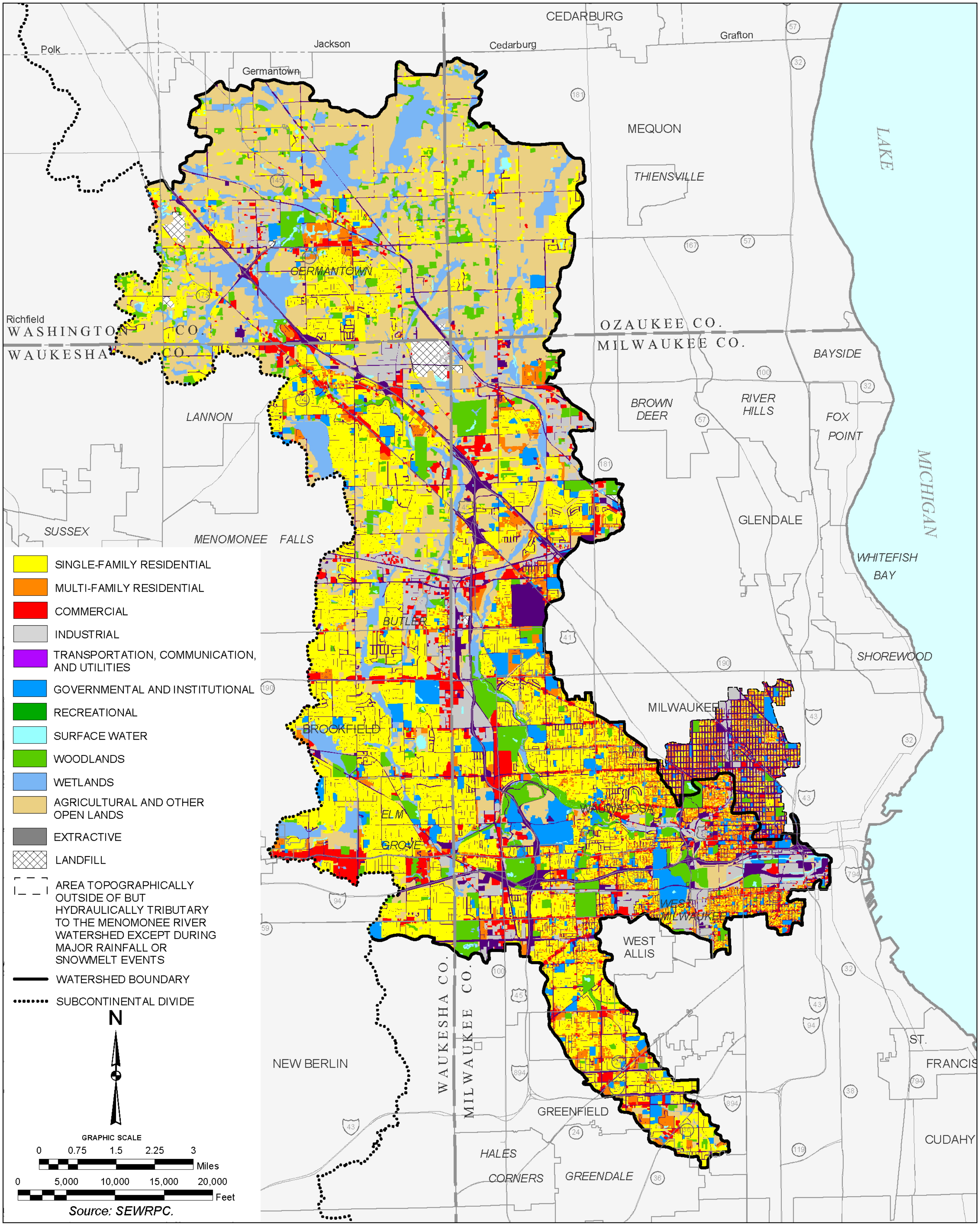
SURFACE WATER QUALITY OF THE MENOMONEE RIVER WATERSHED: 1975-2001

The earliest systematic collection of water quality data in the Menomonee River watershed occurred in the mid-1960s.[1] Data collection after that was sporadic until the 1970s. Since then, considerable data have been collected, especially on the mainstem of the River. The major sources of data include the Milwaukee Metropolitan Sewerage District (MMSD), the Wisconsin Department of Natural Resources (WDNR), and the U.S. Geological Survey

[1]*SEWRPC Technical Report No. 4,* Water Quality and Flow of Streams in Southeastern Wisconsin*, April 1964.*

Map 30

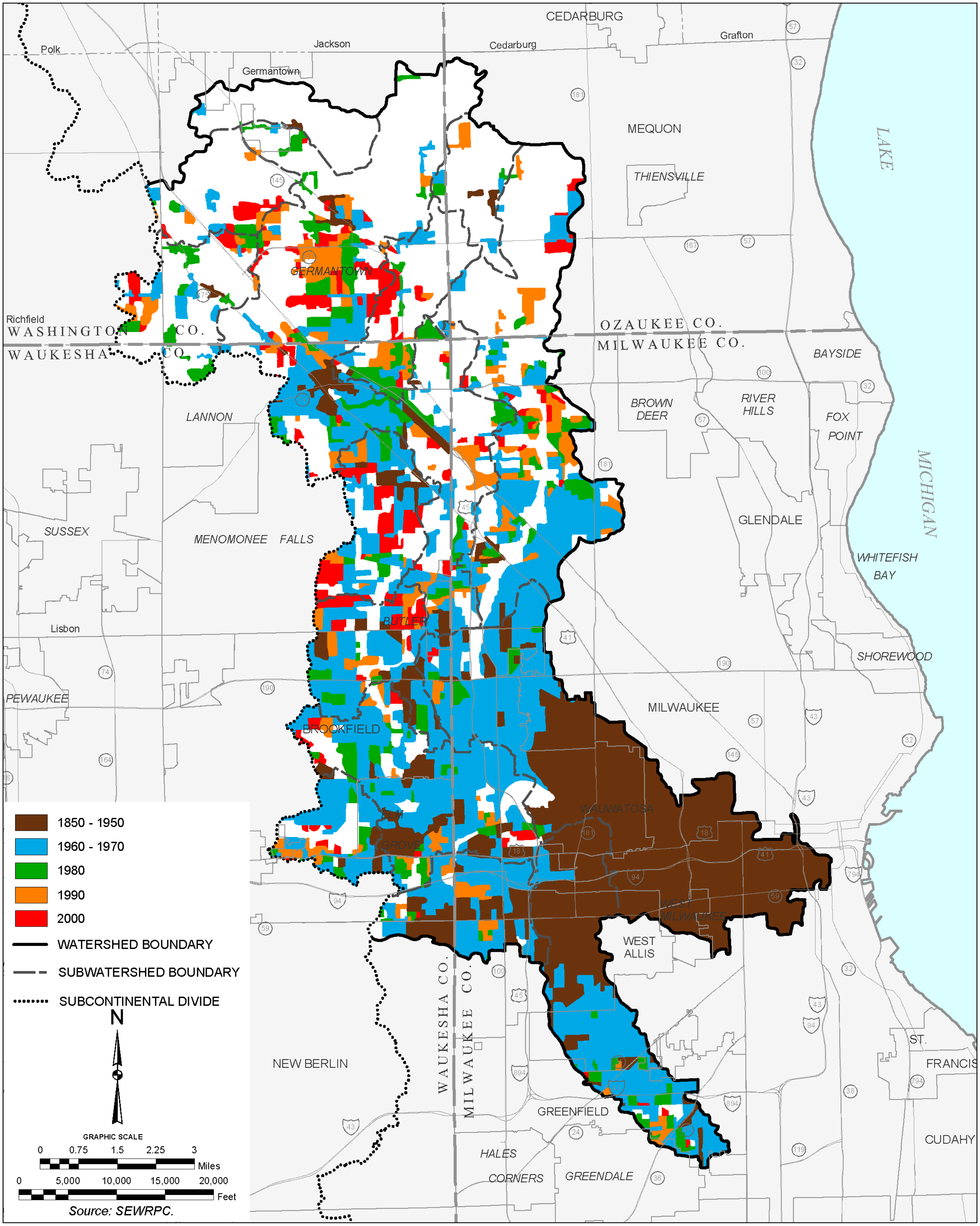
EXISTING LAND USE WITHIN THE MENOMONEE RIVER WATERSHED: 2000



Source: SEWRPC.

Map 31

HISTORICAL URBAN GROWTH WITHIN THE MENOMONEE RIVER WATERSHED: 1850-2000



Source: SEWRPC.

(USGS) (see Map 33). In addition, Commission staff reviewed data collected by citizen monitoring programs including the Testing the Waters Program and the Water Action Volunteers Program. These data are presented in Appendix B. The largest portion of data was collected by MMSD. Most of these data were obtained from sampling stations along the mainstem of the River. The data record for many of the tributary streams is fragmentary.

For analytical purposes, data from four time periods were examined: 1975-1986, 1987-1993, 1994-1997, and 1998-2001. Continuous bimonthly data records exist from two of MMSD's long-term monitoring stations beginning in 1975. After 1986, MMSD no longer conducted sampling during the winter months. In 1994, the Inline Storage System, or Deep Tunnel, came online. The remaining period from 1998-2001 defines the baseline water quality conditions of the river system, developed since the Inline Storage System came online.

Under this plan update, baseline water quality conditions were graphically compared to historic conditions on a monthly basis. As shown in the sample graph presented in Figure 23 of Chapter III of this report, for each water quality parameter examined, the background of the graph summarizes the historic conditions. The white area in the graphs shows the range of values observed during the period 1975-1997. The upper and lower boundaries between the white and gray areas show historic maxima and minima, respectively. A blue background indicates months for which no historic data were available. The dashed black line plots the monthly mean value of the parameter for the historical period. Overlaid on this background is a summary of baseline conditions from the period 1998-2001. The black dots show the monthly mean value of the parameter for that period. The black bars show the monthly ranges of parameter for the same period.

Table 52

EXTENT OF URBAN GROWTH WITHIN THE MENOMONEE RIVER WATERSHED: 1850-2000

Year	Extent of New Urban Development Occurring Since Previous Year (acres)[a]	Cumulative Extent of Urban Development (acres)[a]	Cumulative Extent of Urban Development (percent)[a]
1850	654	654	0.8
1880	556	1,210	1.4
1900	1,412	2,622	3.0
1920	3,145	5,767	6.7
1940	6,610	12,377	14.3
1950	5,487	17,864	20.7
1963	18,473	36,337	42.1
1970	4,811	41,148	47.6
1975	2,015	43,163	50.0
1980	3,117	46,280	53.6
1985	2,523	48,803	56.5
1990	2,080	50,883	58.9
1995	1,759	52,642	60.9
2000	1,744	54,386	63.0

[a]*Urban development, as defined for the purposes of this discussion, includes those areas within which houses or other buildings have been constructed in relatively compact groups, thereby indicating a concentration of urban land uses. Scattered residential developments were not considered in this analysis.*

Source: U.S. Bureau of the Census and SEWRPC.

In addition to this summarization, water quality parameters from the Menomonee River were examined for the presence of several different types of trends: differences between the average values of parameters from sampling stations located in upstream areas and the average values of parameters from sampling stations located in the Milwaukee River Estuary, changes at individual sampling stations over time, changes along the length of the River, and seasonal changes throughout the year. Map 33 and Table 53 show the eight sampling stations, designated by their River Mile locations, which had sufficiently long periods of sampling to be used for this analysis. Figure 65 shows photos of selected river sampling stations within the Menomonee River watershed. Trends were examined along a section of the Menomonee River from the confluence with the Milwaukee River to a station 23.5 miles upstream. Changes over time were assessed both on an annual and on a seasonal basis as set forth in Appendix C. It is important to note that only limited data were available to assess baseline water quality conditions for tributary streams.

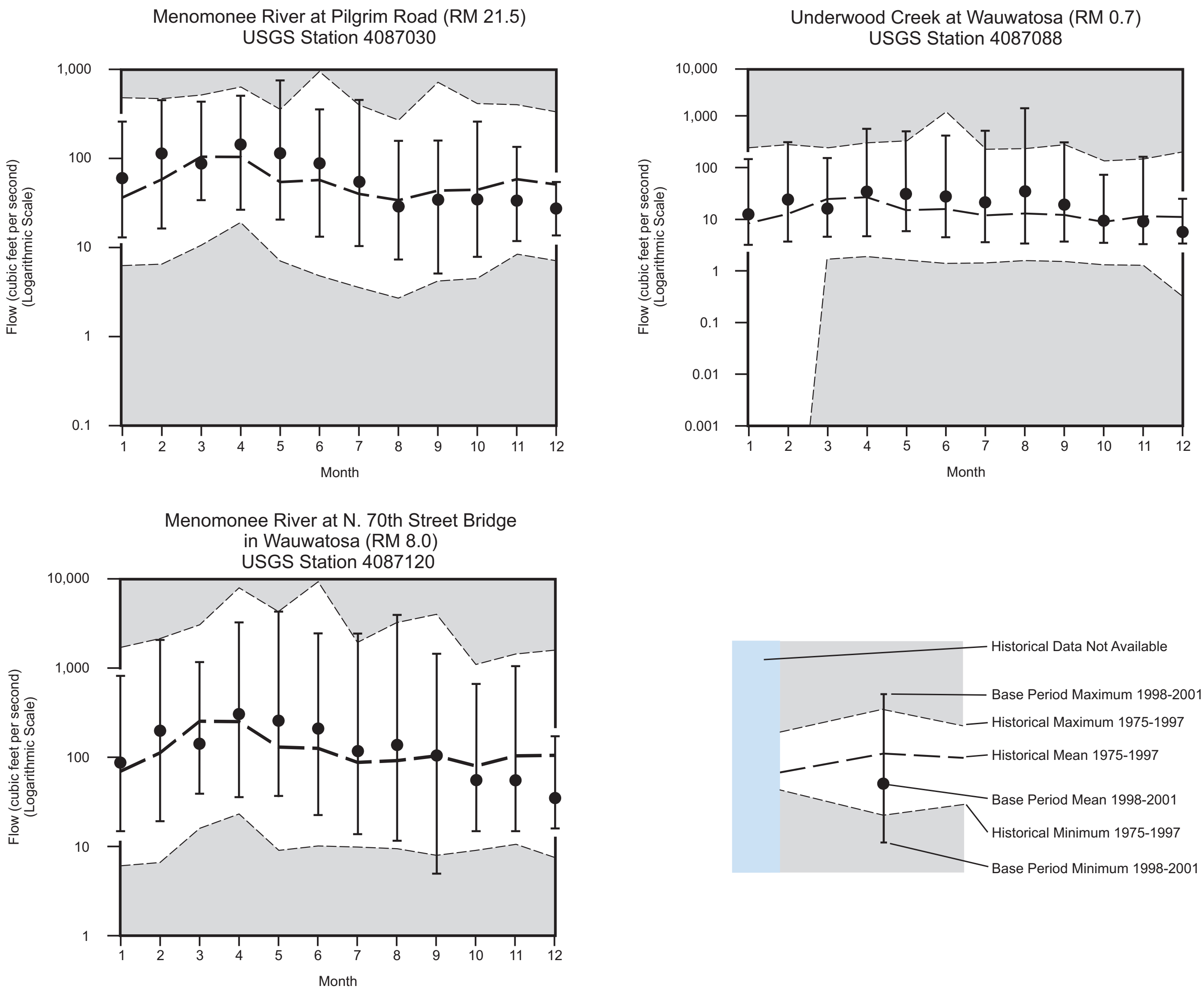
Bacterial and Biological Parameters

Bacteria

As shown in Figure 66, median concentrations of fecal coliform bacteria in the Menomonee River ranged from about 2,000 to 20,000 cells per 100 ml. Fecal coliform counts in the River varied over six orders of magnitude,

Figure 64

HISTORICAL AND BASE PERIOD FLOW AT LONG-TERM STATIONS ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001

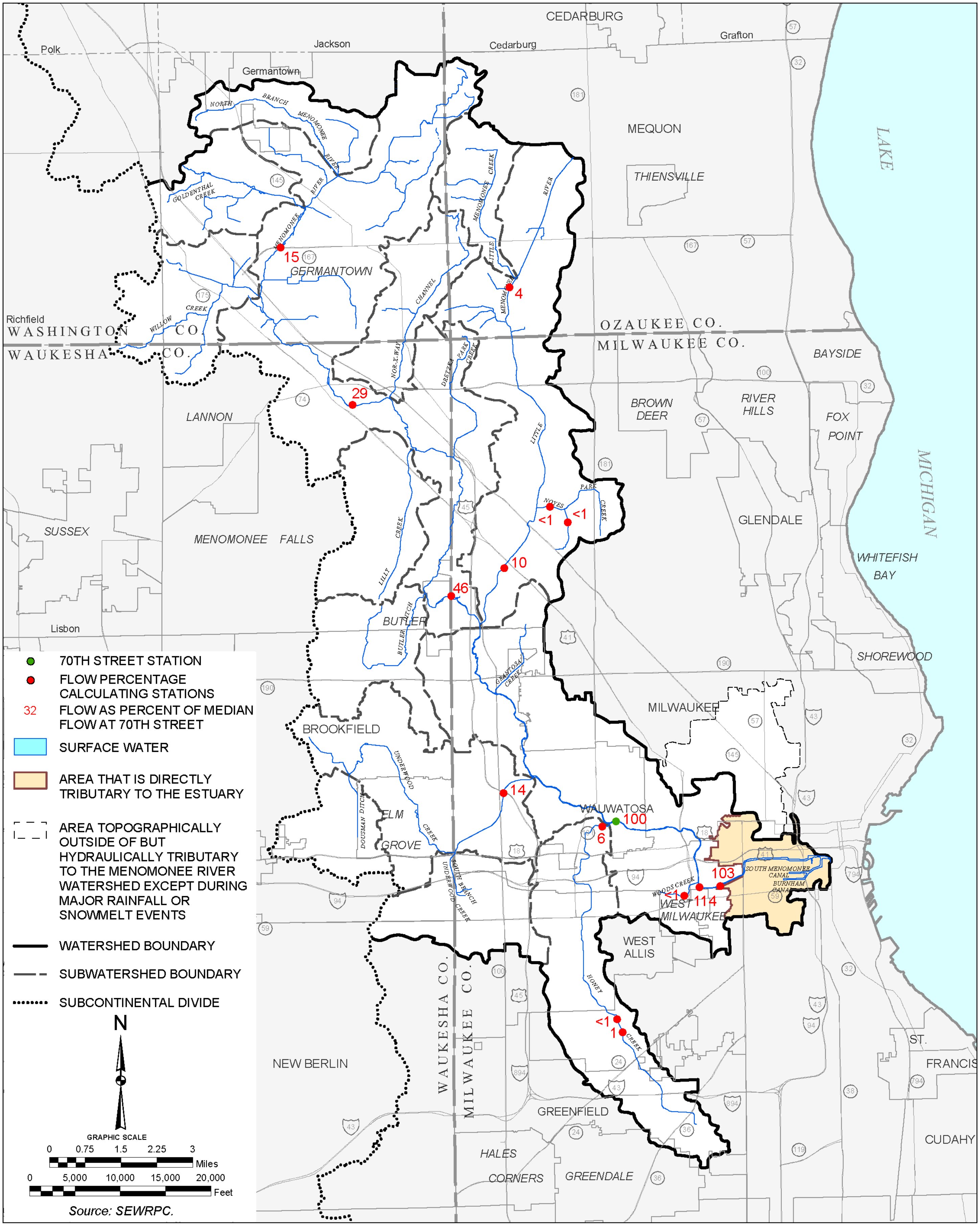


Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

ranging from as low as one cell per 100 ml to over two million cells per 100 ml. The range of variability appears to be higher during the summer and fall as shown in Figure 67, although it is important to note that this may reflect the larger numbers of samples that were taken during the summer and fall than during the spring and winter. Counts in most samples exceed the standard for full recreational use of 200 cells per 100 ml. In addition, the fecal coliform counts in many samples exceed the standard of 1,000 cells per 100 ml applied by the variance covering the Menomonee River. Table 54 shows that prior to 1994, the mean concentrations of fecal coliform bacteria in the estuary were significantly higher than the mean concentrations of fecal coliform bacteria in the section of the River upstream of the estuary. This suggests that water in the estuary was receiving more contamination from sources containing these bacteria than water in the nonestuary sections of the River. Given that the sampling stations in the estuary are the only stations along the Menomonee River that are within the combined sewer overflow area, this suggests that overflows from combined sewers may have been contributing to higher amounts of fecal coliform bacteria in the water of the estuary than in water in the reaches upstream from

Map 32

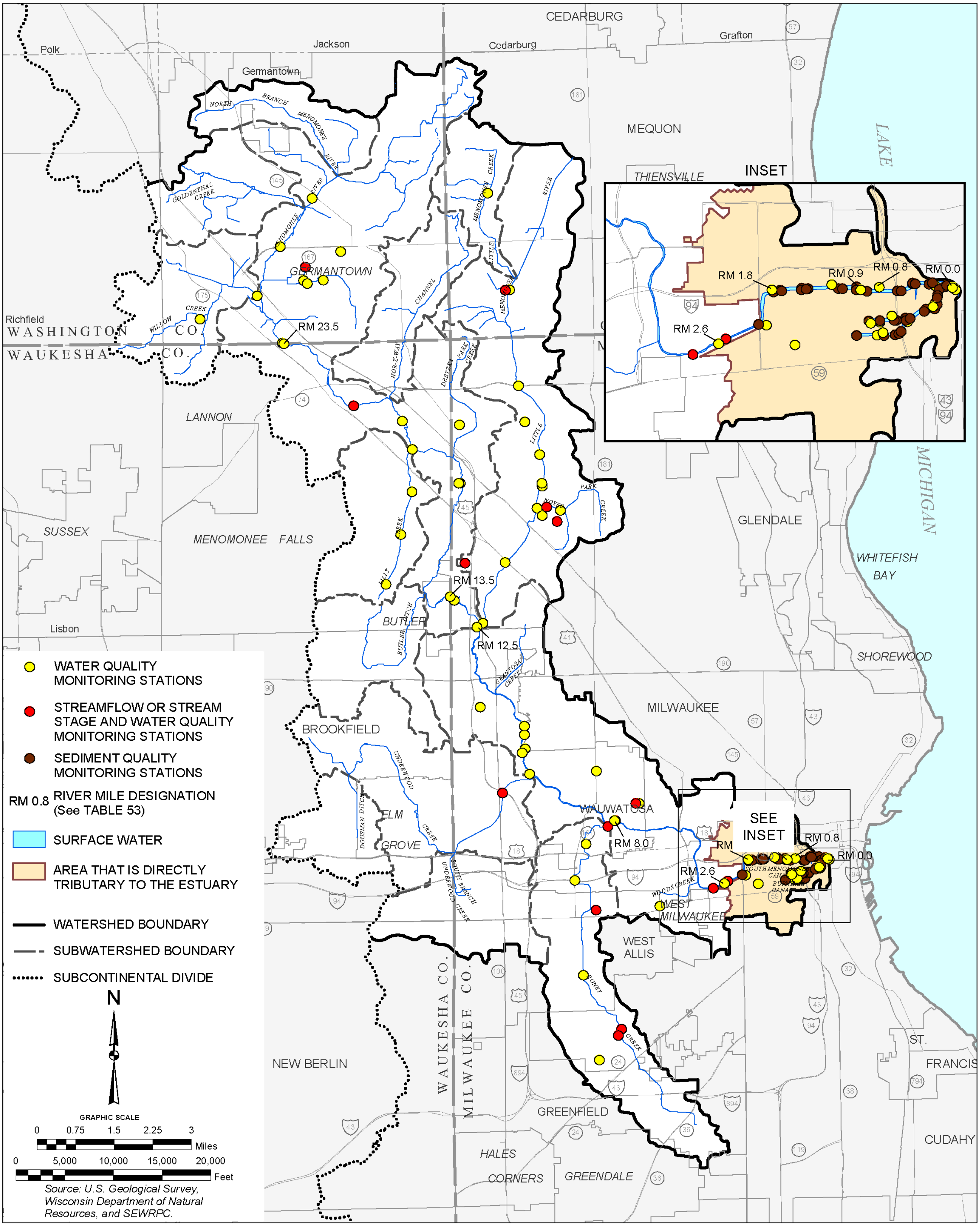
FLOW PERCENTAGES AMONG STATIONS WITHIN THE MENOMONEE RIVER WATERSHED: 2000



Source: SEWRPC.

Map 33

WATER AND SEDIMENT QUALITY MONITORING STATIONS WITHIN THE MENOMONEE RIVER WATERSHED: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

Table 53

SAMPLE SITES USED FOR ANALYSIS OF WATER QUALITY TRENDS IN THE MENOMONEE RIVER

Location	River Mile[a]	Position	Period of Record	Data Sources
Menomonee River at County Line Road	23.5	Upstream	1964-1975, 1982-2001	MMSD, SEWRPC
Menomonee River at 124th Street	13.5	Upstream	1985-2001	MMSD, STORET, USGS
Menomonee River at Hampton Avenue	12.5	Upstream	1985-2001	MMSD
Menomonee River at 70th Street	8.0	Upstream	1964-2001	MMSD, SEWRPC, STORET, USGS
Menomonee River at the Falk Dam[b]	2.6	Upstream	1979-1988	MMSD
Menomonee River at 25th Street	1.8	Estuary	1984-2001	MMSD
Menomonee River at Muskego Avenue	0.9	Estuary	1975-2001	MMSD, STORET
Menomonee River at Burnham Canal	0.8	Estuary	1992-2001	MMSD
Menomonee River at S. 2nd Street	0.0	Estuary	1980-2001	MMSD

[a]River Mile is measured as distance upstream from the confluence with the Milwaukee River.

[b]Data from this site were not analyzed as part of the trend analysis because of the shortness of the period of record and the small number of samples.

Source: SEWRPC.

the estuary. In 1994, this relationship between the estuary and the nonestuary sections of the River changed. In the periods since 1994, the mean concentrations of fecal coliform bacteria in the estuary were lower than the mean concentrations of fecal coliform bacteria in the section of the River upstream from the estuary. This change reflects the fact that since 1994, the concentrations of fecal coliform bacteria observed at the sampling stations in the estuary have sharply decreased. For example, at the estuary sampling station at 25th Street, mean concentrations of fecal coliform bacteria for the period 1994-1997 declined to about one-third of the mean concentrations seen during the period 1987-1993. They declined further during 1998-2001. Similarly, the concentrations at the estuary station at S. 2nd Street declined following 1994, though they have increased somewhat since. The occurrence of these reductions coincides with the period during which the Inline Storage System came on line. It suggests that, since 1994, reductions in inputs from combined sewer overflows related to use of the Inline Storage System have reduced loadings of fecal coliform bacteria into the estuary to concentrations low enough to result in mean concentrations of these bacteria in the estuary that are significantly lower than the mean concentrations of these bacteria into the sections of the River upstream of the estuary and outside of the combined sewer area.

A trend was also detected along the length of the River. Among the stations upstream from the estuary, Table 55 shows a statistically significant trend toward increasing numbers of fecal coliform bacteria from upstream to downstream. Time-based trends were also detected. When analyzed on an annual basis, all four sites in the estuary (S. 2nd Street, Burnham Canal, Muskego Avenue, and 25th Street) show statistically significant declines in fecal coliform concentrations. These declines represent an improvement of water quality in the estuary. Analysis of these trends by season suggests that the changes have occurred during the spring, summer, and fall and have occurred at all estuary sampling sites except for the sampling station at Burnham Canal. In the reaches upstream of the estuary, significant increases in fecal coliform concentrations occurred only during the summer at the 70th street and 124th Street stations. These increases represent a reduction in water quality at these stations, at least during the summer.

Regular sampling for *E. coli* in the Menomonee River began at four sampling stations along the mainstem in 2000. During the years 2001 and 2002, the counts ranged from undetectable to 160,000 cells per 100 ml. Statistical analysis detected no differences between the averages of counts at stations in the estuary and the averages of counts at stations upstream from the estuary. Among the stations outside of the estuary, the data show a statistically significant trend toward increasing numbers of *E. coli* from upstream to downstream. This is

Figure 65

STREAM SAMPLE STATION LOCATIONS IN THE MENOMONEE RIVER WATERSHED: 2003

MENOMONEE RIVER AT RIVER MILE 23.5

MENOMONEE RIVER AT
RIVER MILE 8.0 JUST DOWNSTREAM
OF THE CONFLUENCE WITH HONEY CREEK

MENOMONEE RIVER AT RIVER MILE 13.5

MENOMONEE RIVER AT RIVER MILE 2.6

MENOMONEE RIVER AT RIVER MILE 12.5
JUST DOWNSTREAM OF THE CONFLUENCE
WITH LITTLE MENOMONEE RIVER

HONEY CREEK AT RIVER MILE 4.7

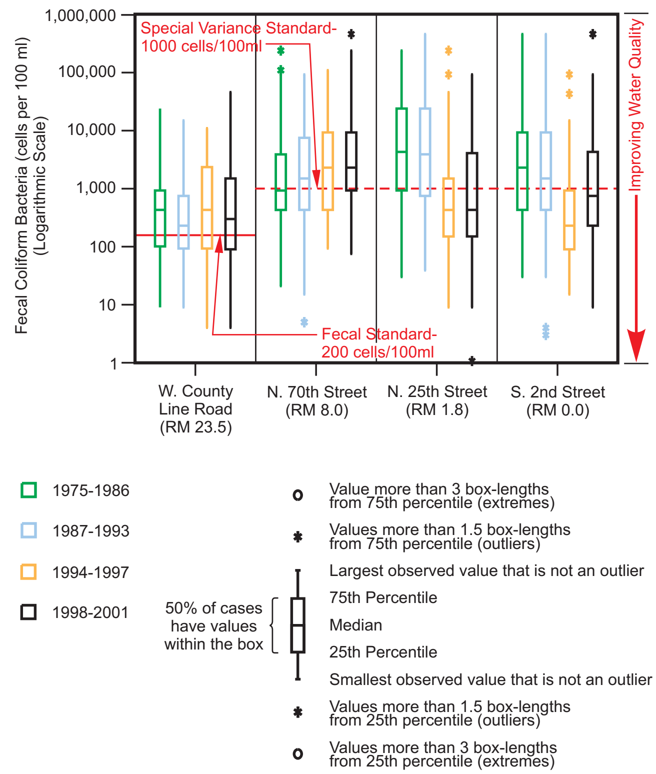
Source: Milwaukee County and Inter-Fluve, Inc.

shown in Table 55. The data are insufficient for assessing whether there are seasonal patterns to the numbers of these bacteria in the River (see Table C-2 in Appendix C of this report).

Honey Creek has a history of high concentrations of bacteria. The mean concentration of fecal coliform bacteria detected in samples from Honey Creek during the years 2001-2004 was 12,218 cells per 100 ml. Average concentrations of fecal coliform bacteria detected in Honey Creek tended to increase from upstream to downstream, from 5,775 cells per 100 ml near Loomis Road to 27,926 cells per 100 ml just upstream from the confluence with the Menomonee River. This increase from upstream to downstream represented a statistically significant trend. The mean concentration of *E. coli* detected in samples from Honey Creek during the years 2001-2004 was 17,427 cells per 100 ml. The mean concentration of fecal coliform bacteria exceeds both Wisconsin's water quality standard for full recreational use and the special variance standard that applies to Honey Creek. In order to identify potential sources of high bacteria concentrations, MMSD conducted an intensive monitoring survey of the Creek during July and August 2006.[2] Concentrations of fecal coliform bacteria and *E. coli* were monitored in the stream, in three storm sewer outfalls that discharge into the stream, and within selected storm sewers. In addition, samples from the stream and from three storm sewer outfalls were tested for the presence of strains of the bacterium *Bacteroides* specific to human fecal material. Several findings emerged from this study:

Figure 66

FECAL COLIFORM BACTERIA CONCENTRATIONS ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001



Source: *U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

- Concentrations of fecal coliform bacteria in Honey Creek exceeded both Wisconsin's water quality standard for full recreational use and the special variance applicable to Honey Creek.

- Concentrations of fecal coliform bacteria and *E. coli* were also very high in the three monitored storm sewer outfalls discharging into Honey Creek. Throughout the investigation, the highest concentrations of fecal coliform bacteria and *E. coli* were detected in the storm sewer outfall at 79th Street and Mt. Vernon Avenue.

- Bacterial counts in the monitored storm sewer outfalls tended to be higher in samples collected during the morning and noon than in samples collected during the afternoon. This corresponds with times that higher flows are typically observed in sanitary sewer systems.

- Tests for human-specific *Bacteroides* showed positive results at all three instream sampling sites and all three monitored storm sewer outfalls, indicating sanitary sewage contamination.

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[2]*Milwaukee Metropolitan Sewerage District*, Honey Creek Bacteria Investigation Survey, *July-August 2006.*

Figure 67

HISTORICAL AND BASE PERIOD FECAL COLIFORM BACTERIA CONCENTRATIONS ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001

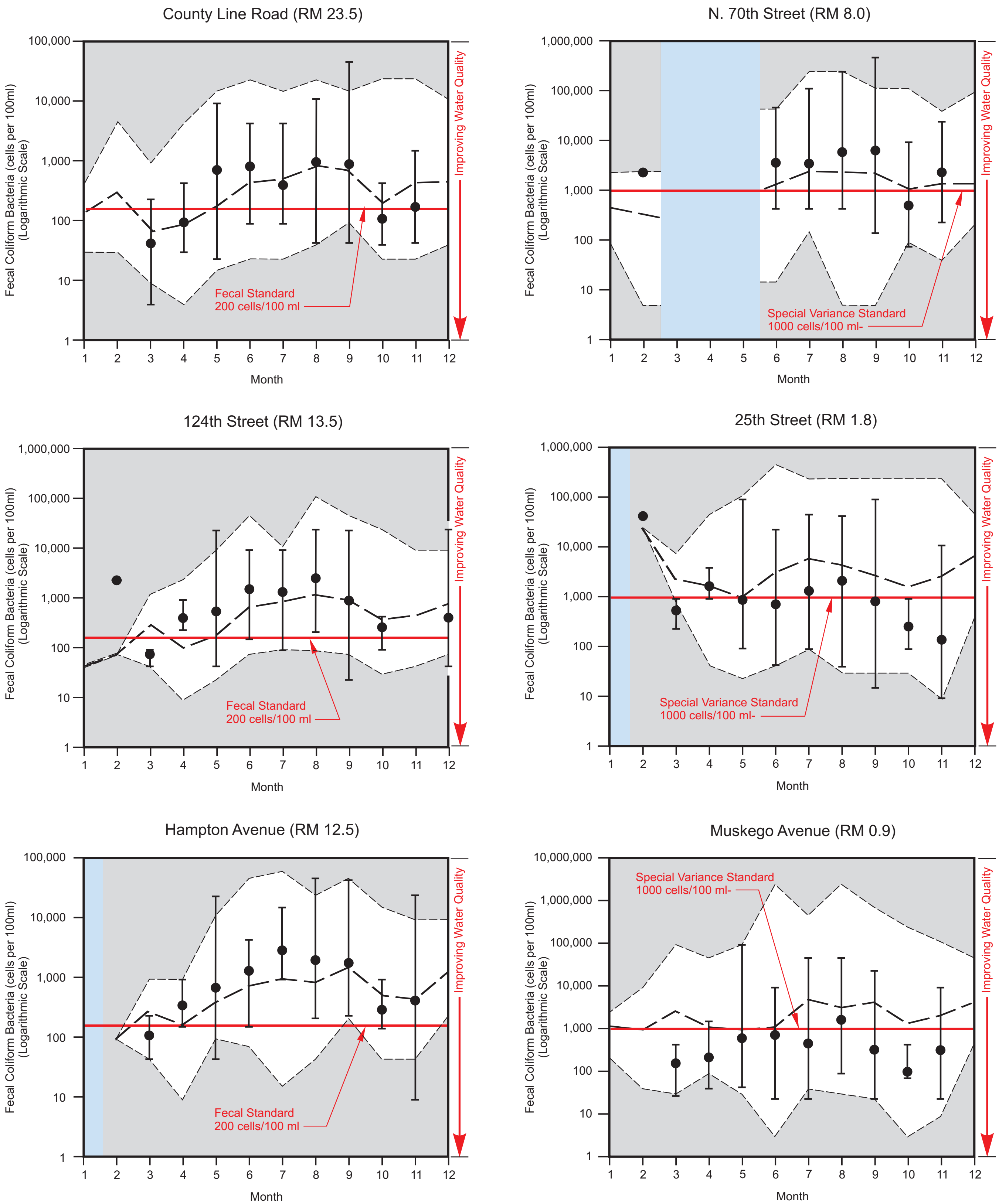
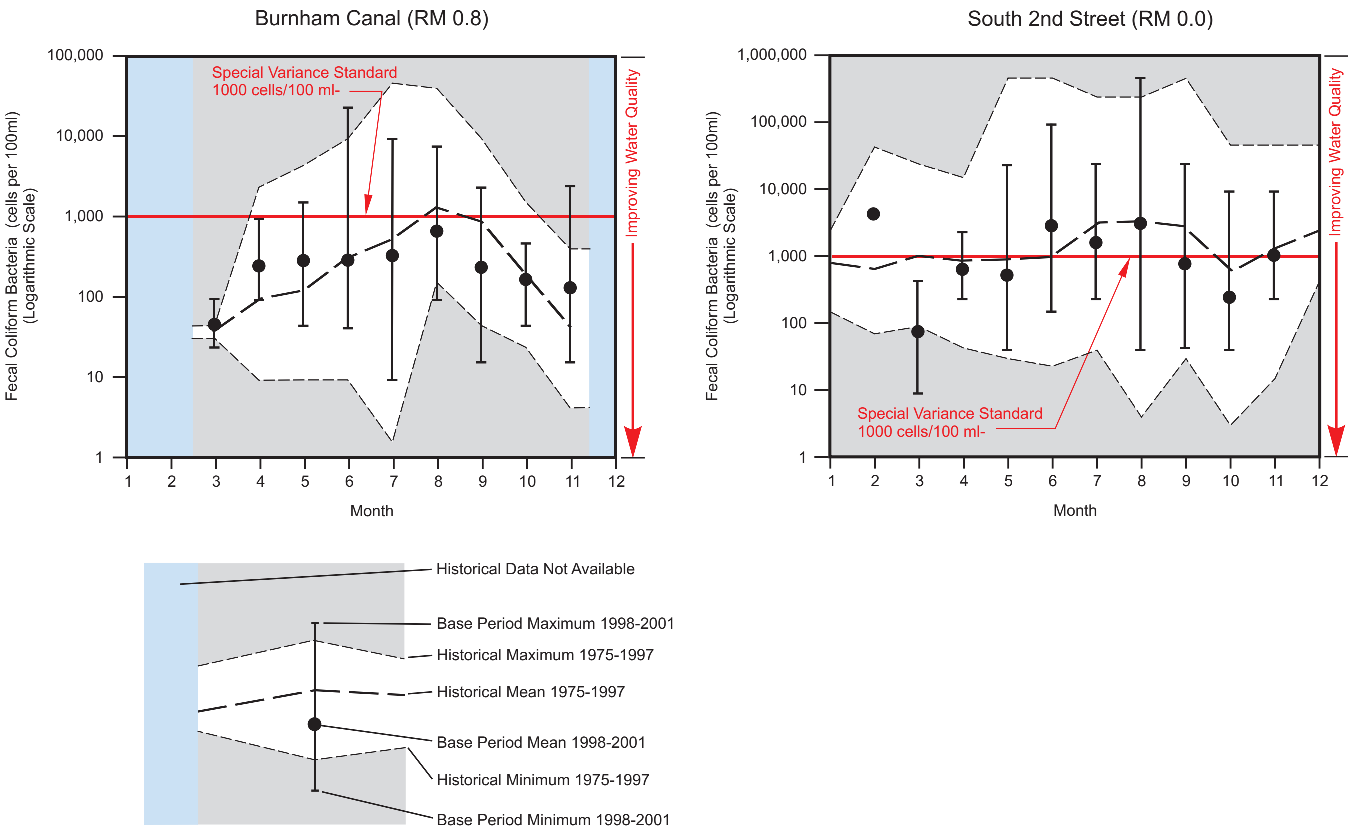


Figure 67 (continued)



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

- Concentrations of fecal coliform bacteria and *E. coli* increased at sampling stations in Honey Creek downstream from State Fair Park during and shortly after the run of the Wisconsin State Fair. In general, concentrations of fecal coliform bacteria and *E. coli* collected at the sampling stations downstream from the fair grounds were higher than concentrations collected at the sampling station upstream of the fair grounds.

- High in-pipe concentrations of fecal coliform bacteria and *E. coli* were detected in storm sewers in State Fair Park.

As a result of the Honey Creek survey, several actions have been taken. The City of Milwaukee has conducted dye and smoke testing of sanitary sewers and has identified, and is in the process of assessing and repairing, some cracked sewers. State Fair Park has increased its use of best management practices, including street sweeping and cleaning, and is conducting an infrastructure inventory to identify the locations of storm sewers within the park. In addition, the Fair Park was recently issued a Wisconsin Pollutant Discharge Elimination System (WPDES) stormwater discharge permit. MMSD continues to monitor Honey Creek for bacterial concentrations, including continuing examination of the stream and storm sewer outfalls for strains of *Bacteroides* specific to human fecal material.

MMSD also sampled Underwood Creek and South Branch Underwood Creek in 2004 and 2005 for concentrations of fecal coliform bacteria. The mean concentration of fecal coliform bacteria in Underwood Creek during this period was 4,367 cells per 100 ml. Concentrations in individual samples ranged between 28 cells per 100 ml and 97,000 cells per 100 ml. The mean concentration of fecal coliform bacteria in South Branch Underwood Creek during this period was 5,422 cells per 100 ml. Concentrations in individual samples ranged between 23 cells per 100 ml and 55,000 cells per 100 ml.

Table 54

COMPARISON OF WATER QUALITY BETWEEN THE MENOMONEE RIVER AND THE MILWAUKEE RIVER ESTUARY: 1975-2001[a]

Parameters	Years			
	1975-1986[b]	1987-1993[b]	1994-1997[b]	1998-2001[b]
Biological/Bacteria				
Fecal Coliform[c]	Estuary	Estuary	River	River
E. coli [c]	- -	- -	- -	0
Chlorophyll-*a*[c]	0	Estuary	River	River
Chemical/Physical				
Alkalinity	River	River	River	River
Biochemical Oxygen Demand[c]	Estuary	Estuary	0	0
Dissolved Oxygen	River	River	River	River
Hardness	River	0	River	River
pH	River	River	River	River
Specific Conductance	River	River	River	River
Suspended Material				
Total Suspended Solids	River	River	River	River
Nutrients				
Ammonia, Dissolved[c]	Estuary	Estuary	Estuary	Estuary
Kjeldahl Nitrogen[c]	Estuary	Estuary	Estuary	Estuary
Nitrate, Dissolved[c]	River	0	Estuary	Estuary
Nitrite, Dissolved[c]	0	Estuary	Estuary	Estuary
Organic Nitrogen[c]	0	0	River	0
Phosphorus, Dissolved[c]	River	River	0	Estuary
Total Nitrogen[c]	0	Estuary	Estuary	Estuary
Total Phosphorus[c]	Estuary	Estuary	0	Estuary
Metals/Salts				
Arsenic[c]	- -	- -	0	0
Cadmium[c]	Estuary	0	0	0
Chloride[c]	River	River	River	River
Chromium[c]	Estuary	0	0	0
Copper[c]	Estuary	Estuary	Estuary	Estuary
Lead[c]	0	0	Estuary	0
Mercury[c]	- -	- -	River	River
Nickel[c]	- -	0	0	0
Zinc[c]	Estuary	Estuary	Estuary	Estuary

NOTE: The following symbols were used:

"Estuary" indicates that the mean value from the estuary is statistically significantly higher than the mean value from upstream section.

"River" indicates that the mean value from the estuary is statistically significantly lower than the mean value from upstream section.

0 indicates that no differences were detected.

- - indicates that the data were insufficient for the analysis.

[a]*The estuary sites used in this analysis were located within the Menomonee River portion of the Milwaukee Harbor estuary.*

[b]*Differences between means were assessed through analysis of variance (ANOVA). Means were considered significantly different at a probability of P = 0.05 or less.*

[c]*These data were log-transformed before being entered into ANOVA.*

Source: SEWRPC.

Table 55

UPSTREAM TO DOWNSTREAM TRENDS IN WATER QUALITY PARAMETERS FROM UPSTREAM SITES ALONG THE MENOMONEE RIVER 1975-2001[a]

Constituent	Trend	Slope	Intercept	R^2
Bacteria and Biological				
Fecal Coliform[b]	⬆	-0.10	7.0	0.10
E. coli [b]	⬆	-0.30	10.0	0.12
Chlorophyll-*a*[b]	⬆	-0.01	2.0	0.01
Chemical				
Alkalinity	⬇	2.7	211.7	0.06
Biochemical Oxygen Demand[b]	0	- -	- -	- -
Chloride[b]	⬆	-0.01	5.0	0.02
Dissolved Oxygen	⬆	-0.12	10.0	0.05
Hardness	⬇	2.4	286.1	0.03
pH	⬆	<-0.01	8.0	0.13
Specific Conductance	⬆	-6.0	988	0.01
Suspended Material				
Total Suspended Sediment	0	- -	- -	- -
Total Suspended Solids	⬆	-1.01	38.2	0.02
Nutrients				
Ammonia[b]	⬇	0.06	-3.0	0.08
Kjeldahl Nitrogen[b]	⬇	0.02	-0.5	0.04
Nitrate[b]	⬇	0.04	-1.0	0.05
Nitrite[b]	⬇	0.05	-4.0	0.10
Organic Nitrogen[b]	⬇	0.01	-0.5	< 0.01
Total Nitrogen[b]	⬇	0.02	0.0	0.08
Dissolved Phosphorus[b]	⬇	0.02	-4.0	0.01
Total Phosphorus[b]	⬇	0.01	-3.0	< 0.01
Metals				
Arsenic[b]	0	- -	- -	- -
Cadmium[b]	⬇	0.02	-1.0	0.01
Chromium[b]	0	- -	- -	- -
Copper[b]	⬆	-0.02	2.0	0.02
Lead[b]	0	- -	- -	- -
Mercury[b]	0	- -	- -	- -
Nickel[b]	0	- -	- -	- -
Zinc[b]	⬆	-0.05	3.0	0.09

NOTE: The following symbols were used:

⬆ indicates a statistically significant increase from upstream to downstream.

⬇ indicates a statistically significant decrease from upstream to downstream.

0 indicates that no trend was detected.

R^2 indicates the fraction of variance accounted for by the regression.

[a]*Upstream sites are those outside the estuary. Trends were assessed through linear regression analysis. Values of water quality parameters were regressed against River Mile. A trend was considered significant if the regression showed a significant slope at P = 0.05 or less. Higher* R^2 *values indicate that higher portions of the variation in the data are attributable to the trend. Lower* R^2 *values indicate that more of the variation is due to random factors.*

[b]*These data were log-transformed before being entered into regression analysis.*

Source: SEWRPC.

***Chlorophyll*-a**

In the section of the River upstream from the estuary, chlorophyll-*a* concentrations tended to increase from upstream to downstream (Table 55). During most periods, mean chlorophyll-*a* concentration dropped between the 70th Street station and the 25th Street station. Prior to 1994, chlorophyll-*a* concentration within the estuary tended to increase from upstream to downstream as shown in Figure 68. This changed after 1994. During the periods after this, mean chlorophyll-*a* concentrations declined along the length of the estuary. Over the period of record, the mean concentration of chlorophyll-*a* in the Menomonee River was 9.28 micrograms per liter (μg/l). Individual samples of this parameter ranged from 0.11 μg/l to 318.23 μg/l. In addition, each station had samples with concentrations in excess of 50 μg/l. The results of statistical analyses given in Table 54 show that the relationship between mean concentrations of chlorophyll-*a* between the estuary and the reaches upstream from the estuary is dynamic and has changed over time. During the period 1987-1993, the mean concentration of chlorophyll-*a* was significantly higher at the stations in the estuary than at the stations upstream from the estuary. Since 1994, the mean concentrations of chlorophyll-*a* in the estuary have been significantly lower than those in the reaches upstream from the estuary. This last change occurred at roughly the time when the Inline Storage System came online. In addition to these differences, the data show a statistically significant trend along the length of the River as shown in Table 55, with the concentration of chlorophyll-*a* increasing from upstream to downstream. Overall, the data suggest that the concentrations of chlorophyll-*a* in the Menomonee River have been declining.

Chemical and Physical Parameters

Temperature

As shown in Figure 69, the annual median water temperature in the Menomonee River during the period 1998-2001 ranged from 14.3ºC at the sampling station at County Line Road to 19.0ºC at the station at S. 2nd Street. Along the length of the River, annual mean water temperatures increase from upstream to downstream. This represents a change from the historic pattern of water temperatures observed along the length of the River as shown in Figure 70. During the periods prior to 1998, mean annual water temperature tended to drop by 0.3 to 1.1ºC between the stations at County Line Road and 70th Street. For the most part, at individual stations annual mean water temperatures have increased over time.

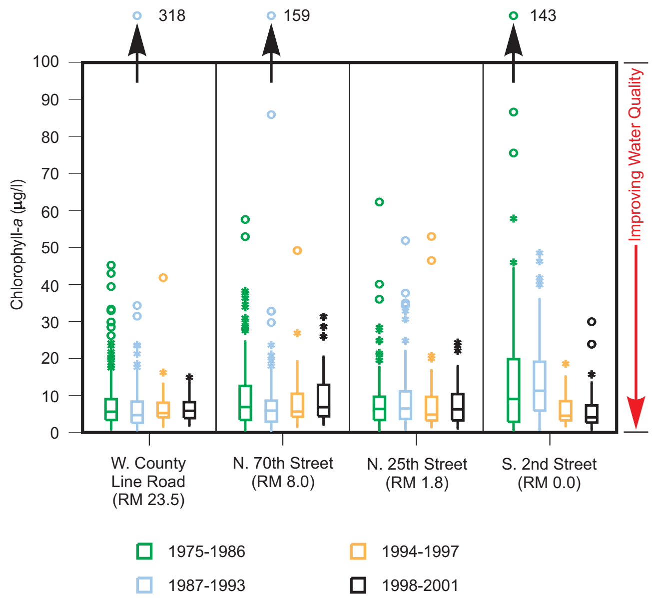
Figure 71 shows continuously recorded water temperature data that were collected during summer 2004 at five sites along the mainstem of the Menomonee River: Grand Avenue in Menomonee Falls, N. 127th Street in Menomonee Falls, W. North Avenue in Wauwatosa, upstream from the confluence with Honey Creek in Wauwatosa, and Miller Park in Milwaukee. There are several noteworthy features in the patterns of variation shown. The overall pattern of temperature variation is similar at each of the five sites. At each site there is a strong daily cycle in water temperature that is driven by changes in air temperature and solar heating over the course of the day. The range of these daily fluctuations varies from about 1.1ºC to 7.9ºC. This diurnal cycle is overlaid upon longer period fluctuations and trends. The longest period trend that is apparent in the data is cooling of the water temperature as part of the seasonal cycle. Intermediate period fluctuations associated with weather systems are also present. Among the sites, water temperatures tend to decrease from upstream to downstream. This may be related to groundwater discharge into the River along its length. The one exception to the upstream to downstream cooling trend occurs at the recording station at Miller Park. This is probably related to the presence of concrete-lined channel near this site. With the exception of the station at Miller Park, the average daily range in water temperature also decreased from upstream to downstream, from about 3.2ºC at the station at Grand Avenue in Menomonee Falls to 2.7ºC at the station upstream from the confluence with Honey Creek. The average daily range in water temperature at the station at Miller Park was 3.1ºC. This wider range is also probably related to the presence of concrete-lined channel near this site.

Continuously recorded water temperature data were also collected from four tributary streams in the Menomonee River watershed during summer 2004. These data are shown in Figure 72. While the temperatures attained and the ranges in daily variation differ among these streams, the overall patterns of variation are quite similar. This reflects the fact that changes in water temperature are driven by changes in air temperature and solar heating.

Due to the complexity of these temperature trends, they were further analyzed using a three-factor analysis of variance. This type of analysis tests for statistically significant differences among mean temperatures based upon

Figure 68

CHLOROPHYLL-*a* CONCENTRATIONS ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001

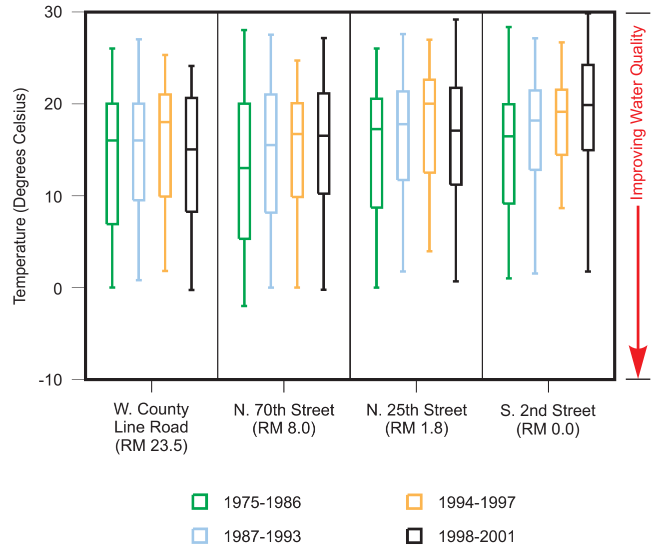


NOTE: See Figure 66 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 69

WATER TEMPERATURE AT SITES ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001



NOTE: See Figure 66 for description of symbols.

Standard temperature is at 31.7 degrees Celsius, which is outside the limits of the graph.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

three different factors which may account for any differences. In addition, it tests for significant effects of any interactions between the factors upon mean temperatures. In this instance, the independent factors examined were sampling station, time period 1985-1994, compared to 1995-2001, and season. Data from winter months were not included in this analysis because of the small number of samples taken during the winter. The results of this analysis suggest that the estuary and the section of the River upstream from the estuary experience different water temperature regimes. As shown in Figure 73, over the period 1985-2001, mean water temperatures generally were warmer downstream. The only exception to this trend occurred in the lower estuary.

Changes in monthly mean water temperatures at the stations upstream from the estuary roughly track changes in monthly mean air temperatures, as shown in Figure 74. This tracking is readily apparent when increases and decreases in monthly mean water temperatures from summer months are compared to increases and decreases in monthly mean air temperatures from summer months. Summer mean water temperatures are higher in years with higher summer mean air temperatures. The situation is more complicated for mean water temperatures in the estuary. Changes in mean monthly water temperature during any year reflect changes in mean monthly air temperature; however, this within-year variation is overlaid upon a warming trend. This trend is most readily apparent when monthly mean water temperatures from summer months are compared from year to year. The most dramatic example of this is seen in the data from the Burnham Canal Station. The highest annual summer monthly mean water temperature at this station increased from 23.5ºC in the period of 1986-1993 to 30.3ºC in the baseline period of 1998-2001. It is important to note that the Muskego Avenue, Burnham Canal, and S. 2nd Street Stations along the mainstem of the Menomonee River are all within the influence of We Energies power plant thermal discharge as well as from influx of Lake Michigan water from the outer harbor areas. Hence, this increase in temperatures in the downstream estuary stations is likely a result of multiple factors.

Figure 70

HISTORICAL AND BASE PERIOD WATER TEMPERATURE ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001

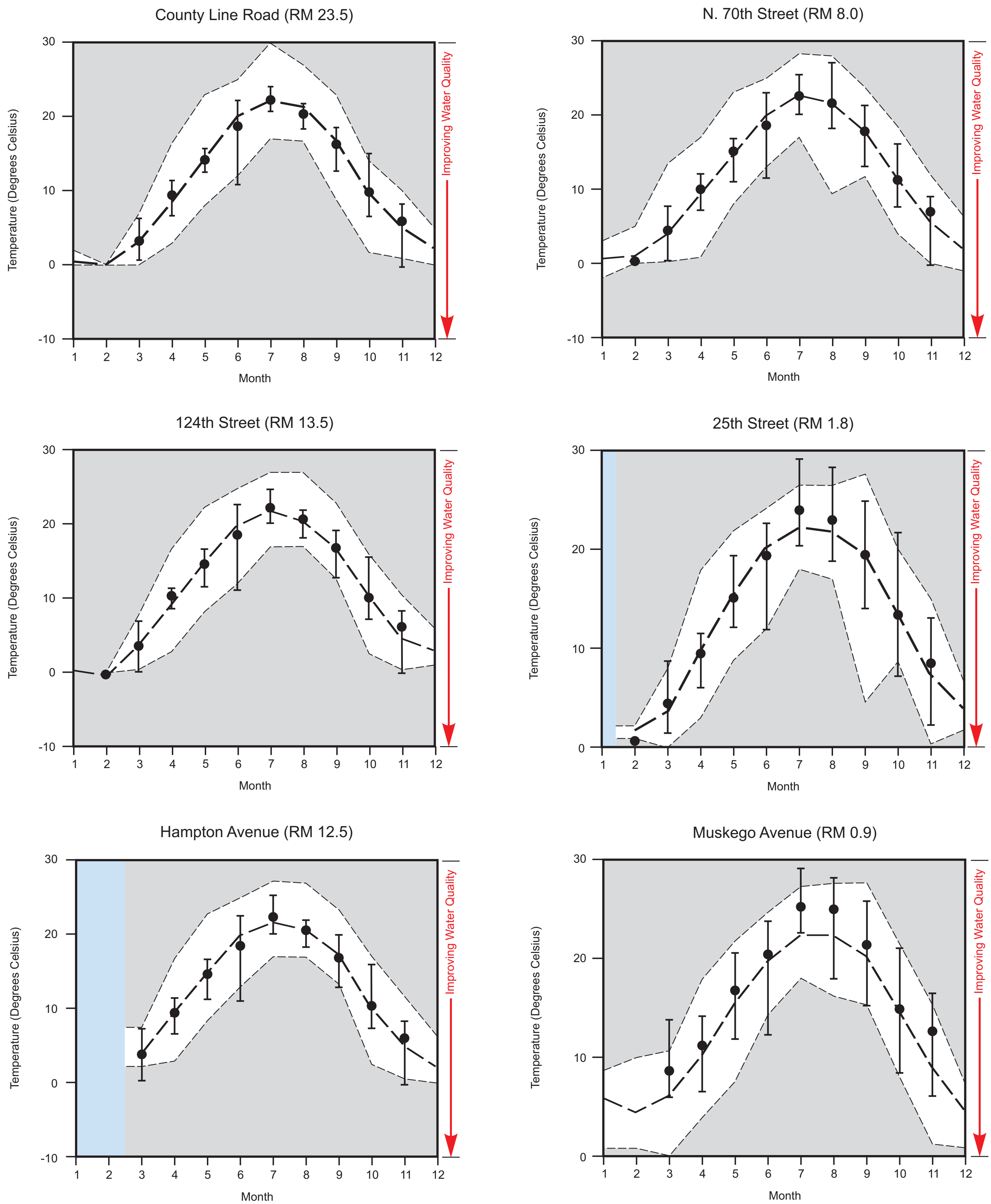
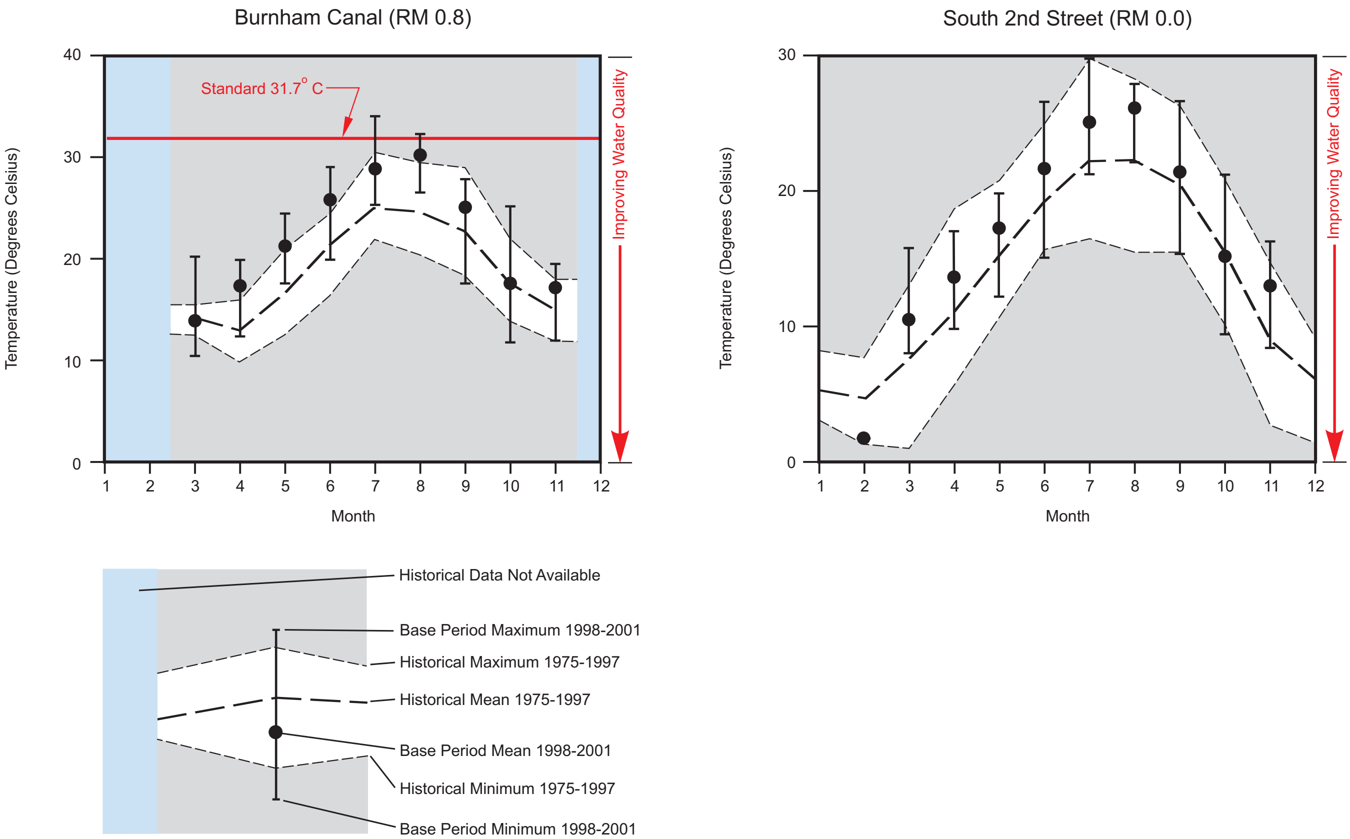


Figure 70 (continued)



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

During 2004 and 2005, MMSD sampled Honey Creek, Underwood Creek, and South Branch Underwood Creek for water temperature. The mean water temperature in Honey Creek was 15.3ºC, with a range of 4.2ºC to 23.5ºC. There was no trend along the length of this stream in water temperature. The mean water temperature in Underwood Creek was 15.6ºC. Average water temperatures in this stream tended to increase from upstream to downstream. The mean water temperature in South Branch Underwood Creek was 21.5ºC. There were not enough sampling stations along this stream to assess trends.

Alkalinity

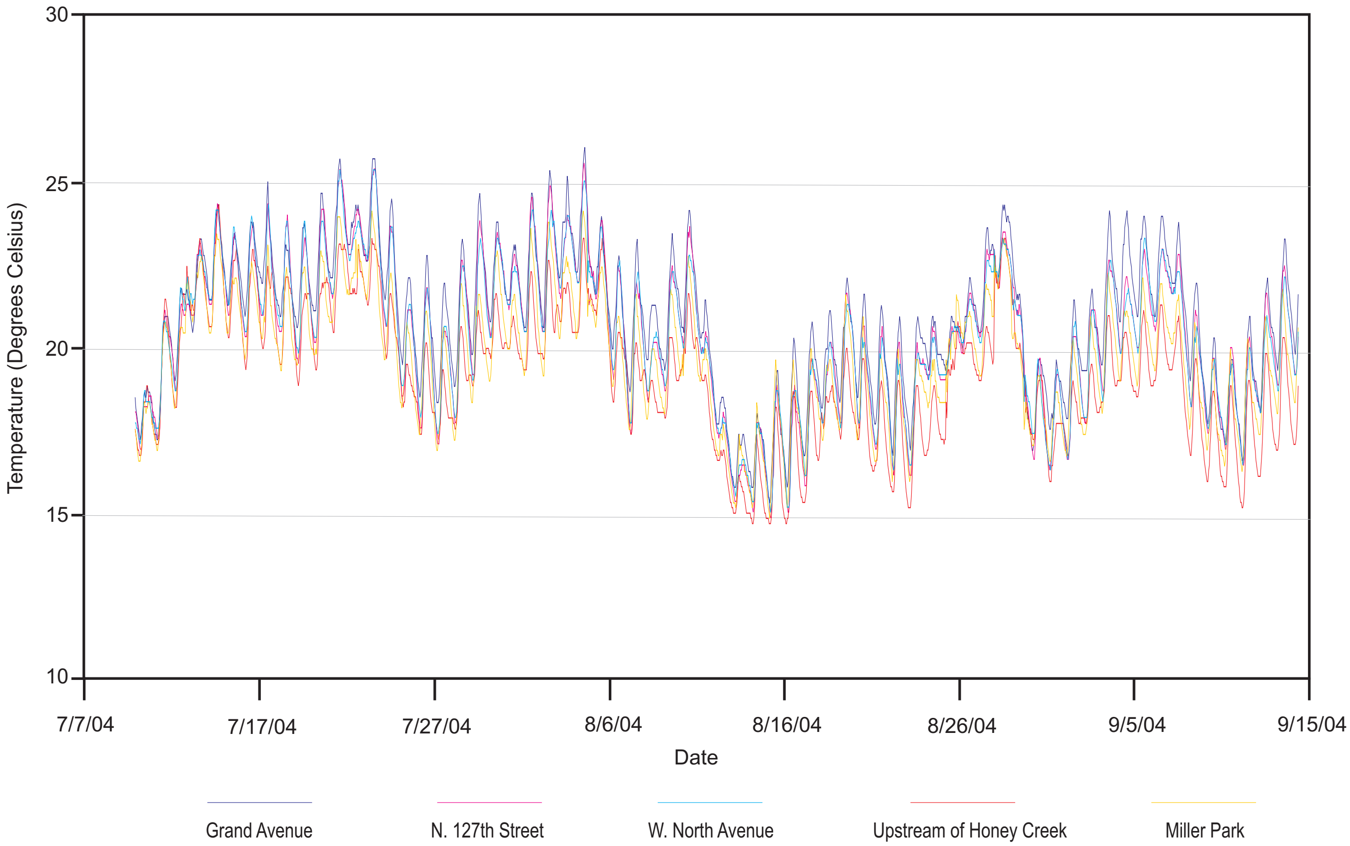
The mean value of alkalinity in the Menomonee River over the period of record was 228.1 milligrams per liter (mg/l) as $CaCO_3$. The data show moderate variability, ranging from 3.5 to 460 mg/l. The analyses in Table 55 show that alkalinity in the River tends to be lower downstream. Few stations showed any significant changes annually or among months, but where there were significant trends the patterns were mostly decreasing in concentration (see Table C-2 in Appendix C). These differences and trends may reflect changes in the relative importance of groundwater and surface runoff on the chemistry of water in the River from upstream to downstream with surface runoff becoming increasingly influential downstream. It is important to note that like hardness, specific conductivity, and pH alkalinity concentrations are greatly influenced by Lake Michigan water dilution in the estuary, which probably causes these concentrations to be lower than the upstream areas.

Biochemical Oxygen Demand (BOD)

The mean concentration of BOD in the Menomonee River during the period of record was 2.80 mg/l. Individual samples varied from below the limit of detection to 21.7 mg/l. As shown in Figure 75, the mean concentrations of BOD declined over time at all the sampling stations along the River. At some stations, the mean concentration of BOD during the period 1998-2001 was less than one-half of the mean concentration during the period 1975-1986.

Figure 71

CONTINUOUSLY RECORDED WATER TEMPERATURE FROM SITES ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 2004



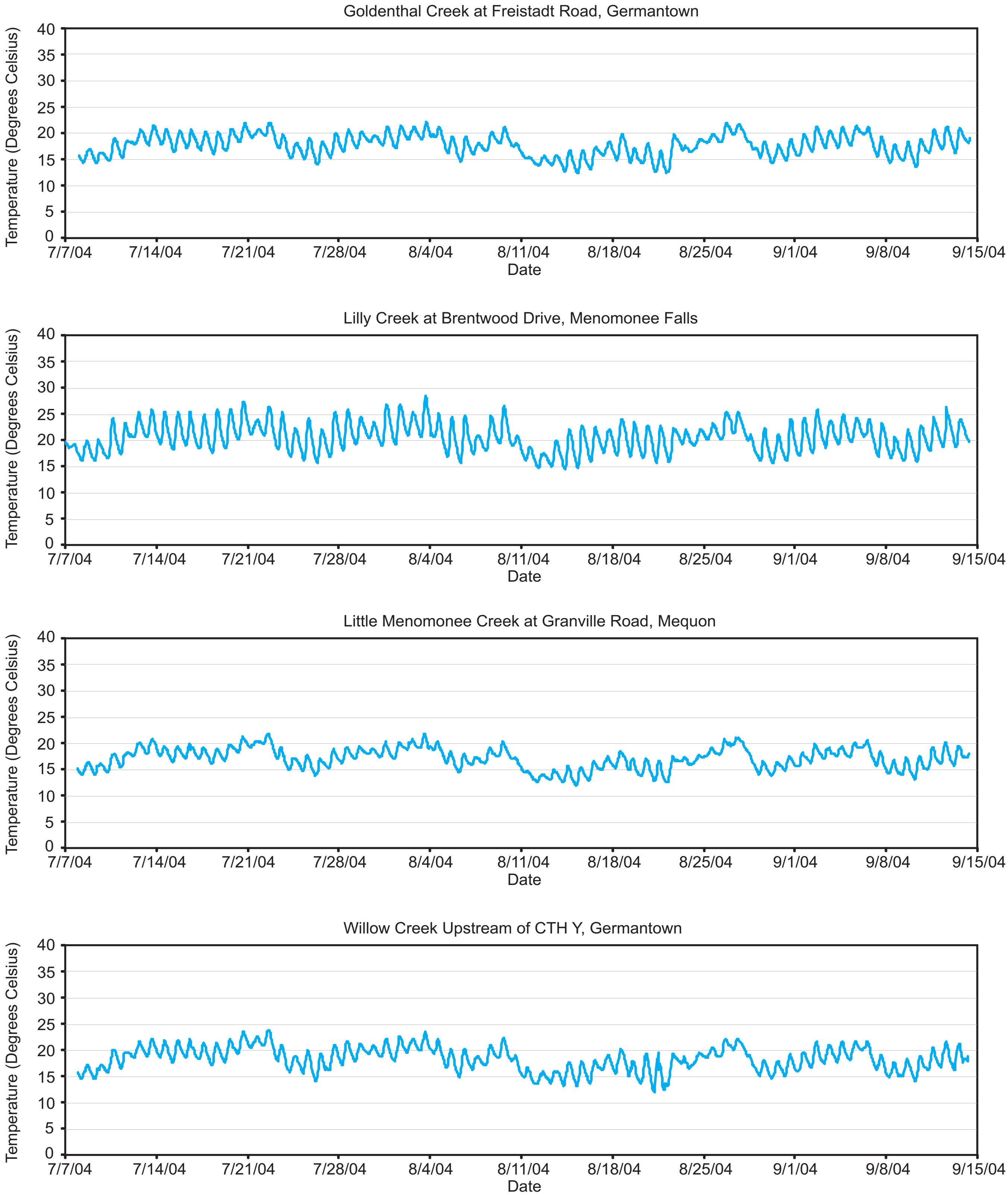
Source: Wisconsin Department of Natural Resources.

Figure 76 shows a monthly comparison of baseline and historic concentrations of BOD at two sites along the River, S. 2nd Street in the estuary and County Line Road in the section of the River upstream from the estuary. At both sites, baseline monthly mean concentrations of BOD are generally below the historic mean concentrations. Baseline minimum monthly mean concentrations are all below the historic monthly minimum concentrations and are often near or below the limit of detection. Similar relationships between baseline and historic concentrations of BOD are seen at the other six long-term sampling stations.

During the periods before 1994, the mean value of BOD at stations in the estuary was significantly higher than the mean value of BOD at the stations upstream from the estuary. This indicates that the water in the estuary contained a higher concentration of organic material. Given that the sampling stations in the estuary are the only stations on the Menomonee River within the combined sewer overflow area, this suggests that overflows from the combined sewers may have been contributing to higher amounts of organic material in the water of the estuary than in the water of the reaches upstream from the estuary. In 1994, this relationship changed. From this year onward, there were no statistically significant differences between the mean concentrations of BOD in the estuary and the reaches upstream of the estuary. This change coincides with the Inline Storage System coming on line. It suggests that, since 1994, reductions in inputs from combined sewer overflows related to use of the Inline Storage System have reduced loadings of organic material into the estuary to levels below concentrations that would produce significant differences in BOD between the estuary and the section of the River upstream of the estuary. Several other factors may influence BOD concentrations in the Menomonee River. BOD concentrations in the River are positively correlated with concentrations of fecal coliform bacteria and some nutrients such as ammonia

Figure 72

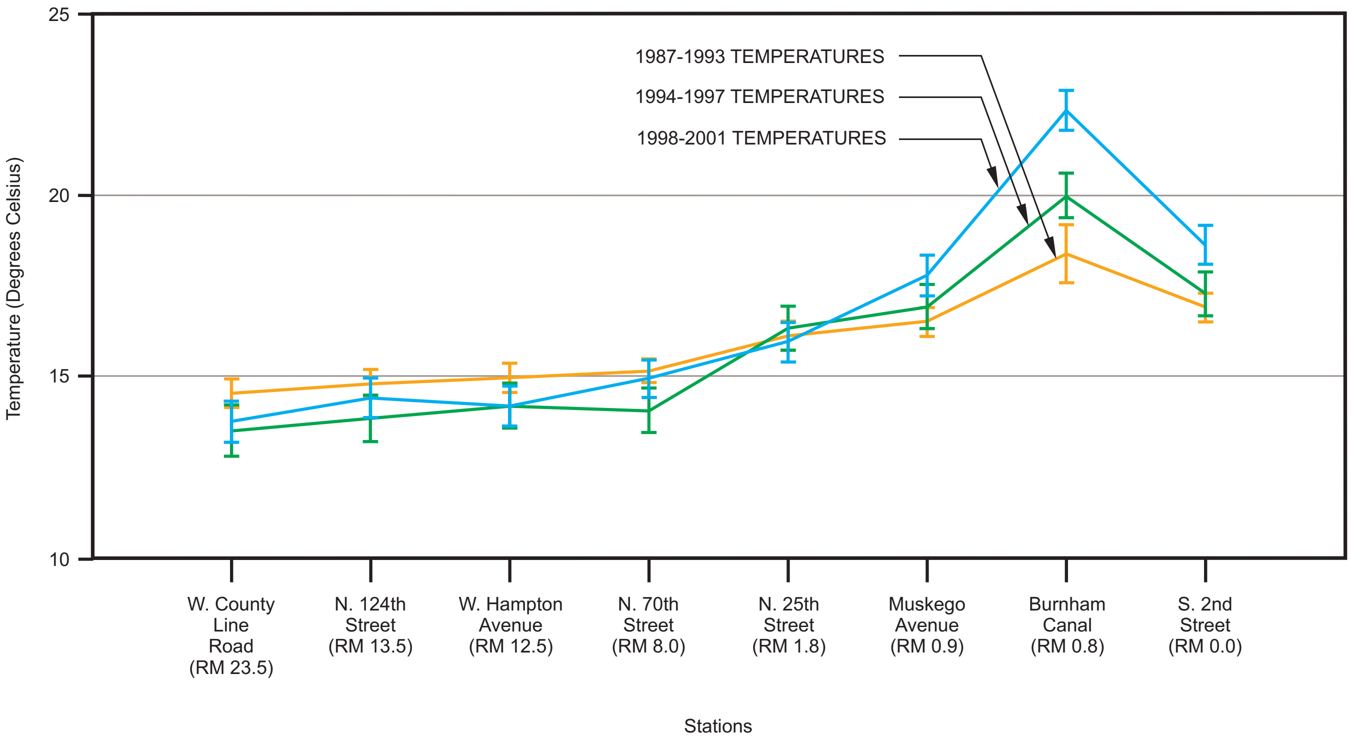
CONTINUOUSLY RECORDED WATER TEMPERATURE FROM STREAMS IN THE MENOMONEE RIVER WATERSHED: 2004



Source: Wisconsin Department of Natural Resources.

Figure 73

MEAN WATER TEMPERATURE AT STATIONS ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1987-2001



NOTES: Error bars (I) represent one standard error of the mean.

Water quality standard is at 31.7 degrees Celsius, which is outside the limits of the graph.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

and total phosphorus. These correlations reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the River. In some parts of the River, decomposition of organic material in the sediment acts as a source of BOD to the overlying water. This is especially the case in the estuary downstream of 35th Street. This section of the estuary acts as a large settling basin for organic material. During the fall, leaf litter settles out in this reach. Decomposition of this material releases BOD to the water. The decreases in concentrations of BOD in the mainstem of the Menomonee River represent an improvement in water quality.

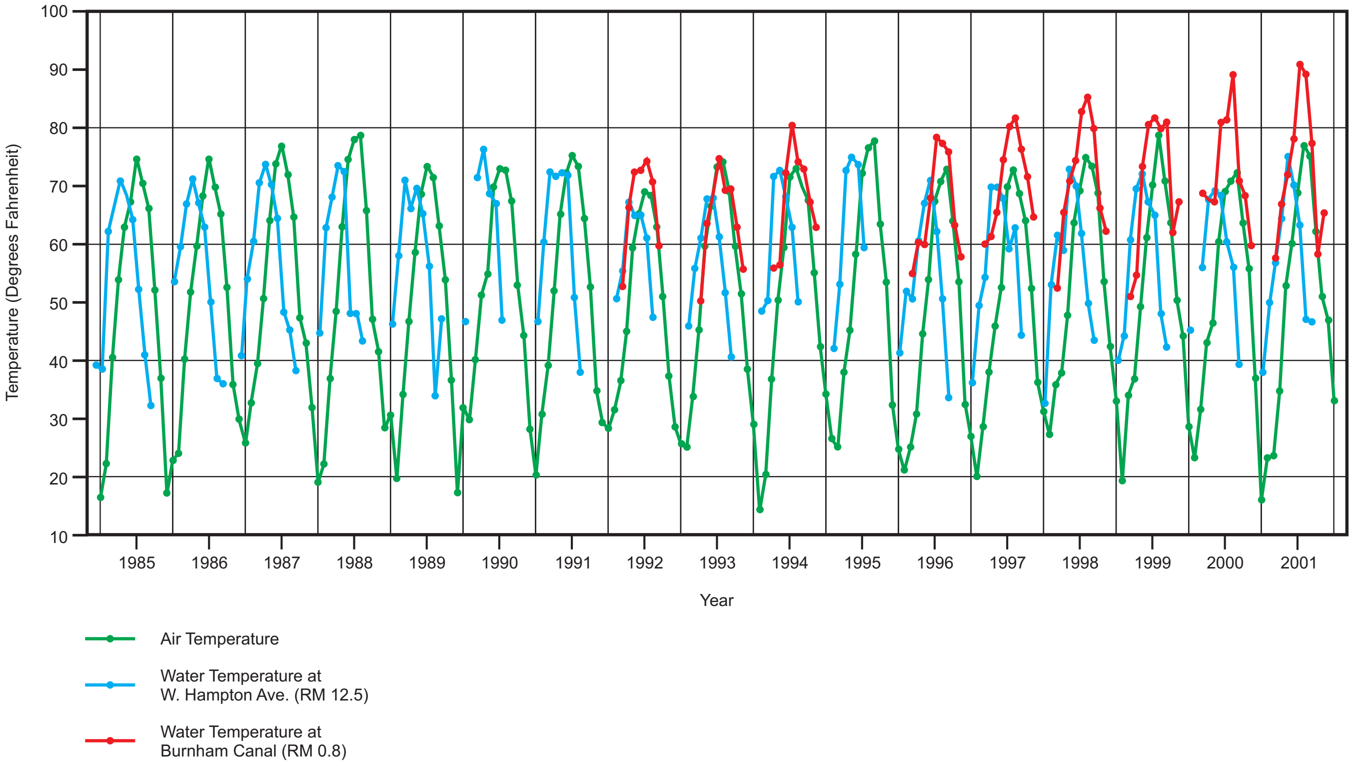
Chloride

The mean chloride concentration in the Menomonee River for the period of record was 99.94 mg/l. All sites show wide variations between minimum and maximum values. Figure 77 shows that the mean concentrations of chloride in the River dropped at all stations between the periods 1975-1986 and 1987-1993. Since 1993, the mean concentration of chloride at all stations has been increasing.

Chloride is a highly conservative water quality parameter. That is, it does not react as readily as many other materials in the water; it does not settle out as readily as other materials, and it is not taken up and metabolized by organisms. As a result, it can serve as a tracer for examining other processes occurring in the waterbody. The rapid change in the rate of dilution of chloride downstream of the Muskego Avenue station is highly suggestive of mixing of water from sources with greatly differing concentrations. Table 55 shows that mean chloride concentrations in the River have been increasing over time. On an annual basis, statistically significant increases have been detected at all the sampling stations in the estuary and at the stations at 70th Street and County Line Road in the section of the River upstream of the estuary (see Table C-2 in Appendix C). Chloride concentrations

Figure 74

MONTHLY MEAN AIR AND WATER TEMPERATURES AT STATIONS ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1985-2001



Source: *U.S. Geological Survey, National Oceanic and Atmospheric Association, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

show a strong seasonal pattern. For the period during which winter data are available, mean chloride concentrations were highest in winter. This is likely related to the use of deicing salts on streets and highways. These concentrations declined through the spring to reach lows during summer and fall.

Observed instream chloride concentrations in the Menomonee River rarely approached the planning standard of 1,000 mg/l that was adopted under the original regional water quality management plan. Observed instream concentrations more frequently exceeded the 250 mg/l secondary drinking water standard.[3] Instream concentrations occasionally exceeded the chronic toxicity criterion of 395 mg/l or the acute toxicity criterion of 757 mg/l as set forth in Chapter NR 105, "Surface Water Quality Criteria and Secondary Values for Toxic Substances," of the *Wisconsin Administrative Code*.

Chloride concentrations in the Menomonee River show strong positive correlations with alkalinity, hardness, and specific conductance, all parameters which, like chloride, measure amounts of material dissolved in water. The increase of chloride concentrations in the Menomonee River represents a decline in water quality.

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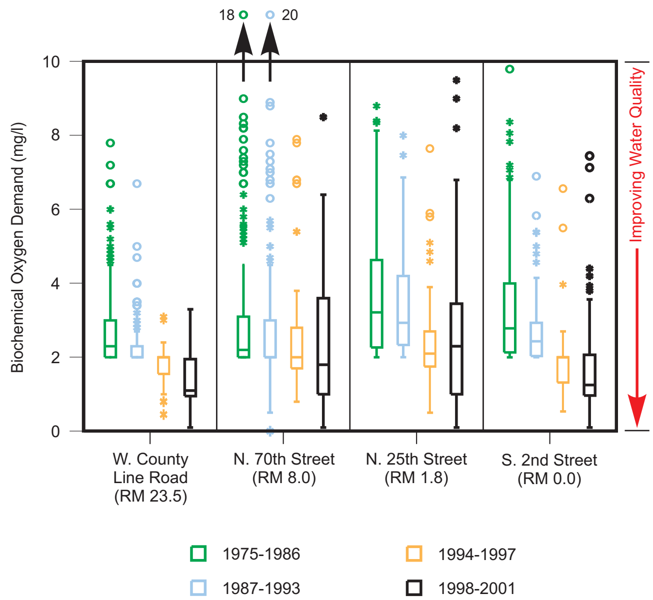
[3]*Section 809.60 of Chapter NR 809, "Safe Drinking Water," of the* Wisconsin Administrative Code, *establishes a secondary standard for chloride of 250 mg/l and notes that, while that concentration is not considered hazardous to health, it may be objectionable to an appreciable number of persons.*

Figure 75

BIOCHEMICAL OXYGEN DEMAND
AT SITES ALONG THE MAINSTEM OF THE
MENOMONEE RIVER: 1975-2001



NOTE: See Figure 66 for description of symbols.

Source: *U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

Dissolved Oxygen

Over the period of record, the mean concentration of dissolved oxygen in the Menomonee River was 8.2 mg/l. The data ranged from concentrations that were undetectable to concentrations in excess of saturation. As shown in Figure 78, this variability is present at individual sample sites. Mean dissolved oxygen concentrations in the estuary are significantly lower than mean concentrations in the section of the River upstream from the estuary (Table 54). Some of this may be the result of lower oxygen solubility due to higher water temperatures related to discharges of cooling water from the Valley power plant at the stations at S. 2nd Street, Burnham Canal, and Muskego Avenue. In the section of the River upstream from the estuary, the mean concentration of dissolved oxygen increases from upstream to downstream. As shown in Table 55, this increase is statistically significant. In the estuary, mean dissolved oxygen concentrations are highest at the 25th Street station and generally decrease from upstream to downstream to reach a minimum at the Burnham Canal Station. Downstream of this station, they increase. Figure 78 shows that the range of dissolved oxygen concentrations decreased at most stations after 1986. Because the solubility of oxygen in water is dependent on water temperature (i.e. as water temperatures decrease dissolved oxygen concentrations increase, see below), this does not reflect any change in the range of dissolved oxygen concentrations in the River. Rather it reflects the fact that MMSD discontinued sampling during the winter after 1986. At most of the stations in the section of the River upstream from the estuary, dissolved oxygen concentrations have decreased slightly over time, especially at the station at 70th Street. In the estuary, dissolved oxygen concentrations have increased. This is most noticeable at the 25th Street station. Statistical analysis shows slight trends toward increasing mean dissolved oxygen concentrations at three stations in the estuary and at one station in the section of the River upstream from the estuary (see Table C-2 in Appendix C of this report). Comparison of the trends toward increasing dissolved oxygen concentrations over time in the estuary to trends toward decreasing BOD (see above) and decreasing ammonia (see below) suggests that a decrease in loadings of organic pollutants may be responsible for the increase in mean dissolved oxygen. This is likely a consequence of a reduction in loadings from combined sewer overflows since MMSD's Inline Storage System went on line.

It is important to note that the majority of the dissolved oxygen concentrations for the areas upstream of the 70th Street station on the Menomonee River are above the 5.0 mg/l standard and the downstream sites are generally above 2.0 mg/l as shown in Figure 78. However, a consistent portion of the samples at all sites continue to fall within the range between 5.0 mg/l and 2.0 mg/l, which may be contributing to the maintenance of the poor to very-poor fishery and macroinvertebrate communities throughout the Menomonee River watershed (see Fisheries and Macroinvertebrates sections below). Researchers have found that dissolved oxygen concentrations below 5.0 mg/1 adversely affect the functioning and survival of biological communities and that the optimum concentration of dissolved oxygen for fish and other aquatic life is 5.0 to 7.0 mg/l (see Water Quality Indicators section in Chapter II of this report).[4]

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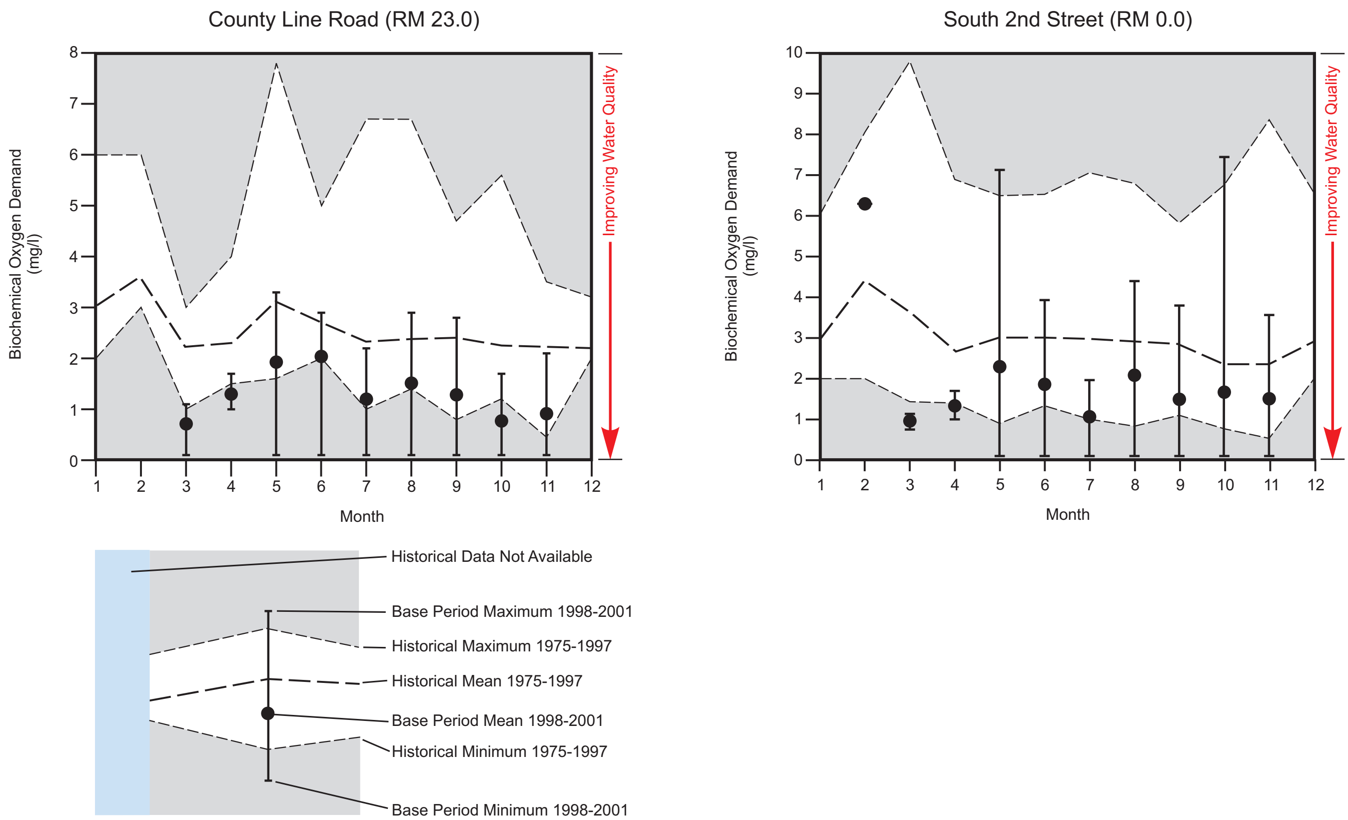
[4]*D. Chapman, V. Kimstach,* The Selection of Water Quality Variable In: Water Quality Assessments*, (Chapman, D. Ed.) Chapman and Hall Ltd., London, 1992.*

Figure 76

HISTORICAL AND BASE PERIOD BIOCHEMICAL OXYGEN DEMAND CONCENTRATIONS ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001



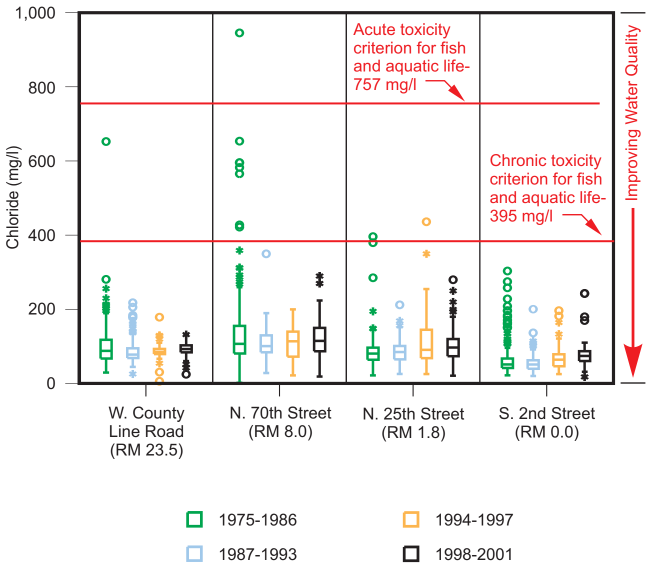
Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 79 compares monthly baseline period concentrations of dissolved oxygen to historical concentrations. At the Muskego Avenue station in the estuary, baseline period monthly mean dissolved oxygen concentrations are near or above historical monthly mean concentrations. The lowest concentrations detected at this station during the base period tend to be higher than the historical minima. Baseline period dissolved oxygen concentrations at other stations in the estuary follow this pattern. At the stations in the section of the River upstream from the estuary, such as the County Line Road station, baseline period monthly mean dissolved oxygen concentrations are generally near or below historical mean concentrations. The minimum concentrations of dissolved oxygen are within the historical range.

The data show strong seasonal patterns to the mean concentrations of dissolved oxygen (Figure 79). The mean concentration of dissolved oxygen is highest during the winter. It declines through spring to reach a minimum during the summer. It then rises though the fall to reach maximum values in winter. This seasonal pattern is driven by changes in water temperature. The solubility of oxygen in water decreases with increasing temperature. In addition, the metabolic demands and oxygen requirements of most aquatic organisms, including bacteria, tend to increase with increasing temperature. Higher rates of bacterial decomposition when the water is warm may contribute to the declines in the concentration of dissolved oxygen observed during the summer. In addition to the reasons mentioned above, dissolved oxygen concentrations can also be affected by a variety of other factors including the presence of aquatic plants, sunlight, turbulence in the water, and the amount and type of sediment as summarized in the Water Quality Indicators section in Chapter II of this report.

Figure 77

CHLORIDE CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001

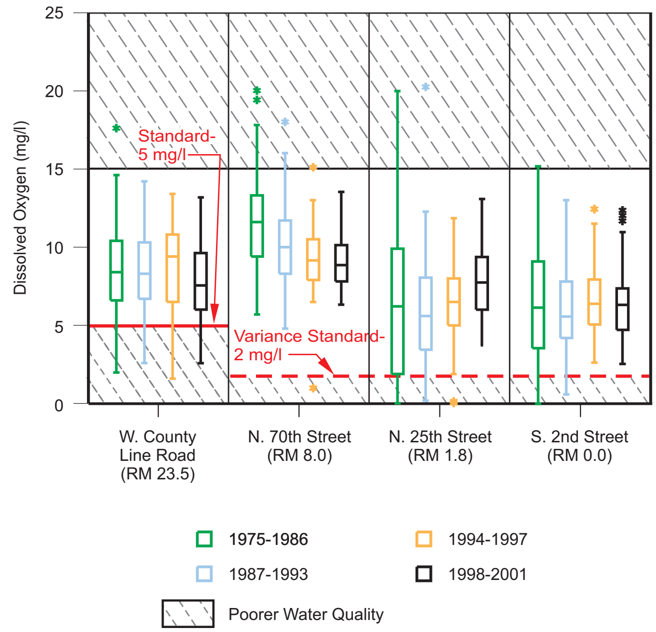


NOTE: See Figure 66 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 78

DISSOLVED OXYGEN CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001



NOTE: See Figure 66 for description of symbols.

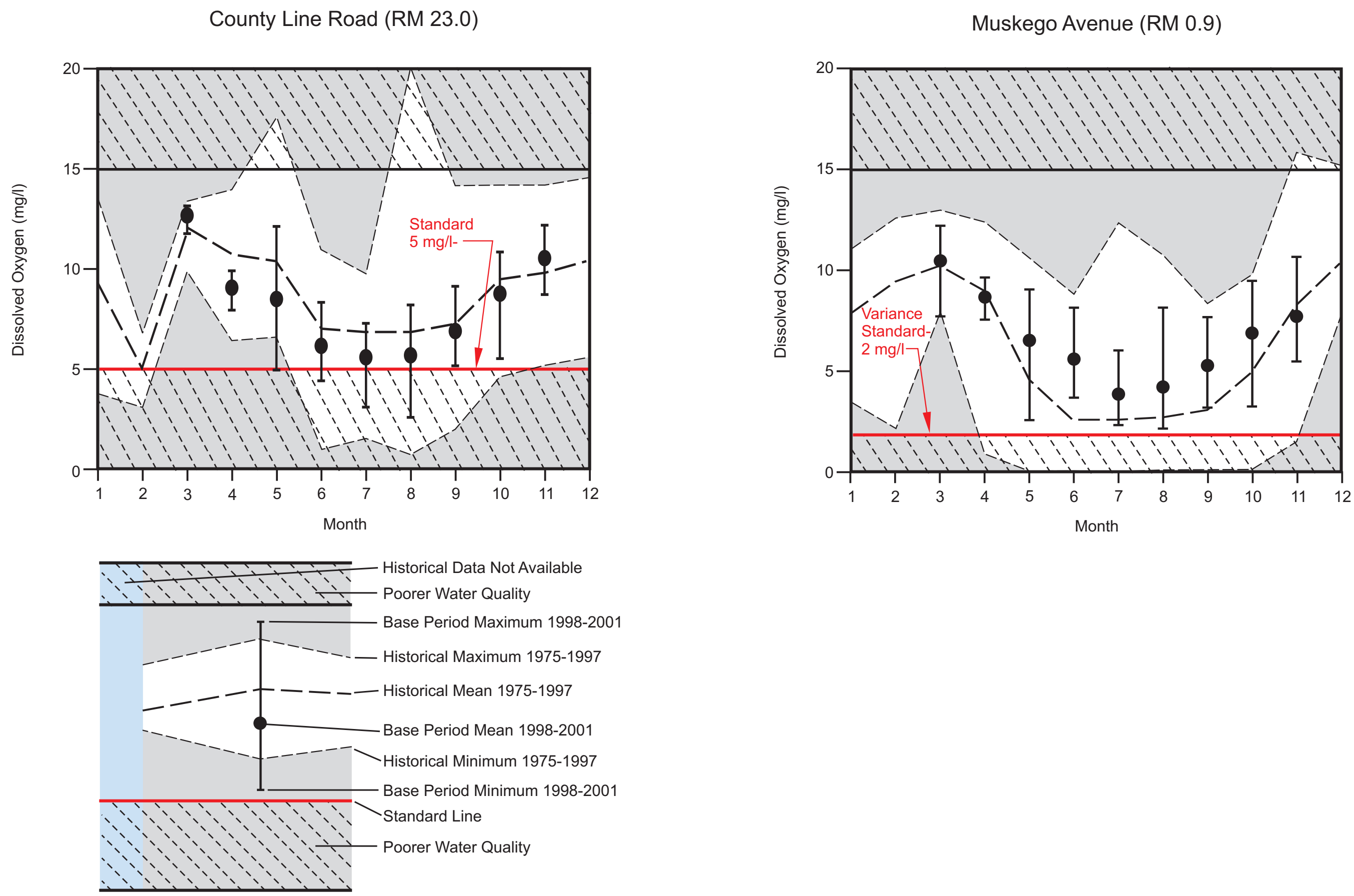
140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Several factors affect dissolved oxygen concentrations in the Menomonee River, especially in the estuary. First, portions of the estuary act as a settling basin in which material suspended in the water sink and fall out into the sediment. This is indicated by the lower concentrations of total suspended solids (TSS) in the estuary (Table 54 and see below). Decomposition of organic matter contained in this material, through chemical and especially biological processes, removes oxygen from the overlying water, lowering the dissolved oxygen concentration. Second, influxes of water from Lake Michigan and the Milwaukee River may influence dissolved oxygen concentrations in the downstream portions of the estuary. When dissolved oxygen concentrations in these waterbodies are higher than in the estuary, mixing may act to increase dissolved oxygen concentrations in the lower estuary. Third, We Energies operates an electric power generating plant which discharges cooling water into the River near the Burnham Canal sampling station. These discharges can raise water temperatures in the estuary, resulting in lower oxygen solubility. Fourth, through much of the mainstem of the Menomonee River, dissolved oxygen concentrations are inversely correlated with ammonia and nitrite concentrations. This suggests that oxidation of ammonia and nitrite to nitrate through biologically mediated nitrification may also be acting to lower dissolved oxygen concentrations when concentrations of these compounds are high. Fifth, dissolved oxygen concentrations are positively correlated with pH. This reflects the effect of photosynthesis on both of these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the water's pH. At the same time, oxygen is released as a byproduct of the photosynthetic reactions.

Figure 79

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF DISSOLVED OXYGEN ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001



NOTE: 140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

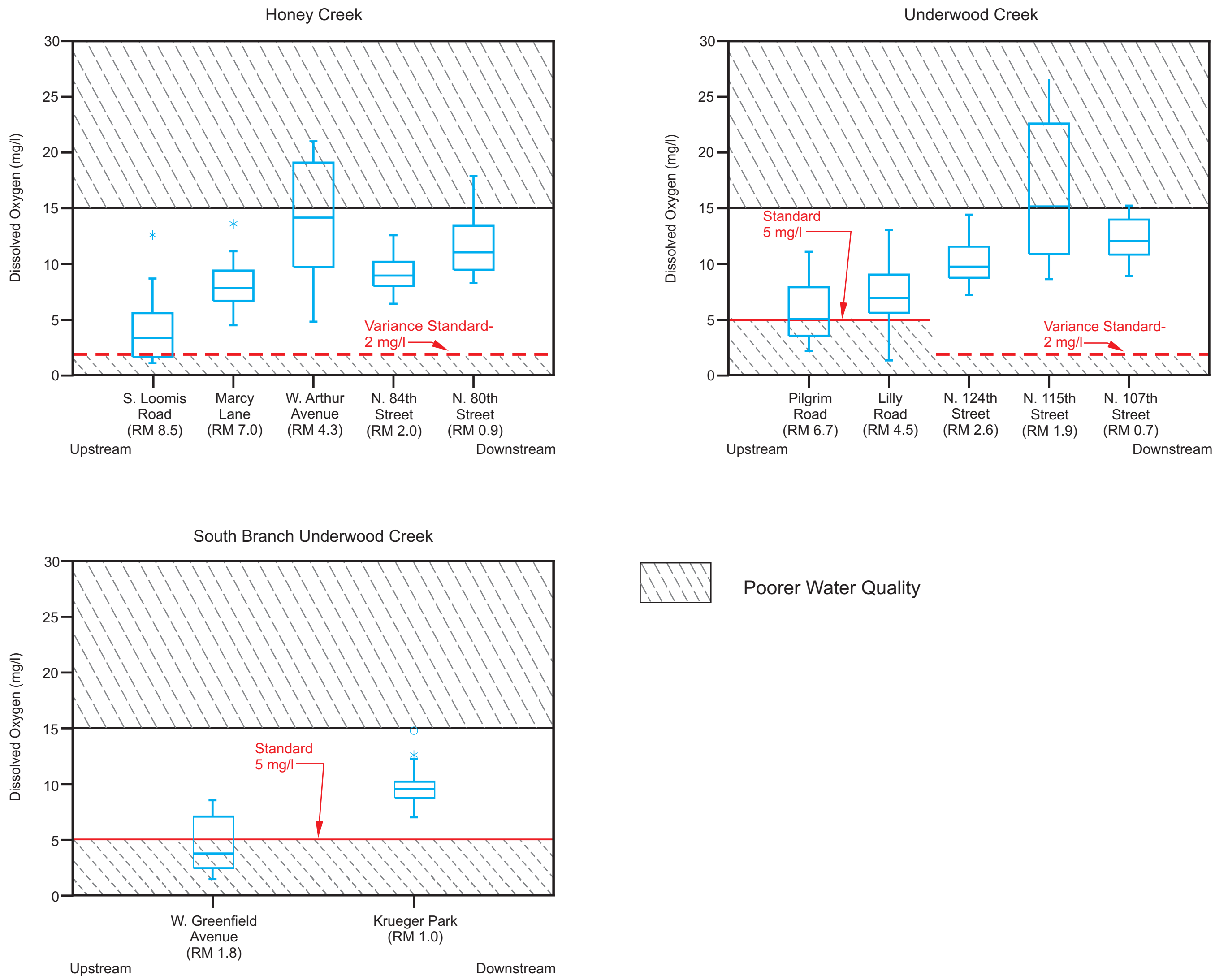
Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, and Milwaukee Metropolitan Sewerage District, and SEWRPC.

In addition to the reasons mentioned above, dissolved oxygen concentrations in water can also be affected by a variety of other factors including the presence of aquatic plants, sunlight, turbulence in the water, and the amount and type of sediment as summarized in the Water Quality Indicators section in Chapter II of this report. In summary, dissolved oxygen concentrations were generally shown to have remained unchanged in the areas upstream from the 70th Street station (RM 8.0) and to have improved (i.e. increase in concentration) in the estuary area downstream from the 25th Street station, during the time period examined from 1975 to 2001.

During 2004 and 2005, MMSD examined water samples from Honey Creek, Underwood Creek, and South Branch Underwood Creek for dissolved oxygen. The mean concentration of dissolved oxygen detected in Honey Creek was 9.8 mg/l Concentrations in individual samples ranged between 1.1 and 21.0 mg/l. As shown in Figure 80, dissolved oxygen concentrations in Honey Creek tended to increase from upstream to downstream. This represented a statistically significant trend. Dissolved oxygen concentrations at the Loomis Road sampling station were occasionally below the 2.0 mg/l variance standard that applies to the Creek (Figure 80). The mean concentration of dissolved oxygen detected in Underwood Creek was 9.9 mg/l. Concentrations in individual samples ranged between 1.3 and 26.6 mg/l. Dissolved oxygen concentrations in Underwood Creek also tended to increase from upstream to downstream (Figure 80). This represented a statistically significant trend. In about half

Figure 80

CONCENTRATIONS OF DISSOLVED OXYGEN IN TRIBUTARY STREAMS IN THE MENOMONEE RIVER WATERSHED: 2004-2005



NOTES: See Figure 66 for description of symbols.

140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: Milwaukee Metropolitan Sewerage District, and SEWRPC.

the samples collected at the Pilgrim Road sampling station and occasional samples collected at the Lilly Road sampling station, concentrations of dissolved oxygen were below the 5.0 mg/l standard for fish and aquatic life. The mean concentration of dissolved oxygen detected in South Branch Underwood Creek was 7.3 mg/l. Concentrations in individual samples ranged between 1.5 and 14.8 mg/l. In the majority of samples collected at the sampling station at W. Greenfield Avenue, the concentration of dissolved oxygen was below the 5.0 mg/l standard for fish and aquatic life.

It is important to note that supersaturation of water with dissolved oxygen occasionally occurs at the stations in the portions of Honey Creek and Underwood Creek (Figure 80). Supersaturation of water with dissolved oxygen occurs when the water contains a higher concentration of dissolved oxygen than is normally soluble at ambient conditions of temperature and pressure. Oxygen supersaturation in these streams is probably caused by high intensities of photosynthesis by attached algae growing in concrete-lined channels at and upstream of the sampling stations. This has two implications. First, because dissolved oxygen samples are often collected during the day, the dissolved oxygen concentrations data presented for these streams may be less representative of average concentrations and more typical of maximum concentrations achieved during diurnal periods. Second, respiration by the same attached algae may cause steep declines in dissolved oxygen concentration at these stations at night when photosynthesis cannot occur due to lack of light.

Hardness

Over the period of record, the mean hardness in the Menomonee River was 299.6 mg/l as $CaCO_3$. On a commonly used scale, this is considered to be very hard water.[5] The range of the data runs from 5.0 to 750.1 mg/l as $CaCO_3$, showing considerable variability. Some of this variability probably results from inputs of relatively soft water during storm events. Table 54 shows that mean concentrations of hardness were significantly lower in the estuary than at the upstream stations in all periods except 1987-1993. It is important to note that like alkalinity, specific conductivity, and pH, hardness concentrations are greatly influenced by Lake Michigan water dilution in the estuary, which probably causes these concentrations to be lower than the upstream areas. At a limited number of sites a decreasing trend in hardness was evident during the summer; however, no other seasonal patterns in hardness were detected (Table C-2 in Appendix C). In summary, although hardness concentrations are lower in the estuary areas downstream of the 70th Street station (RM 8.0), hardness concentrations were generally shown to have remained unchanged among stations during the time period examined from 1975 to 2001.

During 2004 and 2005, MMSD examined water samples from Honey Creek, Underwood Creek, and South Branch Underwood Creek for hardness. The mean hardness detected in Honey Creek was 222 mg/l as $CaCO_3$. Concentrations in individual samples ranged between 64 and 430 mg/l as $CaCO_3$. The mean hardness detected in Underwood Creek was 355 mg/l as $CaCO_3$. Concentrations in individual samples ranged between 120 and 650 mg/l as $CaCO_3$. The mean hardness detected in South Branch Underwood Creek was 266 mg/l as $CaCO_3$. Concentrations in individual samples ranged between 110 and 530 mg/l as $CaCO_3$.

pH

The mean pH in the Menomonee River over the period of record was 7.9 standard units. The mean values at individual sampling stations along the mainstem of the River ranged from 7.6 to 8.1 standard units. At most stations, pH varied only by $\pm$ 1.0 standard unit from the stations' mean values. More variability in pH was seen at the three stations that are farthest upstream. This higher variability upstream is probably related to the relatively lower discharge at these stations. Because a lower volume of water is flowing past these stations, the effect of fluctuations in inputs from groundwater and runoff from precipitation on pH will be greater than at downstream sites. For all periods for which data were available, mean pH was significantly lower at the stations in the estuary than at the stations in the reaches upstream from the estuary (Table 54). It is important to note that like alkalinity, specific conductivity, and hardness, pH concentrations are greatly influenced by Lake Michigan water dilution in the estuary, which probably causes these concentrations to be lower than the upstream areas. At most stations, pH shows positive correlations with concentrations of alkalinity, chloride, and hardness and with specific conductance. At all stations, dissolved oxygen concentrations are positively correlated with pH. This reflects the effect of photosynthesis on both of these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the water's pH. At the same time, oxygen is released as a byproduct of photosynthesis. On an annual basis, statistically significant declines in pH were detected at all of the stations upstream from the estuary except for the 70th Street station (Table C-2 in Appendix C). Summer and fall values of pH in the Menomonee River tend to be lower than spring and winter values. In summary, pH concentrations were generally shown to have decreased in the upstream areas above the Hampton Avenue Station (RM 12.5) and

[5]*E. Brown, M.W. Skougstad, and M.J. Fishman,* Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, *U.S. Department of Interior, U.S. Geological Survey, 1970.*

to have remained unchanged for the rest of the stations downstream from Hampton Avenue during the time period examined from 1975 to 2001.

During 2004 and 2005, MMSD examined water samples from Honey Creek, Underwood Creek, and South Branch Underwood Creek for pH. The mean pH detected in Honey Creek was 7.8 standard units. The range of pH detected in individual samples ranged between 6.6 and 9.4 standard units. The mean pH detected in Underwood Creek was 7.7 standard units. The range of pH detected in individual samples ranged between 6.6 and 8.7 standard units. The mean pH detected in South Branch Underwood Creek was 7.4 standard units. The range of pH detected in individual samples ranged between 6.8 and 8.4 standard units. In both Honey Creek and Underwood Creek, there were statistically significant trends toward pH increasing from upstream to downstream. These longitudinal trends are similar to the trends in dissolved oxygen detected in these streams and may reflect the effects of photosynthesis on both of these constituents.

Specific Conductance

The mean value for specific conductance in the Menomonee River over the period of record was 841.9 μS/cm. Considerable variability was associated with this mean. Specific conductance ranged from 0.1 to 5,950.0 μS/cm. Some of this variability may reflect the discontinuous nature of inputs of dissolved material into the River. Runoff associated with storm events can have a major influence on the concentration of dissolved material in the River. The first runoff from a storm event transports a large pulse of salts and other dissolved material from the watershed into the River. This will tend to raise specific conductance in the River. Later runoff associated with the event will be relatively dilute. This will tend to lower specific conductance. Table 54 shows that mean values of specific conductance were lower in the estuary than reaches upstream from the estuary in all periods examined. This probably results from the greater volume of water passing through the estuary. As shown in Table 55, specific conductance in the section of the River upstream from the estuary shows a significant increasing trend from upstream to downstream. It is important to note that like alkalinity, pH, and hardness; specific conductance concentrations are greatly influenced by Lake Michigan water dilution in the estuary, which probably causes these concentrations to be lower than the upstream areas. Analysis results in the section of the River upstream from the estuary shows that specific conductance values have decreased in the upstream areas as shown in Table 55. The data show a seasonal pattern of variation in specific conductance (Table C-2 in Appendix C). For those years in which data were available, specific conductance was highest during the winter. It then declined during the spring to reach lower levels in the summer and fall. In summary, specific conductance values were generally shown to have decreased in the upstream areas above the 124th Street Station (RM 13.5), increased downstream of the 70th Street Station (RM 8.0), and remained unchanged in the rest of the Menomonee River during the time period examined from 1975 to 2001.

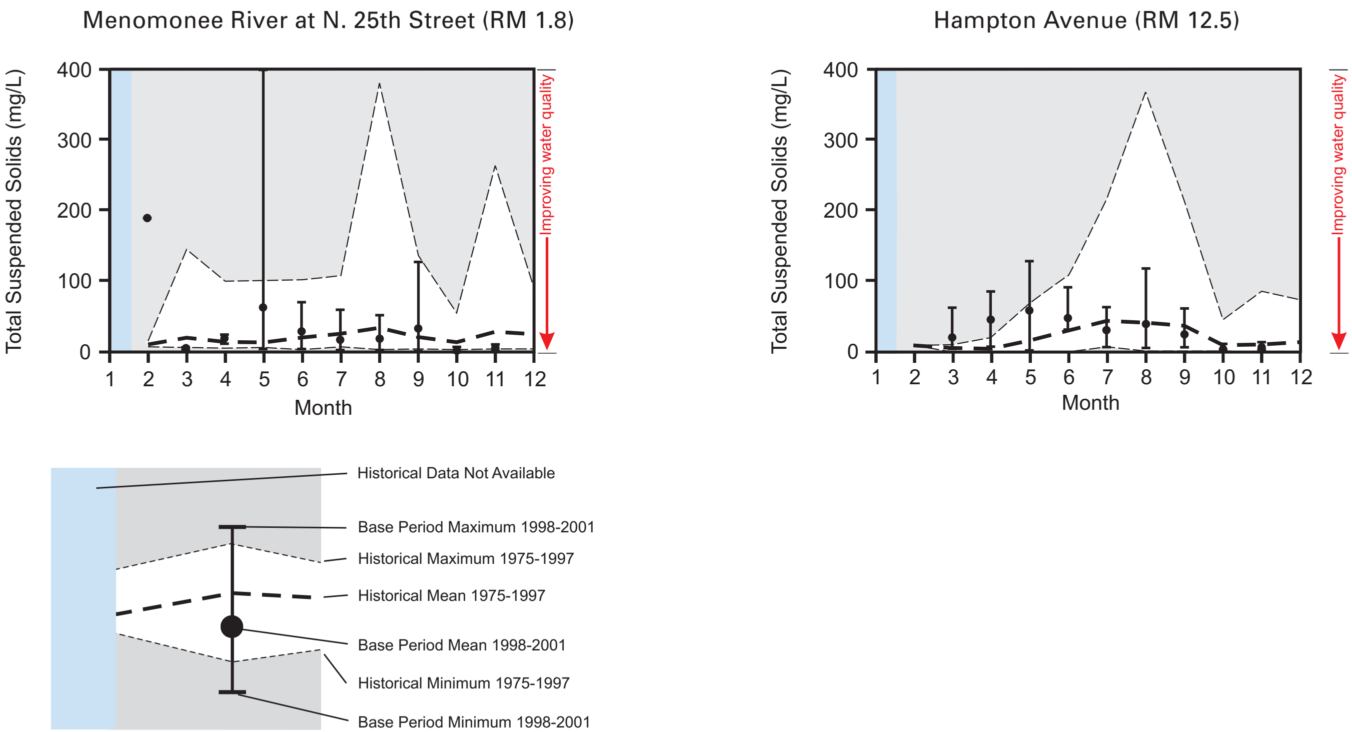
During 2004 and 2005, MMSD examined water samples from Honey Creek for specific conductance. The mean value of specific conductance in the Creek was 1,177 μS/cm, with values in individual samples ranging between 589 and 1,827 μS/cm.

Suspended Material

The mean value for total suspended solids (TSS) concentration in the Menomonee River over the period of record was 21.4 mg/l. Considerable variability was associated with this mean, with values ranging from 1.6 to 727.0 mg/l. At most sampling stations, baseline period monthly mean TSS concentrations generally tend to be near historical means (see Figure 81). During the spring, there is a distinct tendency at several stations for baseline period monthly mean TSS concentrations to be higher than historical means. Mean concentrations of TSS were significantly lower at the estuary stations than at stations upstream from the estuary for all periods for which data were available, as shown in Table 54. This reflects the fact that portions of the estuary act as a settling basin in which material suspended in water sink and fall out into the sediment. Trends toward increasing concentrations of TSS over time were detected at the sampling stations in the estuary (Table C-2 in Appendix C). These trends accounted for a small portion of the variation in the data. TSS concentrations showed strong positive correlations with total phosphorus concentrations, reflecting the fact that total phosphorus concentrations include a large particulate fraction. TSS concentrations were also positively correlated with concentrations of fecal coliform

Figure 81

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF TOTAL SUSPENDED SOLIDS ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

bacteria and nutrients. TSS concentrations were negatively correlated with some measures of dissolved materials, such as alkalinity, chloride, hardness, and specific conductance. The trends toward increasing TSS concentrations at sampling stations in the estuary represent declines in water quality.

Nutrients

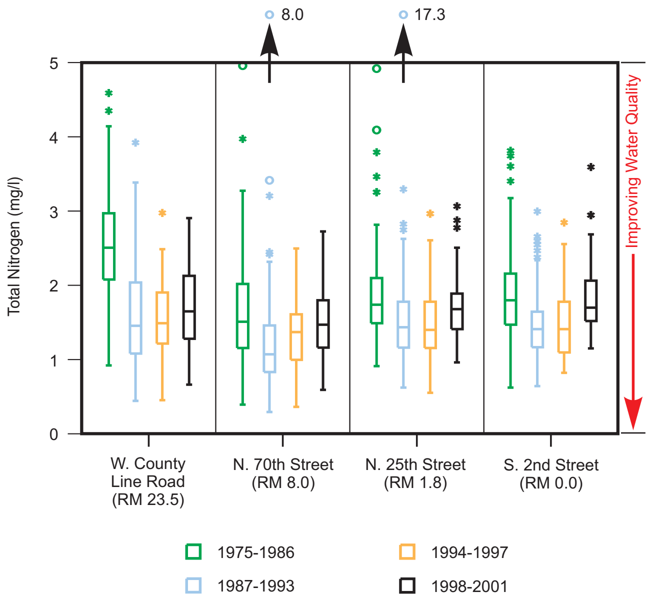
Nitrogen Compounds

The mean concentration of total nitrogen in the Menomonee River over the period of record was 1.68 mg/l as N. Concentrations varied over three orders of magnitude, ranging from 0.140 to 17.26 mg/l as N. As shown in Figure 82, mean total nitrogen concentrations were highest in the River during the period 1975-1986. Following this period, they declined. Depending on the station, they began to rise again either after 1993 or after 1997. The relationship between baseline period and historical monthly mean concentrations of total nitrogen varies along the length of the River. The baseline monthly mean concentrations at stations in the estuary are generally higher than the historical monthly mean concentrations, and the mean concentrations of total nitrogen were significantly higher at stations in the estuary than in stations along the reaches upstream from the estuary in all periods (see Table 54). Table 55 shows that there is a significant trend in the section of the River upstream from the estuary for total nitrogen to decline from upstream to downstream. The concentration of total nitrogen at most stations in the Menomonee River is moderately positively correlated with the concentration of total phosphorus. This probably reflects the nitrogen and phosphorus contained in particulate organic material in the water, including live material such as plankton and detritus.

Total nitrogen is a composite measure of several different compounds which vary in their availability to algae and aquatic plants and vary in their toxicity to aquatic organisms. Common constituents of total nitrogen include ammonia, nitrate, and nitrite. In addition a large number of nitrogen-containing organic compounds, such as

Figure 82

TOTAL NITROGEN CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001

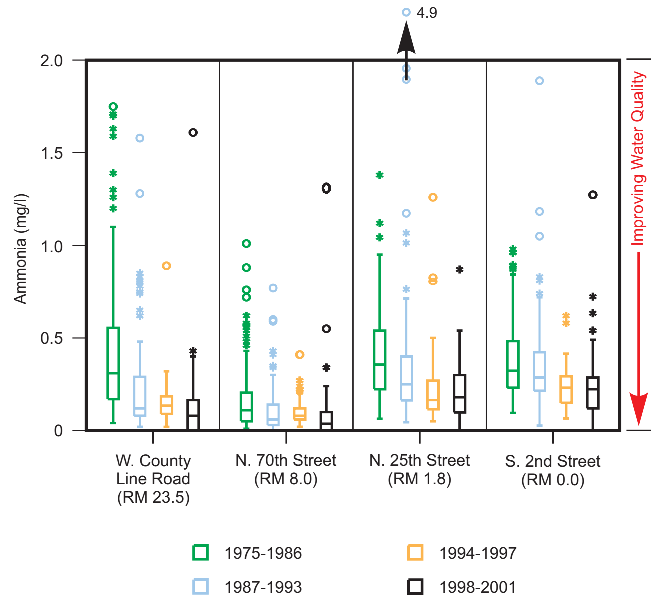


NOTE: See Figure 66 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 83

AMMONIA CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001



NOTES: See Figure 66 for description of symbols.

Standard is dependent on ambient temperature and pH which indicate ammonia concentrations did not exceed those toxicity standards.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

amino acids, nucleic acids, and proteins commonly occur in natural waters. These compounds are usually reported as organic nitrogen.

The mean concentration of ammonia in the Menomonee River was 0.261 mg/l as N. Over the period of record, ammonia concentrations varied between 0.002 and 4.880 mg/l as N. Figure 83 shows that mean ammonia concentrations have been declining over time. In addition, in the section of the River upstream from the estuary, ammonia concentrations decline from upstream to downstream. They increase markedly in the estuary, although, in the estuary, baseline period monthly mean concentrations of ammonia are generally near or below the historic monthly means. There were no clear patterns of seasonal variation in ammonia concentrations in the Menomonee River. While no correlations were detected between concentrations of ammonia and chlorophyll-*a*, ammonia is a nutrient for algal and plant growth. During periods of high algal productivity, algae remove ammonia from the water and incorporate it into cellular material.

The mean concentration of nitrate in the Menomonee River for the period of record was 0.667 mg/l as N. During this time, concentrations in the River varied between 0.010 and 4.400 mg/l as N. Table C-2 in Appendix C indicates that the relationship between the mean concentration of nitrate at stations in the estuary and the mean concentration of nitrate in the section of the River upstream from the estuary changed over time. During the period from 1975 to 1986, the mean concentration in the estuary was lower than the mean concentration at the stations upstream from the estuary (see Table 54). This changed after 1986. From 1987-1994, there was no significant difference between the mean concentration in the estuary and the mean concentration in the reaches upstream from the estuary. The relationship changed again after 1993. During both periods after this year, the mean concentrations in the estuary were higher than those in the reaches upstream. While this last change took place during the period in which the Inline Storage System came on line, it may reflect some change that began earlier. The data show some evidence of seasonal variations in nitrate concentration. During the 1970s and 1980s, nitrate concentration was highest in the winter. It declined through spring to reach lower levels in the summer. In the fall, the concentration began to climb again. This pattern may have changed during the 1990s. After 1995, fall nitrate concentrations tended to be lower than those taken in the summer. At some stations, nitrate concentrations were negatively correlated with concentrations of chlorophyll-*a*. This reflects the role of nitrate as a nutrient for algal growth. During periods of high algal productivity, algae remove nitrate from the water and incorporate it into cellular material.

The mean concentration of nitrite in the Menomonee River was 0.038 mg/l as N over the period of record. Nitrite concentrations showed more variability than ammonia and nitrate. This probably reflects the fact that nitrite in oxygenated water tends to oxidize to nitrate fairly quickly. No significant differences were detected between the mean concentration of nitrite at the stations in the estuary and the mean concentration of nitrite at the stations upstream from the estuary (Table 54). This changed after 1986. From that time onward, mean nitrite concentrations in the estuary were higher than those in the sections of the River upstream from the estuary.

During the period of record the mean concentration of organic nitrogen in the Menomonee River was 0.723 mg/l as N. This parameter showed considerable variability with concentrations ranging from undetectable to over 16 mg/l as N. With one exception, no significant differences were found between the mean concentrations at the stations in the estuary and the stations upstream from the estuary as shown in Table 54. During the period from 1994 to 1997, the mean concentration in the estuary was significantly lower than the mean concentration in the reaches upstream from the estuary. Table 55 indicates that there is a significant trend within the nonestuary section of the River toward organic nitrogen concentrations declining from upstream to downstream. There were no clear patterns in seasonable variation of organic nitrogen.

Several processes can influence the concentrations of nitrogen compounds in a waterbody. As noted above, primary production by plants and algae will result in ammonia and nitrate being removed from the water and incorporated into cellular material. This effectively converts the nitrogen to forms which are detected only as total nitrogen. Decomposition of organic material in sediment can release nitrogen compounds to the overlying water. This may constitute a major source of nitrogen compounds in the estuary. Bacterial action may convert some nitrogen compounds into others.

Several points emerge from this analysis of nitrogen chemistry in the Menomonee River:

- There are distinct differences, with respect to forms of nitrogen, between the estuary and the sections upstream from the estuary. With the exception of organic nitrogen, all forms of nitrogen tend to be found in higher concentrations in the estuary.

- All forms of nitrogen show trends of declining concentration from upstream to downstream in the section of the River upstream from the estuary.

- The relative proportions of different nitrogen compounds in the River seem to be changing with time.

- Throughout the River ammonia concentrations have been declining over time. This represents an improvement in water quality.

- Where trends exist, the concentrations of organic nitrogen compounds seem to be increasing over time.

A few data are available on nitrogen compounds in tributary streams in the Menomonee River watershed. During 2004 and 2005, MMSD examined water samples from Honey Creek for concentrations of ammonia, nitrate, and nitrite and water samples from Underwood Creek and South Branch Underwood Creek for concentrations of ammonia. The mean concentration of ammonia in Honey Creek was 0.108 mg/l. Concentrations in individual samples ranged from below the limit of detection to 0.88 mg/l. There was a statistically significant trend toward ammonia concentrations in Honey Creek decreasing from upstream to downstream. The mean concentration of nitrate in Honey Creek was 0.52 mg/l. Concentrations in individual samples ranged between 0.005 mg/l and 1.40 mg/l. The mean concentration of nitrite in Honey Creek was 0.020 mg/l. Concentrations in individual samples ranged from 0.006 mg/l to 0.063 mg/l. The mean concentration of ammonia in Underwood Creek was 0.054 mg/l. Concentrations in individual samples ranged from below the limit of detection to 0.26 mg/l. The mean concentration of ammonia in South Branch Underwood Creek was 0.171 mg/l. Concentrations in individual samples ranged between 0.011 mg/l and 0.390 mg/l.

Total and Dissolved Phosphorus

Two forms of phosphorus are commonly sampled in surface waters: dissolved phosphorus and total phosphorus. Dissolved phosphorus represents the form that can be taken up and used for growth by algae and aquatic plants. Total phosphorus represents all the phosphorus contained in material dissolved or suspended within the water, including phosphorus contained in detritus and organisms.

The mean concentration of total phosphorus in the Menomonee River during the period of record was 0.116 mg/l (see Figure 84), and the mean concentration of dissolved phosphorus in the Menomonee River over the period of record was 0.044 mg/l. Phosphorus concentrations varied over four orders of magnitude, with concentrations of total phosphorus in the River ranging from 0.0015 to 3.000 mg/l, and of dissolved phosphorus ranging from 0.003 to 3.000 mg/l. At most sampling sites, the data showed moderate variability. Table 54 shows that the relationship between the mean concentrations of dissolved phosphorus at stations in the estuary and at stations in the section of the River upstream of the estuary has been changing over time. During the periods before 1994, Table 54 shows that mean concentrations of dissolved phosphorus were significantly lower in the estuary than in the section of the River upstream of the estuary. At some stations, dissolved phosphorus concentrations were negatively correlated with concentrations of chlorophyll-*a*. This reflects the role of dissolved phosphorus as a nutrient for algal growth. During periods of high algal productivity, algae remove dissolved phosphorus from the water and incorporate it into cellular material.

Since 1994, the mean concentration of total phosphorus has tended to increase from upstream to downstream. Figure 85 shows a monthly comparison of the historic and baseline concentrations of total phosphorus at two sampling stations along the length of the mainstem of the Menomonee River, one in the estuary and one in the section upstream from the estuary. At both stations, concentrations of total phosphorus during the period 1998-2001 were generally within the historic ranges.

Figure 86 shows the annual mean total phosphorus concentration in the Menomonee River for the years 1985-2001. Mean annual total phosphorus concentration increased sharply after 1996. In addition, researchers at the University of Wisconsin-Milwaukee/University of Wisconsin System Great Lakes WATER Institute have found that phosphorus concentrations have been increasing in the upper reaches of the estuary. One possible cause of these increases is phosphorus loads from facilities discharging noncontact cooling water drawn from municipal water utilities. The City of Milwaukee began treating its municipal water with orthophosphate to inhibit release of copper and lead from pipes in the water system and private residences in 1996. In 2004, for instance, concentrations of orthophosphate in plant finished water from the Milwaukee Water Works ranged between 1.46 mg/l and 2.24 mg/l,[6] considerably above average concentrations of total phosphorus in the Menomonee River.

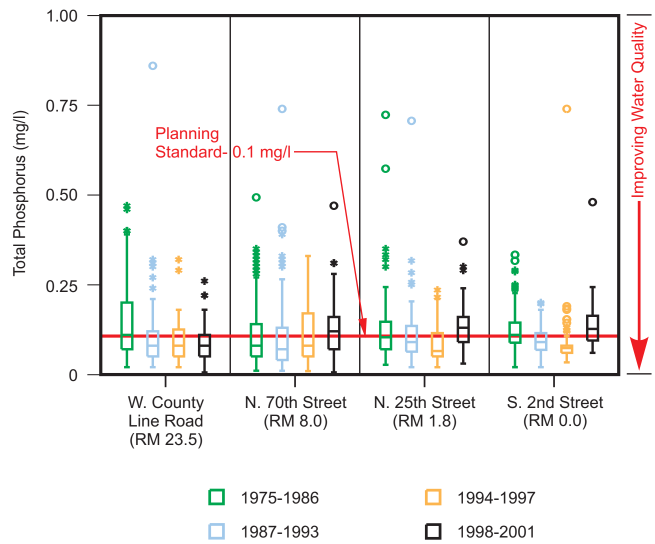
During 2004 and 2005, MMSD examined water samples from Honey Creek, Underwood Creek, and South Branch Underwood Creek for total phosphorus. The mean concentration of total phosphorus detected in Honey Creek was 0.14 mg/l. Concentrations in individual samples ranged between 0.02 and 0.35 mg/l. The mean

[6]*Milwaukee Water Works,* Annual Water Quality Report, 2004, *February 2005.*

concentration of total phosphorus detected in Underwood Creek was 0.12 mg/l. Concentrations in individual samples ranged from below the limit of detection to 1.90 mg/l. The mean concentration of total phosphorus detected in South Branch Underwood Creek was 0.19 mg/l. Concentrations in individual samples ranged between 0.04 and 0.49 mg/l.

Figure 84

TOTAL PHOSPHORUS CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001



NOTE: See Figure 66 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Metals

Arsenic

The mean value for the concentration of arsenic in the water of the Menomonee River over the period of record was 1.93 μg/l. The data ranged from being undetectable to 5.4 μg/l. For the most part, where arsenic was detected variability in concentration was moderate. The data record for arsenic is rather short. Prior to 1996, few water samples from the Menomonee River were analyzed for the presence of arsenic. Table 54 shows that during the periods after 1993, no statistically significant differences were detected between the mean concentrations of arsenic in the estuary and the mean concentrations in the upstream section. Similarly, no trends in arsenic concentration were detected from upstream to downstream along the River as shown in Table 55. Table C-2 in Appendix C reveals that arsenic concentrations appear to be declining annually as well as among each of the seasons in nearly all sampling stations in the Menomonee River. This may reflect changes in the amount and types of industry within the Menomonee River watershed such as the loss of tanneries which utilized arsenic in the processing of hides. In addition, sodium arsenate has not been used in herbicides since the 1960s. Arsenic concentrations in the Menomonee River show no evidence of seasonal variation. The reductions in arsenic concentration in the Menomonee River represent an improvement in water quality.

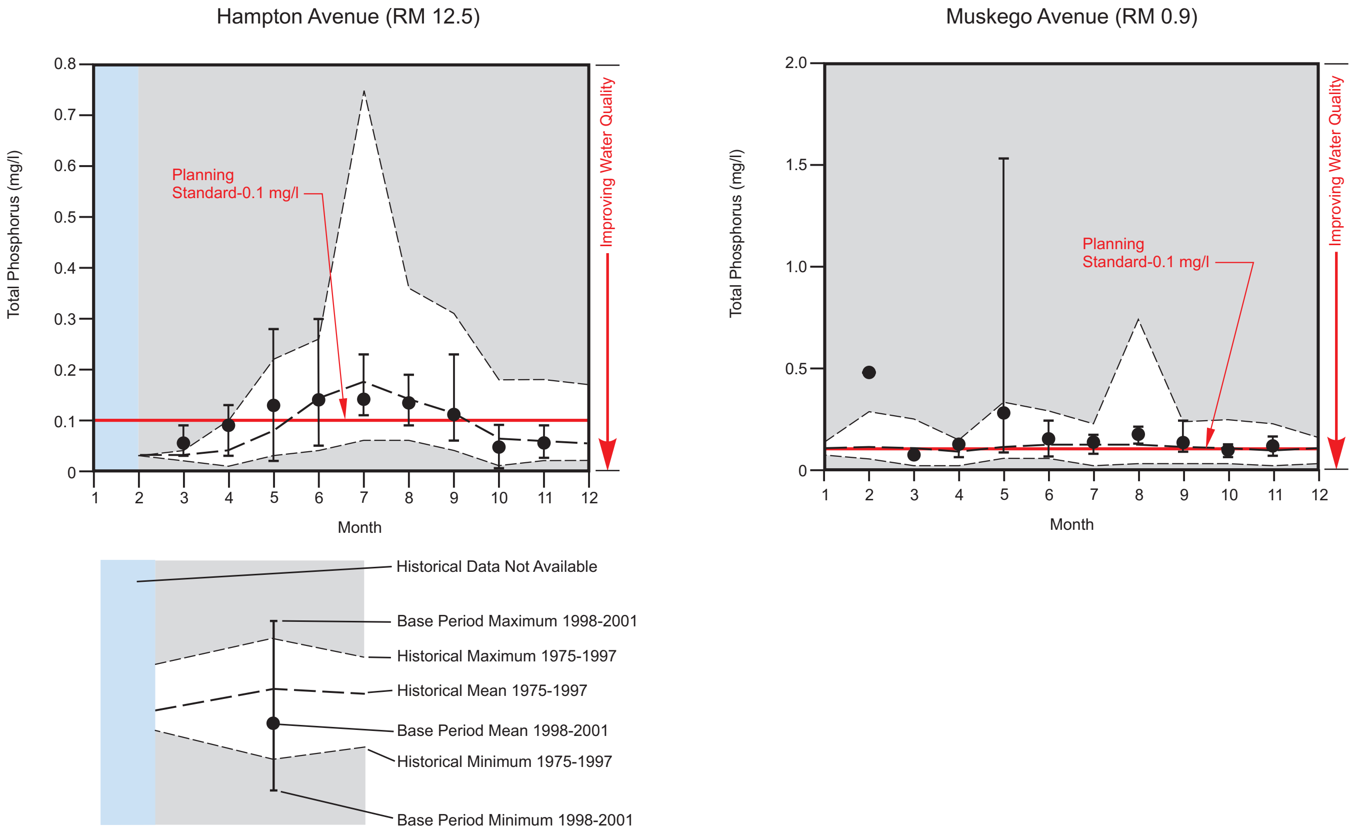
During 2004 and 2005, MMSD examined water samples from Honey Creek, Underwood Creek, and South Branch Underwood Creek for concentrations of arsenic. The mean concentration of arsenic detected in Honey Creek was 4.2 μg/l. Concentrations in individual samples ranged from below the limit of detection to 8.5 μg/l. The mean concentration of arsenic detected in Underwood Creek was 3.1 μg/l. Concentrations in individual samples ranged from below the limit of detection to 11.0 μg/l. The mean concentration of arsenic detected in South Branch Underwood Creek was 1.7 μg/l. Concentrations in individual samples ranged below the limit of detection to 5.2 μg/l.

Cadmium

The mean concentration of cadmium in the Menomonee River over the period of record was 1.7 μg/l. A moderate amount of variability was associated with this mean. Individual samples ranged from 0.05 to 16.8 μg/l. There were few differences among the stations in the amount of variability. During this period the mean concentration of cadmium was higher at stations in the estuary than at stations in the section of the River upstream of the estuary as shown in Table 54. Table 55 shows that the concentration of cadmium tended to decrease from upstream to downstream in the section of the River upstream from the estuary. Table C-2 in Appendix C also shows the presence of a strong decreasing trend in cadmium concentrations at nearly all stations on an annual and seasonal basis. These declines in cadmium concentration may reflect changes in the number and types of industry present

Figure 85

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF TOTAL PHOSPHORUS ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

in the watershed. They may also reflect reductions in airborne deposition of cadmium to the Great Lakes region. Cadmium concentrations in the River showed no evidence of seasonal variation. The reductions in cadmium concentration in the Menomonee River represent an improvement in water quality.

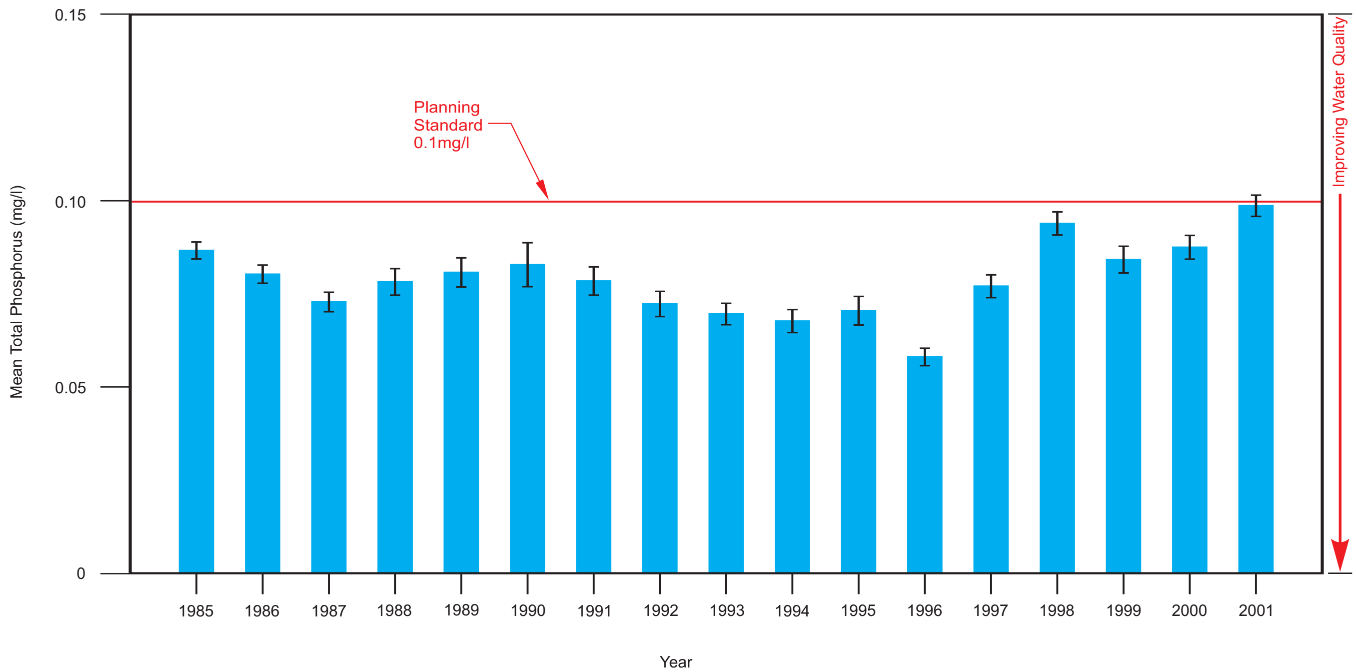
During 2004 and 2005, MMSD examined water samples from Honey Creek, Underwood Creek, and South Branch Underwood Creek for concentrations of cadmium. Cadmium was detected in only one out of 20 samples from Honey Creek at a concentration of 2.0 μg/l. In all other samples collected from these streams during this period, the concentration of cadmium was below the limit of detection.

Chromium

The mean concentration of chromium in the Menomonee River over the period of record was 10.83 μg/l. Chromium concentration showed moderate variability, with individual sample concentrations ranging from 0.5 to 510.0 μg/l. The amount of variability in the data has been declining over time. As shown in Table C-2 in Appendix C, analysis of time-based trends suggests that chromium concentrations are declining within the portions of the River that have been sampled. The decline in chromium concentration and the reduction in the amount of variability in chromium concentration may reflect the loss of industry in some parts of the watershed, including the loss of tanneries from the Menomonee Valley, and the decreasing importance of the metal plating industry in particular, as well as the establishment of mandatory treatment and pretreatment of discharges instituted for the remaining and new industries since the late 1970s. The treatment/pretreatment requirements

Figure 86

MEAN ANNUAL CONCENTRATION OF TOTAL PHOSPHORUS IN THE MENOMONEE RIVER: 1985-2001



NOTE: Error bars (I) represent one standard error of the mean.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

instituted did result in many discharges which previously went to the River being removed and connected to the public sewer system. There is no evidence of seasonal variation in chromium concentrations in the Menomonee River. The reductions in chromium concentrations in the Menomonee River represent an improvement in water quality.

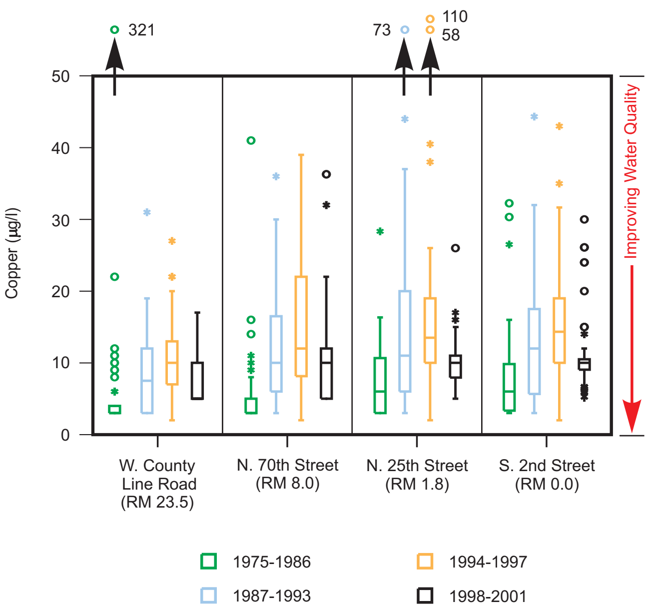
During 2004 and 2005, MMSD examined water samples from Honey Creek, Underwood Creek, and South Branch Underwood Creek for concentrations of chromium. The mean concentration of chromium detected in Honey Creek was 1.0 μg/l. Concentrations in individual samples ranged from below the limit of detection to 3.6 μg/l. The mean concentration of chromium detected in Underwood Creek was 0.8 μg/l. Concentrations in individual samples ranged from below the limit of detection to 4.3 μg/l. The mean concentration of chromium detected in South Branch Underwood Creek was 0.8 μg/l. Concentrations in individual samples ranged from below the limit of detection to 3.1 μg/l.

Copper

The mean concentration of copper in the Menomonee River during the period of record was 11.0 μg/l. Moderate variability was associated with this mean. Figure 87 shows that prior to 1998, the mean concentrations of copper increased over time at all stations. During the period 1998-2001, the mean concentration of copper declined at all sampling stations along the River. Nearly all stations showed that monthly mean copper concentrations are generally near or below the historic monthly means. Table 54 also shows that mean concentrations of copper were significantly higher at stations in the estuary than at stations in the section of the River upstream from the estuary during all periods that were examined. These increases over time may be caused by development in the watershed and increased amounts of vehicle traffic. Wear and tear of brake pads and other metal components of vehicles is a major source of copper to the environment. Once deposited on impervious surfaces, stormwater may carry this metal into the River. While copper compounds are also used in lake management for algae control, the Menomonee River watershed contains few lakes and ponds. This makes it unlikely that algicides constitute a

Figure 87

COPPER CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001



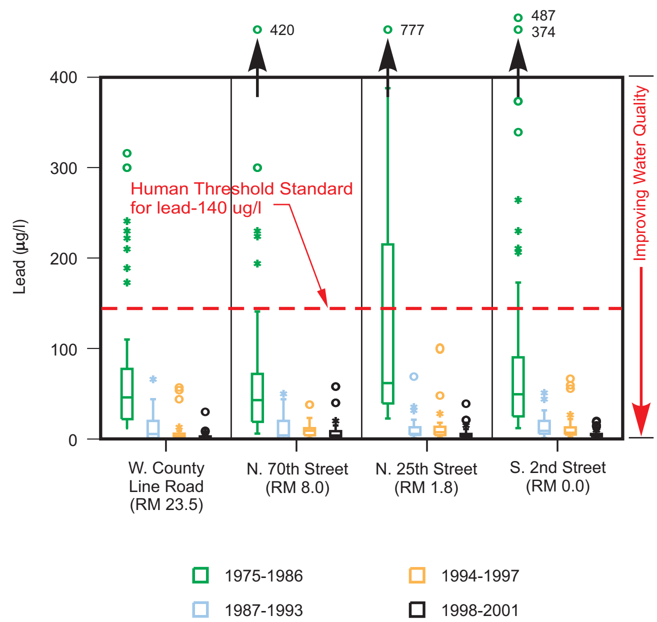
NOTES: See Figure 66 for description of symbols.

Copper acute and chronic toxicity standards depend upon ambient hardness, which indicate that copper concentrations exceeded these standards in less than 15 percent and more than 20 percent of samples in the estuary and upstream of the estuary, respectively.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 88

LEAD CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001



NOTES: See Figure 66 for description of symbols.

The human threshold criteria for public health and welfare for lead is 140 µg/l.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

major source of copper to the Menomonee River. There is no evidence of seasonal variation in copper concentrations in the Menomonee River.

During 2004 and 2005, MMSD examined water samples from Honey Creek, Underwood Creek, and South Branch Underwood Creek for concentrations of copper. The mean concentration of copper detected in Honey Creek was 4.8 μg/l. Concentrations in individual samples ranged between 1.5 μg/l and 8.0 μg/l. The mean concentration of copper detected in Underwood Creek was 3.5 μg/l. Concentrations in individual samples ranged from below the limit of detection to 12.0 μg/l. The mean concentration of copper detected in South Branch Underwood Creek was 3.6 μg/l. Concentrations in individual samples ranged from below the limit of detection to 8.2 μg/l.

Lead

The mean concentration of lead in the Menomonee River over the period of record was 33.6 μg/l. This mean is not representative of current conditions because lead concentrations in the water of the River have been declining since the late 1980s, as shown in Figure 88. At all sampling stations, the baseline ranges of lead concentrations are below the historic mean concentrations. Baseline monthly mean lead concentrations are quite low when compared to the historic means and ranges. This pattern is seen at all of the sampling stations. A major factor causing the decline in lead concentrations has been the phasing out of lead as a gasoline additive. From 1983-1986, the amount of lead in gasoline in the United States was reduced from 1.26 g/gal to 0.1 g/gal. In addition lead was completely banned for use in fuel for on-road vehicles in 1995. The major drop in lead in water in the Menomonee River followed this reduction in use. In freshwater, lead has a strong tendency to adsorb to particulates suspended in the water.[7] As these particles are deposited, they carry the adsorbed lead into residence in the sediment. Because of this, the lower concentrations of lead in the water probably reflect the actions of three processes: reduction of lead entering the environment, washing out of lead in the water into the estuary and Lake Michigan, and deposition of adsorbed lead in the sediment. Lead concentrations in the Menomonee River show no evidence of patterns of seasonal variation. The reductions in lead concentrations in the Menomonee River represent an improvement in water quality.

During 2004 and 2005, MMSD examined water samples from Honey Creek, Underwood Creek, and South Branch Underwood Creek for concentrations of lead. While concentrations of lead in the majority of the samples collected from these streams were below the limit of detection, measurable concentrations were occasionally detected. Concentrations of lead in Honey Creek ranged from below the limit of detection to 7.7 μg/l. Concentrations of lead in Underwood Creek ranged from below the limit of detection to 6.7 μg/l. Concentrations of lead in South Branch Underwood Creek ranged from below the limit of detection to 7.1 μg/l.

Mercury
Few historic data on the concentration of mercury in the water of the Menomonee River exist. Though a few samples were taken during the mid-1970s, most sampling for mercury in water in the River was taken during or after 1995. The mean concentration of mercury in the River over the period of record was 0.093 μg/l. Mercury concentrations showed moderate variability, with a range from 0.02 to 0.78 μg/l. For the period 1997-2001, the mean concentration of mercury in the River was 0.073 μg/l. The means at individual stations during this period ranged from 0.025 μg/l at S. 2nd Street to 0.12 μg/l at 124th Street. Table 54 shows that the mean mercury concentrations at stations in the estuary were significantly lower than the mean mercury concentration in the section of the River upstream from the estuary during the periods 1994-1997 and 1998-2001. As indicated in Table 55, no significant trend in mercury concentration from upstream to downstream was detected in the section of the River upstream from the estuary. When examined on an annual basis, all stations in the estuary show significant trends toward decreasing mercury concentration over time (Table C-2 in Appendix C). There is no evidence of seasonal variation of mercury concentrations in the Menomonee River. The reductions in mercury concentrations in the estuary portion of the Menomonee River represent an improvement in water quality.

During 2004 and 2005, MMSD examined water samples from Honey Creek, Underwood Creek, and South Branch Underwood Creek for concentrations of mercury. While concentrations of mercury in the majority of the samples collected from these streams were below the limit of detection, measurable concentrations were occasionally detected. Concentrations of mercury in Honey Creek ranged from below the limit of detection to 0.56 μg/l. Concentrations of mercury in Underwood Creek ranged from below the limit of detection to 0.35 μg/l. Concentrations of mercury in South Branch Underwood Creek ranged from below the limit of detection to 0.23 μg/l.

Nickel
The mean concentration of nickel in the Menomonee River over the period of record was 11.2 μg/l. While some sites had outliers, variability was generally low. No differences were detected between the mean concentrations of nickel in the estuary and in the section of the River upstream from the estuary in any period for which data existed (Table 54). When examined on an annual basis, significant declines were observed at most stations. There was no evidence of seasonal variation in nickel concentration in the Menomonee River (see Table C-2 in Appendix C). The reductions in nickel concentrations in the Menomonee River represent an improvement in water quality.

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[7] *H.L. Windom, T. Byrd, R.G. Smith, and F. Huan, "Inadequacy of NASQUAN Data for Assessing Metal Trends in the Nation's Rivers,"* Environmental Science and Technology *Volume 25, 1991, pp. 1137-1142.*

During 2004 and 2005, MMSD examined water samples from Honey Creek, Underwood Creek, and South Branch Underwood Creek for concentrations of nickel. The mean concentration of nickel detected in Honey Creek was 1.9μg/l. Concentrations in individual samples ranged between 1.2 μg/l and 2.6 μg/l. The mean concentration of nickel detected in Underwood Creek was 2.3 μg/l. Concentrations in individual samples ranged between 1.1 μg/l and 4.3 μg/l. The mean concentration of nickel detected in South Branch Underwood Creek was 1.6 μg/l. Concentrations in individual samples ranged from below the limit of detection to 2.6 μg/l.

Zinc

The mean concentration of zinc in the Menomonee River during the period of record was 24.4 μg/l. Zinc concentrations showed moderate variability. Concentrations in individual samples ranged from 3.3 to 350 μg/l. Variability tended to be greater in River stations upstream from the estuary than at stations within the estuary as shown in Figure 89. At all of these stations, concentrations of zinc during the baseline period often exceed the historic maxima as shown in Figure 90. This seems to be especially the case during the late spring and early to mid summer. While there is considerable variation in the relation of baseline monthly mean zinc concentration to the historic monthly means, it appears that baseline period mean concentrations during the late spring and early summer generally exceed the historic means. This may reflect high amounts of zinc washing into the River during snowmelt and spring rains. These increases in zinc may be caused by increased development in the watershed and increased amount of vehicle traffic. Zinc can be released to stormwater by corrosion of galvanized gutters and roofing materials. In addition, wear and tear on automobile brake pads and tires are major sources of zinc to the environment. Stormwater can carry zinc from these sources into the River. There is no evidence of seasonal variation in the concentration of zinc in the Menomonee River. The increases in zinc concentrations in the Menomonee River during spring and summer represent a decline in water quality.

During 2004 and 2005, MMSD examined water samples from Honey Creek, Underwood Creek, and South Branch Underwood Creek for concentrations of zinc. The mean concentration of zinc detected in Honey Creek was 26.9 μg/l. Concentrations in individual samples ranged between 5.5 μg/l and 48.0 μg/l. There was a statistically significant trend toward zinc concentrations in Honey Creek increasing from upstream to downstream. This trend was the result of an abrupt increase in mean zinc concentrations at sampling stations downstream from the enclosed section of the Creek. The mean concentration of zinc at sampling stations upstream from the conduit during this period was 18.0 μg/l. The mean concentration at sampling stations downstream from the conduit was 40.3 μg/l. The mean concentration of zinc detected in Underwood Creek was 11.6 μg/l. Concentrations in individual samples ranged from below the limit of detection to 27.0 μg/l. There were no statistically significant trends in zinc concentrations along the length of this stream. The mean concentration of zinc detected in South Branch Underwood Creek was 19.3 μg/l. Concentrations in individual samples ranged between 7.3 μg/l and 40.0 μg/l. There were not enough sampling stations along this stream to assess trends.

Organic Compounds

Between February and June 2004, samples were collected on three dates from two stations on the Menomonee River, located at N. 70th Street and at Pilgrim Road, and examined for the presence and concentrations of three organic compounds dissolved in water. In addition, Honey Creek, the Little Menomonee River, Underwood Creek, and Willow Creek were sampled on the same dates for the same constituents. Concentrations of dissolved bromoform were below the limit of detection in all samples from all of the stations. The compound 1,4-dichlorobenzene was detected at a concentration of 0.2 μg/l in one sample from the 70th Street station on the Menomonee River and from one sample from each of Honey and Underwood Creeks. As shown in Table 18 in Chapter IV of this report, this concentration is below Wisconsin's human cancer criterion for public health and welfare for fish and aquatic life waters. Dissolved isophorone was detected in one sample from each of the stations, except for Willow Creek at a concentration of 0.1 μg/l. As shown in Table 18, this concentration is below Wisconsin's human threshold criterion for public heath and welfare for fish and aquatic life waters.

Pharmaceuticals and Personal Care Products

In February, March, and May 2004, the USGS sampled water from six locations in the Menomonee River watershed for the presence of triclosan, an antibacterial agent commonly found in such personal care products as toothpaste, mouthwash, hand soaps, deodorants, and cosmetics. Samples were taken from two locations on the mainstem of the River, at N. 70th Street and at Pilgrim Road. In addition, Honey Creek, Underwood Creek, Willow Creek, and the Little Menomonee River were sampled. The concentration of triclosan was below the limit of detection in all of the samples. No other data were available regarding the presence or concentrations of pharmaceuticals and personal care products in the Menomonee River or any of its tributaries.

TOXICITY CONDITIONS OF THE MENOMONEE RIVER AND ITS TRIBUTARIES

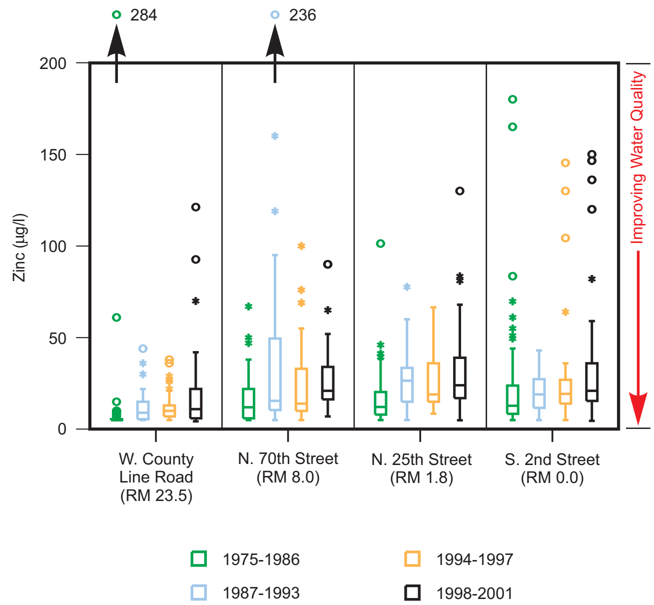
Toxic Substances in Water

Pesticides

Since the 1970s, the Menomonee River watershed has been sampled for the presence of pesticides in water on several occasions. There have been three sampling periods: the mid-1970s, the early-1990s, and 2004. It is important to note that the results from the samples taken in 2004 are not directly comparable to those from the early periods. The data from the 1970s and 1990s were derived from unfiltered samples which included both pesticides dissolved in water and pesticides contained in and adsorbed to particulates suspended in the water. The data from 2004 were derived from filtered samples and measure only the fraction of pesticides dissolved in water. Since most pesticides are poorly soluble in water, the data from 2004 may give an underestimate of ambient pesticide concentrations relative to the earlier data. Sampling during the 1970s focused heavily on the insecticide DDT and its metabolites. In general, the concentrations of these substances were below the limits of detection. Several pesticides were detected in the sampling conducted during the 1990s including the insecticides DDT, chlordane, endosulfan, lindane, and toxaphene and the herbicides 2,4-D and atrazine. DDT metabolites were also detected. During the 2004 sampling, the insecticides carbaryl and diazinon were occasionally detected as were the herbicide atrazine and its metabolite deethylatrazine. Where detectable concentrations of diazinon and atrazine were reported, they were below the U.S. Environmental Protection Agency's (USEPA) draft aquatic life criteria. Detectable concentrations of some herbicides were present, mostly in May and June, corresponding to the periods during which these pesticides were normally applied.

Figure 89

ZINC CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001



NOTES: See Figure 66 for description of symbols.

Acute and chronic toxicity standards for zinc depend upon ambient hardness which indicates that zinc concentrations did not exceed these toxicity standards.

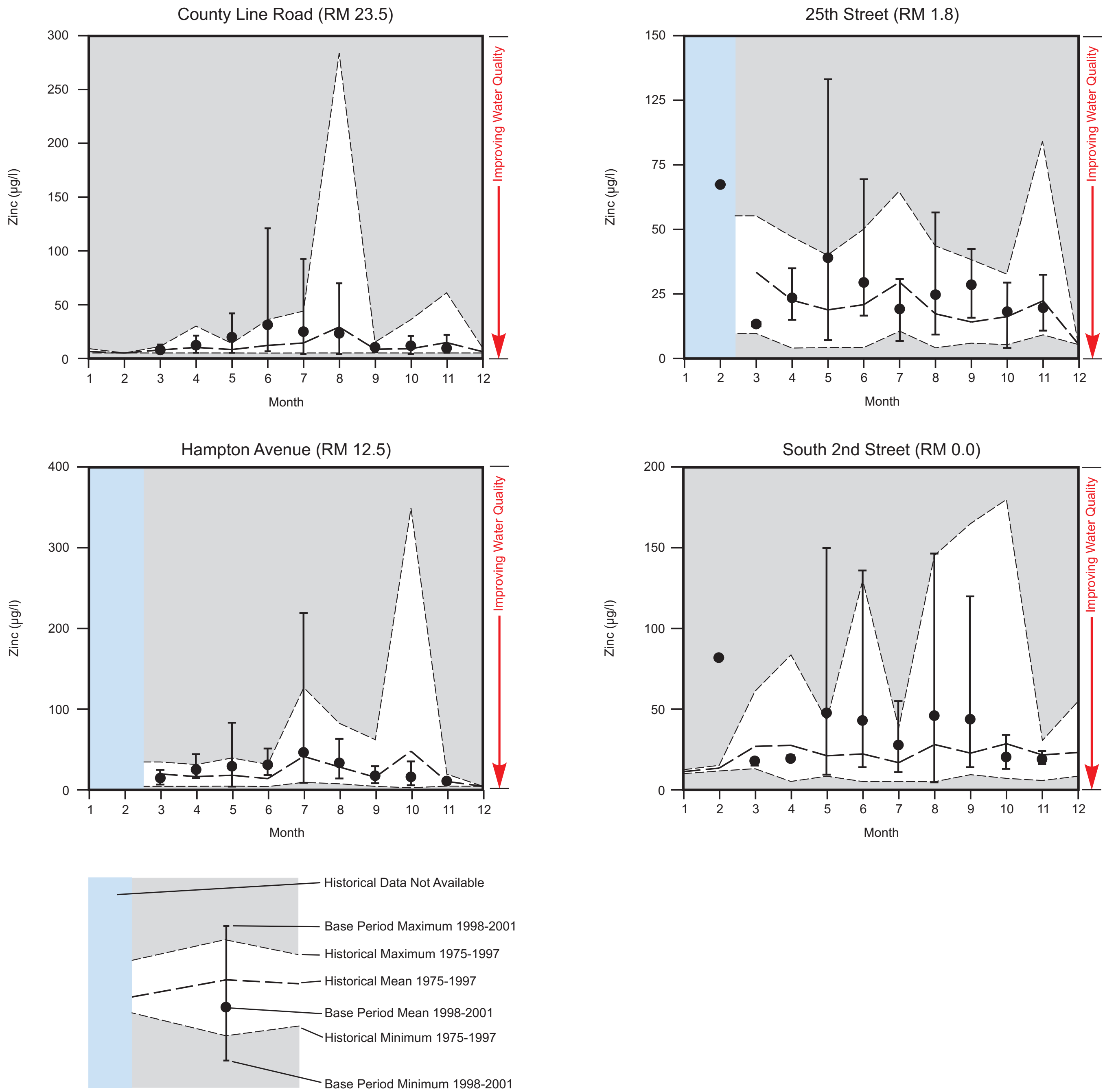
Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Polycyclic Aromatic Hydrocarbons (PAHs)

The Menomonee River watershed has been sampled on several occasions between 1990 and 2004 for the presence of PAHs in water. Extensive sampling for 16 PAH compounds was conducted at the long-term stations along the mainstem between 1995 and 2001. Mean PAH concentration in the water samples from the estuary for the period 1995 to 1997 was 0.57 μg/l. This increased to 1.01 μg/l during the period 1998 to 2001. By contrast, the mean concentration of PAHs in water samples from the reaches upstream from the estuary declined from 1.76 μg/l during the period 1995-1997 to 0.72 μg/l during the period 1998-2001. It is important to note that there was considerable variation in the concentrations detected among different sites within these sections of the River and among samples taken at individual sites on different dates. In 2004, two sites along the mainstem of the River and

Figure 90

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF ZINC ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001



NOTE: Acute and chronic toxicity standards for zinc depend upon ambient hardness, but zinc concentrations were not shown to exceed these toxicity standards.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

sites along four tributaries were sampled on three dates for six PAH compounds dissolved in water. Mean concentrations for any site range from 0.1 to 0.7 μg/l.

Polychlorinated Biphenyls (PCBs)
Between 1995 and 2001 several sites along the mainstem of the Menomonee River were sampled for the presence and concentrations of 14 PCB congeners in water. Since concentrations of only 14 out of 209 congeners from this family of compounds were analyzed, the results from the mainstem should be considered minimum values. While in the majority of samples, the concentrations of these PCB congeners were below the limit of detection, when PCBs were detected they exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 nanogram per liter (ng/l). Detections of PCBs generally increased from upstream to downstream along the mainstem of the River.

Toxic Contaminants in Aquatic Organisms
The WDNR periodically surveys tissue from fish and other aquatic organisms for the presence of toxic and hazardous contaminants. Several surveys were conducted at sites within the Menomonee River watershed between 1979 and 1999. These surveys screened for the presence and concentrations of several contaminants including metals, PCBs, and organochloride pesticides. Because of potential risks posed to humans by consumption of fish containing high levels of contaminants, the WDNR has issued fish consumption advisories for several species of fish taken from the Menomonee River. The statewide fish consumption advisory for mercury applies to fish in the Menomonee River watershed. In addition, a special consumption advisory has been issued for several species due to tissue concentrations of PCBs (see Table 56).

It is important to note that some samples collected from the Menomonee River consisted of whole organism homogenates while other consisted of fillets of skin and muscle tissue. These types of samples are not directly comparable. Consumption advisories are based on fillet samples. In both types of samples, a single sample may represent tissue from several fish of the same species.

Mercury
Between 1979 and 1999 the WDNR sampled tissue from fish collected from the mainstem of the Menomonee River for mercury contamination. As shown in Figure 91, the concentrations detected in whole fish samples ranged from 0.03 micrograms per gram tissue (μg per g tissue) to 0.10 μg per g tissue. It is important to recognize that the number of individual organisms and the range of species taken from this watershed that have been screened for the presence of mercury contamination are quite small. Because of this, these data may not be completely representative of current body burdens of mercury carried by aquatic organisms in the River and its tributaries.

PCBs
Between 1985 and 1990 the WDNR examined fillet samples from several species of fish collected from the Menomonee River watershed for PCB contamination. As shown in Figure 92, the concentrations of PCBs ranged from 0.2 μg per g tissue to 7.6 μg per g tissue. Between 1979 and 1999 the WDNR examined whole fish samples from several species of fish collected from the Menomonee River watershed for PCB contamination. As shown in Figure 92, tissue concentrations of PCBs ranged between 0.1 μg per g tissue and 88.0 μg per g tissue. Tissue concentrations in whole fish samples collected since 1986 have been below 1.0 μg per g tissue; however, only a small number of samples were collected. Special fish consumption advisories for PCBs have been issued by the WDNR for fish from portions of the Menomonee River watershed (see Table 56).

The number of individual organisms and the range of species taken from this watershed that have been screened for the presence of PCB contamination are quite small. Because of this, these data may not be completely representative of current body burdens of PCBs carried by aquatic organisms in the River and its tributaries.

Pesticides
Between 1979 and 1999 the WDNR examined whole fish samples from several species of aquatic organisms collected from the Menomonee River watershed for contamination by historically used, bioaccumulative

Table 56

FISH CONSUMPTION ADVISORIES FOR THE MENOMONEE RIVER WATERSHED[a]

Species	Consumption Advisory Level			
	One Meal per Week	One Meal per Month	One Meal per Two Months	Do Not Eat
Black Crappie	- -	- -	All sizes	- -
Carp	- -	- -	- -	All sizes
Northern Pike	- -	- -	All sizes	- -
Redhorse	- -	- -	All sizes	- -
Rock Bass	- -	All sizes	- -	- -
Smallmouth Bass	- -	- -	All sizes	- -
Walleye	- -	Less than 18 inches	Larger than 18 inches	- -
White Sucker	- -	- -	All sizes	- -
Yellow Perch	All sizes	- -	- -	- -

[a]*The statewide general fish consumption advisory applies to other fish species not listed in this table.*

Source: Wisconsin Department of Natural Resources.

pesticides and their breakdown products. Many of these compounds are no longer in use. For example, crop uses of most of these compounds were banned in the United States between 1972 and 1983. While limited uses were allowed after this for some of these substances, by 1988 the uses of most had been phased out. During the 1990s, measurable concentrations of o,p'-DDT and p,p'-DDT were not detected in tissue of fish collected from the Menomonee River watershed, though these compounds had been detected in tissue samples collected from bluegill, carp and white sucker during the 1970s and 1980s. During the all three decades, measurable concentrations of the DDT breakdown products of o,p'-DDD, p,p'-DDD, o,p'-DDE, and p,p'-DDE were detected in the tissue of fish from several species including bluegill, carp, goldfish, and white sucker.

During the same period, tissue from fish collected in the Menomonee River watershed was analyzed for the presence of several other pesticides. Measurable concentrations of the chlordane isomers α-chlordane, γ-chlordane, and trans-nonachlor were detected in the tissue of several carp and goldfish. Measurable concentrations of aldrin and dieldrin were occasionally detected in tissue from carp and goldfish. Measurable concentrations of α-BHC, γ-BHC, endrin, hexachlorobenzene, methoxychlor, toxaphene, and the chlordane isomer cis-nonachlor were not detected in the tissue of aquatic organisms collected from the Menomonee River watershed during the period 1979-1999.

The number of individual organisms and the range of species taken from this watershed that have been screened for the presence of pesticide contamination are quite small. Because of this, these data may not be completely representative of pesticide body burdens of pesticides carried by aquatic organisms in the River and its tributaries.

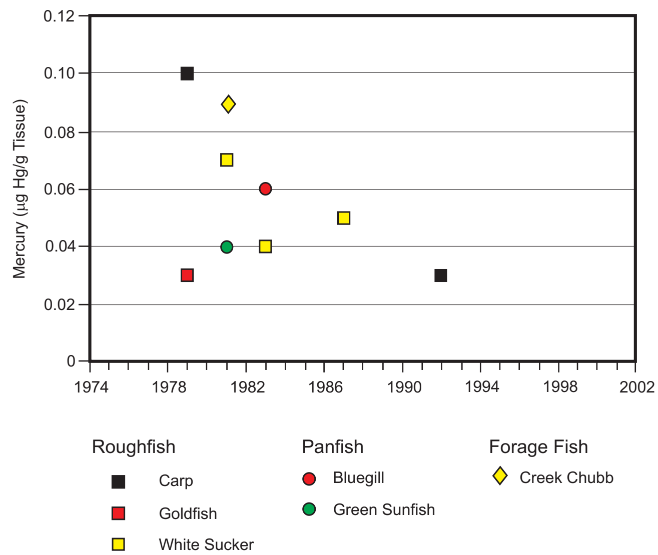
Toxic Contaminants in Sediment

Most of the data on contaminants in sediments of the Menomonee River watershed are from the Little Menomonee River and are related to the Moss-American USEPA Superfund site. This site on Granville Road, west of the River, was formerly the location of a wood preserving facility. This site has been undergoing remediation. From 2003 to 2005, sections of channel between Brown Deer Road and Leon Terrace were relocated. The following data characterize this portion of the site prior to remediation. From 1921 to 1976, the facility treated railroad ties with creosote for preservation. Until 1971, wastes from this operation were discharged into settling ponds which ultimately drained to the Little Menomonee River. Remediation efforts at the Moss-American site and along the Little Menomonee River are ongoing. During 1995 and 1996, about 3,100 gallons of creosote were removed from ground water associated with the site through extraction wells. During 2001 and 2002, about 137,000 tons of soil from the site were treated to remove contaminants. Current plans call for five sections totaling six miles of the

Little Menomonee River to be treated by rerouting the channel, removing and treating the contaminated sediment, filling the old channel, and revegetating the new channel. These remedial efforts represent implementation of recommendations first made in the Commission's comprehensive plan for the Menomonee River watershed.[8] Work on the first segment from W. Brown Deer Road (STH 100) to W. Bradley Road was completed in 2003. Work on the second and third segments from W. Bradley Road to near W. Leon Terrace were completed in spring of 2005. While remediation of the fourth and fifth segments was originally planned to begin in late 2005, it is not certain whether it will proceed. While recent data on toxic metals are not available, sediment samples taken from the Little Menomonee River in 1992 show detectable concentrations of arsenic, cadmium, lead, and zinc (see Table 57). The mean concentration of zinc in these samples exceeds the Probable Effect Concentration (PEC) above which toxicity to benthic organisms is considered highly probable (see Table 13 in Chapter III of this report). Mean concentrations of lead and cadmium in these samples were between the Threshold Effect Concentrations and the PECs, indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms. In addition to metals, sediment samples from several sites in the River show considerable contamination with PAHs. As indicated in Table 58, concentrations of PAHs in the sediment range from below the limit of detection to 11,424,000 μg PAH/kg sediment. PAH concentration is highest in sediments taken from 31-60 cm below the sediment surface. This is shown both in the mean values given in Table 58 and in the depth-related concentrations in individual cores shown in Figure 93. It is important to note that the channel at the Appleton Avenue site has not yet been rerouted. This suggests that these contaminants may be migrating downward in the sediment or may be getting covered by additional sediment deposits. Because total organic carbon data were not available for many of the sediment samples, interpretation of the PAH data is difficult. The amount of organic carbon in sediment can exert considerable influence on the toxicity of certain contaminants to benthic organisms. While the biological responses of benthic organisms to nonionic organic compounds has been found to differ across sediments when the concentrations are expressed on a dry weight basis, they have been found to be similar when the concentrations have been normalized to a standard percentage of organic carbon.[9] For those samples that had associated total organic carbon data, the concentrations of contaminants present in the sediments from near the surface in the Little Menomonee River are high enough to pose substantial risk of toxicity to benthic organisms. Figure 94 shows that overall mean PEC-Q values, a measure that integrates the effects of multiple toxicants on benthic organisms, from sediments are high. These high PEC-Q levels suggest that benthic organisms in the Little Menomonee River are experiencing substantial incidences of toxic effects, as indicated in Figure 95. For much of the length of the River, the predicted incidence of toxicity, based on the available sediment data, to benthic organisms is 100 percent.

Figure 91

TISSUE CONCENTRATIONS OF MERCURY IN WHOLE FISH SAMPLES COLLECTED FROM THE MENOMONEE RIVER WATERSHED: 1975-2001



Source: Wisconsin Department of Natural Resources.

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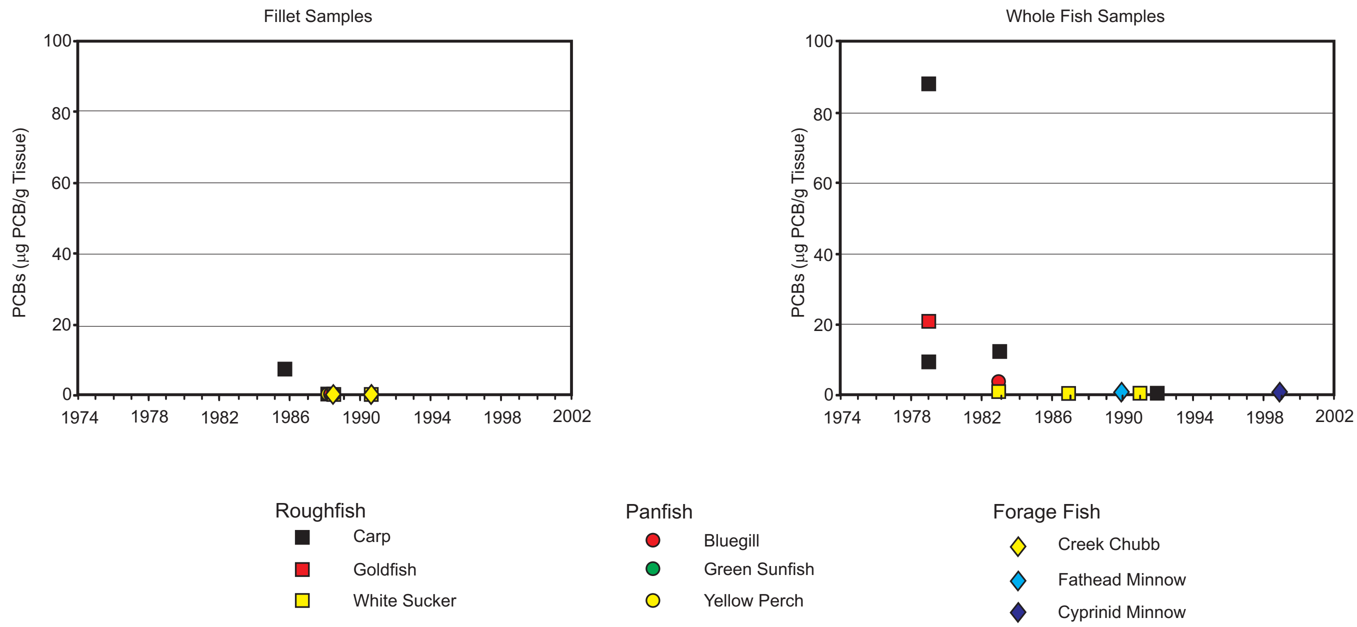
[8]*SEWRPC Planning Report No. 26,* A Comprehensive Plan for the Menomonee River Watershed, *Volume Two*, Alternative Plans and Recommended Plan, *October 1976.*

[9]*U.S. Environmental Protection Agency,* Technical Basis for the Derivation of Equilibrium Partitioning Sediment Guidelines (ESGs) for the Protection of Benthic Organisms: Nonionic Organics*, USEPA Office of Science and Technology, Washington, DC, 2000.*

Figure 92

TISSUE CONCENTRATIONS OF PCBS IN FISH SAMPLES COLLECTED FROM THE MENOMONEE RIVER WATERSHED: 1975-2001



Source: Wisconsin Department of Natural Resources.

BIOLOGICAL CONDITIONS OF THE MENOMONEE RIVER AND ITS TRIBUTARIES

Aquatic and terrestrial wildlife communities have educational and aesthetic values, perform important functions in the ecological system, and are the basis for certain recreational activities. The location, extent, and quality of fishery and wildlife areas and the type of fish and wildlife characteristic of those areas are, therefore, important determinants of the overall quality of the environment in the Menomonee River watershed.

Fisheries

Review of the fishery data collected in the Menomonee River basin over more than 100 years of sampling by the WDNR (known as the Wisconsin Conservation Department until the early 1970s) between 1900 and 2004 indicates an apparent gain of six species throughout the watershed during this time period. This increase does not seem to be due to increased sampling effort among each of the year break outs, at least not on an annual basis for the most recent years as shown in Table 59, but this may reflect recent increased sampling efforts in the lower portions of the Menomonee River watershed (as shown on Map 34), as well as improvements in fishing gear technologies and techniques. Nonetheless, most notable gains of species were the brook trout, brown trout, smallmouth bass, black crappie, walleye, and greater redhorse.

The aforementioned species were all observed in the lower portions of the Menomonee River and seem to be associated with the removals of 1) the Falk dam, 2) the drop structure at N. 45th Street, and 3) the North Avenue dam on the Milwaukee River. The Falk dam removal was completed in February 2001. Although this was a low head dam that was easily overtopped during high-flow events, it was a significant barrier during low flow periods for many species of fishes. The N. 45th Street drop structure, which was also a significant fisheries migratory barrier, was removed and about 1,000 feet of concrete channel was removed and replaced with a rock channel in the early 2000s. Removal of the North Avenue dam and major habitat improvements were completed in the late 1990s on the Milwaukee River. The smallmouth bass, which is an intolerant fish species, have dramatically increased in abundance within the Milwaukee River and Harbor area, and increases in smallmouth bass in the Menomonee River have also been observed during the approximate same time period. The adult brook trout and

Table 57

CONCENTRATIONS OF TOXIC METALS IN SEDIMENT SAMPLES FROM THE LITTLE MENOMONEE RIVER: 1992[a]

Statistic	Metals			
	Arsenic	Cadmium	Lead	Zinc
Mean	4.87	2.00	51.33	491.67
Standard Deviation	1.53	2.45	27.59	788.93
Minimum	2.91	1.00	20.00	100.00
Maximum	5.77	7.00	95.00	2,100.00
Samples	6	6	6	6

[a]*All concentrations in mg/kg based on dry weight.*

Source: Wisconsin Department of Natural Resources.

Table 58

CONCENTRATIONS OF POLYCYCLIC AROMATIC HYDROCARBONS IN SEDIMENT SAMPLES FROM THE LITTLE MENOMONEE RIVER 1992-2000[a]

Parameter	Surface Sediment (0-30 cm)	Intermediate Sediment (31-60 cm)	Deep Sediment (60-152 cm)	All Sediment (0-152 cm)
Mean	677,279	1,573,060	53,523	762,775
Standard Deviation	1,844,068	2,456,244	130,522	1,888,218
Minimum	4,460	53	0	0
Maximum	11,424,000	7,228,000	319,950	11,424,000
Samples	45	10	6	61

[a]*All concentrations expressed as μg/kg on a dry weight basis.*

Source: Wisconsin Department of Natural Resources.

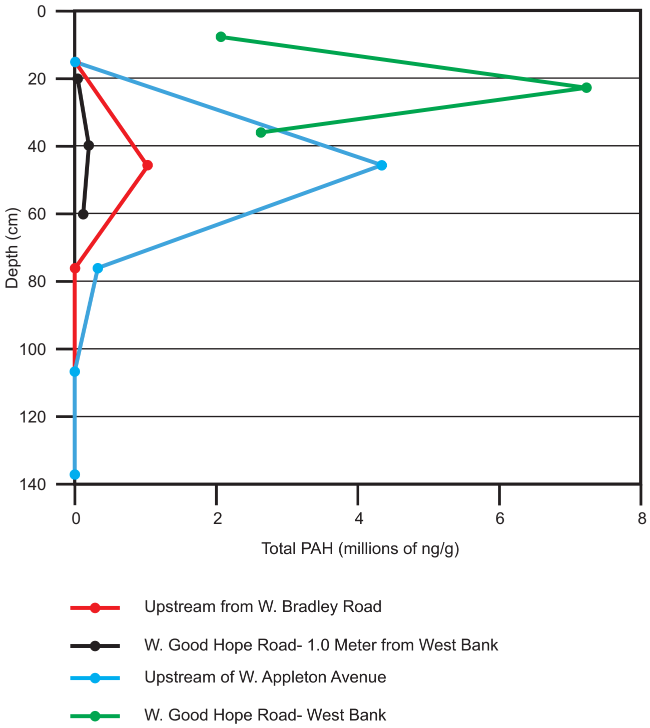
brown trout observations do not likely indicate a developing cold water fishery in the Menomonee, but are probably incidental owing to proximity to the Milwaukee Harbor. The walleye abundances are probably indicative of the WDNR stocking efforts conducted pursuant to walleye population restoration efforts in the Lower Milwaukee River and Harbor since 1995.[10] Radiotelemetry technology was used to track the movements of stocked walleye and it was found that there was a distinct seasonal movement pattern by the adult walleye according to water temperature and food availability. During the summer they moved from the rivers to cooler and deeper harbor waters. In winter they moved to the warmer waters of the Menomonee River canals which receive warmwater discharges from a nearby power plant. This was also associated with a significant increase in angling effort targeted towards walleye in recent years along the Menomonee River canals, Summerfest Lagoon, and the Milwaukee River upstream of the former North Avenue dam to Kletzsch Park.

Despite this increase in overall species numbers there has been a decrease in the percent of native fishes in the Menomonee River watershed over time, as shown in Figure 96. Most notable were losses of several intolerant species including the blacknose shiner and spottail shiner, the least darter and redside dace which are species of

[10]*Wisconsin Department of Natural Resources,* An Evaluation of Walleye Population Restoration Efforts in the Lower Milwaukee River and Harbor, Wisconsin*, 1995-2003, PUB-FH-510-2004, January 2004.*

Figure 93

CONCENTRATIONS OF POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) IN SEDIMENTS FROM THE LITTLE MENOMONEE RIVER: 1998-2000



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

special concern in the State of Wisconsin, and the greater redhorse which is a threatened species in the State of Wisconsin (Table 59). Additional species that have not been observed since 1975 include the southern redbelly dace, northern redbelly dace, and grass pickerel.

In Wisconsin, high-quality warmwater streams are characterized by many native species, darters, suckers, sunfish, and intolerant species (species that are particularly sensitive to water pollution and habitat degradation). Within such environments, tolerant fish species also occur that are capable of persisting under a wide range of degraded conditions and are also typically present within high-quality warmwater streams, but they do not dominate. Insectivores (fish that feed primarily on small aquatic insects) and top carnivores (fish that feed on other fish, vertebrates, or large aquatic insects) are generally common. Omnivores (fish that feed on both plant and animal material) are also generally common, but do not dominate. Simple lithophilous spawners which are species that lay their eggs directly on large substrate, such as clean gravel or cobble, without building a nest or providing parental care for the eggs are also generally common. In addition, deformities, eroded fins, lesions, or tumors on fish species in high-quality streams are generally few to none.

The Menomonee River watershed fishery has been and continues to be largely dominated by a high proportion of low dissolved oxygen tolerant fishes, which is indicative of a poor fishery (Figure 96). The proportions of such tolerant fish species have all increased as shown in Table 59. Most notable is the exotic invasive common carp species, which has increased from 2 percent to nearly 40 percent of the catch from 1975 to present. Carp are likely to be having a negative effect on the overall fishery in this watershed by destroying habitat and competing for food and spawning areas of native fish species.

Index of Biotic Integrity (IBI) results indicate that there has not been any significant change in the quality of the fishery of the Menomonee River watershed compared to the historical conditions (Figure 97 and Map 34). Although some of the samples over time achieved a fair community IBI rating score of 30 to 49, the samples at the majority of the sites over all years have generally remained in the poor (IBI score 20-29) to very poor (IBI score 0-19) classification. Although the data are limited, Figure 98 indicates that there may potentially be a limited improvement in the fishery within the Lilly Creek, Little Menomonee, Lower Menomonee, Underwood Creek, Upper Menomonee, and West Branch of the Menomonee River subwatersheds. However, additional data would have to be collected in order to verify these changes. Figure 98 also shows that the Upper and Lower Menomonee River subwatersheds contain some of the highest scores compared to the rest of the subwatersheds.

Urbanization can experience numerous changes that have the potential to alter aquatic biodiversity that include but are not limited to the following factors which have been observed to varying degrees in the Menomonee River watershed:[11]

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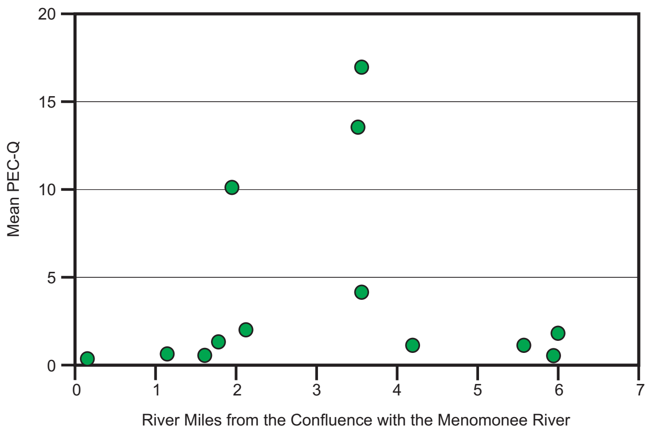
[11]*Center for Watershed Protection,* Impacts of Impervious Cover on Aquatic Systems*, Watershed Protection Research Monograph No. 1, March 2003.*

Figure 94

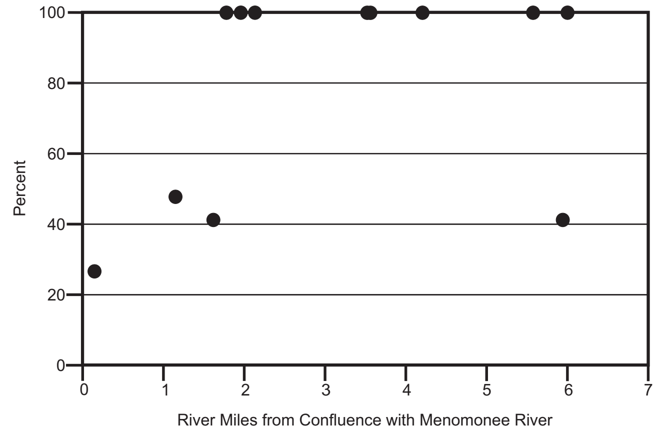
MEAN PROBABLE EFFECT CONCENTRATION QUOTIENTS (PEC-Q) FOR SEDIMENT IN THE LITTLE MENOMONEE RIVER: 1975-2001



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 95

ESTIMATED INCIDENCE OF TOXICITY TO BENTHIC ORGANISMS IN THE LITTLE MENOMONEE RIVER: 1964-2001



Source: Wisconsin Department of Natural Resources and SEWRPC.

- Increased flow volumes and channel-forming storms—These alter habitat complexity, change availability of food organisms related to timing of emergence and recovery after disturbance, reduce prey availability, increase scour-related mortality, deplete large woody debris for cover in the channel, and accelerate streambank erosion;

- Decreased base flows—These lead to increased crowding and competition for food and space, increased vulnerability to predation, and increased sediment deposition;

- Increased sediment transport—This leads to reduced survival of eggs, loss of habitat due to deposition, siltation of pool areas, and reduced macroinvertebrate reproduction;

- Loss of pools and riffles—This leads to a loss of deep water cover and feeding areas causing a shift in balance of species due to habitat changes;

- Changed substrate composition—This leads to reduced survival of eggs, loss of inter-gravel cover refuges for early life stages for fishes, and reduced macroinvertebrate production;

- Loss of large woody debris—This leads to loss of cover from large predators and high flows, reduced sediment and organic matter storage, reduced pool formation, and reduced organic substrate for macroinvertebrates;

- Increased temperatures due to runoff from pavement versus natural landscapes—This leads to changes in migration patterns, increased metabolic activity, increased disease and parasite susceptibility, and increased mortality of sensitive fishes and macroinvertebrates;

- Creation of fish blockages by road crossings, culverts, and dams—This leads to loss of spawning habitat, inability to reach feeding areas and/or overwintering sites, loss of summer rearing habitat, and increased vulnerability to predation;

- Loss of vegetative rooting systems—This leads to decreased channel stability, loss of undercut banks, and reduced streambank integrity;

Table 59

FISH SPECIES COMPOSITION IN THE MENOMONEE RIVER WATERSHED: 1900-2004

Species According to Their Relative Tolerance to Pollution	Percent Occurrence[a]				
	1900-1974	1975-1986	1987-1993	1994-1997	1998-2004
Intolerant					
Blacknose Shiner	0.0	3.6	0.0	0.0	0.0
Brook Trout	0.0	0.0	0.0	0.0	3.3
Greater Redhorse[b]	0.0	0.0	0.0	4.2	0.0
Hornyhead Chub	0.0	9.1	0.0	4.2	6.7
Least Darter[c]	12.0	0.0	0.0	0.0	0.0
Redside Dace[c]	18.0	0.0	0.0	0.0	0.0
Smallmouth Bass	0.0	0.0	0.0	0.0	3.3
Spottail Shiner	0.0	0.0	0.0	4.2	0.0
Tolerant					
Black Bullhead	8.0	25.5	21.9	16.7	36.7
Blacknose Dace	34.0	56.4	84.4	62.5	60.0
Bluntnose Minnow	0.0	9.1	25.0	4.2	36.7
Central Minnow	34.0	43.6	43.8	45.8	50.0
Common Carp	2.0	9.1	31.3	12.5	36.7
Creek Chub	48.0	61.8	100.0	75.0	93.3
Fathead Minnow	42.0	38.2	50.0	37.5	33.3
Golden Shiner	6.0	7.3	3.1	4.2	10.0
Goldfish	14.0	7.3	21.9	4.2	3.3
Green Sunfish	36.0	41.8	93.8	79.2	90.0
White Sucker	40.0	67.3	96.9	75.0	93.3
Intermediate					
Black Crappie	0.0	0.0	0.0	0.0	10.0
Bluegill	4.0	27.3	40.6	33.3	56.7
Brassy Minnow	4.0	0.0	3.1	0.0	0.0
Brook Stickleback	40.0	20.0	34.4	25.0	23.3
Brown Bullhead	0.0	5.5	0.0	0.0	0.0
Brown Trout	0.0	0.0	0.0	0.0	6.7
Central Stoneroller	0.0	3.6	15.6	4.2	23.3
Common Shiner	12.0	29.1	18.8	4.2	26.7
Fantail Darter	12.0	5.5	0.0	8.3	16.7
Gizzard Shad	0.0	0.0	0.0	4.2	0.0
Golden Redhorse	0.0	0.0	0.0	4.2	0.0
Grass Pickerel	2.0	0.0	0.0	0.0	0.0
Hornyhead Chub	0.0	9.1	0.0	4.2	6.7
Johnny Darter	30.0	20.0	53.1	54.2	63.3
Largemouth Bass	10.0	16.4	6.3	12.5	43.3
Largescale Stoneroller	10.0	0.0	0.0	0.0	3.3
Northern Pike	0.0	1.8	15.6	20.8	26.7
Northern Redbelly Dace	2.0	0.0	0.0	0.0	0.0
Pearl Dace	14.0	1.8	0.0	0.0	3.3
Pumpkinseed	12.0	10.9	56.3	8.3	20.0
River Carpsucker	0.0	3.6	0.0	0.0	0.0
Sand Shiner	0.0	0.0	3.1	0.0	0.0
Shorthead Redhorse	0.0	0.0	0.0	0.0	3.3
Southern Redbelly Dace	12.0	0.0	0.0	0.0	0.0
Spotfin Shiner	0.0	0.0	0.0	0.0	3.3
Walleyed Pike	0.0	0.0	0.0	0.0	3.3
Yellow Perch	0.0	3.6	0.0	4.2	3.3
Total Number of Samples	50	55	32	24	30
Total Number of Samples per Year	<1.0	4.2	4.6	6.0	4.3
Total Number of Species	25	26	21	26	31

[a]*Values represent percent occurrence, which equals the number of sites where each species was found divided by the total number of sites within a given time period.*

[b]*Designated threatened species.*

[c]*Designated species of special concern.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 34

FISHERIES SAMPLE LOCATIONS AND CONDITIONS
WITHIN THE MENOMONEE RIVER WATERSHED: 1900-2004

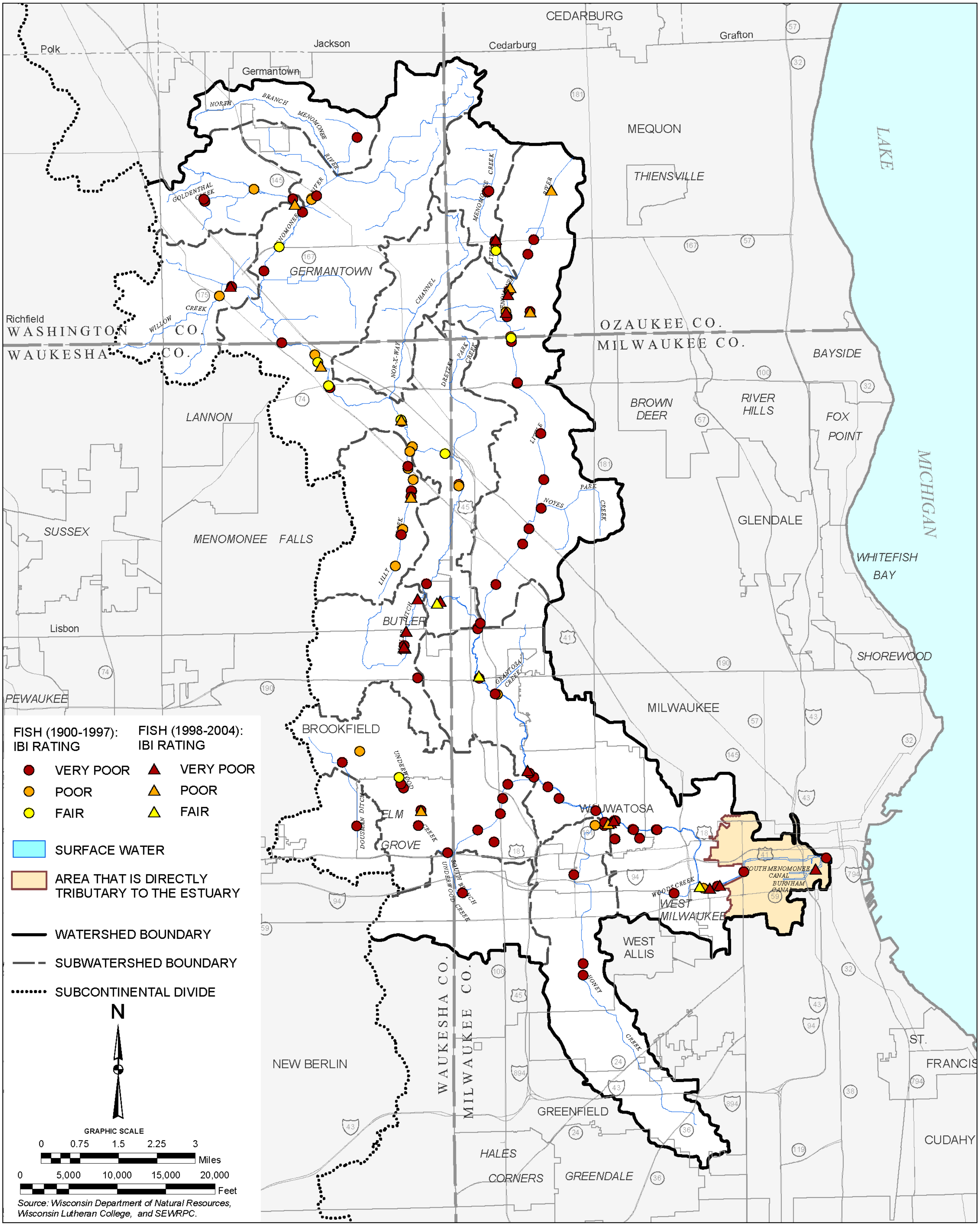
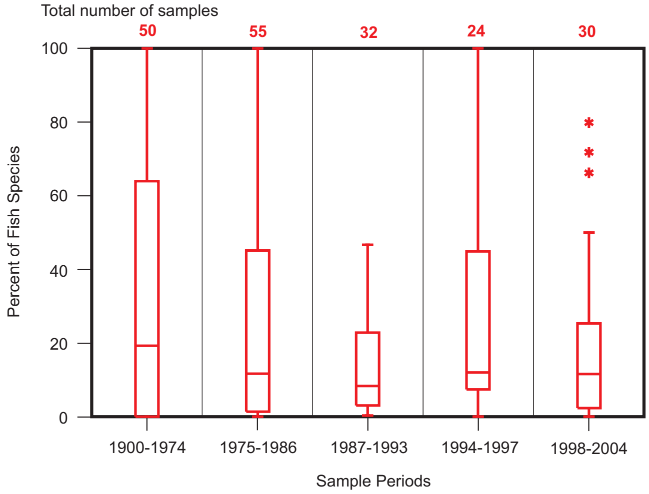


Figure 96

PROPORTIONS OF DISSOLVED OXYGEN TOLERANT FISHES WITHIN THE MENOMONEE RIVER: 1900-2004

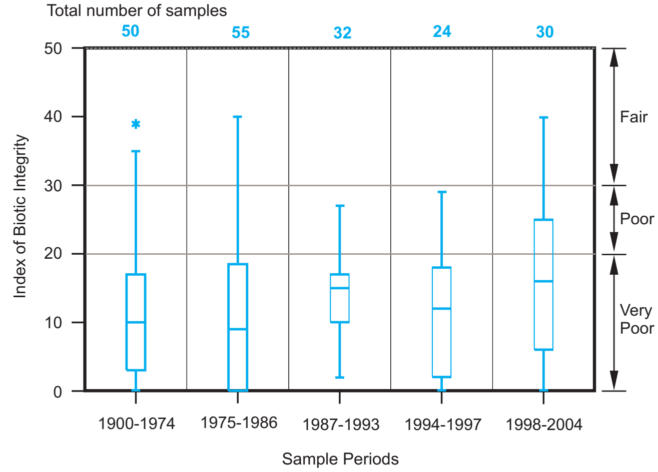


NOTE: See Figure 66 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 97

FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION WITHIN THE MENOMONEE RIVER: 1900-2004



NOTE: See Figure 66 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

- Channel straightening or hardening—This leads to increased stream scour and loss of habitat complexity through disruption of sediment transport ability;

- Reduced water quality—This leads to reduced survival of eggs and juvenile fishes, acute and chronic toxicity to juveniles and adult fishes, and increased physiological stress;

- Increased turbidity—This leads to reduced survival of eggs, reduced plant productivity, and increased physiological stress on aquatic organisms; and

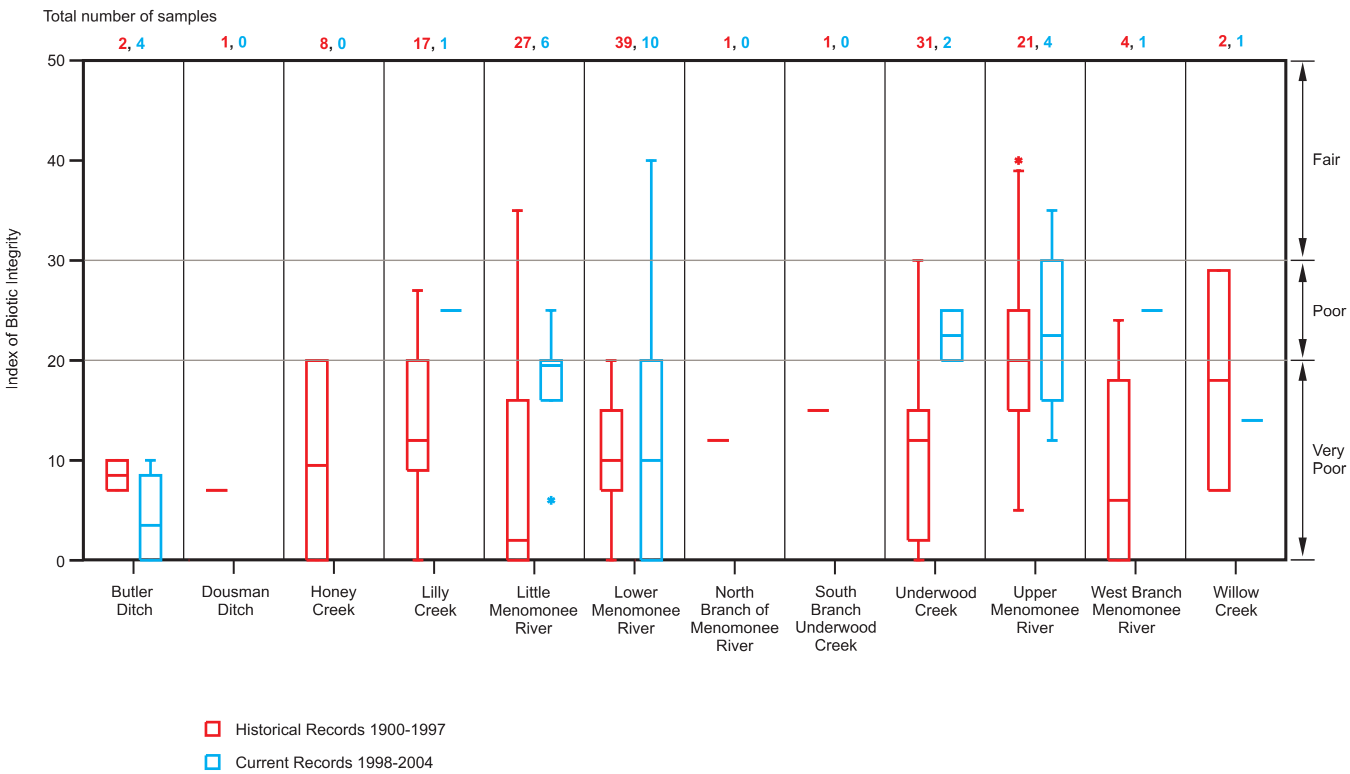
- Increased algae blooms—These lead to oxygen depletion causing fish kills due to chronic algae blooms and increased eutrophication rate of standing waters.

The apparent stagnation of the fishery community within the Menomonee River watershed can be attributed to habitat loss and degradation as a consequence of human activities primarily related to the historic and current development that has occurred within the watershed.

Chapter II of this report includes a description of the correlation between urbanization in a watershed and the quality of the aquatic biological resources. The amount of imperviousness in a watershed that is directly connected to the stormwater drainage system can be used as a surrogate for the combined impacts of urbanization in the absence of mitigation. Urban land use in the Menomonee River watershed increased from about 21 percent urban land in 1950 (5 to 10 percent directly connected imperviousness) to 42 percent in 1963 (approximately 10 to 15 percent directly connected imperviousness), and, as of 2000, it has about 63 percent urban land overall (approximately 20 percent directly connected imperviousness). That level of directly connected imperviousness is beyond the threshold level of 10 percent at which previously cited studies indicate that negative biological impacts have been observed. As also described in Chapter II of this report, studies have indicated that the amount of agricultural land in a watershed can also be correlated with negative instream biological conditions. Agricultural land use has predominated in the extreme upper portions of the Menomonee River watershed,

Figure 98

HISTORICAL AND BASE PERIOD FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION IN STREAMS IN THE MENOMONEE RIVER WATERSHED: 1900-2004



NOTE: See Figure 66 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

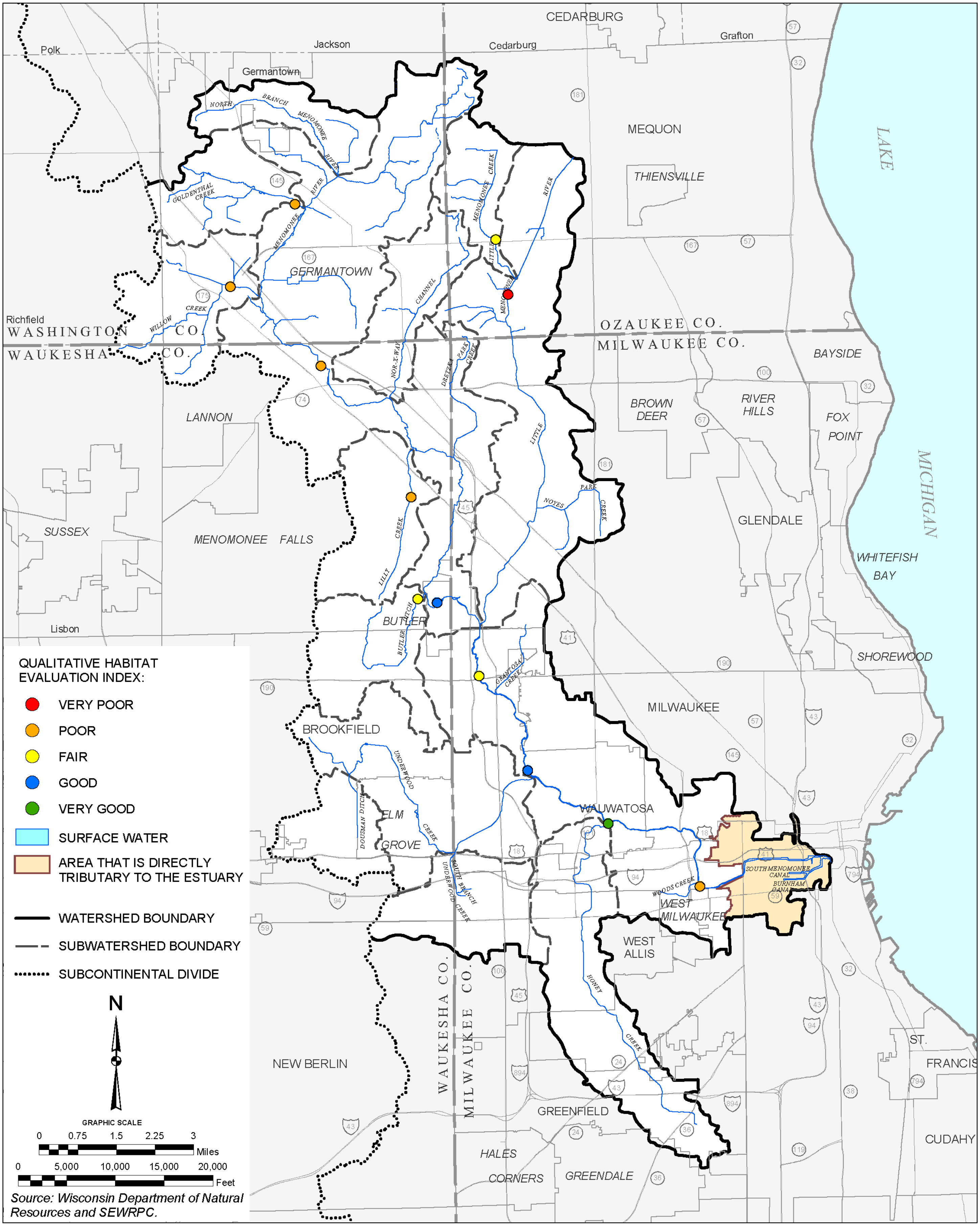
whereas the lower portions of the watershed have been dominated by urban development. Despite the increase in urban development from 1950 to 2004 the quality of the fishery has not significantly changed. However, poor to very poor IBI scores are observed throughout this watershed. Based upon the amount of agricultural and urban lands in the watershed and, in the past, a lack of measures to mitigate the adverse effects of those land uses, the IBI scores are not surprising. The standards and requirements of Chapter NR 151 "Runoff Management," and Chapter NR 216, "Storm Water Discharge Permits," of the *Wisconsin Administrative Code* are intended to mitigate the impacts of existing and new urban development and agricultural activities on surface water resources through control of peak flows in the channel-forming range, promotion of increased baseflow through infiltration of stormwater runoff, and reduction in sediment loads to streams and lakes. The implementation of those rules is intended to mitigate, or improve, water quality and instream/inlake habitat conditions.

The Little Menomonee River has been further degraded by the toxicity of the Moss-American U.S. Environmental Protection Agency superfund site that caused several miles of contaminated sediments and degraded water quality for many years. However, the Moss-American site continues to be remediated and several reaches of the Little Menomonee River channel have been relocated and the contaminated channel reaches have been filled, which should lead to an improvement in the sediment and water quality of the Little Menomonee and downstream reaches.

As shown on Map 35, the collection of habitat data in recent years under the WDNR baseline monitoring program, at the same sites as the fisheries data, has provided the opportunity to assess trends. These data were

Map 35

STREAM HABITAT SAMPLE LOCATIONS AND CONDITIONS WITHIN THE MENOMONEE RIVER WATERSHED: 1998-2004

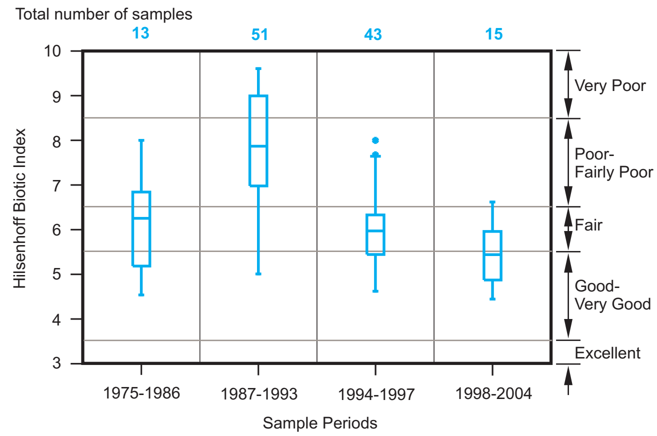


Source: Wisconsin Department of Natural Resources and SEWRPC.

analyzed using the Qualitative Habitat Evaluation Index (QHEI),[12] which integrates the physical parameters of the stream and adjacent riparian features to assess potential habitat quality. This index is designed to provide a measure of habitat that generally corresponds to those physical factors that affect fish communities and which are important to other aquatic life (i.e. macroinvertebrates). This index has been shown to correlate well with fishery IBI scores. The results suggest that fisheries habitat is fair to good throughout the Menomonee River watershed. Comparing these results with previous data and habitat assessments further suggests a trend toward improving habitat quality in this watershed, which, may, over time, be reflected in a gradually improving fishery.

Figure 99

HILSENHOFF BIOTIC INDEX (HBI) MACROINVERTEBRATE SCORES WITHIN THE MENOMONEE RIVER: 1975-2004



NOTE: See Figure 66 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Macroinvertebrates

The Hilsenhoff Biotic Index[13] (HBI) and percent EPT (percent of families comprised of Ephemeroptera, Plecoptera, and Trichoptera) were used to classify the historic and existing macroinvertebrate and environmental quality in this stream system using survey data from various sampling locations of the Menomonee River watershed.

Macroinvertebrate surveys conducted from 1979 through 2004 by the WDNR show that HBI scores generally range from very poor to very good throughout the Menomonee River watershed (Figure 99 and Map 36). Figure 99 also shows that there was a substantial improvement in the macroinvertebrate community quality after 1993. Results generally indicate that current macroinvertebrate diversity and abundance have improved and are indicative of fair to very good water quality throughout the Menomonee River watershed, which corresponds well with the known improvements in water quality within this watershed.

This is further evidenced by the significant improvements in the Lower Menomonee River subwatershed macroinvertebrate community in both HBI and percent EPT as shown in Figure 100. Improvements in macroinvertebrate community quality also seem to be occurring in multiple parts of the drainage area including the Little Menomonee, Upper Menomonee, West Branch of the Menomonee, and Willow Creek subwatersheds.

Synthesis

In evaluating the implications of these indices, which at first glance may appear to be somewhat contradictory, note should be taken of the relative lengths of the life spans of the various organisms used in the indices. Fishes are the longest-lived organisms in the system (typical life spans of two to three years) while macroinvertebrates are relatively short-lived and may respond more quickly to environmental changes. That these changes are occurring is suggested by the emerging trends in water and habitat quality and the macroinvertebrate communities.

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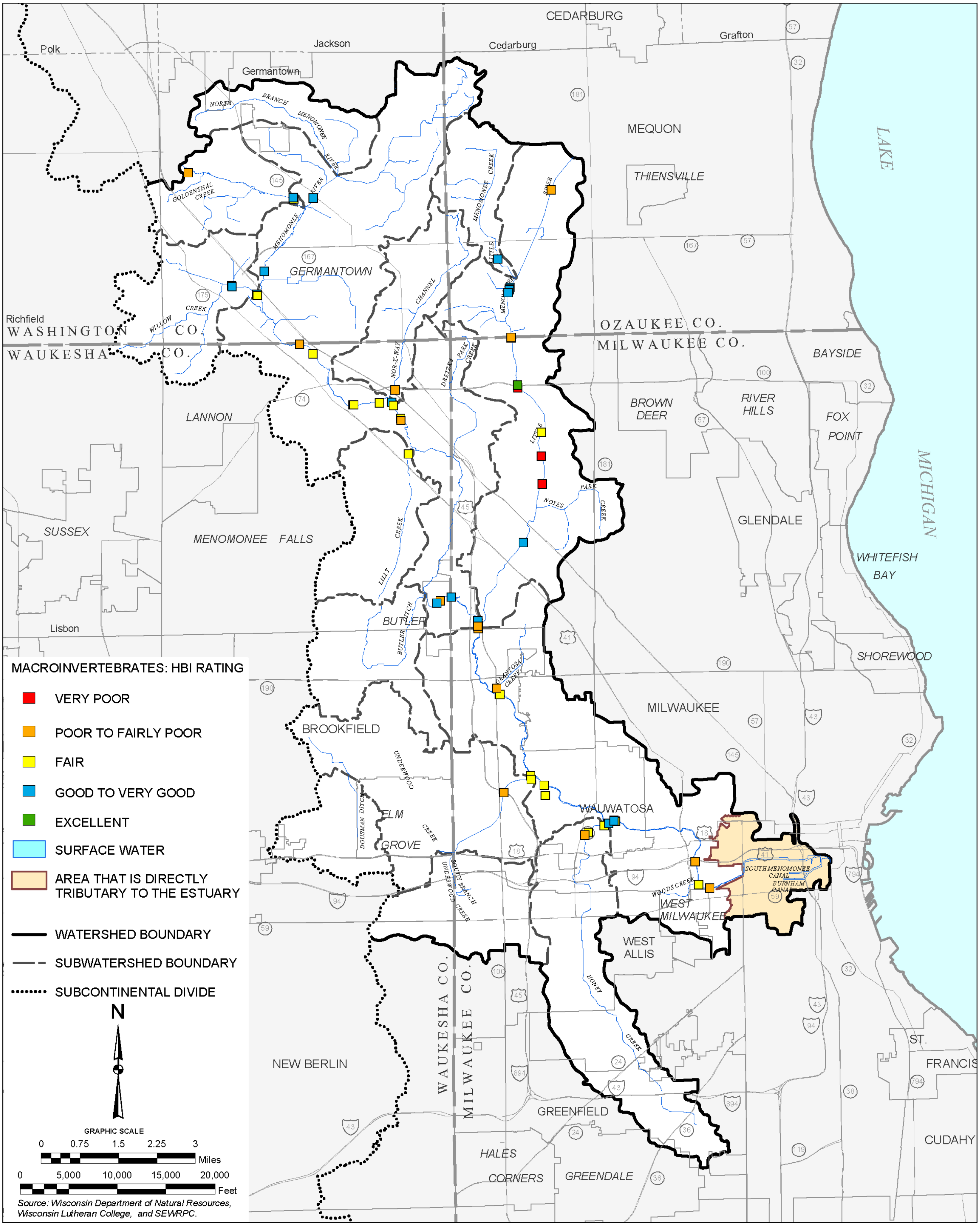
[12] *Edward T. Rankin,* The Quality Habitat Evaluation Index [QHEI]: Rationale, Methods, and Application*, State of Ohio Environmental Protection Agency, November 1989.*

[13] *William L. Hilsenhoff, "Rapid Field Assessment of Organic Pollution with Family-Level Biotic Index," University of Wisconsin, Madison, 1988.*

Map 36

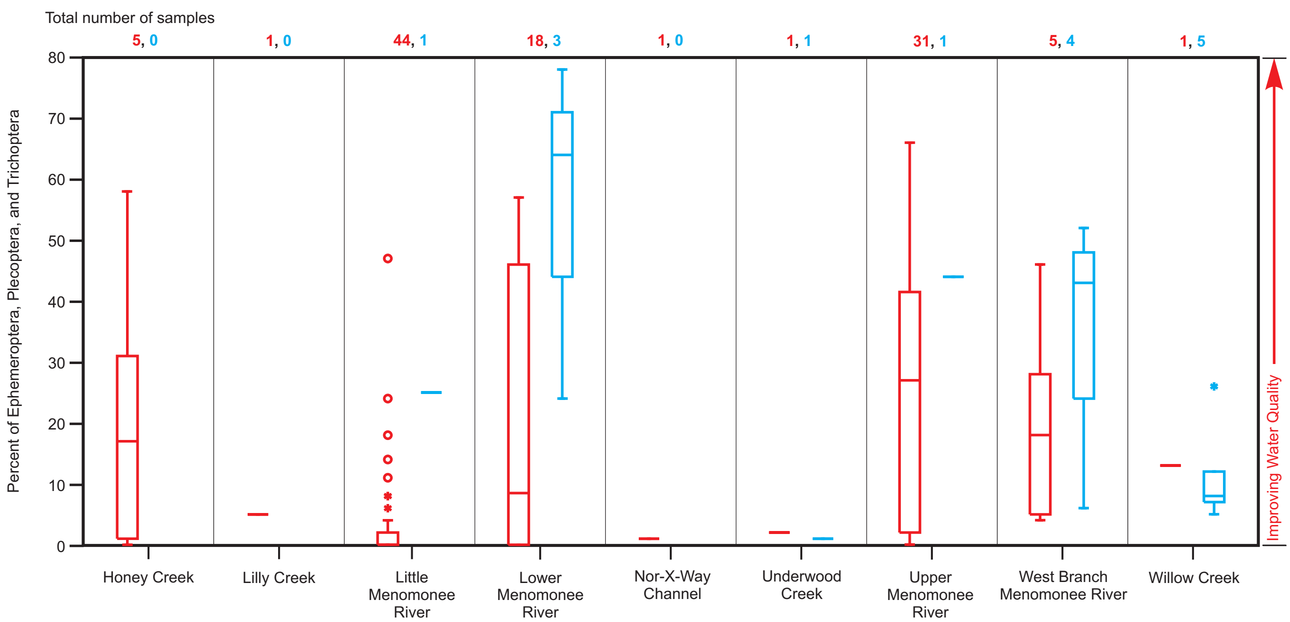
MACROINVERTEBRATE SAMPLE LOCATIONS AND CONDITIONS WITHIN THE MENOMONEE RIVER WATERSHED: 1979-2004

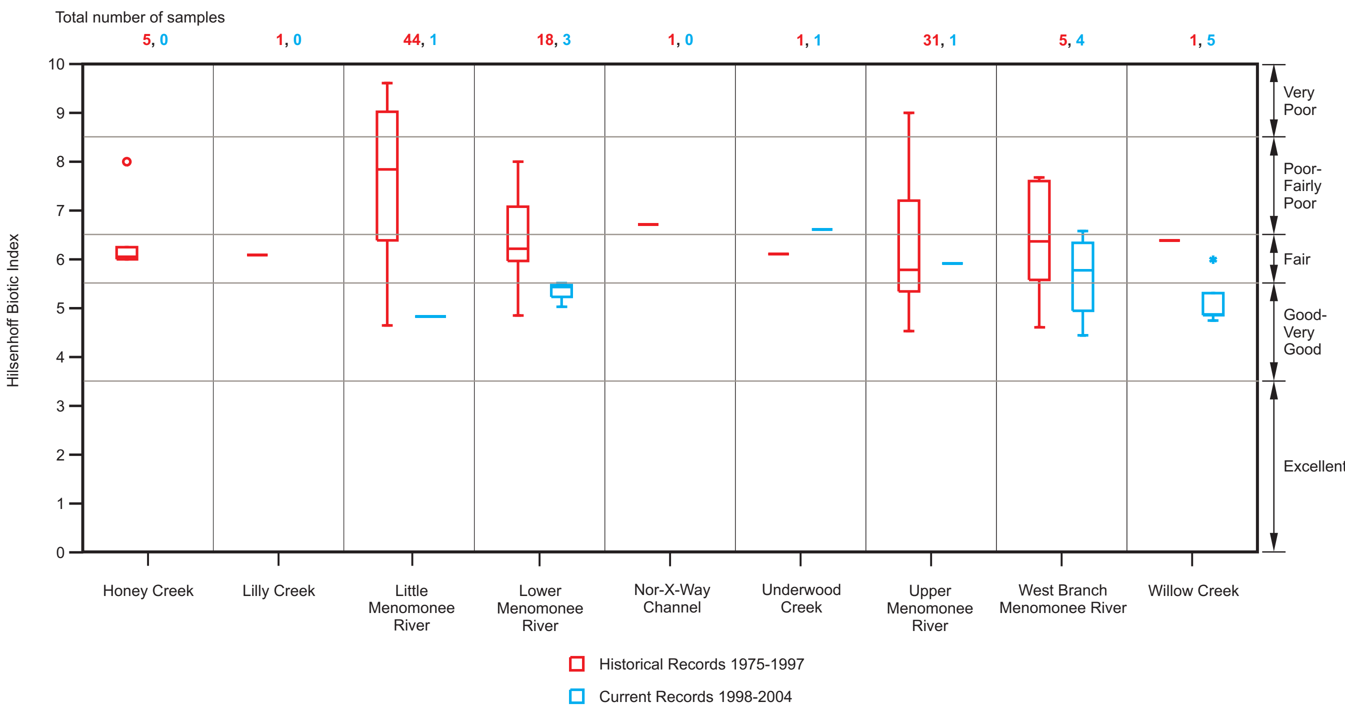


Source: Wisconsin Department of Natural Resources, Wisconsin Lutheran College, and SEWRPC.

Figure 100

HISTORICAL AND BASE PERIOD PERCENT EPHEMEROPTERA, PLECOPTERA, AND TRICHOPTERA (EPT) MACROINVERTEBRATE GENERA AND HILSENHOFF BIOTIC INDEX (HBI) SCORES IN STREAMS IN THE MENOMONEE RIVER WATERSHED: 1975-2004





NOTE: See Figure 66 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

The Menomonee River watershed seems to have a relatively poor fishery. The fish community contains relatively few species of fishes, is trophically unbalanced, contains few or no top carnivores, and is dominated by tolerant fishes. Since water quality has generally been improving in the watershed, and habitat seems to potentially be adequate, it is most likely that other factors are limiting this fishery, including but not limited to 1) periodic stormwater loads; 2) decreased base flows; 3) continued fragmentation due to culverts, concrete lined channels, enclosed conduits, and drop structures; 4) past channelization; and/or 5) increased water temperatures due to urbanization. Nevertheless, the recent observations of increased sportfish in the lower portions of this watershed, particularly smallmouth bass and walleye, may be indicative of a fishery that is potentially becoming more diverse and balanced. It also reflects this watershed's dependence upon the quality of the fishery in the adjacent Milwaukee River and Harbor areas, and the role of these downstream reaches in reestablishing a healthy fishery in the Menomonee River basin.

Other Wildlife

Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of this study, it is possible, by polling naturalists and wildlife managers familiar with the area, to compile lists of amphibians, reptiles, birds, and mammals which may be expected to be found in the area under existing conditions. The technique used in compiling the wildlife data involved obtaining lists of those amphibians, reptiles, birds, and mammals known to exist, or known to have existed, in the Menomonee River watershed area, associating these lists with the historic and remaining habitat areas in the area as inventoried, and projecting the appropriate amphibian, reptile, bird, and mammal species into the watershed area. The net result of the application of this technique is a listing of those species which were probably once present in the drainage area, those species which may be expected to still be present under currently prevailing conditions, and those species which may be expected to be lost or gained as a result of urbanization within the area.

A variety of mammals, ranging in size from large animals like the white-tailed deer, to small animals like the meadow vole, are found in the drainage area of Menomonee River watershed. Mink, muskrat, beaver, white-tailed deer, coyote, red fox, gray squirrel, and cottontail rabbit are mammals reported to frequent the area. Appendix D lists 38 mammals whose ranges are known to extend into the drainage area.

A large number of birds, ranging in size from large game birds to small songbirds, are found in the Menomonee River drainage area. Appendix E lists those birds that normally occur in this watershed. Each bird is classified as to whether it breeds within the area, visits the area only during the annual migration periods, or visits the area only on rare occasions. The Menomonee River watershed also supports a significant population of waterfowl, including mallards and Canada geese. Mallards, wood duck, and blue-winged teal are the most numerous waterfowl and are known to nest in the area. Larger numbers move through the drainage area during the annual migrations when most of the regional species may also be present. Many game birds, songbirds, waders, and raptors also reside or visit the watershed or its environs. Osprey and loons are notable migratory visitors.

Because of the mixture of lowlands and upland woodlots, wetlands, and agricultural lands still present in the area, along with the favorable summer climate, the area supports many other species of birds. Hawks and owls function as major rodent predators within the ecosystem. Swallows, woodpeckers, nuthatches, flycatchers, and several other species serve as major insect predators. In addition to their ecological roles, birds, such as robins, red-winged blackbirds, orioles, cardinals, kingfishers, and mourning doves, serve as subjects for bird watchers and photographers.

Amphibians and reptiles are vital components of the ecosystem within an environmental unit like that of the Menomonee River drainage area. Examples of amphibians native to the area include frogs, toads, and salamanders. Turtles and snakes are examples of reptiles common to the Menomonee River area. Appendix F lists the 14 amphibian and 15 reptile species normally expected to be present in the Menomonee River area under present conditions, and identifies those species most sensitive to urbanization. Most amphibians and reptiles have specific habitat requirements that are adversely affected by advancing urban development, as well as by certain agricultural land management practices. The major detrimental factors affecting the maintenance of amphibians in a changing environment are the destruction of breeding ponds, urban development occurring in migration routes, and changes in food sources brought about by urbanization.

Endangered and threatened species and species of special concern present within the Menomonee River drainage area include 32 species of plants, four species of birds, six species of fish, four species of herptiles, and six species of invertebrates (see Table 60).

The complete spectrum of wildlife species originally native to the watershed, along with their habitat, has undergone significant change in terms of diversity and population size since the European settlement of the area. This change is a direct result of the conversion of land by the settlers from its natural state to agricultural and urban uses, beginning with the clearing of the forest and prairies, the draining of wetlands, and ending with the development of extensive urban areas. Successive cultural uses and attendant management practices, both rural and urban, have been superimposed on the land use changes and have also affected the wildlife and wildlife habitat. In agricultural areas, these cultural management practices include draining land by ditching and tiling and the expanding use of fertilizers, herbicides, and pesticides. In urban areas, cultural management practices that affect wildlife and their habitat include the use of fertilizers, herbicides, and pesticides; road salting for snow and ice control; heavy motor vehicle traffic that produces disruptive noise levels and air pollution and nonpoint source water pollution; and the introduction of domestic pets.

CHANNEL CONDITIONS AND STRUCTURES

The conditions of the bed and bank of a stream are greatly affected by the flow of water through the channel. The great amount of energy possessed by flowing water in a stream channel is dissipated along the stream length by turbulence, streambank and streambed erosion, and sediment resuspension. Sediments and associated substances delivered to a stream may be stored, at least temporarily, on the streambed, particularly where obstructions or irregularities in the channel decrease the flow velocity or act as a particle trap or filter. On an annual basis or a long-term basis, streams may exhibit a net deposition, net erosion, or no net change in internal sediment transport, depending on tributary land uses, watershed hydrology, precipitation, and geology. From 3 to 11 percent of the annual sediment yield in a watershed in southeastern Wisconsin may by contributed by streambank erosion.[14] In the absence of mitigative measures, increased urbanization in a watershed may be expected to result in increased streamflow rates and volumes, with potential increases in streambank erosion and bottom scour, and flooding problems. In the communities in the Menomonee River watershed, the requirements of MMSD Chapter 13, "Surface Water and Storm Water," are applied to mitigate instream increases in peak rates of flow that could occur due to new urban development without runoff controls. Also, where soil conditions allow, the infiltration standards of Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* are applied to limit increases in runoff volume from new development.

The Milwaukee Metropolitan Sewerage District commissioned a study of sediment transport in the Menomonee River watershed.[15] This study, conducted in 2000, examined sediment transport in about 63 miles of stream channel along the mainstem of the River and several of its tributaries. Included among the factors assessed in this study were the characterization of channel bed and bank material composition, the evaluation of bed and bank stability, the examination of the integrity of the WPA walls lining portions of the channel, and the examination of bed and bank stability at road crossings. The impacts of development on streamflow rates and volumes can be mitigated to some degree by properly installed and maintained stormwater management practices. Some level of control is required by current regulations. The effectiveness of such regulations is, in part, dependent upon the level of compliance with, and enforcement of, the regulations.

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[14]*SEWRPC Technical Report No. 21,* Sources of Water Pollution in Southeastern Wisconsin: 1975, *September 1978.*

[15]*Inter-Fluve, Inc.,* Menomonee River Watershed Sediment Transport Study Summary Report, *MMSD Contract No. W021-PE001, February 2001.*

Table 60

ENDANGERED AND THREATENED SPECIES AND SPECIES OF SPECIAL CONCERN IN THE MENOMONEE RIVER WATERSHED: 2004

Common Name	Scientific Name	Status under the U.S. Endangered Species Act	Wisconsin Status
Butterflies and Moths			
Great Copper	*Lycaena xanthoides*	Not listed	Special concern
Little Glassy Wing	*Pompeius verna*	Not listed	Special concern
Dragonflies and Damselflies			
Great Spreadwing	*Archilestes grandis*	Not listed	Special concern
Other Insects			
A Side Swimmer	*Crangonyx gracilis*	Not listed	Special concern
Little White Tiger Beetle	*Cicindela lepida*	Not listed	Special concern
Crustacea			
Prairie Crayfish	*Procambarus gracilis*	Not listed	Special concern
Fish			
Greater Redhorse	*Moxostoma valenciennesi*	Not listed	Threatened
Least Darter	*Etheostoma microperca*	Not listed	Special concern
Longear Sunfish	*Lepomis magalotis*	Not listed	Threatened
Redfin Shiner	*Lythrurus umbratilis*	Not listed	Threatened
Redside Dace	*Clinostomus elongatus*	Not listed	Special concern
Striped Shiner	*Luxilus chrysocephalus*	Not listed	Endangered
Reptiles and Amphibians			
Blanchard's Cricket Frog	*Acris crepitans blanchardi*	Not listed	Endangered
Blanding's Turtle	*Emydoidea blandingii*	Not listed	Threatened
Bullfrog	*Rana catesbeiana*	Not listed	Special concern[a]
Butler's Garter Snake	*Thamnophis butleri*	Not listed	Threatened
Birds			
Common Moorhen	*Gallinula chloropus*	Not listed	Special concern[b]
Dickcissel	*Spiza americana*	Not listed	Special concern[b]
Least Bittern	*Ixobrychus exilis*	Not listed	Special concern[b]
Orchard Oriole	*Icterus spurius*	Not listed	Special concern[b]
Plants			
American Gromwell	*Lithospermum latifolium*	Not listed	Special concern
Bluestem Goldenrod	*Solidago caesia*	Not listed	Endangered
Common Bog Arrow-Grass	*Triglochin maritime*	Not listed	Special concern
Cooper's Milkvetch	*Astragalus neglectus*	Not listed	Endangered
False Hop Sedge	*Carex lupuliformis*	Not listed	Endangered
Forked Aster	*Aster furcatus*	Not listed	Threatened
Great Indian-Plantain	*Cacalia muehlenbergii*	Not listed	Special concern
Hairy Beardtongue	*Penstemon hirsutus*	Not listed	Special concern
Handsome Sedge	*Carex Formosa*	Not listed	Threatened
Harbinger-of-Spring	*Erigenia bulbosa*	Not listed	Endangered
Heart-Leaved Skullcap	*Scutellaria ovata*	Not listed	Special concern
Hemlock Parsley	*Conioselinum chinense*	Not listed	Endangered
Hooker Orchis	*Platanthera hookeri*	Not listed	Special concern
Leafy White Orchis	*Platanthera dilatata*	Not listed	Special concern
Marsh Blazing Star	*Liatris spicata*	Not listed	Special concern
Narrow-Leaved Vervain	*Verbena simplex*	Not listed	Special concern
Prairie White-Fringed Orchid	*Platanthera leucophaea*	Threatened	Endangered
Purple Milkweed	*Asclepias purpurascens*	Not listed	Endangered
Ram's-Head Lady's Slipper	*Cypripedium arietinum*	Not listed	Threatened
Ravenfoot Sedge	*Carex crus-corvi*	Not listed	Endangered
Reflexed Trillium	*Trillium recurvatum*	Not listed	Special concern
Seaside Spurge	*Euphorbia polygonifolia*	Not listed	Special concern
Slim-Stem Small Reedgrass	*Calamagrostis stricta*	Not listed	Special concern

Table 60 (continued)

Common Name	Scientific Name	Status under the U.S. Endangered Species Act	Wisconsin Status
Plants (continued)			
Small White Lady's Slipper	*Cypripedium candidum*	Not listed	Threatened
Small Yellow Lady's-Slipper	*Cypripedium calceolus*	Not listed	Special concern
Smooth Black-Haw	*Viburnum prunifolium*	Not listed	Special concern
Snow Trillium	*Trillium nivale*	Not listed	Threatened
Sparse-Flowered Sedge	*Carex tenuflora*	Not listed	Special concern
Twinleaf	*Jeffersonia diphylla*	Not listed	Special concern
Wafer-Ash	*Ptelea trifoliate*	Not listed	Special concern
Waxleaf Meadowrue	*Thalictrum revolutum*	Not listed	Special concern
Wild Licorice	*Glycyrrhiza lepidota*	Not listed	Special concern

[a]*Taking of this species is regulated by the establishment of open and closed seasons.*

[b]*This species is fully protected under by Federal and State laws under the Migratory Bird Act of 1918.*

Source: Wisconsin Department of Natural Resources, Wisconsin State Herbarium, Wisconsin Society of Ornithology, and SEWRPC.

The study summarized several general characteristics of channel beds and banks in the watershed. Except for limestone bedrock reaches at Menomonee Falls, the Menomonee River has a relatively flat gradient. Much of the watershed is poorly drained and the streams in the watershed form broad alluvial flood plains. The majority of the reaches of the river and its tributaries that were examined are alluvial. Of the 63 miles of channel examined, about 14.5 miles are lined with concrete or riprap, consist of bedrock, or are enclosed in conduit. The majority of the tributaries of the river are alluvial systems. In the upper portions of the River and its major tributaries, bed materials in the alluvial sections range from silt to gravel. The banks in these sections generally consist of cohesive silt and clay banks. The alluvial sections of the lower reaches of the Menomonee River, Underwood Creek, and Butler Ditch contain well armored, platy cobble bed material. The banks of these reaches tend to be less cohesive, containing higher fractions of unconsolidated sand and gravel than in the upper reaches. Nonalluvial sections of the watershed include enclosed reaches of Grantosa Creek, Honey Creek, Underwood Creek, and Woods Creek and concrete-lined reaches of Honey Creek, the South Branch of Underwood Creek, Underwood Creek, Woods Creek, and the mainstem of the River. In addition, the streambed consists of bedrock in portions of Butler Ditch and the mainstem of the Menomonee River. Finally, the streambanks are confined by walls along portions of Woods Creek and the mainstem of the River. The characteristics of streambeds and banks in the Menomonee River watershed are shown on Map 37.

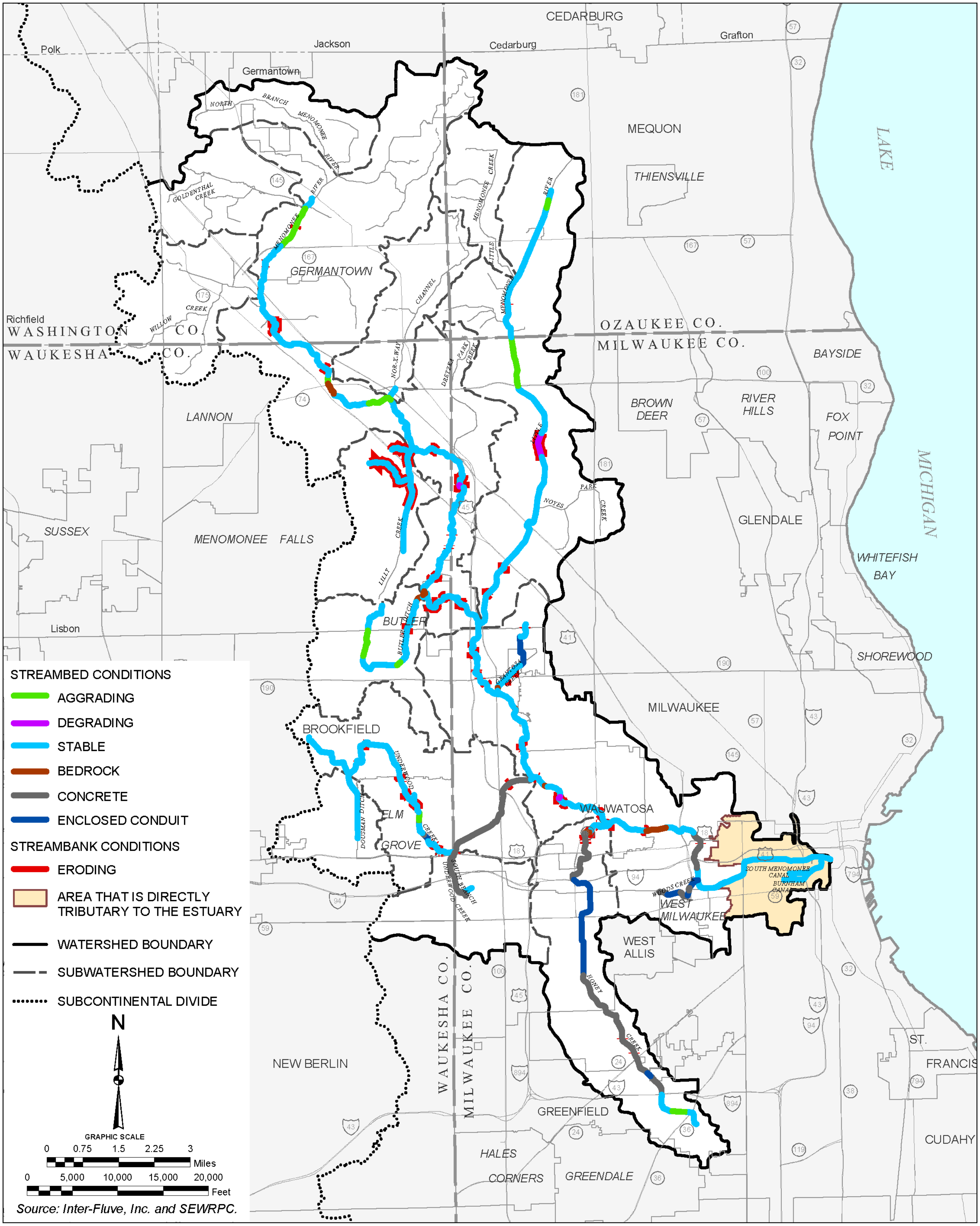
Bed and Bank Stability

Alluvial streams within urbanizing watersheds often experience rapid channel enlargement. As urbanization occurs, the fraction of the watershed covered by impervious materials increases. This can result in profound changes in the hydrology in the watershed. As a result of runoff being conveyed over impervious surfaces to storm sewers which discharge directly to streams, peak flows become higher and more frequent and streams become "flashier" with flows increasing rapidly in response to rainfall events because runoff is directed into the stream via storm sewers. The amount of sediment reaching the channel often declines. Under these circumstances and in the absence of armoring, the channel may respond by incising. This leads to an increase in the height of the streambank, which continues until a critical threshold for stability is exceeded. When that condition is reached, mass failure of the bank occurs, leading to channel widening. Typically, incision in an urbanizing watershed proceeds from the mouth to the headwaters.[16] Lowering of the channel bed downstream increases the energy gradient upstream and in the tributaries. This contributes to further destabilization. Once it begins, incision

[16]*S.A. Schumm, "Causes and Controls of Channel Incision," In: S. E. Darby and A. Simon (eds.),* Incised River Channels: Processes, Forms, Engineering and Management, *John Wiley & Sons, New York, 1999.*

Map 37

STREAMBANK AND STREAMBED CHARACTERISTICS WITHIN THE MENOMONEE RIVER WATERSHED: 2000



Source: Inter-Fluve, Inc. and SEWRPC.

typically follows a sequence of channel bed lowering, channel widening, and deposition of sediment within the widened channel. Eventually, the channel returns to a stable condition characteristic of the altered channel geometry.

Streams in this watershed also show several general trends in lateral geomorphic stability.[17] Map 37, Figure 101, and Table 61 summarize channel bank stability conditions for the Menomonee River and several of its tributaries. Lateral erosion is relatively uncommon, comprising about 5 percent of total streambank conditions. Lateral erosion tends to be more prevalent at heavily encroached sites, especially those with denuded streambank vegetation cover. It is also more common at sites where structures have altered flow to cause more erosive hydraulic conditions. When examined on a reach basis, lateral instability is most apparent in several locations in the watershed. Sections showing lateral instability are found along the mainstem of the Menomonee River at reaches located from 3.58 to 4.09 and 7.56 to 8.00 miles upstream from the confluence with the Milwaukee River, the Little Menomonee River from 4.17 to 4.69 miles upstream from the confluence with the Menomonee River, Grantosa Creek from 0.44 to 0.80 mile upstream from the confluence with the Menomonee, Underwood Creek from 0.50 to 0.63 and 2.54 to 3.25 miles upstream from the confluence with the Menomonee, and the lower end of Honey Creek, up to about 0.68 miles upstream of the confluence with the Menomonee. In addition, alluvial reaches with steep bed profiles located immediately downstream from lower gradient concrete-lined and enclosed channel reaches show high rates of degradation. These sites occur at the lower ends of Honey Creek and Underwood Creek and along Grantosa Creek between 0.44 and 0.80 mile upstream from the confluence with the Menomonee River.

Streams in the Menomonee River watershed show several general trends in vertical geomorphic stability.[18] Table 62 summarizes bed stability for the Menomonee River and several of its tributaries. Most alluvial reaches that were examined appeared to be stable or slightly degrading. Only about 5 percent of alluvial reaches are unstable. The lower portions of the Menomonee River have experienced relatively little streambed and bank degradation. This appears to be the result of armoring of the channel by bedrock, large bed materials, and man-made structures. While upstream reaches of the Menomonee River, the Little Menomonee River, and Grantosa Creek have historically incised two to four feet in response to urbanization, most of the examined tributary reaches in the watershed show little evidence of previous incision or current vertical instability. This may result from the River and its tributaries having a high frequency of drop structures, bedrock-lined reaches, and concrete-lined reaches which serve as grade control. Aggrading alluvial reaches are uncommon in the portions of the watershed which were assessed.

The stability of the channel was also assessed at sites near road crossings.[19] The effects of bridges and culverts on hydraulic processes in streams can influence channel stability near the structure. Local channel instability can undermine the integrity of these structures. For example, bank erosion upstream of bridges and local scour around bridge abutments are common causes of bridge failure. Approximately 240 structures were examined during the geomorphic assessment of streambank and bed stability. Generally, channel stability appears to be very good near structures throughout the portions of the watershed that were examined. Stable geomorphic conditions were found near most of these structures. Ten sites were identified as being potential problem sites and requiring additional evaluation. These sites were evaluated using the methodology developed by Johnson, *et al.* for rapid channel stability assessment in the vicinity of road crossings.[20] This method evaluates the 12 qualitative and quantitative indicators of channel stability, such as streambank soil texture, average bank slope angle, bar development, and

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[17]Ibid.

[18]*Inter-Fluve, Inc., 2001,* op. cit.

[19]Ibid.

[20]*P.A. Johnson, G.L. Gleason, and R.D. Hey. "Rapid Assessment of Channel Stability in the Vicinity of Road Crossings,"* Journal of Hydraulic Engineering, *Volume 125, 1999, pp. 645-651.*

Figure 101

STREAMBANK STABILITY CONDITIONS IN THE MENOMONEE RIVER WATERSHED: 2003

HONEY CREEK (RM 5.3)

MENOMONEE RIVER (RM 21.4)

LITTLE MENOMONEE RIVER (RM 8.2)

MENOMONEE RIVER (RM 13.9)

UNDERWOOD CREEK (RM 4.2)

MENOMONEE RIVER (RM 6.1)

Source: Milwaukee County and Inter-Fluve, Inc.

Table 61

CHANNEL BANK CONDITIONS IN THE MENOMONEE RIVER WATERSHED

Subwatershed	Total Length (feet)	Left Bank				Right Bank			
		Unstable		Stable		Unstable		Stable	
		Length (feet)	Percent	Length (feet)	Percent	Length (feet)	Percent	Length (feet)	Percent
Butler Ditch	17,952	68	0.4	17,884	99.6	132	0.7	17,820	99.3
Dousman Ditch	5,808	0	0.0	5,808	100.0	0	0.0	5,808	100.0
Grantosa Creek	9,715	172	1.8	9,543	98.2	97	1.0	9,618	99.0
Honey Creek	46,622	380	0.8	46,242	99.2	938	2.0	45,684	98.0
Lilly Creek[a]	39,365	12,949	32.9	26,416	67.1	12,949	32.9	26,416	67.1
Little Menomonee River	54,278	2,364	4.4	51,914	95.6	2,086	3.8	52,192	96.2
Menomonee River	132,627	6,602	5.0	126,085	95.0	5,956	4.5	126,731	95.5
South Branch Underwood Creek	5,702	0	0.0	5,702	100.0	0	0.0	5,702	100.0
Underwood Creek	40,550	1,251	3.1	39,299	96.9	1,077	2.7	39,743	97.3
Woods Creek	5,782	20	0.4	5,762	99.6	0	0.0	5,782	100.0

[a]*The assessment of the Lilly Creek subwatershed includes data on the mainstem and tributaries as documented in the SEWRPC Community Assistance Planning Report No. 190,* A Stormwater Management and Flood Control Plan for the Lilly Creek Subwatershed, *1993.*

Source: Inter-Fluve, Inc., and SEWRPC.

Table 62

CHANNEL BED CONDITIONS IN THE MENOMONEE RIVER WATERSHED

Subwatershed	Total Length (feet)	Aggrading		Degrading		Stable	
		Length (feet)	Percent	Length (feet)	Percent	Length (feet)	Percent
Butler Ditch	17,952	3,477	19.4	0	0.0	14,475	80.6
Dousman Ditch	5,808	0	0.0	0	0.0	5,808	100.0
Grantosa Creek	9,715	0	0.0	0	0.0	9,715	100.0
Honey Creek	46,623	1,417	3.0	0	0.0	45,206	97.0
Little Menomonee River	54,279	6,376	11.7	2,764	5.1	45,139	83.2
Menomonee River	132,626	8,737	6.6	993	0.7	122,956	92.7
South Branch Underwood Creek	5,702	0	0.0	0	0.0	5,702	100.0
Underwood Creek	40,551	941	2.3	0	0.0	39,610	97.7
Woods Creek	5,782	0	0.0	0	0.0	5,782	100.0

Source: Inter-Fluve, Inc.

Table 63

RESULTS OF RAPID CHANNEL STABILITY NEAR ROAD CROSSING ASSESSMENT FOR THE MENOMONEE RIVER WATERSHED

Stream	Structure	River Mile	Rating
Menomonee River	70th Street bridge	6.10	Fair
	W. Mill Road bridge	15.98	Fair
	Pedestrian bridge at Rotary Park	20.79	Good
Little Menomonee River	N. Granville Road bridge	3.74	Good
Underwood Creek	Clearwater Road culverts	5.59	Fair
	Santa Maria Court bridge	5.99	Fair
	Woodbridge Road culvert	6.08	Fair
	Private bridge downstream of Pilgrim Parkway bridge	6.64	Fair
	Pilgrim Parkway bridge	6.68	Good
Butler Ditch	Hampton Road culverts	1.02	Excellent

Source: Inter-Fluve, Inc.

degree of channel constriction. The results of these assessments are shown in Table 63. One site received a channel stability rating of "excellent," three sites received channel stability ratings of "good," and six sites received channel stability ratings of "fair." No sites were rated as having "poor" channel stability.

Works Progress Administration (WPA) Walls

The WPA walls were constructed as flood management structures in the 1920s and 1930s along several streams in the Milwaukee metropolitan area. Depending on location, these walls either form the active channel margin or are located within the active floodplain. They serve as channel boundaries and act to inhibit lateral channel migration and associated erosion. They are made from mortared limestone blocks and are generally about two feet wide. They vary in height from five to 12 feet depending on local channel bed, bank, and floodplain elevations. These walls are about 70 years old. As they degrade over time, increases in lateral bank instability and flooding are likely results.

WPA walls are present along three streams within the Menomonee River watershed. Approximately 11,400 feet of the left bank and 10,600 feet of the right bank of the mainstem of the Menomonee River are lined by these walls. Similarly, about 500 feet of the left bank and 1,400 feet of the right bank of Honey Creek are lined by these walls. Finally, about 1,700 feet of both banks of Woods Creek are lined by WPA walls.

The WPA walls have had considerable influence on the geomorphic and hydrologic character of the Menomonee River. In many places, the walls contain the river as originally designed. In isolated segments, the walls are flanked, degraded, or crumbing and no longer provide proper flood conveyance or adequate protection to infrastructure. At some other isolated sites, the stream channel has migrated away from the walls. Table 64 shows the locations and conditions of the WPA walls in the Menomonee River upstream.

Dams

There are currently two dams within the Menomonee River watershed. One is located in the headwaters of Dousman Ditch and the other is located on the Upper Menomonee River in the Village of Menomonee Falls as shown on Map 38. The Falk dam, which was located in the Lower Menomonee watershed was abandoned on November 20, 2000, and physically removed in February 2001. The removal of this dam has allowed greater fish passage between the Milwaukee River and Harbor with the Menomonee River watershed.

HABITAT AND RIPARIAN CORRIDOR CONDITIONS

One of the most important tasks undertaken by the Commission as part of its regional planning effort was the identification and delineation of those areas of the Region having high concentrations of natural, recreational, historic, aesthetic, and scenic resources and which, therefore, should be preserved and protected in order to maintain the overall quality of the environment. Such areas normally include one or more of the following seven elements of the natural resource base which are essential to the maintenance of both the ecological balance and the natural beauty of the Region: 1) lakes, rivers, and streams and the associated undeveloped shorelands and floodlands; 2) wetlands; 3) woodlands; 4) prairies; 5) wildlife habitat areas; 6) wet, poorly drained, and organic soils; and 7) rugged terrain and high-relief topography. While the foregoing seven elements constitute integral parts of the natural resource base, there are five additional elements which, although not a part of the natural resource base per se, are closely related to or centered on that base and therefore are important considerations in identifying and delineating areas with scenic, recreational, and educational value. These additional elements are: 1) existing outdoor recreation sites; 2) potential outdoor recreation and related open space sites; 3) historic, archaeological, and other cultural sites; 4) significant scenic areas and vistas; and 5) natural and scientific areas. The delineation of these 12 natural resource and natural resource-related elements on a map results in an essentially linear pattern of relatively narrow, elongated areas which have been termed "environmental corridors" by the Commission. Primary environmental corridors include a wide variety of the abovementioned important resource and resource-related elements and are at least 400 acres in size, two miles in length, and 200 feet in width. Secondary environmental corridors generally connect with the primary environmental corridors and are at the least 100 acres in size and one mile long. In addition, smaller concentrations of natural resource features that

Table 64

LOCATIONS AND CONDITIONS OF WPA WALLS IN THE MENOMONEE RIVER WATERSHED

Stream	River Miles[a]	Approximate Wall Length (feet)		Wall Condition[b]	Comments on Wall Condition
		Left Bank	Right Bank		
Menomonee River	3.58-4.32	3,641	3,707	Functioning	Eight to 10 foot section of wall failure at RM 4.03
	4.32-4.97	3,432	3,432	Functioning	- -
	4.97-5.15	- -	1,036	Functioning-potentially degrading	Walls show minor degradation with missing stone blocks and crumbling mortar joints
	4.97-5.42	2,375	- -	Functioning-potentially degrading	Walls show some visible degradation
	5.55-5.58	- -	142	Functioning	- -
	5.86-6.03	875	- -	Functioning-potentially degrading	About 30 percent of the lower half of the wall face is missing stone blocks. Mortar joints are cracked and crumbling. High potential for failure as the wall further degrades
	5.96-6.03	- -	320	Functioning-partially abandoned	The baseflow channel has migrated about 50 feet to the left forming and inset floodplain surface between the wall and the right channel margin
	6.03-6.05	94	- -	Degraded	This short wall segment has completely failed, exposing coarse bank material which is laterally eroding
	6.05-6.18	703	- -	Functioning-potentially degrading	Lower half of the wall face is missing stone blocks. Mortar joints are cracked and crumbling. High potential for failure as the wall further degrades
	6.18-6.23	- -	214	Functioning	- -
	6.23-6.39	- -	845	Functioning-potentially degrading	Mass wasting and a large rotational slump are present on the right bank immediately upstream of this wall segment. There is the potential for the river to flank and degrade about 10 percent of the wall on the upstream end
	7.45-7.56	- -	610	Functioning	- -
	7.56-7.62	- -	247	Abandoned	The active channel margin in 40 to 100 feet left of the wall
	7.62-7.64	145	- -	Degraded	A remnant of the wall foundation is located in the active channel as a result of channel erosion and about 80 feet of lateral bank migration
	7.87-7.96	475	- -	Functioning	The upper 146-foot segment is set back from the active channel margin by 20 to 50 feet
	10.10-10.20	494	- -	Functioning	- -
Woods Creek	0.25-0.33	422	422	Functioning	- -
	0.44-0.50	307	307	Functioning	- -
	0.92-1.10	950	950	Functioning	- -

Table 64 (continued)

Stream	River Miles[a]	Approximate Wall Length (feet) Left Bank	Right Bank	Wall Condition[b]	Comments on Wall Condition
Honey Creek	0.00-0.11	- -	415	Functioning-potentially degrading	The right bank consists of three wall segments separated by riprap. The upper 189 feet is in marginal condition. The middle 109 feet is failing. The lower 114 feet is in good condition
	0.22-0.27	- -	238	Functioning-potentially degrading	About 86 feet of this wall segment along the channel bend is actively failing
	0.48-0.50	126	- -	Degraded	The lower half of a 65-foot section of this wall segment is collapsed and unstable
	0.48-0.60	- -	552	Degraded	A 206-foot wall segment below the Honey Creek Parkway Bridge is flanked and failing with extensive erosion along the bank. The 26-foot end segment is also failing
	0.62-0.68	381	- -	Potentially degrading	This entire section has a high potential to degrade
	1.64-1.67	- -	157	Functioning	- -

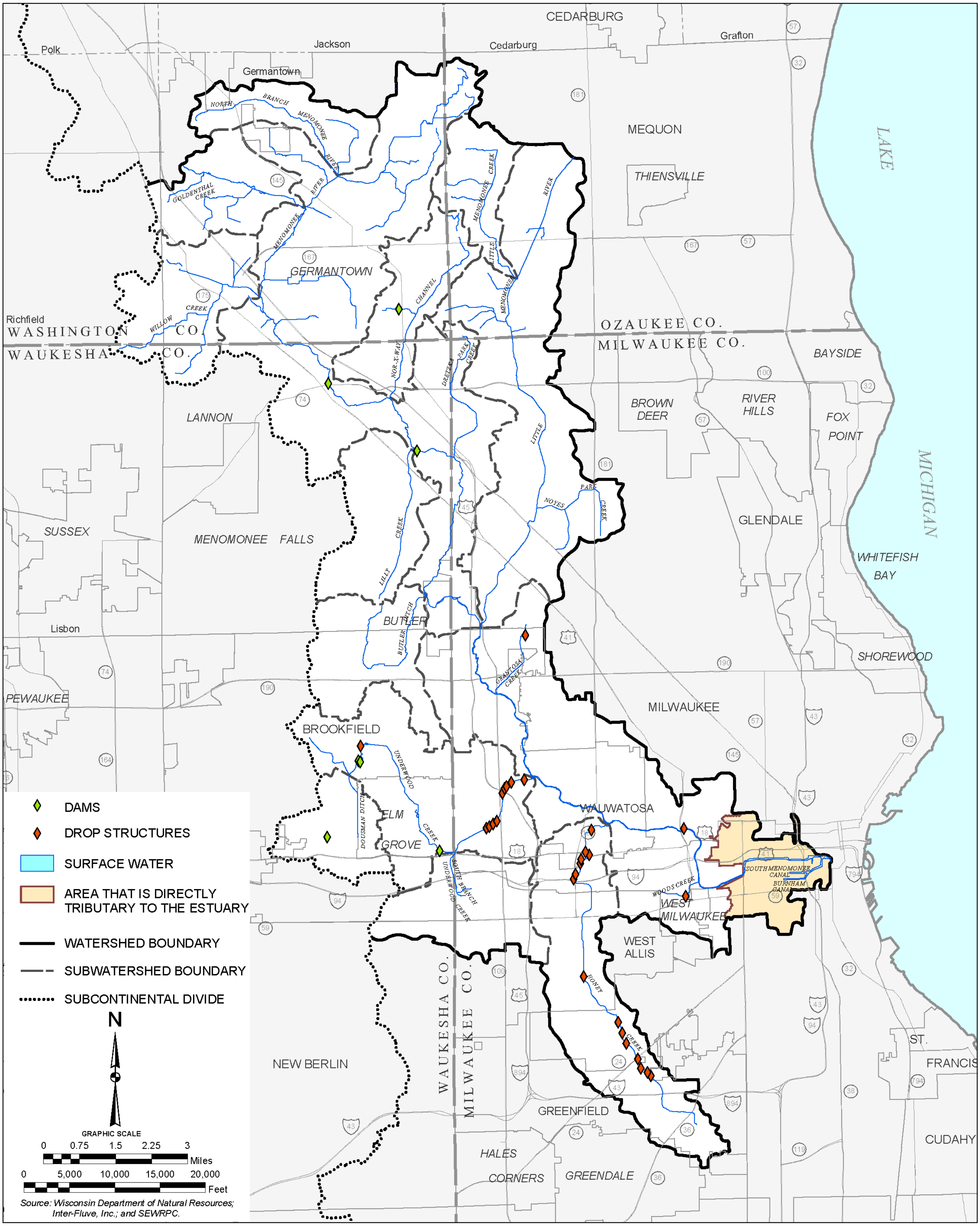
[a]River Mile is measured upstream from the confluence with the receiving water. For the Menomonee River, this is miles upstream from the confluence with the Milwaukee River. For Woods Creek and Honey Creek, it is miles upstream from their respective confluences with the Menomonee River.

[b]Conditions are as follows: Functioning indicates that the walls continue to provide lateral control and flood management as originally designed. Degraded indicates that the structural integrity of the walls have degraded or are actively failing. Abandoned indicates that the active channel has migrated since the walls were constructed. Potentially degrading indicates that the walls function as lateral control, but design life or proximity to unstable channel conditions make the wall segments prone to future degradation.

Source: Inter-Fluve, Inc.

Map 38

DAMS AND DROP STRUCTURES WITHIN THE MENOMONEE RIVER WATERSHED: 2005



Source: Wisconsin Department of Natural Resources; Inter-Fluve, Inc.; and SEWRPC.

have been separated physically from the environmental corridors by intensive urban or agricultural land uses have also been identified. These areas, which are at least five acres in size, are referred to as isolated natural resource areas.

It is important to point out that, because of the many interlocking and interacting relationships between living organisms and their environment, the destruction or deterioration of any one element of the total environment may lead to a chain reaction of deterioration and destruction among the others. The drainage of wetlands, for example, may have far-reaching effects, since such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas of interconnecting lake and stream systems. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater. Groundwater serves as a source of domestic, municipal, and industrial water supply and provides a basis for low flows in rivers and streams. Similarly, the destruction of woodland cover, which may have taken a century or more to develop, may result in soil erosion and stream siltation and in more rapid runoff and increased flooding, as well as destruction of wildlife habitat. Although the effects of any one of these environmental changes may not in and of itself be overwhelming, the combined effects may lead eventually to the deterioration of the underlying and supporting natural resource base, and of the overall quality of the environment for life. The need to protect and preserve the remaining environmental corridors within the area directly tributary to the Menomonee River system, thus, becomes apparent.

Primary Environmental Corridors

The primary environmental corridors in Southeastern Wisconsin generally lie along major stream valleys and around major lakes, and contain almost all of the remaining high-value woodlands, wetlands, and wildlife habitat areas, and all of the major bodies of surface water and related undeveloped floodlands and shorelands. As shown on Map 39, in the year 2000, primary environmental corridors in the Menomonee River drainage area encompassed about 7,000 acres, or about 8 percent of the drainage area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of primary environmental corridors within the watershed. Primary environmental corridors may be subject to urban encroachment because of their desirable natural resource amenities. Unplanned or poorly planned intrusion of urban development into these corridors, however, not only tends to destroy the very resources and related amenities sought by the development, but tends to create severe environmental and development problems as well. These problems include, among others, water pollution, flooding, wet basements, failing foundations for roads and other structures, and excessive infiltration of clear water into sanitary sewerage systems.

Secondary Environmental Corridors

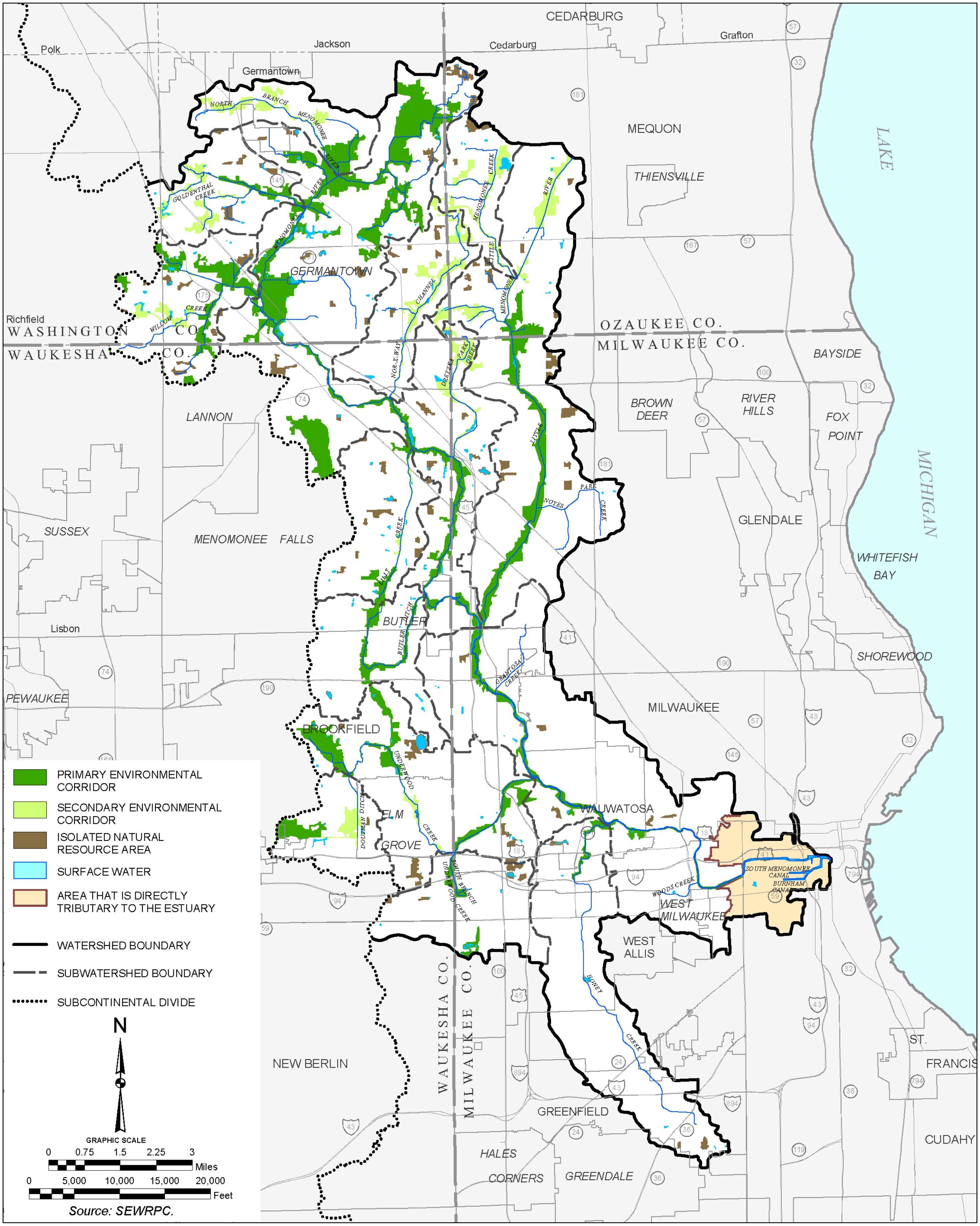
Secondary environmental corridors are located generally along intermittent streams or serve as links between segments of primary environmental corridors. As shown on Map 38, secondary environmental corridors in the Menomonee River drainage area encompassed about 2,250 acres, or about 3 percent of the drainage area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of secondary environmental corridors within the watershed. Secondary environmental corridors contain a variety of resource elements, often remnant resources from primary environmental corridors which have been developed for intensive agricultural purposes or urban land uses, and facilitate surface water drainage, maintain "pockets" of natural resource features, and provide for the movement of wildlife, as well as for the movement and dispersal of seeds for a variety of plant species.

Isolated Natural Resource Areas

In addition to primary and secondary environmental corridors, other small concentrations of natural resource base elements exist within the drainage area. These concentrations are isolated from the environmental corridors by urban development or agricultural lands and, although separated from the primary and secondary environmental corridor network, have important natural values. These isolated natural resource areas may provide the only available wildlife habitat in a localized area, provide good locations for local parks and nature study areas, and lend a desirable aesthetic character and diversity to the area. Important isolated natural resource area features include a variety of isolated wetlands, woodlands, and wildlife habitat. These isolated natural resource area

Map 39

ENVIRONMENTAL CORRIDORS WITHIN THE MENOMONEE RIVER WATERSHED: 2000



Source: SEWRPC.

features should also be protected and preserved in a natural state whenever possible. Such isolated areas five or more acres in size within the Menomonee River drainage area also are shown on Map 38 and total about 1,250 acres, or about 1 percent of the drainage area. In the period from the initial inventory in 1985 through 2000, there was a loss of about 8 percent of the isolated natural resource areas within the watershed.

Natural Areas and Critical Species Habitat

The regional natural areas and critical species habitat protection and management plan[21] ranked natural resource features based upon a system that considered areas to be of statewide or greater significance, NA-1; countywide or regional significance, NA-2; or local significance, NA-3. In addition, certain other areas were identified as critical species habitat sites. Within the Menomonee River drainage area, as shown on Map 40, 28 such sites were identified, six of which were identified as critical species habitat sites. Portions of the Village of Germantown-owned, Germantown Swamp, totaling 190 acres, were identified as being of statewide or great significance (NA-1), and are already in public ownership. A further 187 acres were also proposed to be acquired by the Village. Of the natural areas of countywide or regional significance (NA-2), portions of the Menomonee Falls Tamarack Swamp and Zion Woods are currently under protective ownership by local government units, with additional portions proposed for acquisition. These areas, together with the Held Maple Woods not currently under protective ownership and proposed for acquisition by Waukesha County, total approximately 400 acres in areal extent. A further approximately 1,450 acres of natural area of local significance (NA-3) were identified. Of the approximately 60 acres of critical species habitat identified in the regional natural areas and critical species habitat protection and management plan, only 27 acres at two sites are proposed for acquisition by state and county government, as shown in Table 65. Endangered and threatened species and species of special concern present within the Menomonee River drainage area include 32 species of plants, four species of birds, six species of fish, four species of herptiles, and six species of invertebrates.

Measures for Habitat Protection

Varying approaches to the protection of the stream corridor have been adopted within the Menomonee River basin. In Milwaukee County, stream corridor protection has been focused on public acquisition of the lands adjacent to the stream banks and their preservation as river parkways. These lands are frequently incorporated into public parks and other natural areas. In Washington County, in the headwaters of the Menomonee River system, a comprehensive revision of the County shoreland, floodland, and wetland ordinances resulted in varying setbacks of principle structures, and limitations on impervious surfaces, being incorporated into the County zoning applicable to both lakeshore and streambank development. Integral to these refined provisions was the classification of lakes and streams based upon both physical characteristics and biological characteristics. Class I waters are those lakes and streams to be protected or preserved as high-quality resource waters, including coldwater trout streams; Class II waters are those lakes and streams to be maintained in a currently good quality; and Class III waters comprise those waterbodies that have been historically heavily developed for residential and recreational use in the County, including warmwater stream systems. The Menomonee River is designated as a Class III waterbody, while Willow Creek is a Class II waterbody and the West Branch of the Menomonee River is a Class I waterbody. Class III waterbodies in Washington County would receive a level of protection that approximates the current levels of protection afforded these systems under existing *Wisconsin Statutes*, while the other Classes of waterbodies would receive a somewhat higher degree of protection in order to maintain their existing water quality and habitat value. These higher levels of protection could include provisions for mitigation or alternative means of achieving compliance with the enhanced code requirements, in addition to increased setbacks from the shoreline, increased lot size relative to the amount of impervious surface, and related provisions intended to minimize anthropogenic impacts on these watercourses.

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[21]*SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*, September 1997.*

Map 40

KNOWN NATURAL AREAS AND CRITICAL SPECIES HABITAT SITES WITHIN THE MENOMONEE RIVER WATERSHED: 1994

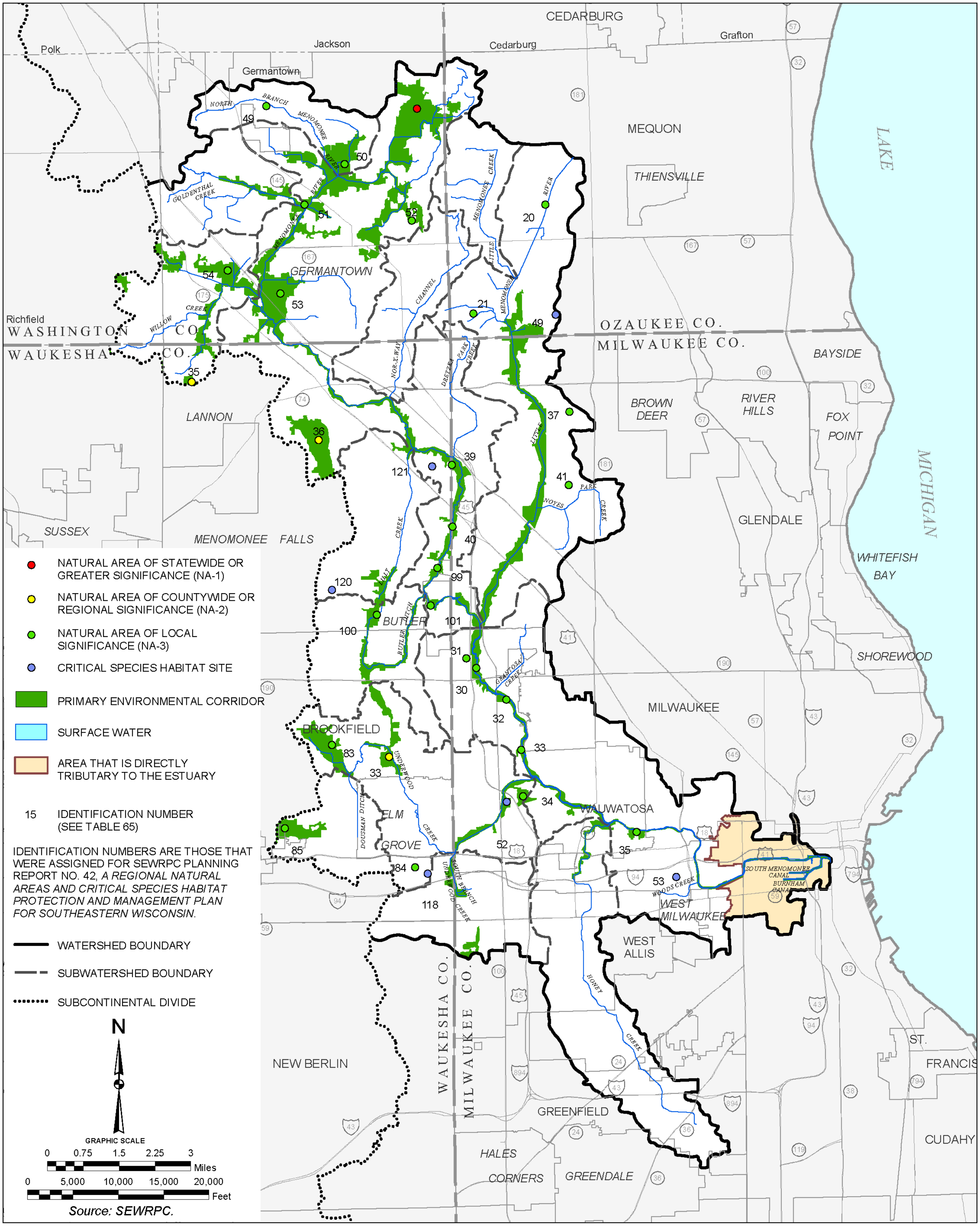


Table 65

NATURAL AREAS AND CRITICAL SPECIES HABITAT AREAS IN THE MENOMONEE RIVER WATERSHED

Number on Map 40	Name	Type of Area	Location	Owned (acres)	Proposed to Be Acquired[a] (acres)	Total	Proposed Acquisition Agency
	Natural Areas						
3	Germantown Swamp	NA-1	Village of Germantown	190	184	374	Village of Germantown
35	Held Maple Woods	NA-2	Village of Menomonee Falls	- -	40	40	Waukesha County
36	Menomonee Falls Tamarack Swamp	NA-2	Village of Menomonee Falls	362	469	831 (306)[b]	Village of Menomonee Falls
33	Zion Woods	NA-2	City of Brookfield	44	11	55	City of Brookfield
84	Bishops Woods	NA-3	City of Brookfield	42	- -	42	Bishops Woods Corporation
33	Blue Mound Country Club Woods	NA-3	City of Wauwatosa	4	12	16	Milwaukee County
37	Bradley Woods	NA-3	City of Milwaukee	16	19	35	City of Milwaukee
85	Brookfield Swamp	NA-3	City of Brookfield	40	163	203	City of Brookfield
101	Clarks Woods	NA-3	Village of Menomonee Falls/ Village of Butler	7	16	23	Village of Menomonee Falls
32	Currie Park Low Woods	NA-3	City of Wauwatosa	27	- -	27	Milwaukee County
49	Faber-Pribyl Woods	NA-3	Village of Germantown	- -	- -[c]	39	- -
39	Harbinger Woods	NA-3	City of Milwaukee/Village of Menomonee Falls	34	13	47	Milwaukee County/Village of Menomonee Falls[d]
31	Harley-Davidson Woods	NA-3	City of Wauwatosa	- -	- -[c]	11	- -
41	Haskell Noyes Park Woods	NA-3	City of Milwaukee	20	- -	20	Milwaukee County
50	Hoelz Swamp	NA-3	Village of Germantown	- -	109	109	Village of Germantown
35	Jacobus Park Woods	NA-3	City of Wauwatosa	11	- -	11	Milwaukee County
54	Kleinman Swamp	NA-3	Village of Germantown	38	33	71	Wisconsin Department of Natural Resources
51	Lake Park Swamp	NA-3	Village of Germantown	9	45	54	Village of Germantown
99	Menomonee River Swamp	NA-3	Village of Menomonee Falls/ City of Milwaukee	- -	29	29	Waukesha County
40	Menomonee River Swamp-North	NA-3	City of Milwaukee/Village of Menomonee Falls	59	19	78	Milwaukee and Waukesha Counties[e]
30	Menomonee River Swamp-South	NA-3	City of Wauwatosa	39	- -	39	Milwaukee County
52	Schoessow Woods	NA-3	Village of Germantown	- -	51	51	Village of Germantown
20	Solar Heights Low Woods	NA-3	City of Mequon	- -	- -[c]	114	- -
100	Theatre Swamp	NA-3	Village of Menomonee Falls	31	60	91	Village of Menomonee Falls
21	Triple Woods	NA-3	City of Mequon	- -	- -[c]	- -	- -
53	USH-41 Swamp	NA-3	Village of Germantown	- -	228	228 (197)	Village of Germantown
34	Wil-O-Way Woods	NA-3	City of Wauwatosa	41	- -	41	Milwaukee County
83	Wirth Swamp	NA-3	City of Brookfield	23	62	85	City of Brookfield

Table 65 (continued)

Number on Map 40	Name	Type of Area	Location	Owned (acres)	Proposed to Be Acquired[a] (acres)	Total	Proposed Acquisition Agency
	Critical Species Habitat						
49	Stauss Woods	CSH	City of Mequon	- -	- -[c]	7	- -
121	Heritage Woods	CSH	Village of Menomonee Falls	- -	- -[c]	12	- -
120	Glass-Glick Woods	CSH	Village of Menomonee Falls	- -	- -[c]	2	- -
52	Underwood Parkway Woods	CSH	City of Wauwatosa	19	- -	19	Milwaukee County
118	Elm Grove Road Pond	CSH	Village of Elm Grove	- -	- -[c]	7	- -
53	Stadium Bluff Woods	CSH	City of Milwaukee	8	- -	8	Wisconsin Department of Natural Resources

[a]*Acquisition is recommended in SEWRPC Planning Report No. 42 (PR No. 42),* Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, *September 1997.*

[b]*Partially within the Menomonee River drainage area, portion within the drainage area is shown in parentheses.*

[c]*Not proposed for acquisition.*

[d]*Includes 34 acres in Milwaukee County—all of which are currently owned by the County—and 13 acres in the Village of Menomonee Falls in Waukesha County. It is recommended that the Village acquire the 13 acres of the Natural Area located with Village limits.*

[e]*Includes 74 acres in Milwaukee County and four acres in Waukesha County. Milwaukee County currently owns 59 acres of that portion of the Natural Area within its boundary. PR No. 42 recommends that Milwaukee County acquire the remaining 15 acres within its boundary and that Waukesha County acquire the four acres within its boundary.*

Source: SEWRPC.

The provision of buffer strips around waterways, in every case, represents an important intervention that addresses anthropogenic sources of contaminants, with even the smallest buffer strip providing environmental benefit.[22] Map 41 shows the current status of riparian buffers along the Menomonee River and its major tributary streams. Approximately 11 miles of the Menomonee River stream system concentrated along Honey Creek, Underwood Creek, the South Branch of Underwood Creek, and Grantosa Creek, are enclosed conduits that in their current state offer limited opportunity for installation of such buffers as shown on Map 40. In general, buffers greater than 75 feet in width are largely associated with adjacent riparian wetland and woodland land types throughout the middle to upper portions of the Menomonee River watershed and these large buffers are primarily associated with adjacent recreational and park lands within the lower portions of the watershed.

Figure 102 shows the current status of buffer widths ranging from less than 25 feet, 25 to 50 feet, 50 to 75 feet, and greater than 75 feet among each of the major Menomonee River subwatersheds. The Honey Creek, Lilly Creek, and Dousman Ditch subwatersheds are dominated by buffers less than 25 feet in width compared to the rest of the subwatersheds, which are generally comprised of about 20 to 40 percent of this buffer width. The subwatersheds contained an average of about 12 percent and 7 percent of the buffer categories that ranged from 25 to 50 feet in width and 50 to 75 feet in width, respectively. The subwatersheds with the greatest proportion of the buffers greater than 75 feet in width include the Nor-X-Way Channel, West Branch, Butler Ditch, Willow Creek, Upper Menomonee River, South Branch of Underwood Creek, and North Branch Menomonee River.

SUMMARY AND STATUS OF IMPLEMENTATION OF ELEMENTS OF THE REGIONAL WATER QUALITY MANAGEMENT PLAN IN THE MENOMONEE RIVER WATERSHED

The initial regional water quality management plan for the Southeastern Wisconsin Region, which was adopted in 1979, had five elements: a land use element, a point source pollution abatement element, a nonpoint source pollution abatement element, a sludge management element, and a water quality monitoring element.[23] For the purposes of documenting current conditions and trends in water quality and pollution sources, it is deemed important to redocument the point source and nonpoint source pollution abatement elements of the regional water quality management plan as amended. This section provides that redocumentation and describes the action taken to implement that plan. Those two specific elements of the plan as they relate to the Menomonee River watershed and actions taken to implement them are described below for those components of the plan elements most directly related to water quality conditions.

Point Source Pollution Abatement Plan Element

The point source pollution abatement element of the initial plan made several recommendations regarding sanitary sewerage service in the Menomonee River watershed. The plan recommended the abandonment of the three public sewage treatment plants, one located in the Village of Germantown, and two located in the Village of Menomonee Falls, that were operating in the watershed in 1975. By 1986, these plants had been abandoned (see below). It also recommended abandonment of a privately owned sewage treatment plant at Brookfield Central High School. This plant was abandoned in 1980. The plan recommended that the attendant service areas for these plants be connected to the Milwaukee Metropolitan Sewerage District's sewerage system for treatment purposes. To facilitate that connection, the plan recommended the construction of two intercommunity trunk sewers to connect the City of Brookfield and the Villages of Germantown and Menomonee Falls to MMSD's system. In addition, the construction of two additional intercommunity trunk sewers was recommended to provide additional

[22] *A. Desbonnet, P. Pogue, V. Lee, and N. Wolff, "Vegetated Buffers in the Coastal Zone - a summary review and bibliography,"* CRC Technical Report No. 2064. *Coastal Resources Center, University of Rhode Island, 1994.*

[23] *SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume One,* Inventory Findings, *September 1978; Volume Two,* Alternative Plans, *February 1979; Volume Three,* Recommended Plan*, June 1979.*

Map 41

RIPARIAN CORRIDOR WIDTHS WITHIN THE MENOMONEE RIVER WATERSHED: 2000

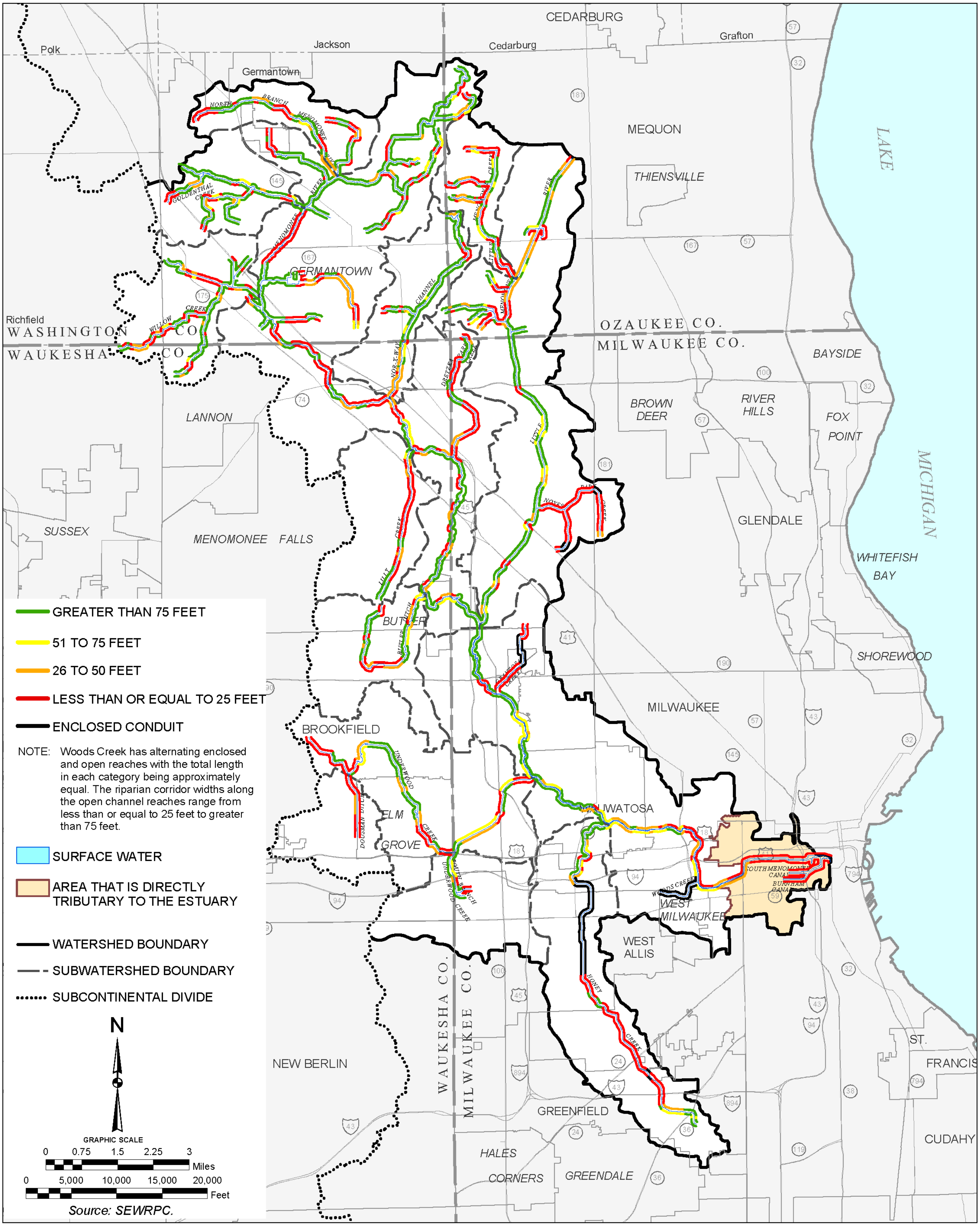
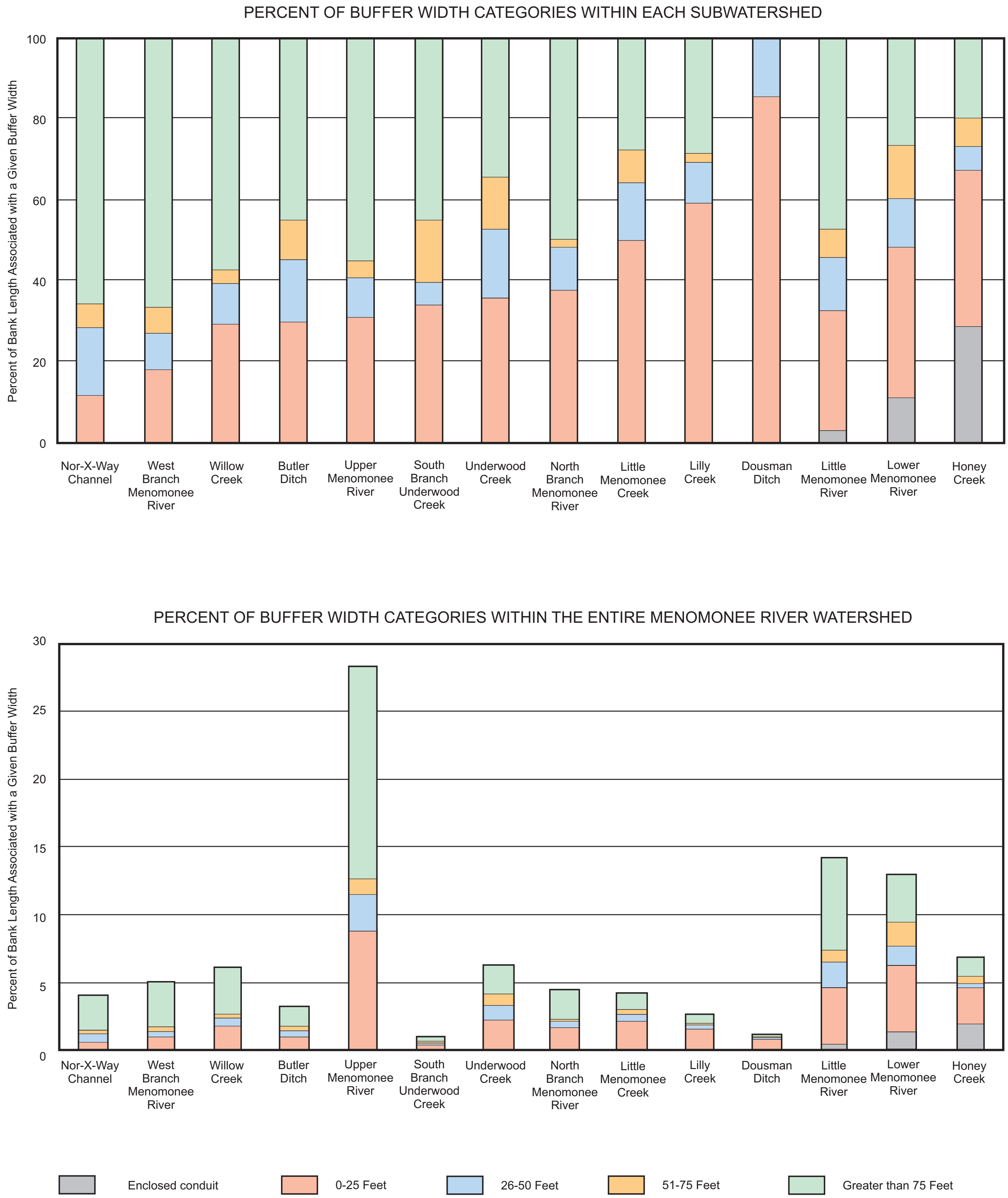


Figure 102

RIPARIAN CORRIDOR BUFFER WIDTHS WITHIN THE MENOMONEE RIVER WATERSHED: 2000



Source: SEWRPC.

capacity to convey wastewater from the Cities of Brookfield and Wauwatosa and the Villages of Butler, Elm Grove, and Menomonee Falls to MMSD's system. These trunk sewers were completed over the period 1977 to 1986. Finally the initial plan recommended the refinement of sanitary sewer service areas for all sewer areas in the watershed. As of 2005, this had been done for all service areas in the watershed except for MMSD, which, in the Menomonee River watershed, is almost entirely served by sewers.

A preliminary recommendation to abate separate sewer overflows and combined sewer overflows through the provision of large subterranean conveyance and storage facilities to contain separate and combined sewer peak flows in excess of sewage system capacity was originally made in the comprehensive plan for the Milwaukee River watershed.[24] The initial regional water quality management plan deferred recommendation on adoption of this alternative pending completion of the facility planning related to MMSD's Water Pollution Abatement Program. This planning effort, documented in a series of reports by MMSD,[25] recommended construction of a deep tunnel inline storage system in conjunction with construction of a shallow relief sewer system. These recommendations were adopted as an amendment to the regional water quality management plan as part of the water resources management plan for the Milwaukee Harbor estuary.[26] This system was subsequently constructed and began operation in 1994.

In 1975, there were 26 combined sewer outfalls and 140 known separate sewer overflow relief devices located in the Menomonee River watershed. Overflows typically occurred over 50 times per year. Currently combined sewer bypasses have been reduced to less than three per year. Likewise, the number of sanitary sewer overflows has been markedly reduced from the 1975 conditions.

In 1975, there were 48 point sources of wastewater other than public and private sewage treatment plants. These sources discharged industrial cooling, process, rinse, and wash waters through 78 outfalls directly, or indirectly, to the surface water system. The initial regional water quality management plan included a recommendation that these industrial point sources of wastewater be monitored, and discharges limited to levels determined on a case-by-case basis under the WPDES permit process. Currently, this recommendation has been nearly fully implemented for the point sources that currently exist in the watershed, the only exception being an unplanned discharge or spill.

Due to the dynamic nature of permitted point sources, it is recognized that the number of wastewater sources changes as industries and other facilities change locations or processes and as decisions are made with regard to the connection of such sources to public sanitary sewer systems. Many of the historic dischargers are now connected to the public sanitary sewer system.

Nonpoint Source Pollution Abatement Plan Element

The nonpoint source element of the original plan described a variety of methods and practices for abatement of nonpoint source pollution in urban and rural areas and estimated the percent reduction of released pollutants that could be achieved through implementation of these methods and practices. It identified ammonia-nitrogen,

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[24]*SEWRPC Planning Report No. 13,* A Comprehensive Plan for the Milwaukee River Watershed, *Volume One,* Inventory Findings and Forecasts, *December 1970; Volume Two,* Alternative Plans and Recommended Plan, *October 1971.*

[25]*Milwaukee Metropolitan Sewerage District,* Combined Sewer Overflows, *June 1980; Milwaukee Metropolitan Sewerage District,* Inline Storage Facilities Plan, *February 1982; Milwaukee Metropolitan Sewerage District,* Combined Sewer Overflows Advanced Facilities Plan, *December 1983.*

[26]*SEWRPC Planning Report No. 37,* A Water Resources Management Plan for the Milwaukee Harbor Estuary, *Volume One,* Inventory Findings, *March 1987; Volume Two,* Alternative and Recommended Plans, *December 1987.*

phosphorus, and fecal coliform bacteria as pollutants requiring nonpoint source control in the Menomonee River watershed. For urban areas, it recommended septic system management, construction site erosion control, and implementation of urban land practices sufficient to produce a 25 percent reduction in pollutants released to the streams of the watershed. For rural areas, it recommended livestock waste control and conservation practices sufficient to produce a 25 percent reduction in pollutants released to the streams of the watershed. In addition, it recommended the remediation of PAH contamination within the channel of the Little Menomonee River that was initially recommended in the comprehensive plan for the Menomonee River watershed.[27] These remediation efforts began in 2001 and are ongoing (see below).

In 1984, the Menomonee River watershed was designated a priority watershed under the Wisconsin Nonpoint Source Priority Watershed Pollution Abatement Program.[28] This plan identified the need for reductions in sediment loadings, phosphorus loadings, and heavy metal loadings to the streams of the watershed in order to meet water quality objectives. In addition, it recommended a number of management actions and practices to be implemented over the period 1991 to 1999 for both urban and rural lands and provided funding for a variety of activities related to abatement of nonpoint source pollution. The plan recommendations for nonpoint source pollution control for both rural and urban land were partially implemented as of 1995.

Several additional measures to abate nonpoint source pollution have been instituted since adoption of the initial plan. Facilities engaged in certain industrial activities have been required to apply for and obtain stormwater discharge permits under the WPDES and to develop and follow storm water pollution prevention plans. All the incorporated communities and two Towns in the watershed have applied for WPDES discharge permits, adopted stormwater management plans or ordinances, and construction site erosion control ordinances. In addition, these communities will be required to develop new or update existing stormwater management ordinances to be consistent with the standards of Chapter NR 151 of the *Wisconsin Administrative Code.* These measures are described more fully in the section on nonpoint source pollution in this chapter.

SOURCES OF WATER POLLUTION

An evaluation of water quality conditions in the Menomonee River watershed must include an identification, characterization, and where feasible, quantification of known pollution sources. This identification, characterization, and quantification is intended to aid in determining the probable causes of water pollution problems.

Point Source Pollution

Point source pollution is defined as pollutants that are discharged to surface waters at discrete locations. Examples of such discrete discharge points include sanitary sewerage system flow relief devices, sewage treatment plant discharges, and industrial discharges.

Sewage Treatment Plants

In 1975, there were three public sewage treatment facilities located in the Menomonee River watershed. All three plants, the Village of Germantown plant and the Village of Menomonee Falls Riverside and Parkview plants, discharged treated effluent directly to the mainstem of the Menomonee River. All three plants were abandoned after 1975 and the attendant service areas were connected to the MMSD system for treatment purposes, as recommended in the initial water quality management plan. The status of implementation in regard to the abandonment of public and private sewage treatment plants in the Menomonee River watershed, as recommended

[27] *SEWRPC Planning Report No. 26,* A Comprehensive Plan for the Menomonee River Watershed, *October 1976.*

[28] *Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the Menomonee River Priority Watershed Project, *Publication WR-244-92, March 1992.*

Table 66

IMPLEMENTATION STATUS OF THE INITIAL REGIONAL WATER QUALITY MANAGEMENT PLAN FOR PUBLIC SEWAGE TREATMENT PLANTS IN THE MENOMONEE RIVER WATERSHED: 2004

Plant	Receiving Water	Plan Recommendation	Implementation Status	Year of Implementation
Village of Germantown Plant	Menomonee River	Abandon plant	Plant abandoned	1986
Village of Menomonee Falls–Riverside Plant	Menomonee River	Abandon plant	Plant abandoned	1981
Village of Menomonee Falls–Parkview Plant............	Menomonee River	Abandon plant	Plant abandoned	1981

NOTE: The Village of Germantown plant was formerly known as the Old Village Plant, the Village of Menomonee Falls Riverside plant was formerly known as the Pilgrim Road plant, and the Village of Menomonee Falls Parkview plant was formerly known as the Lilly Road plant.

Source: SEWRPC.

in the initial regional water quality management plan, is summarized in Table 66. Currently, the Milwaukee Metropolitan Sewerage District Jones Island and South Shore treatment plants serve the existing sewered portions of the Menomonee River watershed. It should be noted that in 1975, the base year of the initial plan, and in 1990, there were no privately owned sewage treatment plants discharging to the stream system of the Menomonee River watershed. There are currently no privately owned sewage treatment plants in the Menomonee River watershed.

The initial regional water quality management plan recommended that all of the sanitary sewer service areas identified in the plan be refined and detailed in cooperation with the local units of government concerned. There were eight sewer service areas identified within, or partially within, the Menomonee River watershed: Mequon, Germantown, Menomonee Falls, Butler, Brookfield East, Elm Grove, New Berlin, and the Milwaukee Metropolitan Sewerage District. Currently, all of the sewer service areas within the watershed have undergone refinements as recommended, with the exception of the Milwaukee Metropolitan Sewerage District which is currently almost entirely served by sewer. Table 67 lists the plan amendment prepared for each initial refinement, the date the Commission adopted the document as an amendment to the regional water quality management plan, and the date the Commission adopted the amendment to the regional water quality management plan for the most recent refinement to the sewer service area. The table also identifies the original service area names and the relationship of these service areas to the service area names following the refinement process. The planned sewer service area in the Menomonee River watershed, as refined through June 2004, totals about 49.3 square miles, or about 38 percent of the total watershed area. Planned sewer service areas in the Menomonee River watershed are shown on Map 42.

Sanitary Sewer Overflow (SSO) Sites in the Watershed

By 1993, work was completed by the Milwaukee Metropolitan Sewerage District on its Water Pollution Abatement Program, including construction of the Inline Storage System and major relief sewers. As a result of this project, many of the flow relief devices within the watershed have recently been eliminated. Those which remain include combined sewer overflows and sanitary sewer overflows. During the period from August 1995 to August 2002, overflows were reported at 26 SSO locations. Table 68 gives the locations of sanitary sewer overflow locations in the Menomonee River watershed for MMSD and four local communities. Several overflow events occurred during the period August 1995 to August 2002. Table 68 indicates the number of days during which overflow occurred at each location. The SSO sites were being incorporated into the water quality model are indicated on Map 43.

Combined Sewer Overflows (CSOs)

Combined sewer overflows are potential sources of pollution within the watershed. MMSD has 28 combined sewer overflow outfalls that discharge to the Menomonee River watershed. These outfalls can convey diluted sewage from the combined sewer system to the surface water system of the watershed as a result of high water

Table 67

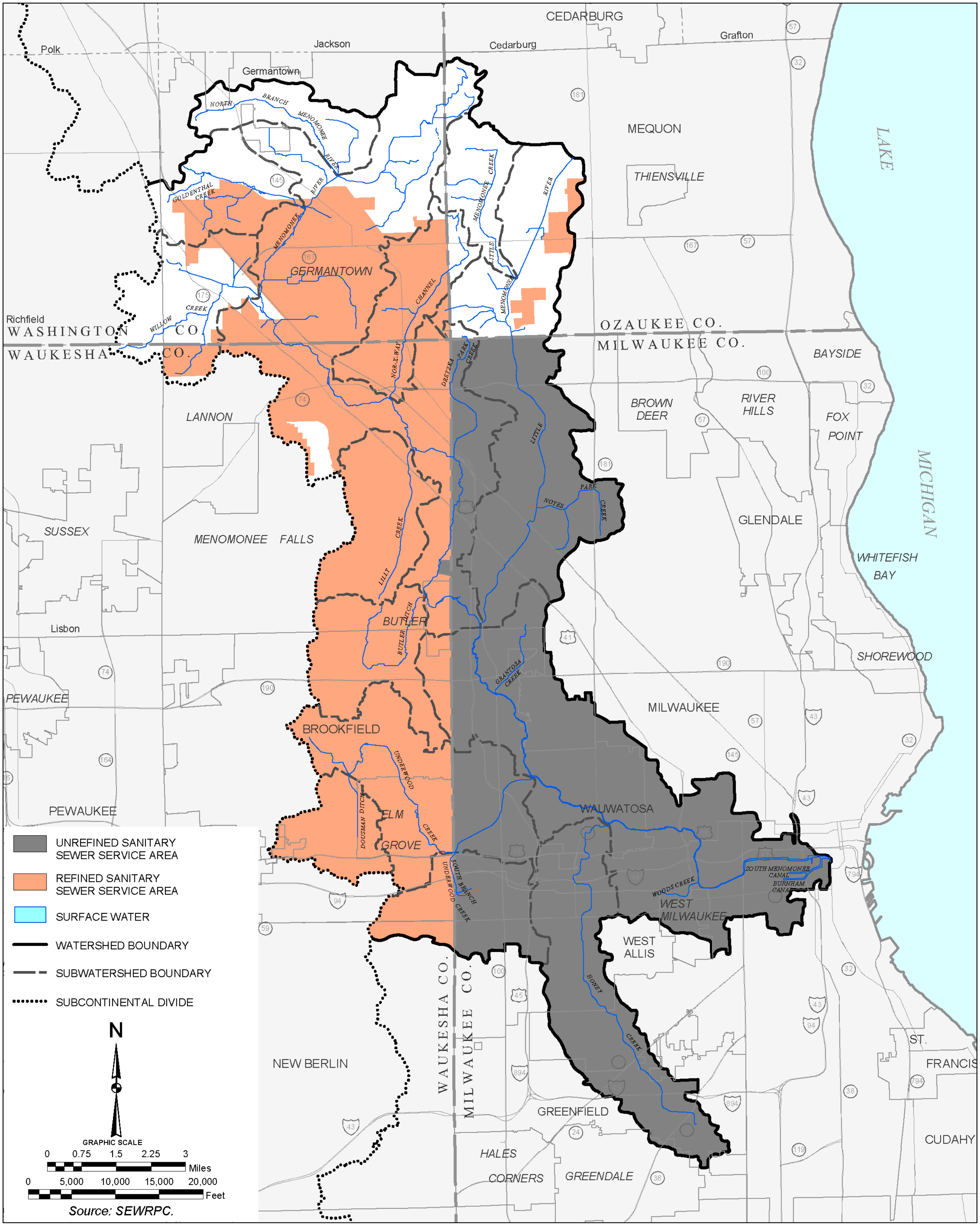
PLANNED SANITARY SEWER SERVICE AREAS IN THE MENOMONEE RIVER WATERSHED: 2004

Name of Initially Defined Sanitary Sewer Service Area	Planned Sewer Service Area (square miles)	Name of Refined and Detailed Sanitary Sewer Service Area(s)	Initial Plan Amendment Document	Date of SEWRPC Adoption of Initial Plan Amendment	Date of SEWRPC Adoption of Most Recent Plan Amendment
Refined Sanitary Sewer Area					
Brookfield East Elm Grove Brookfield West	15.1	Brookfield East Brookfield West	SEWRPC CAPR No. 109, *Sanitary Sewer Service Area for the City and Town of Brookfield and the Village of Elm Grove, Waukesha County, Wisconsin*	December 4, 1991	June 17, 1998
Butler	0.8	Butler	SEWRPC CAPR No. 99, *Sanitary Sewer Service Area for the Village of Butler, Waukesha County, Wisconsin*	March 1, 1984	- -
Germantown	13.9	Germantown	SEWRPC CAPR No. 70, *Sanitary Sewer Service Area for the Village of Germantown, Washington County, Wisconsin*	September 8, 1983	December 3, 2003
Menomonee Falls	17.8	Menomonee Falls Lannon	SEWRPC CAPR No. 208, *Sanitary Sewer Service Area for the Villages of Lannon and Menomonee Falls, Waukesha County, Wisconsin*	June 16,1993	June 16, 2004
Mequon Thiensville	1.0	Mequon-Thiensville	SEWRPC CAPR No. 188, *Sanitary Sewer Service Area for the City of Mequon and the Village of Thiensville, Ozaukee County, Wisconsin*	January 15, 1992	June 21, 1995
New Berlin	0.7	New Berlin	SEWRPC CAPR No. 157, *Sanitary Sewer Service Area for the City of New Berlin, Waukesha County, Wisconsin*	December 7, 1987	March 3, 1999
Subtotal	49.3	- -	- -	- -	- -
Unrefined Sanitary Sewer Service Areas					
Milwaukee Metropolitan Sewerage District	55.2	- -	- -	- -	- -
Subtotal	55.2	- -	- -	- -	- -
Total	104.5	- -	- -	- -	- -

Source: SEWRPC.

Map 42

PLANNED SEWER SERVICE AREAS WITHIN THE MENOMONEE RIVER WATERSHED: 2004



Source: SEWRPC.

Table 68

SEPARATE SANITARY SEWER OVERFLOW LOCATIONS IN THE MENOMONEE RIVER WATERSHED

Identification Number	Location	Community or Agency	Number of Days with Overflow: August 1995 to August 2002
229	W. State Street and N. 46th Street	MMSD	13
233	W. Fisher Parkway and N. 106th Street	MMSD	3
234	Honey Creek Parkway at W. Portland Avenue	MMSD	2
235	Honey Creek Parkway at W. Wisconsin Avenue	MMSD	6
237	Menomonee River Parkway, 300 feet east of N. 68th Street	MMSD	4
247	S. 74th Street and W. Oklahoma Avenue	MMSD	4
262	N. 59th Street and W. Trenton Avenue	MMSD	9
BR01	Burlawn Lift Station	Brookfield	5
BR03	Burlawn Parkway and Robin Lane	Brookfield	1
BR06	Burlawn Parkway and Hampstead Drive	Brookfield	7
BR07	Pinewood Road and Princeton Road	Brookfield	5
BR08	Arbor Drive and Center Drive	Brookfield	1
BR09	Lilly Road and Adelaide Drive	Brookfield	4
BR10	Indianwood Drive	Brookfield	1
BR13	Cardinal Crest Drive	Brookfield	5
BR14	Robinwood Street and Webster Avenue	Brookfield	5
EG01	Manhole 064 Wayburn Drive	Elm Grove	7
EG02	Manhole 035 Notre Dame Boulevard	Elm Grove	1
EG03	15200 Block of Briarridge Court	Elm Grove	1
EG04	Manhole 090 Terrace Drive	Elm Grove	7
GE01	Lift Station 5	Germantown	1
GE02	Division Road (500 feet south of Main Street)	Germantown	1
GE03	Mequon Road (600 feet east of Western Avenue)	Germantown	1
MF05	Appleton Avenue and Jacobson Drive	Menomonee Falls	3
MF13	Greenview Court	Menomonee Falls	1
MF14	Lucerne Drive and Schlafer Drive	Menomonee Falls	3
MI07	N. 110th Street and W. Harvest Lane	Milwaukee	4
MI30	N. 67th Street and W. Center Street	Milwaukee	2
MI33	N. 75th Street and W. Hadley Street	Milwaukee	2
MI35	N. 86th Street and W. Center Street	Milwaukee	0
MI36	N. 87th Street and W. Center Street	Milwaukee	1
MI37	N. 88th Street and W. Center Street	Milwaukee	0
MI38	N. 88th Street and W. Concordia Avenue	Milwaukee	3
MI39	N. 89th Street and W. Center Street	Milwaukee	1
MI42	S. 72nd Street and W. Honey Creek Drive	Milwaukee	1
WA02	S. 77th Street and W. Pierce Avenue	West Allis	2
WA04	S. 110th Street and W. Greenfield Avenue	West Allis	4
WA08	S. 84th Street and W. Cleveland Avenue	West Allis	1

Table 68 (continued)

Identification Number	Location	Community or Agency	Number of Days with Overflow: August 1995 to August 2002
WW01	1930 Menomonee River Parkway	Wauwatosa	7
WW02	8526 W. Meinecke Avenue	Wauwatosa	1
WW03	8848 Ravenswood Circle	Wauwatosa	1
WW04	9123 W. Jackson Park Boulevard	Wauwatosa	9
WW05	Glenview Avenue and Currie Avenue	Wauwatosa	1
WW06	Glenview Avenue and W. Hawthorne Avenue	Wauwatosa	12
WW07	Hillside Lane (200 feet east of N. 66th Street)	Wauwatosa	1
WW08	Hillside Lane (at N. 66th Street in Cul-de sac)	Wauwatosa	2
WW09	N. 90th Street and Menomonee River Parkway	Wauwatosa	1
WW10	W. Palmetto Avenue and N. 98th Street	Wauwatosa	1
WW11	Watertown Plank Road and N. 116th Street	Wauwatosa	1
WW12	Watertown Plank Road and N. 118th Street	Wauwatosa	1
WW13	806 N. 68th Street	Wauwatosa	1
WW14	N. 115th Street (515 feet South of Watertown Plank Road)	Wauwatosa	1
WW15	W. Fisher Parkway and 104th Street	Wauwatosa	1
WW16	115th Street and Underwood Parkway	Wauwatosa	1
WW17	N. 68th Street at Menomonee River	Wauwatosa	1

NOTE: For the MMSD Sanitary Sewer Overflow Locations, the Identification Number corresponds to the WPDES permit number.

Source: Wisconsin Department of Natural Resources; Milwaukee Metropolitan Sewerage District; Triad Engineering, Inc.; and SEWRPC.

volume from stormwater, meltwater, and excessive infiltration and inflow of clear water during wet weather conditions. This conveyance occurs in order to prevent damage to residential dwellings or the mechanical elements of the conveyance system during such events. The locations of these outfalls are shown on Map 43. Associated with these CSO outfalls is a set of sample collectors which obtain samples of the effluent discharged during overflow events for chemical and bacteriological analysis. The assignments of collectors to outfalls is shown in Table 69. Over the period August 1995 to August 2002, the mean number of days during which individual outfalls discharged to the river system was 13.5. Associated with this mean was high variability among outfalls. There were no known discharges from many of these outfalls during this period. Other outfalls discharged over as many as 45 days. There was also variation in the number of outfalls involved in particular discharge events. Some CSO events were quite localized, consisting of discharge from only one outfall. Others occurred over a large portion of the CSO area, involving discharge from as many as 16 outfalls into the river system. The mean number of outfalls discharging on any day that discharge occurred was 7.7.

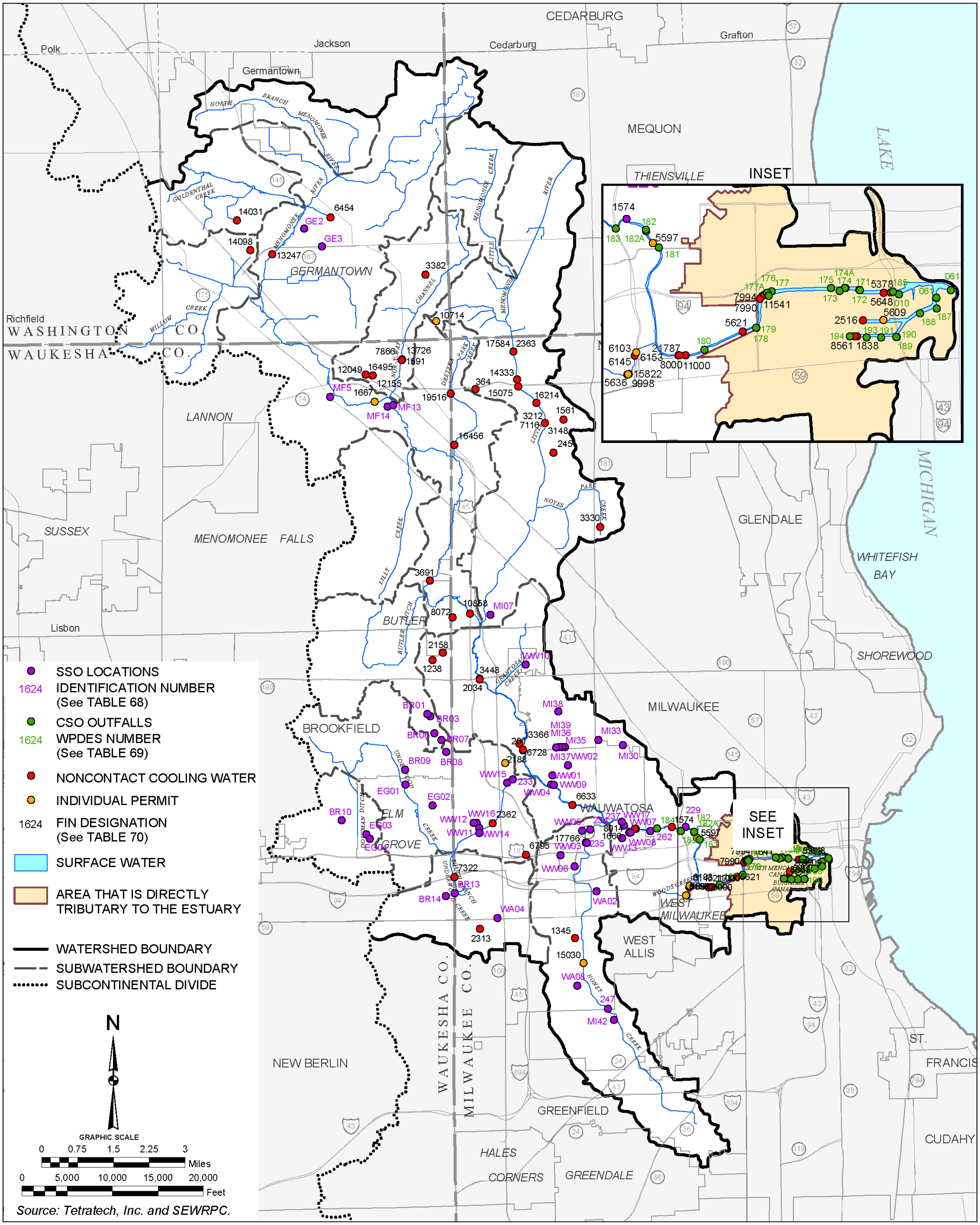
Other Known Point Sources

Industrial Discharges

The number of known industrial wastewater permitted dischargers in the Menomonee River watershed has increased over time. In 1975, there were a total of 48 known industrial wastewater permitted dischargers identified in the watershed. These permitted facilities discharged cooling, process, rinse, and wash waters to

Map 43

POINT SOURCES OF POLLUTION IN THE MENOMONEE RIVER WATERSHED: 2003



Source: Tetratech, Inc. and SEWRPC.

Table 69

COMBINED SEWER OVERFLOW OUTFALL LOCATIONS IN THE MENOMONEE RIVER WATERSHED

WPDES Number	Location	Collector[a]	Outfall Size (inches)	Number of Days with Overflow August 1995 to August 2002
10	W. Canal Street and 8th Street	Unknown	48	0
61	Emergency Wastewater Exit Facility	Unknown	180 x 144	0
170	S. 2nd Street	CT 8	54	5
171	N. Muskego Avenue	CT 7	30	0
172	N. Muskego Avenue	CT 7	54	18
173	N. 15th Street	CT 7	84 x 48[b]	17
174	N. 15th Street	CT 7	84 x 48	17
174A	N. 16th Street and Pittsburgh Street	CT 7	42	16
175	N. 17th Street	CT 7	69 x 42	18
176	N. 17th Street	CT 5/6	84 x 84[b]	45
177	N. 25th Street	CT 5/6	84 x 72[c]	42
177A	N. 25th Street	CT 5/6	96[a]	41
178	S. 27th Street	CT 5/6	48	27
179	S. 27th Street	CT 5/6	48	0
180	S. 35th Street	CT 5/6	60	0
181	W. Wisconsin Avenue	CT 3/4	24	0
182	N. 43rd Street	CT 3/4	144 x 72	37
182A	N. 43rd Street	CT 3/4	54	30
183	N. 45th Street	CT 3/4	60	0
184	N. Hawley Road	CT 2	102 x 60	15
185	N. 9th Street	CT 7	96	18
187	S. 4th Street	CT 8	48	16
188	S. 6th Street	CT 8	30	15
189	S. 9th Street	CT 7	54	0
190	S. 9th Street	CT 7	78	0
191	S. 11th Street	CT 7	36	0
193	S. 13th Street	CT 7	60	0
194	S. Muskego Avenue	CT 7	78	0

[a]*CT stands for Cross Town Tunnel Location.*

[b]*Double outfall.*

[c]*Triple outfall.*

Source: Milwaukee Metropolitan Sewerage District; Triad Engineering, Inc.; and SEWRPC.

surface waters.[29] In 1990, 132 permitted facilities discharged wastewater to the Menomonee River, its tributaries, or the groundwater system.[30]

[29]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *September 1978.*

[30]*SEWRPC Memorandum Report No. 93,* op. cit.

Table 70 lists the industrial discharge permits in effect through the WPDES during February 2003 in the Menomonee River watershed. At that time, 150 WPDES industrial permits were in effect in the watershed. Individual permits represent 12 of these permits, the rest are spread among nine categories of general permits. The most common category of general permit issued in this watershed was for the discharge of noncontact cooling water. There were 67 facilities in the watershed covered by permits in this category which regulates the discharge of noncontact cooling water, boiler blowdown, and air conditioning condensate. The other general permit categories were each represented by 17 or fewer facilities. Data from discharge monitoring reports for several facilities covered by individual permits or general permits for noncontact cooling water were included in water quality modeling for the regional water quality management plan update and the MMSD 2020 Facility Plan. These sites are shown on Map 42.

Due to the dynamic nature of permitted point sources, it is recognized that the number of wastewater sources in the watershed will change as industries and other facilities change locations or processes and as decisions are made with regard to the connection of such sources to public sanitary sewer systems.

Nonpoint Source Pollution

Urban Stormwater Runoff

As shown in Table 51, as of the year 2000, urban land uses within the Menomonee River watershed were primarily residential (29.8 percent), followed by transportation, communication, and utilities (16.8 percent); and industrial, governmental and institutional, commercial, and recreational each of which fell in the range of about 4 to 5 percent of the watershed area. Chapter II of this report includes descriptions of the types of pollutants associated with specific urban nonpoint sources.

Chapter NR 216, "Storm Water Discharge Permits," of the *Wisconsin Administrative Code* establishes the requirements for the stormwater discharge permitting program for industries, municipalities, and construction sites. The rule was promulgated in November of 1994.

Regulation of Urban Nonpoint Source Pollution through the Wisconsin Pollutant Discharge Elimination System Permit Program

Facilities engaged in industrial activities listed in Section NR 216.21(2)(b) of Chapter NR 216 of the *Wisconsin Administrative Code* must apply for and obtain a stormwater discharge permit. The WDNR originally developed a three-tier system of industrial storm water permits. Tier 1 permits apply to facilities involved in heavy industry and manufacturing, including facilities involved in lumber and wood product manufacturing, leather tanning, and primary metal industries. Tier 2 permits apply to facilities involved in light industry and manufacturing and transportation facilities, including facilities involved in printing, warehousing, and food processing. Tier 3 permits previously were be issued to facilities which have certified, with WDNR concurrence, that they have no discharges of contaminated storm water. WDNR authority for Tier 3 permits no longer exists and the Tier 3 permits have been terminated. Facilities now submit a certificate of no exposure. In addition, the WDNR also issues separate permits for automobile parts recycling facilities and scrap recycling facilities. Associated with each category of permit are specific requirements for monitoring and inspection. For all categories of permits except Tier 3 industrial permits, the permit requires the facility to develop and follow a storm water pollution prevention plan (SWPPP). Specific requirements for the SWPPP are listed in Chapter NR 216.27 of the *Wisconsin Administrative Code*. They include provisions related to site mapping, implementation scheduling, conducting annual plan assessments, and monitoring of discharge.

As shown in Appendix G, "WPDES Permitted Stormwater Facilities," 267 industrial stormwater permits were in effect in the Menomonee River watershed in February 2003. All construction sites that disturb one acre of land or more are required to obtain coverage under the General Permit. Permitted construction sites are required to implement a construction erosion control plan, and a post-construction stormwater management plan as required in Chapter NR 216.46 and Chapter NR 216.47 of the *Wisconsin Administrative Code*. Owners of permitted construction sites are also required to conduct inspections of their construction erosion control measures on a weekly basis, and within 24 hours of a precipitation event of 0.5 inch or more. Most of these were Tier 2 permits.

Table 70

PERMITTED WASTEWATER DISCHARGERS UNDER THE WPDES GENERAL PERMIT AND INDIVIDUAL PERMIT PROGRAMS IN THE MENOMONEE RIVER WATERSHED: FEBRUARY 2003

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Carriage/Interstitial Water from Dredging[a]	- -	- -	- -	- -	- -	- -
Concrete Products Operations	American Concrete Pipe Company—Milwaukee	5000 N.124th Street	Milwaukee	0046507	241063020	8072
	Central Ready Mix LP	5013 W. State Street	Milwaukee	0046507	241519410	8219
	Meyer Material Company	633 S. 84th Street	Milwaukee	0046507	999820910	8208
	Stonecast Products, Inc.	N112 W14343 Mequon Road	Germantown	0046507	267147870	456
	Traditional Concrete Products	W142 N9110 Fountain Boulevard	Menomonee Falls	0046507	268028310	6763
	Zignego Ready Mix West—Plant 2	551 S. Curtis Road	West Allis	0046507	241322070	7097
Contaminated Groundwater Remedial Actions	Kaul Oil Company	5931 N. 91st Street	Milwaukee	0046566	241128250	14453
	Better Brands Distributing, Inc.	N162 W11819 N. Fond du Lac Avenue	Germantown	0046566	267116520	14499
	City of West Allis-Quad Graphics	555 S. 108th Street	West Allis	0046566	241083480	14616
	DANA Victor Products Division	11500 W. Brown Deer Road	Milwaukee	0046566	241245180	364
	DOA Wiscraft Facility	5316 W. State Street	Milwaukee	0046566	241347040	14617
	ExxonMobil Oil Corporation	7600 W. Bluemound Drive	Wauwatosa	0046566	268311560	14590
	Jims Auto Mart	6000 W. Forest Home Avenue	Milwaukee	0046566	241407980	14588
	Milsolv Corporation	N59 W14765 Bobolink Avenue	Menomonee Falls	0046566	268549600	14563
	Milwaukee County—Dretzka Park	12010 W. Bradley Road	Milwaukee	0046566	241133420	14506
	Milwaukee Electric Tool Corporation	13135 W. Lisbon Road	Brookfield	0046566	268016540	14471
	Mobil Oil Station 05-F1V	N96 W17500 County Line Road	Germantown	0046566	267094190	14704
	One Stop Mini Mart	4250 W. Greenfield Avenue	West Milwaukee	0046566	241164110	14582
	Sprinkman Sons Corporation	12100 W. Silver Spring Drive	Milwaukee	0046566	241451760	14601
	Total Petroleum	6745 W. Forest Home Avenue	Greenfield	0046566	241399620	14598
	Victor Products Div/Dana Corporation	11500 W. Brown Deer Road	Milwaukee	0046566	241245180	14467
	West Shore Pipe Line Company	W124 N9899 Wasaukee Road	Germantown	0046566	267058990	15438
	Wisconsin Electric Power Company—Valley Power Plant	1035 W. Canal Street	Milwaukee	0000931	241007800	5609
Hydrostatic Test Water and Water Supply System	BP Amoco Oil Company—Marketing Terminal Milwaukee	9101 N. 107th Street	Milwaukee	0057681	241223730	3464
	Butler Water Department	12975 W. Silver Spring Drive	Butler	0057681	268019180	13376
	Citgo Petroleum Corporation	9235 N. 107th Street	Milwaukee	0057681	241309090	13374
	Germantown Water Utility	N122 W17177 Fond du Lac Avenue	Germantown	0057681	267010590	13628
	Koch Pipeline Company LP	9343 N. 107th Street	Milwaukee	0057681	241016160	1866
	Marathon Ashland Petroleum LLC—Milwaukee	9125 N. 127 Street	Milwaukee	0057681	241078640	3620
	Menomonee Falls Water Utility	W152 N8634 Margarett Road	Menomonee Falls	0057681	268008290	14077
	Milwaukee County Grounds	10310 Watertown Plank Road	Wauwatosa	0057681	241077870	14081
	US Oil Company, Inc.	9521 N. 107th Street	Milwaukee	0057681	241017700	14100
	Wauwatosa Waterworks	7725 W. North Avenue	Wauwatosa	0057681	241059620	14103
	West Allis Water Department	6302 W. McGeoch Avenue	West Allis	0057681	241059500	14104
	West Shore Pipeline Company	11115 W. County Line Road	Milwaukee	0057681	241019460	14001
Land Applying Liquid Industrial Wastes	Germantown Orchards Appleworks	W179 N12536 Fond du Lac Avenue	Germantown	0055867	267133680	10137

Table 70 (continued)

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Noncontact Cooling Water	Advanced Metal Treating, Inc.	4501 N. 127th Street	Butler	0044938	268086500	2158
	Aldrich Chemical Co., Inc.—Emmber	230 S. Emmber Lane	Milwaukee	0044938	241222410	2516
	Aldrich Chemical Co., Inc.—St. Paul Avenue	940 St. Paul Avenue	Milwaukee	0044938	241046410	5378
	Alliant Food Service Corporation	W137 N9245 Hwy. 145	Menomonee Falls	0044938	268089690	7866
	American Concrete Pipe Company—Milwaukee	5000 N. 124th Street	Milwaukee	0046507	241063020	8072
	Ampco Metal Manufacturing, Inc.	1745 S. 38th Street	Milwaukee	0044938	241031670	8000
	A. O. Smith Corporation	12100 W. Park Place	Milwaukee	0044938	241336920	16456
	Badger Alloys, Inc.	5120 W. State Street	Milwaukee	0044938	241372120	1574
	Blue Mound Golf & Country Club	10122 W. North Avenue	Wauwatosa	0044938	241407430	13366
	Brenntag Great Lakes	W14765 Bobolink Avenue	Menomonee Falls	0044938	999986020	1951
	Carlisle Tire & Wheel Company—Midwest Division	8480 N. 87th Street	Milwaukee	0044938	241381580	1561
	D. R. Diedrich & Companu Ltd	2615 W. Greves Street	Milwaukee	0044938	241038490	7994
	CHR Hansen, Inc.	9015 W. Maple Street	West Allis	0044938	241013080	1345
	Crestwood Bakery	1710 S. 108th Street	West Allis	0044938	241078750	2313
	DANA Victor Products Division	11500 W. Brown Deer Road	Milwaukee	0044938	241245180	364
	Empire Level Manufacturing Corporation	10950 W. Potter Road	Milwaukee	0044938	241119450	2362
	Falk Corporation	3001 W. Canal Street	Milwaukee	0044938	241008240	5621
	Falk Corporation Plant 2	12001 W. Capitol Drive	Milwaukee	0044938	241018140	2034
	Froedtert Memorial Lutheran Hospital	9200 W. Wisconsin Avenue	Wauwatosa	0044938	241469580	17766
	Gehl Guernsey Farms, Inc.	N116 W15970 Main Street	Germantown	0044938	267005090	6454
	GKN Sinter Metals	N92 W15800 Megal Drive	Menomonee Falls	0044938	268230490	16495
	GKN Sinter Metals	N112 W18700 Mequon Road	Germantown	0044938	268013790	13247
	GKN Sinter Metals	W156 N9305 Tipp Street	Menomonee Falls	0044938	268225100	12049
	Grede Foundries, Inc.—Liberty Foundry	6432 W. State Street	Wauwatosa	0044938	241012310	8014
	Hampel Corporation	W194 N11551 McCormick Drive	Germantown	0044938	267079450	14031
	Handschy Industries	N57 W13640 Reichert Avenue	Menomonee Falls	0044938	268009170	3691
	Harley-Davidson Motor Company Operations, Inc.	W156 N9000 Pilgrim Road	Menomonee Falls	0044938	268523790	12155
	Harley-Davidson Motor Company Operations, Inc.	11700 W. Capitol Drive	Wauwatosa	0044938	241005600	3448
	Helwig Carbon Products, Inc.	8900 W. Tower Avenue	Milwaukee	0044938	241370140	7116
	Hentzen Coatings, Inc.—Milwaukee	6937 W. Mill Road	Milwaukee	0044938	241017590	3330
	IDC Aerospace, LLC	8050 W. Fairlane Avenue	Milwaukee	0044938	341053680	21587
	IFF Dairy Ingredients	N92 W14244 Anthony Avenue	Menomonee Falls	0044938	268483380	23881
	International Flavors & Fragrances, Inc.	N92 W14350 Anthony Avenue	Menomonee Falls	0044938	268510440	13726
	Journal/Sentinel, Inc.	4041 W. Burnham Street	Milwaukee	0044938	341055880	21787
	Kelch Corporation	N85 W12545 Westbrook Crossing	Menomonee Falls	0044938	268190340	19516
	Lesaffre Yeast Corporation	2702 W. Greves Street	Milwaukee	0044938	241031340	11541
	Masterson Company, Inc.	4023 W. National Avenue	Milwaukee	0044938	241018470	11000
	Mid City Foundry	1521 Bruce Street	Milwaukee	0044938	241029800	1838
	Midwestern Anodizing Corporation	10909 Heather Lane	Milwaukee	0044938	241049600	15075
	Miller Compressing Company—Mainyard	1640 Bruce Stret	Milwaukee	0044938	241213720	8561
	Milwaukee Brush Manufacturing Company	W142 N9251 Fountain Boulevard	Menomonee Falls	0044938	268061700	1591
	Milwaukee County Institutions Power Plant	9250 Watertown Plank Road	Milwaukee	0044938	241027050	6633
	Milwaukee Electric Tool Corporation	13135 W. Lisbon Road	Brookfield	0044938	268016540	1238
	Milwaukee Logistic Center	11400 W. Burleigh Street	Milwaukee	0044938	241028700	201
	Milwaukee Wire Products	9201 W. Heather Avenue	Milwaukee	0044938	241001420	16214
	Motor Castings Company—Plant 1 West Allis	1323 S. 65th Street	West Allis	0044938	241008680	5636
	Perlick Corporation	8300 W. Good Hope Road	Milwaukee	0044938	241017370	245
	Phoenix Metal Treating	W190 N11350 Carnegie Drive	Germantown	0044938	267078790	14098
	R & B Wagner, Inc.	10600 W. Brown Deer Road	Milwaukee	0044938	241717960	14333
	ReGenco LLC	6609R W. Washington Street	West Allis	0044938	241000990	15822
	Rexnord Corporation—Milwaukee Facility	4701 W. Greenfield Avenue	Milwaukee	0044938	241012200	6145

Table 70 (continued)

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Noncontact Cooling Water (continued)	Roundys, Inc.	11300 W. Burleigh Street	Wauwatosa	0044938	241279390	2188
	Service Continuous, Inc.	10536 W. Glenbrook Court	Milwaukee	0044938	241003180	17584
	Service Heat Treating, Inc.	9320 N. 107th Street	Milwaukee	0044938	241042010	2363
	Siemens Westinghouse Power Corporation—BOS Facility	6682 Greenfield Avenue	West Allis	0044938	241347920	9998
	Silgan Containers Manufacturing Corporation	N90 W14600 Commerce Drive	Menomonee Falls	0044938	268008400	12688
	Smith & Nephew Rolyan—Rehabilitation Division	N104 W13464 Donges Bay Road	Germantown	0044938	267129280	3382
	Solvox Manufacturing Company	11725 W. Fairview Avenue	Milwaukee	0044938	241249470	7322
	St. Joseph's Hospital	10010 W. Bluemound Road	Wauwatosa	0044938	241063350	6795
	Stroh Die Casting Company, Inc.	11123 W. Burleigh Street	Milwaukee	0044938	241051580	6728
	Super Steel Products Corporation	7900 W. Tower Avenue	Milwaukee	0044938	241026500	3212
	Thiele Tanning Company	123 N. 27th Street	Milwaukee	0044938	241042670	7990
	Western Metal—Specialty Division	1211 N. 62nd Street	Wauwatosa	0044938	241662410	1666
	Wisconsin Electric Power Company—Milwaukee Heating Plant	3rd Street and Water Street and Canal St.	Milwaukee	0044938	241009780	5648
	Xymox Technologies, Inc.	9099 W. Dean Road	Milwaukee	0044938	241709970	3148
	Wis-Pak Foods, Inc.	4700 N. 132nd Street	Butler	0044938	268016430	10858
Nonmetallic Mining Operations	American Asphalt Paving, Inc.	N56 W12828 Silver Spring Road	Menomonee Falls	0046515	268028420	1588
	Lake Shore Sand—Milwaukee	515 W. Canal Street	Milwaukee	0046515	241095800	11528
	Milwaukee Marble & Granite Company, Inc.	4535 W. Mitchell Street	Milwaukee	0046515	241007250	1185
	Northwest Asphalt Products, Inc.	11710 W. Hampton Avenue	Milwaukee	0046515	241027160	620
Petroleum Contaminated Water	BP Amoco Oil Company—Marketing Terminal Milwaukee	9101 N. 107th Street	Milwaukee	0057681	241223730	3464
	Canadian Pacific Railway	504 S. Layton Boulevard	Milwaukee	0046531	241441750	8584
	Citgo Petroleum Corporation	9235 N. 107th Street	Milwaukee	0057681	241309090	13374
	Koch Pipeline Company LP	9343 N. 107th Street	Milwaukee	0046531	241016160	1866
	Milwaukee Petroleum Products Terminal	9135 N. 107th Street	Milwaukee	0046531	241053560	14094
	Milwaukee Regional Medical Center Heliport	9200 W. Wisconsin Avenue	Wauwatosa	0046531	241228680	14082
	Union Pacific Railroad—Butler Yard	4823 N. 119th Street	Milwaukee	0046531	241012860	14099
	US Oil Company, Inc.	9521 N. 107th Street	Milwaukee	0057681	241017700	14100
	US Oil Milwaukee—Central Terminal	9451 N. 107th Street	Milwaukee	0046531	241033760	13345
	Waste Management of Wisconsin, Inc.	W124 N8925 Boundary Road	Menomonee Falls	0046531	268361280	16651
	West Shore Pipeline Company	11115 W. County Line Road	Milwaukee	0057681	241019460	14001
Pit/Trench Dredging	Shea/Kenny JV	1600 Swan Boulevard	Wauwatosa	0049344	341059290	22427
Potable Water Treatment and Conditioning	Citation Corporation—Plant 1	W139 N5470 Oak Lane	Menomonee Falls	0046540	268222240	14054
	Citation Corporation—Plant 2	W140 N5516 Lilly Road	Menomonee Falls	0046540	268439050	14052
	Citation Corporation—Plant 3	W137 N5500 Williams Place	Menomonee Falls	0046540	268358530	14050
	Citation Corporation—Plant 6	W137 N5427 Williams Place	Menomonee Falls	0046540	268438940	14053
	Harley-Davidson Motor Company Operations, Inc.	W156 N9000 Pilgrim Road	Menomonee Falls	0044938	268523790	12155
	Harley-Davidson Motor Company Operations, Inc.	11700 W. Capitol Drive	Wauwatosa	0046540	241005600	3448
	International Flavors & Fragrances, Inc.	N92 W14350 Anthony Avenue	Menomonee Falls	0044938	268510440	13726
	Journal/Sentinel, Inc.	4041 W. Burnham Street	Milwaukee	0044938	341055880	21787
	Maysteel Corporation—Menomonee Falls Division	N89 W14700 Patrita Drive	Menomonee Falls	0046540	268144250	1090
Swimming Pool Facilities	Menomonee Falls School District—Menomonee Falls H.S.	W142 N8101 Merrimac Drive	Menomonee Falls	0046523	268229720	14080
	Menomonee Falls School District—Menomonee Falls Jr. H.S.	N88 W16750 Garfield Avenue	Menomonee Falls	0046523	268353030	14076
	Milwaukee County Parks and Recreation—Hoyt Park Pool	1800 Swan Boulevard	Wauwatosa	0046523	241520290	14057
	Milwaukee County Parks and Recreation—McCarty Park Pool	2567 S. 79th Street	West Allis	0046523	241520730	14061
	Milwaukee County Parks and Recreation—Noyes Park Pool	8235 W. Good Hope Road	Milwaukee	0046523	241520840	14068
	Milwaukee County Parks and Recreation—Washington Park Pool	1849 N. 40th Stree	Milwaukee	0046523	241133310	24208
	Milwaukee Public Schools—Hamilton High School	6215 W. Warnimont Avenue	Milwaukee	0046523	241521390	14073
	Milwaukee Public Schools—Vincent High School	7501 N. Granville Road	Milwaukee	0046523	241428220	14093

Table 70 (continued)

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Swimming Pool Facilities (continued)	Wauwatosa School District—East High School Pool	7500 Milwaukee Avenue	Wauwatosa	0046523	241465070	13542
	Wauwatosa School District—West High School Pool	11400 W. Center Street	Wauwatosa	0046523	241423710	13541
	YMCA of Metro Milwaukee—Tri County Branch	N84 W17501 Menomonee Avenue	Menomonee Falls	0046523	268355120	14108
Individual Permits	A C Reorganization Trust	1126 S. 70th Street	West Allis	0026778	241012420	6153
	Briggs & Stratton Corporation—Wauwatosa	3300 N. 124th Street	Wauwatosa	0026514	241011870	6140
	Gerett Products	W156 N9073 Pilgrim Road	Menomonee Falls	0041505	268007740	1667
	Milwaukee Gray Iron, LLC	1501 S. 83rd Street	West Allis	0000507	241006370	5581
	Miller Brewing	4000 W. State Street	Milwaukee	0000744	241007030	5597
	P & H Mining Equipment	4400 W. National Avenue	Milwaukee	0025321	241010990	6103
	Southeast Wisconsin Professional Baseball Park District	1135 S. 70th Street	Milwaukee	S049921	241051030	16716
	Waste Management—Omega Hills	SH SEQ Sec 36 T9N R20E	Germantown	0049514	267058660	10714
	West Allis Memorial Hospital	8901 W. Lincoln Avenue	West Allis	0059510	241168180	15030
	Wisconsin Electric Power Company—Germantown	N96 W19298 County Line Road	Germantown	0042757	267006190	6745
	Wisconsin Electric Power Company—Valley Power Plant	1035 W. Canal Street	Milwaukee	0000931	241007800	5609

[a]*There were no active WPDES general permits for Carriage/Interstitial Water from Dredging in the Menomonee River watershed during February 2003.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

With 179 of these permits in effect, this category represented about two-thirds of the permitted facilities in the watershed. Tier 3 permits were the next most common in the watershed. In February 2003, 56 of these were in effect. There were 12 or fewer each of Tier 1, Automobile Parts Recycling, and Scrap Recycling permits in effect in the watershed at this time.

The WDNR also issues and administers construction site stormwater permits through the WPDES General Permits program. Due to the dynamic nature of construction activities, it is recognized that the number of sites requiring Construction Site Storm Water permits in the watershed will change as construction projects are completed and new projects are initiated.

The WPDES stormwater permits for municipalities within the watershed are described below.

Chapter NR 151 of the Wisconsin Administrative Code
Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*, which was promulgated in September 2002, establishes performance standards for the control of nonpoint source pollution from agricultural lands, nonagricultural (urban) lands, and transportation facilities. The standards for urban lands apply to areas of existing development, redevelopment, infill, and construction sites. In general, the construction erosion control, post-construction nonpoint source pollution control, and stormwater infiltration requirements of Chapter NR 151 apply to projects associated with construction activities that disturb at least one acre of land.

The urban standards are applied to activities covered under the WPDES program for stormwater discharges. As noted below, communities with WPDES stormwater discharge permits must adopt stormwater management ordinances that have requirements at least as stringent as the standards of Chapter NR 151. Those communities must also achieve levels of control of nonpoint source pollution from areas of existing development (as of October 1, 2004) that are specified under Chapter NR 151.

Stormwater Management Systems
Stormwater management facilities are defined, for purposes of this report, as conveyance, infiltration, or storage facilities, including, but not limited to, subsurface pipes and appurtenant inlets and outlets, ditches, streams and engineered open channels, detention and retention basins, pumping facilities, infiltration facilities, constructed wetlands for treatment of runoff, and proprietary treatment devices based on settling processes and control of oil and grease. Such facilities are generally located in urbanized areas and constructed or improved and operated for purposes of collecting stormwater runoff from tributary drainage areas and conveying, storing, and treating such runoff prior to discharge to natural watercourses. In the larger and more intensively developed urban communities, these facilities consist either of complete, largely piped, stormwater drainage systems which have been planned, designed, and constructed as systems in a manner similar to sanitary sewer and water utility systems, or of fragmented or partially piped systems incorporating open surface channels to as great a degree as possible. In the Menomonee River watershed, the stormwater drainage systems have historically provided the means by which a significant portion of the nonpoint source of pollutants reach the surface water system. However, about 8 percent of the watershed area is served by combined sanitary and storm sewers, with most of the runoff from that area being conveyed to MMSD sewage treatment facilities. That results in a high level of nonpoint source pollution control of runoff from the combined sewer service area.

With the relatively recent application of the WPDES permitting program to stormwater discharges and the adoption of local stormwater management ordinances, controls on the quality of stormwater runoff prior to discharge to receiving streams have become more common. Table 71 indicates the status of stormwater management activities in each of the communities in the Menomonee River watershed.

Table G-2 in Appendix G indicates that the Cities of Brookfield, Greenfield, Mequon, Milwaukee, New Berlin, Wauwatosa, and West Allis; the Villages of Butler, Elm Grove, Germantown, Greendale, Menomonee Falls, and West Milwaukee; and the Towns of Brookfield, Lisbon, and Richfield have WPDES stormwater discharge permits. Thus, all of the incorporated communities in the watershed and three towns, comprising 99 percent of

Table 71

STORMWATER MANAGEMENT INFORMATION FOR CITIES, VILLAGES, AND TOWNS WITHIN THE MENOMONEE RIVER WATERSHED

Civil Division	Stormwater Management Ordinance and/or Plan	Construction Erosion Control Ordinance	Stormwater Utility, General Fund, and/or Established Stormwater Fee Program
Ozaukee County			
City of Mequon	X	X	- -
Milwaukee County			
City of Greenfield	X	X	- -
City of Milwaukee	X	X	X
City of Wauwatosa	X	X	X
City of West Allis	X	X	X
Village of Greendale	X	X	- -
Village of West Milwaukee	- -[a]	X	- -
Washington County			
Town of Germantown	- -	- -	- -
Town of Richfield	- -[a]	- -[a]	- -
Village of Germantown	X	X	- -
Waukesha County			
City of Brookfield	X	X	- -
City of New Berlin	X	X	X
Town of Brookfield	X	X	X
Town of Lisbon	X	X	- -
Village of Butler	X	X	X
Village of Elm Grove	X	X	X
Village of Menomonee Falls	X	X	- -

[a]*Will adopt ordinances as required under their WPDES stormwater discharge permit.*

Source: SEWRPC.

the watershed area have been issued WPDES stormwater discharge permits. In addition to specific nonpoint source pollution control activities recommended under their WPDES permits, these communities will also all be required to develop new, or update existing, stormwater management ordinances to be consistent with the standards of Chapter NR 151 of the *Wisconsin Administrative Code*. As part of their permit application, each community prepared maps of the stormwater outfalls that are part of the municipal separate stormwater system.

Urban Enclaves Outside Planned Sewer Service Areas

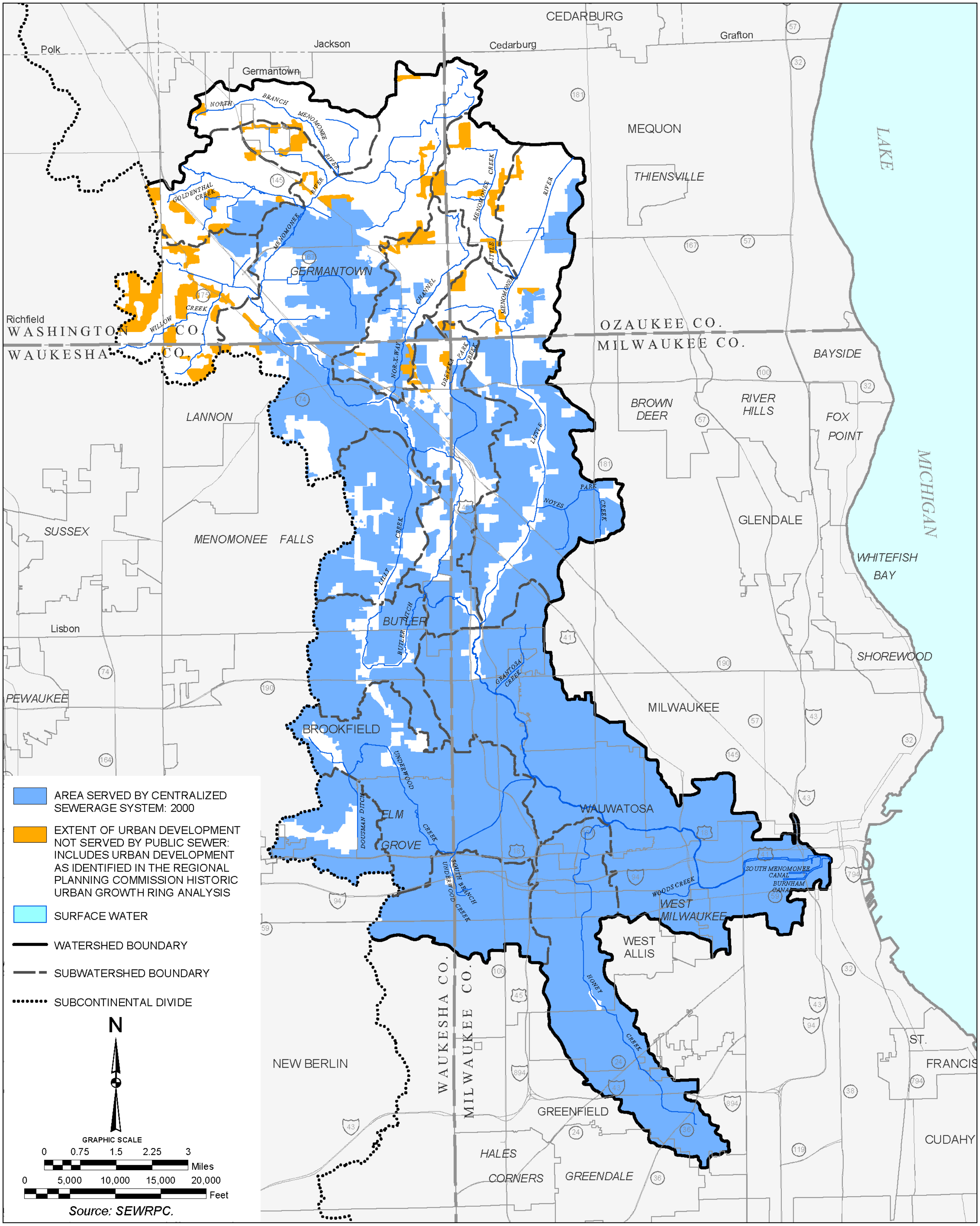
There are limited enclaves of urban development located outside the planned sewer service areas which can be located through comparison of Maps 42 and 44. These cover an area of about 2,909 acres representing about 3.3 percent of the watershed. As described in Chapter II of this report, failure of onsite disposal systems can contribute nonpoint source pollutants to streams and groundwater.

Solid Waste Disposal Sites

Solid waste disposal sites are a potential source of surface water, as well as groundwater, pollution. It is important to recognize, however, the distinction between a properly designed and constructed solid waste landfill and the variety of operations that are referred to as refuse dumps, especially with respect to potential effects on water quality. A solid waste disposal site may be defined as any land area used for the deposit of solid wastes regardless of the method of operation, or whether a subsurface excavation is involved. A solid waste landfill may be defined as a solid waste disposal site which is carefully located, designed, and operated to avoid hazards to public health or safety, or contamination of groundwaters or surface waters. The proper design of solid waste landfills requires

Map 44

AREAS SERVED BY CENTRALIZED SANITARY SEWERAGE SYSTEMS WITHIN THE MENOMONEE RIVER WATERSHED: 2000



careful engineering to confine the refuse to the smallest practicable area, to reduce the refuse mass to the smallest practicable volume, to avoid surface water runoff, to minimize leachate production and percolation into the groundwater and surface waters, and to seal the surface with a layer of earth at the conclusion of each day's operation or at more frequent intervals as necessary.

In order for a landfill to produce leachate, there must be some source of water moving through the fill material. Possible sources include precipitation, the moisture content of the refuse itself, surface water infiltration, groundwater migrating into the fill from adjacent land areas, or groundwater rising from below to come in contact with the fill. In any event, leachate is not released from a landfill until a significant portion of the fill material exceeds its saturation capacity. If external sources of water are excluded from the solid waste landfill, the production of leachates in a well-designed and managed landfill can be effectively minimized if not entirely avoided. The quantity of leachate produced will depend upon the quantity of water that enters the solid waste fill site minus the quantity that is removed by evapotranspiration. Studies have estimated that for a typical landfill, from 20 to 50 percent of the rainfall infiltrated into the solid waste may be expected to become leachate. Accordingly, a total annual rainfall of about 35 inches, which is typical of the Menomonee River watershed, could produce from 190,000 to 480,000 gallons of leachate per year per acre of landfill if the facility is not properly located, designed, and operated.

As of 2005, there was one active, licensed, privately owned and operated solid waste landfill within the Menomonee River watershed, the WMWI Orchard Ridge Landfill in the Village of Menomonee Falls. This facility accepts municipal wastes as well as a variety of other categories of waste including pulp and paper mill manufacturing wastes, foundry wastes, and publicly owned sewage treatment plant sludge. As of January 2004, it had slightly over 1.2 million cubic yards of capacity remaining and had an estimated remaining site life of two years.

As of 2005, there were one active and seven inactive solid waste landfills within the watershed. As set forth in Table 72 and shown on Map 45.

Rural Stormwater Runoff

Rural land uses within the Menomonee River watershed include agricultural—both livestock operations and crop production—and woodlands, wetlands, water, and other open lands as set forth in the beginning of this chapter. As noted above, Chapter NR 151 of the *Wisconsin Administrative Code* establishes performance standards for the control of nonpoint source pollution from agricultural lands, nonagricultural (urban) lands, and transportation facilities. Agricultural performance standards are established for soil erosion, manure storage facilities, clean water diversions, nutrient management, and manure management. Those standards must only be met to the degree that grant funds are available to implement projects designed to meet the standards.

Livestock Operations

The presence of livestock and poultry manure in the environment is an inevitable result of animal husbandry and is a major potential source of water pollutants. Animal manure, composed of feces, urine, and sometimes bedding materials, contributes suspended solids, nutrients, oxygen-demanding substances, bacteria, and viruses to surface waters. Presently in the watershed, there are still several small dairies with less than 100 animals, one large dairy with over 400 animals, and several horse-boarding facilities. Additionally, there are other forms of animal agriculture including hogs, poultry, and a large herd of beef cattle that has over 400 steers. Animal waste constituents of pastureland and barnyard runoff, and animal wastes deposited on pastureland and cropland and in barnyards, feedlots, and manure piles, can potentially contaminate water by surface runoff, infiltration to the groundwater, and volatilization to the atmosphere. During the warmer seasons of the year the manure is often scattered on cropland and pastureland where the waste material is likely to be taken up by the vegetative growth composing the land cover. However, when the animal manure is applied to the land surface during the winter, the animal wastes are subject to excessive runoff and transport, especially during the spring snowmelt period.

Table 72

ACTIVE AND INACTIVE SOLID WASTE DISPOSAL SITES IN THE MENOMONEE RIVER WATERSHED: 2004

Number on Map 45	Facility Name	Address	Municipality	Classification	Subwatershed	License Number	Status
1	Schreiner Landfill	- -	Germantown	Landfill, unclassified	Nor-X-Way Channel	880	Inactive
2	Waste Management WI, Parkview Recycling and Disposal	N96 W13475 County Line Road	Menomonee Falls	Landfill >500,000 cubic yards	Upper Menomonee River	3108	Inactive
3	Waste Management WI, Orchard Ridge Recycling and Disposal	W124 N9355 Boundary Road	Menomonee Falls	Landfill >500,000 cubic yards	Upper Menomonee River	3360	Active
4	Waste Management WI, Boundary Road Landfill	Menomonee Falls	Menomonee Falls	Landfill, unclassified	Upper Menomonee River	11	Inactive
5	Milwaukee County Hartung Quarry Landfill	W. Concordia Avenue	Milwaukee	Landfill >500,000 cubic yards monofil	Lower Menomonee River	1501	Inactive
6	Milwaukee County Institutions	8731 W. Watertown Plank	Wauwatosa	Landfill, unclassified	Underwood Creek	194	Inactive
7	Wauwatosa City Landfill	11100 W. Walnut Road	Wauwatosa	Landfill >500,000 cubic yards monofill	Underwood Creek	525	Inactive
8	Village of West Milwaukee Landfill	4755 W. Beloit Road	West Milwaukee	Landfill 0-50,000 cubic yards	Lower Menomonee River	1272	Inactive

Source: Wisconsin Department of Natural Resources and SEWRPC.

Crop Production

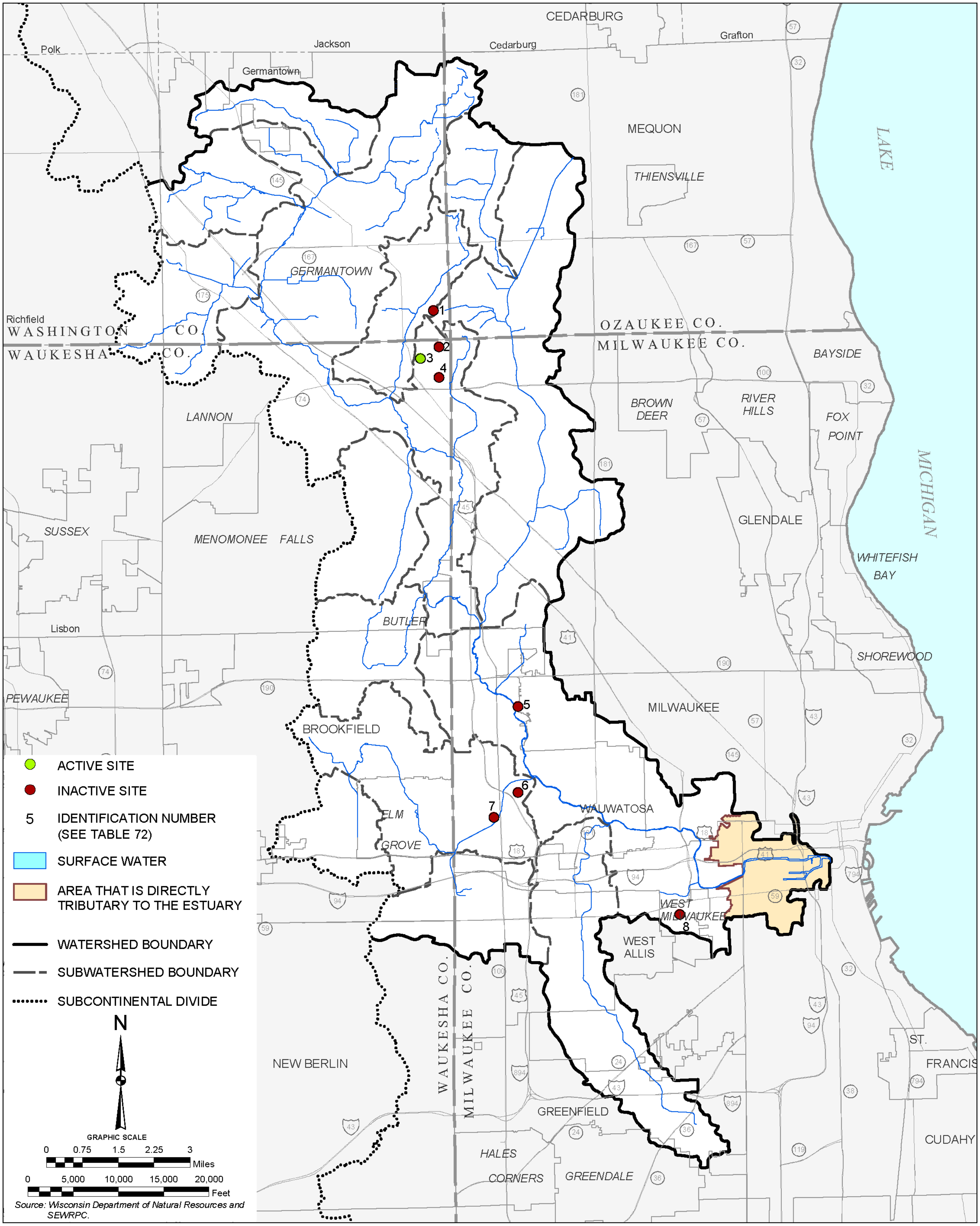
In the absence of mitigating measures, runoff from cropland can have an adverse effect upon water quality within the Menomonee River watershed by contributing excess sediments, nutrients, and organic matter, including pesticides to streams. Negative effects associated with soil erosion and transport to waterbodies includes reduced water clarity, sedimentation on streambeds, and contamination of the water from various agricultural chemicals and nutrients that are attached to the individual soil particles. Some of these nutrients, in particular phosphorus, and to some extent nitrogen, are directly associated with eutrophication of water resources. The extent of the water pollution from cropping practices varies considerably as a result of the soils, slopes, and crops, as well as in the numerous methods of tillage, planting, fertilization, chemical treatment, and conservation practices. Conventional tillage practices, or moldboard plowing, involve turning over the soil completely, leaving the soil surface bare of most cover or residue from the previous year’s crop, and making it highly susceptible to erosion due to wind and rain. The use of conservation tillage practices has become common in the watershed in recent years within areas most susceptible to erosion and surface water impacts.

Crops grown in the Menomonee River watershed include row crops, such as corn and soybeans; small grains, such as wheat and oats; hay, such as clover, alfalfa, and timothy; vegetables, such as cabbage, peas, and sweet corn; and specialty crops, such as strawberries. Row and vegetable crops, which have a relatively higher level of exposed soil surface, tend to contribute higher pollutant loads than do hay and pastureland, which support greater levels of vegetative cover. Crop rotations typically follow a two- or three-year sequence of corn and soybeans and occasionally winter wheat in the third year. However, hay is periodically included as part of a long-term rotation of corn, oats, and alfalfa.

Since the early 1930s, it has been a national objective to preserve and protect agricultural soil from wind and water erosion. Federal programs have been developed to achieve this objective, with the primary emphasis being on sound land management and cropping practices for soil conservation. An incidental benefit of these programs has been a reduction in the amount of eroded organic and inorganic material entering surface waters as sediment or attached to sediment. Some practices are effective in both regards, while others may enhance the soil conditions with little benefit to surface water quality. Despite the implementation of certain practices aimed at

Map 45

ACTIVE AND INACTIVE SOLID WASTE DISPOSAL SITES WITHIN THE MENOMONEE RIVER WATERSHED: 2004



controlling erosion of soil from agricultural land, and development of soil erosion control plans for the portions of the Menomonee River basin in Milwaukee,[31] Ozaukee,[32] Washington,[33] and Waukesha[34] counties, such erosion and the resultant deposition of sediment in the streams of the Menomonee River watershed remains a significant water resource problem. Soil erosion from agricultural lands is one of the major sources of sediment and nutrients in the Menomonee River and its tributaries.

Nutrients such as phosphorus and agri-chemicals, including certain herbicides and pesticides, are electrostatically attracted to silt sized particles and are transported to surface waters through soil erosion. As previously mentioned, phosphorus is one of the primary nutrients associated with eutrophication of water resources, and agri-chemicals can negatively impact the life cycle of aquatic organisms. In the eutrophication process, phosphorus enhances growth of aquatic vegetation and algae, which has the effect of accelerating the aging process of a water resource. Phosphorus is usually not susceptible to downward movement through the soil profile; instead, the majority of phosphorus reaches water resources by overland flow, or erosion. Nitrogen also is a nutrient that contributes to eutrophication; however, it is most often associated with subsurface water quality contamination. Nitrogen in the form of nitrate can be associated with respiration problems in newborn infants. Nitrogen is susceptible to downward movement through the soil profile; however, due to the nature of soils in the watershed, nitrogen is not as significant a threat due to various chemical reactions that occur within the soil.[35]

Woodlands
A well-managed woodland contributes few pollutants to surface waters. Under poor management, however, woodlands may have detrimental water quality effects through the release of sediments, nutrients, organic matter, and pesticides into nearby surface waters. If trees along streams are cut, thermal pollution may occur as the direct rays of the sun strike the water. Disturbances caused by tree harvesting, livestock grazing, tree growth promotion, tree disease prevention, fire prevention, and road and trail construction are a major source of pollution from silvicultural activities. Most of these activities are seldom practiced in the Menomonee River watershed.

Pollution Loadings
Annual Loadings
Annual average point and/or nonpoint pollution loads to the Menomonee River watershed are set forth in Tables 73 through 79. Average annual per acre nonpoint source loads are set forth in Table 80 The nonpoint source load estimates represent loads delivered to the modeled stream reaches after accounting for any trapping factors that would retain pollutants on the surface of the land. They include loads from groundwater. It is important to note that the stream channel pollutant loads may be expected to be different from the actual transport from the watershed, because physical, chemical, and/or biological processes may retain or remove pollutants or change their form during transport within the stream system. These processes include particle deposition or

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[31]*Milwaukee County Land Conservation Committee,* Milwaukee County Land and Water Resource Management Plan, *April 2001.*

[32]*SEWRPC Community Assistance Planning Report No. 171,* Ozaukee County Agricultural Soil Erosion Control Plan, *February 1989.*

[33]*SEWRPC Community Assistance Planning Report No. 170,* Washington County Agricultural Soil Erosion Control Plan, *March 1989.*

[34]*SEWRPC Community Assistance Planning Report No. 159,* Waukesha County Agricultural Soil Erosion Control Plan, *June 1988.*

[35]*Soils that have a high clay content and stay wet for long periods of time, or even well-drained soils after a rainfall event are susceptible to nitrogen losses to the atmosphere through a chemical reaction known as denitrification. This reaction converts nitrate,* NO_3^-*, to gaseous nitrogen,* N_2*, which is lost to the atmosphere.*

Table 73

AVERAGE ANNUAL TOTAL NONPOINT SOURCE POLLUTANT LOADS IN THE MENOMONEE RIVER WATERSHED[a]

Subwatershed	Total Phosphorus (pounds)	Total Suspended Solids (pounds)	Fecal Coliform Bacteria (trillions of cells)	Total Nitrogen (pounds)	Biochemical Oxygen Demand (pounds)	Copper (pounds)
Butler Ditch	1,540	697,190	224.21	11,460	45,940	79
Honey Creek	3,920	1,877,260	2,342.75	27,520	120,120	211
Lilly Creek	1,290	719,720	200.56	12,450	46,640	74
Little Menomonee Creek	430	264,450	150.34	10,140	16,860	15
Little Menomonee River	4,140	2,413,410	2,203.09	47,420	159,030	241
Lower Menomonee River	7,250	4,011,510	4,068.19	50,250	239,060	429
North Branch Menomonee River	270	145,050	17.12	13,310	18,320	10
Nor-X-Way Channel	970	829,790	304.84	12,460	35,730	57
Underwood Creek	6,620	3,077,960	3,455.76	47,900	203,970	343
Upper Menomonee River	5,320	2,966,730	1,354.45	64,510	217,150	330
West Branch Menomonee River	610	335,650	79.21	13,270	32,280	42
Willow Creek	750	349,780	104.43	17,060	34,140	43
Total	33,110	17,688,500	14,504.95	327,750	1,169,240	1,874

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

Table 74

AVERAGE ANNUAL LOADS OF TOTAL PHOSPHORUS IN THE MENOMONEE RIVER WATERSHED[a]

Subwatershed	Point Sources				Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Butler Ditch	0	10	0	10	1,490	50	1,540	1,550
Honey Creek	200	10	0	210	3,900	20	3,920	4,130
Lilly Creek	0	0	0	0	1,200	90	1,290	1,290
Little Menomonee Creek	0	0	0	0	80	350	430	430
Little Menomonee River	360	<10	0	360	3,300	840	4,140	4,500
Lower Menomonee River	15,650	550	1,880	18,080	7,180	70	7,250	25,330
North Branch Menomonee River	0	0	0	0	50	220	270	270
Nor-X-Way Channel	160	0	0	160	630	340	970	1,130
Underwood Creek	30	10	0	40	6,350	270	6,620	6,660
Upper Menomonee River	1,150	<10	0	1,150	4,170	1,150	5,320	6,470
West Branch Menomonee River	0	0	0	0	370	240	610	610
Willow Creek	0	0	0	0	320	430	750	750
Total	17,550	580	1,880	20,010	29,040	4,070	33,110	53,120
Percent of Total Load	33.0	1.1	3.5	37.6	54.7	7.7	62.4	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

Table 75

AVERAGE ANNUAL LOADS OF TOTAL SUSPENDED SOLIDS IN THE MENOMONEE RIVER WATERSHED[a]

Subwatershed	Point Sources				Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Butler Ditch	0	320	0	320	689,190	8,000	697,190	697,510
Honey Creek	800	470	0	1,270	1,874,860	2,400	1,877,260	1,878,530
Lilly Creek	0	0	0	0	666,000	53,720	719,720	719,720
Little Menomonee Creek	0	0	0	0	58,630	205,820	264,450	264,450
Little Menomonee River	2,530	30	0	2,560	1,976,270	437,140	2,413,410	2,415,970
Lower Menomonee River	51,660	31,670	182,960	266,290	4,001,330	10,180	4,011,510	4,277,800
North Branch Menomonee River	0	0	0	0	27,660	117,390	145,050	145,050
Nor-X-Way Channel	280	0	0	280	478,790	351,000	829,790	830,070
Underwood Creek	90	860	0	950	3,031,420	46,540	3,077,960	3,078,910
Upper Menomonee River	3,380	240	0	3,620	2,504,060	462,670	2,966,730	2,970,350
West Branch Menomonee River	0	0	0	0	232,070	103,580	335,650	335,650
Willow Creek	0	0	0	0	197,990	151,790	349,780	349,780
Total	58,740	33,590	182,960	275,290	15,738,270	1,950,230	17,688,500	17,963,790
Percent of Total Load	0.3	0.2	1.0	1.5	87.6	10.9	98.5	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

Table 76

AVERAGE ANNUAL LOADS OF FECAL COLIFORM BACTERIA IN THE MENOMONEE RIVER WATERSHED[a]

Subwatershed	Point Sources				Nonpoint Sources			Total (trillions of cells)
	Industrial Point Sources (trillions of cells)	SSOs (trillions of cells)	CSOs (trillions of cells)	Subtotal (trillions of cells)	Urban (trillions of cells)	Rural (trillions of cells)	Subtotal (trillions of cells)	
Butler Ditch	0.00	6.07	0.00	6.07	223.75	0.46	224.21	230.28
Honey Creek	0.00	9.01	0.00	9.01	2,342.61	0.14	2,342.75	2,351.76
Lilly Creek	0.00	0.00	0.00	0.00	199.31	1.25	200.56	200.56
Little Menomonee Creek	0.00	0.00	0.00	0.00	65.43	84.91	150.34	150.34
Little Menomonee River	0.00	0.52	0.00	0.52	2,097.81	105.28	2,203.09	2,203.61
Lower Menomonee River	0.00	604.24	1,727.39	2,331.63	4,067.91	0.28	4,068.19	6,399.82
North Branch Menomonee River	0.00	0.00	0.00	0.00	9.30	7.82	17.12	17.12
Nor-X-Way Channel	0.00	0.00	0.00	0.00	256.06	48.78	304.84	304.84
Underwood Creek	0.00	16.33	0.00	16.33	3,454.09	1.67	3,455.76	3,472.09
Upper Menomonee River	0.00	4.65	0.00	4.65	1,274.47	79.98	1,354.45	1,359.10
West Branch Menomonee River	0.00	0.00	0.00	0.00	62.41	16.80	79.21	79.21
Willow Creek	0.00	0.00	0.00	0.00	58.69	45.74	104.43	104.43
Total	0.00	640.82	1,727.39	2,368.21	14,111.84	393.11	14,504.95	16,873.16
Percent of Total Load	0.0	3.8	10.2	14.0	83.7	2.3	86.0	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

Table 77

AVERAGE ANNUAL LOADS OF TOTAL NITROGEN IN THE MENOMONEE RIVER WATERSHED[a]

Subwatershed	Point Sources				Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Butler Ditch	0	10	0	10	10,890	570	11,460	11,470
Honey Creek	640	20	0	660	27,300	220	27,520	28,180
Lilly Creek	0	0	0	0	9,530	2,920	12,450	12,450
Little Menomonee Creek	0	0	0	0	530	9,610	10,140	10,140
Little Menomonee River	1,350	<10	0	1,350	25,150	22,270	47,420	48,770
Lower Menomonee River	52,730	1,160	11,610	65,500	49,520	730	50,250	115,750
North Branch Menomonee River	0	0	0	0	310	13,000	13,310	13,310
Nor-X-Way Channel	100	0	0	100	4,350	8,110	12,460	12,560
Underwood Creek	20	30	0	50	45,090	2,810	47,900	47,950
Upper Menomonee River	810	10	0	820	32,240	32,270	64,510	65,330
West Branch Menomonee River	0	0	0	0	2,500	10,770	13,270	13,270
Willow Creek	0	0	0	0	1,930	15,130	17,060	17,060
Total	55,650	1,230	11,610	68,490	209,340	118,410	327,750	396,240
Percent of Total Load	14.1	0.3	2.9	17.3	52.8	29.9	82.7	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

Table 78

AVERAGE ANNUAL LOADS OF BIOCHEMICAL OXYGEN DEMAND IN THE MENOMONEE RIVER WATERSHED[a]

Subwatershed	Point Sources				Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Butler Ditch	0	80	0	80	44,260	1,680	45,940	46,020
Honey Creek	970	120	0	1,090	119,400	720	120,120	121,210
Lilly Creek	0	0	0	0	42,390	4,250	46,640	46,640
Little Menomonee Creek	0	0	0	0	3,570	13,290	16,860	16,860
Little Menomonee River	3,090	10	0	3,100	126,650	32,380	159,030	162,130
Lower Menomonee River	104,920	7,790	58,680	171,390	236,620	2,440	239,060	410,450
North Branch Menomonee River	0	0	0	0	2,200	16,120	18,320	18,320
Nor-X-Way Channel	450	0	0	450	26,530	9,200	35,730	36,180
Underwood Creek	200	210	0	410	194,480	9,490	203,970	204,380
Upper Menomonee River	6,880	60	0	6,940	164,500	52,650	217,150	224,090
West Branch Menomonee River	0	0	0	0	18,000	14,280	32,280	32,280
Willow Creek	0	0	0	0	14,790	19,350	34,140	34,140
Total	116,510	8,270	58,680	183,460	993,390	175,850	1,169,240	1,352,700
Percent of Total Load	8.6	0.6	4.4	13.6	73.4	13.0	86.4	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

Table 79

AVERAGE ANNUAL LOADS OF COPPER IN THE MENOMONEE RIVER WATERSHED[a]

Subwatershed	Point Sources				Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Butler Ditch	0	<1	0	<1	78	1	79	79
Honey Creek	1	<1	0	1	211	<1	211	212
Lilly Creek	0	0	0	0	73	1	74	74
Little Menomonee Creek	0	0	0	0	6	9	15	15
Little Menomonee River	0	<1	0	<1	224	17	241	241
Lower Menomonee River	3	5	48	56	428	1	429	485
North Branch Menomonee River	0	0	0	0	4	6	10	10
Nor-X-Way Channel	0	0	0	0	49	8	57	57
Underwood Creek	0	<1	0	<1	340	3	343	343
Upper Menomonee River	0	<1	0	<1	295	35	330	330
West Branch Menomonee River	0	0	0	0	33	9	42	42
Willow Creek	0	0	0	0	27	16	43	43
Total	4	5	48	57	1,768	106	1,874	1,931
Percent of Total Load	0.2	0.3	2.4	2.9	91.6	5.5	97.1	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

Table 80

AVERAGE ANNUAL PER ACRE NONPOINT SOURCE POLLUTANT LOADS IN THE MENOMONEE RIVER WATERSHED[a]

Subwatershed	Total Phosphorus (pounds)	Total Suspended Solids (pounds)	Fecal Coliform Bacteria (trillions of cells)	Total Nitrogen (pounds)	Biochemical Oxygen Demand (pounds)	Copper (pounds)
Butler Ditch	0.43	193	0.06	3.18	12.74	0.022
Honey Creek	0.56	270	0.34	3.95	17.25	0.030
Lilly Creek	0.36	198	0.06	3.42	12.81	0.020
Little Menomonee Creek	0.20	124	0.07	4.78	7.94	0.007
Little Menomonee River	0.35	205	0.19	4.03	13.52	0.020
Lower Menomonee River	0.59	328	0.33	4.11	19.53	0.035
North Branch Menomonee River	0.11	60	0.01	5.55	7.63	0.004
Nor-X-Way Channel	0.29	253	0.09	3.79	10.88	0.017
Underwood Creek	0.53	245	0.28	3.82	16.27	0.027
Upper Menomonee River	0.29	160	0.07	3.47	11.69	0.018
West Branch Menomonee River	0.21	115	0.03	4.53	11.02	0.014
Willow Creek	0.19	89	0.03	4.33	8.67	0.011

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

entrapment in floodplains, stream channel deposition or aggradation, biological uptake, and chemical transformation and precipitation. The total nonpoint source pollution loads set forth in Table 73 are representative of the total annual quantities of potential pollutants moved from the Menomonee River watershed into stream channels, but are not intended to reflect the total amount of the pollutants moving from those sources through the entire hydrologic-hydraulic system.

Tables 74 through 79 indicate that nonpoint source pollution loads comprise from 62 to 98 percent of the total pollution load, while point sources only account for 2 to 38 percent of the total load, depending on the pollutant.

Point Source Loadings

Annual average total point source pollutant loads of six pollutants in the Menomonee River watershed are set forth in Tables 74 through 79. Contributions of these pollutants by point sources represent from 2 percent of the total average annual load of total suspended solids to 38 percent of the total average annual loads of phosphorus.

Average annual point source loads of total phosphorus in the Menomonee River watershed are shown in Table 74. The total average annual point source load of total phosphorus is about 20,010 pounds. Most of this is contributed by the Lower Menomonee River subwatershed. Industrial dischargers represent about 88 percent of the point source contributions of total phosphorus, combined sewer overflows represent about 9 percent, and separate sanitary sewer overflows represent approximately 3 percent.

Average annual point source loads of total suspended solids in the Menomonee River watershed are shown in Table 75. The total average annual point source load of total suspended solids is about 275,290 pounds. About 97 percent of that load is contributed by the Lower Menomonee River subwatershed. Combined sewer overflows represent about 67 percent of the point source contributions of total suspended solids, industrial discharges represent about 21 percent, and separate sanitary sewer overflows represent about 12 percent.

Average annual point source loads of fecal coliform bacteria in the Menomonee River watershed are shown in Table 76. The total average annual point source loads of fecal coliform bacteria is about 2,368.21 trillion cells per year, which is contributed by separate sanitary sewer overflows in the Butler Ditch, Honey Creek, Little Menomonee River, Underwood Creek, and Upper and Lower Menomonee River subwatersheds (27 percent of the point source total) and combined sanitary sewer overflows in the Lower Menomonee River watershed (73 percent of the point source total).

Average annual point source loads of total nitrogen in the Menomonee River watershed are shown in Table 77. The total average annual point source load of total nitrogen is about 68,490 pounds. Most of this is contributed by the Lower Menomonee River subwatershed. Industrial discharges represent about 81 percent of the point source contributions of total nitrogen, combined sewer overflows represent about 17 percent, and separate sanitary sewer overflows represent about 2 percent.

Average annual point source loads of BOD in the Menomonee River watershed are shown in Table 78. The total average annual point source load of BOD is about 183,460 pounds. Most of this is contributed by the Lower Menomonee River subwatershed. Industrial discharges represent about 64 percent of the point source contributions of BOD, combined sewer overflows represent about 32 percent, and separate sanitary sewer overflows represent about 4 percent.

Average annual point source loads of copper in the Menomonee River watershed are shown in Table 79. The total average annual point source load of copper is about 57 pounds per year, almost all of which is contributed by the Lower Menomonee River subwatershed. Combined sewer overflows represent about 84 percent of the point source contributions of total suspended solids, industrial discharges represent about 7 percent, and separate sanitary sewer overflows represent about 9 percent.

Nonpoint Source Loads

Because nonpoint source pollution is delivered to streams in the watershed through many diffuse sources, including direct overland flow, numerous storm sewer and culvert outfalls, and swales and engineered channels, it would be prohibitively expensive and time-consuming to directly measure nonpoint source pollution loads to streams. Thus, the calibrated water quality model was applied to estimate average annual nonpoint source pollutant loads delivered to the streams in the watershed during the period from 1993 to 2002. The results of that analysis are set forth in Tables 73 through 79 and depicted graphically on Maps H-13 through H-24 in Appendix H. General water quality modeling procedures are described in Chapter V of SEWRPC Planning Report No. 50, *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds.*

Table 73 shows the average annual nonpoint pollutant loads in the Menomonee River watershed. Average annual per acre nonpoint source pollution loads for subwatersheds of the Menomonee River watershed are shown in Table 80. For some pollutants, such as total phosphorus, fecal coliform bacteria, biochemical oxygen demand, and copper, average per acre loads increase from upstream to downstream in the watershed and are higher in the more highly urbanized subwatersheds.

The average annual nonpoint load of total phosphorus is estimated to be 33,110 pounds per year. The distribution of the total load among the subwatersheds is shown on Map H-13 in Appendix H. Map H-14 shows the annual per acre loads of total phosphorus for the subwatersheds. Contributions of total phosphorus vary among the subwatersheds (see Table 73) from a low of 270 pounds per year from the North Branch Menomonee River subwatershed to 7,250 pounds per year from the Lower Menomonee River subwatershed. The highest loads of total phosphorus are contributed by the Lower Menomonee River and Underwood Creek subwatersheds. This reflects a combination of relatively large subwatershed size and relatively high unit area loads. The highest unit area loads occur in the Lower Menomonee subwatershed.

The average annual nonpoint load of total suspended solids is estimated to be 17,688,500 pounds per year. The distribution of this load among the subwatersheds is shown on Map H-15 in Appendix H. Map H-16 shows the annual per acre loads of total suspended solids for the subwatersheds. Contributions of total suspended solids vary among the subwatersheds (see Table 73) from a low of 145,050 pounds per year from the North Branch Menomonee River subwatershed to 4,011,510 pounds per year from the Lower Menomonee River subwatershed. The highest loads of total suspended solids are contributed by the Lower Menomonee River and Underwood Creek subwatersheds. That reflects a combination of relatively large subwatershed size and relatively high unit area loads. The highest unit area loads occur in the Lower Menomonee subwatershed.

The average annual nonpoint load of fecal coliform bacteria is estimated to be 14,504.95 trillion cells per year. The distribution of this load among the subwatersheds is shown on Map H-17 in Appendix H. Map H-18 shows the annual per acre loads of fecal coliform bacteria for the subwatersheds. Contributions of fecal coliform bacteria vary among the subwatersheds (see Table 73) from a low of 17.12 trillion cells per year from the North Branch Menomonee River subwatershed to 4,068.19 trillion cells per year from the Lower Menomonee River subwatershed. The highest loads of fecal coliform bacteria are contributed by the Lower Menomonee River and Underwood Creek subwatersheds. That reflects a combination of relatively large subwatershed size and relatively high unit area loads. The highest unit area loads occur in the Honey Creek and Lower Menomonee subwatersheds.

The average annual nonpoint load of total nitrogen in the watershed is estimated to be 327,750 pounds per year. The distribution of this load among the subwatersheds is shown on Map H-19 in Appendix H. Map H-20 shows the annual per acre loads of total nitrogen for the subwatersheds. Contributions of total nitrogen vary among the subwatersheds (see Table 73) from a low of 10,140 pounds per year from the Little Menomonee Creek subwatershed to 64,510 pounds per year from the Upper Menomonee River subwatershed. The highest loads of total nitrogen are contributed by the Upper and Lower Menomonee River subwatersheds. For the Upper Menomonee, that reflects the relatively large area of the subwatershed, and for the Lower Menomonee it results from a combination of a relatively large subwatershed size and relatively high unit area loads. The highest unit area loads occur in the North Branch Menomonee River subwatershed, but because of the relatively small size of that subwatershed, its total load does not rank among the highest.

The average annual nonpoint load of BOD in the watershed is estimated to be 1,169,240 pounds per year. The distribution of this load among the subwatersheds is shown on Map H-21 in Appendix H. Map H-22 shows the annual per acre loads of BOD for the subwatersheds. Contributions of BOD vary among the subwatersheds (see Table 73) from a low of 16,860 pounds per year from the Little Menomonee Creek subwatershed to 239,060 pounds per year from the Lower Menomonee River subwatershed. The highest loads of BOD are contributed by the Upper and Lower Menomonee River and Underwood Creek subwatersheds. For the Upper Menomonee, this reflects the relatively large area of the subwatershed, and for the Lower Menomonee and Underwood Creek subwatersheds, it results from a combination of relatively large subwatershed size and relatively high unit area loads. The highest unit area loads occur in the Lower Menomonee River subwatershed.

The average annual nonpoint load of copper in the watershed is estimated to be 1,874 pounds per year. The distribution of this load among the subwatersheds is shown on Map H-23 in Appendix H. Map H-24 in Appendix H shows the annual per acre loads of copper for the subwatersheds. Contributions of copper vary among the subwatersheds (see Table 73) from a low of 10 pounds per year from the North Branch Menomonee River subwatershed to 429 pounds per year from the Lower Menomonee River subwatershed. The high loads of copper contributed by the Lower Menomonee River subwatershed reflect the relatively large subwatershed size and the highest unit area loads of all the subwatersheds.

Wet-Weather and Dry-Weather Loads

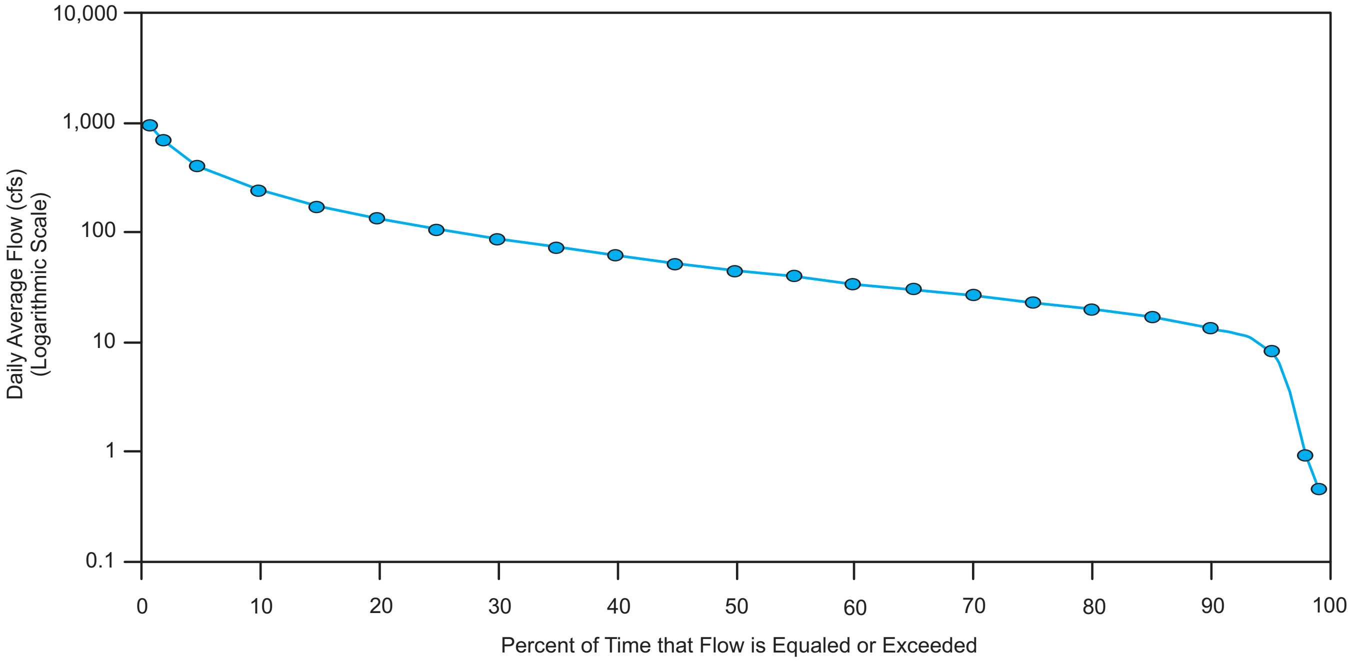
It is important to distinguish between instream water quality during dry weather conditions and during wet weather conditions. Differences between wet-weather and dry-weather instream water quality reflect differences between the dominant sources and loadings of pollutants associated with each condition. Dry-weather instream water quality reflects the quality of groundwater discharge to the stream plus the continuous or intermittent discharge of various point sources, for example industrial cooling or process waters, and leakage or other unplanned dry-weather discharges from sanitary sewers or private process water systems. While instream water quality during wet weather conditions includes the above discharges, and in extreme instances, discharges from separate and/or combined sanitary sewer overflows, the dominant influence, particularly during major rainfall or snowmelt runoff events, is likely to be the soluble or insoluble substances carried into streams by direct land surface runoff. That direct runoff moves from the land surface to the surface waters by overland routes, such as drainage swales, street and highway ditches, and gutters, or by underground storm sewer systems.

Daily average loads of six pollutants—total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, biochemical oxygen demand, and copper, were estimated for both wet-weather and dry-weather conditions for one site along the Menomonee River—the 70th Street station (River Mile 8.0)—based upon flow and water quality data. A water quality sample was assumed to represent wet-weather conditions when daily mean flow was in the upper 20th percentile of the flow duration curve for the relevant flow gauge. This includes flows that are high due to rainfall events, runoff from snowmelt, or a combination of rainfall and snowmelt. The flow duration curve for the Menomonee River at 70th Street in Wauwatosa is shown in Figure 103. For this station, water quality samples were considered to reflect wet-weather conditions when daily mean flow for the corresponding date equaled or exceeded 125.38 cubic feet per second (cfs). On dates when daily mean flow was less than this threshold, the corresponding water quality samples were considered to reflect dry-weather conditions. Daily average pollutant loads were estimated by appropriately combining daily average flow and pollutant ambient concentration.

Figure 104 shows the daily average pollutant loads for total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, biochemical oxygen demand, and copper from the Menomonee River at the 70th Street sampling station. In all cases, the estimated loads occurring during wet-weather periods were considerably higher than the estimated loads occurring during dry-weather periods. For the 1998 through 2001 baseline period, the mean estimated daily average wet-weather load of total phosphorus was about 964 pounds, which is about 44 times the mean estimated daily average dry-weather load of about 22 pounds. For the baseline period, the mean estimated daily average wet-weather load of total suspended solids was about 400,300 pounds, about 133 times the mean estimated daily average dry-weather load of about 3,020 pounds. For the baseline period, the mean estimated daily average wet-weather load of fecal coliform bacteria was about 304 trillion cells, about 16 times

Figure 103

FLOW DURATION CURVE FOR USGS STREAM GAUGE ON THE MENOMONEE RIVER AT 70TH STREET (USGS GAUGE 04087120): 1961-2004



Source: U.S. Geological Survey and SEWRPC.

the mean estimated daily average dry-weather load of 19 trillion cells. For the baseline period, the mean estimated daily average wet-weather load of total nitrogen was 9,003 pounds, about 26 times the mean estimated daily average dry-weather load of 342 pounds. For the baseline period, the mean estimated daily average wet-weather load of BOD was about 15,830 pounds, about 39 times the mean estimated daily average dry-weather load of about 408 pounds. For the baseline period, the mean estimated daily average wet-weather load of copper was about 66.6 pounds, almost 28 times the mean estimated daily average dry-weather load of about 2.4 pounds.

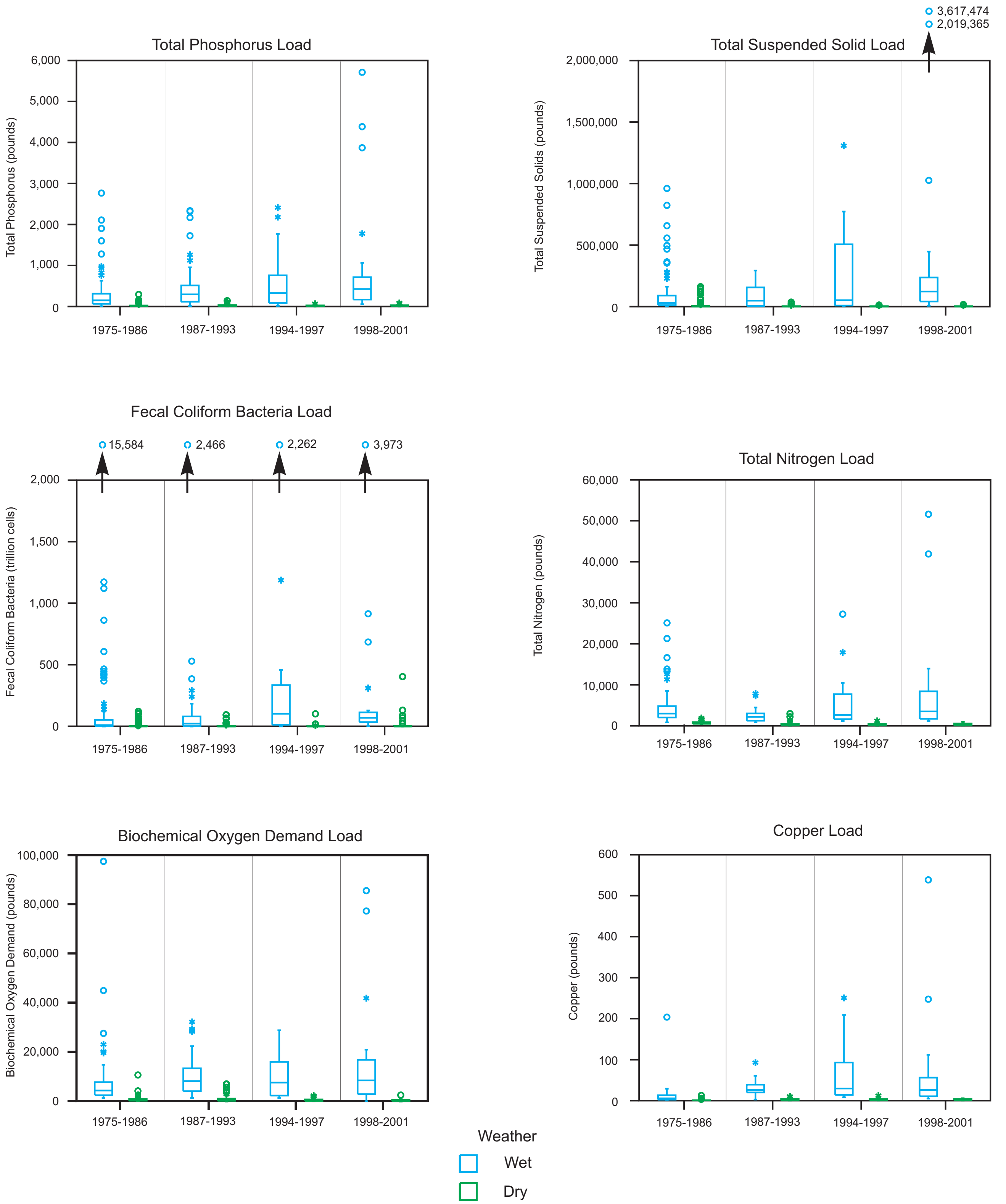
Figure 104 also shows the occurrence of individual wet-weather events during which the estimated daily average pollutant load was many times higher than typical wet-weather loads. The presence of these outliers indicates that individual wet-weather events can contribute a substantial fraction of the annual pollutant load to the stream. For example, Figure 104 shows that the maximum estimated daily average wet-weather load of total suspended solids detected at the 70th Street station during the baseline period of 1998-2001 was about 3,617,000 pounds. Comparing this to Table 75 shows that this single day's load represents about 20 percent of the estimated average annual load of total suspended solids in the entire watershed. Similarly, Figure 104 shows that the maximum estimated daily average wet-weather load of copper detected during the baseline period of 1998-2001 was about 539 pounds. Comparing this to Table 79 shows that this single day's load represents about 28 percent of estimated average annual load of copper in the entire watershed. While these two examples may represent extreme cases, they do indicate that a large fraction of the annual pollutant load to the watershed can be contributed by a small number of wet-weather events.

ACHIEVEMENT OF WATER USE OBJECTIVES IN THE MENOMONEE RIVER AND ITS TRIBUTARIES

The water use objectives and the supporting water quality standards and criteria for the Menomonee River watershed are discussed in Chapter IV of this report. Most of the stream reaches in the Menomonee River watershed are recommended for fish and aquatic life and full recreational uses. The exceptions to this are all subject to

Figure 104

DAILY AVERAGE POLLUTION LOADS IN THE MENOMONEE RIVER AT 70TH STREET (RIVER MILE 8.0): 1975-2001



NOTE: See Figure 66 for description of symbols.

Source U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

special variances under Chapter NR 104 of the *Wisconsin Administrative Code*. Honey Creek, Underwood Creek from Juneau Boulevard in the Village of Elm Grove downstream to the confluence with the Menomonee River, and the mainstem of the Menomonee River downstream from the confluence with Honey Creek are subject to special variances under which dissolved oxygen is not to be less than 2.0 mg/l and counts of fecal coliform bacteria are not to exceed 1,000 per 100 ml. Burnham Canal and South Menomonee Canal are subject to special variances that impose the same requirements with the additional requirement that the water temperature shall not exceed 89ºF.

Based upon the available data for sampling stations in the watershed, the mainstem of the Menomonee River and its major tributaries did not fully meet the water quality standards associated with the recommended water use objectives during and prior to 1975, the base year of the initial plan. Review of subsequent data indicated that as of 1995, the recommended water use objectives were only being partially achieved in the majority of the streams in the watershed.[36]

During the 1998-2001 baseline period, the standards associated with the recommended water use objectives were only being partially achieved in much of the Menomonee River watershed. Table 81 shows the results of comparisons of water quality data from the baseline period to supporting water quality standards. Review of data from 1998 to 2001 shows the following:

- Ammonia concentrations in all samples taken along the mainstem and along three tributaries were under the acute toxicity criterion for fish and aquatic life for ammonia.
- Dissolved oxygen concentrations from the mainstem and four tributaries were at or above the relevant standard in the vast majority of samples. Exceptions to this occurred occasionally at the County Line Road station and in one sample at the 124th Street station.
- Except for one station, water temperatures in all samples taken from the mainstem and four tributaries were at or below the relevant standard. During the summer, surface water temperature at the Burnham Canal station occasionally exceeds the standard.
- Fecal coliform bacteria standards are commonly exceeded at stations along the mainstem of the Menomonee River and Honey Creek.
- Concentrations of total phosphorus in the mainstem of the Menomonee River commonly exceeded the recommended levels in the regional water quality management plan. Total phosphorus concentrations in the Little Menomonee River and Willow Creek occasionally exceeded the recommended standard.

Thus, during the baseline period the stream reaches for which data are available only partially achieved the recommended water use objectives.

An additional issue to consider when examining whether stream reaches are achieving water use objectives is whether toxic substances are present in water, sediment, or tissue of aquatic organisms in concentrations sufficient to impair beneficial uses. Table 82 summarizes the data from 1998 to 2004 regarding toxic substances in water, sediment, and tissue from aquatic organisms for the Menomonee River watershed. For toxicants, the baseline period was extended to 2004 in order to take advantage of results from phase III of the MMSD Corridor Study Project conducted by the USGS. Pesticides were detected in water from stations along the mainstem and four tributaries. The concentrations detected did not exceed water quality standards. Only one sample was available for concentrations of pesticides in tissue from aquatic organisms. Several pesticides were detected in this sample. No data were available from the period 1998 to 2004 on the concentration of pesticides in sediment. Examination of water samples from the eight long-term stations on the mainstem for 12 (out of 209) PCB congeners revealed

[36]*SEWRPC Memorandum Report No. 93,* op. cit.

Table 81

CHARACTERISTICS OF STREAMS IN THE MENOMONEE RIVER WATERSHED: 1998-2001[a]

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[b]					Fish Biotic Index Rating[b,c]	Macroinvertebrate Biotic Index Rating (HBI)[b,c]	303(d)[d] Impairments
		Dissolved Oxygen	Temperature	NH_3[e]	Total Phosphorus[f]	Fecal Coliform Bacteria			
Menomonee River above County Line Road	4.5	87.9 (58)	100.0 (58)	100.0 (16)	66.7 (57)	36.2 (58)	- -	- -	- -
Menomonee River between N. 124th Street and County Line Road	10.0	100.0 (89)	100.0 (63)	100.0 (28)	67.4 (89)	24.4 (90)	Poor (4)	Fair (1)	- -
Menomonee River between W. Hampton Avenue and N. 124th Street	1.0	98.7 (76)	100.0 (61)	100.0 (21)	59.1 (77)	26.0 (77)	- -	- -	- -
Menomonee River between N. 70th Street and W. Hampton Avenue	4.5	100.0 (117)	100.0 (71)	100.0 (44)	43.1 (102)	39.3 (117)	Very poor (9)[g]	Good-very good (3)[g]	- -
Menomonee River between N. 25th Street and N. 70th Street	6.2	100.0 (64)[i]	100.0 (64)	100.0 (18)	31.7 (63)	62.5 (64)[h]	Very poor (9)[g]	Good-very good (3)[g]	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory[j]
Menomonee River between Muskego Avenue and N. 25th Street	0.9	100.0 (66)[i]	100.0 (60)	100.0 (21)	36.9 (65)	71.8 (64)[h]	Very poor (1)[k]	- -	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory
Menomonee River between Burnham Canal and Muskego Avenue	0.1	100.0 (62)[i]	93.5 (62)	100.0 (16)	63.7 (61)	85.2 (61)[h]	Very poor (1)[k]	- -	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory
Menomonee River between S. 2nd Street and Burnham Canal	0.8	100.0 (114)[i]	100.0 (67)	100.0 (30)	32.7 (113)	59.6 (111)[h]	Very poor (1)[k]	- -	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory
North Branch of the Menomonee River	10.0	- -	- -	- -	- -	- -	- -	- -	- -
West Branch of the Menomonee River	4.2	- -	- -	- -	- -	- -	Poor (1)	Fair (4)	- -
Willow Creek	2.8	100.0 (5)	100.0 (6)	100.0 (10)	81.8 (11)	- -	Very poor (1)	Good-very good (5)	- -
Nor-X-Way Channel	3.1	- -	- -	- -	- -	- -	- -	- -	- -
Lilly Creek	4.7	- -	- -	- -	- -	- -	Poor (1)	- -	- -
Butler Ditch[l]	2.9	100.0 (3)	100.0 (3)	- -	- -	- -	Very poor (4)	- -	- -
Little Menomonee Creek	3.9	- -	- -	- -	- -	- -	Very poor (1)	- -	- -
Little Menomonee River	11.2	100.0 (5)	100.0 (6)	100.0 (6)	83.3 (6)	100.0 (1)	Very poor (5)	Good-very good (1)	Aquatic toxicity
Dousman Ditch	2.5	- -	- -	- -	- -	- -	- -	- -	- -
South Branch of Underwood Creek[m]	1.0	71.9 (32)	100.0 (32)`	100.0 (32)	43.3 (30)	21.9 (32)	- -	- -	- -
Underwood Creek from Juneau Boulevard to Headwaters[m]	7.4	68.8 (32)	100.0 (32)	100.0 (32)	77.4 (31)	43.8 (32)	Very poor (3)	- -	- -
Underwood Creek from confluence with the Menomonee River to Juneau Boulevard[m]	1.5	100.0 (48)[i]	100.0 (48)	100.0 (48)	68.2 (44)	70.8 (48)[h]	- -	Poor-fairly poor (1)	- -
Honey Creek	10.0	94.6 (92)[i]	100.0 (80)	100.0 (92)	33.8 (77)	32.6 (92)[h]	- -	- -	- -

Table 81 Footnotes

[a]*Except as noted, evaluations of dissolved oxygen, temperature, ammonia, total phosphorus, and fecal coliform bacteria are based on data from 1998-2001.*

[b]*Number in parentheses shows number of samples.*

[c]*The State of Wisconsin has not promulgated water quality standards or criteria for biotic indices.*

[d]*As listed in the Approved Wisconsin 303(d) Impaired Waters List.*

[e]*Based upon the acute toxicity criterion for ammonia.*

[f]*Total phosphorus is compared to the concentration recommended in the regional water quality management plan.*

[g]*The lower Menomonee River upstream from the estuary was evaluated for biotic indices as a single reach.*

[h]*A special variance standard for fecal coliform bacteria concentration applies to the Menomonee River downstream from the confluence with Honey Creek, Honey Creek, and Underwood Creek from the confluence with the Menomonee River upstream to Juneau Boulevard. Membrane filter fecal coliform counts shall not exceed 1,000 per 100 ml as a monthly geometric mean based on not less than five samples per month nor exceed 2,000 per 100 ml in more than 10 percent of all samples in any month.*

[i]*A special variance dissolved oxygen standard of 2.0 milligrams per liter applies to the Menomonee River downstream from the confluence with Honey Creek, Honey Creek, and Underwood Creek from the confluence with the Menomonee River upstream to Juneau Boulevard.*

[j]*The downstream 1.2 miles of this reach are listed as impaired due to aquatic toxicity, bacteria, low dissolved oxygen concentration, and fish consumption advisories. The upstream portion of this reach is not listed as impaired.*

[k]*The estuary was evaluated for biotic indices as a single reach.*

[l]*Based upon data collected in 2003.*

[m]*Based upon data collected in 2001-2004.*

Source: SEWRPC.

Table 82

TOXICITY CHARACTERISTICS OF STREAMS IN THE MENOMONEE RIVER WATERSHED: 1998-2001[a]

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
Mainstem															
Menomonee River above County Line Road	- -	- -	- -	E-8 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-57 (45)	- -	- -
Menomonee River between N. 124th Street and County Line Road	D[d] (3)	- -	- -	N (13)	- -	- -	D (13)	- -	- -	D[d] (3)	- -	- -	E-66 (67)	- -	- -
Menomonee River between W. Hampton Avenue and N. 124th Street	- -	- -	- -	E-8 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-48 (60)	- -	- -
Menomonee River between N. 70th Street and W. Hampton Avenue	D (3)	- -	- -	N (13)	- -	- -	D (16)	- -	- -	D (3)	- -	- -	E-58 (77)	- -	- -
Menomonee River between N. 25th Street and N. 70th Street	- -	- -	D[c] (1)	E-8 (13)	- -	D[c] (1)	D (13)	- -	- -	- -	- -	- -	E-48 (48)	- -	- -
Menomonee River between Muskego Avenue and N. 25th Street	- -	- -	- -	E-8 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-13 (48)	- -	- -
Menomonee River between Burnham Canal and Muskego Avenue	- -	- -	- -	E-23 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-40 (47)	- -	- -
Menomonee River between S. 2nd Street and Burnham Canal	- -	- -	- -	E-38 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-13 (80)	- -	- -
Tributaries															
North Branch of the Menomonee River	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
West Branch of the Menomonee River	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Willow Creek	D (3)	- -	- -	- -	- -	- -	D (3)	- -	- -	N (3)	- -	- -	- -	- -	- -
Nor-X-Way Channel	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Lilly Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Butler Ditch[j]	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Little Menomonee Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Little Menomonee River	D (3)	- -	- -	- -	- -	- -	D (3)	D	- -	D (3)	- -	- -	- -	- -	- -
Dousman Ditch	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
South Branch of Underwood Creek	- -	- -	- -	- -	- -	- -	D (8)	- -	- -	- -	- -	- -	E-25 (8)	- -	- -
Underwood Creek	D (3)	- -	- -	- -	- -	- -	D (23)	- -	- -	D (3)	- -	- -	E-35 (20)	- -	- -
Honey Creek	D (3)	- -	- -	- -	- -	- -	D (23)	- -	- -	D (3)	- -	- -	E-35 (20)	- -	- -

NOTE: E-X denotes exceedence of a water quality standard in X percent of the samples, D denotes detection of a substance in this class in at least one sample, N denotes that no substances in this class were detected in any sample.

[a]*Number in parentheses indicates sample size.*

[b]*Metals sampled were arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. Sample sizes are shown for most metals. Mercury was sampled less frequently.*

[c]*These samples were taken upstream of N. 35th Street.*

[d.]*These samples were taken at Pilgrim Road.*

Source: SEWRPC.

concentrations that exceeded the human cancer criterion for public health and welfare at six stations. This standard was exceeded more often in the estuary than in the reaches upstream of the estuary. Only one sample was available for concentration of PCBs in tissue from aquatic organisms. PCBs were detected in this sample. No data were available from the period 1998 to 2004 on the concentration of PCBs in sediment. Water samples from all eight stations along the mainstem of the Menomonee River and from four tributaries showed detectable concentrations of PAHs. In addition, PAHs were detected in sediment samples from the Little Menomonee River. It is important to note that remediation activities are currently ongoing to address the presence of PAHs in sediment in this tributary. Limited sampling for other organic compounds showed detectable concentrations of the solvent isophorone at all sampling stations examined, except for Willow Creek. The concentrations of this substance detected were below the human threshold criterion for public health and welfare. In addition, the deodorizer 1,4-dichlorobenzene was detected in single water samples from the N. 70th Street station and Honey and Underwood Creeks at concentrations below the human cancer criterion for public health and welfare. Finally, water samples from the eight long-term stations along the mainstem of the River were examined for concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. While the sample sizes given in Table 82 are representative of sampling for most of these metals, it is important to note that mercury was sampled less intensively. The number of samples analyzed for mercury was about two-thirds to three-quarters the number analyzed for other metals. Detectable concentrations of each of these metals were present in samples from each of the stations tested. Three of these metals were present at times in concentrations that exceeded water quality standards. Concentrations of mercury in water commonly exceeded both the human threshold concentration for public health and welfare and the wildlife criterion for surface water quality. The percent of samples exceeding the lower of these two concentrations is given in Table 82. In addition, concentrations of copper in water samples occasionally exceeded the EPA's criterion maximum concentration (CMC) for copper. In the estuary, about 10 to 13 percent of samples, depending on the station, had copper concentrations exceeding this standard. At the N. 70th Street station, over 20 percent of the samples had copper concentrations exceeding this standard. At the three long-term stations upstream of N. 70th Street, the percentage of samples exceeding the CMC for copper was about 2 percent. Finally, one sample from the station on the mainstem of the River at County Line Road contained arsenic at concentrations exceeding the human cancer criterion for public health and welfare. This sample may represent an outlier.

The summary above suggests that some beneficial uses are being impaired by the presence of contaminants, especially PCBs and mercury. The fish consumption advisories in effect for the Menomonee River shown in Table 56 reflect this.

Section 303(d) of the Clean Water Act requires that the states periodically submit a list of impaired waters to the USEPA for approval. Wisconsin most recently submitted this list in 2004.[37] This list was subsequently approved by the USEPA. Table 81 and Map 46 indicate stream reaches in the Menomonee River watershed that are classified as being impaired waters. The variance water reach of the mainstem of the Menomonee River from S. 70th Street downstream to the confluence with the Milwaukee River estuary is listed as impaired due to aquatic toxicity, bacteria, dissolved oxygen, and fish consumption advisories necessitated by high concentrations of PCBs and mercury in the tissue of fish collected from this reach. Bacteria, metals, PCBs, and phosphorous from a combination of point and nonpoint source pollution and contaminated sediment are cited as factors contributing to these impairments. The reach of the Little Menomonee River from W. Brown Deer Road (STH 100) downstream to its confluence with the Menomonee River is listed as impaired due to aquatic toxicity.[38] Creosote (PAHs) in contaminated sediments is cited as the factor contributing to the impairment of this reach.

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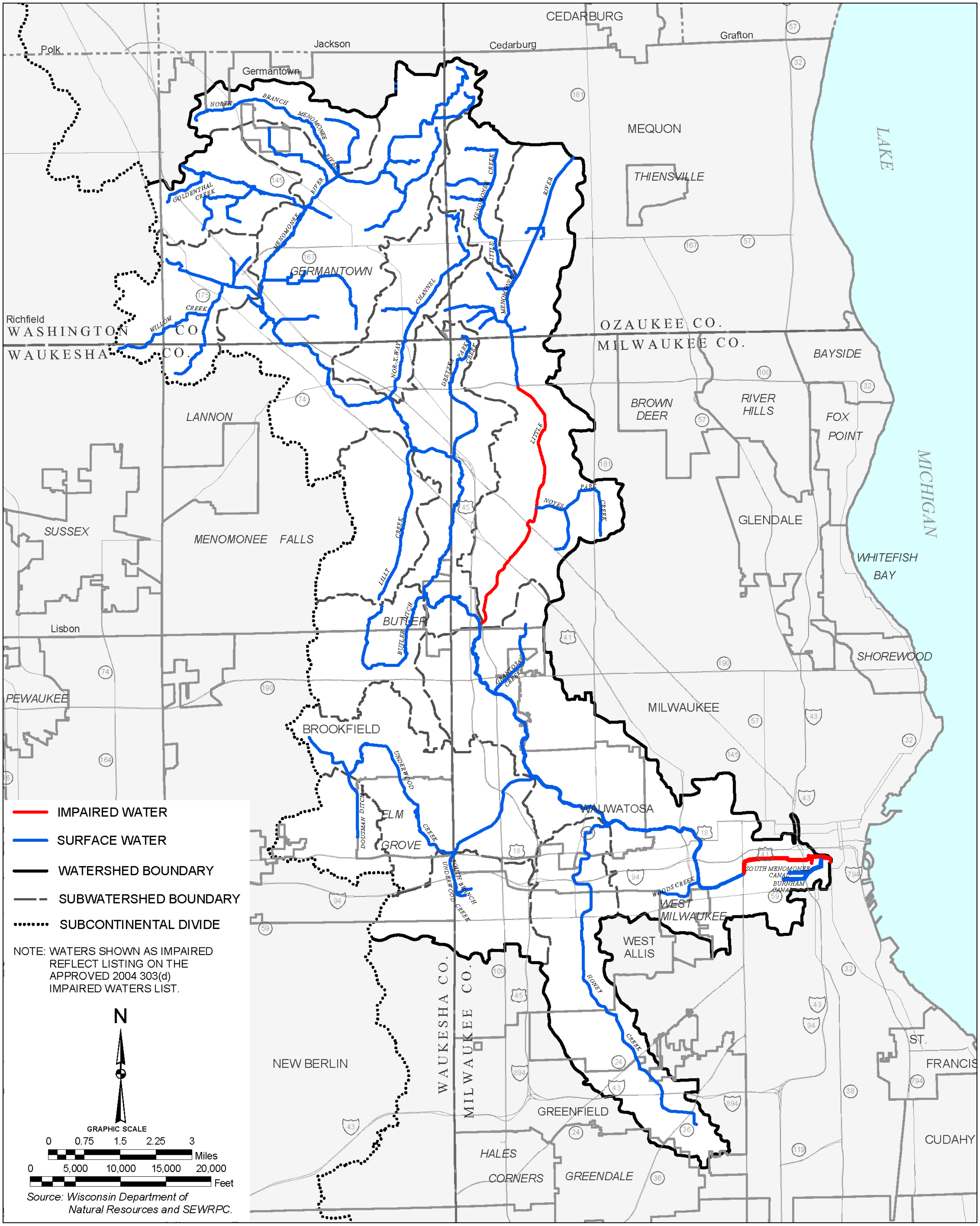
[37]*Wisconsin Department of Natural Resources,* Approved 2004 Wisconsin 303(d) Impaired Waters List, *August 2004.*

[38]*As noted previously, remediation efforts along the Little Menomonee River, as first recommended under the Commission's comprehensive plan for the Menomonee River watershed, have been implemented from W. Brown Deer Road (STH 100) to near W. Leon Terrace. It is uncertain when remediation of the remainder of the River will proceed.*

Map 46

IMPAIRED WATERS WITHIN THE MENOMONEE RIVER WATERSHED: 2004



SUMMARY

The summary of water quality and pollution sources inventory for the Menomonee River system have been summarized by answering five basic questions. The chapter provided detailed information needed to answer the questions. The information is summarized below.

How Have Water Quality Conditions Changed Since 1975?
Water quality conditions in the Menomonee River watershed have both improved in some respects and declined in other respects since 1975.

Improvements in Water Quality
Concentrations in the estuary portion of the Menomonee River of several pollutants associated with combined sewer overflows, such as BOD, fecal coliform bacteria, and ammonia, have decreased. These reductions in nutrients and oxygen-demanding wastes have produced some improvements in dissolved oxygen concentration and have resulted in lower chlorophyll-*a* concentrations in the estuary portion of the River. In addition, concentrations of ammonia and BOD have also declined in the sections of the River upstream from the estuary. Improvements have also occurred in the concentrations of some toxic metals detected in the Menomonee River. One important, though not the only, factor responsible for these decreases is the reduction in combined and separate sewer overflows resulting from construction and operation of MMSD's inline storage system. These improvements also likely reflect both changes in the types of industries present in the watershed, the connection of most process wastewaters to the MMSD sewerage system, and the implementation of treatment requirements for all industrial discharges. Concentrations of lead have also declined, due largely to the phasing out of the use of lead as an additive to gasoline. Concentrations of mercury in the water have declined.

No Change or Reductions in Water Quality
Concentrations of suspended and dissolved pollutants typically associated with stormwater runoff and other nonpoint source pollution, such as chloride, copper, total suspended solids, and zinc have remained unchanged or increased. For some of these pollutants, such as zinc, increases in concentration have occurred in all reaches sampled along the Menomonee River. For others, such as copper, chloride, and total suspended solids, concentrations have increased in some reaches while remaining unchanged in others. In addition, specific conductance has increased in at least three reaches of the River, suggesting that the total concentration of dissolved material in the water has increased. In other reaches, the concentration of dissolved material, as indicated by specific conductance, has remained unchanged. Water temperatures in the estuary, especially at the Burnham Canal sampling station, have increased, especially during the summer.

How Have Toxicity Conditions Changed Since 1975?
In some respects, toxicity conditions in the Menomonee River have improved since 1975; in other respects, they have declined or not changed.

Improvements in Toxicity Conditions
The concentrations of PAHs in water in the section of the Menomonee River upstream from the estuary have declined. In additions, as described above, there have been reductions in concentrations of some toxic metals in the water column. The pesticide DDT has not been detected in fish tissue samples since the 1980s; however, this conclusion is based upon a small number of samples. As part of remediation efforts, sediments contaminated with PAHs have been removed from the Little Menomonee River and treated and the channel of this tributary has been relocated. This should reduce the toxic effects related to contaminated sediments in the Little Menomonee River.

Worsened Toxicity Conditions
Other toxicity conditions in the Menomonee River are now worse. The concentrations of PAHs detected in the water in the estuary portion of the River have increased. Also, concentrations of zinc in the water column have increased along the entire Menomonee River mainstem.

Inconclusive Toxicity Data
In some cases the available data are not adequate to assess changes. For example, the concentrations of PCBs detected in water during the period 1998 to 2001 were lower than the concentrations detected in previous samplings; however, the most recent samplings may underestimate PCB concentrations both because of methodological differences in sample collection and because they only screened for a subset of PCB congeners. Various pesticides have been detected in water in the Menomonee River, but different compounds were screened for in recent samplings than were examined in historical samplings.

Sediment Conditions
As part of remediation efforts, sediments contaminated with PAHs have been removed from the Little Menomonee River and treated. This should reduce the toxicity of sediments in the Little Menomonee River.

What Are the Sources of Water Pollution?
The Menomonee River watershed contains several potential sources of water pollution. These fall into two broad categories: point sources and nonpoint sources.

Point Sources
There are no public or private sewage treatment plants discharging into the Menomonee River watershed. MMSD has 28 combined sewer overflow outfalls that discharge to the streams in the Menomonee River watershed. These outfalls convey a combination of stormwater runoff and sanitary sewage from the combined sewer system to the surface water system of the watershed as a result of high water volume from stormwater, meltwater, and excessive infiltration and inflow of clear water during wet weather conditions. Prior to 1994, overflows from these sites typically occurred around 50 times per year. Since MMSD's inline storage system came online in 1994, the number of combined sewer overflows per year has declined to about three. Since 1995, separate sewer overflows have been reported at 26 locations: seven within MMSD's SSO area and 19 within local communities. The number of SSO events occurring per year has shown a decline similar to that of CSO events. As of February 2003, 150 industrial dischargers and other point sources were permitted through the WPDES program to discharge wastewater to streams in the Menomonee River watershed. Almost half of the permitted facilities discharged noncontact cooling water. The remaining discharges are of several types as indicated in Table 70. All of the permitted discharges are of a nature which typically complies with the WPDES permit levels which are designed to meet water quality standards.

Nonpoint Sources
The Menomonee River watershed is comprised of a combination of urban land uses and rural land uses. As of 2000, about 36 percent of the watershed was in rural and other open land uses. About 77 percent of the watershed is contained within planned sewer service areas: 41 percent within MMSD's planned sewer service area and 36 percent within the sanitary sewer service areas of local communities that are connected to MMSD's conveyance and treatment systems. About 3 percent of the watershed consists of urban enclaves outside of the planned sewer service area. Failure of onsite sewage treatment systems is an issue of concern in these portions of the watershed. About 8 percent of the watershed is served by combined sanitary and storm sewers which convey sewage and stormwater to MMSD's sewage treatment facilities, resulting in a high degree of nonpoint source pollution control from the combined sewer service area. All communities in the watershed have adopted construction erosion control ordinances except for the Towns of Germantown and Richfield. All communities in the watershed except for the Towns of Germantown and Richfield and the Village of West Milwaukee have adopted stormwater management ordinances or plans. It is anticipated that the Village of West Milwaukee will adopt a stormwater management ordinance in order to fulfill the conditions of the WPDES stormwater discharge permit that they have applied for. As of February 2003, 267 facilities engaged in industrial activities in the watershed had applied for and obtained WPDES stormwater discharge permits. As a condition of these permits, these facilities are required to develop and follow a stormwater pollution prevention plan. There is currently one active solid waste landfill in the watershed. The watershed contains seven inactive solid waste landfills.

Quantification of Pollutant Loads

The annual average load of BOD to streams of the Menomonee River watershed is estimated to be 1,352,700 pounds per year. Combined sewer overflows and separate sewer overflows contribute about 4.4 percent and 0.6 percent, respectively, of this load. Industrial discharges contribute about 8.6 percent of this load. The rest of BOD loadings to streams in the Menomonee River watershed, about 86.4 percent, are contributed by nonpoint sources, with 73.4 percent coming from urban sources and 13.0 percent from rural sources.

The annual average load of TSS to streams of the Menomonee River watershed is estimated to be 17,936,790 pounds per year. Combined sewer overflows and separate sewer overflows contribute about 1.0 percent and 0.2 percent, respectively, of this load. Industrial discharges contribute about 0.3 percent of this load. The rest of TSS loadings to streams in the watershed, about 98.5 percent, are contributed by nonpoint sources, with 87.6 percent coming from urban sources and 10.9 percent from rural sources.

The annual average load of fecal coliform bacteria to streams of the Menomonee River watershed is estimated to be 16,873.16 trillion cells per year. Combined sewer overflows and separate sewer overflows contribute about 10.2 percent and 3.8 percent, respectively, of this load. The rest of the fecal coliform bacteria loadings to streams in the watershed, about 86.0 percent, are contributed by nonpoint sources, with 83.7 percent coming from urban sources and 2.3 percent from rural sources.

The annual average load of total phosphorus to streams of the Menomonee River watershed is estimated to be 53,120 pounds per year. Combined sewer overflows and separate sewer overflows contribute about 3.5 percent and 1.1 percent, respectively, of this load. Industrial discharges contribute about 33.0 percent of this load. The rest of total phosphorus loadings to streams in the watershed, about 62.4 percent, are contributed by nonpoint sources, with 54.7 percent coming from urban sources and 7.7 percent from rural sources.

What is the Current Condition of the Fishery?

The Menomonee River watershed seems to have a poor fishery community at present. The fish community contains relatively few species of fishes, is trophically unbalanced, contains few or no top carnivores, and is dominated by tolerant fishes. The quality of the macroinvertebrate community has improved substantially since 1993 and is generally indicative of fair to very good water quality. Since water quality has generally been improving in the watershed and habitat seems to be adequate, it is likely that some other factor, such as periodic stormwater loads, is limiting the fishery community.

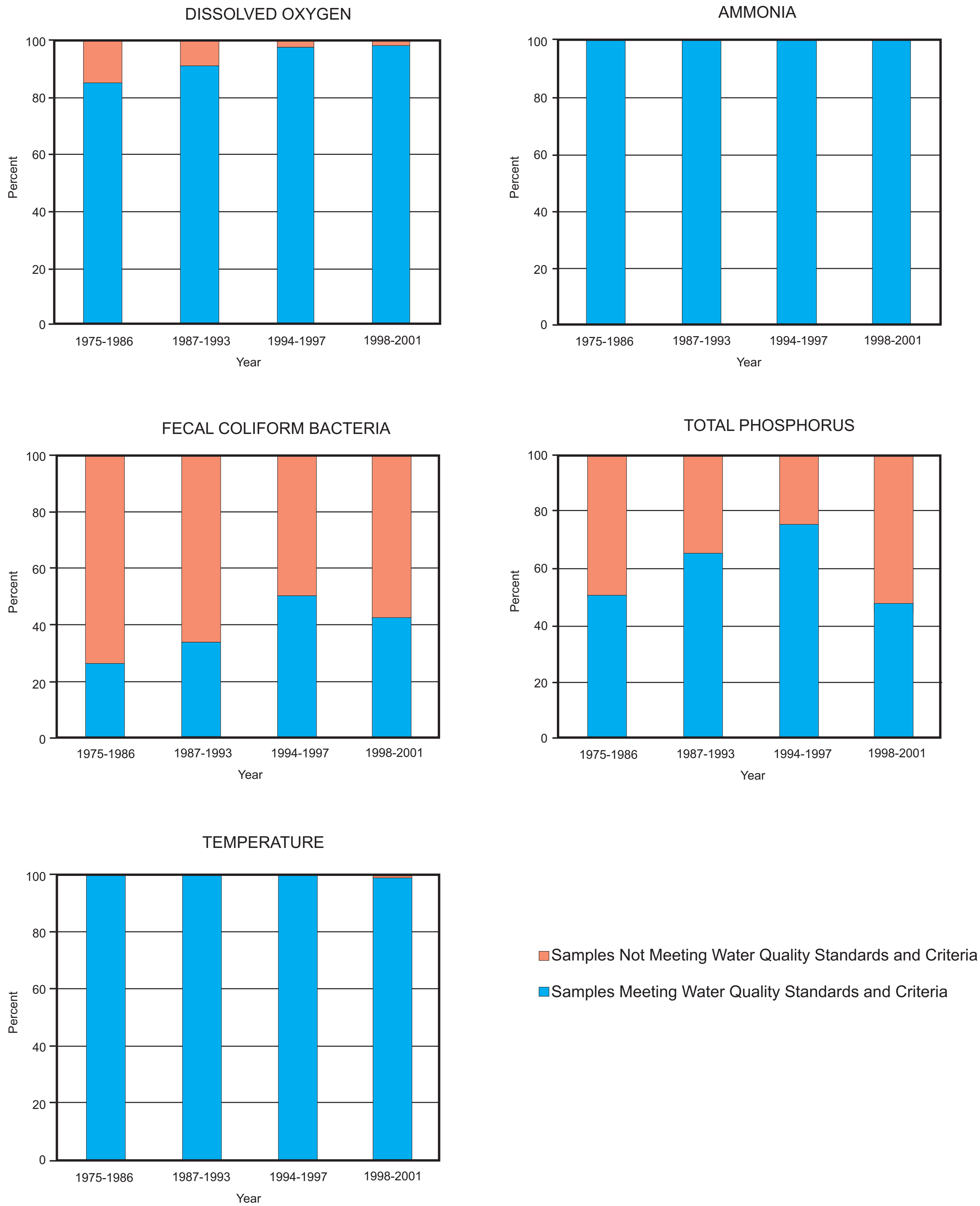
To What Extent Are Water Use Objectives and Water Quality Standards Being Met?

During the 1998 to 2001 study baseline period, the Menomonee River only partially met the water quality criteria supporting its recommended water use classification. In the vast majority of the samples taken from the mainstem of the River temperatures and concentrations of dissolved oxygen and ammonia were in compliance with the relevant water quality standards. Only in occasional samples at the Burnham Canal station were temperatures above the standard of 89ºF. In occasional samples collected in the reaches upstream from W. Hampton Avenue, dissolved oxygen concentrations were below the standard of 5.0 mg/l that applies to fish and aquatic life waters. Concentrations of fecal coliform bacteria in the estuary portion of the Menomonee River often exceeded the special variance standard of 1,000 cells per 100 ml which applies to the estuary. Similarly, in the vast majority of samples collected from the section of the River upstream of the estuary, the concentrations of fecal coliform bacteria exceed the standard of 200 cells per 100 ml. The rate of compliance with this standard varies among reaches. At the N. 70th Street station, fecal coliform counts were below the standard in about 24 percent of samples. This increased to about 60 percent at the station at the Hampton Avenue station. Compliance with the standard for total phosphorus recommended in the regional water quality management plan also varied among reaches: the number of samples showing total phosphorus below the 0.1 mg/l standard ranged from a low of about 32 percent at the N. 25th Street station to a high of about 66 percent at the County Line Road station.

Figure 105 shows changes over time in the proportions of samples showing compliance with applicable water quality standards for the Menomonee River. Over the entire study period of 1975-2001, water temperatures and concentrations of ammonia were in compliance with the applicable water quality standards in all samples, and

Figure 105

PROPORTION OF SAMPLES FOR SEVERAL CONSTITUENTS MEETING WATER QUALITY STANDARDS AND CRITERIA ALONG THE MAINSTEM OF THE MENOMONEE RIVER: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, and Milwaukee Metropolitan Sewerage District.

dissolved oxygen concentrations were in compliance approximately 85 percent or more of the time, with the proportion of samples in compliance increasing over time. By contrast, significant percentages of samples collected in each period had concentrations of fecal coliform bacteria and total phosphorus that were not in compliance with the applicable water quality standard. In just below 30 percent of the samples collected during the period 1975-1986, fecal coliform bacteria concentrations were in compliance with the standard. This rate of compliance increased to close to 50 percent of the samples collected during the period 1994-1997, and then decreased somewhat to just above 40 percent of the samples in the period from 1998-2001. The rate of compliance with the standard recommended for total phosphorus in the regional water quality management plan increased from about 50 percent of samples collected being in compliance during the period 1975-1986 to about 75 percent of all samples being in compliance during the period 1994-1997. During the period 1998-2001 the percentage of samples collected in compliance with the standard decreased to just below 50 percent.

Relatively few data are available for assessing whether streams tributary to the Menomonee River are meeting water use objectives and water quality standards. Based on available data, Honey Creek, the Little Menomonee River, and Willow Creek are only partially meeting their water use objectives. In all samples collected from each of these streams, ammonia concentrations were below the acute toxicity standard for fish and aquatic life, water temperatures are under the 89ºF standard, and dissolved oxygen concentrations were above the applicable standard. Concentrations of fecal coliform bacterial in Honey Creek generally exceeded the standard of 1,000 cells per 100 ml which applies to this stream. Total phosphorus concentrations in the Little Menomonee River and Willow Creek exceeded the recommended concentration in about 20 percent of the samples. Based on limited sampling, Butler Ditch appears to be meeting water use objectives and water quality standards. In all of the samples taken, dissolved oxygen concentrations and temperatures were in compliance with the applicable water quality standards.

Some toxic substances have been detected in the Menomonee River watershed at concentrations that may impede beneficial uses. In 8 to 38 percent of the water samples taken at the six sampling stations along the mainstem of the Menomonee River, PCBs were present in concentrations that exceeded the human cancer criterion for public health and welfare. In addition, concentrations of mercury in water samples taken from the Menomonee River often exceeded both the human threshold concentration for public health and welfare and the wildlife criterion for surface water quality. Also, concentrations of copper in water samples occasionally exceeded the EPA's criterion maximum concentration.

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Chapter VII

SURFACE WATER QUALITY CONDITIONS AND SOURCES OF POLLUTION IN THE MILWAUKEE RIVER WATERSHED

INTRODUCTION AND SETTING WITHIN THE STUDY AREA

A basic premise of the Commission watershed studies is that the human activities within a watershed affect, and are affected by, surface and groundwater quality conditions. This is especially true in the urban and urbanizing areas of the Milwaukee River watershed, where the effects of human activities on water quality tend to overshadow natural influences. The hydrologic cycle provides the principal linkage between human activities and the quality of surface and ground waters in that the cycle transports potential pollutants from human activities to the environment and from the environment into the sphere of human activities.

Comprehensive water quality planning efforts such as the regional water quality management plan update, should include an evaluation of historical, present, and anticipated water quality conditions and the relationship of those conditions to existing and probable future land and water uses. The purpose of this chapter is to determine the extent to which surface waters in the Milwaukee River watershed have been and are polluted, and to identify the probable causes for, or sources of, that pollution. More specifically, this chapter documents current surface water pollution problems in the watershed utilizing field data from a variety of water quality studies, most of which were conducted during the past 30 years; indicates the location and type of the numerous and varied sources of wastewater, industrial, stormwater runoff, and other potential pollutants discharged to the surface water system of the watershed; describes the characteristics of the discharges from those sources; and, to the extent feasible, quantifies the pollutant contribution of each source. The information presented herein provides an important basis for the development and testing of the alternative water quality control plan elements under the regional water quality management plan update.

DESCRIPTION OF THE WATERSHED

The Milwaukee River watershed is located in the north central portion of the Southeastern Wisconsin Region and covers an area of approximately 700 square miles. The mainstem of the Milwaukee River originates in southeastern Fond du Lac County and flows approximately 101 miles in a southerly and easterly direction to its confluence with Lake Michigan in the City of Milwaukee in Milwaukee County. Tributaries of the Milwaukee River extend into Dodge, Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington Counties. Rivers and streams in the watershed are part of the Lake Michigan drainage system as the watershed lies east of the subcontinental divide. Approximately 62 percent, or 434 square miles, of the watershed is located within the Southeastern Wisconsin Region. The remaining 38 percent, or 266 square miles, is located in Dodge, Fond du

Lac, and Sheboygan Counties. The boundaries of the basin, together with the locations of the main channels of the Milwaukee River watershed and its principal tributaries, are shown on Map 47. The Milwaukee River watershed contains 20 lakes with a surface area of 50 acres or more, along with numerous smaller named lakes and ponds.

Civil Divisions
Superimposed on the watershed boundary is a pattern of local political boundaries. As shown on Map 48, the watershed lies in Dodge, Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington Counties. Fifty-six civil divisions lie partially, or entirely, within the Milwaukee River watershed, as also shown on Map 48 and in Table 83. Geographic boundaries of the civil divisions are an important factor which must be considered in the regional water quality management plan update since the civil divisions form the basic foundation of the public decision making framework within which intergovernmental, environmental, and developmental problems must be addressed.

LAND USE

This section describes the changes in land use which have occurred within the Milwaukee River watershed since 1970, the approximate base year of the initial regional water quality management plan, and indicates the changes in such land uses since 1990, the base year of the initial plan update, as shown in Table 84. Although much of the watershed is urbanized, about 79 percent of the watershed was still in rural and other open space land uses in 2000. These rural and open space uses included about 4 percent of the total area of the watershed in unused and other open lands and about 17 percent in surface water and wetlands. Most of the rural and open spaces remaining in the watershed are located in southeastern Fond du Lac County, northeastern Ozaukee County, southwestern Sheboygan County, and eastern Washington County. The remaining approximately 21 percent of the total watershed was devoted to urban uses, as shown on Map 49.

While urban development exists throughout much of the Milwaukee River watershed, it is especially concentrated in the southeastern portion of the watershed in Milwaukee and Ozaukee Counties and the west-central portion of the watershed in and around the City of West Bend. As shown in Table 84, residential land represents about one-half of the urban land use in the watershed. The historic urban growth within the Milwaukee River watershed is summarized on Map 50 and in Table 85. Since 1990, much, though not all, of the urban growth in the watershed has occurred near existing urban centers such as the Cities of Cedarburg, Mequon, and West Bend and the Villages of Campbellsport, Grafton, Jackson, Kewaskum, Random Lake, and Saukville.

The changes in land use reflect changes in population and population distribution within the watershed. Several trends are apparent in the data. Over the long term the number of persons living in the watershed has decreased. From 1970 through 1990, the population in the watershed decreased by about 20,253, from 511,010 to 490,757; however, during that time period the number of households increased by 18,152, from 165,099 to 183,251. Between 1990 and 2000 the size of the population in the watershed continued to decline, decreasing to 484,199 persons, or a decrease of 6,558 persons. During this decade of decreasing population, the number of households in the watershed increased by 5,360 units to 188,611.

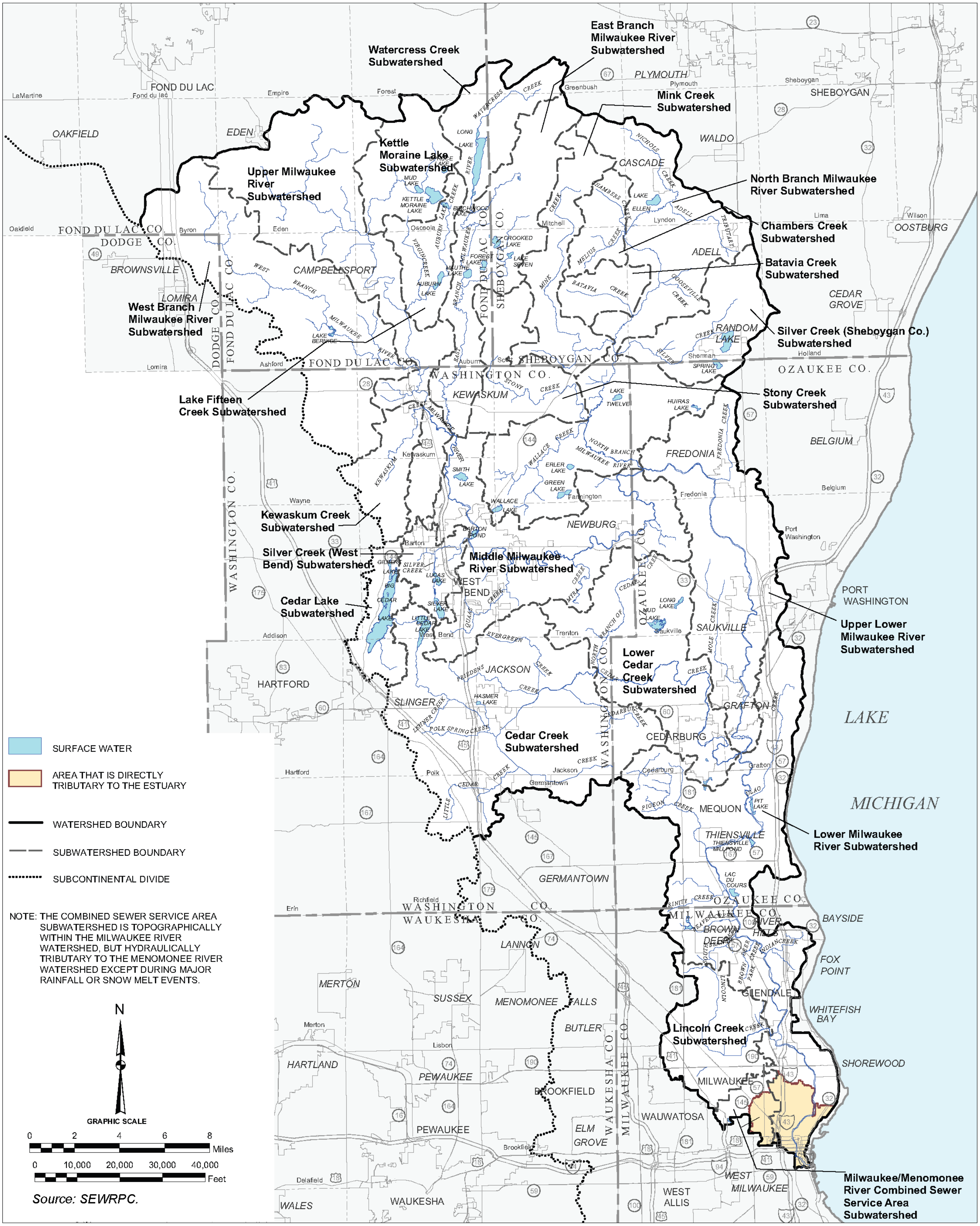
QUANTITY OF SURFACE WATER

Since 1963, measurements of discharge have been taken at a number of locations along the Milwaukee River and its tributaries. The period of record for some of these stations is rather short, with data collection occurring over periods ranging from about four months to about 14 months. Three stations on the mainstem of the Milwaukee River at Pioneer Road, Estabrook Park, and Waubeka, have periods of record of about 23, 29, and nine years, respectively. Three stations along tributaries, those on the East Branch Milwaukee River at New Fane, the North Branch Milwaukee River near Fillmore, and Cedar Creek at Cedarburg, have periods of record of seven, seven, and 27 years, respectively.

Figure 106 shows historical and baseline period discharge for the five stations along the mainstem of the River and Figure 107 shows similar discharge data for tributaries to the Milwaukee River. Generally similar annual

Map 47

SURFACE WATER WITHIN THE MILWAUKEE RIVER WATERSHED: 2000



Map 48

CIVIL DIVISIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000

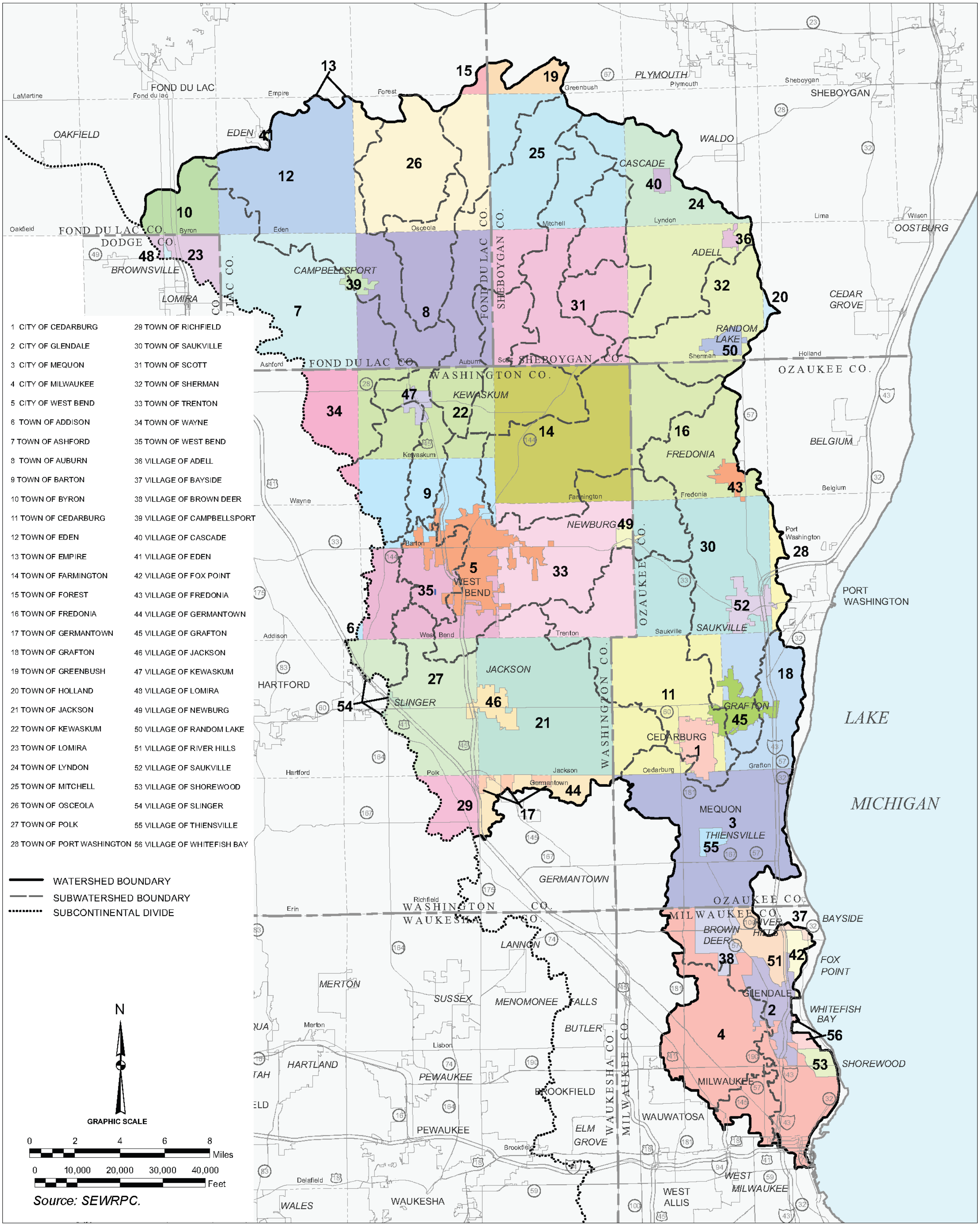


Table 83

AREAL EXTENT OF COUNTIES, CITIES, VILLAGES, AND TOWNS WITHIN THE MILWAUKEE RIVER WATERSHED

Civil Division	Area (square miles)	Percent of Total
Dodge County		
Town of Lomira	4.40	0.63
Village of Lomira	0.16	0.02
Subtotal	4.56	0.65
Fond du Lac County		
Town of Ashford	29.36	4.19
Town of Auburn	35.81	5.11
Town of Byron	8.85	1.26
Town of Eden	29.69	4.24
Town of Empire	0.03	0.00
Town of Forest	0.84	0.12
Town of Osceola	33.52	4.79
Village of Campbellsport	1.12	0.16
Village of Eden	0.05	0.01
Subtotal	139.29	19.88
Milwaukee County		
City of Glendale	5.93	0.85
City of Milwaukee	38.84	5.54
Village of Bayside	0.38	0.06
Village of Brown Deer	4.39	0.63
Village of Fox Point	1.60	0.23
Village of River Hills	4.28	0.61
Village of Shorewood	1.48	0.21
Village of Whitefish Bay	0.75	0.11
Subtotal	57.68	8.23
Ozaukee County		
City of Cedarburg	3.65	0.52
City of Mequon	31.47	4.49
Town of Cedarburg	25.96	3.71
Town of Fredonia	28.06	4.01
Town of Grafton	16.49	2.35
Town of Port Washington	2.42	0.35
Town of Saukville	33.42	4.77
Village of Fredonia	1.30	0.19
Village of Grafton	4.12	0.59
Village of Saukville	2.89	0.41
Village of Thiensville	1.05	0.15
Subtotal	150.87	21.54
Sheboygan County		
Town of Greenbush	3.66	0.52
Town of Holland	0.45	0.07
Town of Lyndon	12.58	1.80
Town of Mitchell	33.47	4.78
Town of Scott	36.54	5.22
Town of Sherman	32.63	4.66
Village of Adell	0.55	0.08
Village of Cascade	0.77	0.11
Village of Random Lake	1.70	0.24
Subtotal	122.40	17.47

Table 83 (continued)

Civil Division	Area (square miles)	Percent of Total
Washington County		
City of West Bend	12.62	1.80
Town of Addison	0.18	0.03
Town of Barton	18.00	2.57
Town of Farmington	36.78	5.25
Town of Germantown	1.06	0.15
Town of Jackson	34.24	4.89
Town of Kewaskum	22.93	3.27
Town of Polk	24.17	3.45
Town of Richfield	5.62	0.80
Town of Trenton	33.47	4.78
Town of Wayne	9.14	1.30
Town of West Bend	17.20	2.46
Village of Germantown	5.02	0.72
Village of Jackson	2.54	0.36
Village of Kewaskum	1.41	0.20
Village of Newburg	0.89	0.13
Village of Slinger	0.38	0.05
Subtotal	224.92	32.22
Total	700.00	100.00

Source: SEWRPC.

patterns are seen in the baseline period mean discharge at the main stem and tributary sites. Mean monthly streamflow tends to reach a low point during the late summer or early fall. Mean monthly discharge remains reasonably constant through December. This is followed by a sharp increase during late winter and early spring that is associated with spring snowmelt and rains. It then declines through the spring and early summer to the late summer/early fall minimum. Considerable variability is associated with these patterns, but some of this variability is more likely attributed to sampling conditions rather than actual changes in discharge.

For the most part, stream flow from the baseline period is within historical ranges at the stations with long-term flow data. During winter and spring months, monthly maximum discharges during the baseline period were higher than the historical monthly maxima at the station at Jones Island. This may reflect the small amount of historical data available at this station. Baseline period monthly mean discharges tended to be lower than the historical means during the fall at the Pioneer Road and Estabrook Park stations. By contrast, baseline period monthly mean discharges were higher than the historical means during the spring at the Waubeka station. This may reflect the small amount of data from the baseline period for this station.

Flow fractions were calculated for all stations relative to the discharge at the Estabrook Park station using the procedure described in Chapter III of this report. The results are shown on Map 51. Several generalizations emerge from this analysis:

- The magnitude of average discharge increases rapidly in the headwaters of the River. For example, while median discharge at the gauge in the upper reaches of the West Branch Milwaukee River (river mile 15.90) represents about 2 percent of the median discharge at Estabrook Park, median discharge along the mainstem near Kewaskum represents about 23 percent of the median discharge at Estabrook Park. Much of the increase in discharge represents contributions of water from the mainstem of the Milwaukee River, the West Branch of the Milwaukee River, and Auburn Lake Creek. Similarly, median discharge along the North Branch of the Milwaukee River increases from about 9 percent to about 20 percent of the median discharge at Estabrook Park between the stations near Random

Lake (River Mile 10.09) and at Fillmore (River Mile 2.22). Much of this increase in discharge represents contributions from Silver Creek (Sheboygan County), Stony Creek and Wallace Creek.

- Much of the discharge at downstream stations can be accounted for by discharge from stations upstream and from tributaries entering the River upstream. For instance, median discharge from the Milwaukee River and its tributaries upstream at the Newburg station (River Mile 78.10) represents about 42 percent of the median discharge at the Estabrook Park Station. Much of this, about 23 percent of the median discharge at the Estabrook Park station, is contributed by the mainstem of the Milwaukee River, the West Branch of the Milwaukee River, and their tributaries upstream of the Village of Kewaskum. Given that Quaas Creek contributes less than 2 percent of the median discharge at Estabrook Park, the remaining 19 percent from the area at, and downstream from, Kewaskum is contributed by Kewaskum Creek, Myra Creek, and other tributaries along the mainstem between Kewaskum and Newburg.

- Similarly, median discharge at the station along the mainstem of the River at Waubeka (River Mile 45.44) represents about 60 percent of the median discharge at the Estabrook Park station. Most of the increase in discharge between Newburg and Waubeka can be accounted for by contributions from the North Branch of the Milwaukee River.

Table 84

LAND USE IN THE MILWAUKEE RIVER WATERSHED: 2000[a,b]

Category	2000[c]	
	Square Miles	Percent of Total
Urban		
Residential	71.64	10.2
Commercial	6.32	0.9
Industrial and Extractive	8.89	1.3
Transportation, Communication, and Utilities[d]	44.54	6.3
Governmental and Institutional	6.90	1.0
Recreational	10.30	1.5
Subtotal	148.58	21.2
Rural		
Agricultural and Related	342.45	48.9
Water	12.05	1.7
Wetlands	104.86	15.0
Woodlands	62.24	8.9
Unused and Other Open Lands	29.81	4.3
Subtotal	551.42	78.8
Total	700.00	100.0

[a]As approximated by whole U.S. Public Land Survey one-quarter sections.

[b]Prior to 2000, detailed land use data are not available for the portions of the watershed outside the Southeastern Wisconsin Region.

[c]This represents the entire watershed, including those portions in Dodge, Fond du Lac, and Sheboygan Counties.

[d]Off-street parking of more than 10 spaces is included with the associated land use.

Source: SEWRPC.

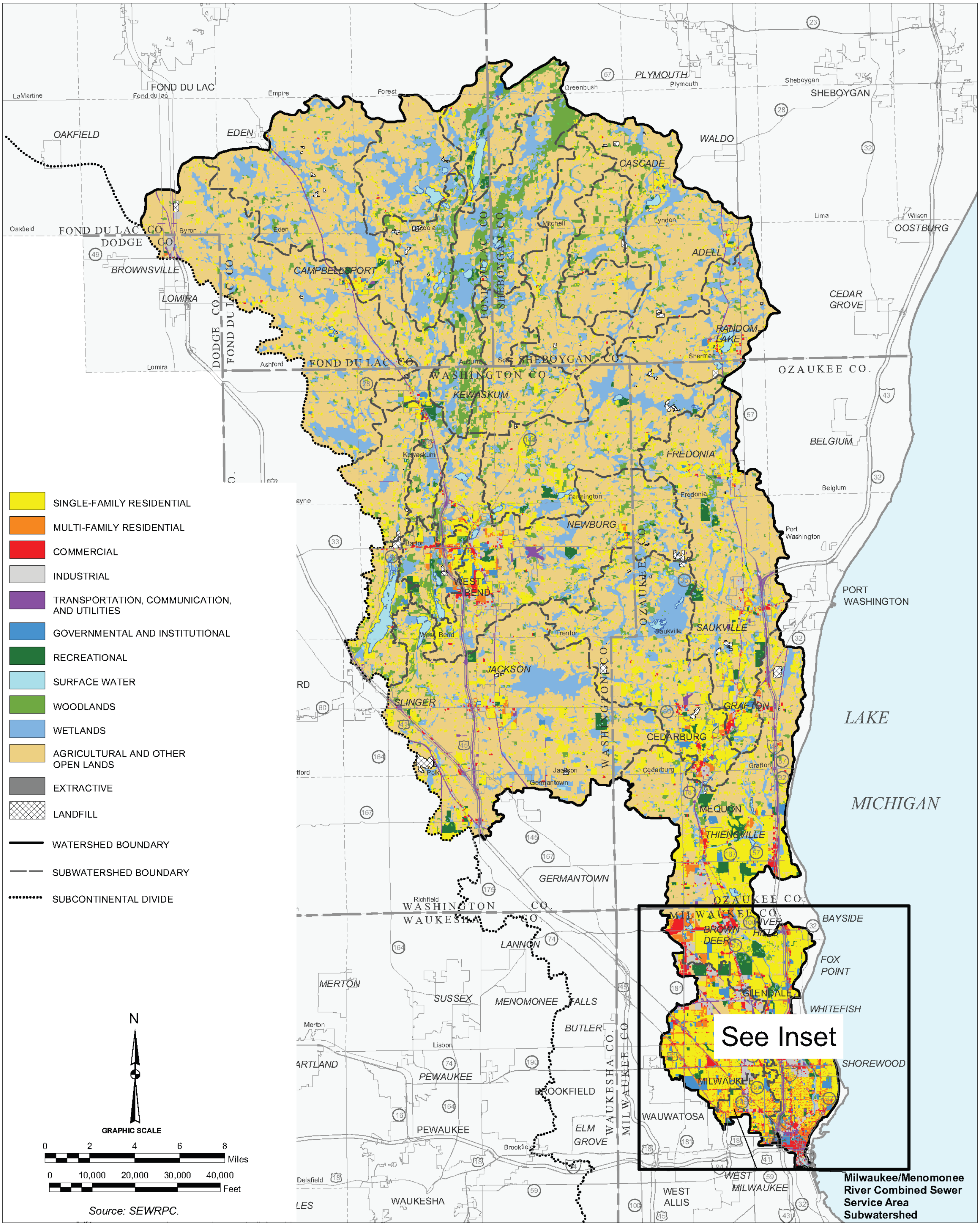
- Median discharge at the station along the mainstem of the River at Pioneer Road (River Mile 26.25) represents about 85 percent of the median discharge at the Estabrook Park station. Much of the increase between Waubeka and Pioneer Road can be accounted for by contributions from Cedar Creek. Discharge at the Cedar Creek gauge at STH 60 (River Mile 6.77) represents about 16 percent of the median discharge at Estabrook Park. This suggests that contributions from Fredonia Creek, Mole Creek, and other tributaries entering the River between Waubeka and Pioneer Road represent about 9 percent of the flow at Estabrook Park.

- Contributions from a number of tributaries, as well as direct runoff, account for the increase in median discharge between Pioneer Road and Estabrook Park.

- Median discharge at Jones Island, which includes contributions from the Kinnickinnic and Menomonee Rivers, represents about 132 percent the median discharge at Estabrook Park. Through comparison of that percentage with the 100 percent contribution at Estabrook Park, suggests that the Milwaukee River contributes about three quarters of the median discharge into the harbor.

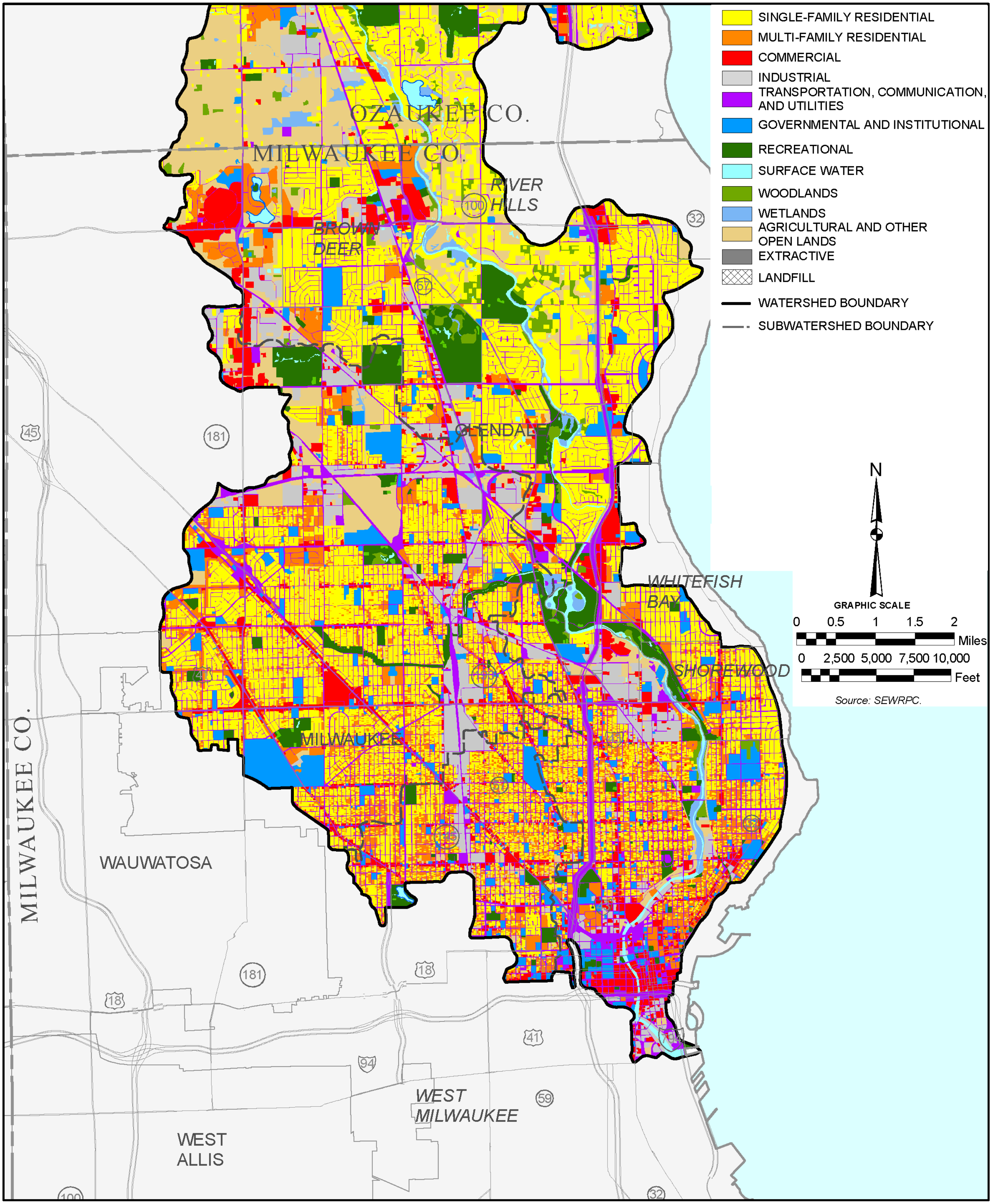
Map 49

EXISTING LAND USE WITHIN THE MILWAUKEE RIVER WATERSHED: 2000



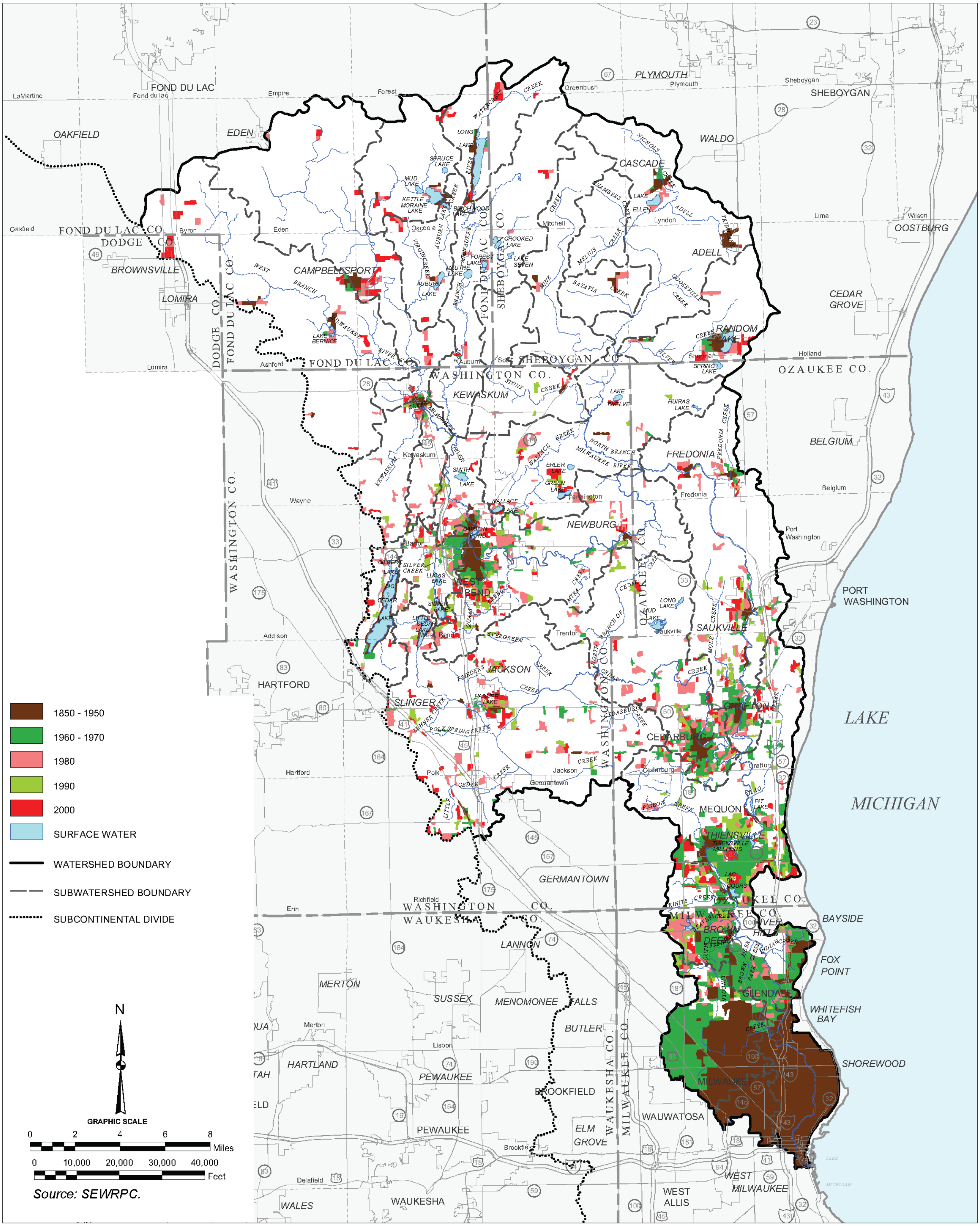
Source: SEWRPC.

INSET to Map 49



Map 50

HISTORICAL URBAN GROWTH WITHIN THE MILWAUKEE RIVER WATERSHED: 1850-2000



Source: SEWRPC.

SURFACE WATER QUALITY OF THE MILWAUKEE RIVER WATERSHED: 1975-2004

Water Quality of Streams

The earliest systematic collection of water quality data in the Milwaukee River watershed occurred in the mid-1960s.[1] Data collection after that was sporadic until the 1970s. Since then, considerable data have been collected, especially on the mainstem of the River. The major sources of data include the Milwaukee Metropolitan Sewerage District (MMSD), the Wisconsin Department of Natural Resources (WDNR), the U.S. Geological Survey (USGS), the Washington County Land and Water Conservation Division, the University of Wisconsin-Milwaukee, and the U.S. Environmental Protection Agency's (USEPA) STORET legacy and modern databases (see Map 52). In addition, the Commission staff reviewed data collected by citizen monitoring programs including the Testing the Waters Program and the Water Action Volunteers Program. These data are presented in Appendix B. Most of these data were obtained from sampling stations along the mainstem of the River. In addition, sufficient data were available for several tributaries to assess baseline period water quality for several water quality parameters. These tributaries are listed in Table 86. The data record for the other tributary streams in the watershed is fragmentary.

Table 85

EXTENT OF URBAN GROWTH WITHIN THE MILWAUKEE RIVER WATERSHED: 1850-2000

Year	Extent of New Urban Development Occurring Since Previous Year (acres)[a]	Cumulative Extent of Urban Development (acres)[a]	Cumulative Extent of Urban Development (percent)[a]
1850	2,680	2,680	0.6
1880	2,773	5,453	1.2
1900	1,614	7,067	1.6
1920	3,751	10,818	2.4
1940	6,943	17,761	3.9
1950	7,441	25,202	5.6
1963	14,592	39,794	8.9
1970	5,487	45,281	10.1
1975	5,116	50,397	11.2
1980	8,054	58,451	13.0
1985	3,232	61,683	13.7
1990	2,780	64,463	14.4
1995	3,127	67,590	15.1
2000	4,608	72,198	16.1

[a]*Urban development, as defined for the purposes of this discussion, includes those areas within which houses or other buildings have been constructed in relatively compact groups, thereby, indicating a concentration of urban land uses. Scattered residential developments were not considered in this analysis.*

Source: U.S. Bureau of the Census and SEWRPC.

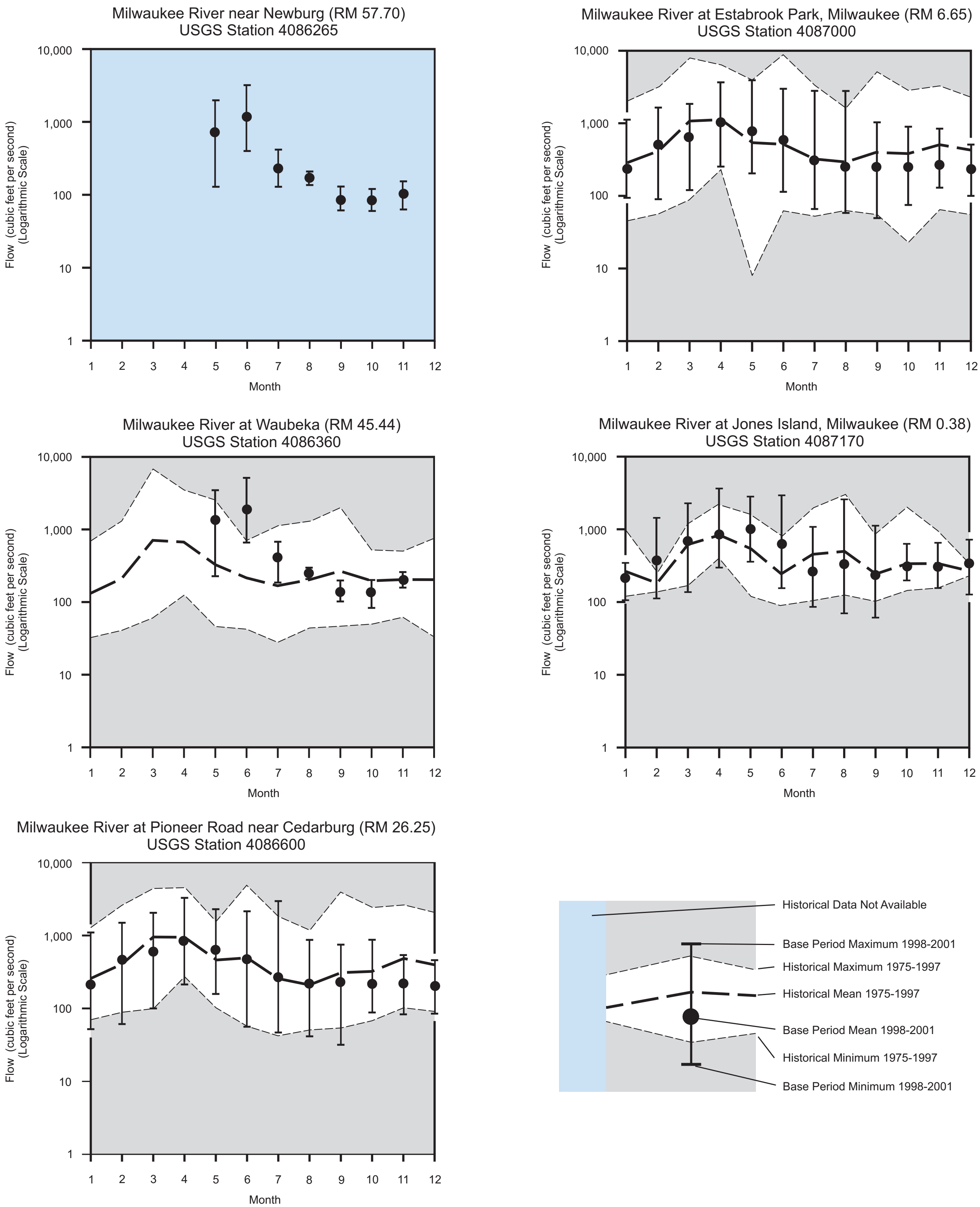
For analytical purposes, data from four time periods were examined: 1975-1986, 1987-1993, 1994-1997, and 1998-2004. Bimonthly data records exist from several of MMSD's long-term monitoring stations beginning in 1975. After 1986, MMSD no longer conducted sampling during the winter months. In 1994, the Inline Storage System (ISS), or Deep Tunnel, came online. The remaining period from 1998-2004 defines the baseline water quality conditions of the river system, since the Inline Storage System came online.

Under this plan update, baseline water quality conditions were graphically compared to historical conditions on a monthly basis. As shown in the sample graph presented in Figure 23 of Chapter III of this report, for each water quality parameter examined, the background of the graph summarizes the historical conditions. The white area in the graphs shows the range of values observed during the period 1975-1997. The upper and lower boundaries between the white and gray areas show historical maxima and minima, respectively. A blue background indicates months for which no historical data were available. The black dashed line plots the monthly mean value of the parameter for the historical period. Overlaid on this background is a summary of baseline conditions from the period 1998-2004. Relative to the Kinnickinnic River, Menomonee River, and Oak Creek watersheds, the baseline period examined for the Milwaukee River was extended to 2004 in order to take advantage of data collected specifically for the regional water quality management plan update in 2004 by the USGS and by the Washington County Land and Water Conservation Division during the period 2003-2004. The black dots show the monthly mean value of the parameter for the 1998-2004 period. The black bars show the monthly ranges of parameter for the same period.

[1]*SEWRPC Technical Report No. 4,* Water Quality and Flow of Streams in Southeastern Wisconsin*, April 1964.*

Figure 106

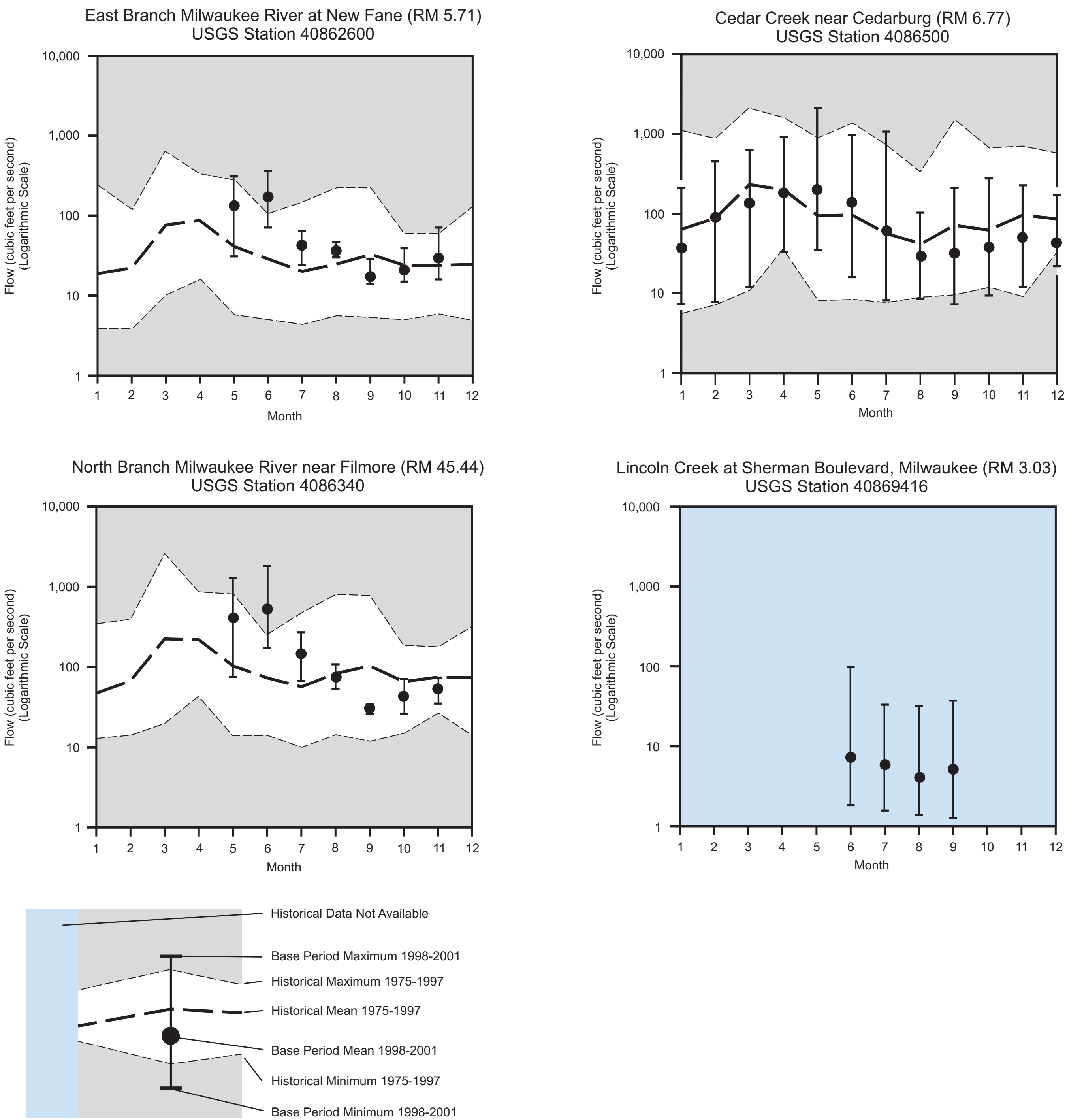
HISTORICAL AND BASE PERIOD FLOW ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



Source: U.S. Geological Survey and SEWRPC.

Figure 107

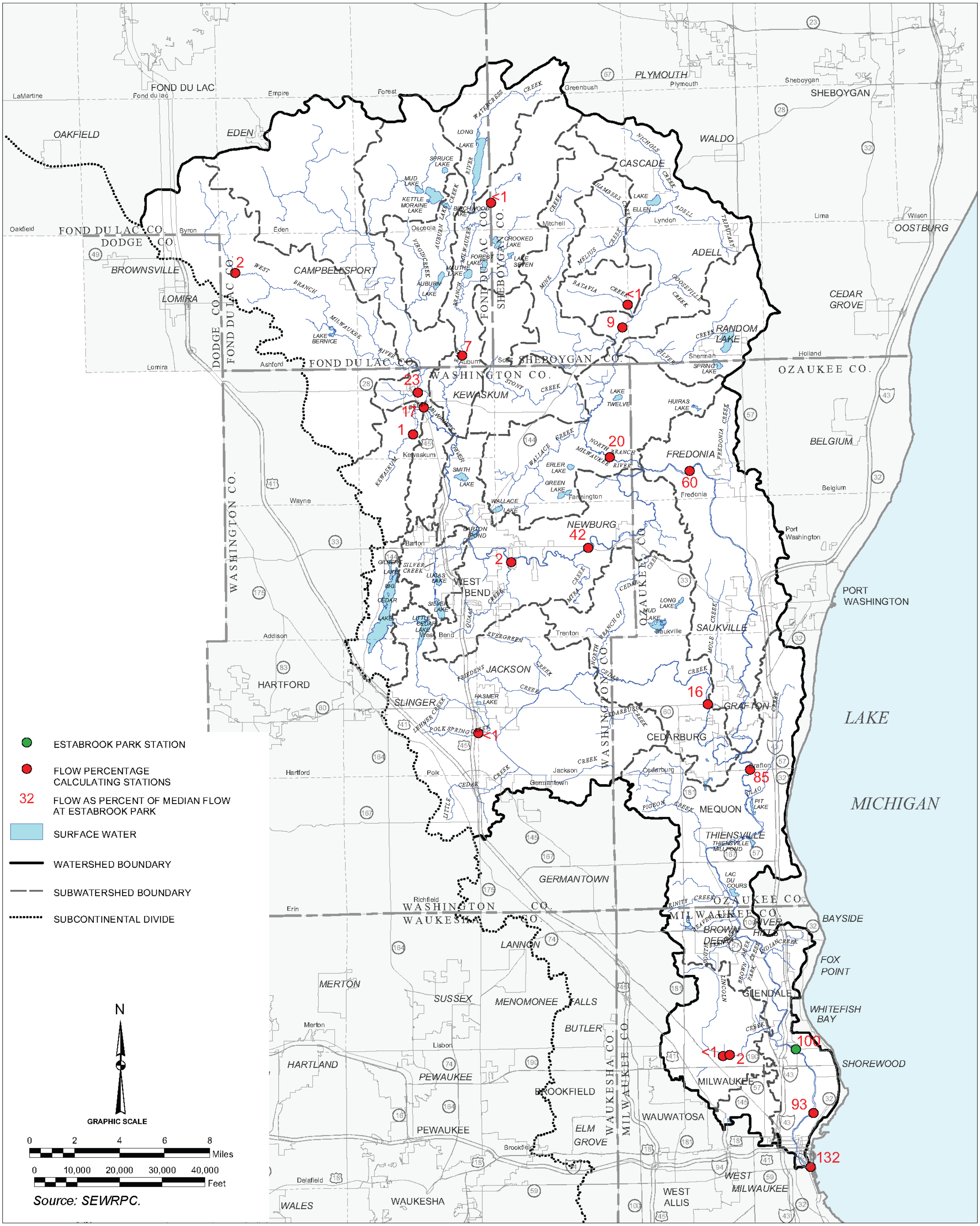
HISTORICAL AND BASE PERIOD FLOW IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



Source: U.S. Geological Survey and SEWRPC.

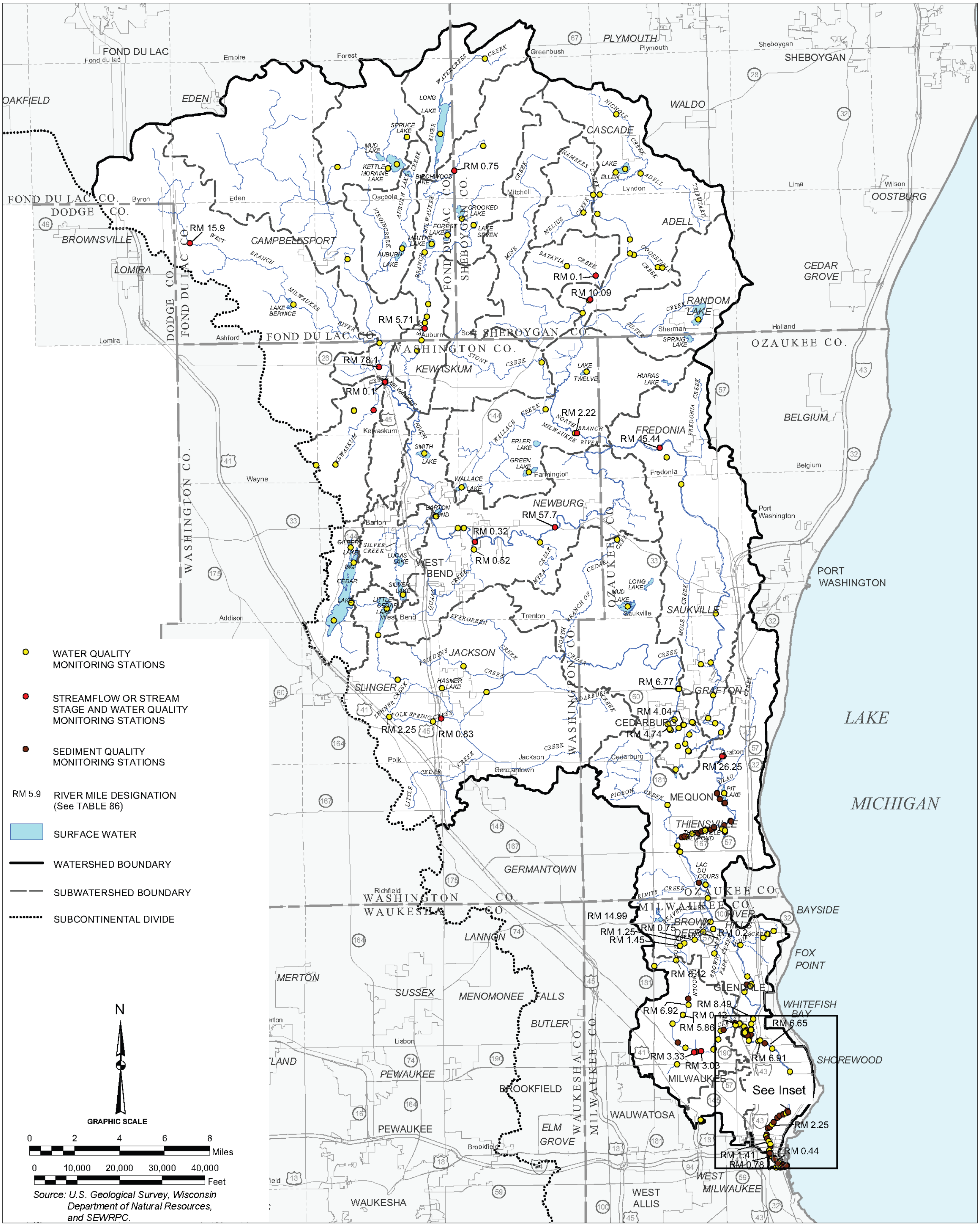
Map 51

FLOW PERCENTAGES AMONG STATIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 2004



Map 52

WATER AND SEDIMENT QUALITY MONITORING STATIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 1975-2001



INSET to Map 52

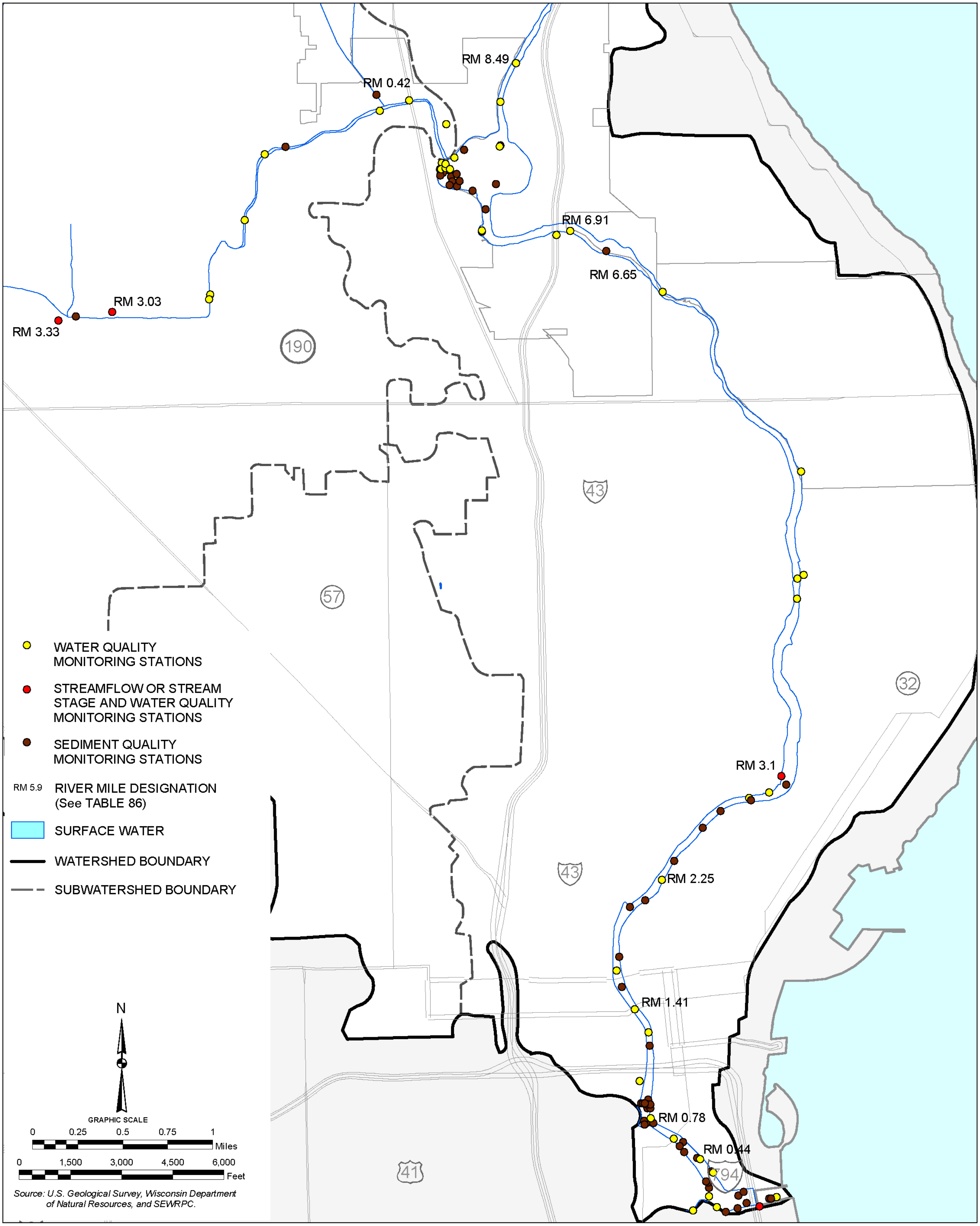


Table 86

SAMPLE SITES USED FOR ANALYSIS OF WATER QUALITY TRENDS IN THE MILWAUKEE RIVER

Location	River Mile	Period of Record	Data Sources
Tributaries			
West Branch Milwaukee River at Drumlin Drive near Lomira	15.90[a]	1998-1999, 2001	USGS, USEPA
Kewaskum Creek at USH 45 at Kewaskum	0.10[a]	1998-1999	USGS, USEPA
Parnell Creek near Dundee	0.75[b]	1996-1997; 2001-2002	USGS
East Branch Milwaukee River at New Fane	5.71[a]	1993, 1995, 2004	USGS, USEPA, WDNR
Quaas Creek upstream of Decorah Road near West Bend	0.52[a]	2000-2003	UW-Milwaukee, Washington County Land and Water Conservation Division
Quaas Creek at Decorah Road near West Bend	0.32[a]	1998-1999	USGS, USEPA
Batavia Creek near Batavia	0.10[c]	1993-1994, 1998-1999	USGS, USEPA
North Branch Milwaukee River near Random Lake	10.09[a]	1992-1995, 2001-2002	USGS
North Branch Milwaukee River near Fillmore	2.22[a]	2004	USGS
Polk Springs Creek downstream of CTH Z near Jackson	2.25[d]	2003	Washington County Land and Water Conservation Division
Polk Springs Creek at CTH P near Jackson	0.83[d]	1998-2001, 2003-2004	USGS, EPA, Washington County Land and Water Conservation Division
Cedar Creek at STH 60 near Cedarburg	6.77[a]	1970, 1973-1987, 1990-2004	USGS, WDNR
Cedar Creek at Columbia Road at Cedarburg	4.74[a]	1990-1991, 1994-1995, 2001	USGS
Cedar Creek at Highland Road at Cedarburg	4.04[a]	1990-1991, 1994-1995, 2001	USGS
Southbranch Creek at Bradley Road	1.45[a]	1999-2002	MMSD
Southbranch Creek at 55th Street	1.25[a]	1999-2002	MMSD
Southbranch Creek at 47th Street	0.75[a]	1999-2002	MMSD
Southbranch Creek at Teutonia Avenue	0.20[a]	1999-2002	MMSD
Lincoln Creek at 60th Street	8.42[a]	1997-2002	MMSD
Lincoln Creek at 51st Street	6.92[a]	1997-2002	MMSD
Lincoln Creek at 55th Street	5.86[a]	1997-2002	MMSD
Lincoln Creek at 47th Street	3.33[a]	1992-2004	USGS, USEPA, WDNR, MMSD
Lincoln Creek at Sherman Boulevard	3.03[a]	2003-2004	USGS
Lincoln Creek at Green Bay Avenue	0.42[a]	1997-2002	MMSD
Mainstem			
Milwaukee River above Dam at Kewaskum	78.10[e]	2004	USGS
Milwaukee River at CTH M near Newburg	57.70[e]	2004	USGS
Milwaukee River at Waubeka	45.44[e]	2004	USGS
Milwaukee River at Pioneer Road near Cedarburg	26.25[e]	1981-2004	USGS, USEPA, WDNR, MMSD
Milwaukee River at Brown Deer Road	14.99[e]	1975; 1981-2002	USEPA, MMSD
Milwaukee River at Silver Spring Drive	8.49[e]	1975, 1976, 1981-2002	USEPA, MMSD
Milwaukee River at Port Washington Road	6.91[e]	1975, 1981-2002	MMSD
Milwaukee River at Estabrook Park	6.65[e]	1971-2004	USGS, USEPA, WDNR
Milwaukee River at North Avenue Dam	3.10[e]	1975-1976, 1979-2002	USGS, USEPA, MMSD
Milwaukee River at Walnut Street	2.25[e]	1975, 1980-2002	MMSD
Milwaukee River at Wells Street	1.41[e]	1975, 1980-2002	USEPA, MMSD
Milwaukee River at Water Street	0.78[e]	1975, 1980-2002	MMSD
Milwaukee River at Union Pacific Railroad (formerly Chicago & North Western Railway)	0.44[e]	1975, 1982-2002	MMSD

[a]*River Mile is measured as distance upstream from the confluence with the mainstem of the Milwaukee River.*

[b]*River Mile is measured as distance upstream from the confluence with the East Branch Milwaukee River.*

[c]*River Mile is measured as distance upstream from the confluence with the North Branch Milwaukee River.*

[d]*River Mile is measured as distance upstream from the confluence with Cedar Creek.*

[e]*River Mile is measured as distance upstream from the confluence with Lake Michigan.*

Source: SEWRPC.

In addition to this summarization, water quality parameters from the Milwaukee River were examined for the presence of several different types of trends: differences between the average values of parameters from sampling stations located in upstream areas and the average values of parameters from sampling stations located in the Milwaukee River Estuary, changes along the length of the River, changes at individual sampling stations over time, and seasonal changes throughout the year. Map 52 and Table 86 show the 13 sampling stations on the Milwaukee River, designated by their River Mile locations, which had sufficiently long periods of sampling to be used for these analyses. Trends over time and seasonal changes were examined along a section of the Milwaukee River from the confluence with Lake Michigan to a station 78.10 river miles upstream. Longitudinal trends and comparisons between water quality in the estuary and at stations upstream from the estuary were examined along a section of Milwaukee River from the confluence with Lake Michigan to a station 26.25 river miles upstream. Changes over time were assessed both on an annual and on a seasonal basis as set forth in Appendix C. Where sufficient data were available, water quality parameters from tributary streams were also examined for the presence of trends. It is important to note that only limited data were available to assess baseline water quality conditions for tributary streams. Figure 108 shows photographs of selected river sampling stations along the mainstem of the Milwaukee River and several tributaries.

Bacterial and Biological Parameters

Bacteria

Fecal coliform bacteria data for selected locations are shown in Figure 109. Based on data for all of the sampling locations analyzed, median concentrations of fecal coliform bacteria in the Milwaukee River during the period of record ranged from about 50 to 2,300 cells per 100 milliliters (ml). Fecal coliform counts in the River varied over seven orders of magnitude, ranging from as low as one cell per 100 ml to over 1,100,000 cells per 100 ml. The range of variability appears to be higher during late spring, summer, and fall as shown in Figure 110, although it is important to note that this may reflect the larger numbers of samples that were taken during the these months than during other months. Counts in most samples exceed the standard for full recreational use of 200 cells per 100 ml. In addition, the fecal coliform bacteria concentrations in the estuary in many samples exceed the standard of 1,000 cells per 100 ml applied by the variance covering the estuary portion of the Milwaukee River. Table 87 shows that prior to 1994, the mean concentrations of fecal coliform bacteria in the estuary were significantly higher than the mean concentrations of fecal coliform bacteria in the section of the River upstream from the estuary. This relationship changed after 1994. During the period 1994-1997, there were no differences between the mean concentrations of fecal coliform bacteria in the estuary and the mean concentrations of fecal coliform bacteria in the section of the River upstream of the estuary. This change was the result of a decrease in fecal coliform bacterial concentrations in the estuary (see Figure 109) after the Inline Storage System came online in 1994. After 1997, the relationship between the mean concentrations of fecal coliform bacteria in the estuary and in the section of the River upstream of the estuary changed again. During the period 1998-2004, the mean concentrations in the estuary were significantly higher than those in the section of the River upstream from the estuary (see Table 87). This change is attributable to increases in the concentration of fecal coliform bacteria at most stations in the estuary (see Figure 109). At some stations, these increases in concentration during the period 1998-2004 were accompanied by increases in variability. For example, the coefficient of variation, a measure of variability in a data set, at the sampling station at the Union Pacific Railroad increased from 3.10 during the period 1994-1997 to 3.52 during the period 1998-2004. The higher concentrations of fecal coliform bacteria in the estuary suggest that water in the estuary was receiving more contamination from sources containing these bacteria than water in the nonestuary sections of the River. It is important to note, that since 1994, median concentrations of fecal coliform bacteria in the estuary have tended to decrease from upstream to downstream. This is consistent with the trends seen in the Kinnickinnic River (see Chapter V of this report) and may be the result of dilution effects from the influence of Lake Michigan. Table 88 shows that there is a statistically significant trend toward concentrations of fecal coliform bacteria increasing from upstream to downstream along the portion of the mainstem of the Milwaukee River upstream of the estuary. This relationship accounts for a small portion of the variation in the concentrations of fecal coliform bacteria in the River. This may be the result of water in the downstream sections of the River receiving more contamination from sources containing these bacteria than water in the upstream sections. Several generalizations emerge from the comparison of baseline period fecal coliform concentrations to historical concentrations shown in Figure 110: First, fecal coliform concentrations in the

Figure 108

SAMPLE STATION LOCATIONS ALONG THE MILWAUKEE RIVER: 2003-2005

MILWAUKEE RIVER AT RIVER MILE 76.97

MILWAUKEE RIVER AT RIVER MILE 45.44

MILWAUKEE RIVER AT RIVER MILE 26.25

MILWAUKEE RIVER AT RIVER MILE 14.99

MILWAUKEE RIVER AT RIVER MILE 6.45

MILWAUKEE RIVER AT RIVER MILE 0.71

Figure 108 (continued)

NORTH BRANCH MILWAUKEE RIVER AT RIVER MILE 10.09

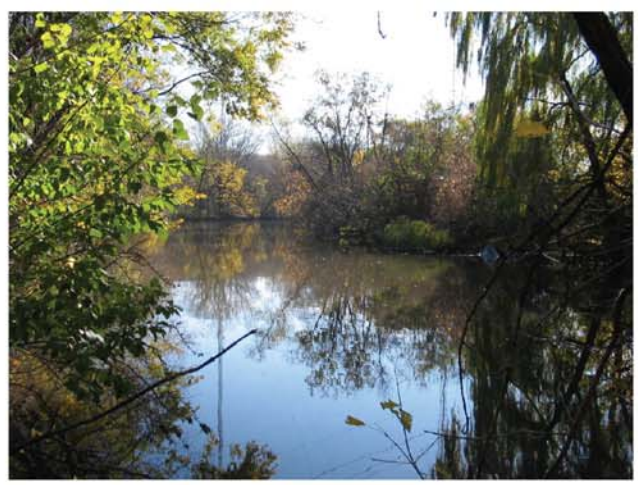
CEDAR CREEK NEAR RIVER MILE 4.74

EAST BRANCH MILWAUKEE RIVER AT RIVER MILE 2.21

SOUTHBRANCH CREEK AT RIVER MILE 0.75

QUAAS CREEK AT RIVER MILE 0.16

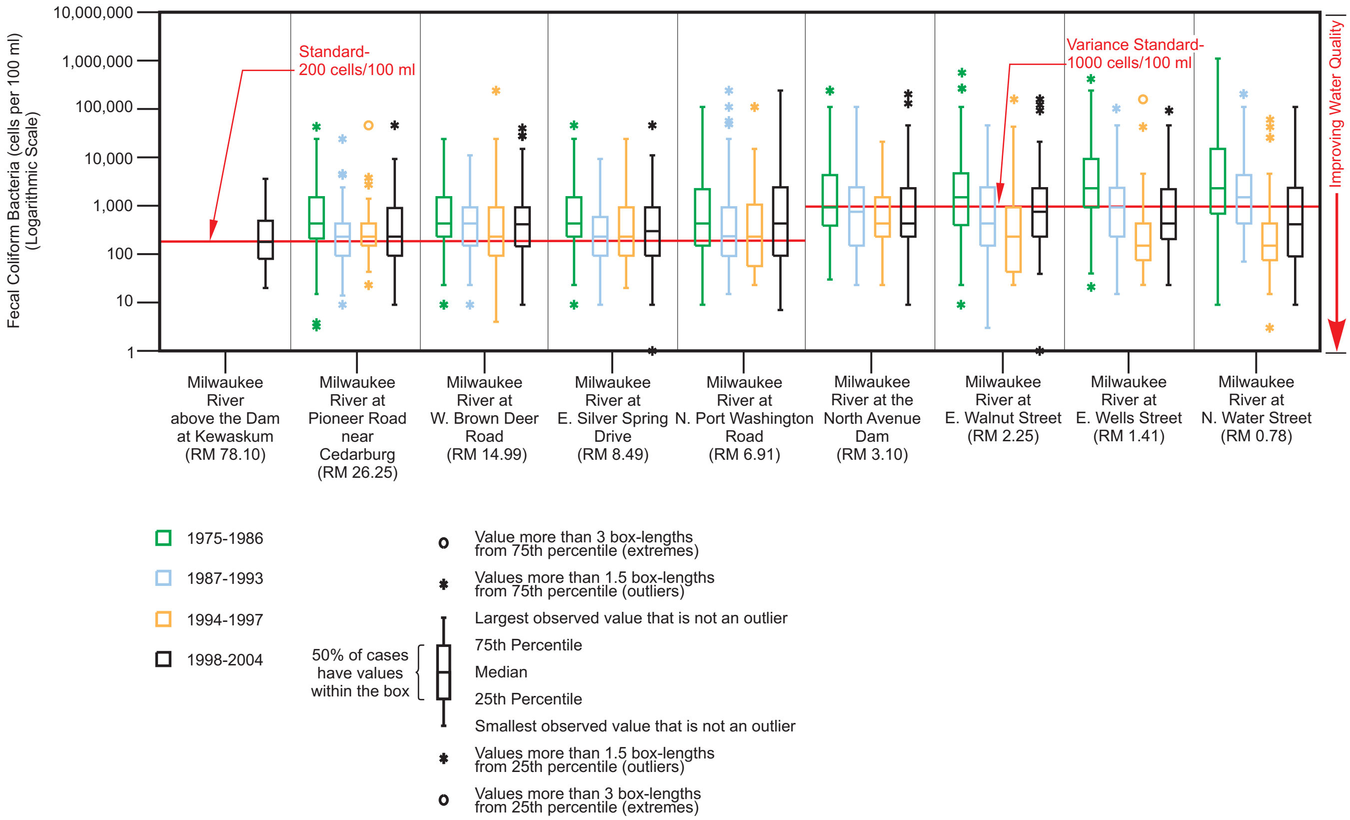
LINCOLN CREEK AT RIVER MILE 0.42



Source: Inter-Fluve, Inc., and SEWRPC.

Figure 109

FECAL COLIFORM BACTERIA ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



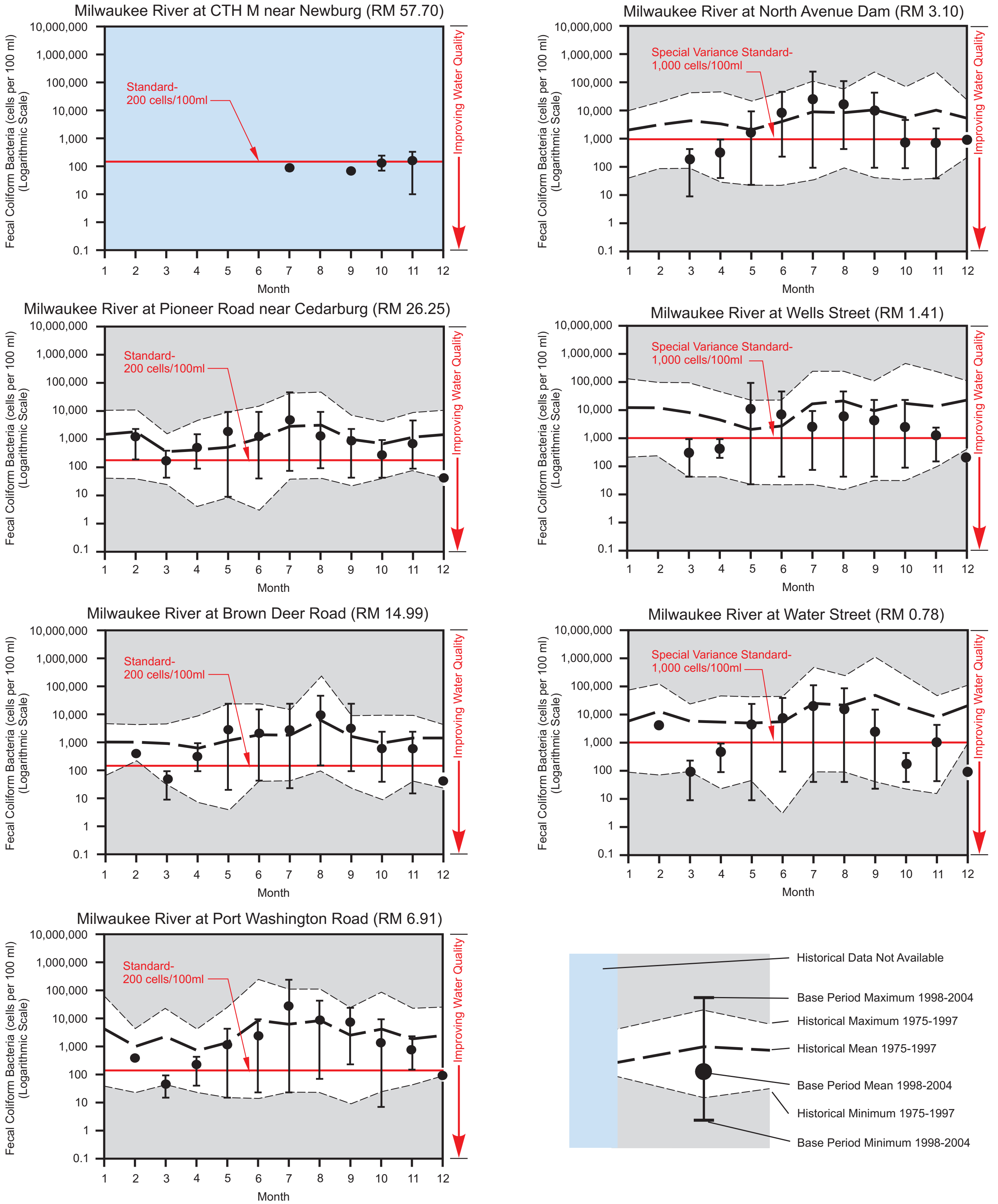
Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Milwaukee River tend to be relatively low during the late winter and early spring. They increase sharply during the spring and early summer. This is followed by a decrease that, depending upon the station, occurs during summer or fall. Second, baseline period monthly mean concentrations of fecal coliform bacteria during the late winter, early spring, and fall were lower than the historical monthly mean concentrations. During the late spring and summer, baseline period mean monthly concentrations of fecal coliform bacteria were near or above the historical monthly mean concentrations. These patterns varied somewhat among the sampling stations.

As shown in Table C-5 in Appendix C of this report, several time-based trends in fecal coliform bacteria concentrations were detected in the Milwaukee River. When analyzed on an annual basis, all the long-term sampling sites in the estuary showed statistically significant trends toward decreasing fecal coliform concentrations. In addition, statistically significant decreasing trends were detected at two stations upstream from the estuary, those at Brown Deer Road and Silver Spring Drive. These trends account for small fractions of the variation observed at these stations. When examined on a seasonal basis, decreasing trends in the concentrations of fecal coliform bacteria were detected at most stations during the spring and several stations during the summer and fall. Fecal coliform bacteria concentrations in the Milwaukee River tend to be positively correlated with concentrations of biochemical oxygen demand, especially in the estuary, and with concentrations of several nutrients including ammonia, dissolved phosphorus, total phosphorus, and total nitrogen. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the River. Fecal coliform bacteria concentrations are also strongly positively correlated with concentrations of *E. coli*, reflecting the fact that *E. coli* constitute a major component of fecal coliform bacteria. In addition, fecal coliform bacteria concentrations in the River are negatively correlated with several measures of dissolved material, such as

Figure 110

HISTORICAL AND BASE PERIOD FECAL COLIFORM BACTERIA ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Table 87

COMPARISON OF WATER QUALITY BETWEEN THE MILWAUKEE RIVER AND THE MILWAUKEE RIVER ESTUARY: 1975-2004[a]

Parameters	Years			
	1975-1986[b]	1987-1993[b]	1994-1997[b]	1998-2004[b]
Biological/Bacteria				
Fecal Coliform[c]	Estuary	Estuary	0	Estuary
E. coli [c]	- -	- -	- -	Estuary
Chlorophyll-*a*[c]	0	River	River	River
Chemical/Physical				
Alkalinity	River	River	River	River
Biochemical Oxygen Demand[c]	Estuary	River	River	0
Dissolved Oxygen	River	River	River	River
Hardness	River	River	River	River
pH	River	River	River	River
Specific Conductance	River	River	River	River
Suspended Material				
Total Suspended Solids	River	River	River	River
Nutrients				
Ammonia, Dissolved[c]	Estuary	Estuary	Estuary	Estuary
Kjeldahl Nitrogen[c]	0	River	River	0
Nitrate, Dissolved[c]	River	0	0	River
Nitrite, Dissolved[c]	Estuary	Estuary	Estuary	Estuary
Organic Nitrogen[c]	River	River	River	0
Phosphorus, Dissolved[c]	River	River	0	0
Total Nitrogen[c]	River	River	River	River
Total Phosphorus[c]	0	River	0	0
Metals/Salts				
Arsenic[c]	- -	0	0	0
Cadmium[c]	Estuary	Estuary	0	0
Chloride[c]	Estuary	River	0	River
Chromium[c]	Estuary	Estuary	0	0
Copper[c]	Estuary	Estuary	Estuary	Estuary
Lead[c]	Estuary	Estuary	Estuary	Estuary
Mercury[c]	- -	- -	River	River
Nickel[c]	0	0	0	0
Zinc[c]	Estuary	Estuary	Estuary	Estuary

NOTE: The following symbols were used:

"Estuary" indicates that the mean value from the estuary is statistically significantly higher than the mean value from the upstream section.

"River" indicates that the mean value from the estuary is statistically significantly lower than the mean value from the upstream section.

0 indicates that no differences were detected.

- - indicates that the data were insufficient for the analysis.

[a]*The estuary sites used in this analysis were located within the Milwaukee River estuary.*

[b]*Differences between means were assessed through analysis of variance (ANOVA). Means were considered significantly different at a probability of P = 0.05 or less.*

[c]*These data were log-transformed before being entered into ANOVA.*

Source: SEWRPC.

Table 88

UPSTREAM TO DOWNSTREAM TRENDS IN WATER QUALITY PARAMETERS FROM UPSTREAM SITES ALONG THE MILWAUKEE RIVER 1975-2004[a]

Constituent	Trend	Slope	Intercept	R^2
Bacteria and Biological				
Fecal Coliform[b]	⬆	<-0.01	2.699	<0.01
E. coli [b]	⬆	-0.02	2.434	0.02
Chlorophyll-*a*[b]	⬆	<-0.01	1.336	<0.01
Chemical				
Alkalinity	⬇	0.76	241.715	0.02
Biochemical Oxygen Demand[b]	⬆	<-0.01	0.440	0.01
Chloride[b]	⬆	<-0.01	1.682	<0.01
Dissolved Oxygen	⬇	0.11	8.590	0.10
Hardness	⬇	0.54	286.424	0.01
pH	0	- -	- -	- -
Specific Conductance	⬇	0.64	642.664	<0.01
Temperature	0	- -	- -	- -
Suspended Material				
Total Suspended Sediment	⬆	-0.58	42.089	0.01
Total Suspended Solids	⬇	0.31	28.400	0.01
Nutrients				
Ammonia[b]	⬇	<0.01	-1.212	<0.01
Kjeldahl Nitrogen[b]	0	- -	- -	- -
Nitrate[b]	⬇	0.02	-0.582	0.06
Nitrite[b]	⬇	<0.01	-1.923	<0.01
Organic Nitrogen[b]	⬆	<-0.01	-0.033	<0.01
Total Nitrogen[b]	⬇	<0.01	0.206	0.03
Dissolved Phosphorus[b]	⬇	<0.01	-1.517	0.04
Total Phosphorus[b]	0	- -	- -	- -
Metals				
Arsenic[b]	⬆	<-0.01	0.275	<0.01
Cadmium[b]	⬇	<0.01	-0.424	<0.01
Chromium[b]	⬇	<0.01	0.672	0.02
Copper[b]	0	- -	- -	- -
Lead[b]	0	- -	- -	- -
Mercury[b]	0	- -	- -	- -
Nickel[b]	⬇	<0.01	0.939	0.01
Zinc[b]	⬆	<-0.01	1.110	<0.01

NOTE: The following symbols were used:

⬆ indicates a statistically significant increase from upstream to downstream.

⬇ indicates a statistically significant decrease from upstream to downstream.

0 indicates that no trend was detected.

R^2 indicates the fraction of variance accounted for by the regression.

[a]*Trends were assessed through linear regression analysis. Values of water quality parameters were regressed against River Mile. A trend was considered significant if the regression showed a significant slope at P = 0.05 or less. Higher* R^2 *values indicate that higher portions of the variation in the data are attributable to the trend. Lower* R^2 *values indicate that more of the variation is due to random factors.*

[b]*These data were log-transformed before being entered into regression analysis.*

Source: SEWRPC.

alkalinity, hardness, specific conductance, and pH. The long-term trends toward declining fecal coliform bacteria concentrations at several stations represent a long-term improvement in water quality in the Milwaukee River. The recent increases in fecal coliform bacteria concentrations at many of these same stations suggest that water quality may currently be declining although the long-term trend still indicates an improvement.

Figure 111 shows concentrations of fecal coliform bacteria in three tributaries to the Milwaukee River: Cedar Creek, Southbranch Creek, and Lincoln Creek. The median concentration of fecal coliform bacteria in Cedar Creek during the period of record was 140 cells per 100 milliliters (ml). Fecal coliform bacteria counts in the Creek varied over three orders of magnitude, ranging between 10 cells per 100 ml and 1,500 cells per 100 ml. Concentrations appear to be higher during summer than during other seasons (see Figure 112), although this may reflect the larger numbers of samples that were taken during this season. Counts in many samples exceed the standard for full recreational use of 200 cells per 100 ml. No time-based trends were detected in fecal coliform bacteria concentrations in Cedar Creek (Table C-5 in Appendix C). The median concentration of fecal coliform bacteria in Southbranch Creek during the period of record was 930 cells per 100 milliliters (ml). Fecal coliform bacteria counts in the Creek varied over five orders of magnitude, ranging between one cell per 100 ml and 46,000 cells per 100 ml. Figure 111 shows that fecal coliform concentrations in the Creek tend to increase from upstream to downstream. While this trend was statistically significant, it accounted for a relatively small portion of the variation in fecal coliform bacteria concentrations (see Table 89). Concentrations of fecal coliform bacteria appear to be highest during the mid-summer and late fall (see Figure 112). Counts in most samples exceed the standard for full recreational use of 200 cells per 100 ml. Few time-based trends were detected in fecal coliform bacteria concentrations in Southbranch Creek (Table C-5 in Appendix C). This may be due to the short period of record for this stream (see Tables 86 and 89). The median concentration of fecal coliform bacteria in Lincoln Creek during the period of record was 1,200 cells per 100 milliliters (ml). Fecal coliform bacteria counts in the Creek varied over seven orders of magnitude, ranging between one cell per 100 ml and 1,100,000 cells per 100 ml. Figure 111 shows that fecal coliform concentrations in the Creek tend to increase from upstream to downstream. While this trend was statistically significant, it accounted for a relatively small portion of the variation in fecal coliform bacteria concentrations (see Table 90). Concentrations of fecal coliform bacteria appear to be highest during the summer (see Figure 112). Counts in most samples exceed the standard for full recreational use of 200 cells per 100 ml. In addition, counts in many samples exceed the variance standard of 1,000 cells per 100 ml which applies to Lincoln Creek. The proportion of samples in which fecal coliform bacteria concentrations exceed the variance standard increases from upstream to downstream along the Creek (see Figure 111). At most sampling stations, the median concentrations of fecal coliform bacteria has decreased over time; however, this has been accompanied by an increase in the maximum concentrations (see Figure 111). Few statistically significant time-based trends were detected in fecal coliform bacteria concentrations in Lincoln Creek (Table C-5 in Appendix C).

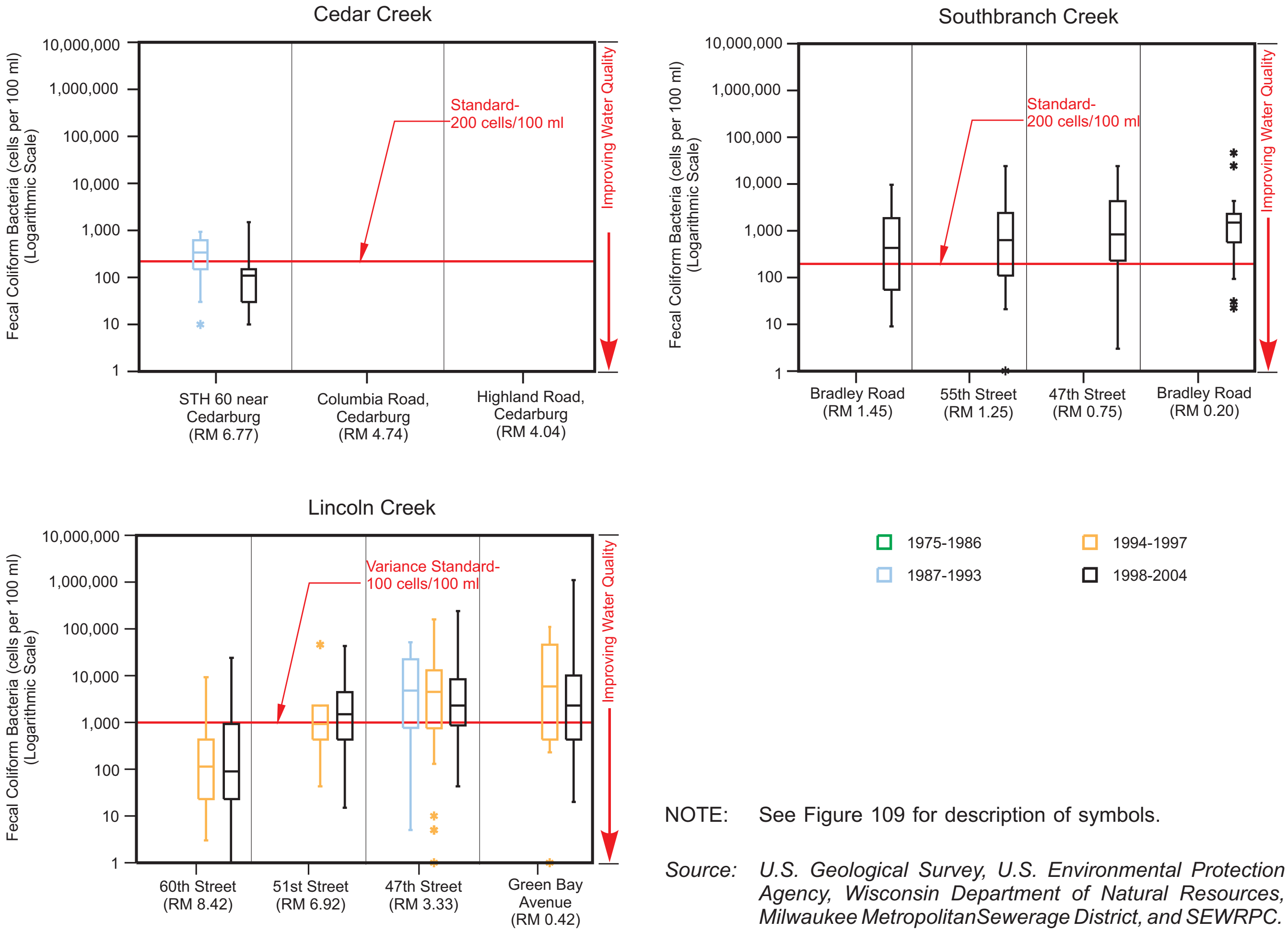
MMSD began regular sampling for *E. coli* in the Milwaukee River at six long-term sampling stations along the mainstem and two sampling stations along Lincoln Creek in 2000. In addition, the USGS and WDNR have conducted some sampling for *E. coli* in the Milwaukee River watershed. Figure 113 shows the concentrations of *E. coli* at eight sites along the mainstem of the Milwaukee River. Concentrations of *E. coli* in the River ranged from 0.5 cells per 100 ml to 130,000 cells per 100 ml. During the baseline period, mean concentrations of *E. coli* in the estuary were significantly higher than mean concentrations in the portion of the River upstream from the estuary (see Table 87). A statistically significant decreasing trend in *E. coli* concentration was detected from upstream to downstream along the portion of the Milwaukee River upstream from the estuary (see Table 88). Few statistically significant time-based trends were detected in *E. coli* concentrations (see Table C-5 in Appendix C of this report). Figure 114 shows baseline period monthly mean concentrations of *E. coli* for two stations along the mainstem of the Milwaukee River and one station along Lincoln Creek. Concentrations of *E. coli* in these streams tend to be highest during the summer. Variability in *E. coli* concentrations is also high during the summer.

Chlorophyll-a

Over the period of record, the mean concentration of chlorophyll-*a* in the Milwaukee River was 28.3 micrograms per liter (μg/l). Individual samples of this parameter ranged from below the limit of detection to 628.4 μg/l. Figure 115 shows that concentrations of chlorophyll-*a* at most stations along the mainstem of the Milwaukee

Figure 111

FECAL COLIFORM BACTERIA AT SITES IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



NOTE: See Figure 109 for description of symbols.

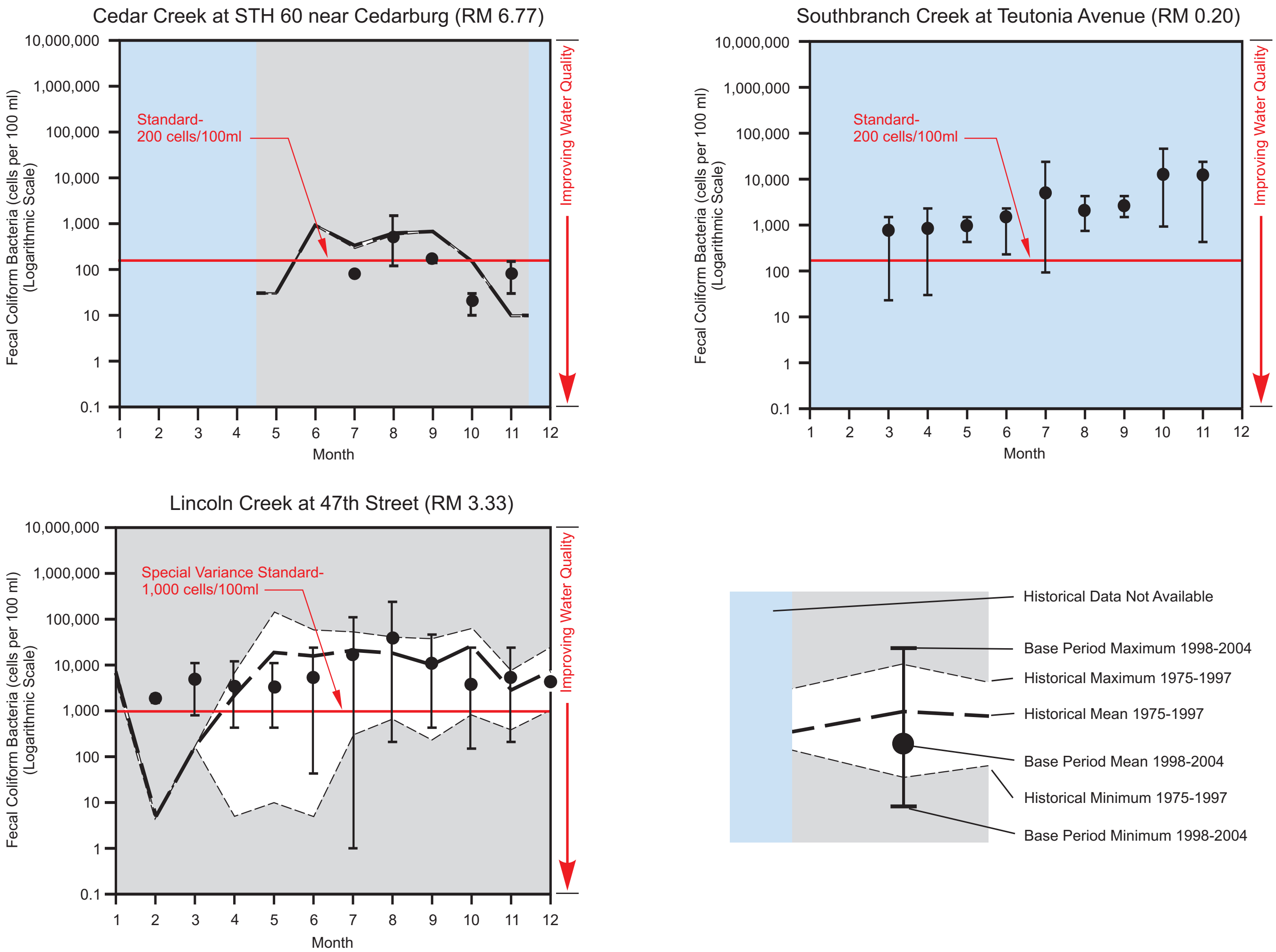
Source: *U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee MetropolitanSewerage District, and SEWRPC.*

River were lower during the period 1998-2004 than they were during previous periods. With one exception, mean chlorophyll-*a* concentrations in the estuary were lower than mean chlorophyll-*a* concentrations in the section of the River upstream of the estuary (see Table 87). During the period 1975-1986, there was no difference between mean chlorophyll-*a* concentrations in these two sections of the River. Table 88 shows that there is a statistically significant trend toward chlorophyll-*a* concentration increasing from upstream to downstream in the section of the River upstream from the estuary. When examined on an annual basis, few statistically significant time-based trends were detected in chlorophyll-*a* concentrations at stations along the mainstem (Table C-5 in Appendix C). Trends toward decreasing chlorophyll-*a* concentrations were detected at the stations at Water Street and the Union Pacific Railroad, the two stations farthest downstream. When examined on a seasonal basis, trends toward decreasing chlorophyll-*a* concentrations during the summer were detected at most stations along the mainstem of the River.

Mean concentrations of chlorophyll-*a* in tributary streams were generally lower than the mean concentration in the mainstem of the River, ranging from 2.48 μg/l in the East Branch Milwaukee River to 13.58 μg/l in Lincoln Creek. Mean concentrations of chlorophyll-*a* tended to be lower in tributaries in the upper reaches of the watershed than in lower reaches of the watershed, though this generalization may be an artifact of the small number of tributaries in which this parameter was sampled. In Lincoln Creek, chlorophyll-*a* concentrations tended to decrease from upstream to downstream (see Table 90). The opposite trend was observed in Southbranch Creek (see Table 89). Some time-based trends were detected in tributaries (Table C-5 in Appendix C). In Lincoln and Southbranch Creeks, trends toward increasing chlorophyll-*a* concentrations over time were detected at some sites,

Figure 112

HISTORICAL AND BASE PERIOD FECAL COLIFORM BACTERIA IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

especially during the summer. By contrast, when examined on an annual basis, trends toward decreasing chlorophyll-*a* concentrations over time were detected at all three stations along Cedar Creek.

At most stations along the mainstem, chlorophyll-*a* concentrations are negatively correlated with concentrations of nitrate and dissolved phosphorus. This reflects the role of these compounds as nutrients for algal growth. As algae grow, they remove these compounds from the water and incorporate them into cellular material. Chlorophyll-*a* concentrations are also positively correlated with temperature. Chlorophyll-*a* concentrations are also negatively correlated with alkalinity. Since chlorophyll-*a* concentrations in water strongly reflect algal productivity, this correlation probably reflects lowering of alkalinity during photosynthesis through removal of inorganic carbon, mostly carbon dioxide, bicarbonate, and carbonate, from the water. The trends toward decreasing chlorophyll-*a* concentrations along the mainstem of the River and along Cedar Creek represent improvements in water quality. The trends toward increasing chlorophyll-*a* concentrations at some stations along Lincoln and Southbranch Creeks represent reductions in water quality.

Table 89

UPSTREAM TO DOWNSTREAM TRENDS IN WATER QUALITY PARAMETERS FROM UPSTREAM SITES ALONG SOUTHBRANCH CREEK 1999-2004[a]

Constituent	Trend	Slope	Intercept	R^2
Bacteria and Biological				
Fecal Coliform[b]	⬆	-0.42	3.176	0.05
E. coli [b]	0	- -	- -	- -
Chlorophyll-*a*[b]	⬆	-0.43	0.969	0.08
Chemical				
Alkalinity	0	- -	- -	- -
Biochemical Oxygen Demand[b]	0	- -	- -	- -
Chloride[b]	⬆	-0.13	2.202	0.05
Dissolved Oxygen	0	- -	- -	- -
Hardness	0	- -	- -	- -
pH	0	- -	- -	- -
Specific Conductance	⬆	-170.14	991.198	0.05
Temperature	0	- -	- -	- -
Suspended Material				
Total Suspended Sediment	0	- -	- -	- -
Total Suspended Solids	⬆	-98.55	611.196	0.05
Nutrients				
Ammonia[b]	⬇	0.50	-1.962	0.07
Kjeldahl Nitrogen[b]	0	- -	- -	- -
Nitrate[b]	⬇	0.40	-0.721	0.11
Nitrite[b]	⬇	0.32	-1.818	0.10
Organic Nitrogen[b]	0	- -	- -	- -
Total Nitrogen[b]	⬇	0.16	-0.029	0.09
Dissolved Phosphorus[b]	⬇	0.30	-1.102	0.20
Total Phosphorus[b]	⬇	0.30	-0.976	0.20
Metals				
Arsenic[b]	0	- -	- -	- -
Cadmium[b]	0	- -	- -	- -
Chromium[b]	0	- -	- -	- -
Copper[b]	0	- -	- -	- -
Lead[b]	0	- -	- -	- -
Mercury[b]	0	- -	- -	- -
Nickel[b]	0	- -	- -	- -
Zinc[b]	⬇	0.19	1.344	0.11

NOTE: The following symbols were used:

⬆ indicates a statistically significant increase from upstream to downstream.

⬇ indicates a statistically significant decrease from upstream to downstream.

0 indicates that no trend was detected.

R^2 indicates the fraction of variance accounted for by the regression.

[a]*Trends were assessed through linear regression analysis. Values of water quality parameters were regressed against River Mile. A trend was considered significant if the regression showed a significant slope at P = 0.05 or less. Higher R^2 values indicate that higher portions of the variation in the data are attributable to the trend. Lower R^2 values indicate that more of the variation is due to random factors.*

[b]*These data were log-transformed before being entered into regression analysis.*

Source: SEWRPC.

Table 90

UPSTREAM TO DOWNSTREAM TRENDS IN WATER QUALITY PARAMETERS FROM UPSTREAM SITES ALONG LINCOLN CREEK 1997-2004[a]

Constituent	Trend	Slope	Intercept	R^2
Bacteria and Biological				
Fecal Coliform[b]	⬆	-0.14	3.733	0.14
E. coli [b]	- -	- -	- -	- -
Chlorophyll-*a*[b]	⬇	0.02	0.682	0.01
Chemical				
Alkalinity	0	- -	- -	- -
Biochemical Oxygen Demand[b]	⬆	-0.02	0.447	0.01
Chloride[b]	0	- -	- -	- -
Dissolved Oxygen	0	- -	- -	- -
Hardness	0	- -	- -	- -
pH	⬆	-0.02	7.831	0.02
Specific Conductance	0	- -	- -	- -
Temperature	0	- -	- -	- -
Suspended Material				
Total Suspended Sediment	- -	- -	- -	- -
Total Suspended Solids	⬆	-11.32	607.460	0.01
Nutrients				
Ammonia[b]	0	- -	- -	- -
Kjeldahl Nitrogen[b]	0	- -	- -	- -
Nitrate[b]	⬆	-0.06	-0.249	0.08
Nitrite[b]	⬆	-0.05	-1.456	0.14
Organic Nitrogen[b]	0	- -	- -	- -
Total Nitrogen[b]	⬆	-0.02	0.171	0.05
Dissolved Phosphorus[b]	⬆	-0.06	-0.147	0.15
Total Phosphorus[b]	⬆	-0.05	-0.792	0.12
Metals				
Arsenic[b]	0	- -	- -	- -
Cadmium[b]	0	- -	- -	- -
Chromium[b]	0	- -	- -	- -
Copper[b]	0	- -	- -	- -
Lead[b]	⬆	-0.04	0.639	0.09
Mercury[b]	⬆	-0.07	-1.363	0.14
Nickel[b]	0	- -	- -	- -
Zinc[b]	0	- -	- -	- -

NOTE: The following symbols were used:

⬆ indicates a statistically significant increase from upstream to downstream.

⬇ indicates a statistically significant decrease from upstream to downstream.

0 indicates that no trend was detected.

R^2 indicates the fraction of variance accounted for by the regression.

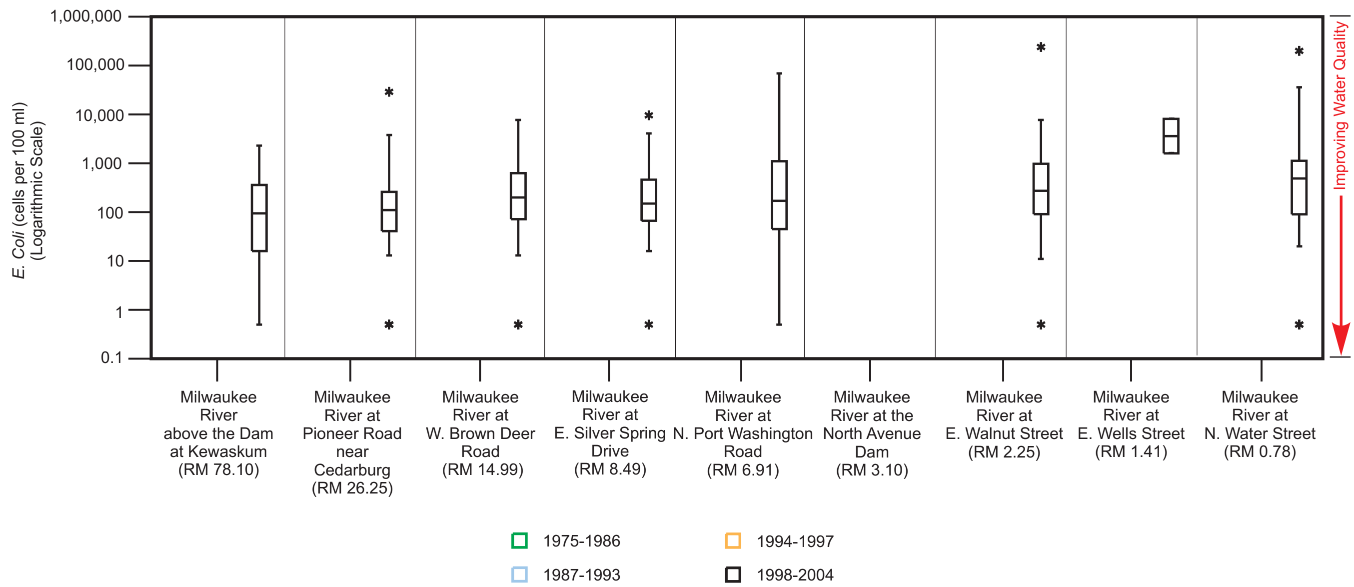
[a]*Trends were assessed through linear regression analysis. Values of water quality parameters were regressed against River Mile. A trend was considered significant if the regression showed a significant slope at P = 0.05 or less. Higher* R^2 *values indicate that higher portions of the variation in the data are attributable to the trend. Lower* R^2 *values indicate that more of the variation is due to random factors.*

[b]*These data were log-transformed before being entered into regression analysis.*

Source: SEWRPC.

Figure 113

E. COLI **BACTERIA CONCENTRATIONS ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004**



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Chemical and Physical Parameters

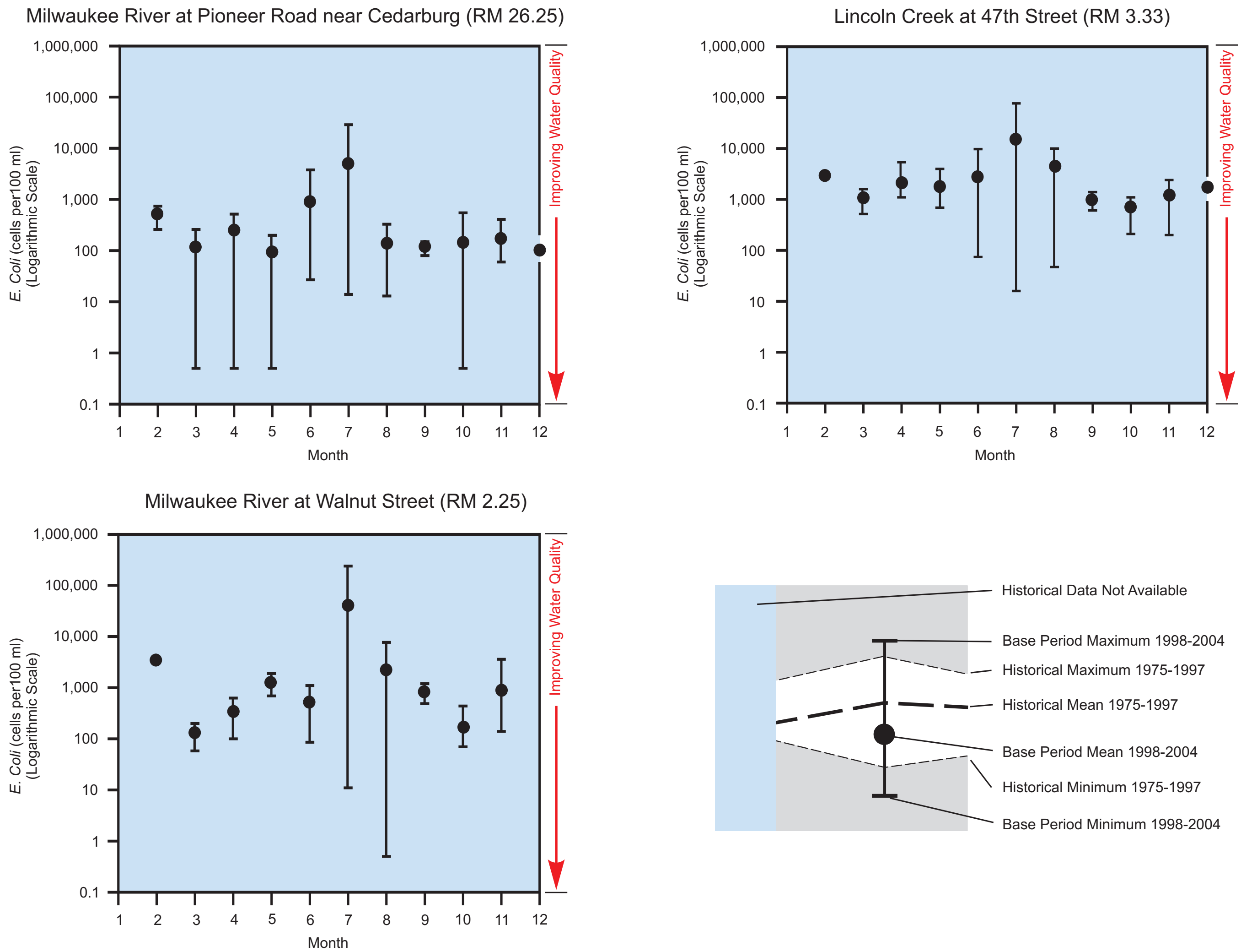
Temperature

Figure 116 shows water temperature at nine sites along the mainstem of the Milwaukee River. The median water temperature in the Milwaukee River during the period 1998-2004 ranged from 9.8 degrees Celsius (ºC) at Estabrook Park to 19.0ºC at CTH M near Newburg. The low median at the Estabrook Park station is probably due to this site having a high proportion of samples collected during the winter. The next lowest median temperature during this period was 15.0ºC at Silver Spring Drive. Because few samples were collected during the winter at most stations during the period 1998-2004, the median from the Silver Spring Drive station is probably a more representative number than the median from Estabrook Park. As shown in Table 88, no statistically significant longitudinal trends in water temperatures were detected along the Milwaukee River. Figure 117 shows historical and baseline period monthly mean temperatures for seven sampling stations along the mainstem of the River. At most of the stations for which historical data were available, water temperatures from the baseline period generally tended to be within historical ranges. During summer months, monthly mean baseline period water temperatures at most stations tended to be slightly higher than historical monthly means. Few trends over time were detected in water temperatures at stations along the River (see Table C-5 in Appendix C). When examined on an annual basis, slight trends toward increasing water temperatures were detected at three estuary stations: Wells Street, Water Street, and the Union Pacific Railroad. These trends account for a very small portion of the variation in the data and are likely attributable to slight increasing trends during summer months.

Mean water temperatures for downstream sections of the River are shown in Figure 118. The greatest difference in mean water temperatures observed at the stations between Pioneer Road and the Union Pacific Railroad was about 1.3ºC. In the estuary, mean water temperature increased from 15.0ºC at the Wells Street station to 15.3ºC at the Water Street station. Some of the increase between the Wells Street and Water Street stations can be accounted for by contributions of warmer water entering the Milwaukee River from the Menomonee River. The mean water temperature of the Menomonee River at the station at S. 2nd Street, near the confluence with the Milwaukee River, during the same time period was 17.3ºC. Downstream from Water Street along the Milwaukee

Figure 114

HISTORICAL AND BASE PERIOD *E. COLI* BACTERIA CONCENTRATIONS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



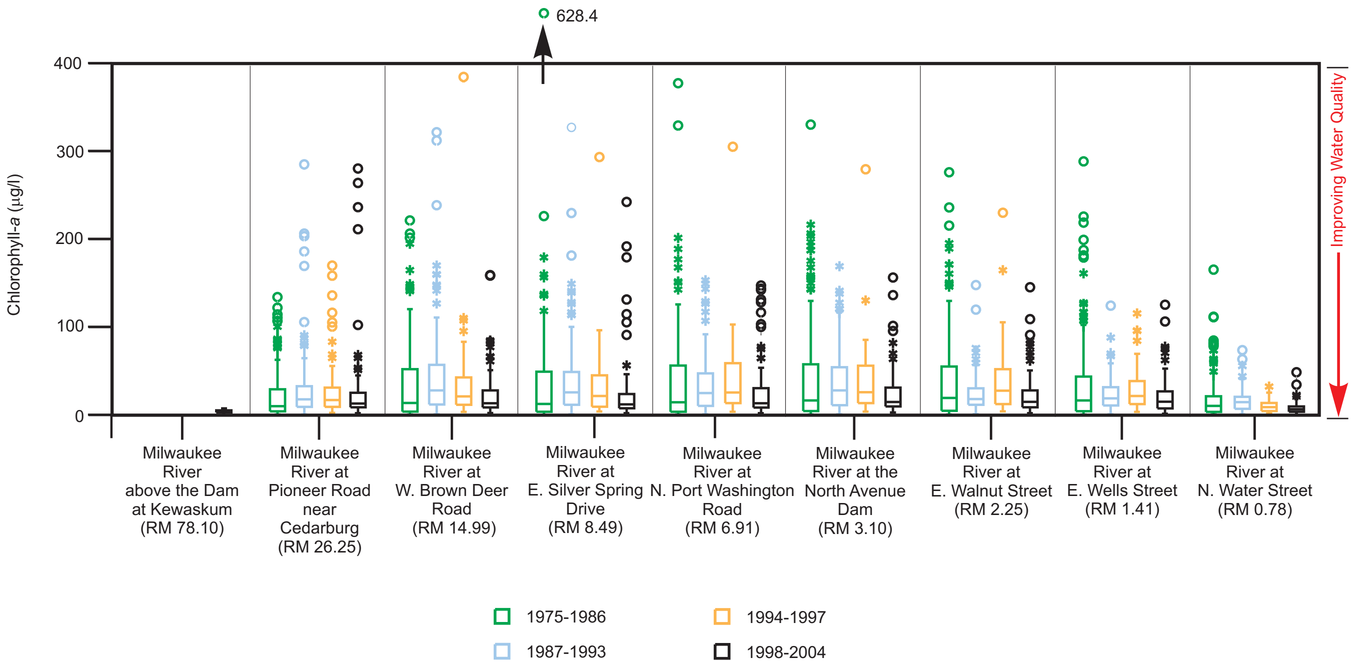
Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

River, mean water temperature decreases. This may be the result of complex flow interactions with Lake Michigan.

Due to the complexity of temperature trends in a River the length of the Milwaukee River, the data were further analyzed using a three-factor analysis of variance. This type of analysis tests for statistically significant differences among mean temperatures based upon three different factors which may account for any differences. In addition, it tests for significant effects on mean temperatures of any interactions between the factors. In this instance, the independent factors examined were sampling station, time period, and season. The sampling stations examined in the analysis include the station at Pioneer Road and all major stations downstream from Pioneer Road. Four time periods were examined: 1975-1986, 1987-1993, 1994-1997, and 1998-2004. Data from winter months were not included in this analysis because of the small number of samples taken during the winter. This analysis revealed no statistically significant differences among mean water temperatures at different sampling stations. The results did indicate that mean water temperatures in the Milwaukee River were significantly lower during the period 1975-1986 than during subsequent periods. In addition, the analysis found a significant

Figure 115

CHLOROPHYLL-*a* CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004

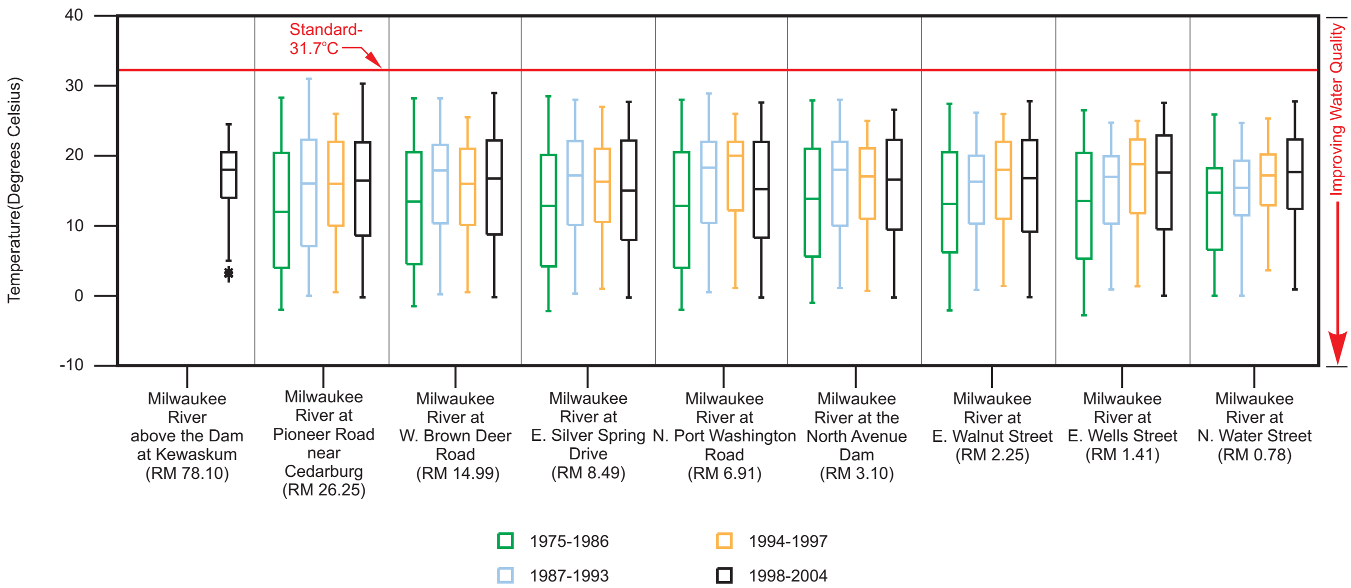


NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 116

WATER TEMPERATURE AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004

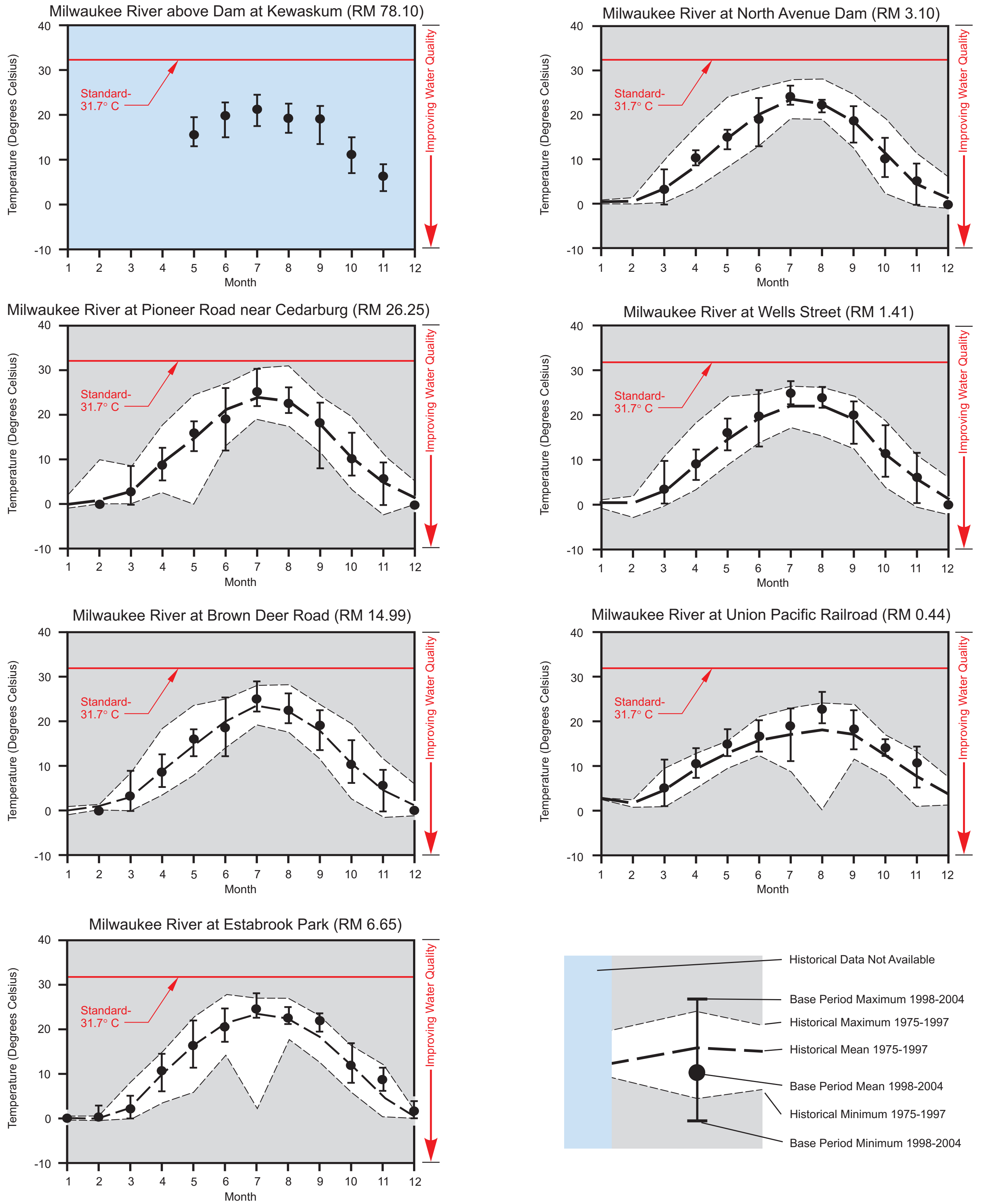


NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 117

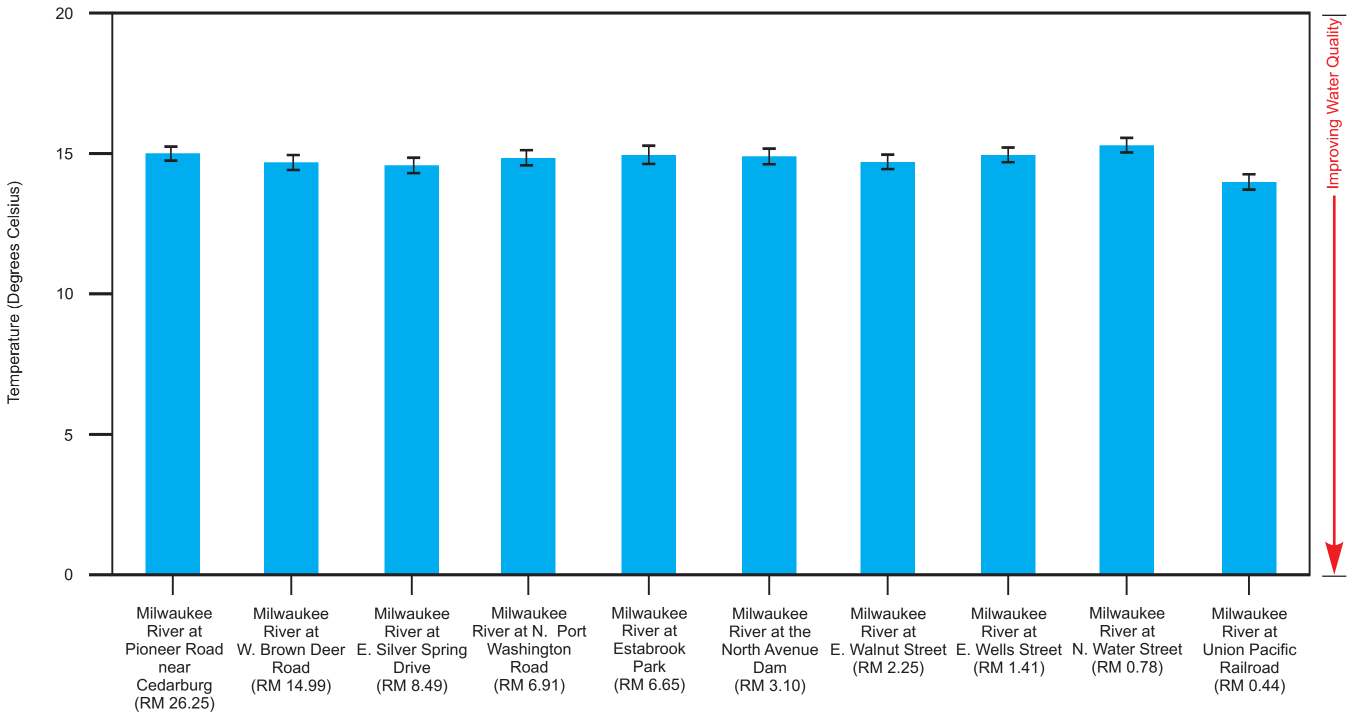
HISTORICAL AND BASE PERIOD WATER TEMPERATURE ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 118

MEAN WATER TEMPERATURES AT STATIONS ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTES: The temperature standard is 31.7 degrees Celsius, which is outside the limits of the graph.

Error Bars (I) indicate one standard error of the mean.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

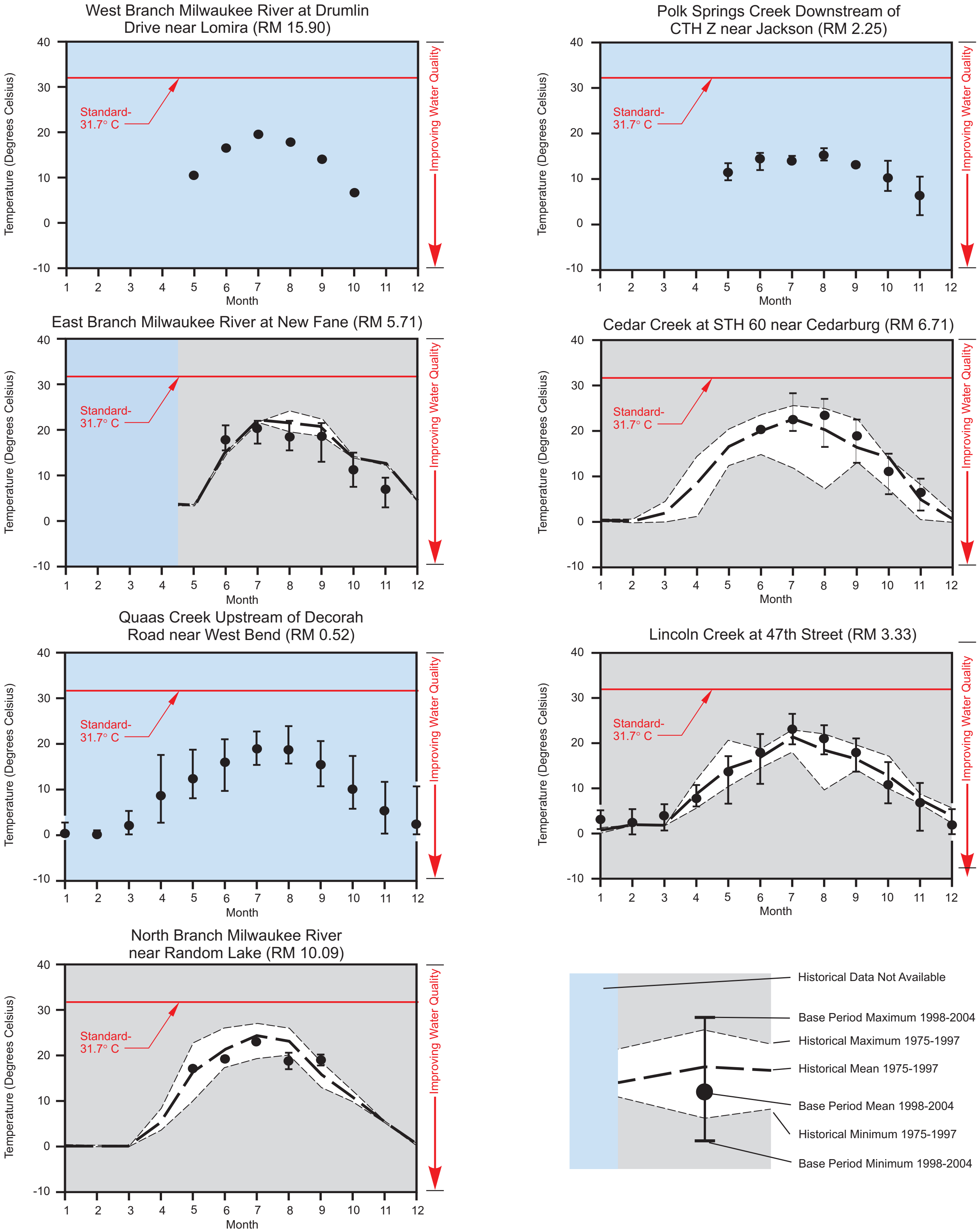
interaction between the effects of sample site and season. Seasonal differences in mean water temperature were less pronounced at the two stations farthest downstream, Water Street and the Union Pacific Railroad. These differences most likely result from interactions with water from Lake Michigan.

Figure 119 shows historical and baseline period mean water temperatures for sampling stations on seven Milwaukee River tributaries. In some tributaries, such as Cedar Creek at STH 60 and Lincoln Creek at N. 47th Street, baseline period monthly mean temperatures during the late summer and early fall were higher than the historical means. At other tributaries, such as the East Branch Milwaukee River at New Fane, period monthly mean temperatures during the late summer and early fall were lower than the historical means. No statistically significant longitudinal trends were found in water temperature along Lincoln Creek (see Table 90) or Southbranch Creek (see Table 89). Statistically significant increasing trends in water temperature were detected at some tributary sampling stations (Table C-5 in Appendix C). The increasing trend detected at the N. 47th Street station on Lincoln Creek accounts for over half the variation in the data. Increasing trends were also detected at two stations along Southbranch Creek; however, the short length of the period of record for this stream makes it difficult to determine whether this represents a long-term trend or short-period interannual variation.

The trends toward increasing water temperature at some estuary stations on the mainstem and at some tributary stations represent a reduction in water quality.

Figure 119

HISTORICAL AND BASE PERIOD WATER TEMPERATURE IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



Source: *U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, Washington County Land and Water Conservation Division, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

Alkalinity
The mean value of alkalinity in the Milwaukee River over the period of record was 235.6 milligrams per liter (mg/l) expressed as the equivalent concentration of calcium carbonate (mg/l as $CaCO_3$). The data show moderate variability, ranging from 5.0 to 999.0 mg/l as $CaCO_3$. During all periods, mean alkalinity in the estuary was significantly lower than mean alkalinity in the portion of the River upstream from the estuary (see Table 87). In addition, Table 88 shows that there is a statistically significant trend toward alkalinity decreasing from upstream to downstream along the length of the River. Few stations showed any evidence of significant time-based trends when analyzed annually or seasonally. Where significant trends were detected, they generally indicated increasing concentrations and accounted for a small portion of the variation in the data (see Table C-5 in Appendix C). These differences and trends may reflect changes in the relative importance of groundwater and surface runoff on the chemistry of water in the River from upstream to downstream with surface runoff becoming increasingly influential downstream. Alkalinity concentrations in the Milwaukee River are strongly positively correlated with hardness, pH, specific conductance, and concentrations of chloride, all parameters which, like alkalinity, measure amounts of dissolved material in water. Alkalinity is negatively correlated with chlorophyll-*a,* reflecting the removal of carbon dioxide from the water through photosynthesis. At some stations, alkalinity is negatively correlated with temperature, reflecting the fact that it indirectly measures concentrations of carbon dioxide in water and that solubility of gases in water decreases with increasing temperature.

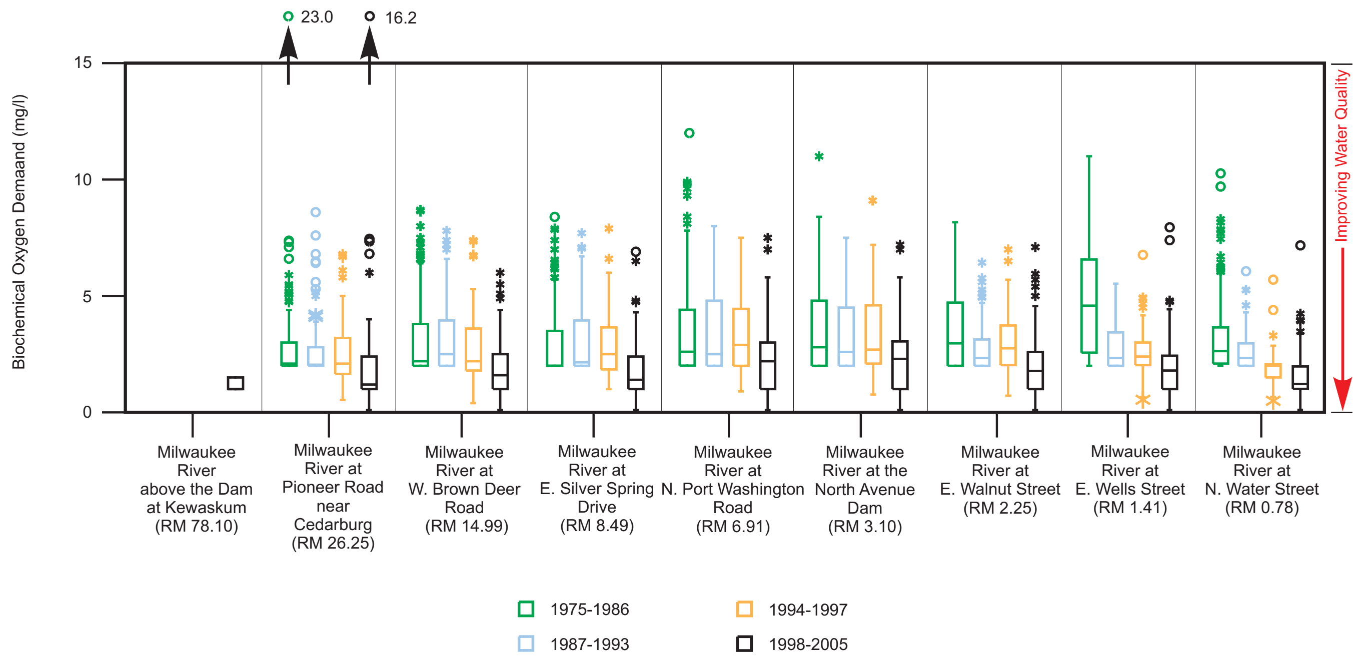
Biochemical Oxygen Demand (BOD)
The mean concentration of BOD in the Milwaukee River during the period of record was 2.90 mg/l. Individual samples varied from below the limit of detection to 23.00 mg/l. As shown in Figure 120, the concentrations of BOD have declined at those sampling stations that have sufficiently long data records to permit comparison. Figure 121 shows a monthly comparison of baseline and historical concentrations of BOD at three sites along the mainstem of the River and sites along four tributaries. At stations along the mainstem of the River, baseline period monthly mean concentrations are generally below the historical monthly mean concentrations and are often near or below the historical minima. Baseline period monthly minimum concentrations in many months are at or near the limit of detection. The relationship between mean BOD concentrations in the estuary and mean BOD concentrations in the portion of the River upstream from the estuary has changed over time (see Table 87). During the period 1975-1986, mean BOD concentrations in the estuary were higher than mean BOD concentrations in the section of the River upstream from the estuary. This changed after 1986. During the periods 1987-1993 and 1994-1997, mean BOD concentrations in the section of the River upstream from the estuary were higher than mean BOD concentrations in the estuary. This changed again after 1997. During the period 1998-2004, there were no significant differences between the mean BOD concentrations in these two sections of the River. In the section of the River upstream from the estuary, there is a statistically significant trend toward BOD concentrations along the mainstem increasing from upstream to downstream (see Table 88). This trend accounts for a small portion of the variation in the data. When examined on an annual basis, statistically significant decreasing trends in BOD concentration over time were detected at all stations along the mainstem of the River (see Table C-5 in Appendix C of this report).

BOD concentrations in most tributaries for which data exist are comparable to concentrations in the mainstem of the River (see Figure 121). In some months, historical monthly maximum BOD concentrations in Lincoln Creek are higher than those detected in other tributaries or in the mainstem of the River. There is a statistically significant trend toward BOD concentrations in Lincoln Creek increasing from upstream to downstream (see Table 90). This trend accounts for a small portion of the variation in the data. Few time-based trends were detected in BOD concentration in tributaries (Table C-5 in Appendix C). When examined on an annual basis, trends toward decreasing BOD concentrations over time were detected at two stations along Lincoln Creek. By contrast, a trend toward increasing BOD concentration over time was detected at one station along Southbranch Creek. Because of the short period of record for this creek, it is uncertain whether this latter trend represents a long-term trend or interannual variation.

Several factors may influence BOD concentrations in the Milwaukee River. BOD concentrations in the River are positively correlated at most stations with concentrations of fecal coliform bacteria and some nutrients such as organic nitrogen, and total phosphorus. In addition, at some stations BOD concentrations are negatively correlated

Figure 120

BIOCHEMICAL OXYGEN DEMAND AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

with dissolved oxygen concentrations. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the River. In addition, aerobic metabolism of many organic nitrogen compounds requires oxygen and thus these compounds contribute to BOD. In some parts of the River, decomposition of organic material in the sediment acts as a source of BOD to the overlying water. This may especially be the case in the estuary and in impoundments associated with dams.

The declining trends in BOD concentrations over time detected at all of the stations along the mainstem of the River and two stations along Lincoln Creek represent an improvement in water quality.

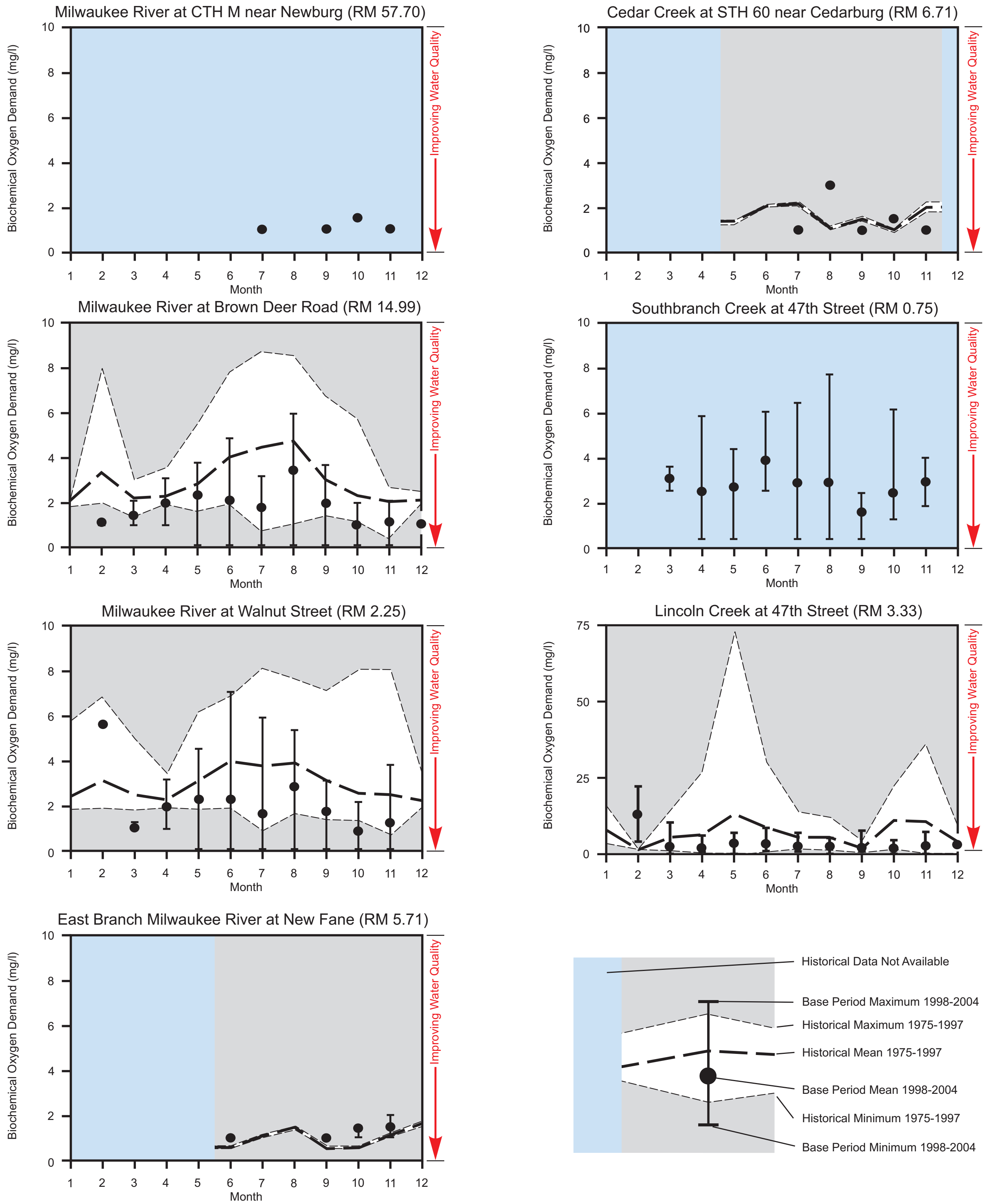
Chloride

The mean chloride concentration in the Milwaukee River for the period of record was 50.1 mg/l. All sites show wide variations between minimum and maximum values. Figure 122 shows that concentrations of chloride in the River increased over time at all stations for which historical data are available. Table C-5 in Appendix C of this report shows statistically significant trends toward mean chloride concentrations increasing over time at all sampling stations along the mainstem of the River, except for the Estabrook Park station. The lack of detection of a trend at this station probably results from the small number of samples analyzed for chloride concentration. Chloride concentrations show a strong seasonal pattern. For the period during which winter data are available, mean chloride concentrations were highest in winter or early spring. This is likely to be related to the use of deicing salts on streets and highways. These concentrations declined through the spring to reach lows during summer and fall. In the section of the River upstream from the estuary, there was a significant trend toward chloride concentrations increasing from upstream to downstream (see Table 88). This trend accounted for a small portion of the variation in the data.

Figure 123 shows chloride concentrations for three tributaries of the Milwaukee River. Chloride concentrations have been increasing with time in each of these tributaries.

Figure 121

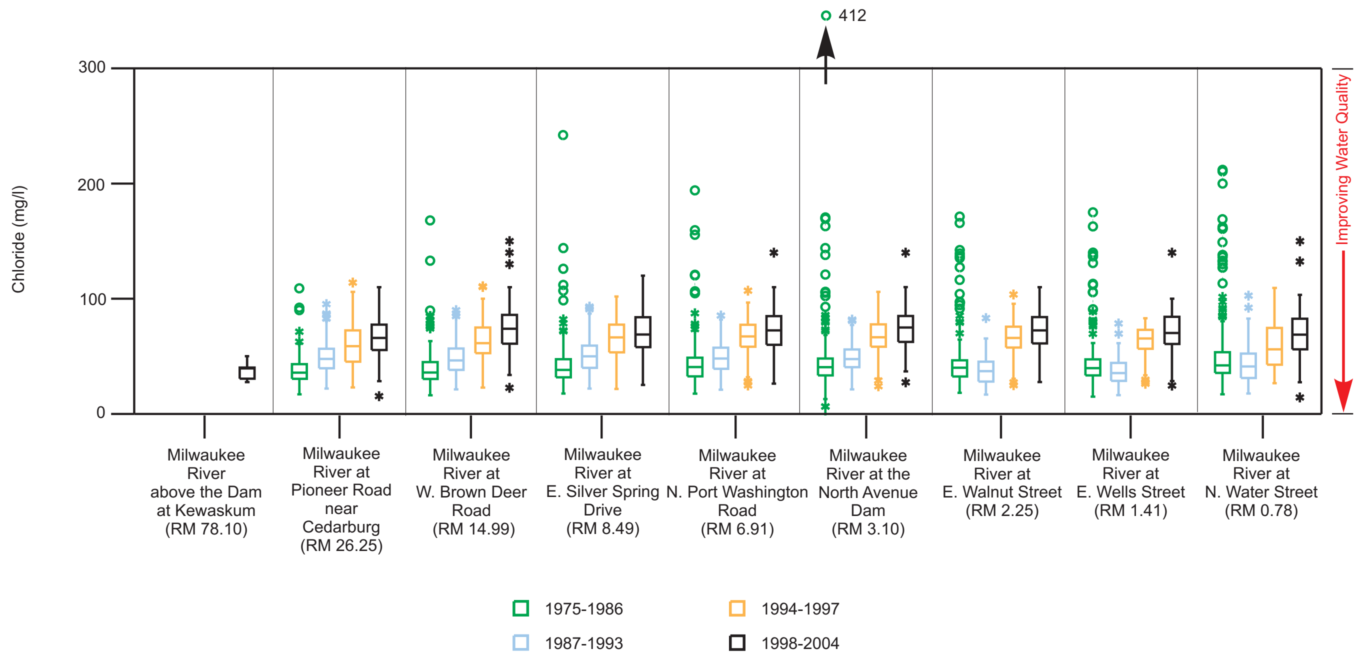
HISTORICAL AND BASE PERIOD CONCENTRATIONS OF BIOCHEMICAL OXYGEN DEMAND IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, Washington County Land and Water Conservation Division, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 122

CHLORIDE CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTES: See Figure 109 for description of symbols.

The acute toxicity criterion for fish and aquatic life is 757 mg/l, and the chronic toxicity criterion for fish and aquatic life is 395 mg/l.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Observed instream chloride concentrations in the main stem of the Milwaukee River and tributaries for which measurements are available have not approached the planning standard of 1,000 milligrams per liter (mg/l) that was adopted under the original regional water quality management plan. Observed instream concentrations in the Milwaukee River rarely approached the 250 mg/l secondary drinking water standard.[2] In the North Branch of the Milwaukee River and Cedar Creek, observed concentrations have always been considerably less than the secondary drinking water standard. Also, observed instream concentrations in those two streams have also been well below both the chronic toxicity criterion of 395 mg/l and the acute toxicity criterion of 757 mg/l as set forth in Chapter NR 105, "Surface Water Quality Criteria and Secondary Values for Toxic Substances," of the *Wisconsin Administrative Code*. Observed concentrations in the Milwaukee River were generally below the State chronic and acute toxicity criteria.

In Lincoln Creek, observed instream chloride concentrations relatively frequently exceeded the 250 mg/l secondary drinking water standard, but they did not often exceed the chronic toxicity criterion, and they have not exceeded the acute toxicity criterion.

As shown in Figure 148 on page 438, in the lakes of the Milwaukee River watershed for which data are available, chloride concentrations were generally less than 50 mg/l, although concentrations appear to be increasing over time.

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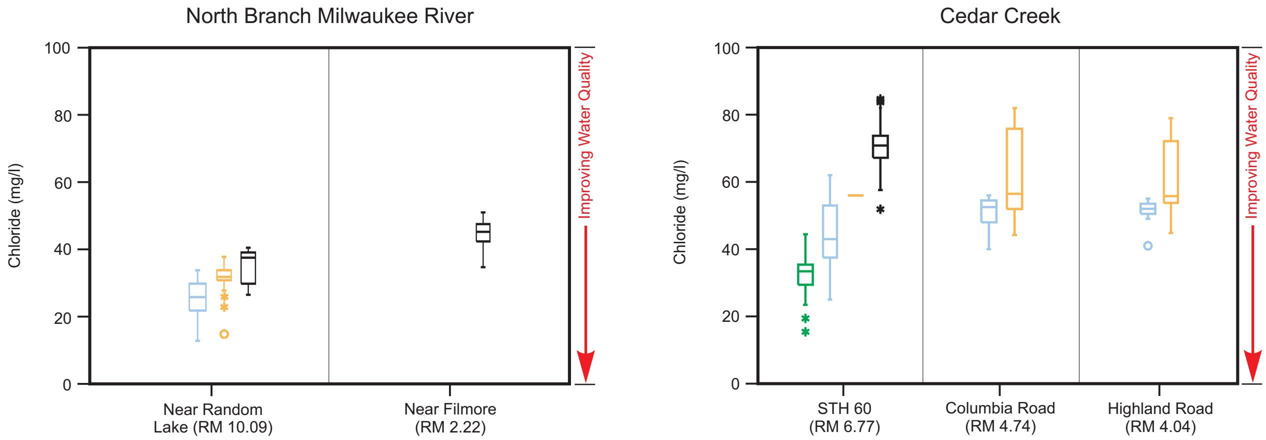
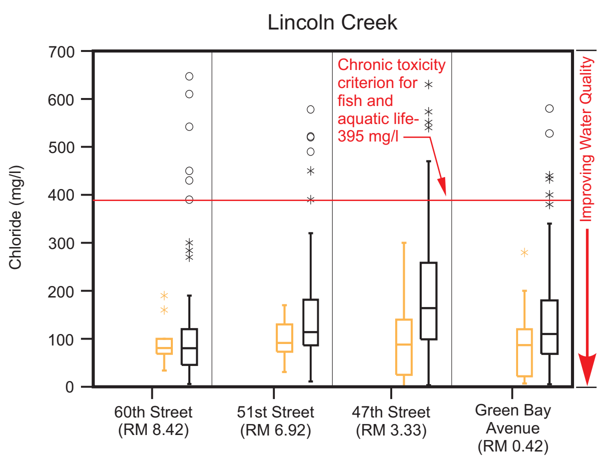
[2]*Section 809.60 of Chapter NR 809, "Safe Drinking Water," of the* Wisconsin Administrative Code, *establishes a secondary standard for chloride of 250 mg/l and notes that, while that concentration is not considered hazardous to health, it may be objectionable to an appreciable number of persons.*

Figure 123

CHLORIDE CONCENTRATIONS AT SITES IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004





1975-1986
1987-1993
1994-1997
1998-2004

NOTES: See Figure 109 for description of symbols.

The acute toxicity criterion for fish and aquatic life, which is 757 mg/l, is greater than the maximum values on each vertical axis; therefore, it is not shown. Also, the chronic toxicity criterion for fish and aquatic life, which is 395 mg/l, exceeds the maximum values on the vertical axes for the North Branch and Cedar Creek.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

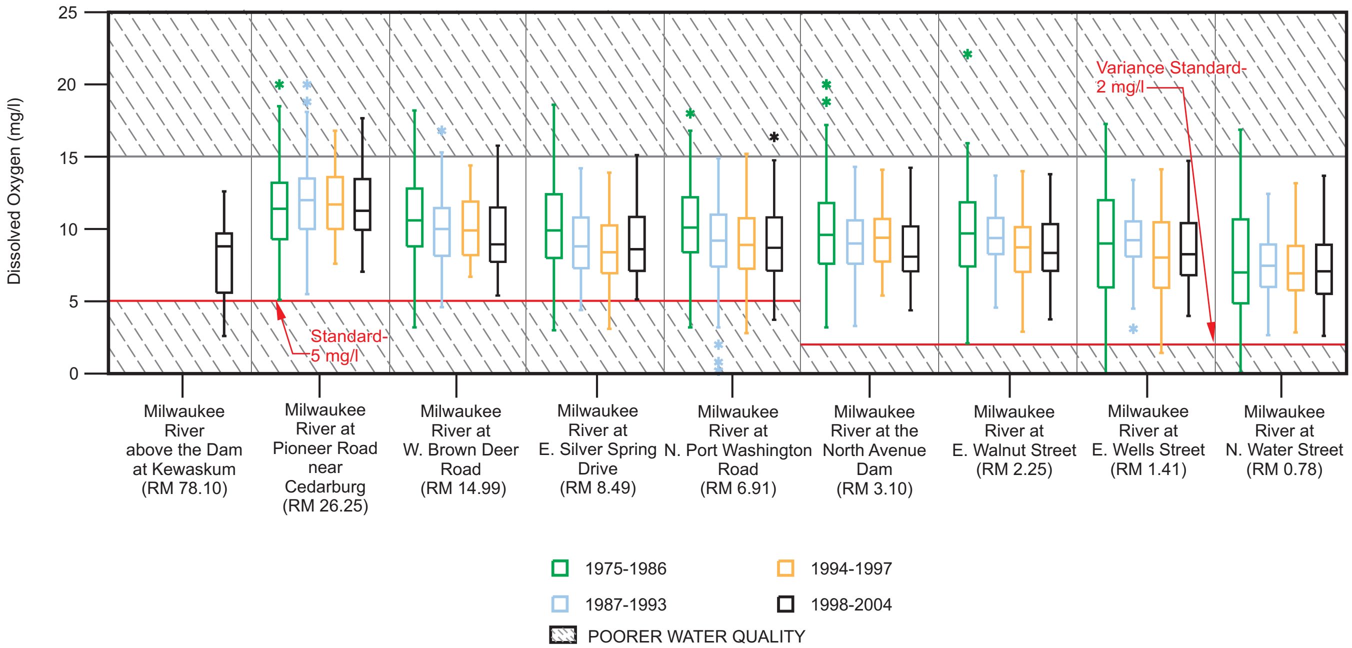
Chloride concentrations in the Milwaukee River show strong positive correlations with alkalinity, hardness, and specific conductance, all parameters which, like chloride, measure amounts of dissolved material in water. This may reflect common mechanisms of entry into the River. The increase in chloride concentrations detected at some stations along the Milwaukee River represents a decline in water quality.

Dissolved Oxygen

Over the period of record, the mean concentration of dissolved oxygen in the Milwaukee River was 9.4 mg/l. The data ranged from concentrations that were undetectable to concentrations in excess of saturation. Figure 124 shows the distributions of dissolved oxygen concentrations at nine sampling stations along the River. Considerable variability in dissolved oxygen concentration is present at individual sample sites. At two stations upstream of the estuary, Pioneer Road and Brown Deer Road, median dissolved oxygen concentrations in the samples collected during the period 1998-2004 were lower than the median dissolved oxygen concentrations in the samples collected during the period 1994-1997. Declines in median dissolved oxygen concentration were also observed in the estuary: at the Walnut Street and Wells Street stations after 1993 and at the North Avenue dam station after 1997. Figure 125 indicates that these decreases are probably attributable to lower concentrations of dissolved oxygen in the late spring and summer. Figure 124 also shows that the range of dissolved oxygen concentrations decreased at most stations after 1986. Because the solubility of oxygen in water is dependent on water temperature (i.e. as water temperatures decrease dissolved oxygen concentrations increase), this does not reflect any change in the range of dissolved oxygen concentrations in the River. Rather it reflects the fact that MMSD discontinued sampling during the winter after 1986.

Figure 124

DISSOLVED OXYGEN CONCENTRATIONS AT SITES
ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTES: See Figure 109 for description of symbols.

140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

The Milwaukee River below the site of the abandoned North Avenue dam is subject to a special variance under which dissolved oxygen concentrations are not to be less than 2.0 mg/l.

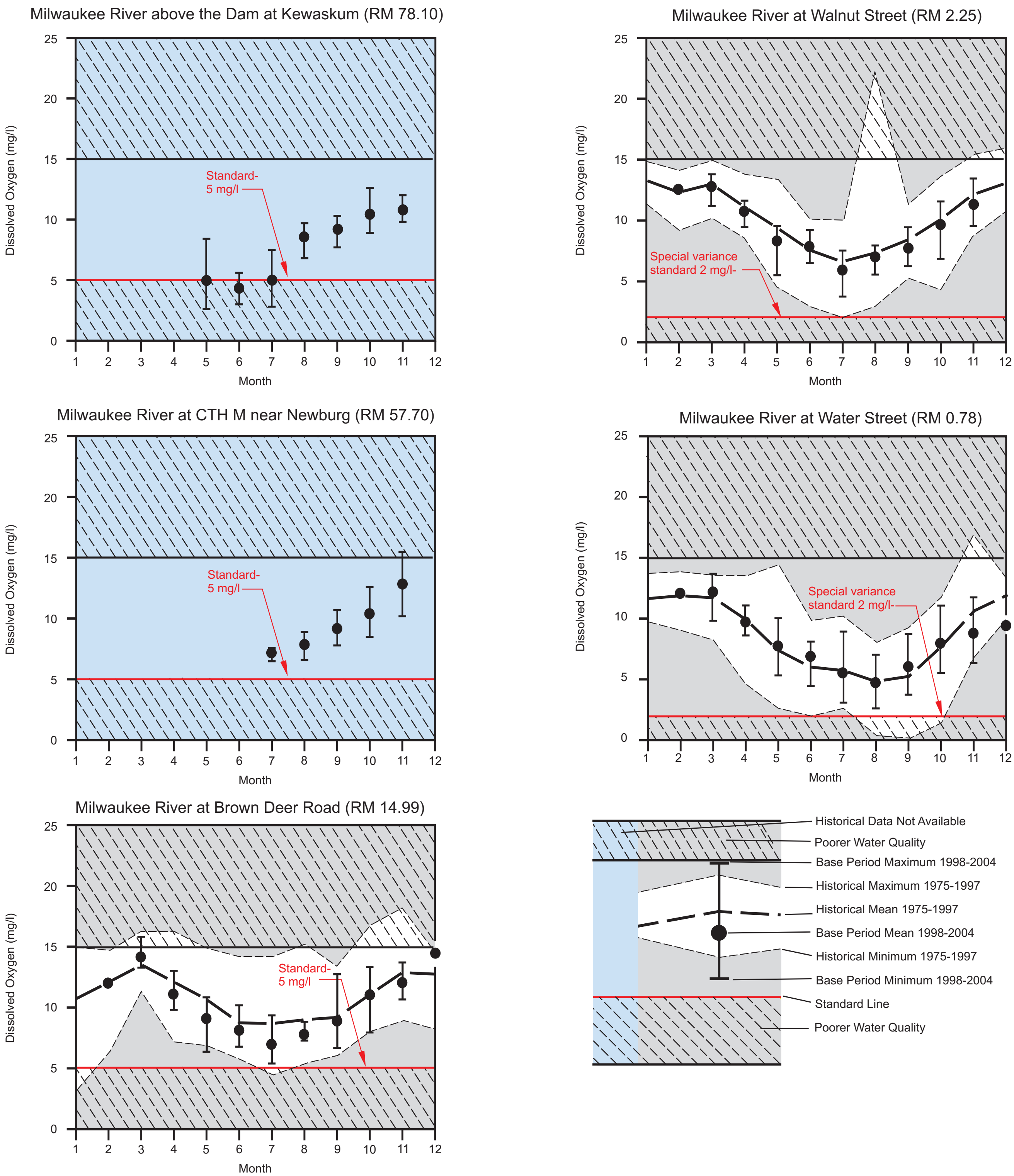
Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 125 compares monthly baseline period concentrations of dissolved oxygen to historical concentrations at five stations along the mainstem of the River. At those stations for which historical data exist, baseline period monthly minimum dissolved oxygen concentrations were generally higher than the historical minimum concentrations. Baseline period monthly mean dissolved oxygen concentrations were below historical monthly means at the Brown Deer Road station during the spring and summer. With the exception of the station at Pioneer Road, this was observed at all stations in the section of the River upstream from the estuary for which historical data exist. This pattern was also observed in the upper estuary at the North Avenue dam site and Walnut Street stations. In the lower estuary, baseline period mean monthly dissolved oxygen concentrations during the summer and fall tended to be near or slightly above historical means.

There were several trends in dissolved oxygen concentration in the Milwaukee River. During all time periods examined, dissolved oxygen concentrations were lower in the estuary than in the section of the River upstream from the estuary (see Table 87). There was a statistically significant trend toward dissolved oxygen concentrations decreasing from upstream to downstream along the mainstem of the River (see Table 88). Few time-based trends were detected in dissolved oxygen concentrations (see Table C-5 in Appendix C of this report). When examined on an annual basis, significant trends toward decreasing dissolved oxygen concentrations were detected at three nonestuary stations: Brown Deer Road, Silver Spring Drive, and Port Washington Road. These decreasing trends are attributable to lower concentrations at these stations during the summer. Upstream from these stations, an increasing trend over time was detected at the Pioneer Road station. When examined on a seasonal basis,

Figure 125

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF DISSOLVED OXYGEN ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: The Milwaukee River below the site of the abandoned North Avenue dam is subject to a special variance under which dissolved oxygen concentrations are not to be less than 2.0 mg/l.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

statistically significant increasing trends in dissolved oxygen concentration during the summer were detected at three stations in the estuary. Comparison of these trends toward increasing dissolved oxygen concentrations in the lower estuary to trends toward decreasing BOD and decreasing ammonia suggests that a decrease in loadings of organic pollutants may be responsible for the increase in dissolved oxygen concentration at these sites during the summer. This is a likely consequence of a reduction in loadings from combined sewer overflows since MMSD's Inline Storage System went on line.

The data show strong seasonal patterns to the mean concentrations of dissolved oxygen (see Figure 125). The mean concentration of dissolved oxygen is highest during the winter. It declines through spring to reach a minimum during the summer. It then rises though the fall to reach maximum values in winter. This seasonal pattern is driven by changes in water temperature. The solubility of oxygen in water decreases with increasing temperature. In addition, the metabolic demands and oxygen requirements of most aquatic organisms, including bacteria, tend to increase with increasing temperature. Higher rates of bacterial decomposition when the water is warm may contribute to the declines in the concentration of dissolved oxygen observed during the summer.

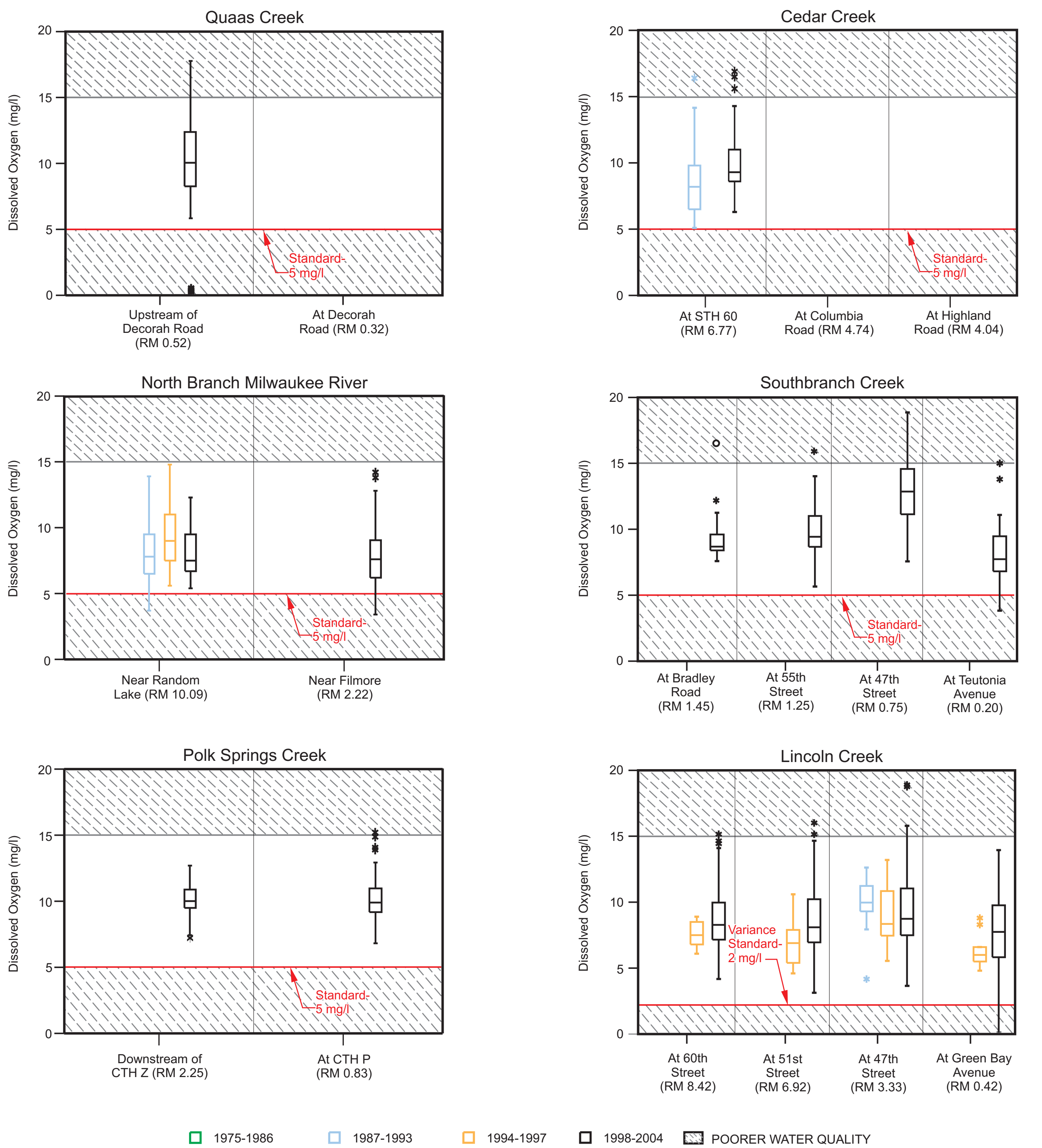
Figure 126 shows dissolved oxygen concentrations at sampling stations along six Milwaukee River tributaries. Dissolved oxygen concentrations in these tributaries are generally above the applicable standards; however, dissolved oxygen concentrations below the standards are occasionally detected in samples from Lincoln Creek, the North Branch Milwaukee River, and Southbranch Creek. No statistically significant longitudinal trends in dissolved oxygen concentration were detected in those streams with more than one sampling station. Dissolved oxygen concentrations at the STH 60 station along Cedar Creek were higher during the period 1998-2004 than during the period 1987-1993. This difference represents a statistically significant increasing trend (Table C-5 in Appendix C). Figure 126 shows that dissolved oxygen concentrations at several stations along Lincoln Creek were higher during the period 1998-2004 than during the period 1994-1997. This represented a significant increasing trend only at the station at N. 55th Street (Table C-5 in Appendix C).

Several other factors can affect dissolved oxygen concentrations in the Milwaukee River. First, portions of the estuary act as a settling basin in which material suspended in water sink and fall out into the sediment. This is indicated by the lower concentrations of total suspended solids (TSS) in the estuary (see Table 87 and the section on TSS below). Decomposition of organic matter contained in this material, through chemical and especially biological processes, removes oxygen from the overlying water, lowering the dissolved oxygen concentration. This process can also occur in impoundments upstream of dams. Second, influxes of water from Lake Michigan and the Menomonee and Kinnickinnic Rivers may influence dissolved oxygen concentrations in the downstream portions of the estuary. When dissolved oxygen concentrations in these waterbodies are higher than in the estuary, mixing may act to increase dissolved oxygen concentrations in the lower estuary. Similarly, when dissolved oxygen concentrations in these waterbodies are lower than in the estuary, mixing may act to decrease dissolved oxygen concentrations in the lower estuary. Third, dissolved oxygen concentrations at some stations along the Milwaukee River are positively correlated with pH. This reflects the effect of photosynthesis on both of these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the pH of the water. At the same time, oxygen is released as a byproduct of the photosynthetic reactions. Fourth, dissolved oxygen concentrations in water can be affected by numerous other factors including the presence of aquatic plants, sunlight, and the amount of and type of sediment as summarized in the Water Quality Indicators section in Chapter II of this report.

The increase in dissolved oxygen concentrations at some stations in the estuary during the summer and the increases at some stations along Cedar and Lincoln Creek represent an improvement in water quality. The decreases in dissolved oxygen at some upstream stations along the mainstem of the River represent a decline in water quality.

Figure 126

DISSOLVED OXYGEN CONCENTRATIONS IN THE MILWAUKEE RIVER TRIBUTARIES: 1975-2004



NOTES: See Figure 109 for description of symbols.

140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Lincoln Creek is subject to a special variance under which dissolved oxygen concentrations are not to be less than 2.0 mg/l.

Source: *U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, Washington County Land and Water Conservation Division, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

Hardness

Over the period of record, the mean hardness in the Milwaukee River was 284.8 mg/l as $CaCO_3$. On a commonly used scale, this is considered to be very hard water.[3] The range of the data runs from 18.6 to 818.8 mg/l as $CaCO_3$, showing considerable variability. Some of this variability probably results from inputs of relatively soft water during storm events. Table 87 shows that water in the section of the River upstream from the estuary is significantly harder than water in the estuary. This probably results, at least in part, from interactions between the estuary and Lake Michigan. In the section of the River upstream from the estuary, there is a statistically significant trend toward hardness decreasing from upstream to downstream (see Table 88). When examined on an annual basis, significant trends toward increasing hardness concentrations over time were detected at six stations along the mainstem of the River (Table C-5 in Appendix C). These trends appear to be attributable to increases during the spring. They account for a small portion of the variation in the data. Hardness concentrations in the Milwaukee River show strong positive correlations with alkalinity, chloride, pH, and specific conductance, all parameters which, like hardness, measure amounts of dissolved material in water.

Mean hardness in tributaries to the Milwaukee River range from 228.5 mg/l as $CaCO_3$ to 354 mg/l as $CaCO_3$. No statistically significant longitudinal trends were found in Lincoln Creek (see Table 90) or Southbranch Creek (see Table 89). Few time-based trends were detected in hardness in Milwaukee River tributaries. Trends toward increasing hardness were detected at one station along Cedar Creek and one station along Lincoln Creek (Table C-5 in Appendix C).

pH

The mean pH in the Milwaukee River over the period of record was 8.2 standard units. The mean values at individual sampling stations along the mainstem of the River ranged from 7.8 to 8.3 standard units. At most stations, pH varied only by $\pm$1.0 standard unit from the stations' mean values. Variability in pH was very similar among stations, with coefficients of variation ranging from 0.03 to 0.05. No longitudinal trends were detected in pH along the Milwaukee River. Table C-5 in Appendix C, shows that at four stations, significant trends were detected toward pH decreasing over time. These trends account for a small portion of the variation in the data. Mean pHs in tributaries to the Milwaukee River range from 7.4 standard units to 8.2 standard units. Positive correlations are seen between pH and alkalinity, hardness, and specific conductance at some stations but they are neither as common nor as strong as the correlations detected among alkalinity, hardness, and specific conductance. At some stations, dissolved oxygen concentrations and chlorophyll-*a* concentrations are positively correlated with pH. These correlations reflect the effect of photosynthesis on these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the water's pH. At the same time, oxygen is released as a byproduct of the photosynthetic reactions. This often results in increased algal growth, which is reflected in higher chlorophyll-*a* concentrations. In summary, pH concentrations at most stations along the Milwaukee River have not changed substantially during the time period examined from 1975 to 2004.

Specific Conductance

The mean value for specific conductance in the Milwaukee River over the period of record was 635.7 microSiemens per centimeter (μS/cm). Considerable variability was associated with this mean. Specific conductance ranged from below the limit of detection to 2,100.0 μS/cm. Some of this variability may reflect the discontinuous nature of inputs of dissolved material into the River. Runoff associated with storm events can have a major influence on the concentration of dissolved material in the River. The first runoff from a storm event transports a large pulse of salts and other dissolved material from the watershed into the River. This will tend to raise specific conductance in the River. Later runoff associated with the event will be relatively dilute. This will tend to lower specific conductance. Figure 127 shows that specific conductance has been consistently increasing at most stations along the mainstem of the River since the period 1975-1986. These increases represent statistically significant trends toward specific conductance in the Milwaukee River increasing over time

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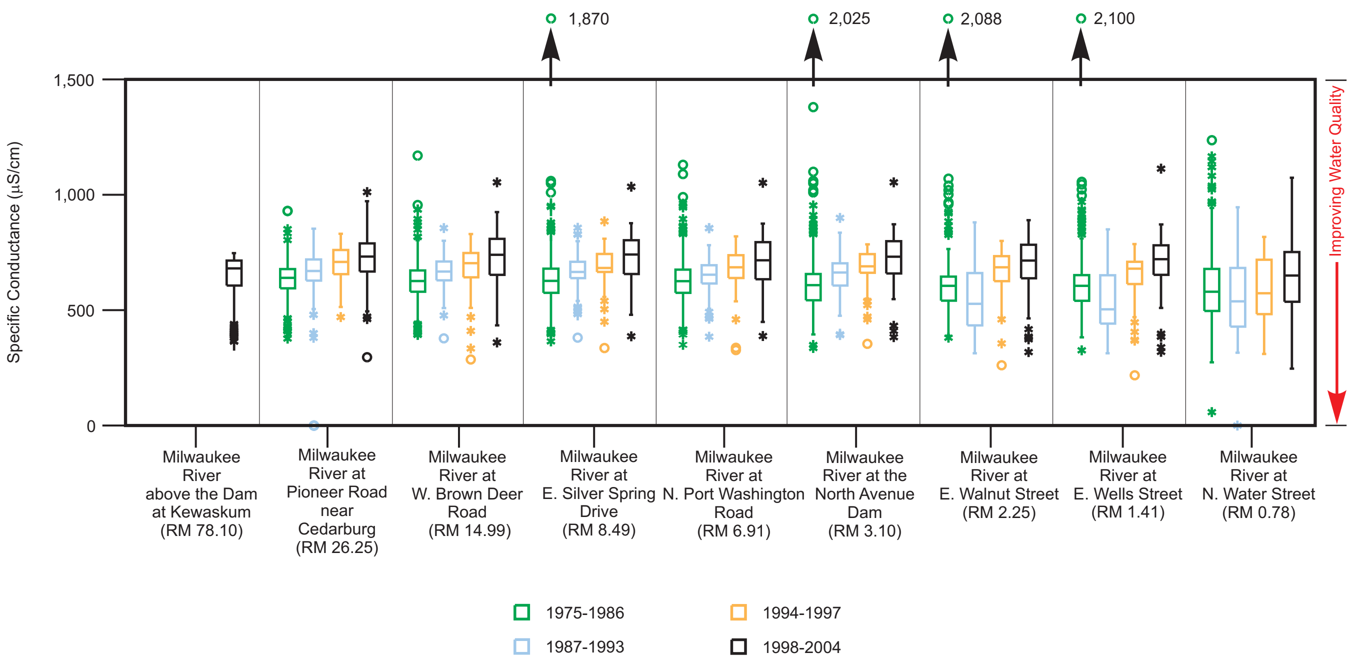
[3] *E. Brown, M.W. Skougstad, and M.J. Fishman,* Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, *U.S. Department of Interior, U.S. Geological Survey, 1970.*

Figure 127

SPECIFIC CONDUCTANCE AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

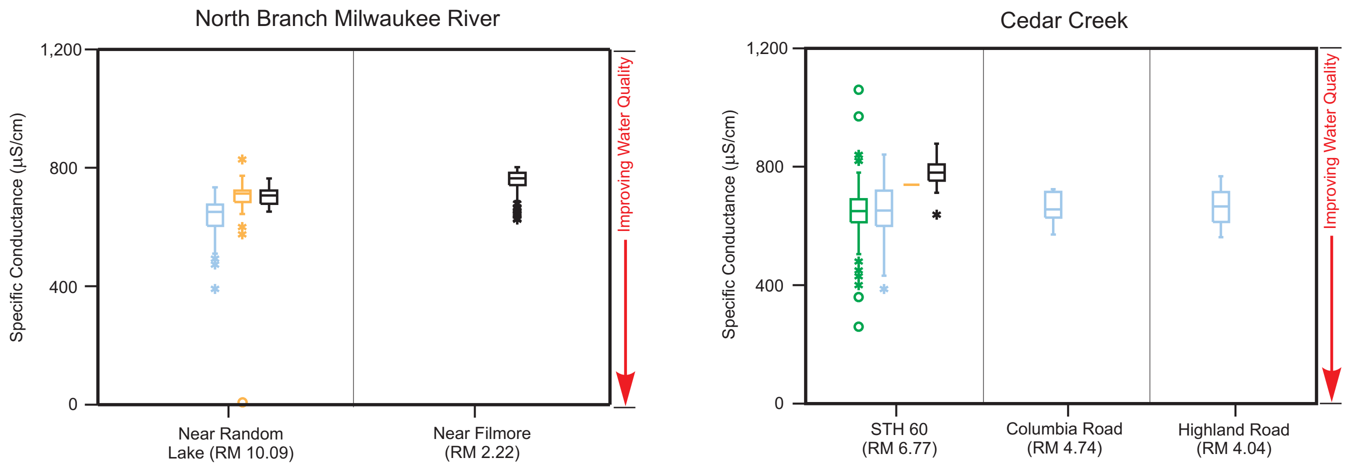
(Table C-5 in Appendix C). Mean specific conductance in the estuary was lower than mean specific conductance in the section of the River upstream from the estuary in all periods (see Table 87). In addition, Table 88 shows that there was a statistically significant trend toward specific conductance decreasing from upstream to downstream in the section of the River upstream from the estuary. The data show a seasonal pattern of variation in specific conductance. For those years in which data were available, specific conductance was highest during the winter. It then declined during the spring to reach lower levels in the summer and early fall. Specific conductance in the Milwaukee River show strong positive correlations with alkalinity, chloride, hardness, and pH, all parameters which, like specific conductance, measure amounts of dissolved material in water. At most stations, specific conductance also shows negative correlations with water temperature, reflecting the fact that specific conductance in the River tends to be lower during the summer. Figure 128 shows specific conductance in three Milwaukee River tributaries: Cedar Creek, Lincoln Creek, and the North Branch Milwaukee River. In each of these streams, specific conductance has increased over time. Table C-5 in Appendix C shows that statistically significant trends toward specific conductance increasing over time were detected at three stations along Lincoln Creek and one station along Cedar Creek. In summary, specific conductance was shown to have increased at stations along the mainstem of the Milwaukee River and at least three tributaries. These increases in specific conductance indicate that the concentrations of dissolved materials in water in the River and some tributaries are increasing and represent a decline in water quality.

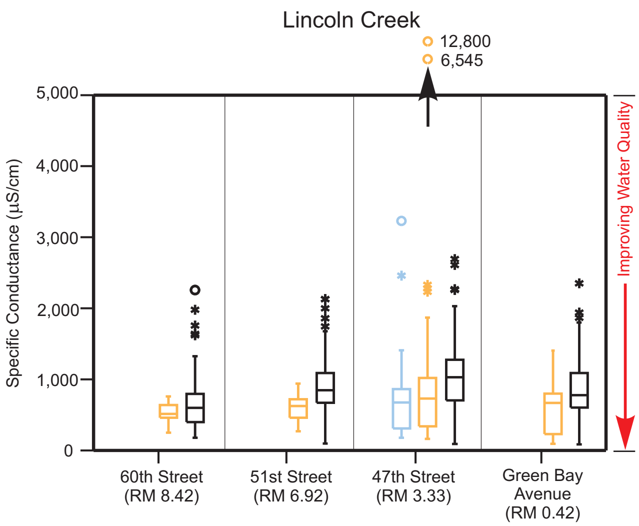
Suspended Material

The mean value for total suspended solids (TSS) concentration in the Milwaukee River over the period of record was 25.1 mg/l. Considerable variability was associated with this mean, with values ranging from 1.2 to 892.0 mg/l. Figure 129 shows that TSS concentrations at most stations along the mainstem of the River for which data exist have increased over time. At several stations along the mainstem of the River, these increased concentrations represent statistically significant trends (Table C-3 in Appendix C). When analyzed on an annual

Figure 128

SPECIFIC CONDUCTANCE AT SITES IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004





1975-1986 1994-1997
1987-1993 1998-2004

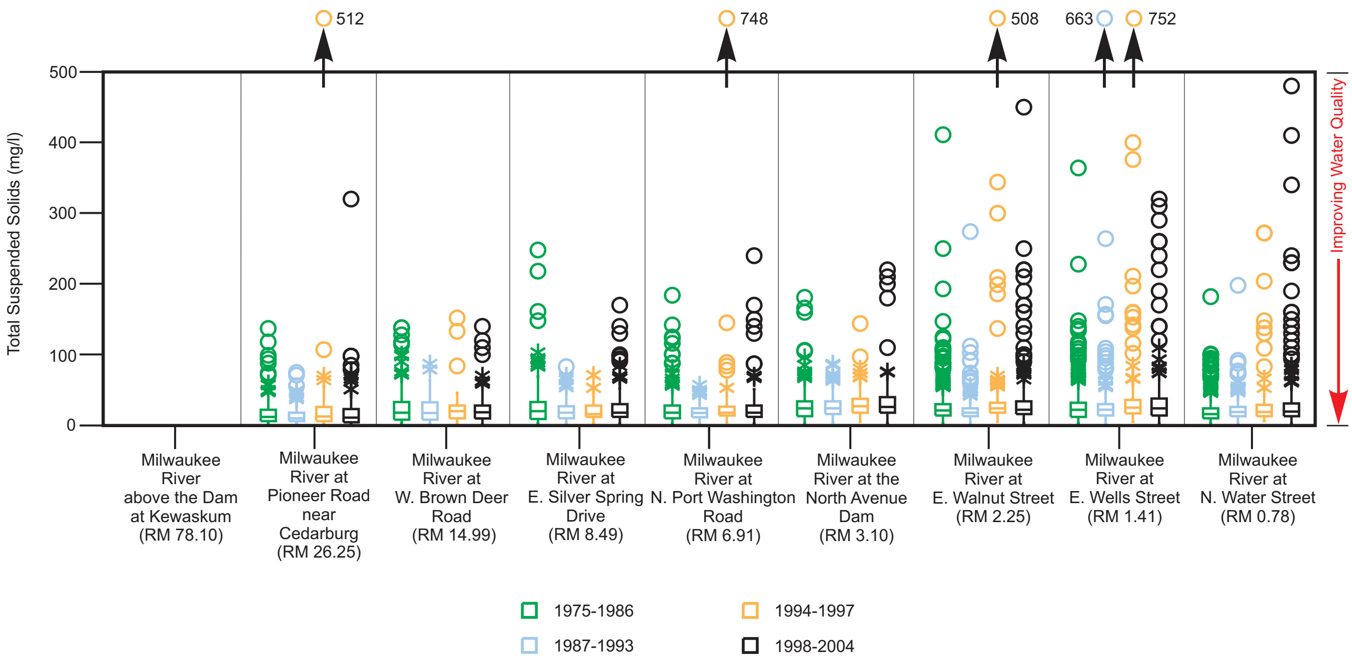
NOTE: See Figure 109 for description of symbols.

Source: *U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

basis, statistically significant trends toward increasing TSS concentrations were detected at several sampling stations in the estuary. When analyzed on a seasonal basis, statistically significant trends toward increasing TSS concentrations were detected at most stations along the mainstem of the River. In the section of the River upstream from the estuary, TSS concentrations tended to decrease from upstream to downstream (see Table 88). Mean concentrations of TSS were lower at estuary stations than at stations upstream from the estuary in all periods (see Table 87). This reflects the fact that portions of the estuary act as a settling basin in which material suspended in water sink and fall out into the sediment. Data on TSS concentrations exist for only a few tributary streams. Mean TSS concentrations for Cedar, Indian, Lincoln, and Southbranch Creeks were 12.7, 14.4, 16.7, and 12.3 mg/l, respectively. TSS concentrations in the Milwaukee River showed strong positive correlations with total phosphorus concentrations, reflecting the fact that total phosphorus concentrations include a large particulate fraction. TSS concentrations were also positively correlated with concentrations of fecal coliform bacteria, BOD, and nutrients. TSS concentrations were negatively correlated with some measures of dissolved materials, such as alkalinity, hardness, pH, and specific conductance. The trends toward increasing TSS concentrations at some sampling stations represent a decline in water quality.

Figure 129

CONCENTRATIONS OF TOTAL SUSPENDED SOLIDS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

In addition to TSS, total suspended sediment concentration was sampled at four sites along the mainstem of the Milwaukee River. The mean value for total suspended sediment concentration over the period of record was 33.7 mg/l. Considerable variability was associated with this mean, with values ranging from 1.0 to 323.0 mg/l. Table 87 shows that there was a statistically significant trend toward total suspended sediment concentrations increasing along the length of the River. This parameter was not sampled at stations in the estuary, so the relationship between mean concentrations of total suspended sediment in the estuary and mean concentrations in the section of the River upstream from the estuary is not known; however it is reasonable to assume that if portions of the estuary are acting as a settling basin, then concentrations of total suspended sediment are probably lower in the estuary. The lower concentrations of TSS in the estuary support this idea. Few time-based trends in total suspended sediment concentrations were detected in the Milwaukee River (Table C-5 in Appendix C). It is important to note that total suspended sediment concentrations are not comparable to TSS concentrations.[4]

Nutrients

Nitrogen Compounds

The mean concentration of total nitrogen in the Milwaukee River over the period of record was 1.87 milligrams per liter measured as nitrogen (mg/l as N). Concentrations ranged from below the limit of detection to 12.94 mg/l as N. Figure 130 shows changes in total nitrogen concentrations over time since 1975 at several stations along the mainstem of the River. At all stations, concentrations of total nitrogen during the period 1987-1993 were lower

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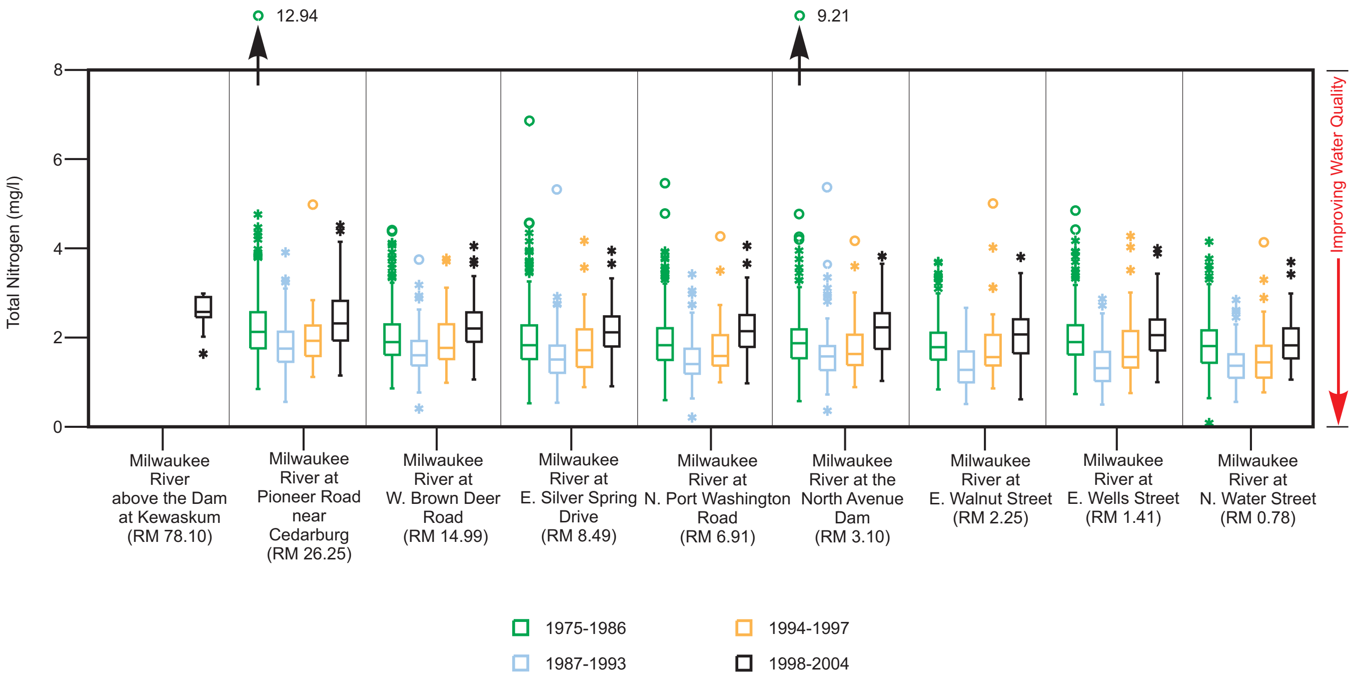
[4]*J.R. Gray, G.D. Glysson, L.M. Turcios, and G.E. Schwartz,* Comparability of Suspended-Sediment Concentration and Total Suspended Solids Data, *U. S. Geological Survey Water-Resources Investigations Report No. 00-4191, 2000.*

Figure 130

TOTAL NITROGEN CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

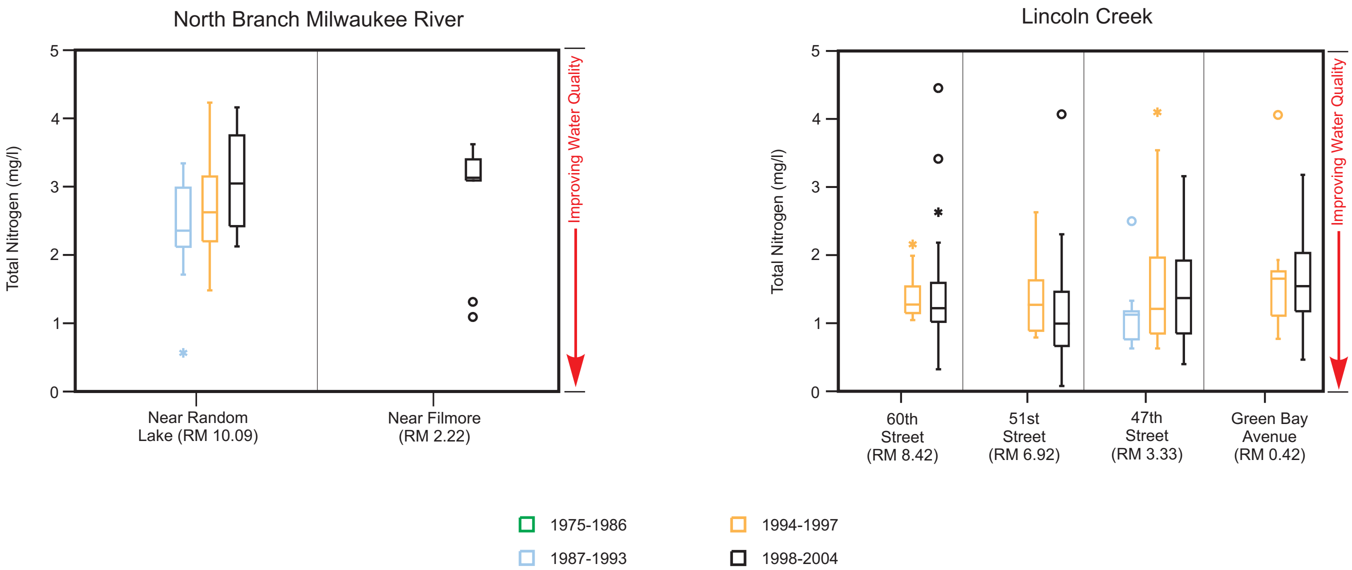
Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

than during the period 1975-1986. In subsequent periods, concentrations of total nitrogen increased. By the period 1994-1997, mean concentrations of total nitrogen had returned to levels similar to the mean concentrations from 1975-1986. During all periods, mean concentrations of total nitrogen were higher in the section of the River upstream of the estuary than in the estuary (see Table 87). In addition, there was a statistically significant trend toward total nitrogen concentrations decreasing from upstream to downstream along the River (see Table 88). Table C-5 in Appendix C shows that significant trends toward increasing total nitrogen concentrations were detected in the Milwaukee River. When examined on an annual basis, increasing concentrations were detected at six stations. Trends were not detected at the three stations in the estuary that are farthest downstream. This may reflect the influence of mixing with water from Lake Michigan and the Menomonee and Kinnickinnic Rivers at these stations. When examined on a seasonal basis, increasing concentrations of total nitrogen were detected during the summer at all stations except Estabrook Park. Given that concentrations decreased between the periods 1975-1986 and 1987-1994, the results set forth in Table C-5 in Appendix C may understate current trends. The concentration of total nitrogen in the Milwaukee River is positively correlated with the concentrations of nitrate and organic nitrogen, reflecting the fact that these tend to be the major forms of nitrogen compounds in the River. In addition, concentrations of total nitrogen were positively correlated with concentrations of total phosphorus at most stations. This probably reflects the nitrogen and phosphorus contained in particulate organic matter in the water, including live material such as plankton and detritus. Finally, total nitrogen concentrations in the Milwaukee River are negatively correlated with temperature, reflecting the fact that total nitrogen concentrations tend to be highest during the winter.

Mean concentrations of total nitrogen in some upstream tributaries are higher than the mean concentration of total nitrogen in the mainstem of the River, but this generalization is based upon much less extensive sampling in the tributaries. Figure 131 shows changes in total nitrogen concentrations in two tributaries of the Milwaukee River. Concentrations of total nitrogen at the station near Random Lake along the North Branch Milwaukee River have

Figure 131

TOTAL NITROGEN CONCENTRATIONS IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

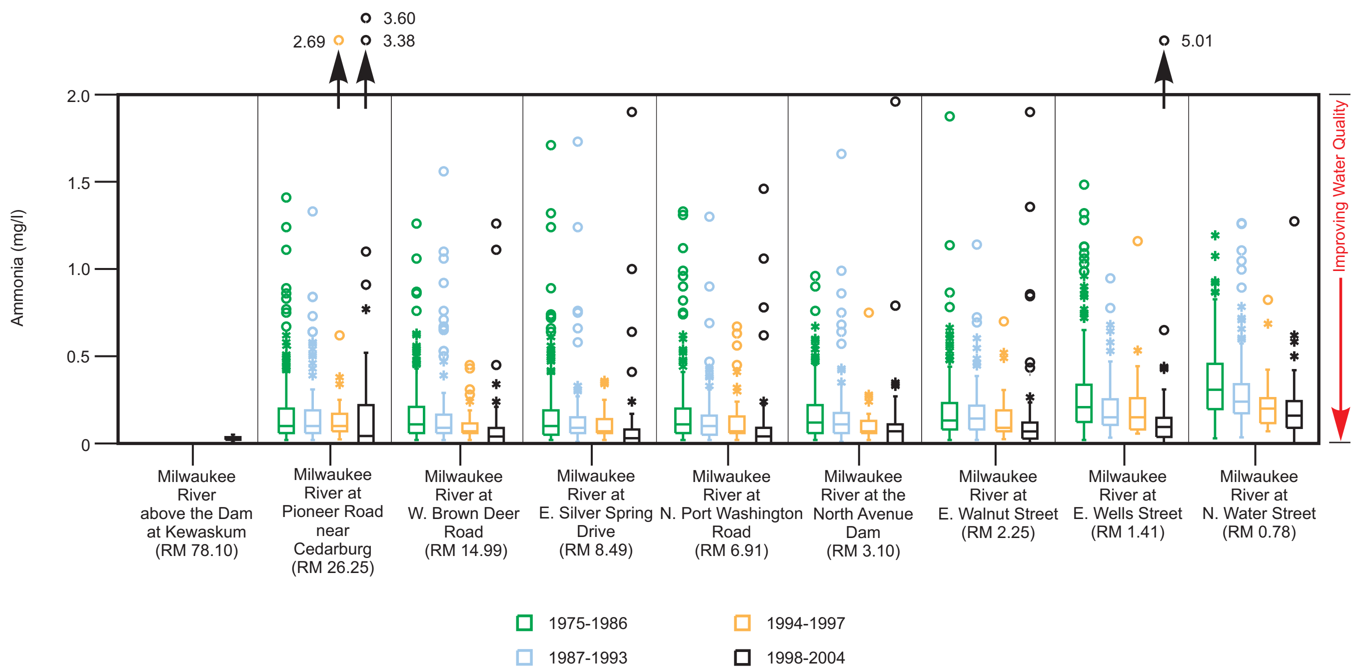
increased over time. A more complicated situation emerges for Lincoln Creek. At upstream stations, concentrations of total nitrogen have decreased. This is especially true of the minimum concentrations detected. Concentrations at downstream stations have increased or remained the same. Table C-5 in Appendix C shows significant trends toward total nitrogen concentrations decreasing at upstream stations in Lincoln Creek.

Total nitrogen is a composite measure of several different compounds which vary in their availability to algae and aquatic plants and vary in their toxicity to aquatic organisms. Common constituents of total nitrogen include ammonia, nitrate, and nitrite. In addition a large number of nitrogen-containing organic compounds, such as amino acids, nucleic acids, and proteins commonly occur in natural waters. These compounds are usually reported as organic nitrogen.

The mean concentration of ammonia in the Milwaukee River was 0.20 mg/l as N. Over the period of record, ammonia concentrations varied from below the limit of detection to 5.01 mg/l as N. Figure 132 shows that ammonia concentrations have decreased over time at all stations. These decreases represent significant decreasing trends in ammonia concentrations when examined on an annual basis and during all seasons (Table C-5 in Appendix C). Ammonia concentrations in the Milwaukee River tend to be higher during the winter than during other seasons. Mean ammonia concentrations in the estuary are significantly higher than mean concentrations of ammonia in the section of the River upstream from the estuary (see Table 87). In the section of the River upstream from the estuary, there is a significant trend toward ammonia concentrations decreasing from upstream to downstream. Mean concentrations of ammonia in many tributary streams were lower than the mean concentrations detected in the mainstem of the River. This is not the case, however, in all tributaries. Mean ammonia concentrations in Lincoln Creek, Parnell Creek, and Polk Springs Creek were 0.15 mg/l as N, 0.28 mg/l as N, and 0.35 mg/l as N respectively. Significant trends toward ammonia concentrations decreasing over time were detected in Lincoln Creek (Table C-5 in Appendix C). Ammonia concentrations at several stations, especially in the estuary, are positively correlated with concentrations of fecal coliform bacteria. This may reflect common sources and modes of transport into the River for these two pollutants.

Figure 132

AMMONIA CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



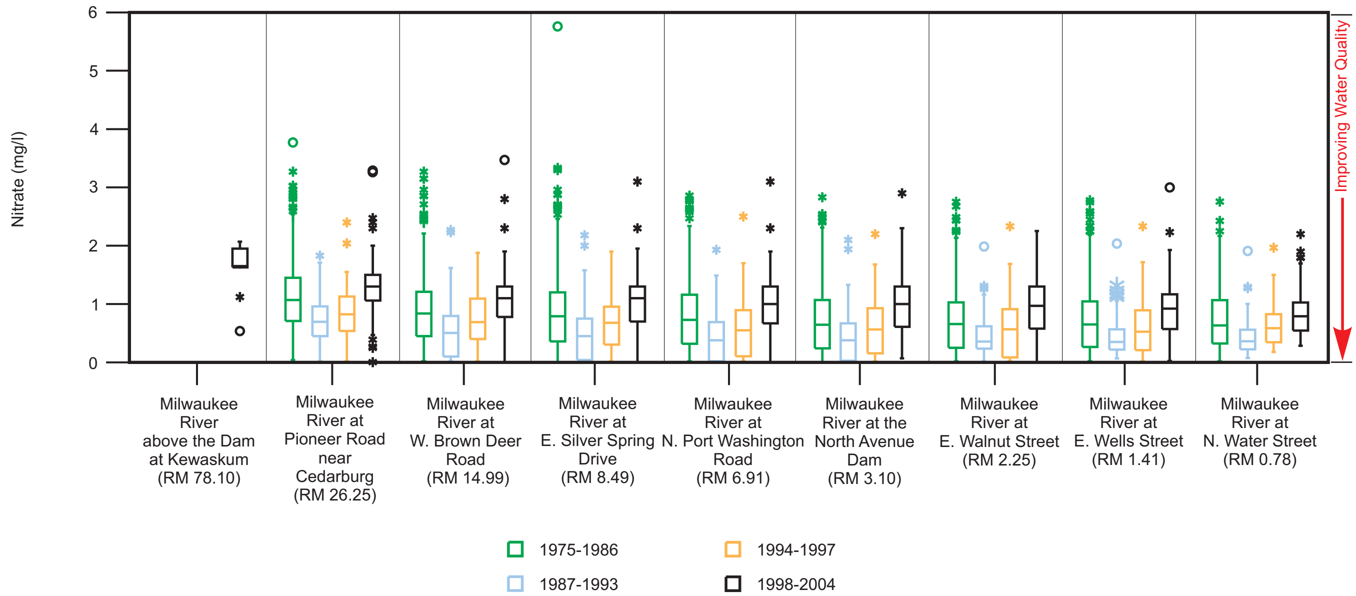
NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

The mean concentration of nitrate in the Milwaukee River for the period of record was 0.78 mg/l as N. During this time, concentrations in the River varied from below the limit of detection to 5.76 mg/l as N. In general, the changes in nitrate concentrations at most stations along the mainstem of the River (see Figure 133) are similar to the changes in concentrations of total nitrogen. At all stations, concentrations of nitrate during the period 1987-1993 were lower than during the period 1975-1986. In subsequent periods, concentrations of nitrate increased. This suggests that the changes over time in nitrate concentrations within the River may be driving the changes over time in total nitrogen concentrations. In the section of the River upstream from the estuary, there is a statistically significant trend for nitrate concentrations to decrease from upstream to downstream along the mainstem of the River. The relationship between the mean concentrations of nitrate in the estuary and in the section of the River upstream from the estuary has changed over time (see Table 87). During the period 1975-1986, mean concentrations of nitrate in the estuary were lower than those in the section of the River upstream from the estuary. This changed after 1986. During the periods 1987-1993 and 1994-1997, there were no statistically significant differences between mean nitrogen concentrations in these two sections of the River. It changed again after 1997. During the period 1998-2004, concentrations of nitrate in the estuary were lower than those in the section of the River upstream from the estuary. Table C-5 in Appendix C shows that significant trends toward nitrate concentrations increasing over time were detected at most stations along the mainstem of the River. The data show evidence of seasonal variations in nitrate concentration. Nitrate concentration was highest in the winter. It declined through fall to reach lower levels during summer or early fall. In the fall, the concentration began to climb again. At some stations, nitrate concentrations rise during late spring and early summer to reach a second peak. Mean nitrate concentrations in tributary streams were quite variable, ranging from 0.12 mg/l as N on the East Branch Milwaukee River to 13.7 mg/l as N on Polk Springs Creek. Few time-based trends were detected in nitrate concentrations in tributaries (Table C-5 in Appendix C). Trends toward nitrate concentrations decreasing over time were detected at three stations along Southbranch Creek; however, the short period of record on this stream make it difficult to determine whether these actually represent long term trends. Nitrate concentrations in

Figure 133

NITRATE CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

the Milwaukee River were negatively correlated with concentrations of chlorophyll-*a* and organic nitrogen. These correlations reflect the role of nitrate as a nutrient for algal growth. During periods of high algal productivity, algae remove nitrate from water and incorporate it into cellular material.

The mean concentration of nitrite in the Milwaukee River was 0.024 mg/l as N over the period of record. Nitrite concentrations showed more variability than nitrate. This probably reflects the fact that nitrite in oxygenated water tends to oxidize to nitrate fairly quickly. Mean nitrite concentrations in the estuary were higher than mean nitrite concentrations in the section of the River upstream from the estuary in all periods (see Table 87). Nitrite concentrations tended to decrease from upstream to downstream in the section of the River upstream from the estuary (see Table 88). When examined on an annual basis, there were few trends in nitrite concentration over time (Table C-5 in Appendix C). Some significant trends were detected when the data were analyzed on a seasonal basis, but the directions of the trends varied by station and season. None of these trends accounted for more than a small portion of the variation in the data. Mean nitrite concentrations in tributary streams range from 0.010-0.060 mg/l as N.

During the period of record the mean concentration of organic nitrogen in the Milwaukee River was 0.90 mg/l as N. This parameter showed considerable variability with concentrations ranging from undetectable to 10.46 mg/l as N. Few time-based trends were detected in organic nitrogen concentrations (Table C-5 in Appendix C). There is a statistically significant trend toward organic nitrogen concentration increasing from upstream to downstream in the section of the River upstream from the estuary (see Table 88). During most periods, mean concentrations of organic nitrogen in the estuary were lower than mean concentrations in the section of the River upstream from the estuary (see Table 87). Organic nitrogen concentrations in the Milwaukee River tend to be high during the summer. Mean concentrations of organic nitrogen in tributary streams range from 0.65 mg/l as N to 0.98 mg/l as N. Organic nitrogen concentrations in the Milwaukee River show positive correlations with chlorophyll-*a*, temperature, and total phosphorus. These correlations may reflect the roles of phosphorus and nitrogen as nutrients for algal growth. During periods of high algal productivity, algae remove dissolved phosphorus and nitrogen compounds from the water and incorporate them into cellular material. These periods usually occur during warmer weather. In addition, concentrations of organic nitrogen in the Milwaukee River are negatively correlated with concentrations of dissolved oxygen. This reflects the fact that aerobic metabolism of many organic nitrogen compounds requires oxygen. Concentrations of organic nitrogen in the Milwaukee River do not appear to have changed much over time.

Several processes can influence the concentrations of nitrogen compounds in a waterbody. Primary production by plants and algae will result in ammonia and nitrate being removed from the water and incorporated into cellular material. This effectively converts the nitrogen to forms which are detected only as total nitrogen. Decomposition of organic material in sediment can release nitrogen compounds to the overlying water. Bacterial action may convert some nitrogen compounds into others.

Several things emerge from this analysis of nitrogen chemistry in the Milwaukee River:

- Concentrations of total nitrogen have been increasing at several stations along the mainstem of the River. This represents a decrease in water quality.
- The relative proportions of different nitrogen compounds in the River seem to be changing with time.
- Ammonia concentrations have been declining over time. This represents an improvement in water quality.
- Concentrations of nitrate have been increasing at most stations along the mainstem of the River. This appears to account for at least some of the increase in total nitrogen concentrations. This represents a decrease in water quality.
- Concentrations of other forms of nitrogen in the River do not appear to be changing with time.

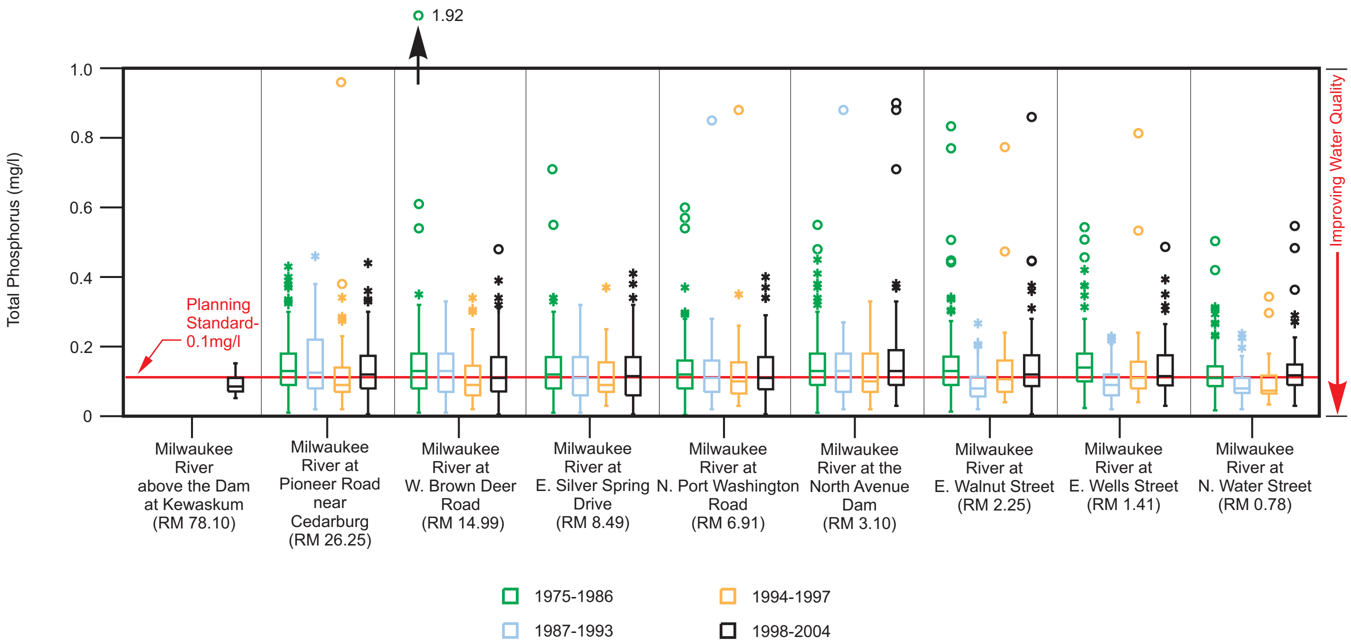
Total and Dissolved Phosphorus

Two forms of phosphorus are commonly sampled in surface waters: dissolved phosphorus and total phosphorus. Dissolved phosphorus represents the form that can be taken up and used for growth by algae and aquatic plants. Total phosphorus represents all the phosphorus contained in material dissolved or suspended within the water, including phosphorus contained in detritus and organisms and attached to soil and sediment.

The mean concentration of total phosphorus in the Milwaukee River during the period of record was 0.129 mg/l, and the mean concentration of dissolved phosphorus in the Milwaukee River over the period of record was 0.050 mg/l. Total phosphorus concentrations varied over four orders of magnitude, ranging from 0.004 to 1.920 mg/l. Dissolved phosphorus concentrations varied over three orders of magnitude from 0.003 to 0.870 mg/l. At most sampling sites, the data showed moderate variability. Figure 134 shows the pattern of changes in total phosphorus concentrations over time along the mainstem of the River. At most estuary stations, median concentrations of total phosphorus during the period 1987-1993 were lower than median concentrations of total phosphorus during the period 1975-1986. This decrease was followed by increases in median concentrations of total phosphorus in the subsequent periods. The pattern followed by median concentrations of total phosphorus at stations in the section of the River upstream from the estuary was similar, except that the decrease in median concentrations occurred later, following the period 1987-1994. Median total phosphorus concentrations at one estuary station, the site of the former North Avenue dam, followed this latter pattern. At all stations during all periods, total phosphorus concentrations in a substantial fraction of samples exceeded the planning standard of 0.1 mg/l recommended in the regional water quality management plan. During most periods, there were no statistically significant differences between mean total phosphorus concentrations in the estuary and mean total phosphorus concentrations in the section of the River upstream from the estuary (see Table 87). The exception to this generalization occurred during the period 1987-1993 when the mean concentration in the section of the River upstream from the estuary were higher than the mean concentration in the estuary. During the periods 1975-1986 and 1987-1993, mean concentrations of dissolved phosphorus in the section of the River upstream from the estuary were higher than

Figure 134

TOTAL PHOSPHORUS CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

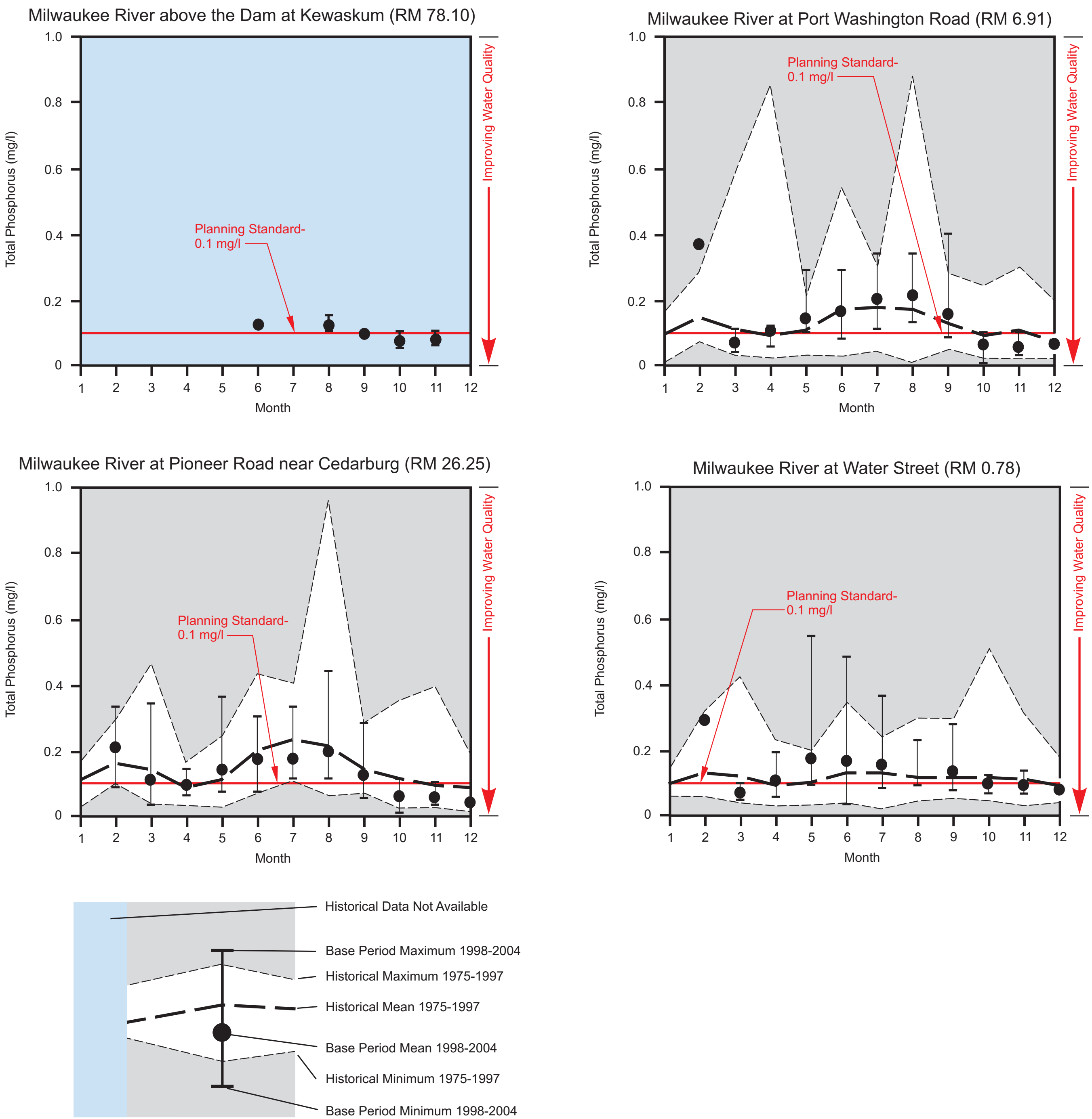
Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

mean concentrations of dissolved phosphorus in the estuary. In subsequent periods, there were no significant differences between mean dissolved phosphorus concentrations in these two sections of the River. A statistically significant trend toward dissolved phosphorus concentration decreasing from upstream to downstream in the Milwaukee River was detected (see Table 88). No longitudinal trend was detected for total phosphorus concentration.

Figure 135 shows a monthly comparison of the historical and baseline concentrations of total phosphorus at four sampling stations along the length of the mainstem of the Milwaukee River. All stations except the Kewaskum station show a distinct seasonal pattern in total phosphorus concentrations. Total phosphorus concentrations are highest in the summer. At upstream stations, such as Pioneer Road or Port Washington Road, this peak concentration tends to occur in June. It tends to occur later in the summer downstream. At the Pioneer Road station, mean monthly total phosphorus concentrations during the baseline period were lower than historical means during summer and fall. At some downstream stations, baseline period mean monthly total phosphorus concentrations during the summer were near or above historical means. On an annual basis, trends toward decreasing total phosphorus concentrations over time were detected at most stations along the mainstem of the River (see Table C-5 in Appendix C). These trends appear to result largely from declines during the fall. These trends represent an improvement in water quality. Dissolved phosphorus concentrations show a more complicated pattern of time-based trends. When examined on an annual basis, trends toward dissolved phosphorus concentrations decreasing over time were detected at three stations in the section of the River upstream from the estuary. A trend toward dissolved phosphorus concentrations increasing over time was detected at one estuary station. When examined on a seasonal basis, statistically significant trends toward increases in dissolved phosphorus concentration during the summer were detected at most stations along the mainstem. These trends represent a decline in water quality. Trends toward decreases in dissolved phosphorus concentrations during the fall were detected at several stations. These trends represent an improvement in water quality.

Figure 135

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF TOTAL PHOSPHORUS ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



Source: *U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

In tributary streams, mean concentrations of total phosphorus ranged from 0.043 to 0.258 mg/l and mean concentrations of dissolved phosphorus ranged from 0.039 to 0.199 mg/l. Figure 136 shows historical and baseline period total phosphorus concentrations for stations on seven tributary streams. At those stations where sufficient data are available to assess seasonal trends, total phosphorus concentrations in tributary streams appear to be highest during the summer. At some stations, such as the STH 60 station on Cedar Creek and the N. 47th Street station on Lincoln Creek, baseline period monthly mean total phosphorus concentrations were below historical means.

Dissolved phosphorus concentrations in the Milwaukee River were negatively correlated with concentrations of chlorophyll-*a*. Total phosphorus concentrations were positively correlated with temperature, chlorophyll-*a* concentrations, and concentrations of organic nitrogen and total nitrogen. These correlations reflect the roles of phosphorus and nitrogen as nutrients for algal growth. During periods of high algal productivity, algae remove dissolved phosphorus and nitrogen compounds from the water and incorporate them into cellular material. Because the rates of biological reactions are temperature dependent, these periods tend to occur when water temperatures are warmer. At most stations, concentrations of total phosphorus were also positively correlated with concentrations of BOD and fecal coliform bacteria. This correlation may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the River.

Figure 137 shows the annual mean total phosphorus concentrations in the Milwaukee River for the years 1985 to 2002. While mean annual total phosphorus concentrations from the years 1996-2002 were within the range of variation from previous years, they increased after 1996. The increase in the Milwaukee River was not as significant as those observed in the Kinnickinnic and Menomonee Rivers (see Figures 45 and 84 in Chapters V and VI, respectively, in this report). One possible cause of this increase was phosphorus loads from facilities discharging noncontact cooling water drawn from municipal water utilities. The City of Milwaukee, for example, began treating its municipal water with orthophosphate to inhibit release of copper and lead from pipes in the water system and private residences in 1996. In 2004, for instance, concentrations of orthophosphate in plant finished water from the Milwaukee Water Works ranged between 1.46 mg/l and 2.24 mg/l,[5] considerably above average concentrations of total phosphate in the Milwaukee River. In addition, between 1992 and 2003, a number of other municipalities in the Milwaukee River watershed began treating their municipal water with orthophosphate or polyphosphate for corrosion control (see Table 91). The weaker increase in mean annual total phosphorus concentrations after 1996 in the Milwaukee River relative to the increases in the Kinnickinnic and Menomonee River may be due to the greater volume of water flowing through the Milwaukee River.

Metals

Arsenic

The mean value for the concentration of arsenic in the water of the Milwaukee River over the period of record was 1.94 μg/l. The data ranged from below the limit of detection to 14.00 μg/l. No differences were detected between mean arsenic concentrations in the estuary and mean arsenic concentrations in the section of the River upstream from the estuary (see Table 87). In the section of the River upstream from the estuary, there was a statistically significant trend toward arsenic concentrations increasing from upstream to downstream. This trend accounts for a small portion of the variation in the data. When examined on an annual basis, decreasing concentrations of arsenic over time were detected at all stations examined along the mainstem of the River (Table C-5 in Appendix C). This may reflect changes in the amount and types of industry within the Milwaukee River watershed such as the loss of tanneries which utilized arsenic in the processing of hides. In addition, sodium arsenite has not been used in herbicides in Wisconsin since 1969. Data on arsenic concentrations are available for few Milwaukee River tributaries. Mean concentrations of arsenic in Indian Creek, Lincoln Creek, and Southbranch Creek over the period of record were 1.25 μg/l, 1.68 μg/l, and 1.08 μg/l respectively. Significant trends toward arsenic concentrations decreasing over time were detected at all stations along Lincoln Creek (Table C-5 in Appendix C). Trends toward decreasing arsenic concentrations over time were also detected at stations along

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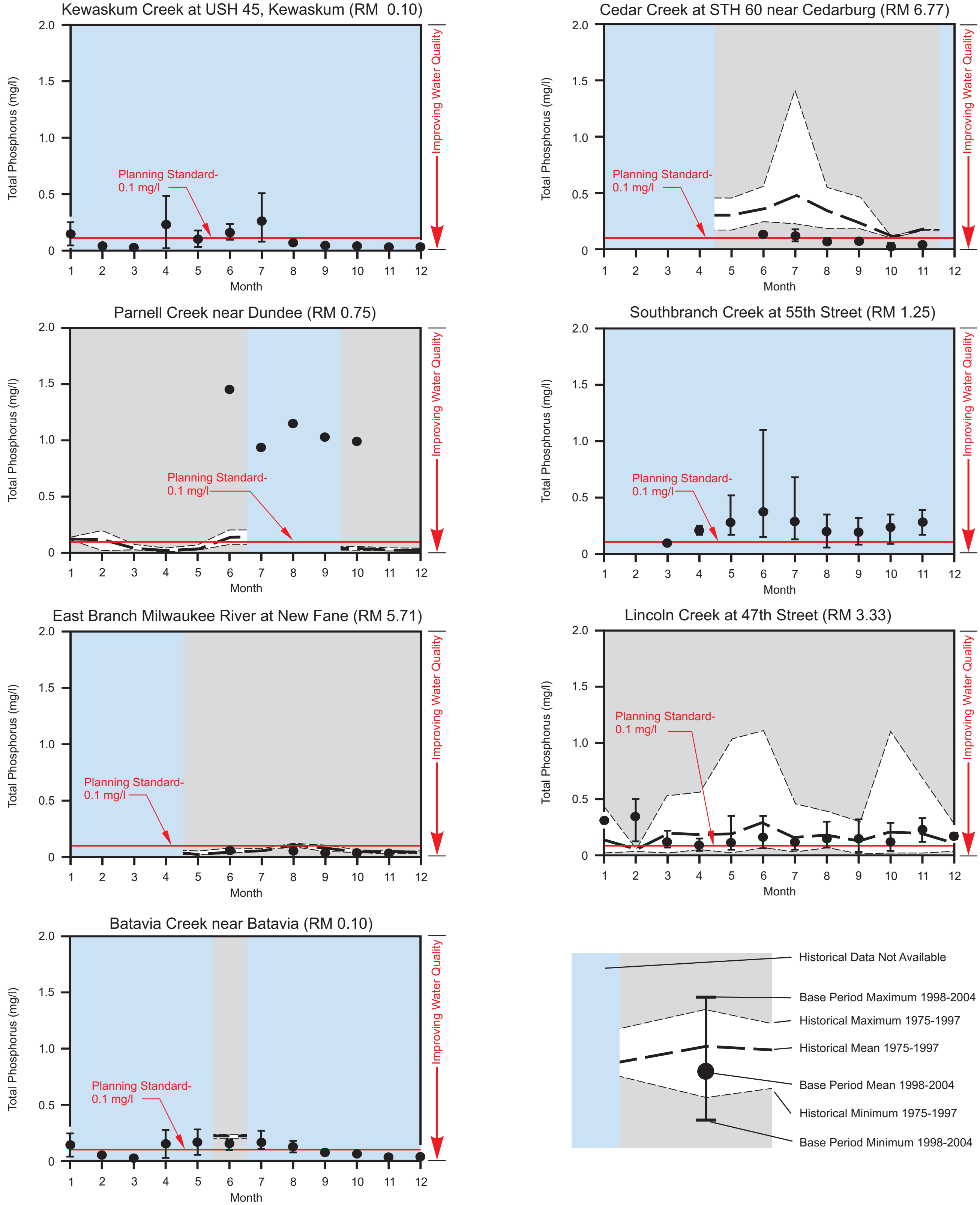
[5]*Milwaukee Water Works,* Annual Water Quality Report, 2004, *February 2005.*

Figure 136

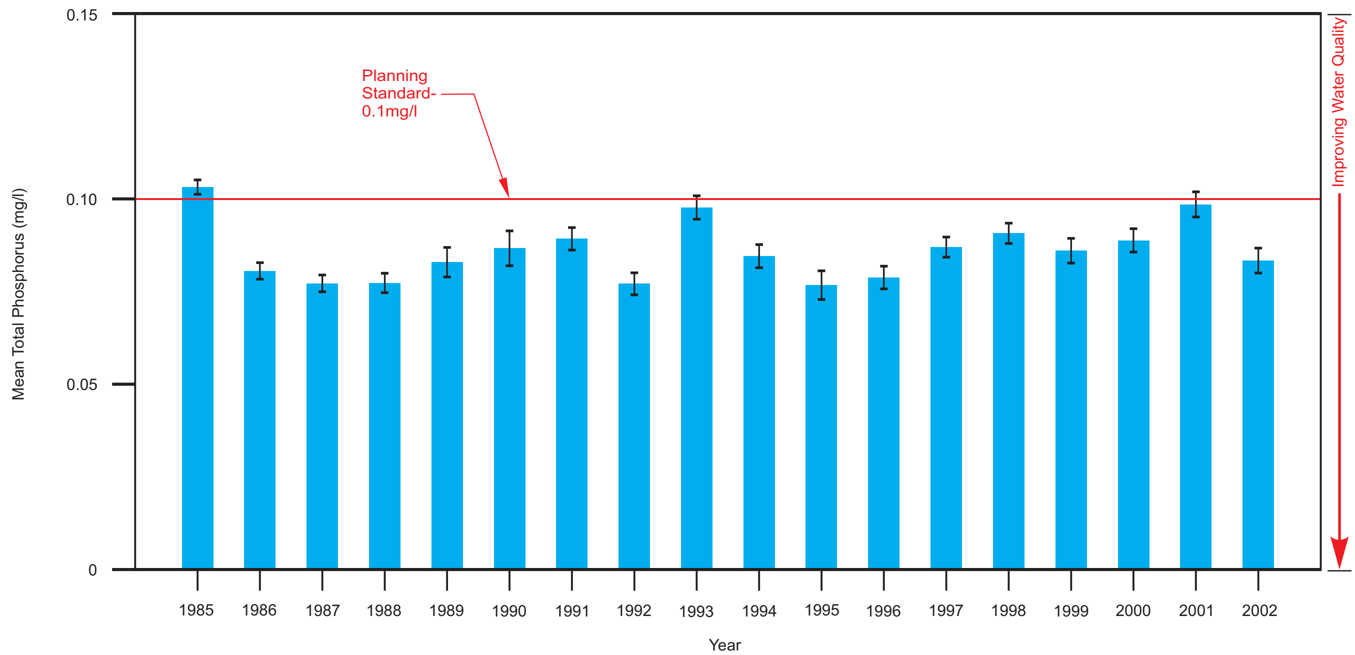
HISTORICAL AND BASE PERIOD CONCENTRATIONS OF TOTAL PHOSPHORUS IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



Source: *U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

Figure 137

MEAN ANNUAL CONCENTRATIONS OF TOTAL PHOSPHORUS IN THE MILWAUKEE RIVER WATERSHED: 1985-2002



NOTE: Error bars (I) represent one standard error of the mean.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Table 91

MUNICIPAL WATER UTILITIES THAT USE PHOSPHATES AS CORROSION INHIBITORS IN THE MILWAUKEE RIVER WATERSHED

Water Utility	Treatment	Year Treatment Began
Adell Waterworks	Polyphosphate	2000
Cascade Waterworks	Polyphosphate	2000
Cedarburg Light & Water Commission	Orthophosphate	2000
Grafton Waterworks	Polyphosphate	1992
Milwaukee Waterworks	Orthophosphate	1996
North Shore Water Commission	Polyphosphate	2000
Slinger Water Utility	Polyphosphate	2000
West Bend Waterworks	Polyphosphate	2000

Source: Wisconsin Department of Natural Resources and SEWRPC.

Southbranch Creek; however, the short period of record for this stream makes it difficult to ascertain whether these represent long-term trends (Table C-5 in Appendix C). The reductions in arsenic concentration in the Milwaukee River and Lincoln Creek represent an improvement in water quality.

Cadmium

The mean concentration of cadmium in the Milwaukee River over the period of record was 1.53 μg/l. A moderate amount of variability was associated with this mean. Individual samples ranged from below the limit of detection to 17.8 μg/l. Concentrations tended to be slightly more variable at stations in the estuary than at stations in the section of the River upstream from the estuary. The relationship between mean concentrations in the estuary and mean concentrations in the section of the River upstream of the estuary has changed over time (see Table 87). Prior to 1994, mean concentrations in the estuary were significantly higher than mean concentrations in the section of the River upstream from the estuary. Since 1994, there has been no significant difference between these means. Table 88 shows a significant trend toward cadmium concentrations in the section of the River upstream of the estuary decreasing from upstream to downstream. This trend accounts for a very small portion of the variation in the data. Table C-5 in Appendix C shows the presence of strong decreasing trends in cadmium concentration at all stations along the mainstem of the River for which data were available when the data were analyzed on an annual basis. These declines in cadmium concentration may reflect changes in the number and types of industry present in the watershed, reductions due to treatment of industrial discharges, and reductions in airborne deposition of cadmium to the Great Lakes region. Cadmium concentrations in the River showed no evidence of seasonal variation. Data on cadmium concentrations are available for few tributaries to the Milwaukee River. Mean concentrations of cadmium in samples from Indian, Lincoln, and Southbranch Creeks are 0.13 μg/l, 0.18 μg/l, and 0.11 μg/l respectively. These means are about an order of magnitude lower than the mean from the mainstem of the River. In part, this reflects the shorter period of record for these streams. The mean concentration of cadmium in the only headwater stream for which data are available, Parnell Creek, is 0.01 μg/l, another order of magnitude lower. The reduction in cadmium concentrations in the Milwaukee River represents an improvement in water quality.

Chromium

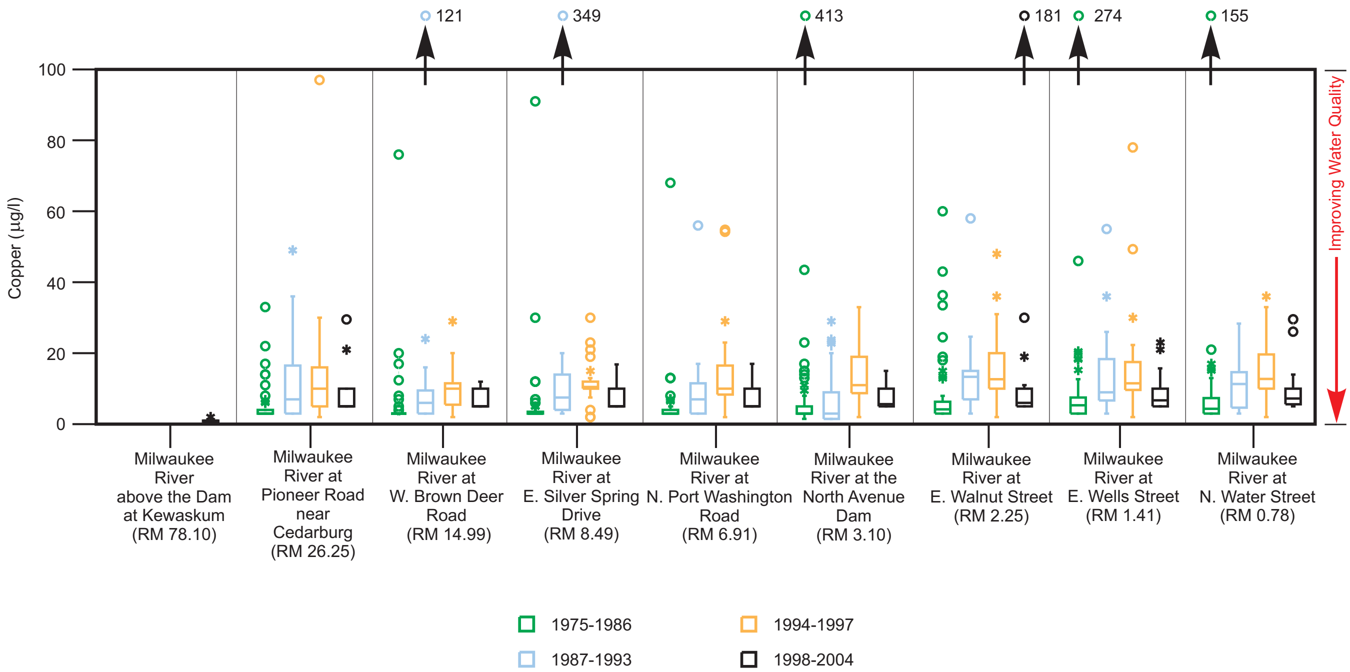
The mean concentration of chromium in the Milwaukee River over the period of record was 14.2 μg/l. Chromium concentration showed moderate variability, with individual sample concentrations ranging from below the limit of detection to 8,866.4 μg/l. Prior to 1994, mean concentrations of chromium in the estuary were higher than mean concentrations in the section of the River upstream from the estuary (see Table 87). Since 1994, there have been no significant differences between the mean concentrations of chromium in these two sections of the River. There is a statistically significant trend toward chromium concentrations in the section of the River upstream from the estuary decreasing from upstream to downstream (see Table 88). As shown in Table C-5 in Appendix C, analysis of time-based trends suggests that chromium concentrations are declining within much, though not all, of the River. Only a few Milwaukee River tributaries have been sampled for chromium concentrations. Mean concentrations for Lincoln Creek and Southbranch Creek were 6.78 μg/l and 6.37 μg/l respectively. Significant trends toward decreasing chromium concentrations were detected in both of these tributaries (Table C-5 in Appendix C). The decline in chromium concentration in the Milwaukee River may reflect the loss of industry in some parts of the watershed and the decreasing importance of the metal plating industry in particular, as well as the establishment of treatment of discharges instituted for the remaining and new industries since the late 1970s. There is no evidence of seasonal variation in chromium concentrations in the Milwaukee River. The decline in chromium concentrations represents an improvement in water quality.

Copper

The mean concentration of copper in the Milwaukee River during the period of record was 8.96 μg/l. Concentrations varied from below the limit of detection to 413.00 μg/l. Figure 138 shows copper concentrations at several stations along the mainstem of the River. At most stations, median (and mean) copper concentration increased over time, reaching their highest levels during the period 1994-1997. Table C-5 in Appendix C shows that these trends were statistically significant at several stations. At most stations, median (and mean) copper concentrations were lower during the period 1998-2004 than during the period 1994-1997; however, they were

Figure 138

COPPER CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

still higher than during the period 1975-1986. During all periods, mean copper concentrations in the estuary were higher than mean concentrations in the section of the River upstream of the estuary. Mean copper concentrations in tributaries to the Milwaukee River range from 1.05 μg/l in the East Branch Milwaukee River to 8.72 μg/l in Lincoln Creek. Figure 139 shows copper concentrations at four stations along Lincoln Creek. Concentrations of copper in Lincoln Creek were lower during the period 1998-2004 than during the period 1994-1997. At most stations this represents a significant trend toward decreasing concentrations of copper over time (Table C-5 in Appendix C). The recent decreases in copper concentrations in the Milwaukee River and the trend toward decreasing copper concentrations in the Lincoln Creek represent improvements in water quality.

Lead

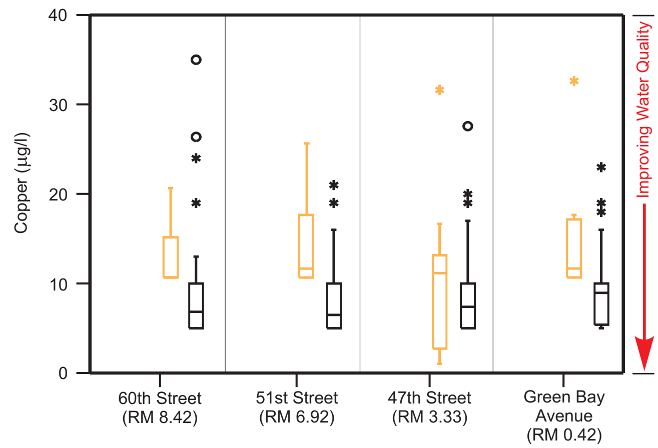
The mean concentration of lead in the Milwaukee River over the period of record was 26.5 μg/. This mean is not representative of current conditions because lead concentrations in the water of the River have been decreasing since the late 1980s, as shown in Figure 140. At all sampling stations for which sufficient data exist to assess trends in lead concentrations, baseline period monthly mean lead concentrations are quite low when compared to historical means and ranges. These decreases represent statistically significant decreasing trends (Table C-5 in Appendix C). A major factor causing the decline in lead concentrations has been the phasing out of lead as a gasoline additive. From 1983 to 1986, the amount of lead in gasoline in the United States was reduced from 1.26 grams per gallon (g/gal) to 0.1 g/gal. In addition, lead was completely banned for use in fuel for on-road vehicles in 1995. The major drop in lead in water in the Milwaukee River followed this reduction in use. In freshwater, lead has a strong tendency to adsorb to particulates suspended in water.[6] As these particles are deposited, they

[6] *H.L. Windom, T. Byrd, R.G. Smith, and F. Huan, "Inadequacy of NASQUAN Data for Assessing Metal Trends in the Nation's Rivers,"* Environmental Science and Technology *Volume 25, 1991.*

carry the adsorbed lead into residence in the sediment. Because of this, the lower concentrations of lead in the water probably reflect the actions of three processes: reduction of lead entering the environment, washing out of lead into the estuary and Lake Michigan, and deposition of adsorbed lead in the sediment. Lead concentrations in the Milwaukee River show no evidence of patterns of seasonal variation. Few data are available for lead concentrations in tributaries of the Milwaukee River. Trends toward lead concentrations decreasing over time were detected at several sampling stations along Lincoln and Southbranch Creeks. The decrease in lead concentrations over time in the Milwaukee River represents an improvement in water quality.

Figure 139

COPPER CONCENTRATIONS AT SITES ALONG LINCOLN CREEK: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Mercury

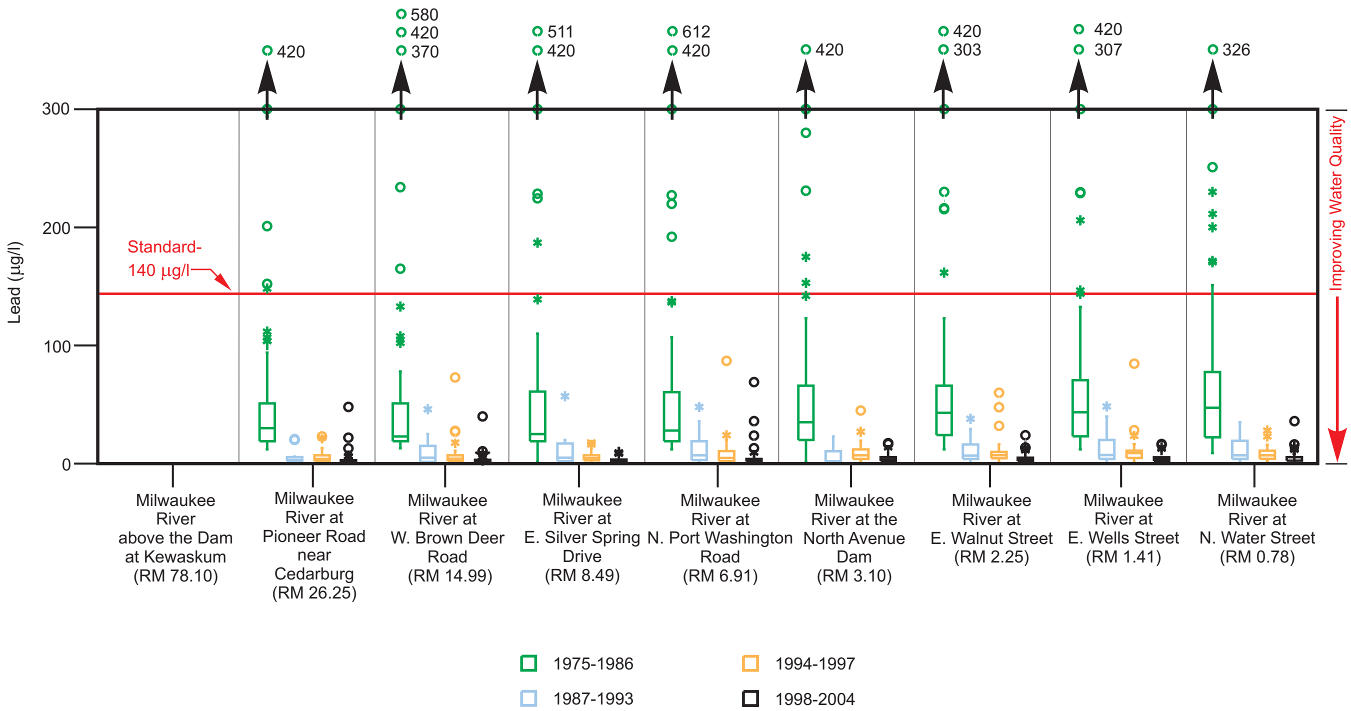
Few historical data on the concentration of mercury in the water of the Milwaukee River exist. Most sampling for mercury in water in the River was taken during or after 1995. The mean concentration of mercury in the River over the period of record was 0.105 μg/l. Mercury concentrations showed moderate variability, with a range from below the limit of detection to 0.880 μg/l. The means at individual stations ranged from 0.001 μg/l at the station at CTH M near Newburg and the stations near the River's mouth to 0.194 μg/l at Pioneer Road. Table 87 shows that during the periods 1994-1997 and 1998-2004, mean concentrations of mercury were higher in the section of the River upstream from the estuary than in the estuary. When examined on an annual basis, significant trends toward decreasing mercury concentrations were detected at all stations in the estuary (Table C-5 in Appendix C). No time-based trends were detected at stations in the section of the River upstream from the estuary. There is no evidence of seasonal variation of mercury concentrations in the Milwaukee River. Few data exist on mercury concentrations in tributary streams. Mean concentrations of mercury detected in Lincoln Creek and Southbranch Creek were 0.045 μg/l and 0.038 μg/l respectively. Significant trends toward mercury concentrations decreasing over time were detected at most stations along Lincoln Creek and two stations along Southbranch Creek (Table C-5 in Appendix C). The trends toward decreasing mercury concentrations at stations in the Milwaukee River estuary and Lincoln and Southbranch Creeks represent improvements in water quality.

Nickel

The mean concentration of nickel in the Milwaukee River over the period of record was 13.5 μg/l. Concentrations in individual samples ranged from below the limit of detection to 3,810.8 μg/l. No significant differences were found between mean concentrations in the estuary and in the section of the River upstream from the estuary (see Table 87). A significant trend toward nickel concentration decreasing from upstream to downstream in the section of the River upstream from the estuary was detected (see Table 88). When examined on an annual basis, significant declines over time were observed at several sampling stations along the mainstem of the River (Table C-5 in Appendix C). This may reflect changes in the amount and types of industry within the Milwaukee River watershed. There was no evidence of seasonal variation in nickel concentration in the Milwaukee River. Data on nickel concentrations are available for few Milwaukee River tributaries. Mean concentrations of nickel in Indian Creek, Lincoln Creek, and Southbranch Creek over the period of record were 8.7 μg/l, 10.5 μg/l, and 8.1 μg/l respectively. Significant trends toward nickel concentrations decreasing over time were detected at all stations along Lincoln Creek (see Table 87). Trends toward decreasing nickel concentrations over time were also

Figure 140

LEAD CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

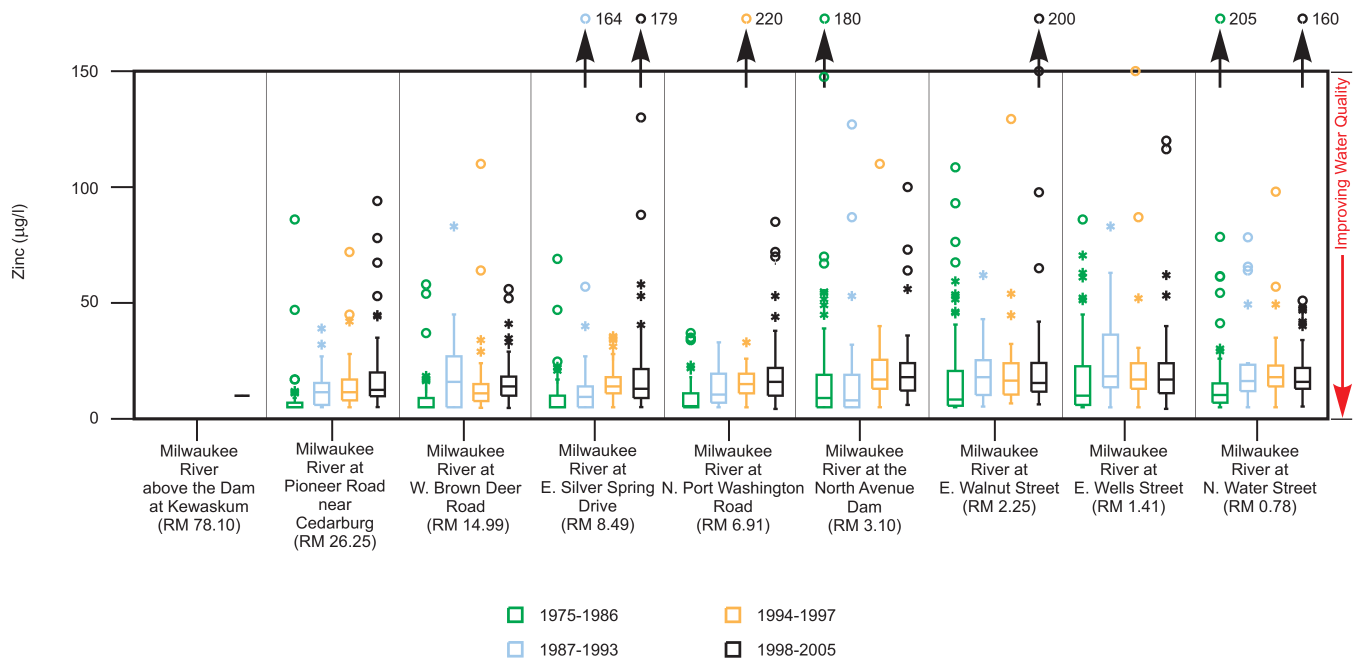
detected at stations along Southbranch Creek; however, the short period of record for this stream makes it difficult to ascertain whether these represent long-term trends (Table C-5 in Appendix C). The decreases in nickel concentrations in the Milwaukee River and Lincoln Creek represent an improvement in water quality.

Zinc

The mean concentration of zinc in the Milwaukee River during the period of record was 18.2 µg/l. Zinc concentrations showed moderate variability. Concentrations in individual samples ranged from 4.3 to 220.0 µg/l. Mean concentrations of zinc were higher in the estuary than in the section of the River upstream of the estuary in all periods (see Table 87). Figure 141 shows that zinc concentrations in the section of the River upstream from the estuary tended to increase from upstream to downstream. This represented a statistically significant trend (see Table 88). The higher concentrations of zinc at the downstream stations may reflect higher amounts of zinc washing into the River during snowmelt and spring rains caused by higher amounts of vehicle traffic in this portion of the watershed. Wear and tear on automobile brake pads and tires are major sources of zinc in the environment. In addition, zinc can be released to stormwater by corrosion of galvanized gutters and roofing materials. Stormwater can carry zinc from these sources into the River. Table C-5 in Appendix C of this report shows that there were statistically significant trends toward zinc concentrations increasing over time at most stations along the River. The station at Estabrook Park was an exception to this generalization. There is no evidence of seasonal variation in the concentration of zinc in the Milwaukee River. Data on zinc concentrations are available for only a few Milwaukee River tributaries. Mean concentrations of zinc in tributaries range from 4.6 µg/l in Parnell Creek to 40.2 µg/l in Southbranch Creek. Trends toward zinc concentrations decreasing over time were detected at two stations along Lincoln Creek (Table C-5 in Appendix C). While similar decreasing trends were also detected at stations along Southbranch Creek, the short period of record for this stream makes it difficult to assess whether

Figure 141

ZINC CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

this represents a long-term trend. The trend toward decreasing zinc concentrations at two stations along Lincoln Creek represents an improvement in water quality. The trends toward increasing zinc concentrations in the mainstem of the Milwaukee River represents a reduction in water quality.

Organic Compounds

Between February and June 2004, samples were collected by the USGS on three dates from three sites along the Milwaukee River—Pioneer Road, Estabrook Park, and Jones Island—and at N. 47th Street along Lincoln Creek. Those samples were examined for the presence and concentrations of several organic compounds dissolved in water. Whole water samples were also collected from the Lincoln Creek site on eight dates during the winter of 2001-2002. Bromoform, a disinfectant byproduct, was detected in one sample from Lincoln Creek collected in 2002 at a concentration of 0.06 μg/l. It was not detected in the Milwaukee River or Lincoln Creek during the 2004 sampling. Dissolved isophorone, a solvent, was detected in 2004 in one sample each from the Milwaukee River at Pioneer Road and Jones Island and from Lincoln Creek at a concentration of 0.1 μg/l. As shown in Table 18 in Chapter IV of this report, this concentration is below Wisconsin's human threshold criterion for public health and welfare for fish and aquatic life waters. Carbazole, a component of dyes, lubricants, and pesticides, was detected in two samples from Lincoln Creek and one sample from the Milwaukee River at Jones Island in 2004 at a concentration of 0.1 μg/l. In 2004, the plasticizer triphenyl phosphate was found in all samples collected from Lincoln Creek and from samples collected from the Milwaukee River at Estabrook Park and Jones Island at a concentration of 0.1 μg/l. Three flame retardant chemicals were detected in samples from the Milwaukee River and Lincoln Creek. Tri(2-chloroethyl) phosphate was detected in all three samples collected from Lincoln Creek in 2004 at concentrations ranging between 0.1 μg/l and 0.2 μg/l. It was also detected in five samples from the Milwaukee River at a concentration of 0.1 μg/l. In 2004, Tri(dichloroisopropyl) phosphate was detected in all samples collected from Lincoln Creek and four samples collected from the Milwaukee River at a concentration of 0.1 μg/l. Tributyl phosphate was detected in two samples collected from Lincoln Creek and one sample from each

Milwaukee River station at a concentration of 0.1 μg/l. Vinyl chloride was detected in eight whole water samples collected from Lincoln Creek in 2001 and 2002 at concentrations ranging between 0.21 μg/l and 0.94 μg/l. Finally, the compound p-nonylphenol, a metabolite of nonionic detergents, was detected in two samples in Lincoln Creek and one sample each at Pioneer Road and Jones Island at concentrations ranging between 1.0 μg/l and 2.0 μg/l. This compound is known to be an endocrine disruptor.

Pharmaceuticals and Personal Care Products
During fall 2001, the Milwaukee River at Estabrook Park and Lincoln Creek at N. 47th Street were sampled for the presence of caffeine in water. In addition, in February, March, and May 2004, the USGS sampled water from three sites along the Milwaukee River—Pioneer Road, Estabrook Park, and Jones Island—and at N. 47th Street along Lincoln Creek for the presence of several compounds found in pharmaceuticals and personal care products. Caffeine, a stimulant found in beverages and analgesics, was detected in all of the samples collected from Lincoln Creek at concentrations ranging between 0.08 μg/l and 0.65 μg/l. It was detected in some samples from the Milwaukee River at concentrations ranging between 0.004 μg/l and 0.200 μg/l. N,N-diethyl-meta-toluamide (DEET), the active ingredient used in many insect repellants, was detected in most of the samples collected in Lincoln Creek and the Milwaukee River at concentrations ranging between 0.1 μg/l and 0.2 μg/l. Cotinine, a metabolite of nicotine, was detected in two samples from Lincoln Creek at concentrations of about 0.24 μg/l. It was not detected in samples from the Milwaukee River. Camphor, a fragrance and flavoring agent, was detected in samples from both Lincoln Creek and the Milwaukee River at a concentration of 0.1 μg/l. Menthol, another fragrance and flavoring agent, was detected in samples from Lincoln Creek at a concentration of 0.1 μg/l. Acetophenone, a fragrance used in soaps and detergents was detected in two samples from Lincoln Creek and two samples from the Milwaukee River at a concentration of 0.1 μg/l. Benzophenone, a fixative used in soaps and perfumes, was detected in all samples at concentrations ranging between 0.1 μg/l and 0.2 μg/l. Acetyl-hexamethyl-tetrahydro-naphthalene (AHTN), a synthetic musk fragrance, was detected in most samples at a concentration of 0.1 μg/l. Hexahydrohexamethylcyclopentabenzopyran (HHCB), another musk fragrance, was detected in samples from each site at a concentration of 0.1 μg/l. A final fragrance, d-limonene, was detected in one sample collected from Lincoln Creek at a concentration of 0.1 μg/l. Finally, triethyl citrate, a component of cosmetics, was detected at least once at each station at a concentration of 0.1 μg/l. The sources of these compounds to the Milwaukee River are not known. Given that no combined sewer overflows or separate sanitary sewer overflows were reported in the week before each of the 2001 samplings for caffeine, it is unlikely that sewer overflows are the source of this compound in Lincoln Creek and the Milwaukee River. Additional information on pharmaceuticals and personal care products, including general descriptions of possible sources of these pollutants, is set forth in Chapter II of this report.

Water Quality of Lakes and Ponds
The Milwaukee River watershed contains 20 lakes with a surface area of 50 acres or more, as well as numerous other named lakes and ponds with surface areas of less than 50 acres. These lakes are distributed within 12 subwatersheds: the Cedar Creek, Cedar Lake, East Branch Milwaukee River, Kettle Moraine Lake, Lake Fifteen Creek, Lower Cedar Creek, Lower Milwaukee River, Middle Milwaukee River, North Branch Milwaukee River, Silver Creek (Sheboygan County), Silver Creek (Washington County), and Watercress Creek subwatersheds. The major lake in the Cedar Creek subwatershed is Little Cedar Lake. The major lake in the Cedar Lake subwatershed is Big Cedar Lake. The three major lakes in the East Branch Milwaukee River subwatershed are Crooked, Forest, and Mauthe Lakes. The two major lakes in the Kettle Moraine Lake subwatershed are Kettle Moraine Lake and Mud Lake (Fond du Lac County). The major lake in the Lake Fifteen Creek subwatershed is Auburn Lake. The major lake in the Lower Cedar Creek subwatershed is Mud Lake (Ozaukee County). The major lake in the Lower Milwaukee River subwatershed is Lac du Cours. The two major lakes in the Middle Milwaukee subwatershed are Barton Pond and Smith Lake. The four major lakes in the North Branch subwatershed are Lake Ellen and Green, Twelve, and Wallace Lakes. The two major lakes in the Silver Creek (Sheboygan County) subwatershed are Random Lake and Spring Lake. The two major lakes in the Silver Creek (Washington County) subwatershed are Lucas Lake and Silver Lake. The major lake in the Watercress Creek subwatershed is Long Lake (Fond du Lac County). The physical characteristics of the lakes and ponds in the Milwaukee River watershed are given in Table 92.

Table 92

LAKES AND PONDS OF THE MILWAUKEE RIVER WATERSHED

Name	Area (acres)	Maximum Depth (feet)	Mean Depth (feet)	Lake Type	Public Access
Allis Lake	9	34	- -	Seepage lake	- -
Auburn Lake (Lake Fifteen)	107	29	14	Drainage lake	Walk in trail
Barton Pond	67	5	3	Drainage lake	Walk in trail
Batavia Pond	1	5	- -	Drainage lake	- -
Beechwood Lake	11	20	- -	Seepage lake	Boat ramp
Big Cedar Lake	932	105	34	Spring lake	Barrier free boat ramp
Birchwood Lake	31	- -	- -	- -	- -
Boltonville Pond	10	10	5	- -	- -
Brickyard Lake	1	4	- -	Seepage lake	- -
Brown Deer Park Pond	6	6	4	Drainage lake	- -[a]
Butler Lake	7	13	- -	Drainage lake	Boat Ramp
Buttermilk Lake	13	6	2	Seepage lake	Roadside
Butzke Lake	16	8	4	Drainage lake	Walk in trail
Cambellsport Millpond	22	10	4	Drainage lake	Walk in trail
Cascade Millpond	7	3	- -	Drainage lake	Walk in trail
Cedar Lake (Fond du Lac County)	19	19	9	Seepage lake	Walk in trail
Cedar Lake (Sheboygan County)	10	10	6	Seepage lake	Wilderness in public ownership
Cedarburg Pond	14	9	- -	Drainage lake	- -
Cedarburg Stone Quarry	6	10	- -	Seepage lake	- -
Chair Factory Millpond	6	7	- -	Drainage lake	- -
Columbia Pond	- -	- -	- -	- -	- -
Crooked Lake	91	32	12	Seepage lake	Barrier free boat ramp
Daly Lake	13	8	- -	Seepage lake	- -
Dickman Lake	9	12	7	Seepage lake	- -
Dineen Park Pond	2	5	- -	Drainage lake	- -[a]
Donut Lake	4	3	- -	Drainage lake	- -
Drzewiceki Lake	2	17	- -	Spring lake	- -
Ehne Lake	18	15	5	Spring lake	- -
Erler Lake	37	34	14	Spring lake	- -
Estabrook Park Lagoon	1	6	- -	Drainage lake	- -[a]
Forest Lake	51	32	11	Seepage lake	Walk in trail
Fromm Pit	4	28	- -	Spring lake	Navigable water
Gilbert Lake	44	30	3	Spring lake	Navigable water
Gooseville Millpond	38	7	- -	Drainage lake	- -
Gough Lake	5	29	- -	Seepage lake	- -
Grafton Millpond	25	8	- -	Drainage lake	Boat ramp
Green Lake	71	37	17	Seepage lake	Boat ramp
Haack Lake	16	18	7	Drainage lake	- -
Hamilton Pond[b]	6	18	- -	Seepage lake	- -
Hanneman Lake	6	18	- -	Seepage lake	- -
Hansen Lake	6	9	- -	Seepage lake	- -
Hasmer Lake	15	34	17	Drainage lake	Walk in trail
Hawthorn Lake	8	12	- -	Seepage lake	- -
Hawthorn Hills Pond	- -	- -	- -	- -	- -
Horn Lake	12	30	- -	Seepage lake	- -
Hurias Lake	26	7	- -	Seepage lake	- -
Juneau Park Lagoon	15	6	4	Drainage lake	- -[a]
Kelling Lakes #1	1	7	- -	Seepage lake	Wilderness in public ownership
Kelling Lakes #2	1	7	- -	Seepage lake	Wilderness in public ownership
Kelling Lakes #3	3	7	- -	Seepage lake	Wilderness in public ownership
Keowns Pond	1	15	- -	Drainage lake	- -
Kettle Moraine Lake	227	30	6	Seepage lake	Roadside
Kewaskum Millpond	5	8	- -	Drainage lake	Walk in trail
Lake Bernice	35	11	5	Drainage lake	Roadside
Lake Ellen	121	42	16	Drainage lake	Barrier free boat ramp
Lake Lenwood	15	38	19	Spring lake	- -
Lake Seven	27	25	12	Seepage lake	Barrier free boat ramp

Table 92 (continued)

Name	Area (acres)	Maximum Depth (feet)	Mean Depth (feet)	Lake Type	Public Access
Lake Sixteen	8	13	- -	Seepage lake	- -
Lake Twelve	53	20	6	Spring lake	- -
Lehner Lake	3	22	15	Spring lake	- -
Lent Lake	8	7	- -	Drainage lake	Navigable water
Lime Kiln Millpond	4	7	- -	Drainage lake	Walk in trail
Lincoln Park Lagoon	- -	- -	- -	- -	- -
Lindon Pond	2	15	- -	Spring lake	- -
Mauthe Lake	78	23	12	Drainage lake	Boat ramp, Barrier free pier
McGovern Park Pond	5	5	3	Drainage lake	- -[a]
Mee-Quon Park Pond	- -	- -	- -	- -	- -
Miller Lake	3	16	- -	Seepage lake	- -
Moldenhaur Lake	3	32	- -	Seepage lake	Walk in trail
Mud Lake (Ozaukee County)	245	4	3	Seepage lake	Wilderness in public ownership
Mud Lake (Fond du Lac County)	55	17	8	Drainage lake	- -
New Fane Millpond	5	5	3	Drainage lake	Navigable water
Newburg Pond	7	8	- -	Drainage lake	Walk in trail
Paradise Valley Lake	9	35	- -	Drainage lake	- -
Pit Lake	35	14	- -	Seepage lake	- -
Proschinger Lake	6	23	- -	Seepage lake	- -
Quaas Lake	7	12	- -	Spring lake	- -
Radke Lake	10	14	7	Seepage lake	- -
Random Lake	209	21	6	Drainage lake	Boat ramp
Roeckl Lake	3	12	- -	Seepage lake	- -
Ruck Pond	- -	- -	- -	- -	- -
Schwietzer Pond	8	4	- -	Drainage lake	- -
Senn Lake	16	8	6	Drainage lake	- -
Silver Lake	118	47	20	Drainage lake	- -
Smith Lake	86	5	3	Seepage lake	Boat ramp
Spring Lake (Fond du Lac County)	10	2	2	Seepage lake	- -
Spring Lake (Ozaukee County)	57	22	7	Seepage lake	- -
Spruce Lake	34	4	3	Seepage lake	Walk in trail
Thiensville Millpond	45	8	- -	Drainage lake	Boat ramp
Tily Lake	13	48	24	Spring lake	- -
Tittle Lake	17	26	- -	Drainage lake	Navigable water
Uihlein Pond	1	8	- -	Drainage lake	- -
Unnamed Lake (T11N R21E S17)	12	5	- -	- -	- -
Wallace Lake	52	35	11	Spring lake	Boat ramp
Washington Park Pond	11	5	3	Drainage lake	- -[a]
Wire and Nail Pond	- -	- -	- -	- -	- -
Zeunert Pond	- -	- -	- -	- -	- -

[a]*Private boats of any kind are not allowed on ponds in Milwaukee County Parks. Where available, commercial facilities provide boat liveries operated by the park.*

[b]*The dam at Hamilton Pond failed in 1996.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Rating of Trophic Condition

Lakes and ponds are commonly classified according to their degree of nutrient enrichment—or trophic status. The ability of lakes and ponds to support a variety of recreational activities and healthy fish and other aquatic life communities is often correlated with their degrees of nutrient enrichment. Three terms are generally used to describe the trophic status of a lake or pond: oligotrophic, mesotrophic, and eutrophic.

Oligotrophic lakes are nutrient-poor lakes and ponds. These lakes characteristically support relatively few aquatic plants and often do not contain very productive fisheries. Oligotrophic lakes and ponds may provide excellent opportunities for swimming, boating, and waterskiing. Because of the naturally fertile soils and the intensive land use activities, there are relatively few oligotrophic lakes in southeastern Wisconsin.

Mesotrophic lakes and ponds are moderately fertile lakes and ponds which may support abundant aquatic plant growths and productive fisheries. However, nuisance growths of algae and macrophytes are usually not exhibited by mesotrophic lakes and ponds. These lakes and ponds may provide opportunities for all types of recreational activities, including boating, swimming, fishing, and waterskiing. Many lakes and ponds in southeastern Wisconsin are mesotrophic.

Eutrophic lakes and ponds are nutrient-rich lakes and ponds. These lakes and ponds often exhibit excessive aquatic macrophyte growths and/or experience frequent algae blooms. If they are shallow, fish winterkills may be common. While portions of such lakes and ponds are not ideal for swimming and boating, eutrophic lakes and ponds may support very productive fisheries.

The Trophic State Index (TSI) assigns a numerical trophic condition rating based on Secchi-disc transparency, and total phosphorus and chlorophyll-*a* concentrations. The original Trophic State Index, developed by Carlson,[7] has been modified for Wisconsin lakes by the Wisconsin Department of Natural Resources using data on 184 lakes throughout the State.[8] The Wisconsin Trophic State Index (WTSI) ratings for Ellen, Forest, Green, and Wallace Lakes are shown in Figure 142 as a function of sampling date. Figure 143 shows the WTSI ratings for Big Cedar, Little Cedar, Long (Fond du Lac County), and Random Lakes as a function of sampling date.

Based on the Wisconsin Trophic State Index ratings shown, the eight lakes for which data were available may be classified as meso-eutrophic, although the Wisconsin Trophic State Index values ranged from oligotrophic to eutrophic during the periods of record. The data shown in Figures 142 and 143 suggest that the eight lakes behaved in a similar manner during the study period, although, for some of the lakes, the data are not sufficient to assess whether the trophic status of these lakes have changed over the study period. Nevertheless, viewed in their totality, it could be suggested that the eight lakes all behaved in a similar manner. Data on water clarity form the most complete data sets for all eight lakes, with Green, Big Cedar, Long (Fond du Lac County), and Random Lakes having data sets that encompassed all or most of the study period.

These data suggest an approximately decadal periodicity, with high WTSI values occurring during the mid-1980s, declining to lower values during the early 1990s, and returning to slightly high values toward the middle of the decade. This period repeated, with lower values being observed during the late 1990s. For a given lake, the significant degree of overlap among years, as shown in Figures 142 and 143, would suggest that these differences are not statistically significant. These same distribution patterns are reflected in the chlorophyll-*a* and total phosphorus concentration data, to the extent that they are available. Also, the pattern of periodicity is consistent among both larger and smaller lakes, those with a surface area of less than 200 acres and those with a surface area of greater than 200 acres. Green, Long (Fond du Lac County), and Big Cedar Lakes have the most complete records of the eight lakes for which data are presented.

Based on the Wisconsin Trophic State Index ratings shown, Ellen Lake may be classified as meso-eutrophic. The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 45 to about 55, or from mesotrophic to slightly eutrophic as would be consistent with a meso-eutrophic status. Available chlorophyll-*a* data and total phosphorus data are largely within the mesotrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 46 to 49 in the mid-1980s to about 47 in 1997, while the median WTSI values based upon total phosphorus concentrations range from about 41 to 47 during the mid-1980s to about 48 in 1997. The overlap of these annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

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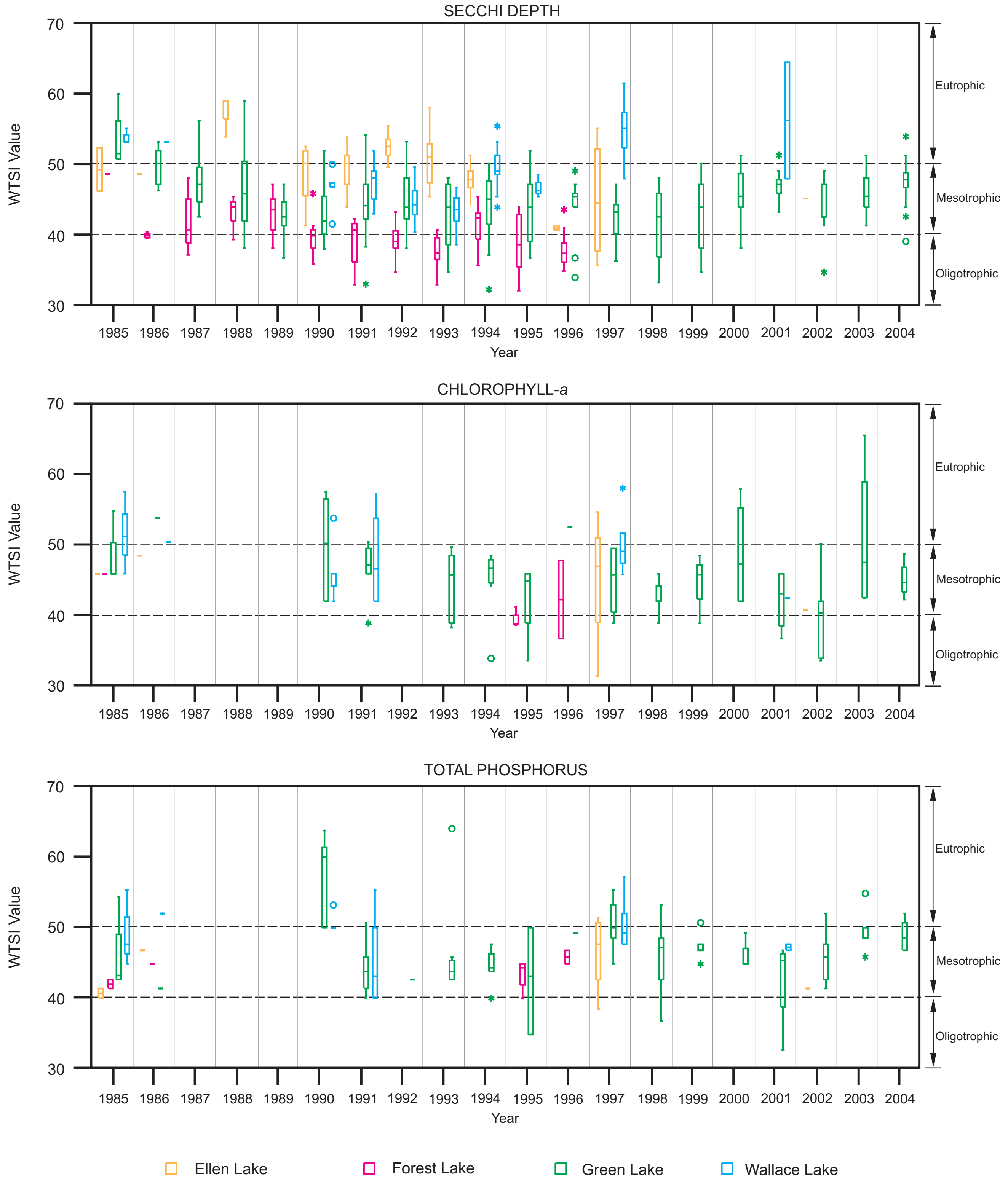
[7]*R.E. Carlson, "A Trophic State Index for Lakes,"* Limnology and Oceanography, *Vol. 22, No. 2, 1977*.

[8]*R.A. Lillie, S. Graham, and P. Rasmussen, "Trophic State Index Equations and Regional Predictive Equations for Wisconsin Lakes,"* Research and Management Findings*, Wisconsin Department of Natural Resources Publication No. PUBL-RS-735 93, May 1993.*

Figure 142

WISCONSIN TROPHIC STATE INDEX (WTSI) OF LAKES UNDER 200 ACRES IN THE MILWAUKEE RIVER WATERSHED: 1985-2004

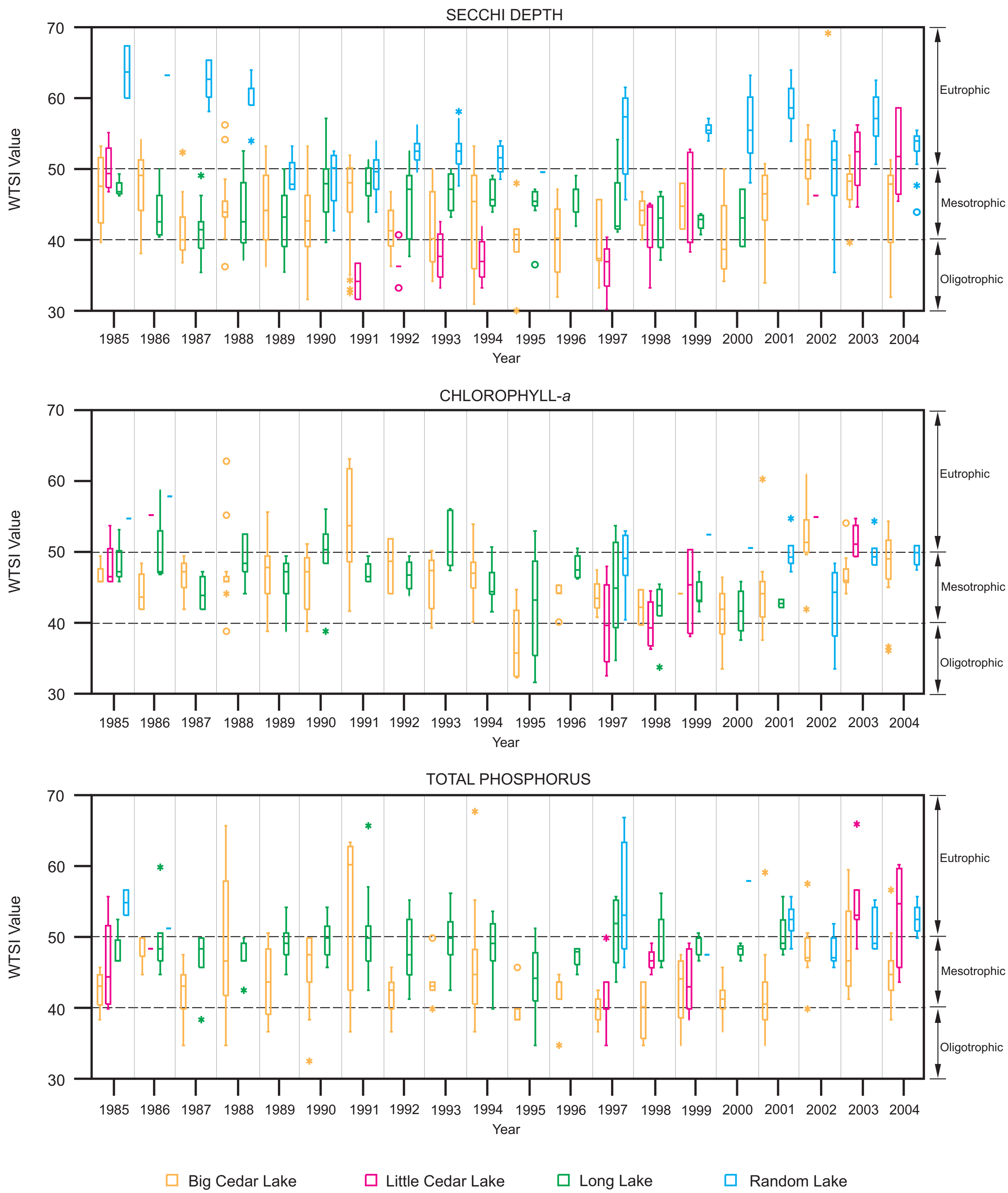


NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 143

WISCONSIN TROPHIC STATE INDEX (WTSI) OF LAKES OVER 200 ACRES IN THE MILWAUKEE RIVER WATERSHED: 1985-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Based on the Wisconsin Trophic State Index ratings shown, Forest Lake may be classified as oligo-mesotrophic. The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 37 to about 45, or from oligotrophic to moderately mesotrophic. Available chlorophyll-*a* data and total phosphorus data suggest that these values are largely within the mesotrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 46 in the mid-1980s to about 39 to 43 in 1995 and 1996. The median WTSI values based upon total phosphorus concentrations range from about 41 to 45 during the mid-1980s to about 45 and 46 in 1995 and 1996. The overlap of these annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

Based on the Wisconsin Trophic State Index ratings shown, Green Lake may be classified as mesotrophic. The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 42 to about 51, or from mesotrophic to slightly eutrophic as would be consistent with a mesotrophic status. Available chlorophyll-*a* data and total phosphorus data suggest that these values are largely within the mesotrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 40 in 2002 to about 50 in 1990, while the median WTSI values based upon total phosphorus concentrations range from about 43 during the mid-1980s to about 60 in 1990, although the majority of the total phosphorus-based WTSI values were at or below a value of 50.[9] The overlap of these annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

Based on the Wisconsin Trophic State Index ratings shown, Wallace Lake may be classified as meso-eutrophic. The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 44 in 1992 and 1993 to about 55 to 57 during 1997 and 2001, or from mesotrophic to moderately eutrophic. Available chlorophyll-*a* data and total phosphorus data suggest that these values are largely within the mesotrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 51 in the mid-1980s to about 46 in the early 1990s to about 49 in 1997. The median WTSI values based upon total phosphorus concentrations range from about 43 during 1991 to about 48 to 49 in 1985, 1997, and 2001. The overlap of these annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

Based on the Wisconsin Trophic State Index ratings shown, Big Cedar Lake may be classified as mesotrophic.[10] The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 38 to about 51, or from slightly oligotrophic to slightly eutrophic as would be consistent with a mesotrophic status. Available chlorophyll-*a* data and total phosphorus data suggest that these values are largely within the mesotrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 36 in the mid-1990s to about 53 in 1991, while the median WTSI values based upon total phosphorus concentrations range from about 40 during the mid-1990s to about 60 in 1991. The overlap of these annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

Based on the Wisconsin Trophic State Index ratings shown, Little Cedar Lake may be classified as meso-eutrophic.[11] The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 33 to about 52, or from oligotrophic to moderately mesotrophic. Available chlorophyll-*a* data and total

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[9]*The total phosphorus-based WTSI values reported during 1990 suggest that the Lake was eutrophic and high in total phosphorus; however, the corresponding Secchi disk and chlorophyll-a based WTSI values are inconsistent with this and suggest a mesotrophic classification.*

[10]*See also SEWRPC Memorandum Report No. 137,* A Water Quality Protection and Stormwater Management Plan for Big Cedar Lake, Washington County, Wisconsin*, Volume 1.* Inventory Findings, Water Quality Analyses, Recommended Management Measures*, August 2001.*

[11]*See also SEWRPC Memorandum Report No. 146,* An Aquatic Plant Management Plan for Little Cedar Lake, Washington County, Wisconsin*, May 2004.*

phosphorus data suggest that these values are largely within the mesotrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 40 in 1997 and 1998 to about 51 in 2003. The median WTSI values based upon total phosphorus concentrations range from about 40 during 1997 to about 54 and 55 in 2003 and 2004. The annual ranges set forth in Figure 143 suggest that any trends in WTSI ratings for this lake probably are the result of interannual variability, at least through the end of the 1990s, with consistently higher values being reported during the 2000s, which may be suggestive of a trend toward increasing trophic state during these more recent years.

Based on the Wisconsin Trophic State Index ratings shown, Long Lake (Fond du Lac County) may be classified as mesotrophic. The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 41 to about 48, consistent with a mesotrophic status. Available chlorophyll-*a* data and total phosphorus data suggest that these values are largely within the mesotrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 42 in the late-1990s to about 50 in the early 1990s, while the median WTSI values based upon total phosphorus concentrations range from about 44 during the mid-1990s to about 52 during the late-1990s. The overlap of these annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

Based on the Wisconsin Trophic State Index ratings shown, Random Lake may be classified as eutrophic. The annual median WTSI ratings based on Secchi depth have ranged over the study period from about 48 to about 65, or from meso-eutrophic to highly eutrophic. Available chlorophyll-*a* data and total phosphorus data suggest that these values are largely within the meso-eutrophic range. Median WTSI values based upon chlorophyll-*a* concentrations range from about 46 in 2002 to about 50 in 2004. The median WTSI values based upon total phosphorus concentrations range from about 47 during 2002 to between about 53 and 55 in 1985, 1997, 2001 and 2004. The overlap of these annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

Bacterial Parameters

No data on concentrations of fecal coliform bacteria were available for lakes within the Milwaukee River watershed. Some limited data on concentrations of *E. coli* were available for four lakes. During the period 1998-2004, the concentrations of *E. coli* in 22 samples from Big Cedar Lake ranged between 37 cells per 100 ml and 62 cells per 100 ml, with a mean of 48.7 cells per 100 ml. During the period 1998-2004, the concentrations of *E. coli* in 29 samples from Green Lake ranged between 35 cells per 100 ml and 66 cells per 100 ml, with a mean of 44.8 cells per 100 ml. During 2004, the concentrations of *E. coli* in 4 samples from Little Cedar Lake ranged between 51 cells per 100 ml and 61 cells per 100 ml, with a mean of 52.8 cells per 100 ml. During the period 2002-2004, the concentrations of *E. coli* in 13 samples from Green Lake ranged between 40 cells per 100 ml and 55 cells per 100 ml, with a mean of 49.2 cells per 100 ml. The USEPA requires that beaches be posted with warning signs informing the public of increased health risks when the concentration of *E. coli* exceeds 235 cells per 100 ml. All of the samples collected from these four lakes during the baseline period are below this threshold.

Chemical and Physical Parameters

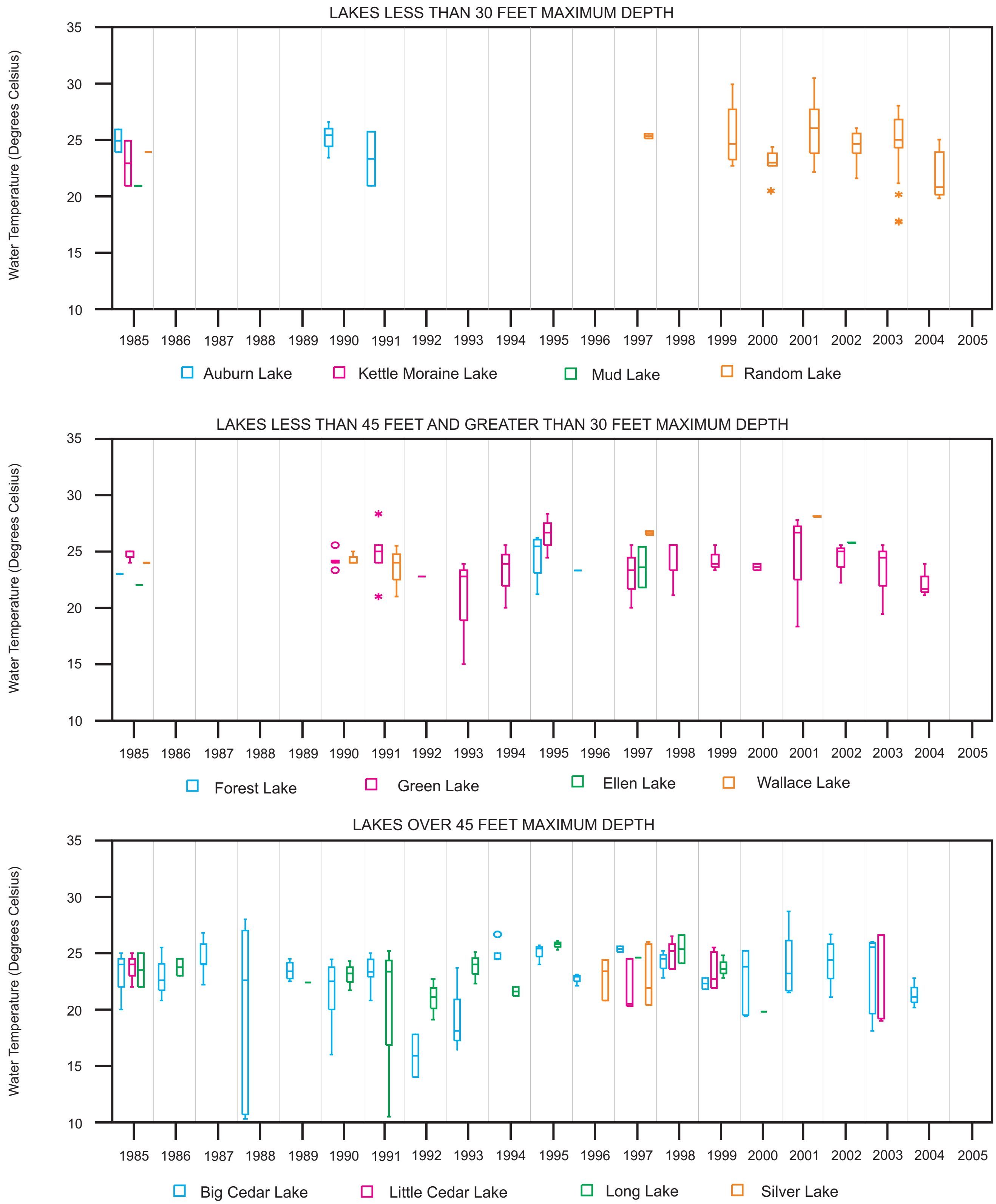
Data on water chemistry were available for twelve lakes in the Milwaukee River watershed: Auburn, Big Cedar, Ellen, Forest, Green, Kettle Moraine, Little Cedar, Long (Fond du Lac County), Mud (Fond du Lac County), Random, Silver, and Wallace Lakes.

Figures 144 and 145 show the summer surface and hypolimnetic water temperatures in the twelve lakes for which data are available for the years 1985 through 2004. Surface water temperatures represent those samples taken within three feet of the lake's surface. Hypolimnetic temperatures represent samples taken from depths below 15 feet from the lake's surface.

The temperature data indicate that the majority of lakes for which data are available thermally stratify during the summer months, with hypolimnetic water temperatures being about 5°C to 15°C below surface water temperatures on average. Lakes with a maximum depth of less than 35 feet typically have a lesser thermal

Figure 144

SURFACE WATER TEMPERATURES IN LAKES IN THE MILWAUKEE RIVER WATERSHED: 1985-2004

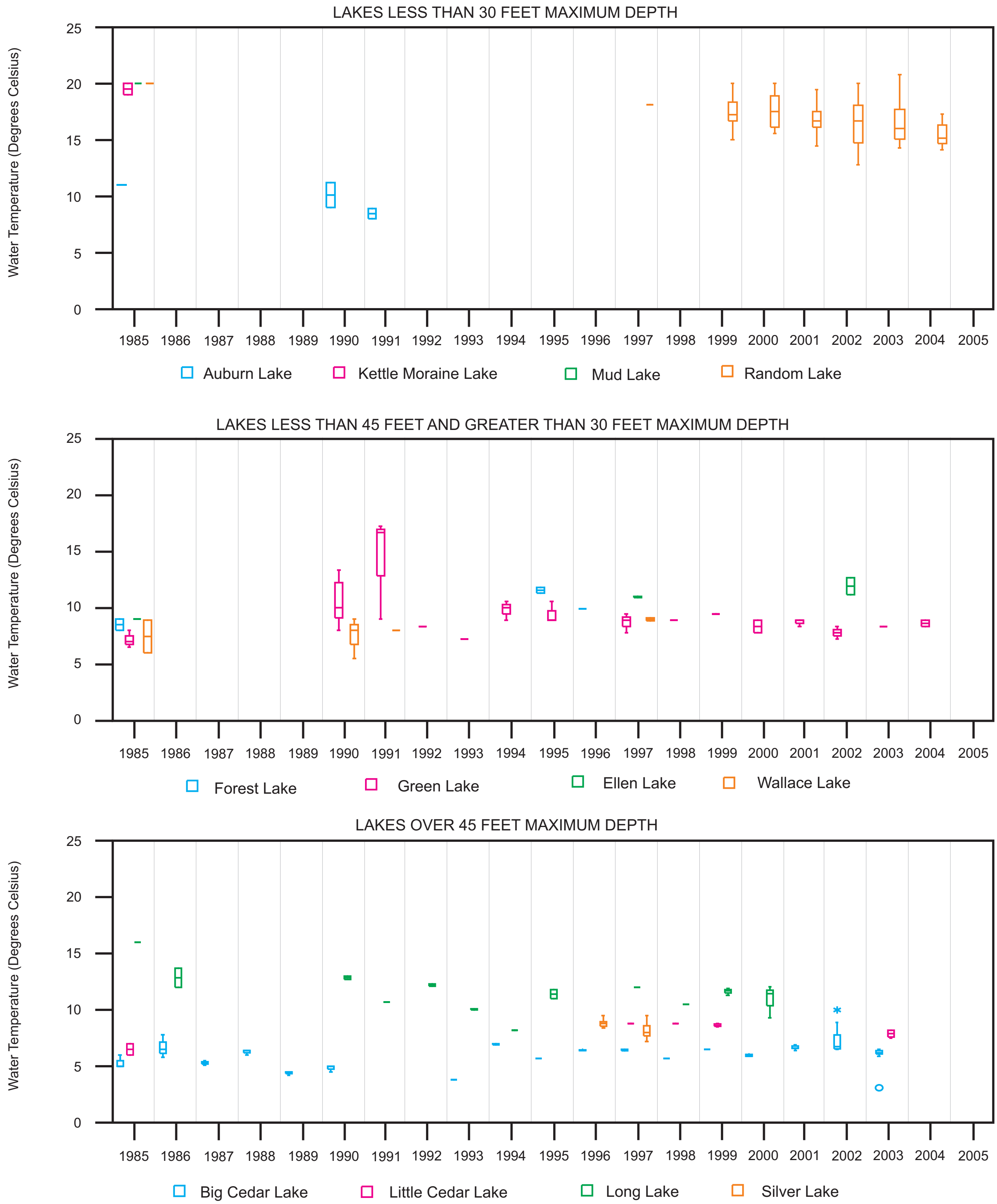


NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 145

DEEP (HYPOLIMNETIC) WATER TEMPERATURES IN LAKES IN THE MILWAUKEE RIVER WATERSHED: 1985-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

gradient than the deeper lakes. During thermal stratification, a layer of relatively warm water floats on top of a layer of cooler water. Thermal stratification is a result of the differential heating of the lake water, and the resulting water temperature-density relationships at various depths within the lake water column. Water is unique among liquids because it reaches its maximum density, or mass per unit of volume, at about 4°C. During stratification, the top layer, or epilimnion, of the waterbody is cut off from nutrient inputs from the sediment. At the same time, the bottom layer, or hypolimnion, is cut off from the atmosphere and sunlight penetration. Over the course of the summer, water chemistry conditions can become different between the layers of a stratified waterbody. In southeastern Wisconsin, the development of summer thermal stratification begins in late spring or early summer when surface waters begin to heat up, reaches its maximum in late summer, and disappears in the fall when surface waters cool.

Average surface water temperatures ranged between about 20°C and 30°C, with the warmer surface water temperatures being reported from the lakes with a maximum depth of less than 30 feet, as shown in Figure 144. The deeper water lakes, with maximum depths greater than 45 feet, tended to have slightly cooler surface water temperatures during the period of record, ranging between 20°C and 25°C, during most years. Likewise, average hypolimnetic water temperatures typically ranged between 10°C and 20°C in the shallower lakes with maximum depths of less than 30 feet, and between 5°C and 15°C in the deeper water lakes. These temperature differences were sufficient to set up stable stratification within these lakes during most years.

Variations in surface water temperatures can be discerned in the data for Big Cedar Lake, Green Lake, and Little Cedar Lake, shown in Figure 144, with a tendency toward a cyclical pattern of slightly warmer and slightly cooler water temperatures being observed. The early- to mid-1990s appeared to be a period of slightly cooler surface temperatures, while the late-1990s appeared to be slightly warmer. The early-2000s again appeared to be slightly cooler, suggesting an approximately decadal cycle corresponding to that indicated by the WTSI values. These surface water temperature variations were less pronounced than those observed in several major lakes outside of the Milwaukee River watershed in Waukesha County, where increases in surface water temperatures of up to 5°C to 10°C have been noted during this period.[12] Hypolimnetic water temperatures generally show less variation, especially since 1992.

Figures 146 and 147 show summer surface and hypolimnetic dissolved oxygen concentrations from the twelve lakes during the study period, from 1985 through 2004. During the summer, dissolved oxygen concentrations in the hypolimnia of the lakes tend to be substantially lower than dissolved oxygen concentrations at the surface. In the deeper lakes, with maximum depths of greater than 45 feet, the hypolimnia become anoxic during most summers. This is consistent with the characterization of these lakes as meso-eutrophic or eutrophic waterbodies. The lower oxygen concentration in the hypolimnion results from depletion of available oxygen through chemical oxidation and microbial degradation of organic material in water and sediment.

Hypolimnetic anoxia is common in many of the lakes in southeastern Wisconsin during summer stratification. The depleted oxygen levels in the hypolimnion cause fish to move upward, nearer to the surface of the lakes, where higher dissolved oxygen concentrations exist. This migration, when combined with temperature, can select against some fish species that prefer the cooler water temperatures that generally prevail in the lower portions of the lakes. When there is insufficient oxygen at these depths, these fish are susceptible to summer-kills, or, alternatively, are driven into the warmer water portions of the lake where their condition and competitive success may be severely impaired.

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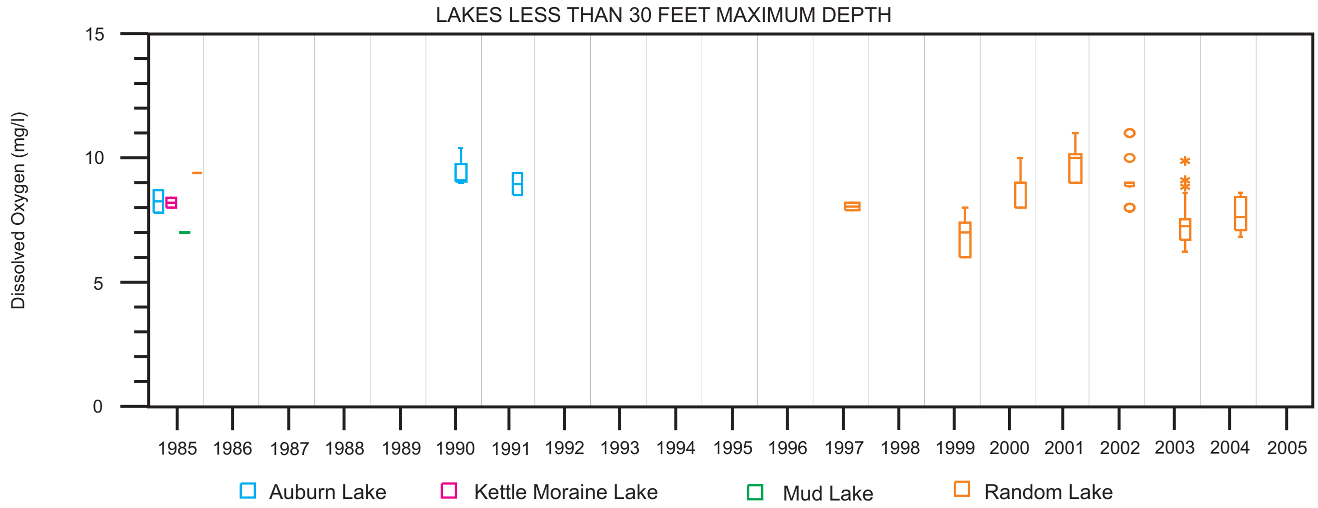
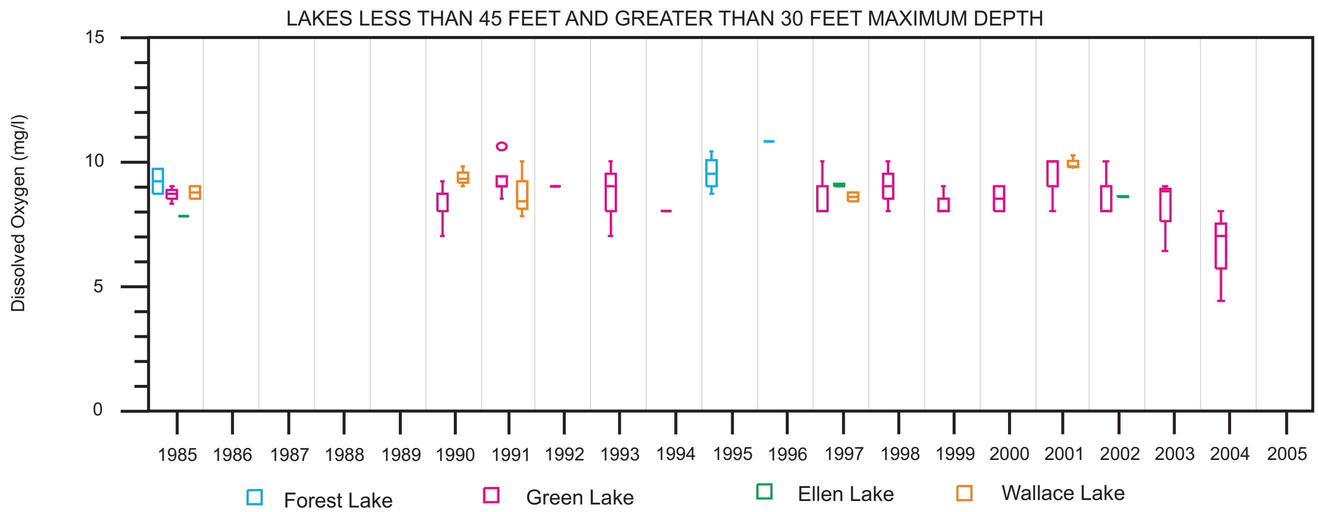
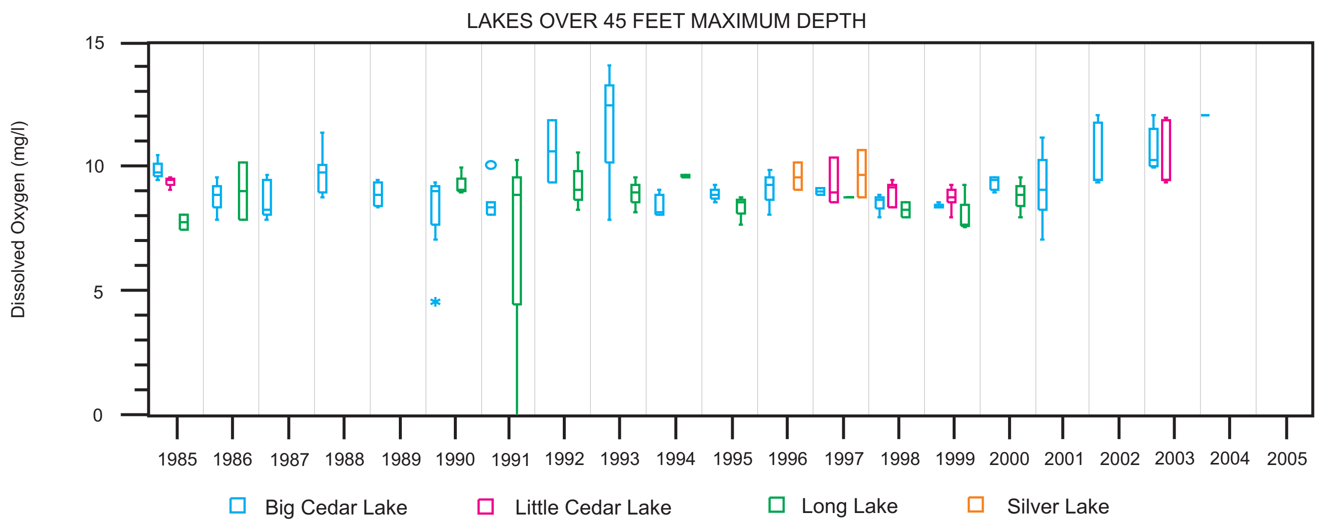
[12]*See, for example, SEWRPC Community Assistance Planning Report No. 58, 2nd Edition,* A Lake Management Plan for Pewaukee Lake, Waukesha County, Wisconsin*, May 2003; SEWRPC Community Assistance Planning Report No. 53, 2nd Edition,* A Lake Management Plan for Okauchee Lake, Waukesha County, Wisconsin*, December 2003; SEWRPC Community Assistance Planning Report No. 47, 2nd Edition,* A Lake Management Plan for Lac La Belle, Waukesha County, Wisconsin*, May 2007.*

Figure 146

SURFACE DISSOLVED OXYGEN IN LAKES IN THE MILWAUKEE RIVER WATERSHED: 1985-2004





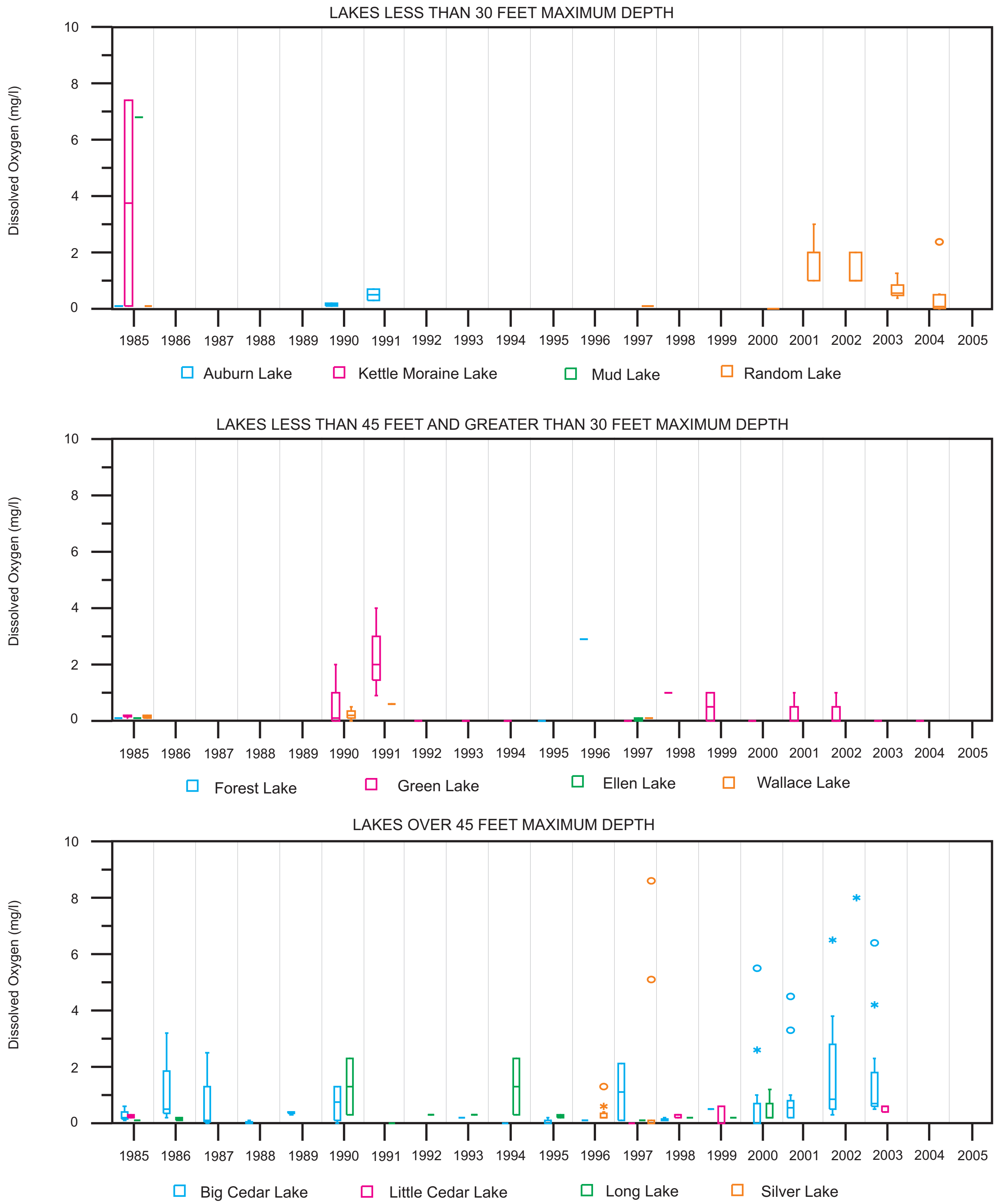


NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 147

DEEP (HYPOLIMNETIC) DISSOLVED OXYGEN IN LAKES IN THE MILWAUKEE RIVER WATERSHED: 1985-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

In addition to these biological consequences, the lack of dissolved oxygen at depth can enhance the development of chemoclines, or chemical gradients, with an inverse relationship to the dissolved oxygen concentration. For example, the sediment-water exchange of elements such as phosphorus, iron, and manganese is increased under anaerobic conditions, resulting in higher hypolimnetic concentrations in these elements. Under anaerobic conditions, iron and manganese change oxidation states enabling the release of phosphorus from the iron and manganese complexes to which they are bound under aerobic conditions. This "internal loading" can affect water quality significantly if these nutrients and salts are mixed into the epilimnion, especially during early summer when these nutrients can become available for algal and rooted aquatic plant growth.

Limited other water chemistry data were available for several of the lakes in the Milwaukee River watershed. Data for chloride are summarized in Figure 148. As has been noted in other lakes in southeastern Wisconsin, most lakes for which data were available in the Milwaukee River watershed show an increasing trend in chloride concentrations. This trend is most discernable in those lakes with longer term data sets. These trends suggest that most lakes within the watershed have increased chloride levels over the period of record. During the 1970s, Lillie and Mason reported chloride concentrations of between 5.0 and 10 milligrams per liter (mg/l) in Milwaukee River watershed lakes.[13] Since that time, concentrations in most lakes for which data are available have increased to between 20 and 50 mg/l. Sources of these chlorides include road salts applied to area roadways during the winter months, and water softener salts utilized in home water softeners year round. The relative proportions of these sources vary with proximity to major human settlements and road systems; however, geological sources of chloride in southeastern Wisconsin are few, leading to the conclusion that the rapid increase in chloride concentrations is of anthropogenic origin. Threshold concentrations for chloride, above which instream and in-lake biological impacts may be expected to be observed, are on the order of about 250 mg/l.[14] Consequently, while the lakes of the Milwaukee River watershed are well below this threshold, salination of these lakes may be considered as an emerging issue of concern.

TOXICITY CONDITIONS OF THE MILWAUKEE RIVER

Much, though not all, of the data on toxic contaminants in the Milwaukee River watershed is related to two sites with PCB-contaminated sediments: the Cedar Creek USEPA Superfund site and Estabrook Impoundment on the Milwaukee River.

The Cedar Creek Superfund site consists of the Mercury Marine Plant 2 on St. John Avenue, the Amcast Facility on Hamilton Road, and Zeunert Pond, all in the City of Cedarburg, and a 5.1 mile segment of Cedar Creek from below the Ruck Pond dam in the City of Cedarburg downstream to the confluence with the Milwaukee River in the Town of Grafton. PCBs from two sources have contaminated Cedar Creek. Mercury Marine, a boat engine manufacturer, operated a plant on St. John Avenue from 1951 to 1982. Fluids containing PCBs leaked from equipment in this plant and were washed into floor drains, which emptied into storm sewers. Those sewers emptied into Ruck Pond and ultimately flowed into the Milwaukee River. Amcast, an automotive industry supplier, operated an aluminum and magnesium die-cast plant on Hamilton Road that discharged PCBs into the Creek via storm sewers. One of those sewers emptied into Hamilton Pond, an impoundment on Cedar Creek. In 1996, as a result of heavy rains and high stream flow, the Hamilton dam failed and was removed. The pond was drained, leaving behind several acres of mud flats containing PCBs. Several remediation efforts have been undertaken at this site. In 1994, storm sewer lines near Ruck Pond were cleaned and sealed to reduce PCB movement. In 1994 and 1995, Mercury Marine removed about 7,700 cubic yards of contaminated sediment and soil from Ruck Pond. While this removed about 96 percent of the PCB mass from the pond, samples from residual

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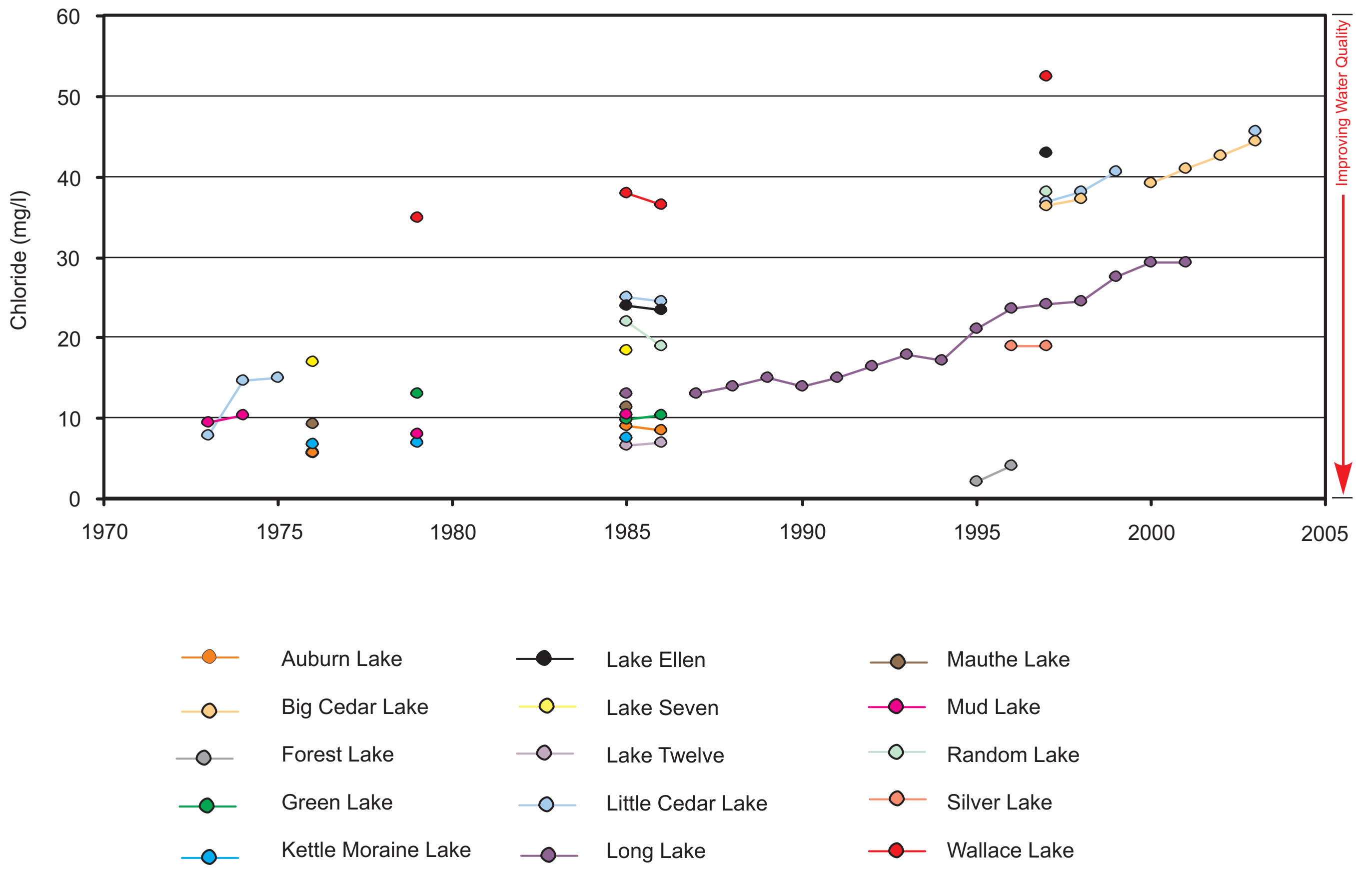
[13]*R.A. Lillie and J.W. Mason,* Limnological Characteristics of Wisconsin Lakes*, Wisconsin Department of Natural Resources Technical Bulletin No. 138, 1983.*

[14]*Fritz van der Leeden, Fred L. Troise, and David Keith Todd,* The Water Encyclopedia*, Lewis Publishers, 1990.*

Figure 148

CHLORIDE CONCENTRATIONS IN LAKES IN THE MILWAUKEE RIVER WATERSHED: 1973-2004



Source: *Wisconsin Department of Natural Resources and SEWRPC.*

sediment remaining in the pond exhibited an average PCB concentration of 76 mg/kg.[15] After the removal, the area was restored through bank reconstruction and landscaping. In 2000 and 2001, Mercury Marine removed about 14,000 tons of contaminated soils from the banks of the former Hamilton Pond. These banks were restored by backfilling, revegetation, and wetland construction. Mercury Marine has been conducting studies on PCBs in Cedar Creek and soil along the banks of Cedar Creek, and Amcast has been conducting studies on soil and ground water at its facility and sediment in Zeunert Pond.

Estabrook Impoundment is formed by the Estabrook dam on the Milwaukee River. This site contains about 100,000 cubic yards of sediment contaminated with about 5,200 kg of PCBs.[16] The site includes the western channel of the Milwaukee River, sections of the mainstem of the Milwaukee River from the confluence with the western channel downstream to Estabrook dam, and Lincoln Creek from Green Bay Road to the confluence with the Milwaukee River. A study of PCB transport in the Milwaukee River watershed estimated that, through resuspension of sediment and dissolution of PCBs stored in sediment, this impoundment increases annual mass

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[15]*Baird and Associates,* Final Report, Milwaukee PCB Mass Balance Project, *September 1997.*

[16]Ibid.

transport of PCBs in the Milwaukee River from about 5 kg to about 15 kg.[17] The source of the PCBs in this impoundment is not known; however, the mixture of PCB congeners found at this site contains a greater proportion of lighter, less chlorinated congeners than those found at sites along Cedar Creek or at upstream sites along the mainstem of the Milwaukee River, suggesting that these contaminants may have entered the watershed through Lincoln Creek.

Toxic Substances in Water

Pesticides

Since the 1970s, the Milwaukee River has been sampled for the presence of pesticides in water on several occasions. There have been four periods of sampling: 1975-1976, 1982, 1993-2002, and 2004. It is important to note that the results from the samples taken during 1993-2002 and 2004 are not directly comparable to those from the earlier periods. The data from the earlier periods were derived from unfiltered samples which included both pesticides dissolved in water and pesticides contained in and adsorbed to particulates suspended in the water. The data from 1993-2002 and 2004 were derived from filtered samples and measure only the fraction of pesticides dissolved in water. Since most pesticides are poorly soluble in water, the data from 1993-2002 and 2004 may underestimate ambient pesticide concentrations relative to the earlier data. During 1975 and 1976, water samples from six sites along the mainstem of the Milwaukee River in Milwaukee County were examined for the presence of the insecticides DDT, dieldrin, and lindane and for the DDT metabolites DDD and DDE. In all samples the concentrations of these substances were below the limit of detection. In 1982, three samples collected from the Milwaukee River at Estabrook Park were examined for presence of the herbicide atrazine. Atrazine was detected in all samples at a mean concentration of 0.33 μg/l. During the period 1993-2002, samples collected from the Milwaukee River at Estabrook Park were examined for the presence of several pesticides. The herbicide atrazine and its metabolite deethylatrazine were detected in all samples at mean concentrations of 0.10 μg/l and 0.03 μg/l, respectively. In addition, the atrazine metabolite deisopropylatrazine was detected in all samples that were screened for it. The mean concentration of this compound was 0.02 μg/l. The insecticides carbaryl and diazinon were frequently detected at mean concentrations of 0.014 μg/l and 0.010 μg/l, respectively. The insecticides dieldrin, lindane, and malathion and the DDT metabolite DDE were detected in a few samples at concentrations of 0.011 μg/l, 0.06 μg/l, 0.018 μg/l, and 0.014 μg/l, respectively. In 2004, samples were collected from the mainstem of the Milwaukee River at Pioneer Road, Estabrook Park, and Jones Island and examined for the presence of several pesticides. Atrazine and deethylatrazine were detected in all samples that were screened for these compounds at mean concentrations of 0.190 μg/l. and 0.055 μg/l, respectively. Carbaryl and diazinon were occasionally detected with mean concentrations of 0.008 μg/l and 0.007 μg/l, respectively. When they were detected in the Milwaukee River, the concentrations of atrazine and diazinon reported were below the USEPA draft aquatic life criteria. The USEPA has not promulgated criteria for the other pesticides that were detected.

Since the 1970s, Lincoln Creek has been sampled for the presence of pesticides in water on several occasions. There have been four periods of sampling: 1975, 1993-1994, 2001 and 2004. The results from the samples taken during 2001 and 2004 are not directly comparable to those from the earlier periods for the reasons given above. During 1975, water samples from three sites along Lincoln Creek were examined for the presence of the insecticides DDT, dieldrin, and lindane and for the DDT metabolites DDD and DDE. In all samples the concentrations of these substances were below the limit of detection. During the period 1993-1994, water samples were collected from Lincoln Creek at N. 47th Street and examined for the presence of several pesticides. Atrazine was occasionally detected with a mean concentration of 0.20 μg/l. The insecticide chlordane was detected in one sample at a concentration of 0.08 μg/l. In 2001, water samples collected from Lincoln Creek at N. 47th Street were examined for the presence of several pesticides. Atrazine was detected in most of the samples, with a mean concentration of 0.040 μg/l. Deethylatrazine was detected in all samples with a mean concentration of 0.016 μg/l. Diazinon was frequently detected and had a mean concentration of 0.203 μg/l. Carbaryl, deisopropylatrazine, and

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[17] *Jeffrey S. Steuer, Sharon A. Fitzgerald, and David W. Hall,* Distribution and Transport of Polychlorinated Biphenyls and Associated Particulates in the Milwaukee River System, Wisconsin, 1993-1995, *U.S. Geological Survey Water-Resources Investigations Report 99-4100, 1999.*

malathion were each detected in one sample at concentrations of 0.035 μg/l, 0.008 μg/l, and 0.127 μg/l, respectively. In 2004, water samples collected from Lincoln Creek at N. 47th Street were examined for the presence of several pesticides. Atrazine, carbaryl, deethylatrazine, and diazinon were each detected in one sample at concentrations of 0.148 μg/l, 0.004 μg/l, 0.046 μg/l, and 0.009 μg/l. When they were detected in Lincoln Creek, the concentrations of atrazine and diazinon reported were below the USEPA draft aquatic life criteria. The USEPA has not promulgated criteria for the other pesticides that were detected.

Relatively few data are available on concentrations of pesticides in water in other tributaries to the Milwaukee River. In 1993, samples were collected from Batavia Creek, Chambers Creek, Gooseville Creek, the Lake Ellen Outlet, Melius Creek, Nichols Creek, and the North Branch of the Milwaukee River and examined for the presence of atrazine and deethylatrazine. Both of these compounds were found in all of the samples. Concentrations of atrazine in these streams ranged between 0.07 μg/l and 0.043 μg/l, with a mean of 0.023 μg/l. Concentrations of deethylatrazine ranged between 0.011 μg/l and 0.041 μg/l, with a mean of 0.022 μg/l. During the period 1993-1994, the North Branch of the Milwaukee River was sampled extensively at a site near Random Lake for the presence of several pesticides. Atrazine and deethylatrazine were found in all samples with mean concentrations of 0.060 μg/l and 0.031 μg/l, respectively. Carbaryl, diazinon, and malathion were also occasionally detected. In 2001, additional sampling was conducted at this site. Atrazine and deethylatrazine were found in all samples with mean concentrations of 0.080 μg/l and 0.021 μg/l, respectively. The concentrations of atrazine and diazinon reported in tributary streams in the Milwaukee River watershed were below the USEPA draft aquatic life criteria. The USEPA has not promulgated criteria for the other pesticides that were detected.

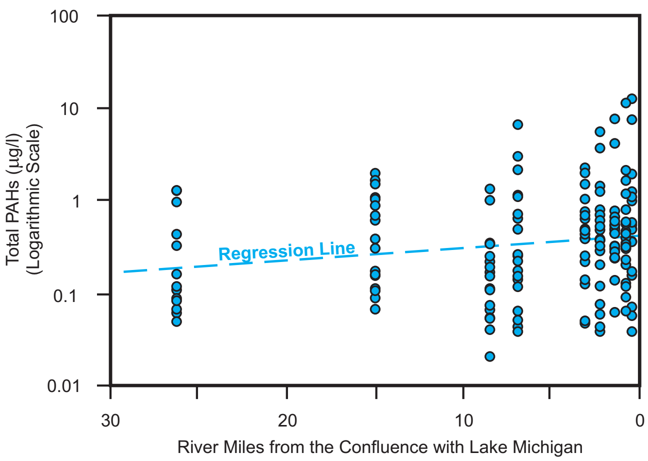
Polycyclic Aromatic Hydrocarbons (PAHs)

Between 1995 and 2001, MMSD conducted extensive sampling for 15 PAH compounds in unfiltered water at its nine long-term water quality sampling stations along the mainstem of the Milwaukee River. Measurable concentrations of PAHs were detected in about 85 percent of the samples. Concentrations of total PAHs in these samples ranged from below the limit of detection to 12.83 μg/l, with a mean concentration of 0.85 μg/l. The frequency at which PAHs were detected changed along the length of the River. At the farthest upstream MMSD station at Pioneer Road, PAHs were detected in about 60 percent of the samples. The frequency of detection increased from upstream to downstream, reaching 100 percent at the two stations farthest downstream, the stations at Water Street and the Union Pacific Railway. Figure 149 shows that while there was considerable variation in the concentrations of total PAHs detected among samples taken at individual sites on different dates, concentrations of total PAHs tended to increase from upstream to downstream. Regression analysis indicates that this represents a statistically significant trend which accounts for about 3 percent of the variation in the data. Some PAH compounds were more commonly detected in water from the Milwaukee River than other PAH compounds. The compounds fluoranthene, chrysene, pyrene, benzo(a)pyrene, benzo(b)fluoranthene, and phenanthrene were frequently detected. The compounds acenaphthalene, acenaphthene, fluorene, and anthracene were rarely detected. In 2004, the USGS sampled three sites along the mainstem of the River on three dates for six PAH compounds dissolved in water. At the Pioneer Road and Estabrook Park stations, dissolved PAHs were detected in one sample each at a concentration of 0.1 μg/l. At Jones Island, dissolved PAHs were detected in each sample with a mean concentration of 0.17 μg/l. It is important to note that the results from the samples taken in 2004 are not directly comparable to those from the earlier period. The samples collected in 2004 were screened for six compounds as opposed to the 15 compounds that were screened for in the earlier samples. In addition, the data from the earlier period were derived from unfiltered samples which included both PAHs dissolved in water and PAHs contained in and adsorbed to particulates suspended in the water. The data from 2004 were derived from filtered samples and measured only the fraction of PAHs dissolved in water. Since PAHs are poorly soluble in water and tend to adsorb to suspended material, the data from 2004 may underestimate ambient PAH concentrations relative to the earlier data.

Few tributary streams in the Milwaukee River watershed have been examined for the presence of PAHs in water. Between 1997 and 2001, MMSD conducted extensive sampling for 15 PAH compounds in unfiltered water at its five long-term water quality sampling stations along Lincoln Creek in the City of Milwaukee. In addition, during the period 1993-2001 the USGS and WDNR each conducted sampling in Lincoln Creek for 16 PAH compounds in unfiltered water at N. 47th Street. Measurable concentrations of PAHs were detected in about 80 percent of the

Figure 149

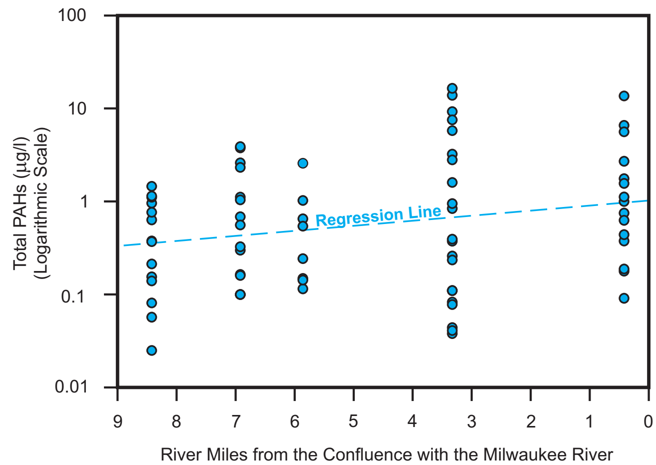
CONCENTRATIONS OF TOTAL PAHs IN WATER IN THE MILWAUKEE RIVER: 1995-2001



Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 150

CONCENTRATIONS OF TOTAL PAHs IN WATER IN LINCOLN CREEK: 1997-2001



Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

samples. Concentrations of total PAHs in these samples ranged from below the limit of detection to 40.16 μg/l, with a mean concentration of 2.68 μg/l. Figure 150 shows that while there was considerable variation in the concentrations of total PAHs detected among samples taken at individual sites on different dates, concentrations of total PAHs tended to increase from upstream to downstream. This did not represent a statistically significant trend. Some PAH compounds were more commonly detected in water from Lincoln Creek than other PAH compounds. The compounds fluoranthene, pyrene, benzo(b)fluoranthene, benzo(a)pyrene, and benz(a)anthracene were frequently detected. The compounds acenaphthalene, acenaphthene, fluorene, and anthracene were rarely detected. This pattern is very similar to the pattern observed in the mainstem of the Milwaukee River, suggesting that inputs of PAHs from Lincoln Creek may represent a major source of PAHs entering the River. In 1997, the USGS sampled Lincoln Creek at N. 47th Street on seven dates for 14 PAH compounds dissolved in water. Dissolved PAHs were detected in five of these samples. Concentrations of total dissolved PAHs in these samples ranged from below the limit of detection to 0.31 μg/l, with a mean concentration of 0.12 μg/l. In 2004, the USGS sampled Lincoln Creek at N. 47th Street on three dates for six PAH compounds dissolved in water. Dissolved PAHs were detected in each of these samples. Concentrations of total dissolved PAHs in these samples ranged from 0.10 μg/l to 0.70 μg/l, with a mean concentration of 0.43 μg/l. It is important to note that the results of the 1997 and 2004 samplings for dissolved PAHs are not directly comparable to the results from the samplings of Lincoln Creek for total PAHs for the reasons given above.

Between 1999 and 2001, MMSD sampled four locations along Southbranch Creek in the Village of Brown Deer for 15 PAH compounds in unfiltered water. PAHs were detected in about 56 percent of the samples. Concentrations of total PAHs in these samples ranged from below the limit of detection to 1.26 μg/l, with a mean concentration of 0.42 μg/l. During the period 1996-1997, the USGS conducted extensive sampling for 16 PAH compounds in unfiltered water samples collected from Parnell Creek in the headwaters of the East Branch of the Milwaukee River. Additional unfiltered water samples were collected from this stream in 2002 and examined for the presence of 17 PAH compounds. In all samples, concentrations of PAHs were below the limit of detection. No other data on the concentrations of PAHs in water were available for streams in the Milwaukee River watershed.

Polychlorinated Biphenyls (PCBs)

Between 1993 and 1995, the USGS collected samples at four sites along the mainstem of the Milwaukee River which were analyzed for the presence of polychlorinated biphenyls (PCBs) in water. These samples were divided by filtration into two portions: one portion consisting of PCBs dissolved in water and another portion consisting of PCBs associated with suspended sediment particles. These portions were analyzed on a congener-specific basis that examined 62 fractions representing 85 of the 209 individual PCB compounds.[18] Because only some congeners were analyzed, the results should be considered to represent minimum concentrations. In all of the samples collected, the sum of the PCB concentrations in the dissolved and suspended portions of the samples exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 nanograms per liter (ng/l). Table 93 summarizes congener-specific PCB data for the dissolved portion of the samples. Several trends are apparent in this summary. The number of PCB fractions detected, the number of potential congeners represented, and concentration of PCBs increased between the CTH T station and the Pioneer Road station. Increases in these quantities also occurred between the stations at STH 167 and Estabrook Park. Similar trends are apparent in the summary of the suspended sediment portion of the samples shown in Table 94. Higher average numbers of fractions and potential congeners and higher average concentrations of PCBs were detected in the suspended portion of the samples than in the dissolved portion (compare Tables 93 and 94). This reflects the facts that PCBs are poorly soluble in water and tend to adsorb to sediment particles. The congener composition of the samples was examined to estimate what proportion of each sample consisted of PCB congeners that are considered to be of greatest environmental concern due to toxicity. Toxicity was judged by the ability of the congeners to induce toxic effects through mechanisms similar to those involved in the toxicity of dioxins.[19] It is important to note that toxic effects unrelated to dioxin-like toxicity have been reported; however, less information is available on nondioxin-like PCB congeners and their toxicology is not well understood.[20] The results of this assessment are presented in Table 95. The data have several notable features. First, there was considerable variation among samples in the percentage of PCBs in the sample consisting of congeners considered to be of greatest environmental concern. Second, the portion of the PCB samples associated with suspended sediment contains a higher percentage of congeners considered to be of greatest environmental concern than the dissolved portion. This was the case at all four sites. Third, samples collected at the Pioneer Road and STH 167 stations contain a higher percentage of congeners considered to be of greatest environmental concern than samples collected at the CTH T and Estabrook Park stations. This may reflect contributions of PCBs to the Milwaukee River from Cedar Creek (see the *PCB Transport* section below).

Between 1995 and 2001, the MMSD long-term sampling stations along the mainstem of the Milwaukee River were sampled for the presence and concentrations of 14 PCB congeners in water. Since concentrations of only 14 out of 209 congeners were examined, the results of this sampling should be considered minimum values. While in the majority of samples, the concentrations of these PCB congeners were below the limit of detection, when PCBs were detected they exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 ng/l.

Three tributary streams in the Milwaukee River watershed have been examined for the presence and concentrations of PCBs in water: Cedar Creek, Lincoln Creek, and Southbranch Creek.

Between 1991 and 2001, the USGS collected samples at four sites along Cedar Creek which were analyzed for the presence of PCBs in water. These samples were divided into portions, and analyzed on a congener-specific basis using the same methods described above for the samples the USGS collected from the mainstem of the

[18]*In several cases, the analytical method used is not able to distinguish between two or more specific congeners.*

[19]*Victor A. McFarland and Joan U. Clarke, "Environmental Occurrence, Abundance, and Potential Toxicity of Polychlorinated Biphenyl Congeners: Considerations for a Congener-Specific Analysis,"* Environmental Health Perspectives, *Vol. 81, 1989; Stephen Safe, "Toxicology, Structure-Function Relationships, and Human and Environmental Impacts of Polychlorinated Biphenyls: Progress and Problems,"* Environmental Health Perspectives, *Vol. 100, 1992*

[20]*Tala R. Henry and Michael J. DeVito, "Non-dioxin-like PCBs: Effects and Consideration in Ecological Risk Assessment", U.S. Environmental Protection Agency Ecological Risk Assessment Support Center, June 2003.*

Table 93

DISSOLVED PCB CONGENERS IN THE MILWAUKEE RIVER: 1993-1995

Sample Site	Samples[a]	Fractions Detected			Potential Congeners Represented			Concentrations (nanograms per liter)		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
CTH T	5	2	22	12.2	3	35	19.6	0.09	1.86	0.94
Pioneer Road	27	11	50	27.3	16	70	40.4	0.54	17.97	3.36
STH 167	16	17	42	28.3	28	58	42.4	1.13	25.83	4.09
Estabrook Park	32	18	47	34.5	30	66	49.9	1.24	14.92	8.09

[a]*PCBs consist of a family of 209 related congener compounds. Samples were analyzed for 62 PCB fractions representing 85 individual PCB congeners. Results listed should be considered minimum values.*

Source: U.S. Environmental Protection Agency, U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

Table 94

PCB CONGENERS ASSOCIATED WITH SUSPENDED SEDIMENT IN THE MILWAUKEE RIVER: 1993-1995

Sample Site	Samples[a]	Fractions Detected			Potential Congeners Represented			Concentrations (nanograms per liter)		
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
CTH T	5	2	29	17.0	3	41	24.8	0.07	6.74	2.38
Pioneer Road	27	16	53	33.6	22	74	47.5	1.13	76.36	11.48
STH 167	16	19	49	37.9	25	69	53.8	1.06	23.88	9.31
Estabrook Park	32	26	58	51.3	36	81	72.3	1.47	101.37	23.45

[a]*PCBs consist of a family of 209 related congener compounds. Samples were analyzed for 62 PCB fractions representing 85 individual PCB congeners. Results listed should be considered minimum values.*

Source: U.S. Geological Survey and SEWRPC.

Table 95

PERCENT OF PCB MASS REPRESENTED BY CONGENERS OF GREATEST ENVIRONMENTAL CONCERN IN THE MILWAUKEE RIVER: 1994-1995[a]

Sample Site	Dissolved PCBs (percent[b])			PCBs Associated with Suspended Sediment (percent[b])		
	Minimum	Maximum	Average	Minimum	Maximum	Average
CTH T Grafton	0	32	10	11	57	34
Pioneer Road	7	27	18	36	50	42
STH 167	8	32	18	37	46	40
Estabrook Park	2	20	7	15	39	26

[a]*Congeners of greatest environmental concern are as described in Victor A. McFarland and Joan U. Clarke, "Environmental Occurrence, Abundance, and Potential Toxicity of Polychlorinated Biphenyl Congeners: Considerations for a Congener-Specific Analysis,"* Environmental Health Perspectives, *Vol. 81, 1989; Stephen Safe, "Toxicology, Structure-Function Relationships, and Human and Environmental Impacts of Polychlorinated Biphenyls: Progress and Problems,"* Environmental Health Perspectives, *Vol. 100, 1992.*

[b]*Percent by weight.*

Source: U.S. Environmental Protection Agency, U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

Milwaukee River. Because only some congeners were analyzed, the results should be considered to represent minimum concentrations. At two of the sites, samples were collected during three periods: 1990-1991, 1994-1995, and 2000-2001. In all but one of the samples collected, the sum of the PCB concentrations in the dissolved and suspended portions of the samples exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 nanograms per liter (ng/l).

Table 96 summarizes congener-specific PCB data for the dissolved portion of the samples. Several trends are apparent in this summary. During the 1990-1991 sampling, the number of PCB fractions detected, the number of potential congeners represented, and concentration of PCBs increased between the stations at Columbia Road and below Wire and Nail Pond. Concentrations then decreased between the stations at Wire and Nail Pond and Green Bay Road. At the Columbia Road and Highland Road sites, the number of PCB fractions detected, the number of potential congeners represented, and concentration of PCBs in the samples collected during 2000-2001 were considerably lower than those in the samples collected during the previous two periods. This reflects the effects of the remediation efforts in and around Ruck Pond.

Similar trends are apparent in the summary of the suspended sediment portion of the samples shown in Table 97. Higher average numbers of fractions and potential congeners and higher average concentrations of PCBs were detected in the suspended portion of the samples than in the dissolved portion (compare Tables 96 and 97). This reflects the facts that PCBs are poorly soluble in water and tend to adsorb to sediment particles.

The congener composition of the samples was examined to estimate what proportion of each sample consisted of PCB congeners that are considered to be of greatest environmental concern due to toxicity using the approach described above. The results of this assessment are presented in Table 98. The data have several notable features. First, there was considerable variation among samples in the percentage of PCBs in the sample consisting of congeners considered to be of greatest environmental concern. Second, the portion of the PCB samples associated with suspended sediment contains a higher percentage of congeners considered to be of greatest environmental concern than the dissolved portion. This was the case at all four sites. Third, in samples collected at the Columbia Road site, the percentage of PCBs in the sample consisting of congeners considered to be of greatest environmental concern appears to be lower in the samples collected during 2000-2001 than the percentage in samples collected during the previous two periods. This may be a result of the remediation efforts in and around Ruck Pond. It does not appear that this change has occurred at the Highland Road site.

Between 1997 and 2001, the MMSD long-term sampling stations along Lincoln Creek were sampled for the presence and concentrations of 14 PCB congeners in water. Since concentrations of only 14 out of 209 congeners were examined, the results of this sampling should be considered minimum values. While in the majority of samples, the concentrations of these PCB congeners were below the limit of detection, when PCBs were detected they exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 ng/l.

Between 1999 and 2001, the MMSD long-term sampling stations along Southbranch Creek were sampled for the presence and concentrations of 14 PCB congeners in water. Since concentrations of only 14 out of 209 congeners were examined, the results of this sampling should be considered minimum values. None of the 14 congeners sampled for were detected in any of these samples.

PCB Transport

During the period 1993-1995, the USGS studied the transport of PCBs in Cedar Creek and the Milwaukee River.[21] This study found that dissolved phase PCB congener distributions in water showed higher abundances of lighter, more soluble, less chlorinated congeners than PCB congener distributions in suspended particles or surface sediments. In addition, concentrations of PCBs associated with suspended particles increased with algal growth during spring and summer and with episodic resuspension of bed sediments during storms. Estimated

[21]Ibid.

Table 96

DISSOLVED PCB CONGENERS IN CEDAR CREEK: 1990-2001

Sample Site	Period	Samples[a]	Fractions Detected			Potential Congeners Represented			Concentrations (nanograms per liter)		
			Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Columbia Road	1990-1991	12	7	40	23.7	10	56	33.7	0.53	16.90	4.67
	1994-1995	11	9	51	25.5	13	74	38.1	0.67	17.06	4.73
	2000-2001	8	1	33	15.3	1	47	21.0	0.05	2.37	0.93
	Total	31	1	51	22.2	1	74	31.7	0.05	17.06	3.72
Highland Road	1990-1991	13	19	57	38.9	28	80	55.7	2.40	50.82	16.83
	1994-1995	13	19	59	36.7	27	82	61.4	1.13	48.74	22.39
	2000-2001	14	3	53	28.3	3	74	39.2	0.11	9.71	3.04
	Total	40	3	59	36.7	3	82	51.8	0.11	50.82	13.81
Below Wire and Nail Pond	1991	7	25	56	46.3	39	79	68.0	4.28	40.71	25.31
Green Bay Road	1990-1991	13	24	52	40.4	38	73	57.7	4.07	24.12	12.66

[a]*PCBs consist of a family of 209 related congener compounds. Samples were analyzed for 62 PCB fractions representing 85 individual PCB congeners. Results listed should be considered minimum values.*

Source: U.S. Geological Survey and SEWRPC.

Table 97

PCB CONGENERS ASSOCIATED WITH SUSPENDED SEDIMENT IN CEDAR CREEK: 1990-2001

Sample Site	Period	Samples[a]	Fractions Detected			Potential Congeners Represented			Concentrations (nanograms per liter)		
			Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Columbia Road	1990-1991	11	4	52	34.6	6	72	48.9	0.27	75.31	17.73
	1994-1995	11	18	44	28.8	25	64	38.8	1.54	44.83	12.07
	2000-2001	8	0	37	23.5	0	50	32.3	0.00	1.73	0.82
	Total	30	0	52	29.5	0	72	41.4	0.00	75.31	11.15
Highland Road	1990-1991	12	29	58	45.4	41	81	64.3	6.16	167.74	50.86
	1994-1995	13	23	57	47.5	33	79	66.7	1.91	288.93	84.06
	2000-2001	14	12	53	38.6	16	74	53.9	0.26	31.49	12.00
	Total	39	12	58	43.7	16	81	61.4	0.26	288.93	47.98
Below Wire and Nail Pond	1991	7	44	57	50.6	61	80	71.7	24.21	126.27	74.92
Green Bay Road	1990-1991	13	32	57	47.5	45	80	66.8	8.47	113.00	44.04

[a]*PCBs consist of a family of 209 related congener compounds. Samples were analyzed for 62 PCB fractions representing 85 individual PCB congeners. Results listed should be considered minimum values.*

Source: U.S. Geological Survey and SEWRPC.

daily loads of PCBs at two sites along Cedar Creek and four sites along the Milwaukee River are given in Table 99. The estimated loads of PCBs in the Milwaukee River increase sharply between CTH T and Pioneer Road. Given that the confluence with Cedar Creek is between these two stations, it suggests that Cedar Creek is a major source of dissolved and suspended PCBs to the Milwaukee River. The daily PCB loads at Highland Road on Cedar Creek suggest that during 1993-1995, Cedar Creek contributed between 0.1 and 7.3 kg per year of PCBs to the Milwaukee River. These estimates are consistent with the results of the Cedar Creek Mass Balance Study, which concluded that Cedar Creek transported between 4 and 38 kg of PCBs per year to the Milwaukee River.[22] The USGS study also concluded that Estabrook Impoundment increases annual mass transport of PCBs in the Milwaukee River from about 5 kg to about 15 kg and that some PCB deposition may have occurred between the Highland Road and Pioneer Road sites, possibly in the impoundments of lower Cedar Creek.[23]

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[22]*S. Westenbroek,* Cedar Creek Polychlorinated Biphenyls Mass Balance, Phase I – Data Summary and Analysis, Final Draft, *Wisconsin Department of Natural Resources, 1993.*

[23]*Steuer,* et al.*, 1999,* op cit.

Table 98

PERCENT OF PCB MASS REPRESENTED BY CONGENERS OF GREATEST ENVIRONMENTAL CONCERN IN CEDAR CREEK: 1990-2001[a]

Sample Site	Period	Dissolved PCBs (percent[b])			PCBs Associated with Suspended Sediment (percent[b])		
		Minimum	Maximum	Average	Minimum	Maximum	Average
Columbia Road	1990-1991	5	24	13	33	59	39
	1994-1995	9	23	16	37	52	44
	2000-2001	0	13	6	26	36	32
	Total	0	24	12	26	59	39
Highland Road	1990-1991	10	21	15	36	39	37
	1994-1995	15	24	19	35	51	38
	2000-2001	0	28	14	32	48	35
	Total	0	28	16	32	51	37
Below Wire and Nail Pond	1991	10	21	16	36	39	38
Green Bay Road	1990-1991	9	21	17	33	39	37

[a]*Congeners of greatest environmental concern are as described in Victor A. McFarland and Joan U. Clarke, "Environmental Occurrence, Abundance, and Potential Toxicity of Polychlorinated Biphenyl Congeners: Considerations for a Congener-Specific Analysis,"* Environmental Health Perspectives, *Vol. 81, 1989; Stephen Safe, "Toxicology, Structure-Function Relationships, and Human and Environmental Impacts of Polychlorinated Biphenyls: Progress and Problems,"* Environmental Health Perspectives, *Vol. 100, 1992.*

[b]*Percent by weight.*

Source: U.S. Environmental Protection Agency, U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

Table 99

ESTIMATED LOADS OF PCBs TRANSPORTED IN THE MILWAUKEE RIVER WATERSHED: 1993-1995

Stream	PCB Loads (g/day)				Percent of Load Associated with Particulates	Samples
	Minimum	Maximum	Median	Mean		
Cedar Creek						
Columbia Avenue	0.2	2.8	1.5	1.3	36.7	11
Highland Road	0.3	20.2	6.5	9.4	67.1	13
Milwaukee River						
CTH T	0.2	3.9	0.8	1.3	55.3	5
Pioneer Road	0.6	105.9	4.8	20.1	61.0	26
Thiensville	2.6	208.6	9.6	25.0	74.7	16
Estabrook Park	1.1	221.1	26.1	51.4	64.1	31

Source: U.S. Geological Survey and SEWRPC.

Toxic Contaminants in Aquatic Organisms

The WDNR periodically surveys tissue from fish and other aquatic organisms for the presence of toxic and hazardous contaminants. Several surveys were conducted at sites within the Milwaukee River watershed between 1977 and 2002. These surveys screened for the presence and concentrations of several contaminants including metals, PCBs, and organochloride pesticides. Because of potential risks posed to humans by consumption of fish containing high levels of contaminants, the WDNR has issued fish consumption advisories for several species of fish taken from the Milwaukee River. The statewide fish consumption advisory for mercury applies to fish in the Milwaukee River watershed. In addition, special consumption advice has been issued for several species taken from portions of the Milwaukee River and from Cedar Creek, Lincoln Creek, and Zeunert Pond due to tissue concentrations of PCBs (see Table 100).

Table 100

FISH CONSUMPTION ADVISORIES FOR THE MILWAUKEE RIVER WATERSHED[a]

Species	Consumption Advisory Level			
	One Meal per Week	One Meal per Month	One Meal per Two Months	Do Not Eat
Cedar Creek from the Milwaukee River to Bridge Road in Cedarburg				
All Species	- -	- -	- -	All sizes
Lincoln Creek				
Black Crappie	- -	- -	All sizes	- -
Carp	- -	- -	- -	All sizes
Northern Pike	- -	- -	All sizes	- -
Redhorse	- -	- -	All sizes	- -
Rock Bass	- -	All sizes	- -	- -
Smallmouth Bass	- -	- -	All sizes	- -
Walleyed Pike	- -	Less than 18 inches	Larger than 18 inches	- -
White Sucker	- -	- -	All sizes	- -
Yellow Perch	All sizes	- -	- -	- -
Milwaukee River Up to the First Dam				
Chubs	- -	All sizes	- -	- -
Chinook Salmon	- -	Less than 32 inches	Larger than 32 inches	- -
Coho Salmon	- -	All sizes	- -	- -
Brown Trout	- -	Less than 22 inches	Larger than 22 inches	- -
Lake Trout	- -	Less than 23 inches	23-27 inches	Larger than 27 inches
Rainbow Trout	Less than 22 inches	Larger than 22 inches	- -	- -
Smelt	All sizes	- -	- -	- -
Whitefish	- -	All sizes	- -	- -
Yellow Perch	All sizes	- -	- -	- -
Milwaukee River Estuary to Estabrook Falls				
Black Crappie	- -	- -	All sizes	- -
Carp	- -	- -	- -	All sizes
Northern Pike	- -	- -	All sizes	- -
Redhorse	- -	- -	All sizes	- -
Rock Bass	- -	All sizes	- -	- -
Smallmouth Bass	- -	- -	All sizes	- -
Walleyed Pike	- -	Less than 18 inches	Larger than 18 inches	- -
White Sucker	- -	- -	All sizes	- -
Yellow Perch	All sizes	- -	- -	- -
Milwaukee River above Estabrook Falls to Grafton				
Black Crappie	- -	- -	All sizes	- -
Carp	- -	- -	- -	All sizes
Largemouth Bass	- -	All sizes	- -	- -
Northern Pike	- -	- -	All sizes	- -
Redhorse	- -	All sizes	- -	- -
Rock Bass	- -	All sizes	- -	- -
Smallmouth Bass	- -	All sizes	- -	- -
Milwaukee River above Grafton				
Carp	- -	- -	- -	All sizes
Zeunert Pond in Cedarburg				
All Species	- -	- -	- -	All sizes

[a]*The statewide general fish consumption advisory applies to other fish species not listed in this table.*

Source: Wisconsin Department of Natural Resources.

It is important to note that some samples collected from the Milwaukee River consisted of whole organism homogenates while other consisted of fillets of skin and muscle tissue. These types of samples are not directly comparable. Consumption advisories are based on fillet samples. In both types of samples, a single sample may represent tissue from several fish of the same species.

It is also important to note that dams fragment the Milwaukee River fishery by preventing both upstream and downstream migration of fishes to and from Lake Michigan as well as from the mainstem of the Milwaukee River to tributary streams and between reaches of the mainstem of the Milwaukee River. Because of the limits on fish migration imposed by dams, the body burdens of some toxic substances found in aquatic organisms, especially those substances that are poorly soluble in water, may differ substantially among different portions of the watershed. In general, organisms inhabiting those reaches of the River that contain legacy deposits of toxic substances in the sediment may be expected to have high body burdens of the toxic substances, while organisms inhabiting reaches that are upstream from any legacy sediment deposits may be expected to have lower body burdens.

To reflect these factors, the presence and concentrations of toxic contaminants in aquatic organisms was analyzed within the framework of the fragmentation of the fishery imposed by the presence of dams and drop structures. Map 53 shows the extent of the fragmentation of reaches from downstream to upstream within the Milwaukee River watershed as defined by the location of dams and drop structures. As shown on Map 53, some reaches are very short, such as Reaches 4a and 5, while some reaches are much longer. In addition, some reaches have no tributary streams, such as Reaches 4d and 6c. In contrast, other reaches are both extensive and well connected to many tributary streams, such as Reaches 6 and 10.

Mercury

Between 1978 and 2002 the WDNR sampled tissue from fish and other aquatic organisms collected from the Milwaukee River watershed for mercury contamination. Figures 151 and 152 show concentrations of mercury in the tissue of aquatic organisms in fillet samples and whole organism samples, respectively, from stream reaches defined by the location of dams and drop structures. Tissue concentrations of mercury in fillet samples in organisms collected from the watershed ranged from below the limit of detection to 1.2 micrograms per gram tissue (μg per g tissue) (see Figure 151). Average tissue concentrations of mercury in fillet samples ranged from 0.14 μg per g tissue in Reach 4b along Cedar Creek to 0.38 μg per g tissue in Reach 9a along the East Branch Milwaukee River. It is important to note that Reach 9a includes Mauthe Lake, and that this average largely reflects tissue concentrations of mercury in fish collected from this lake. Tissue concentrations of mercury in whole organism samples collected from the watershed ranged from below the limit of detection to 0.28 μg per g tissue (see Figure 152). Average tissue concentrations of mercury in whole organism samples ranged from 0.03 μg per g tissue in Reach 2 along the mainstem of the Milwaukee River and Lincoln Creek to 0.20 μg per g tissue in Reach 7 along the mainstem of the Milwaukee River between Newburg and West Bend. The highest tissue concentrations tended to be detected in fillet samples. This reflects the fact that mercury tends to accumulate in muscle tissue in fish. Figure 153 shows tissue concentrations of mercury from fillet samples of fish collected from several lakes in the Milwaukee River watershed. Tissue concentrations of mercury in fillet samples from fish collected from lakes ranged between 0.04 μg per g tissue and 1.10 μg per g tissue. The average tissue concentration of mercury in fillet samples from fish collected from lakes in the watershed was 0.40 μg per g tissue. Within lake averages ranged between 0.23 μg per g tissue in Kettle Moraine Lake and 0.58 μg per g tissue in Big Cedar Lake. Tissue concentrations of mercury tended to be higher in gamefish than in panfish, but this is based upon a small number of samples.

The statewide consumption advisory for mercury applies to fish from the Milwaukee River watershed. In addition, Forest Lake, Long Lake, and Mauthe Lake are considered impaired due to fish consumption advisories related to atmospheric deposition of mercury.

It is important to recognize that the number of individual organisms and the range of species taken from this watershed that have been screened for the presence of mercury contamination are quite small. Because of this, these data may not be completely representative of current body burdens of mercury carried by aquatic organisms in the River and its tributaries.

PCBs

Between 1977 and 2002 the WDNR examined fillet and whole organism samples from several species of fish collected from the Milwaukee River watershed for PCB contamination. Over this time period, tissue concentrations

Map 53

STREAM REACHES SEPARATED BY DAMS AND DROP STRUCTURES WITHIN THE MILWAUKEE RIVER WATERSHED: 2004

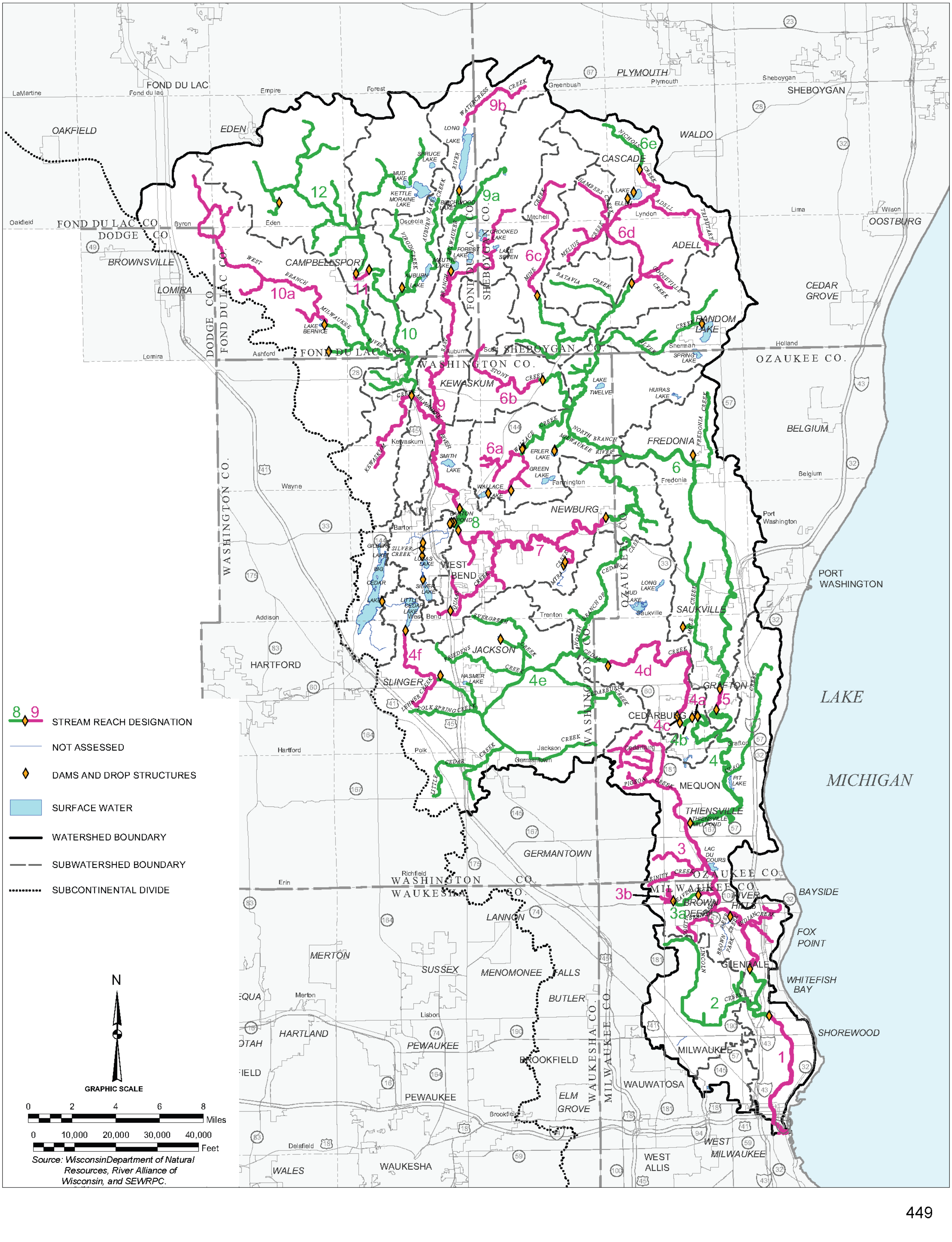
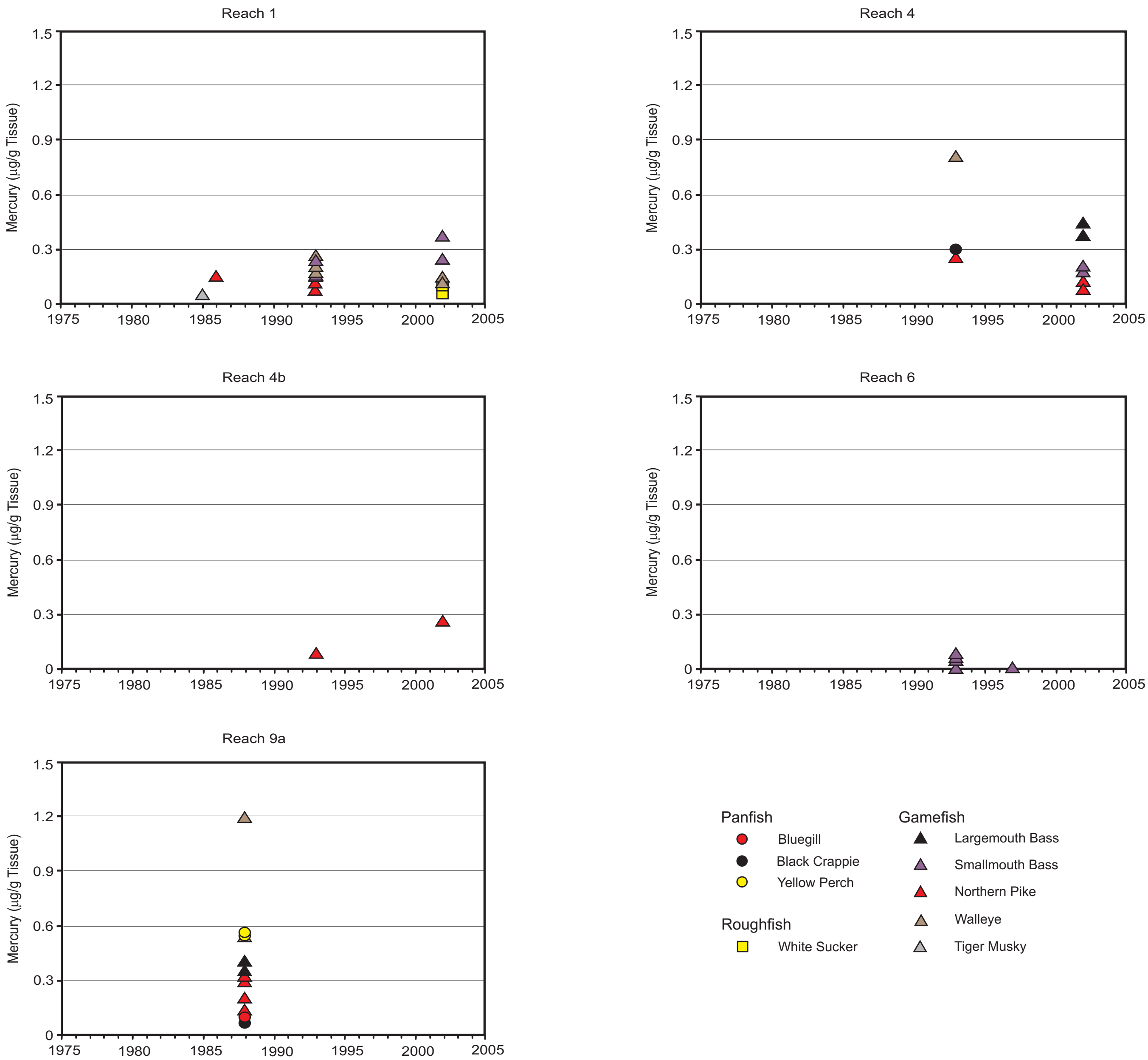


Figure 151

TISSUE CONCENTRATIONS OF MERCURY IN FILLETS FROM FISH SAMPLES COLLECTED FROM STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1977-2002



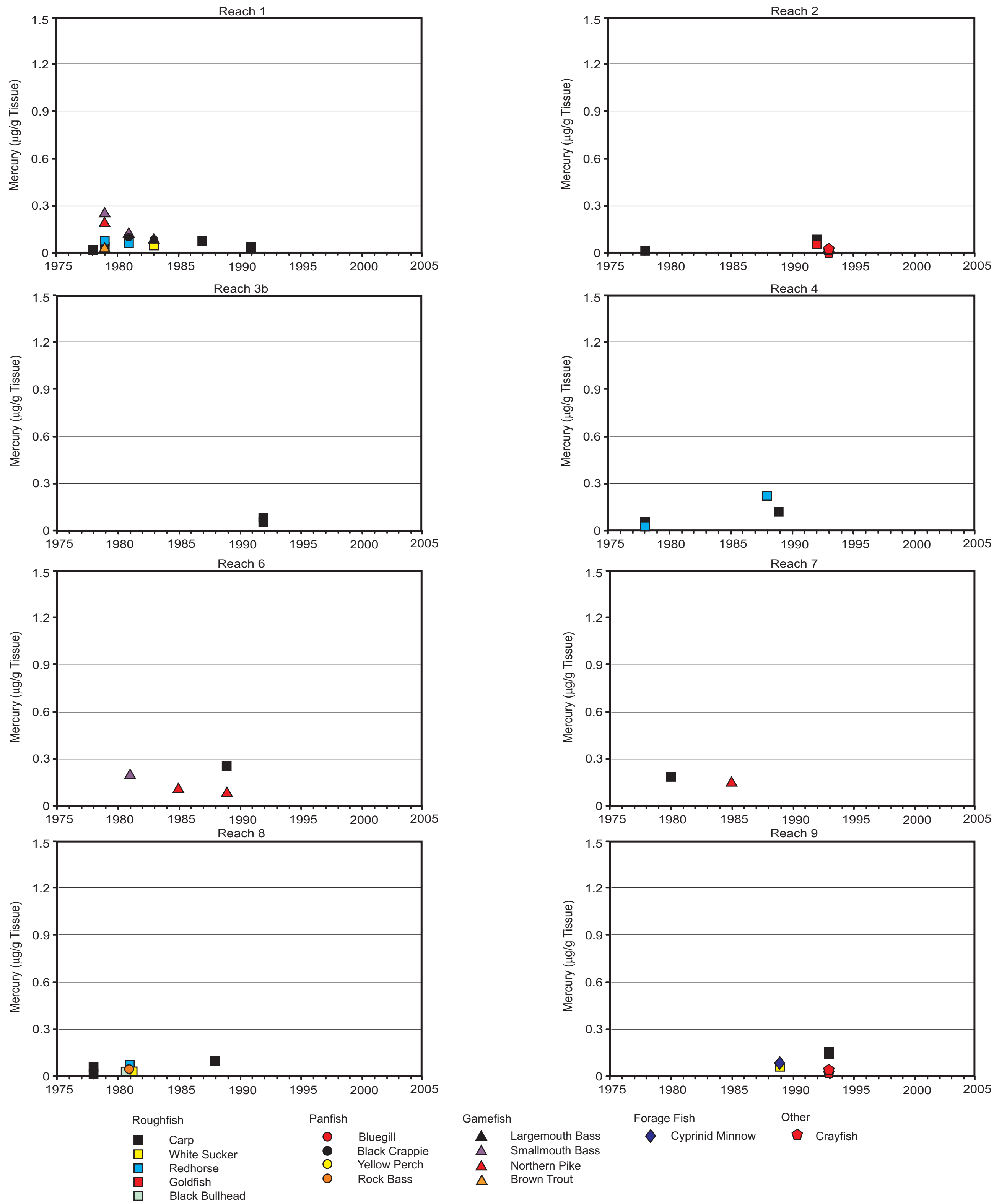
NOTE: Reaches correspond to those shown on Map 53.

Source: Wisconsin Department of Natural Resources and SEWRPC.

of PCBs in whole organism samples ranged from below the limit of detection to 110 μg per g tissue. Tissue concentrations in fillet samples ranged from below the limit of detection to 160 μg per g tissue. Figure 154 shows concentrations of PCBs in the tissue from both whole organism samples and fillet sample of fish collected from stream reaches separated by dams and drop structures in the Milwaukee River watershed. Two trends are apparent. First, tissue concentrations in whole fish samples tend to be higher in whole organism samples than in fillet samples. This may reflect the fact that PCBs are more soluble in lipids than in water and consequently tend

Figure 152

TISSUE CONCENTRATIONS OF MERCURY IN WHOLE FISH SAMPLES COLLECTED FROM STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1977-2002

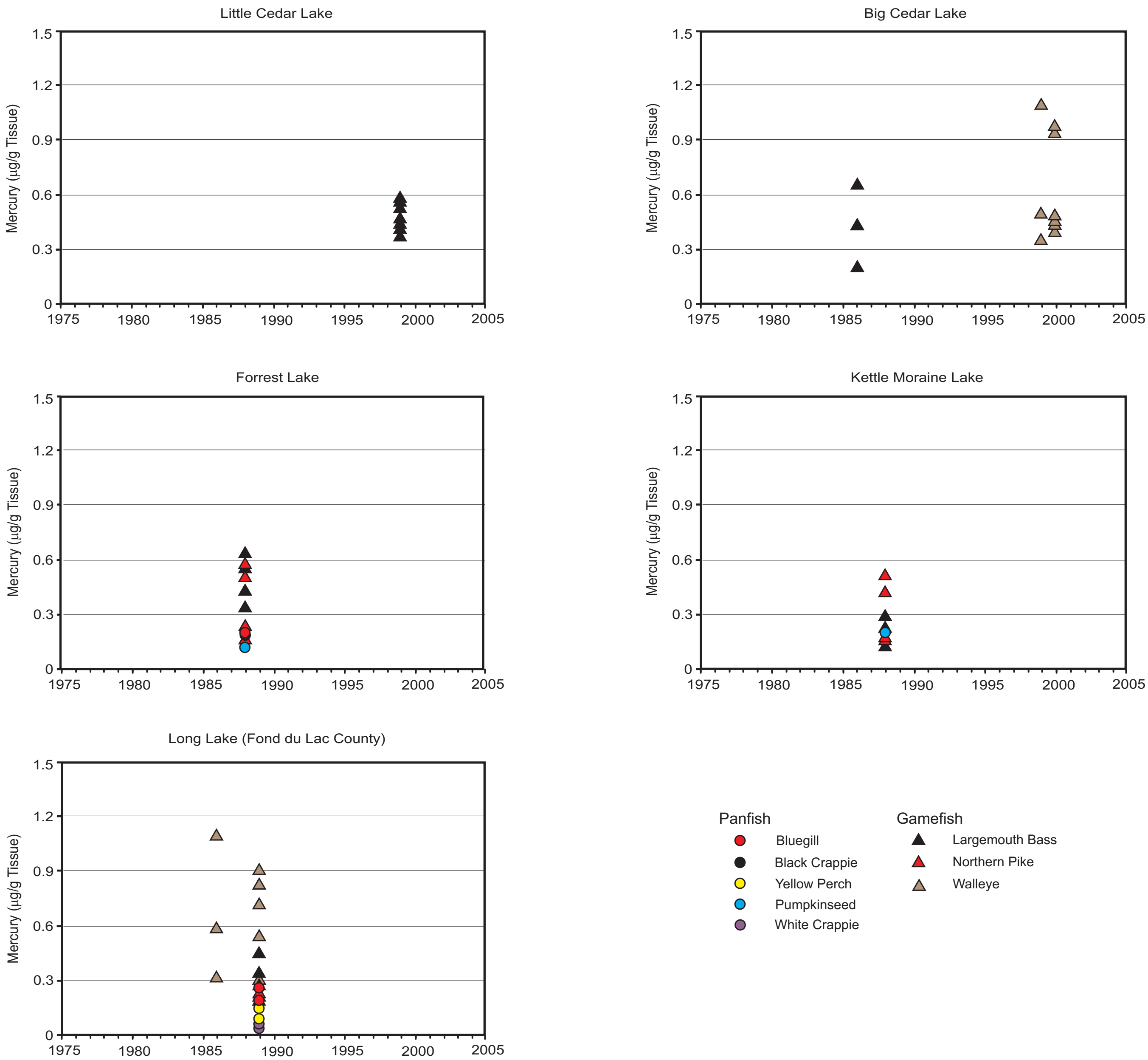


NOTE: Reaches correspond to those shown on Map 53.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 153

TISSUE CONCENTRATIONS OF MERCURY IN FILLETS FROM FISH SAMPLES COLLECTED FROM LAKES IN THE MILWAUKEE RIVER WATERSHED: 1977-2002



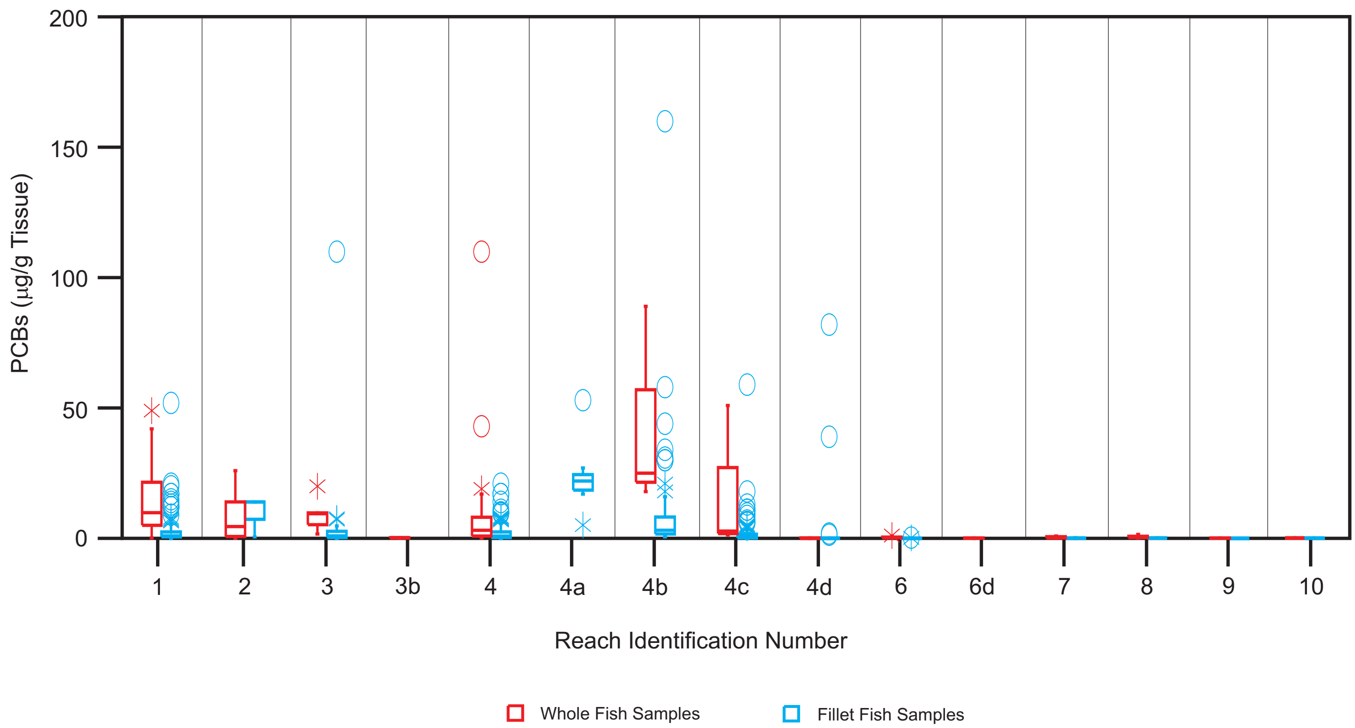
Source: Wisconsin Department of Natural Resources and SEWRPC.

to accumulate in fatty tissue. Second, higher tissue concentrations of PCBs are detected in fish collected from stream reaches along Cedar Creek in and downstream from Cedarburg and in the mainstem of the Milwaukee River below the confluence with Cedar Creek than from other locations in the watershed. These are stream reaches that either contain deposits of PCB-contaminated sediment or are downstream of reaches containing deposits of PCB-contaminated sediment (see the following subsection on Toxic Contaminants in Sediment).

Figures 155 through 158 show tissue concentrations of PCBs from aquatic organisms from stream reaches separated by dams and drop structures in the Milwaukee River watershed for reaches downstream from Thiensville Millpond (see Figure 155), between the Villages of Grafton and Thiensville (see Figure 156), and

Figure 154

TISSUE CONCENTRATIONS OF PCBs IN FISH SAMPLES COLLECTED FROM STREAM REACHES SEPARATED BY DAMS AND DROP STRUCTURES IN THE MILWAUKEE RIVER WATERSHED: 1977-2002



NOTES: See Figure 109 for description of symbols.

Reaches correspond to those shown on Map 53.

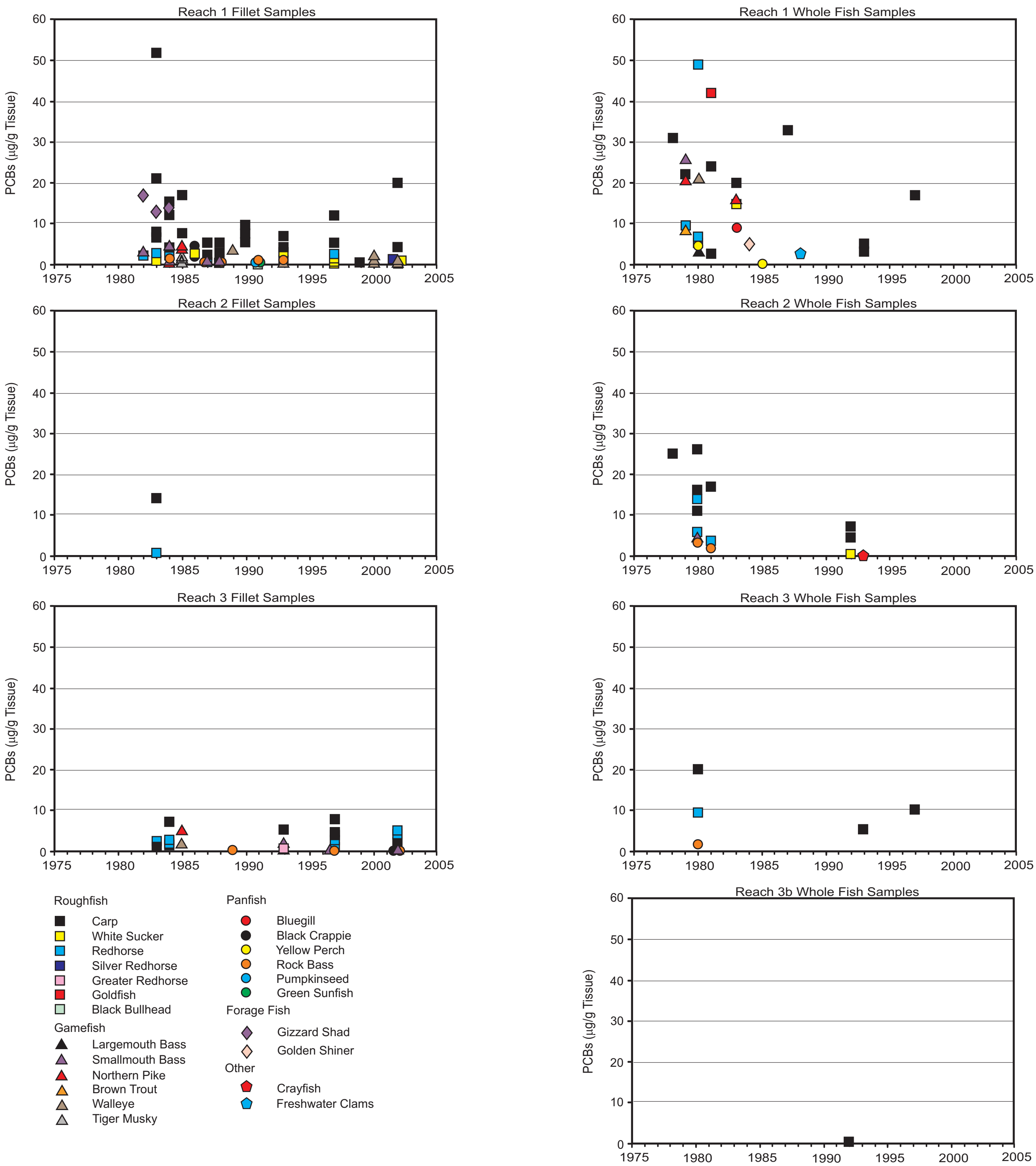
Source: Wisconsin Department of Natural Resources and SEWRPC.

upstream from the Village of Grafton (see Figure 157). In some stream reaches, tissue concentrations of PCBs appear to be decreasing with time, for example tissue concentrations in whole organism samples in Reaches 2 and 3 (see Figure 155). These apparent trends must be interpreted with caution, both because of the small number of samples that they are based upon, and because in many reaches different fish species were examined at different dates. In most of the stream reaches where data are available, no trend is apparent in tissue concentrations of PCBs. Among species, the body burdens of PCBs detected often reflected trophic mechanisms. Piscivorous fish tended to have larger body burdens than fish that feed primarily or largely on invertebrates. Highest body burdens were detected in omnivorous, bottom-dwelling species. For example, in fillet samples of fish collected from Reach 1, the mean tissue concentration of PCBs in northern pike, a primarily piscivorous species, was 1.92 μg per g tissue. Mean tissue concentrations of PCBs in this reach in black crappie and rock bass, two species that feed largely on invertebrates, were 1.69 μg per g tissue and 0.69 μg per g tissue, respectively. The mean tissue concentration in this reach in carp, an omnivorous, bottom-dwelling species, was 8.36 μg per g tissue. Similar relationships were detected in other stream reaches.

The WDNR measured tissue concentrations of PCB congeners in whole-fish samples in caged fathead minnows prior to and after the removal of contaminated sediment from Ruck Pond along Cedar Creek. These studies were designed to indicate the amount of bioaccumulation of PCBs in fish tissue during a fixed period of exposure. Cages were placed at three locations: in Cedarburg Pond upstream from Ruck Pond, within Ruck Pond, and in Columbia Pond downstream from Ruck Pond. In experiments conducted in July 1994, prior to the remediation, the average tissue concentration of PCBs was 0.12 μg per g tissue at the upstream site, 24 μg per g tissue at the Ruck Pond site, and 12 μg per g tissue at the downstream site. The average tissue concentration of PCBs detected

Figure 155

TISSUE CONCENTRATIONS OF PCBs IN FISH SAMPLES COLLECTED FROM THE MILWAUKEE RIVER WATERSHED BELOW THIENSVILLE MILLPOND: 1977-2002

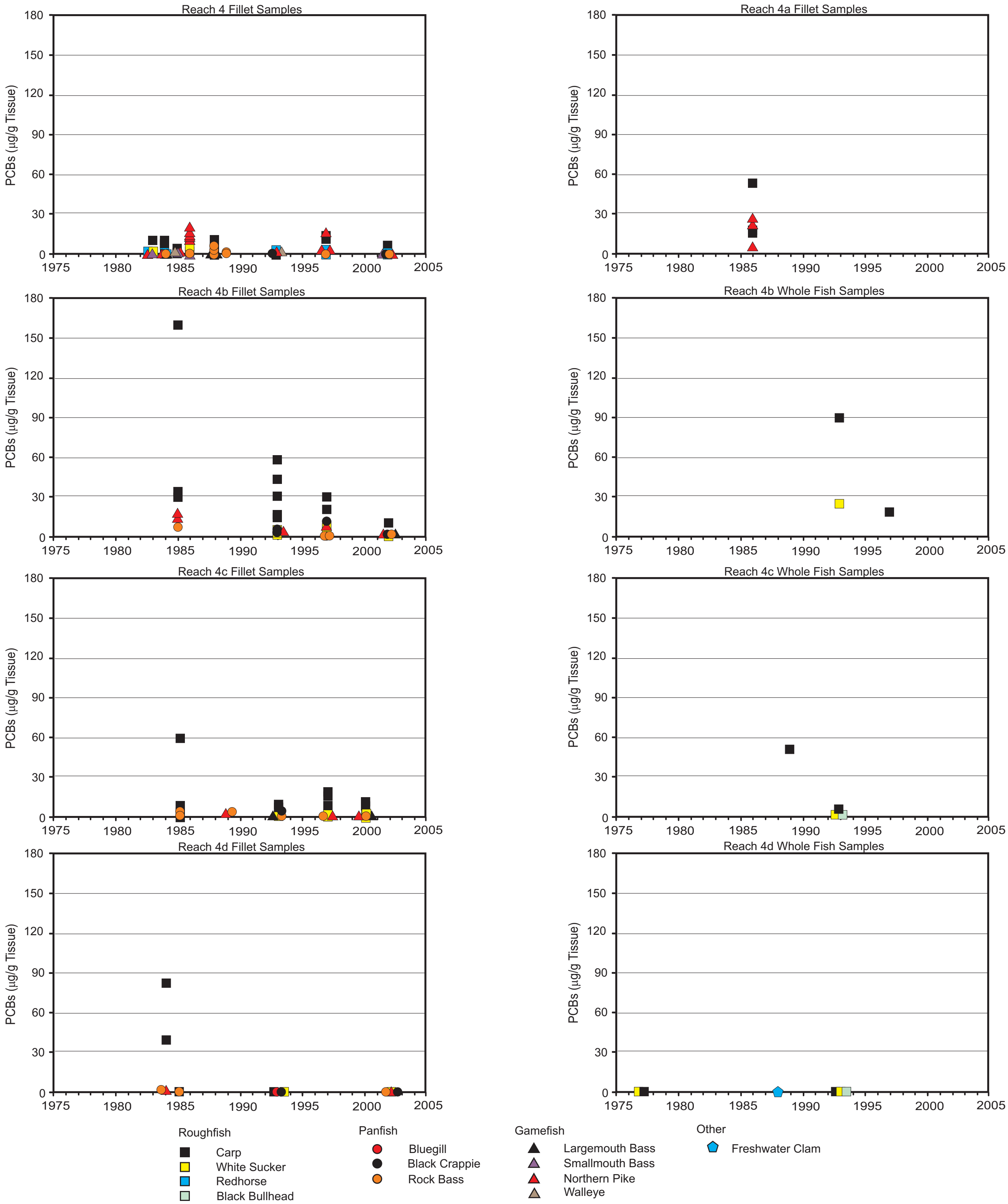


NOTE: Reaches correspond to those shown on Map 53.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 156

TISSUE CONCENTRATIONS OF PCBs IN FISH SAMPLES COLLECTED FROM CEDAR CREEK AND THE MILWAUKEE RIVER BETWEEN THE VILLAGES OF GRAFTON AND THIENSVILLE: 1977-2002



NOTE: Reaches correspond to those shown on Map 53.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 157

TISSUE CONCENTRATIONS OF PCBs IN FISH SAMPLES COLLECTED FROM THE MILWAUKEE RIVER WATERSHED ABOVE THE VILLAGE OF GRAFTON: 1977-2002

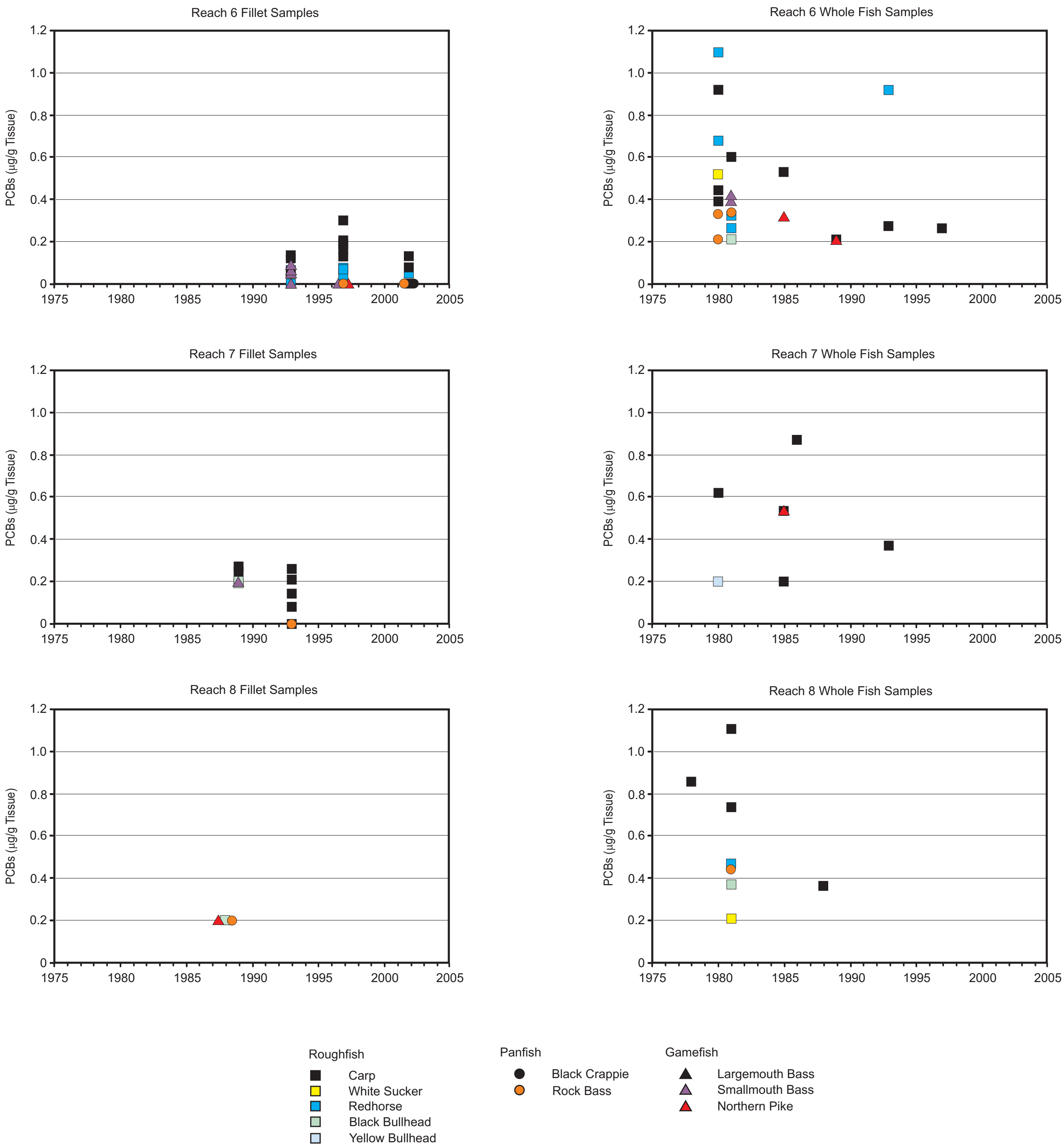
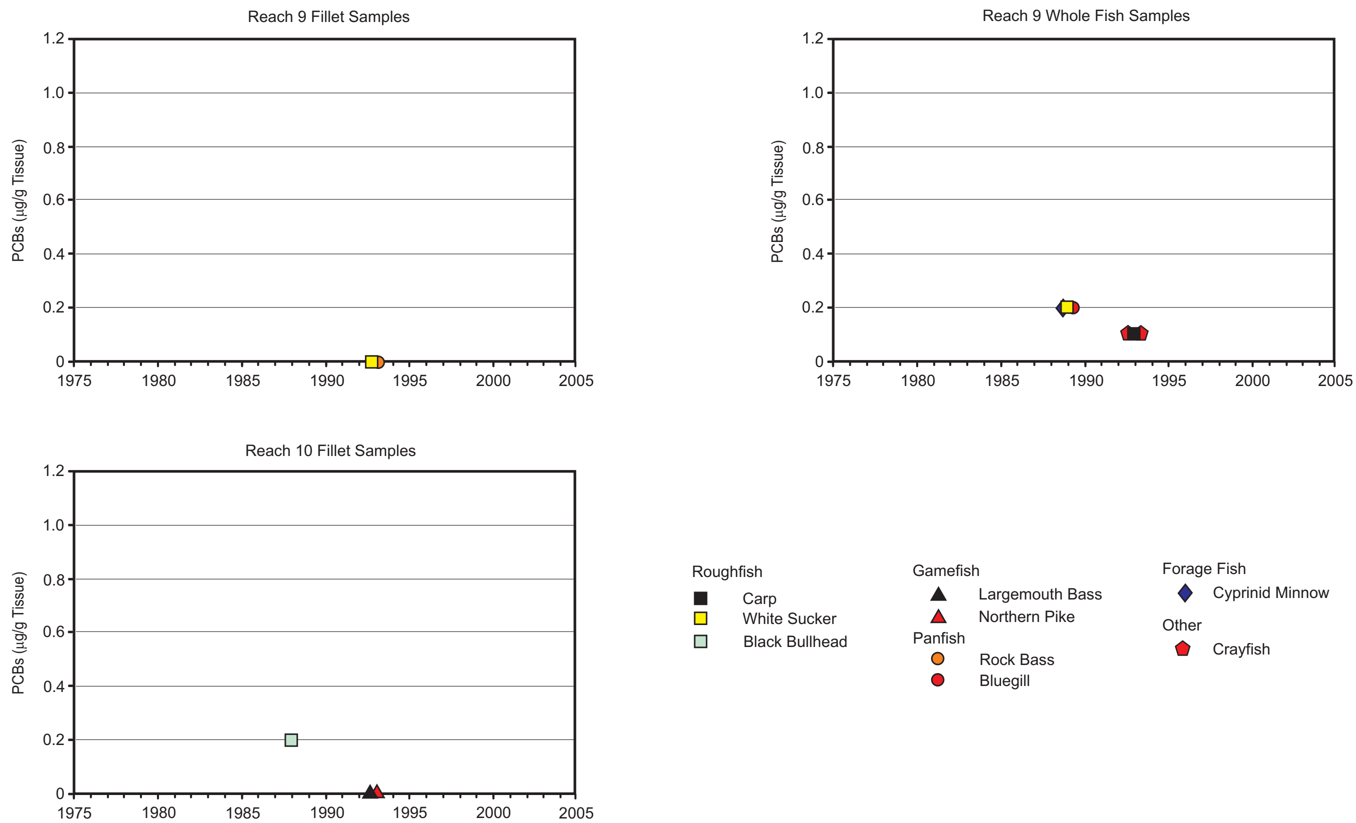


Figure 157 (continued)



NOTE: Reaches correspond to those shown on Map 53.

Source: Wisconsin Department of Natural Resources and SEWRPC.

in experiments conducted in July and August of 1995, one year after the remediation, was 0.09 μg per g tissue at the upstream site, 4.2 μg per g tissue at the Ruck Pond site, and 11 μg per g tissue at the downstream site. In Ruck Pond, this represents about an 82 percent reduction in PCB bioaccumulation in caged fish experiments. In similar studies conducted in 2001, the average tissue concentration of PCBs in caged fathead minnows in Ruck Pond was about 0.36 μg per g tissue. It is important to note that this reduction may not entirely reflect the results of the remediation. Between 1994 and 1995, tissue concentrations of PCBs at the upstream site also decreased by about 25 percent and tissue concentrations at the downstream site decreased by about 10 percent. In addition, disturbance of the Ruck Pond site may be a factor in the concentrations detected. During the experiments prior to the remediation, in-water construction preparations and disturbances were occurring in Ruck Pond. This may have resulted in greater exposure of the caged minnows to PCBs than would have occurred under undisturbed conditions.

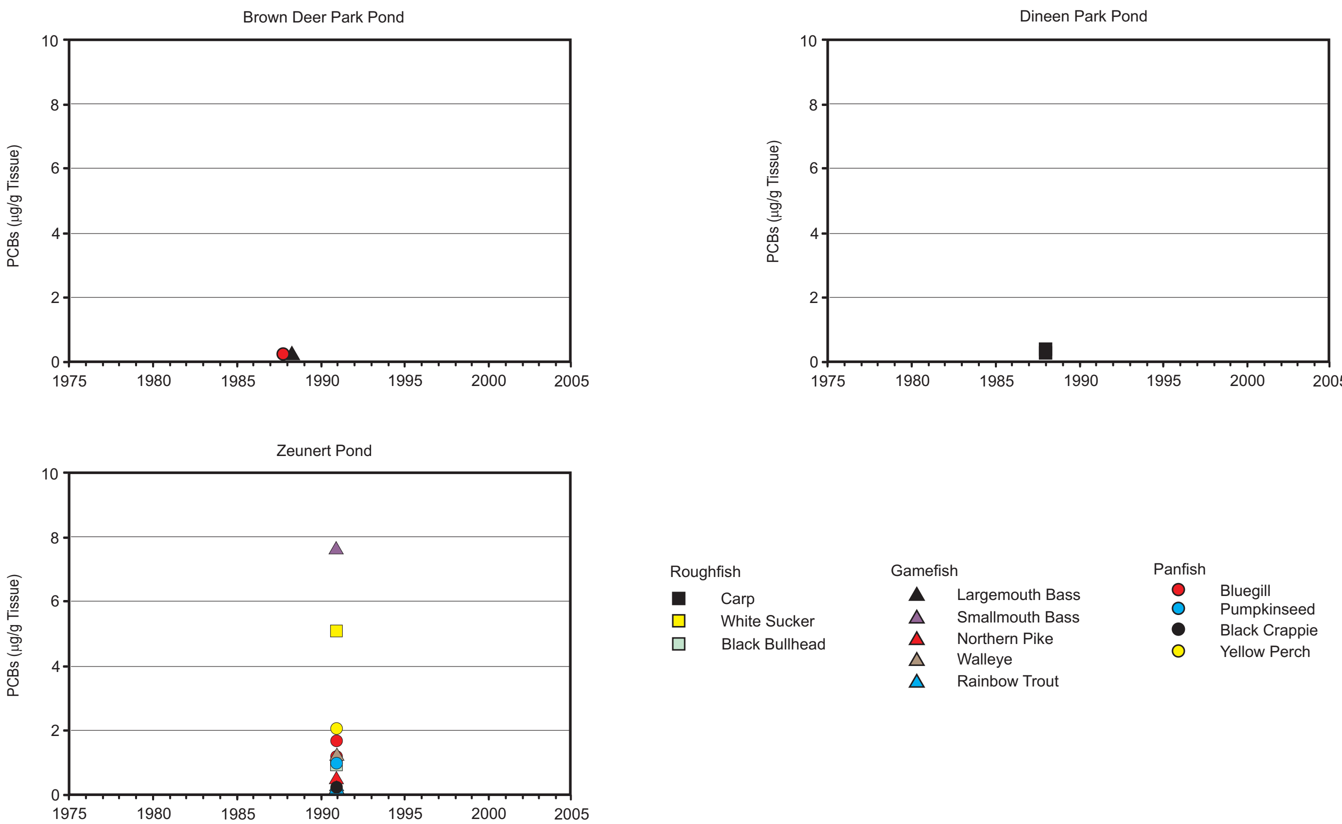
It is important to recognize that the number of individual organisms and the range of species taken from this watershed that have been screened for the presence of PCB contamination are quite small. Because of this, these data may not be completely representative of current body burdens of PCB**s** carried by aquatic organisms in the River and its tributaries.

Pesticides

Between 1977 and 1993 the WDNR examined whole fish samples from several species of aquatic organisms from the Milwaukee River watershed for contamination by historically used, bioaccumulative pesticides and their

Figure 158

TISSUE CONCENTRATIONS OF PCBs IN FILLETS FROM FISH SAMPLES COLLECTED FROM PONDS IN THE MILWAUKEE RIVER WATERSHED: 1977-2002



Source: Wisconsin Department of Natural Resources and SEWRPC.

breakdown products. Many of these compounds are no longer in use. For example, crop uses of most of these compounds were banned in the United States between 1972 and 1983. While limited uses were allowed after this for some of these substances, by 1988 the uses of most had been phased out.

During the early 1980s, measurable concentrations of o,p'-DDT and p,p'-DDT were occasionally detected in tissue of fish from several species collected from stream reaches in the Milwaukee River watershed downstream from Kletzsch Park Dam (Reaches 1 and 2). These compounds were not detected in tissue samples collected in subsequent sampling. Between 1977 and 1993, measurable concentrations of the DDT breakdown products p,p'-DDD and p,p'-DDE were detected in the tissue of fish from several species in most of the stream reaches separated by dams and drop structures in the watershed that were sampled. There were no detections in Reaches 9 and 10. In addition, the DDT breakdown products o,p'-DDD and o,p'-DDE were occasionally detected in tissue samples of fish collected in Reach 1, downstream from Estabrook Park Dam.

During the same period, tissue from fish collected in the Milwaukee River watershed was analyzed for the presence of several other pesticides. Measurable concentrations of the chlordane isomers α-chlordane and γ-chlordane and of the insecticide methoxychlor were occasionally detected in fish tissue samples collected from Reaches 1, 2, 4, and 8. Similarly, measurable concentrations of the chlordane isomer trans-nonachlor and of the insecticides aldrin and pentachlorophenol were occasionally detected in the tissue of fish collected from Reach 1. Measurable concentrations of dieldrin were occasionally detected in tissue from carp and goldfish. Measurable concentrations of α-BHC, γ-BHC, endrin, hexachlorobenzene, toxaphene, and the chlordane isomer cis-nonachlor were not detected in the tissue of aquatic organisms collected from the Milwaukee River watershed during the period 1977-1993.

It is important to recognize that the number of individual organisms and the range of species taken from this watershed that have been screened for the presence of pesticide contamination are quite small. Because of this, these data may not be completely representative of pesticide body burdens of pesticides carried by aquatic organisms in the River and its tributaries.

Toxic Contaminants in Sediment

Between 1973 and 2000 the WDNR sampled sediment from streams in the Milwaukee River watershed for the presence and concentrations of toxic substances. Sampling sites and dates of sampling are shown in Table 101. Sediment samples collected from the Milwaukee River during the period 1989 to 2003 show detectable concentrations of arsenic, barium, cadmium, chromium, copper, cobalt, iron, lead, manganese mercury, nickel, selenium, and zinc. Summary statistics for concentrations of selected metals are shown in Table 102. The mean concentrations of arsenic, cadmium, chromium, copper, lead, mercury, and zinc in these samples were between the Threshold Effect Concentrations (TEC) and the Probable Effect Concentrations (PECs), indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms (see Table 13 in Chapter III of this report).

The amount of organic carbon in sediment can exert considerable influence on the toxicity of nonpolar organic compounds such as PAHs, PCBs, and certain pesticides to benthic organisms. While the biological responses of benthic organisms to nonionic organic compounds has been found to differ across sediments when the concentrations are expressed on a dry weight basis, they have been found to be similar when the concentrations have been normalized to a standard percentage of organic carbon.[24] Because of this, the concentrations of PAHs, PCBs, and pesticides were normalized to 1 percent organic carbon prior to analysis.

Concentrations of PAHs in 37 sediment samples collected between 1989 and 1999 ranged between about 146 micrograms PAH per kilogram sediment (μg PAH/kg sediment) and about 84,500 μg PAH/kg sediment with a mean value of 19,500 μg PAH/kg sediment (see Table 103). Total organic carbon data were not available for 25 of the samples. For the two samples collected from the Milwaukee River that had associated total organic carbon data, the concentrations of PAHs were between the TEC and the PEC, indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms. In one sample collected from Lincoln Creek that had associated total organic carbon data, the concentrations of PAHs exceed the PEC for total PAHs and are high enough to pose substantial risk of toxicity to benthic organisms. In a second sample collected from this stream, the concentrations of PAHs were between the TEC and the PEC. In five samples collected from the North Branch Milwaukee River and three samples collected from Gooseville Creek that had associated total organic carbon data, the concentrations of PAHs were below the TEC. During the period 2003-2004, the WDNR examined 15 sediment cores collected from Estabrook Impoundment in the Milwaukee River and Lincoln Creek near the confluence with the Milwaukee River for the presence of PAHs.[25] Concentrations of total PAHs detected in these samples ranged from 318 μg PAH/kg sediment to 333,800 μg PAH/kg sediment. In most of these samples, individual PAH concentrations normalized to 1 percent total organic carbon were between the TEC and the PEC. In three samples, individual PAH concentrations exceeded the PEC. Areas with the highest concentrations of PAHs tended to be from Lincoln Creek sediments.

Concentrations of PCBs in 311 sediment samples collected from the Milwaukee River watershed between 1980 and 2000 ranged from below the limit of detection to about 870 milligrams PCB per kilogram sediment (mg PCB/kg sediment) with a mean value of 21.0 mg PCB/kg sediment. Total organic carbon data were not available

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[24]*U.S. Environmental Protection Agency,* Technical Basis for the Derivation of Equilibrium Partitioning Sediment Guidelines (ESGs) for the Protection of Benthic Organisms: Nonionic Organics*, USEPA Office of Science and Technology, Washington, D.C., 2000.*

[25]*Wisconsin Department of Natural Resources,* Estabrook Impoundment Sediment Remediation Pre-Design Study Project Completion Report to USEPA, *PUBL-WT 826, August 2005.*

Table 101

SEDIMENT SAMPLING IN THE MILWAUKEE RIVER WATERSHED: 1973-2003

Location	Years	Contaminants Examined
East Branch Milwaukee River		
Two Sites near CTH S	1993	Metals, PCBs, Pesticides
New Fane Millpond	1999	Metals, PAHs, PCBs, Pesticides
Gooseville Creek		
Three Sites	1995	Metals, PAHs, PCBs
North Branch Milwaukee River		
One Site near CTH A	1995	Metals, PAHs, PCBs
Two Sites near Waubeka	1999	Metals, PAHs, PCBs, Pesticides
Cedar Creek		
Six Sites near CTH C	1999	Metals
Mayfield Pond	1998	Metals, PAHs, PCBs, Pesticides
Ruck Pond	1990	Metals, PCBs
	2000	PCBs
Columbia Pond	1995	PCBs
Wire and Nail Pond	2000	PCBs
CTH T	1995	PCBs
Hamilton Pond	1996	PCBs
Trinity Creek		
Confluence with the Milwaukee River	1995	PCBs
Indian Creek		
Bradley Road	1989	Metals, PAHs, PCBs
Crestwood Creek		
Above Confluence with Lincoln Creek	1995	PCBs
Wahl Creek		
47th Street	1989	Metals, PAHs, PCBs, Pesticides
Lincoln Creek		
N. 51st Street and W. Woolworth Avenue	1980	Pesticides
	1993	Pesticides
Havenwoods	1995	PCBs
N. 60th Street	1995	PCBs
N. 47th Street	1980	Pesticides
	1992-1993	Pesticides
	1995	PCBs
N. 46th Street	1995	PCBs
N. Teutonia Avenue	1995	PCBs
Below N. Green Bay Avenue	2001-2003	Metals, PAHs, PCBs, Pesticides
Meaux Park	1980	Pesticides
	1993	Pesticides
Confluence with Milwaukee River	1990	PAHs, PCBs, Pesticides
Milwaukee River Mainstem		
Chair Factory Impoundment-Grafton	1993	PAHs, PCBs
CTH T	1995	PCBs
Thiensville Millpond	1973	PCBs
	1993	PCBs
Kletzsch Park Impoundment	1993	PCBs
Estabrook Impoundment	1973	Metals
	1982	PCBs
	1993	PCBs
	1995	PCBs
	2001-2003	Metals, PAHs, PCBs, Pesticides
Multiple Locations Downstream from Thiensville	1984	Metals, PCBs, Pesticides
	1989	Metals, PAHs, PCBs, Pesticides
	1990-1991	PAHs, PCBs
Three Estuary Sites	1980	PCBs

Source: Wisconsin Department of Natural Resources.

Table 102

CONCENTRATIONS OF TOXIC METALS IN SEDIMENT SAMPLES FROM THE MILWAUKEE RIVER WATERSHED: 1989-2003[a]

Statistic	Metals							
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Mean	13.2	1.61	92.1	43.5	83.2	0.67	16.0	180.8
Standard Deviation	13.9	1.65	134.3	39.8	88.5	0.98	17.6	174.6
Minimum	0.0	0.00	8.0	4.0	2.3	0.00	5.0	0.4
Maximum	52.0	6.10	540.0	160.0	350.0	3.35	40.0	680.0
Number of Samples	37	42	34	41	41	31	31	41
Date of Earliest Sample	1973	1973	1973	1973	1973	1973	1973	1973
Date of Latest Sample	1999	1999	1999	1999	1999	1999	1999	1999

[a]*All concentrations in mg/kg based on dry weight.*

Source: Wisconsin Department of Natural Resources.

Table 103

CONCENTRATIONS OF POLYCYCLIC AROMATIC HYDROCARBONS IN SEDIMENT SAMPLES FROM THE MILWAUKEE RIVER WATERSHED: 1989-1999[a]

Parameter	Surface Sediment (0-30 cm)	Intermediate Sediment (31-60 cm)	Deep Sediment (60-152 cm)	All Sediment (0-152 cm)
Mean	21,110	1,518	- -	19,512
Standard Deviation	23,555	2,237	- -	23,200
Minimum	146	152	- -	146
Maximum	84,498	4,100	- -	84,498
Number of Samples	34	3	0	37

[a]*All concentrations expressed as µg/kg on a dry weight basis.*

Source: Wisconsin Department of Natural Resources.

for 52 of the samples. For 56 of the samples that had associated total organic carbon data, the concentrations of PCBs found in sediments from the Milwaukee River watershed were below the TEC for total PCBs, indicating that these concentrations are unlikely to be producing toxic effects in benthic organisms. The concentrations of PCBs in 102 samples were between the TEC and the PEC, indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms. The concentrations of PCBs in 101 samples exceed the PEC for total PCBs and are high enough to pose substantial risk of toxicity to benthic organisms.

Much of the sediment sampling for PCBs in the Milwaukee River watershed is related to two sites known to contain sediment contaminated with PCBs: the lower reaches of Cedar Creek and Estabrook Impoundment. In addition, several sediment samples were collected from the Thiensville Millpond, an impoundment of the Milwaukee River in the Village of Thiensville and Zeunert Pond, a quarry pond in the City of Cedarburg.

Table 104 shows concentrations of PCBs in sediment collected at five sites along Cedar Creek between 1995 and 2000. The highest average concentrations of PCBs are in sediment collected from Columbia Pond and Wire and Nail Pond. The samples from Ruck Pond were collected about five years after the removal of about 7,700 cubic

Table 104

CONCENTRATIONS OF PCBs IN SEDIMENT SAMPLES FROM CEDAR CREEK: 1985-2000[a]

Statistic	Ruck Pond	Columbia Pond	Wire and Nail Pond	CTH T	Hamilton Pond[b]
Mean	7.11	27.03	11.14	2.14	1.70
Standard Deviation	24.40	41.64	12.20	1.64	1.75
Minimum	0.07	0.05	0.09	0.98	0.05
Maximum	120.00	190.00	49.00	3.30	4.30
Number of Samples	24	50	25	2	6
Date of Sample	2000	1995	2000	1995	1996

[a]*All concentrations in mg/kg based on dry weight.*

[b]*Samples from the former Hamilton Pond were collected during removal of the Hamilton dam.*

Source: Wisconsin Department of Natural Resources.

yards of contaminated sediment and still displayed high residual PCB levels. The samples collected from Hamilton Pond were collected during removal of the Hamilton dam following its failure.

Figure 159 shows PCB concentrations in 12 sediment cores collected from Thiensville Millpond in 1993. Concentrations of PCBs in sediment from this impoundment range from below the limit of detection to 4.9 mg PCB/kg sediment with a mean concentration of 0.53 mg PCB/kg sediment. The mean concentration of PCBs in surface sediments were 0.18 mg PCB/kg sediment, relatively low compared to deeper sediment. The highest concentrations of PCBs were detected at depths below the sediment surface between 30 cm and 40 cm. The mean concentration at this stratum was about 1.01 mg PCB/kg sediment. Below sediment depths of about 50 cm, PCB concentrations in this impoundment decrease sharply.

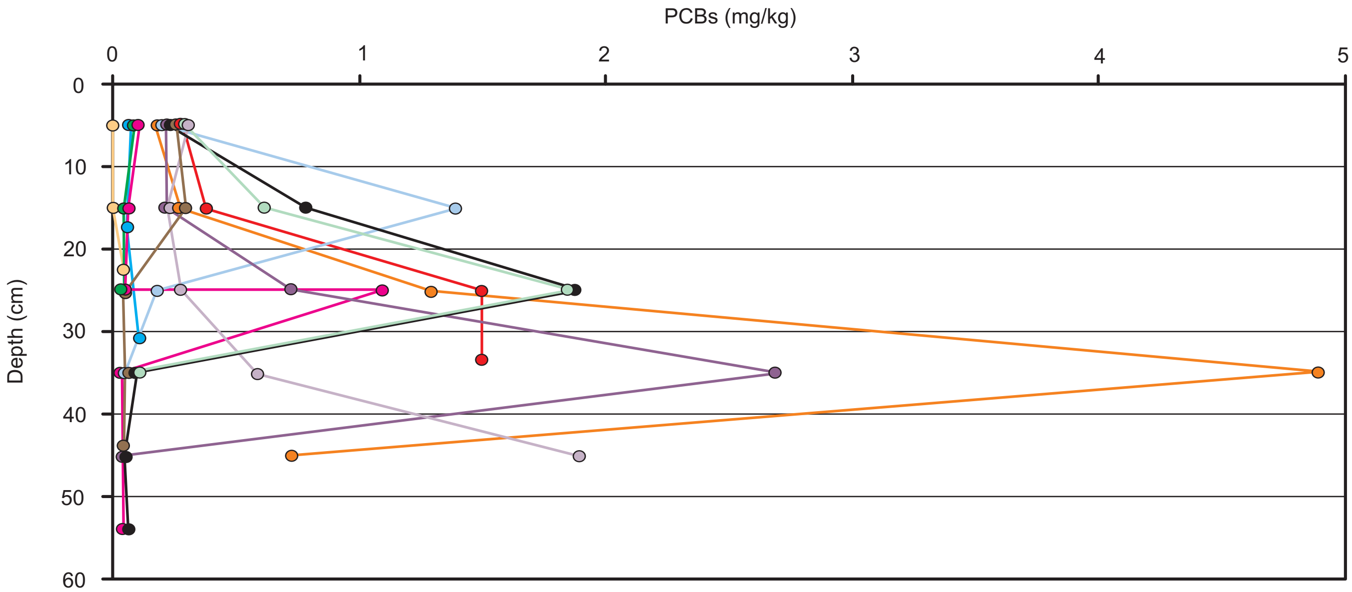
Figure 160 shows PCB concentrations in four sediment cores collected in 1993 and 14 sediment cores collected in 1995 from Estabrook Impoundment. In the 1993 samples, concentrations of PCBs in sediment ranged from 0.06 mg PCB/kg sediment to 380 mg PCB/kg sediment with a mean concentration of 49.2 mg PCB/kg sediment. The highest concentrations of PCBs were detected at depths below the sediment surface between 20 cm and 30 cm. In the 1995 samples, concentrations of PCBs in sediment ranged from 0.2 mg PCB/kg sediment to 870 mg PCB/kg sediment with a mean concentration of 51.5 mg PCB/kg sediment. The mean concentration of PCBs in surface sediments was 11.2 mg PCB/kg sediment, relatively low compared to deeper sediment. The highest concentrations of PCBs were detected at depths below the sediment surface between 30 cm and 40 cm. The mean concentration at this stratum was about 132 mg PCB/kg sediment. Below sediment depths of about 50 cm, PCB concentrations in this impoundment decrease sharply.

Between 2001 and 2003, the WDNR conducted additional sampling for PCBs in sediment in the Estabrook Impoundment and Lincoln Creek downstream from N. Green Bay Avenue.[26] Map 54 shows the depth of soft sediments in selected portions of Estabrook Impoundment. Sediment mapping was confined to areas of the impoundment where there is known sediment contamination. Accumulated soft sediment was thickest in the two side channels of the River, ranging up to 5.4 feet. Sediment depths in the main channel of the River were generally below about 1.6 feet, with some thicker deposits located near the Estabrook dam. The WDNR estimated the volume of soft sediments in the impoundment to be about 98,800 cubic yards. Map 55 shows the concentrations of PCBs in sediment in the Estabrook Impoundment and Lincoln Creek. Concentrations ranged from below the limit of detection to 460 mg PCB/kg sediment. The highest concentrations of PCBs were detected in sediments from the western channel of the River, nearshore deposits at the Blatz Pavilion inlet, and on the west

[26]*Wisconsin Department of Natural Resources,* PUBL-WT 826, op. cit.

Figure 159

CONCENTRATIONS OF PCBs IN SEDIMENT FROM THIENSVILLE MILL POND: 1993



Source: Wisconsin Department of Natural Resources and SEWRPC.

bank of the Milwaukee River below the side channels. The PCBs in the sediment were identified as a mixture of Aroclors 1242, 1248, and 1254. The WDNR estimated the mass of PCBs in the impoundment in sediments with PCBs at a concentration above 1.5 mg PCB/kg sediment to be about 2,400 kg.

Available information shows PCB concentrations in sediment in some samples collected from Zeunert Pond being as high as 11,000 mg/kg.[27] Shallow samples collected from locations near the present shoreline have PCB concentrations ranging between 0.85 mg/kg and 12 mg/kg. This suggests that the currently exposed shoreline of the pond may be contaminated. Shallow sediments collected in the center of the pond have PCB concentrations ranging between 12 mg/kg and 140 mg/kg. The highest PCB concentrations were reported from sediments taken between 22 and 28 inches below the sediment surface. Concentrations in several of these samples exceeded 1,300 mg/kg PCBs, with the maximum being 11,000 mg/kg.

The combined effects of several toxicants in sediment of the Milwaukee River were estimated using the methodology described in Chapter III of this report. Figure 161 shows overall mean PEC-Q values, a measure that integrates the effects of multiple toxicants on benthic organisms, for streams in the Milwaukee River watershed. Figure 162 shows estimated incidences of toxicity to benthic organisms from sediment contaminants for the same streams. For sediments in the Milwaukee River, mean PEC-Q values range between 0.008 and 49.310. These mean PEC-Q levels suggest that benthic organisms in the Milwaukee River are experiencing moderate to high incidences of toxic effects. In these samples, the estimated incidence of toxicity ranges between about 0.8 and 100 percent. At sites upstream of the confluence with Cedar Creek, which is around River Mile 25, mean PEC-Q values are relatively low, ranging from 0.027-0.052. This suggests that benthic organisms at these sites are experiencing relatively low incidences of toxic effects, incidences less than or equal to about 5 percent. The mean PEC-Q values are higher at sites downstream from the confluence with Cedar Creek. The highest mean

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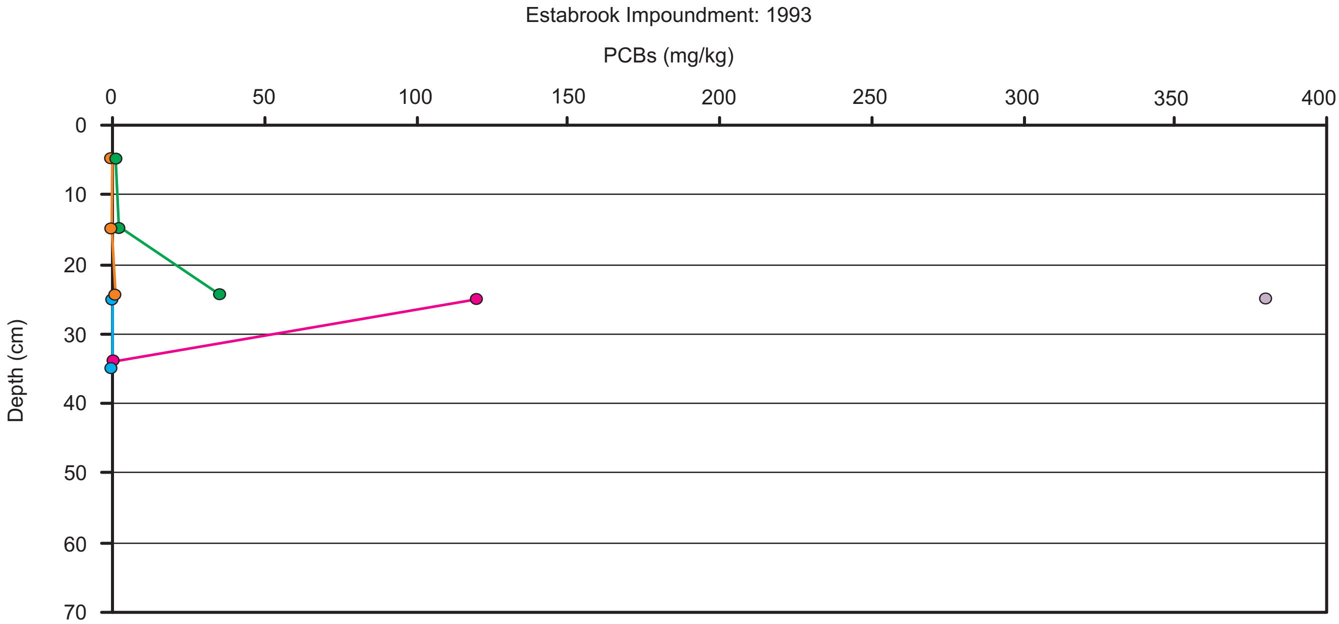
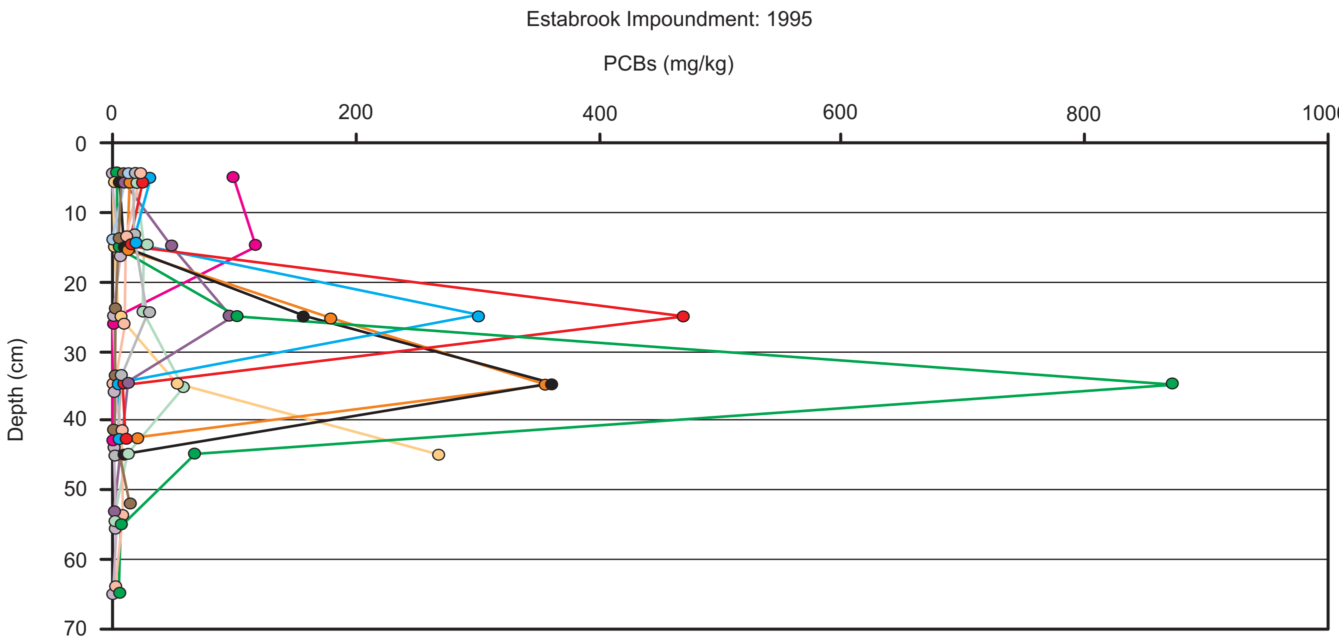
[27] *U.S. Department of Health and Family Services Agency for Toxic Substances and Disease Registry,* Health Consultation: Zeunert Quarry Pond Polychlorinated Biphenyl Site, City of Cedarburg, Ozaukee County, Wisconsin, *April 11, 2005.*

Figure 160

CONCENTRATIONS OF PCBs IN SEDIMENT FROM ESTABROOK IMPOUNDMENT: 1993-1995



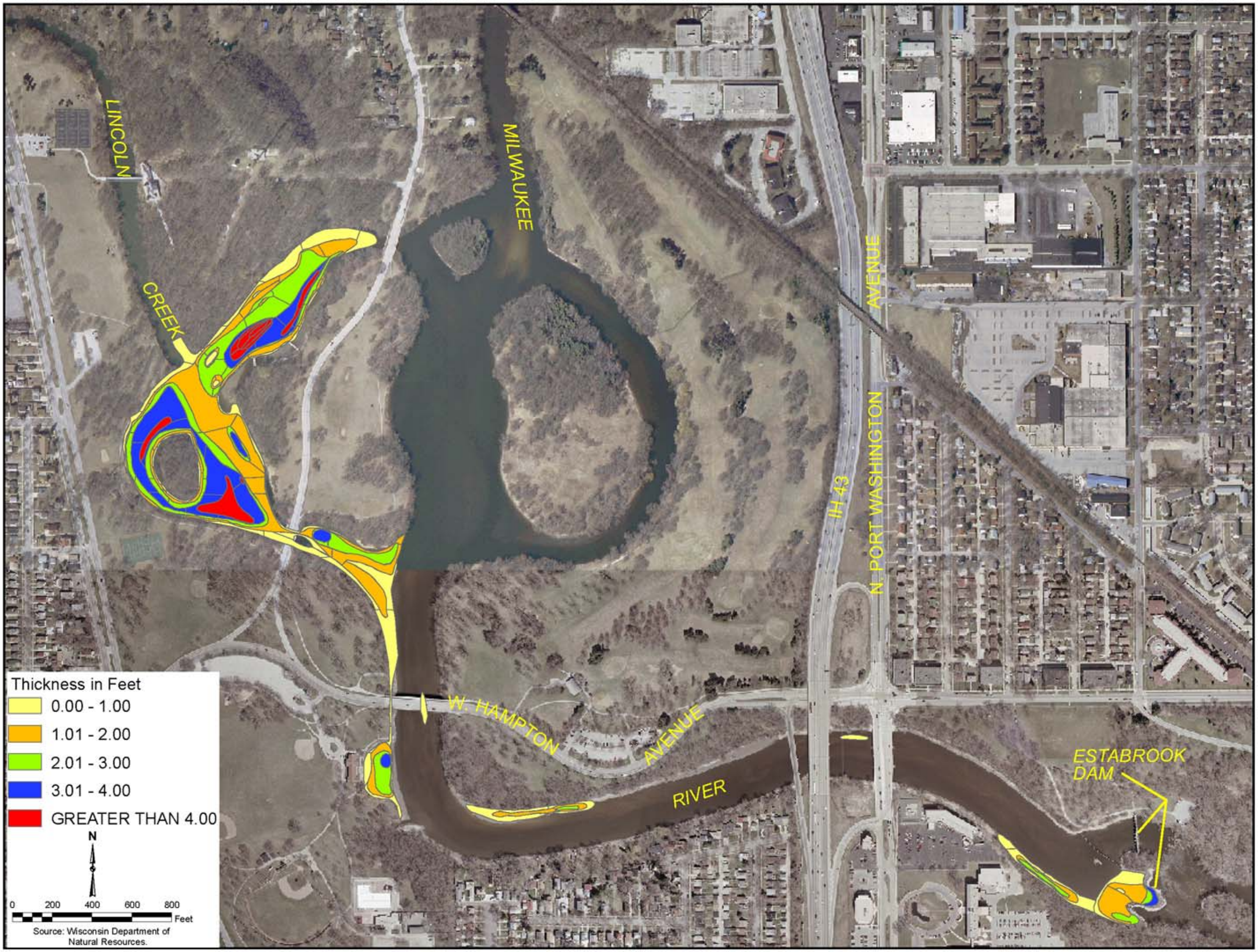


Source: Wisconsin Department of Natural Resources and SEWRPC.

PEC-Q values and the greatest range in mean PEC-Q values are observed at Estabrook impoundment. For sediments in Lincoln Creek, mean PEC-Q values range from about 0.22 to 5.34 (see Figure 161). These mean PEC-Q levels suggest that benthic organisms in Lincoln Creek are experiencing moderate to high incidences of toxic effects. In these samples the estimated incidences of toxicity range between about 20 and 100 percent. High mean PEC-Q values were also observed in sediment from Cedar Creek. Values of mean PEC-Q for this stream range from 0.01 to 81.43, with associated estimated incidences of toxic effects to benthic organisms ranging between about 9 and 100 percent. In upstream reaches, above River Mile 25, these high mean PEC-Q values are

Map 54

SEDIMENT DEPTH DISTRIBUTION IN SELECTED AREAS OF THE ESTABROOK IMPOUNDMENT WITHIN THE MILWAUKEE RIVER WATERSHED: 2001-2003



Map 55

PCB CONCENTRATION DISTRIBUTION WITHIN LINCOLN CREEK AND THE ESTABROOK IMPOUNDMENT WITHIN THE MILWAUKEE RIVER WATERSHED: 2001-2003

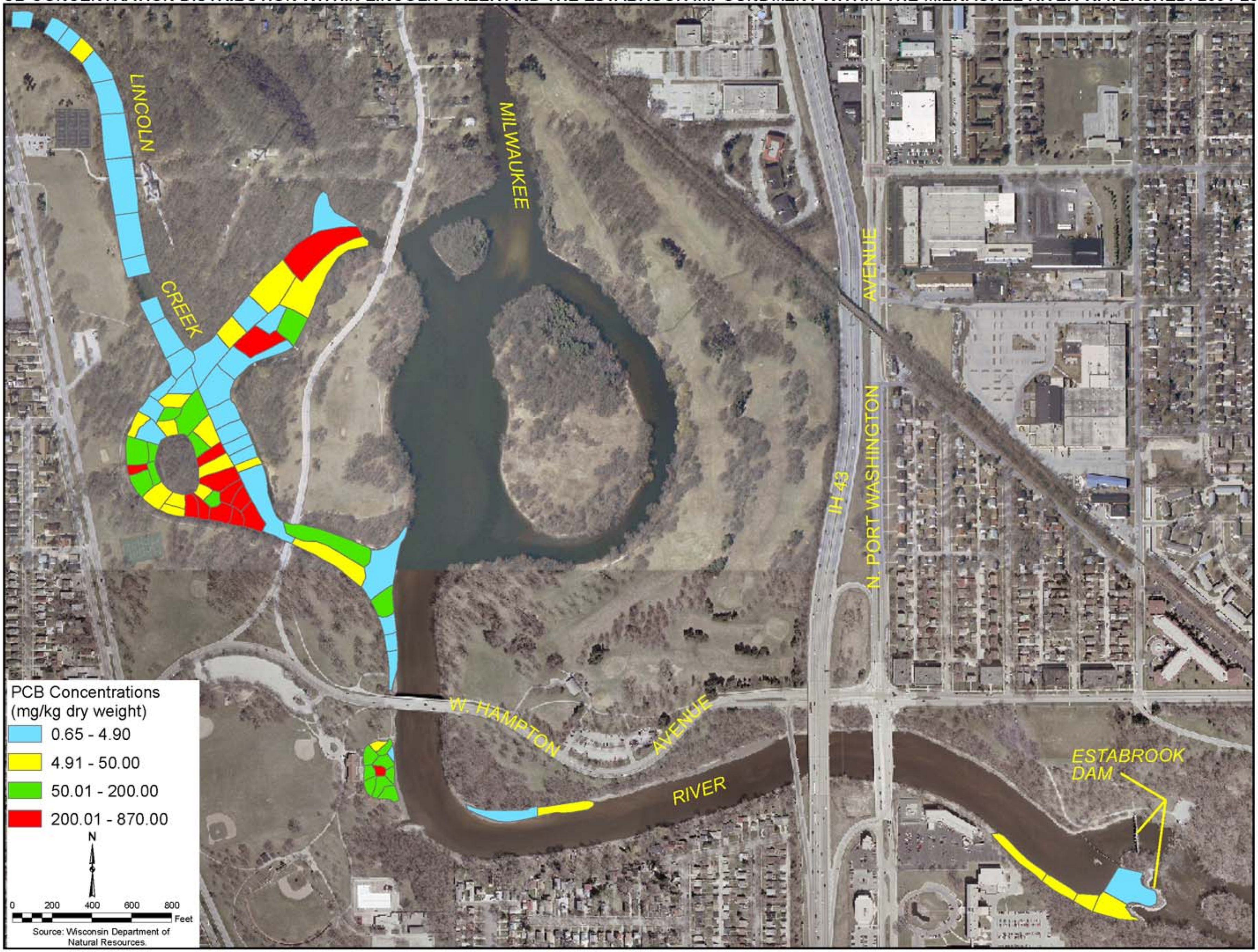
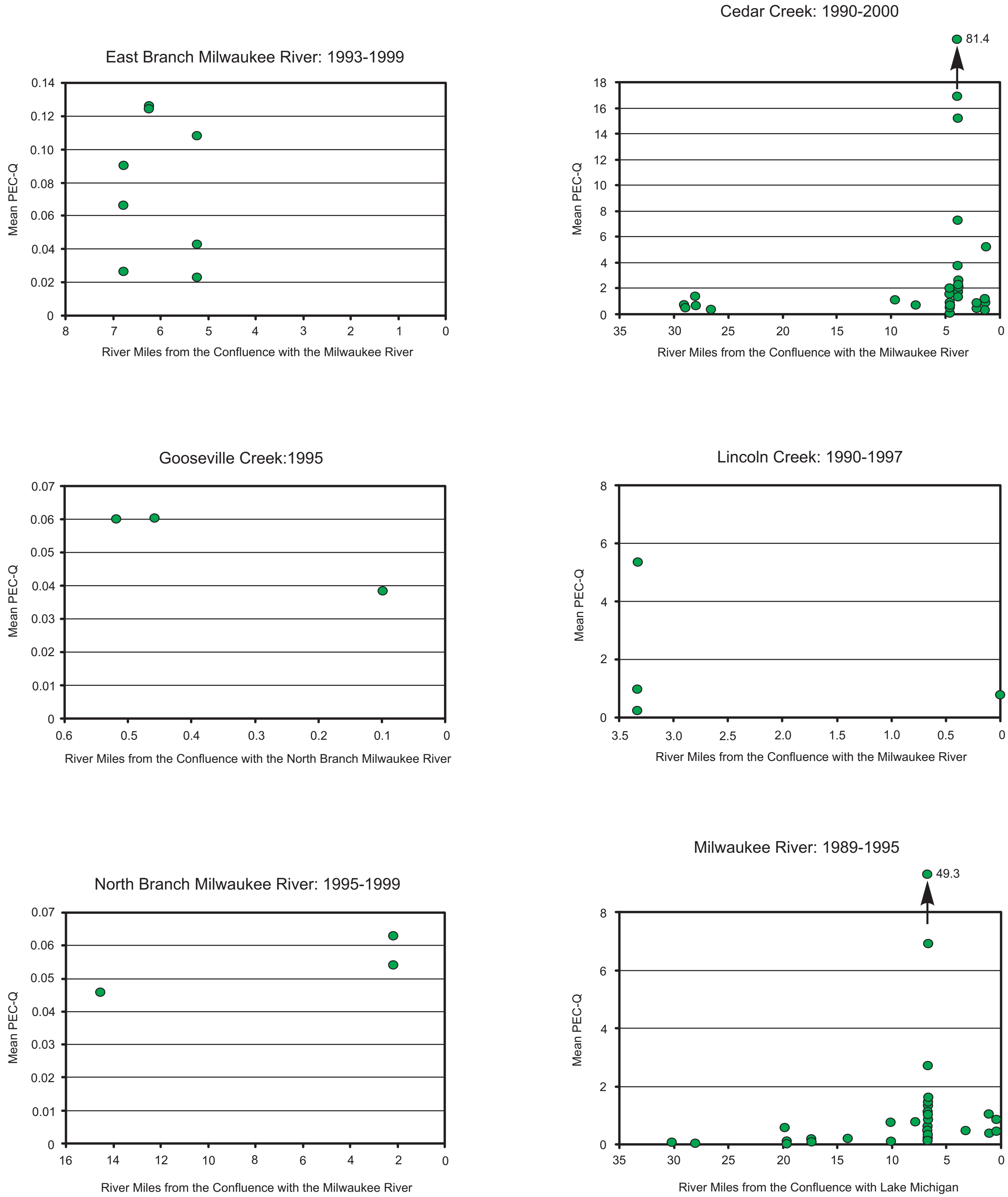


Figure 161

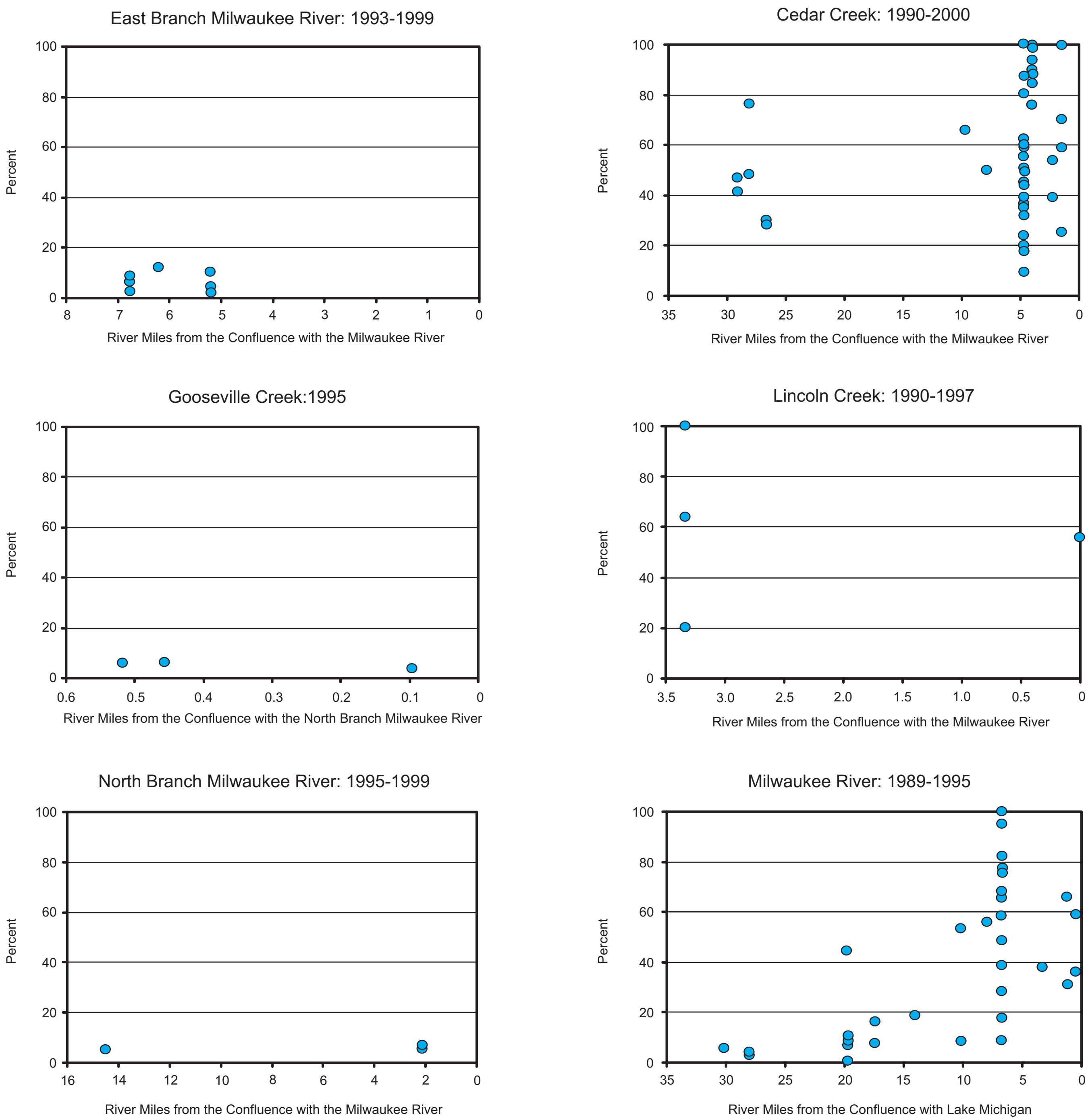
MEAN PROBABLE EFFECT QUOTIENTS (PEC-Q) FOR SEDIMENT IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1989-2000



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 162

ESTIMATED INCIDENCE OF TOXICITY TO BENTHIC ORGANISMS IN THE MILWAUKEE RIVER WATERSHED: 1989-2000



Source: Wisconsin Department of Natural Resources and SEWRPC.

due to the presence of heavy metals in the sediment. In downstream reaches, the high values of mean PEC-Q result from PCB contamination. By comparison, mean PEC-Q values are lower in sediment from the East Branch of the Milwaukee River, Gooseville Creek, and the North Branch of the Milwaukee River. In these three streams, mean PEC-Q is below 0.14 in all samples. Estimated incidences of toxic effects to benthic organisms are below 20 percent for samples from the East Branch of the Milwaukee River and below 10 percent for samples from Gooseville Creek and the North Branch of the Milwaukee River.

BIOLOGICAL CONDITIONS OF THE MILWAUKEE RIVER AND ITS TRIBUTARIES

Aquatic and terrestrial wildlife communities have educational and aesthetic values, perform important functions in the ecological system, and are the basis for certain recreational activities. The location, extent, and quality of fishery and wildlife areas and the type of fish and wildlife characteristics of those areas are, therefore, important determinants of the overall quality of the environment in the Milwaukee River watershed.

Fisheries

Creeks and Rivers

Review of the fishery data collected in the Milwaukee River basin between 1900 and 2004 indicates an apparent net loss of about 10 total species throughout the watershed during this time period as shown in Table 105.[28] Table 105 indicates a loss of more than 20 species during the period of 1987 through 1997; however, this apparent decrease seems to be due, in part, to a decreased sampling effort. For example, the 1987-1993 time period contained about one-eighth the number of recorded total samples per year compared to the 1975-1986 time period. Table 105 also shows that the historical and current numbers of species have been, and continue to be, relatively high with a total of more than 60 different species, but the overall fish species composition has changed during this time period. The most recent fishery surveys in 1998-2004 indicated an apparent loss of about 12 species that have not been observed since 1986 that include the pugnose shiner, which is a threatened species in the State of Wisconsin; weed shiner and banded killifish, which are species of special concern in the State of Wisconsin; and the banded darter, northern hog sucker, pallid shiner, pugnose minnow, bullhead minnow, longnose dace, river shiner, warmouth, and yellow bass. Six of these species lost were intolerant fish species sensitive to degraded water quality conditions. The 1998-2004 surveys also indicate an apparent gain of two species that include the emerald shiner and gizzard shad, which are both intermediate tolerance species. It is important to note that these new fish species observations were found in the most downstream reach of the Milwaukee River between the confluence with Lake Michigan and the Estabrook Park dam, which indicates the potential influence of Lake Michigan fishes on the abundance and diversity of fishes within this lower reach of the Milwaukee River (see the "Influence of Dams/Dam Removal" subsection below). Stocking of a third species, lake sturgeon, has also begun in this lower section of the Milwaukee River as part of the Wisconsin Department of Natural Resources continued efforts to enhance this fishery community.

The Milwaukee River watershed contains a variety of both warmwater (maximum daily mean temperature greater than 24 degrees Celsius) and coldwater (maximum daily mean temperature less than 22 degrees Celsius) streams as well as lake and pond systems.[29] The majority of the streams and lakes in the Milwaukee River watershed are considered warmwater fisheries. However, there are several coldwater stream systems that are generally located in the upstream portions of the watershed and include Auburn Lake Creek, Chambers Creek, East Branch of the Milwaukee River, Gooseville Creek, Melius Creek, Mink Creek, Nichols Creek, North Branch of the Milwaukee River, Stony Creek, and Watercress Creek. In terms of the lake systems, only Big Cedar Lake is considered to contain a coldwater fishery (see the "Lakes and Ponds" subsection below). These coldwater systems are generally comprised of either brook trout or brown trout species, which require cold, well-oxygenated water to survive. These systems are rare in southeastern Wisconsin and persist due to a high proportion of groundwater discharge that helps maintain the physiological conditions necessary for these species to survive.

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[28]*Wisconsin Department of Natural Resources,* The State of the Milwaukee River Basin*, PUBL WT-704-2001, August 2001; Don Fago, Wisconsin Department of Natural Resources, "Distribution and Relative Abundance of Fishes in Wisconsin: VIII. Summary Report,"* Technical Bulletin No. 75*, 1992; Wisconsin Department of Natural Resources, "Distribution and Relative Abundance of Fishes in Wisconsin: IV. Root, Milwaukee, Des Plaines, and Fox River Basins,"* Technical Bulletin No. 147*, 1984; George Becker,* Fishes of Wisconsin*, University of Wisconsin Press, 1983; and M. Miller, J. Ball, and R. Kroner, Wisconsin Department of Natural Resources,* An Evaluation of Water Quality in the Milwaukee River Priority Watershed*, Publication WR-298-92, January 1992.*

[29]*John Lyons, "Development and Validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin,"* North American Journal of Fisheries Management, Volume 16, May 1996.

Table 105

FISH SPECIES COMPOSITION IN THE MILWAUKEE RIVER WATERSHED: 1900-2004

Species According to Their Relative Tolerance to Pollution	Percent Occurrence[a]				
	1900-1974	1975-1986	1987-1993	1994-1997	1998-2004
Intolerant					
Banded Darter	0	1	0	0	0
Blackchin Shiner	2	4	2	0	1
Blacknose Shiner	6	6	10	0	1
Greater Redhorse[b]	5	9	57	12	14
Least Darter[c]	1	2	0	0	1
Longear Sunfish[b]	6	3	4	0	7
Iowa Darter	1	7	2	99	18
Mimic Shiner	41	1	0	0	7
Mottled Sculpin	3	10	2	4	29
Northern Hog Sucker	1	0	0	0	0
Pallid Shiner	0	<1	0	0	0
Pugnose Minnow	0	<1	0	0	0
Pugnose Shiner[b]	1	2	0	0	0
Rock Bass	22	30	65	9	30
Rosyface Shiner	8	1	0	0	1
Smallmouth Bass[d]	6	6	35	7	18
Spottail Shiner	2	2	0	0	2
Stonecat	7	15	31	7	29
Weed Shiner[c]	2	0	0	0	0
Tolerant					
Banded Killifish[c]	1	2	0	0	0
Black Bullhead	22	39	31	19	33
Blacknose Dace	9	15	10	10	34
Bluntnose Minnow	1	6	0	9	34
Brown Bullhead	8	4	0	3	0
Central Mudminnow	8	37	16	30	57
Common Carp	13	23	67	9	23
Creek Chub	20	37	24	22	74
Fathead Minnow	8	15	18	48	36
Golden Shiner	6	16	6	7	7
Goldfish	1	30	4	16	2
Green Sunfish	17	43	73	55	52
White Sucker	40	66	80	49	83
Yellow Bullhead	7	19	33	16	25
Intermediate					
Black Crappie	17	14	22	7	13
Blackside Darter	7	8	33	6	18
Blackstripe Topminnow	0	2	4	0	4
Bluegill	27	38	63	25	43
Bigmouth Shiner	0	0	2	0	2
Brassy Minnow	0	<1	2	0	0
Brook Stickleback	5	14	4	16	38
Brook Trout[d]	1	6	2	- -[d]	8
Brown Trout[d]	1	2	- -[d]	- -[d]	3
Bullhead Minnow	0	4	0	0	0
Central Stoneroller	1	11	12	12	13
Channel Catfish	1	1	0	0	3
Chinook Salmon[d]	- -[d]	<1	- -[d]	- -[d]	- -[d]
Coho Salmon[d]	- -[d]	<1	- -[d]	- -[d]	- -[d]
Common Shiner	24	42	51	36	63
Emerald Shiner	0	0	0	0	3
Fantail Darter	9	21	12	21	36
Gizzard Shad	0	0	0	1	1
Golden Redhorse	2	7	51	6	13

Table 105 (continued)

Species According to Their Relative Tolerance to Pollution	Percent Occurrence[a]				
	1900-1975	1975-1986	1987-1993	1994-1997	1998-2004
Intermediate (continued)					
Hornyhead Chub	22	25	51	21	45
Johnny Darter	41	28	33	99	42
Lake Chubsucker[c]	1	2	0	0	1
Lake Sturgeon[e]	0	0	0	0	- -[e]
Largemouth Bass	30	37	33	13	36
Largescale Stoneroller	13	3	20	9	4
Logperch	6	10	18	9	18
Longnose Dace	2	0	0	0	0
Northern Pike	29	39	51	25	25
Northern Redbelly Dace	1	6	0	0	5
Orangespotted Sunfish	0	1	0	0	1
Pearl Dace	1	7	0	0	8
Pumpkinseed	30	40	59	30	27
Rainbow Trout[d]	3	1	- -[d]	- -[d]	4
Redfin Shiner[b]	10	2	8	1	0
River Shiner	1	0	0	0	0
Sand Shiner	13	10	29	9	5
Shorthead Redhorse	1	3	2	1	3
Silver Redhorse	1	1	0	4	3
Southern Redbelly Dace	10	5	6	1	6
Spotfin Shiner	4	11	31	7	13
Striped Shiner[f]	8	3	0	1	0
Tadpole Madtom	7	6	12	7	13
Walleye[d]	9	4	8	- -[d]	- -[d]
Warmouth	3	1	0	0	0
White Bass	3	<1	2	0	0
White Crappie	0	1	2	0	0
Yellow Bass	3	<1	0	0	0
Yellow Perch	29	24	24	15	22
Total Number of Samples	143	446	49	67	119
Total Number of Samples per Year	1.9	40.5	4.9	22.3	19.8
Total Number of Species	69	73	53	50	63

NOTE: Data includes samples in both streams and lakes within the Milwaukee River watershed.

[a]*Values represent percent occurrence, which equals 100 times the number of sites where each species was found divided by the total number of sites within a given time period.*

[b]*Designated threatened species.*

[c]*Designated species of special concern.*

[d]*These species are stocked by Wisconsin Department of Natural Resources managers.*

[e]*Lake Sturgeon were stocked in 2004 in the Milwaukee River in Ozaukee County.*

[f]*Designated endangered species.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

It is important to note that in order to provide quality recreational fishing opportunities throughout the Milwaukee River watershed, some of the warmwater and coldwater fisheries in both streams and lakes are supplemented by stocking to enhance the existing fishery where habitat, water quality, and/or overharvesting have led to decreased stocks (see Table 106). As shown in Table 106 stocking occurs in Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington Counties. Largemouth bass, smallmouth bass, walleye, northern pike, walleye, and muskellunge tend to be stocked in warmwater areas. Brook trout, brown trout, and rainbow trout tend to be stocked in the coldwater areas.

Table 106

FISH STOCKING OF FRY, FINGERLING, AND JUVENILE FISHES IN STREAM REACHES AND LAKES/PONDS IN THE MILWAUKEE RIVER WATERSHED: 1982-2004

Stream/Pond	Species	Earliest Record	Recent	Annual Average Number Stocked
Milwaukee County				
Milwaukee River	Brook Trout Brown Trout Chinook Salmon Coho Salmon Rainbow Trout Walleye	1992 1992 1989 1992 1989 1986	- - 1998 1997 2004 2004 2004	9,200 20,834 149,375 14,137 17,485 7,758
Brown Deer Park Pond	Largemouth Bass Rainbow Trout	1991 1984	- - 2004	1,250 2,321
Dineen Park Pond	Rainbow Trout	1984	2004	989
Estabrook Park Pond	Largemouth Bass Rainbow Trout	1991 1984	- - 2004	50 458
Juneau Park Lagoon	Largemouth Bass Rainbow Trout	1991 1988	- - 2004	725 3,070
McGovern Park Pond	Largemouth Bass Rainbow Trout Centrarchid species	1987 1986 1986	1991 2004 1988	1,075 2,264 2,056
Fond du Lac County				
Auburn Lake	Walleye	1986	1987	400,000
Auburn Lake Creek	Brook Trout Brown Trout	1972 1988	2003 - -	488 500
Campbellsport Millpond	Northern Pike	1977	1978	78,500
Forest Lake	Largemouth Bass	1974	1984	6,500
Kettle Moraine Lake	Largemouth Bass Northern Pike Walleye	1976 1977 1986	- - - - 1992	10,000 20,000 262,225
Lake Bernice	Largemouth Bass	1972	1976	3,083
Long Lake	Northern Pike Walleye	- - 1983	2004 2003	240,000 76,171
Milwaukee River	Smallmouth Bass	1983	1985	4,593
Silver Creek	Brown Trout	1998	2001	10,805
Ozaukee County				
Cedarburg Pond	Centrarchid hybrid	1987	- -	4,860
Cedarburg Stone Quarry	Largemouth Bass Rainbow Trout Centrarchid hybrid	1988 1985 1986	- - 1991 - -	650
Hawthorne Hills Pond	Largemouth Bass	1982	1983	450
Milwaukee River	Lake Sturgeon	- -	2004	2,200
North Branch Milwaukee River	Catfishes	1973	- -	30,450

Table 106 (continued)

Stream/Pond	Species	Earliest Record	Recent	Annual Average Number Stocked
Sheboygan County				
Beechwood Lake	Largemouth Bass Northern Pike	1982 1982	1983 2001	1,750 10,815
Butler Lake	Brook Trout Rainbow Trout	1981 1972	1985 1992	1,017 1,090
Crooked Lake	Northern Pike	1980	1992	428
Lake Ellen	Northern Pike Walleye	1980 1975	1995 2004	640 8,035
Melius Creek	Brook Trout Brown Trout	1980 1972	1992 2003	640 764
Mink Creek	Brook Trout	1994	2002	335
Random Lake	Muskellunge Northern Pike Walleye	1991 1991 1991	2004 1996 2004	453 1,216 15,909
Watercress Creek	Brook Trout	1972	1997	828
Washington County				
Big Cedar Lake	Lake Trout Walleye	1985 1986	2004 2003	20,849 73,550
Green Lake	Northern Pike Walleye	1991 1984	1993 - -	39 5,605
Kewaskum Millpond	Rainbow Trout	1994	1999	1,200
Little Cedar Lake	Walleye	2001	2003	15,643
Milwaukee River	Northern Pike Smallmouth Bass Walleye	1983 1984 1982	- - - - 1984	2,015 2,079 10,284
Wallace Lake	Largemouth Bass	1988	- -	24,000

Source: Wisconsin Department of Natural Resources and SEWRPC.

In Wisconsin, high-quality warmwater streams are characterized by many native species including cyprinids, darters, suckers, sunfish, and percids that typically dominate the fish assemblage. Intolerant species (species that are particularly sensitive to water pollution and habitat degradation) are also common in high-quality warmwater systems.[30] Tolerant fish species (species that are capable of persisting under a wide range of degraded conditions) are also typically present within high-quality warmwater streams, but they do not dominate. Insectivores (fish that feed primarily on small invertebrates) and top carnivores (fish that feed on other fish, vertebrates, or large invertebrates) are generally common. Omnivores (fish that feed on both plant and animal material) are also generally common, but do not dominate. Simple lithophilous spawners which are species that lay their eggs directly on large substrate, such as clean gravel or cobble, without building a nest or providing parental care for the eggs are also generally common.

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[30]*John Lyons, "Using the Index of Biotic Integrity (IBI) to Measure Environmental Quality in Warmwater Streams of Wisconsin," United States Department of Agriculture,* General Technical Report NC-149*, 1992.*

In contrast to warmwater streams, coldwater systems are characterized by few native species, with salmonids (trout) and cottids (sculpin) dominating, and they lack many of the taxonomic groups that are important in high-quality warmwater streams as summarized above. An increase in fish species richness in coldwater fish assemblages often indicates environmental degradation. When degradation occurs the small number of coldwater species are replaced by a larger number of more physiologically tolerant cool and warmwater species, which is the opposite of what tends to occur in warmwater fish assemblages. Due to the fundamental differences between warmwater versus coldwater streams a separate IBI was developed to assess the health of coldwater streams.[31] This coldwater IBI is based upon the following elements: number of intolerant species, percent of individuals that are tolerant, percent of all individuals that are top carnivore species, percent of all individuals that are native or exotic coldwater (coho salmon, chinook salmon, rainbow trout, brown trout) or coolwater species, and percent of salmonid individuals that are brook trout. Since brook trout are the only native stream dwelling salmonid in the State of Wisconsin, the presence and abundance of brook trout dramatically improves the coldwater IBI scores.

Both the warmwater IBI and coldwater IBI were used to assess the fishery among warmwater and coldwater streams as appropriate in the analyses of the fisheries abundance and distribution that are presented below.

When applying the Index of Biotic Integrity (IBI) that is used to measure environmental quality in warmwater and coldwater streams of Wisconsin, it is recommended that electrofishing gear be used as opposed to other techniques such as seining or fyke netting.[32] Table 105 summarizes all fish species found within both stream and lake systems by selected time periods throughout the entire Milwaukee River watershed from samples collected by a variety of gear types. Maps 56 and 57 show the location and quality of fisheries samples collected by all gear types for the Milwaukee River watershed from 1900 to 1997 and 1998 to 2004. Figure 163 shows the fisheries samples collected among rivers and creeks throughout the Milwaukee River watershed by selected time periods and their associated IBI scores among specific gear types that include the backpack electrofisher (generator carried on a backpack), long line electrofisher, stream electrofisher (generator towed by hand in the stream), boom electrofisher (generator located on a boat), and net or any type of net or seine. Since different sampling gear types affect the type and amount of different fish species caught, samples collected with any net or seine and long line electrofisher methods were removed prior to computing IBI scores among each of the time periods. The backpack electrofishing, stream electrofishing, and boom shocking gear types are legitimate gear types when applying the fisheries IBI and these are the only gear types sampled most consistently among the selected time periods as shown in Figure 164. Therefore, only samples using backpack, stream electrofishing, and boom electrofishing gear types were used to assess the fisheries community in the Milwaukee River watershed as summarized below.

Index of Biotic Integrity (IBI) results indicate that there has been an improvement in the quality of the fishery of the Milwaukee River watershed compared to the historical conditions moving from the very poor (IBI score 0-20) to a fair community IBI rating score of 30 to 49 based on mean IBI scores for each time period as shown in Figure 163. In addition, 25 percent of the current 1998-2004 time period samples were classified as good to excellent. However, 25 percent of the samples in the current time period still remain classified within the very poor categories, which indicate that the majority of the watershed contains a high abundance and diversity of fishes.

The Milwaukee River watershed fishery has consistently had about 25 percent of samples that are dominated by a high proportion of low dissolved oxygen tolerant fishes as shown in Figure 165 and Table 105, which is supported by dissolved oxygen problems identified in the water quality analysis above for the North Branch Milwaukee River, Lincoln Creek, and Lower Milwaukee River subwatersheds. Tolerant fish species tend to become dominant when water quality conditions become degraded, potentially leading to low levels of dissolved oxygen

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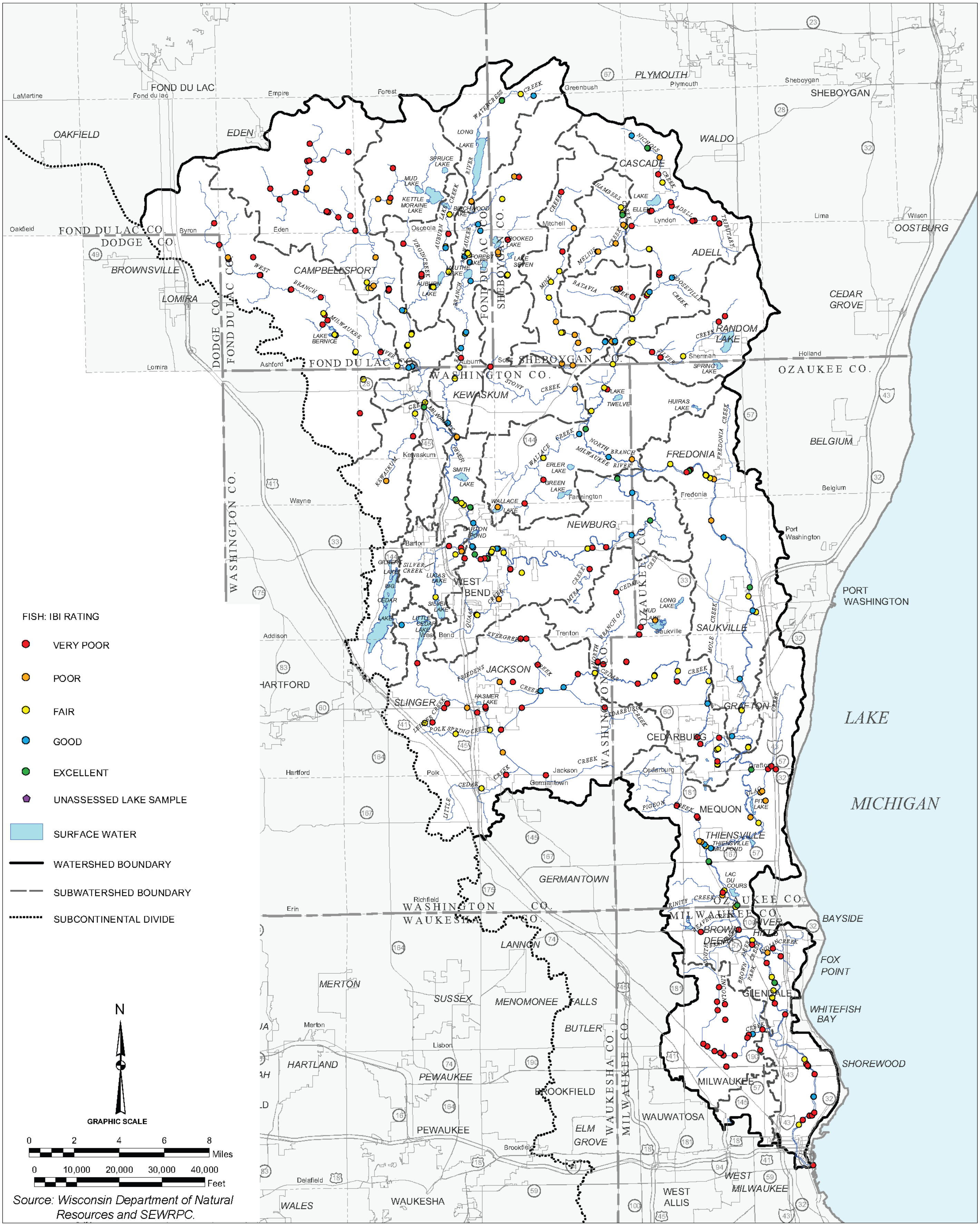
[31]*John Lyons, "Development and Validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin,"* North American Journal of Fisheries Management, Volume 16, May 1996.

[32]*John Lyons,* General Technical Report NC-149*,* op. cit.

Map 56

FISHERIES SAMPLE LOCATIONS AND CONDITIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 1900-1997



Map 57

FISHERIES SAMPLE LOCATIONS AND CONDITIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 1998-2004

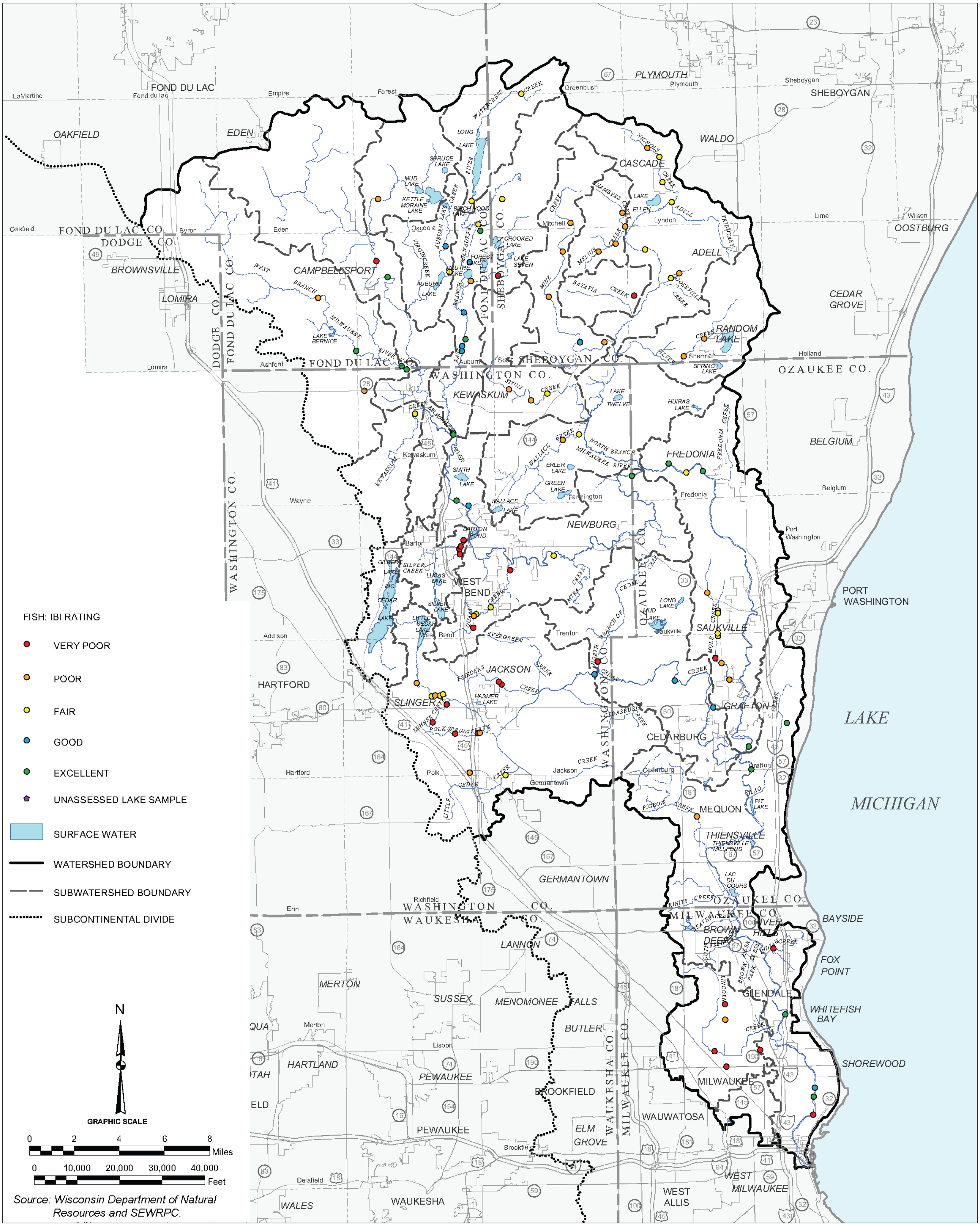
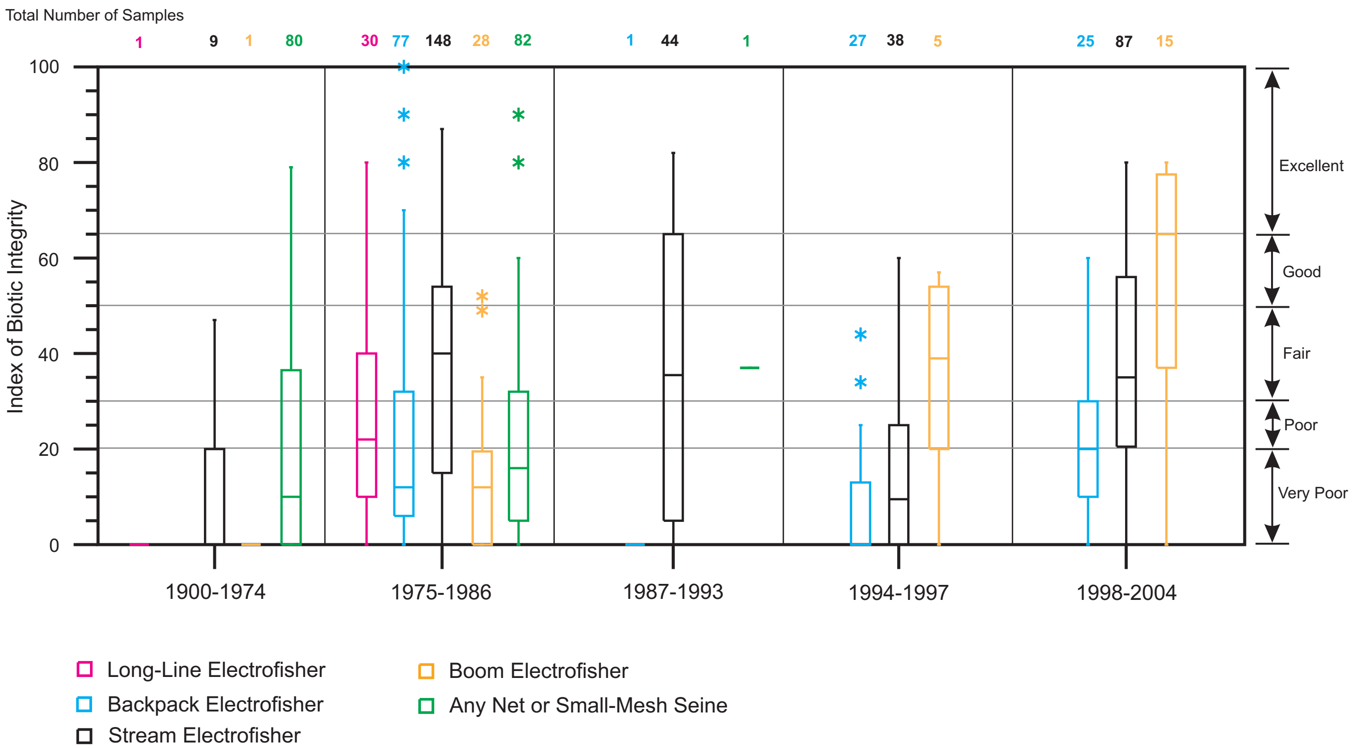


Figure 163

FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION BY GEAR TYPE IN THE MILWAUKEE RIVER WATERSHED: 1900-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

concentrations, increased levels of ammonia and other toxic substances, and/or high turbidity levels.[33] However, as shown in Figure 165 and Table 105 the proportions of dissolved oxygen tolerant fishes in the majority of the samples from 1975 to present have not exceeded 40 percent, which is consistent with a healthy and diverse fish community. Low dissolved oxygen concentrations and extreme high or low temperature fluctuations have been identified to be one of the major factors negatively impacting the warm and coldwater fishery on this system.[34] Carp, an exotic invasive species, are present but are not a dominant component of the fishery in this watershed. They continue to threaten the overall quality of this fishery by destroying habitat and competing for food and spawning areas of native fish species.

In addition to the relatively consistent low proportions of tolerant species in this watershed over time, there has also been a sustained good proportion of top carnivore fish species, which is indicative of a good balance of predator fishes to forage fishes ratio in this system as shown in Figure 166. The top carnivore species also tend to be highly sought after gamefish species by anglers, which indicate that recreational fishing opportunities may be increasing. The top carnivore species responsible for this shift include the largemouth bass, northern pike, and rock bass. (see Table 105).

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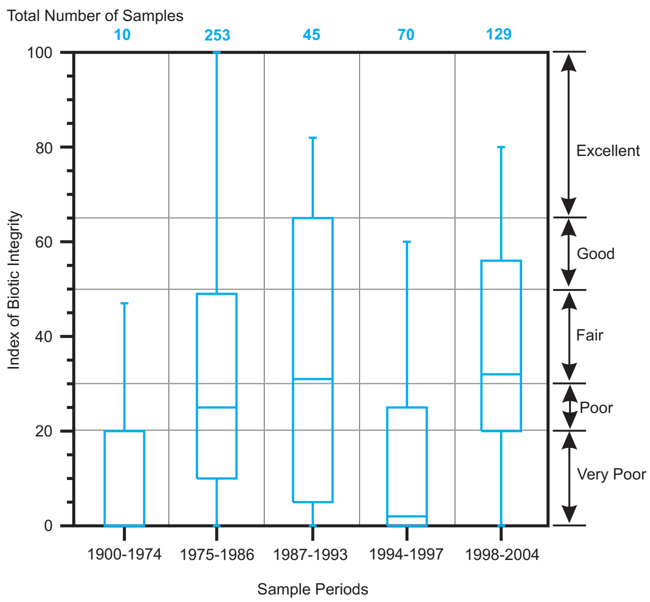
[33]*George Becker,* op. cit.

[34]*Wisconsin Department of Natural Resources, PUBL WT-704-2001,* op. cit.

Figure 164

FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION FROM ELECTROFISHING EFFORT IN THE MILWAUKEE RIVER WATERSHED: 1900-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

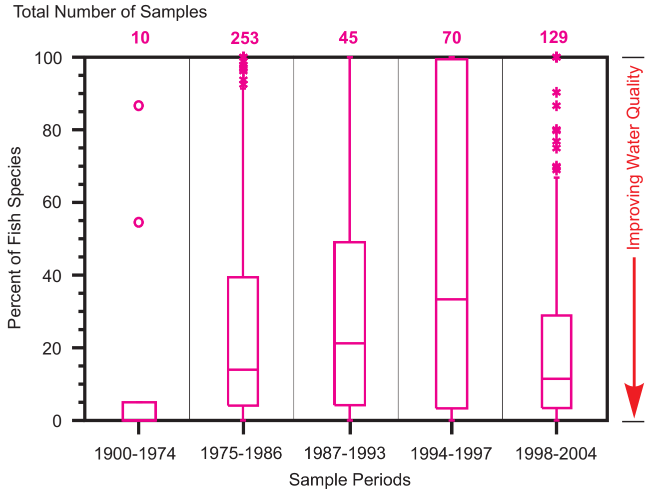
There are adequate data to assess the current fishery conditions within most of the subwatersheds during the 1998 through 2004 period as shown in Figure 167. For example, only the Kettle Moraine Lake, Kewaskum Creek, and Batavia Creek subwatersheds have only one survey record in the current time period. However, the results for these subwatersheds generally indicate that there has been an improvement in the fishery community quality from the historic very poor IBI rating, with the possible exception of the Batavia Creek subwatershed that shows a very poor IBI classification. Figure 167 also shows that nearly all of the subwatersheds either remained the same quality—as demonstrated in the Middle Milwaukee, North Branch Milwaukee River, Mink Creek, Silver Creek (Sheboygan County), Upper Lower Milwaukee River, Stony Creek, Cedar Creek, and Lincoln Creek subwatersheds—or improved in quality—as demonstrated in the Upper Milwaukee River, Kettle Moraine Lake, Lake Fifteen Creek, West Branch of the Milwaukee River, East Branch of the Milwaukee River, Lower Cedar Creek, and Lower Milwaukee River subwatersheds. However, several subwatersheds including Watercress Creek, Silver Creek (West Bend), and Chambers Creek have decreased in quality.

In general, most of the subwatersheds indicating an improvement in the abundance and diversity of fishes are located in the upper portions of the Milwaukee River watershed (see Figure 167), with the exception of the Lower Cedar Creek and Lower Milwaukee River subwatersheds in the downstream areas (see the "Influence of Dams/Dam Removal" subsection below). The poorest quality subwatersheds include Silver Creek (West Bend), Chambers Creek, Batavia Creek, and Lincoln Creek, each of which achieved a classification of very poor (HBI score 0-20). Samples within the Mink, Silver (Sheboygan County), and Stony Creek subwatersheds are classified as poor, which indicates that these subwatersheds are also on the lower end of the fishery quality spectrum. The Chambers Creek, Mink Creek, Silver Creek (Sheboygan County), and Stony Creek subwatersheds include Melius Creek, Chambers Creek, Mink Creek, and Stony Creek, which are coldwater streams. That indicates that these trout streams contain degraded fisheries. In addition, the Watercress Creek subwatershed, which is also a coldwater system, moved from an excellent fishery to a fair classification, further indicating that many of the coldwater streams have become, or are becoming, degraded. The Silver Creek (West Bend), Batavia Creek, and Lincoln Creek subwatersheds are degraded warmwater systems.

The fishery IBI quality among subwatersheds within the Milwaukee River watershed spans the entire range in quality from very poor (IBI score 0-19) to excellent (IBI score 65-100). The majority of the subwatersheds ranged from a poor to fair (IBI score 20-49) classification. However, 10 subwatersheds, or about 50 percent, also achieved scores within the good (IBI score 50-64) classification and six subwatersheds, or about 30 percent, achieved scores within the excellent range. The highest quality subwatersheds include the Upper Milwaukee River, West Branch of the Milwaukee River, East Branch of the Milwaukee River, and Middle Milwaukee River, which comprise state designated exceptional resource waters, coldwater, and warmwater systems. The Upper Lower Milwaukee River and Lower Milwaukee River subwatersheds also contain selected areas of high quality warmwater fisheries. Figure 167 demonstrates that, except for some areas within the Upper Milwaukee River, West Branch of the Milwaukee River, East Branch of the Milwaukee River, Middle Milwaukee River, Upper

Figure 165

PROPORTIONS OF DISSOLVED OXYGEN TOLERANT FISHES FROM ELECTROFISHING EFFORT IN THE MILWAUKEE RIVER WATERSHED: 1900-2004

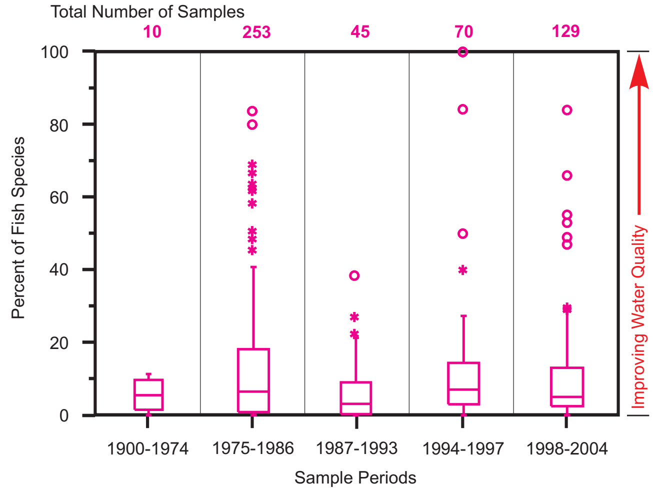


NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 166

PROPORTIONS OF TOP CARNIVORES FROM ELECTROFISHING EFFORT IN THE MILWAUKEE RIVER WATERSHED: 1900-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Lower Milwaukee River, and Lower Milwaukee River subwatersheds that contain good, and in some cases, excellent fishery quality, the majority of the samples throughout the Milwaukee River watershed indicate only a poor to fair fishery.

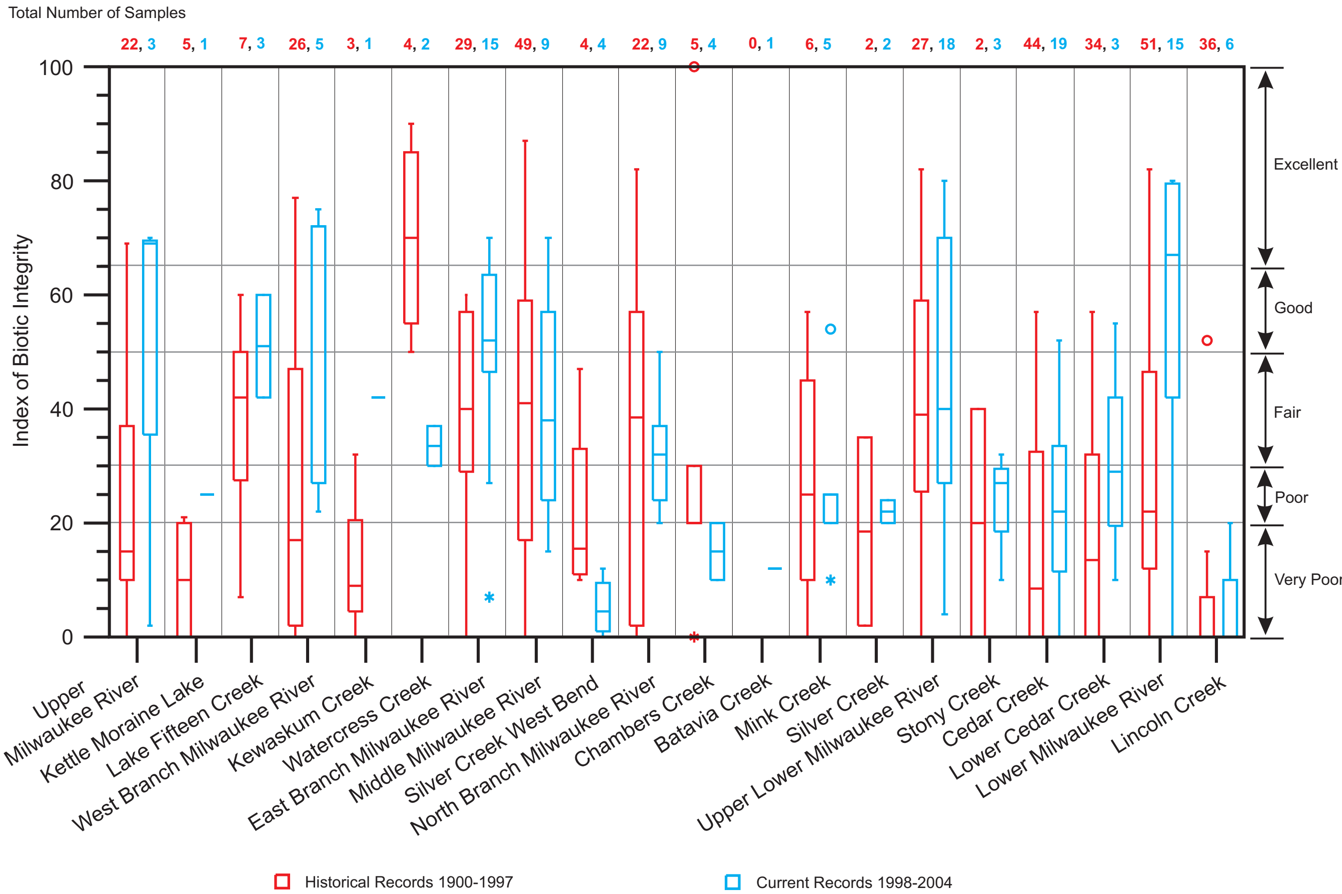
Further analysis of both the East Branch of the Milwaukee River and Lower Milwaukee River subwatersheds indicates that the proportions of insectivorous fishes have generally remained consistently high from 1975 to 2004 as shown in Figure 168. This demonstrates that these communities are fairly balanced trophically and implies that the diversity and abundance of the food base throughout most of the areas in each of these subwatersheds has remained high. This result also agrees with the high quality macroinvertebrate communities found in the East Branch of the Milwaukee River and Lower Milwaukee River subwatersheds as summarized below. However, as previously mentioned, these subwatersheds contain areas with some of the highest quality fisheries in the Milwaukee River watershed and most of the areas in the rest of the watershed have only poor to fair diversity and abundance of fishes.

Although a small portion of the fishery is of high quality, the majority of these areas are located either in tributary streams in the northern portions of the Milwaukee River watershed, or in the lower portions in proximity to Lake Michigan, where recruitment from the lake has enriched the fishery. There are many areas throughout the watershed where the fishery quality has remained poor to fair or where the fishery quality has declined. The apparent stagnation of the majority of the fishery community within the Milwaukee River watershed can be attributed to habitat loss and degradation as a consequence of human activities primarily related to the historic and current agricultural and urban land use development that has occurred within the watershed. Agricultural and/or urban development can cause numerous changes to streams that have the potential to alter aquatic biodiversity that include but are not limited to the following factors which have been observed to varying degrees in the Milwaukee River watershed:[35]

[35]*Center for Watershed Protection, "Impacts of Impervious Cover on Aquatic Systems,"* Watershed Protection Research Monograph No. 1*, March 2003.*

Figure 167

HISTORICAL AND BASE PERIOD FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION FROM ELECTROFISHING EFFORT IN THE MILWAUKEE RIVER WATERSHED: 1900-2004

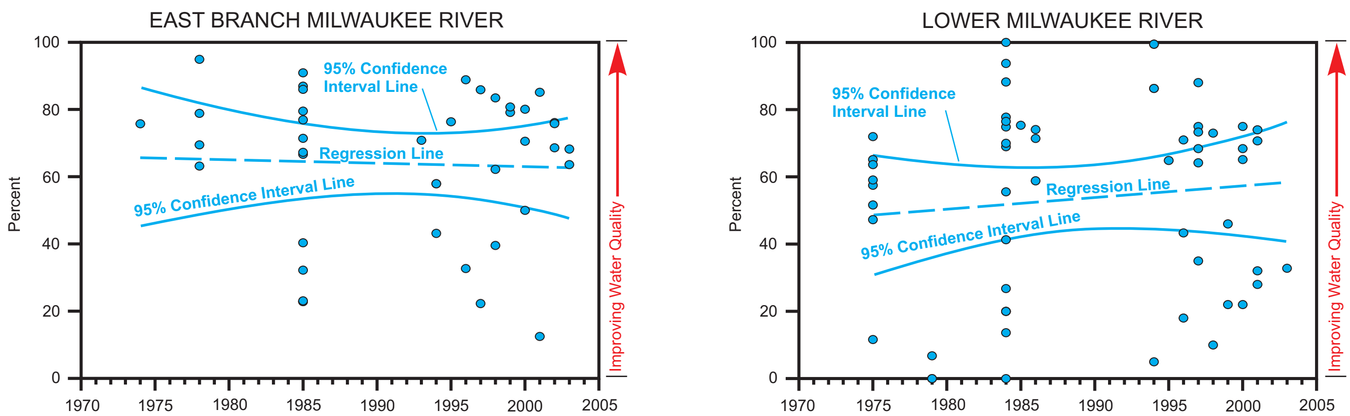


NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 168

PROPORTIONS OF INSECTIVOROUS FISHES AMONG SUBWATERSHEDS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



Source: Wisconsin Department of Natural Resources and SEWRPC.

- Increased flow volumes and channel-forming storms—These alter habitat complexity, change availability of food organisms related to timing of emergence and recovery after disturbance, reduce prey availability, increase scour related mortality, deplete large woody debris for cover in the channel, and accelerate streambank erosion;

- Decreased base flows—These lead to increased crowding and competition for food and space, increased vulnerability to predation, decrease in habitat quality, and increased sediment deposition;

- Increased sediment load from cultivated agricultural lands and urban lands during and after construction of urban facilities, resulting in sediment transport and deposition in streams—This leads to reduced survival of eggs, loss of habitat due to deposition, siltation of pool areas, and reduced macroinvertebrate reproduction;

- Loss of pools and riffles—This leads to a loss of deep water cover and feeding areas causing a shift in balance of species due to habitat changes;

- Changed substrate composition—This leads to reduced survival of eggs, loss of inter-gravel cover refuges for early life stages for fishes, and reduced macroinvertebrate production;

- Loss of large woody debris—This leads to loss of cover from large predators and high flows, reduced sediment and organic matter storage, reduced pool formation, and reduced organic substrate for macroinvertebrates;

- Increased temperatures due to loss of riparian buffers as well as runoff from pavement–This leads to changes in migration patterns, increased metabolic activity, increased disease and parasite susceptibility, and increased mortality of sensitive fishes and macroinvertebrates;

- Creation of fish blockages by road crossings, culverts, drop structures, and dams—This leads to loss of spawning habitat, inability to reach feeding areas and/or overwintering sites, loss of summer rearing habitat, and increased vulnerability to predation;

- Loss of vegetative rooting systems—This leads to decreased channel stability, loss of undercut banks, and reduced streambank integrity;

- Channel straightening or hardening—This leads to increased stream scour and loss of habitat quality and complexity (i.e. width, depth, velocity, and substrate diversity) through disruption of sediment transport ability;

- Reduced water quality—This leads to reduced survival of eggs and juvenile fishes, acute and chronic toxicity to juveniles and adult fishes, and increased physiological stress;

- Increased turbidity—This leads to reduced survival of eggs, reduced plant productivity, and increased physiological stress on aquatic organisms; and

- Increased algae blooms due to increased nutrient loading—Chronic algae blooms, resulting from increased nutrient loading, lead to oxygen depletion, causing fish kills, and to increased eutrophication of standing waters. These effects can be worsened through encroachment into the riparian buffer adjacent to the waterbody and loss of riparian canopy which increases light penetration.

Chapter II of this report includes a description of the correlation between urbanization in a watershed and the quality of the aquatic biological resources. The amount of imperviousness in a watershed that is directly connected to the stormwater drainage system can be used as a surrogate for the combined impacts of urbanization in the absence of mitigation. The Milwaukee River watershed included about 10 percent urban land use by 1970, which approximately corresponds to less than 5 percent directly connected imperviousness in the watershed, and, as of 2000, it has about 21 percent urban land overall (approximately 7 percent directly connected imperviousness). That level of imperviousness is just below the threshold level of 10 percent at which previously cited studies indicate that negative biological impacts have been observed.

However, given the pattern of development in the lower portions of this watershed the Lower Milwaukee River, Lincoln Creek, and the Milwaukee/Menomonee River Combined Sewer Service Area subwatersheds are predominantly in urban land uses, and approach 50 to 60 percent directly connected imperviousness. These downstream areas are well above the threshold level of 10 percent where negative biological impacts are expected. As also described in Chapter II of this report, studies have indicated that the amount of agricultural land in a watershed can also be correlated with negative instream biological conditions. The Milwaukee River watershed was comprised of about 70 percent agricultural land use by 1970 and it currently has about 50 percent agricultural land. Agricultural land use has dominated the upper and middle portions of the Milwaukee River watershed, whereas the lower portions of the watershed have been dominated by urban development. Based upon the amount of agricultural and urban lands in the watershed and, in the past, a lack of measures to mitigate the adverse effects of those land uses, the resultant poor to fair IBI scores observed throughout this watershed are not surprising.[36] Consequently, the Wisconsin Department of Natural Resources has recently concluded that the quality of the fishery remains impaired throughout the Milwaukee River watershed primarily due to the impacts of instream habitat loss, undesirable rooted aquatic plants, fish migration interference, eutrophication, flow modifications, temperature extremes, dissolved oxygen, turbidity, and bacteriological contamination. In addition, the fishery in the lower portions of the Milwaukee River watershed are also impaired by general toxicity problems, PCB bioaccumulation, sediment contamination, and heavy metal toxicity.[37]

As shown on Map 58, habitat data for 100 sites have been collected as part of the WDNR baseline monitoring program and by the WDNR Fish and Habitat Research Section in the Milwaukee River watershed. The baseline monitoring program data were analyzed using the Qualitative Habitat Evaluation Index (QHEI),[38] which integrates the physical parameters of the stream and adjacent riparian features to assess potential habitat quality. This index is designed to provide a measure of habitat that generally corresponds to those physical factors that affect fish communities and which are important to other aquatic life (i.e. macroinvertebrates). This index has been shown to correlate well with fishery IBI scores. The habitat data from the WDNR Research Section evaluated the quality of fish habitat at sites based upon the guidelines developed from several publications.[39] Based upon the data collected, the results suggest that fisheries habitat is generally fair to good throughout the Milwaukee River watershed as shown on Map 58. Specifically, about 6 percent of the sites were classified as very

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[36]*The standards and requirements of Chapter NR 151 "Runoff Management," and Chapter NR 216, "Storm Water Discharge Permits," of the* Wisconsin Administrative Code *are intended to mitigate the impacts of existing and new urban development and agricultural activities on surface water resources through control of peak flows in the channel-forming range, promotion of increased baseflow through infiltration of stormwater runoff, and reduction in sediment loads to streams and lakes. The implementation of those rules is intended to mitigate, or improve, water quality and instream/inlake habitat conditions.*

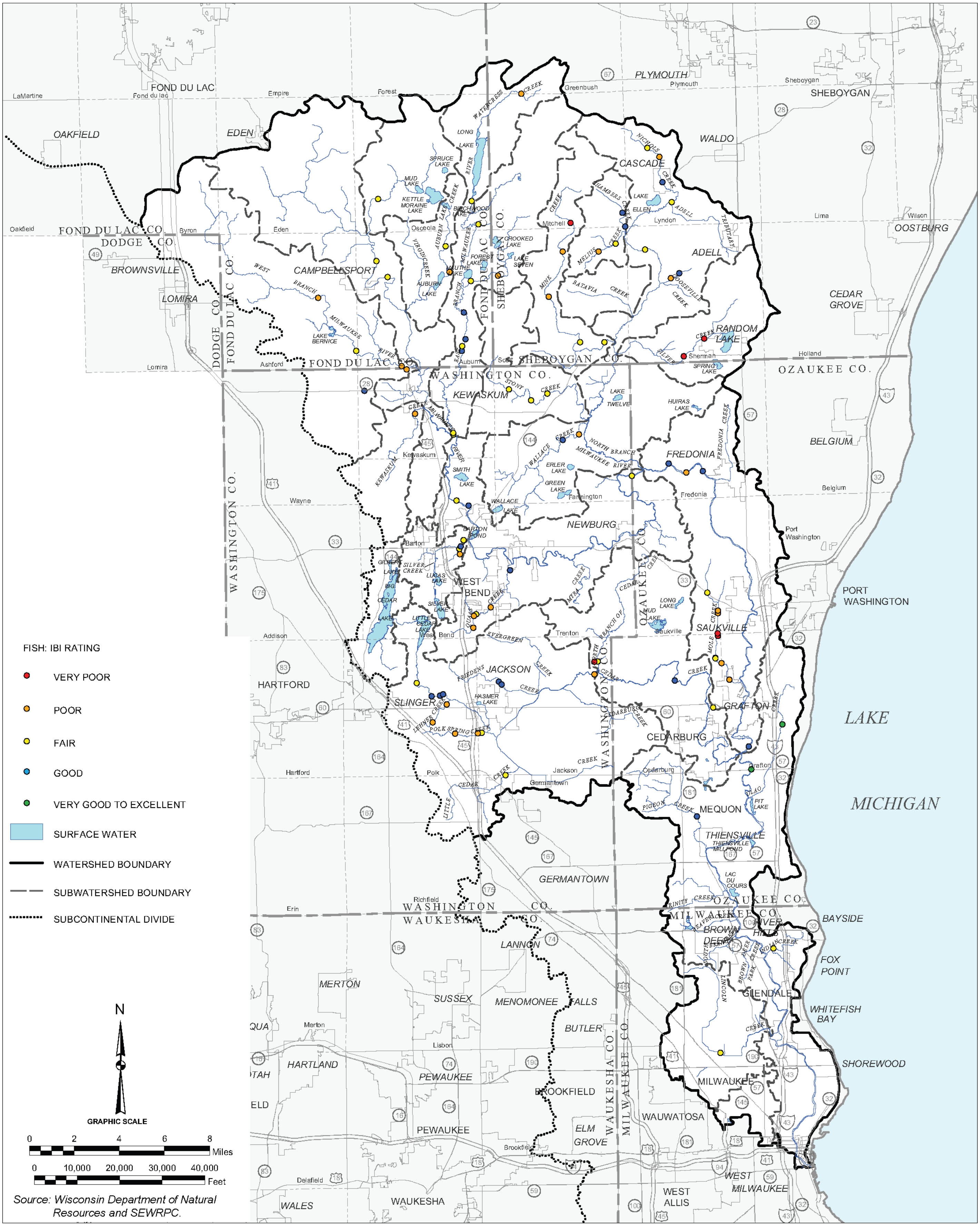
[37]*Wisconsin Department of Natural Resources, PUBL WT-704-2001,* op. cit.

[38]*Edward T. Rankin,* The Quality Habitat Evaluation Index [QHEI]: Rationale, Methods, and Application*, State of Ohio Environmental Protection Agency, November 1989.*

[39]*Timothy Simonson, John Lyons, and Paul Kanehl, "Guidelines for Evaluating Fish Habitat in Wisconsin Streams,"* General Technical Report NC-164*, 1995; and Lihzu Wang, "Development and Evaluation of a Habitat Rating System for Low-Gradient Wisconsin Streams,"* North American Journal of Fisheries Management*, Vol. 18, 1998.*

Map 58

STREAM HABITAT SAMPLE LOCATIONS AND CONDITIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 1998-2004



Source: Wisconsin Department of Natural Resources and SEWRPC.

poor, 27 percent were poor, 35 percent were fair, 28 percent were good, and 4 percent were ranked as very good-excellent. The main limiting factors to habitat quality were siltation among many sites, both at sites with adjacent agricultural and urban lands, as well as reduced amounts and quality of instream cover. Since there are no data available to compare specific locations over time it is not possible to definitively assess changes in habitat conditions over time. It is important to note that significant lengths of streams have been channelized within the Milwaukee River watershed. Such channelization impacts habitat quality by reducing instream and riparian vegetative cover, increasing sedimentation, decreasing diversity of flow, decreasing water depths, and decreasing substrate diversity. Consequently, despite the habitat classification of fair to good, the WDNR has recently concluded that instream habitat is impaired in nearly every reach of the Milwaukee River watershed, primarily due to the impacts of hydrologic modification, stream flow fluctuations caused by unnatural conditions, stream bank erosion, urban storm water runoff, cropland erosion, and roadside erosion emanating from both agricultural and urban land use areas of this watershed.[40]

Influence of Dams/Dam Removal

Dams limit the Milwaukee River fishery by preventing both upstream and downstream immigration and emigration of fishes to and from Lake Michigan, as well as the mainstem of the Milwaukee River to headwater tributaries and/or vice versa; preventing the ability of fishes to reach feeding areas, spawning areas, juvenile rearing habitat, and/or overwintering sites; and increasing the vulnerability of fishes to predation, especially in the downstream area spillways. Limits on fish migration imposed by dams potentially contribute to the reduced abundance and diversity of the fishery over time. Therefore, the fishery was analyzed within the framework of the fragmentation to better understand the abundance and diversity of fishes within this watershed.

It is important to note that drop structures and even culverts can also obstruct fish migration. Map 53 shows the extent of the fragmentation of reaches from downstream to upstream within the Milwaukee River watershed as defined by the location of both dams and drop structures. As shown on Map 53, some reaches are very short, such as Reaches 6 and 10, while some reaches are much longer. In addition, some reaches are completely separated from tributary streams, such as Reaches 4 and 8c, or only connected to one tributary as for Reach 7. In contrast, some reaches are both extensive and well connected to many tributary streams, such as Reaches 8 and 12.

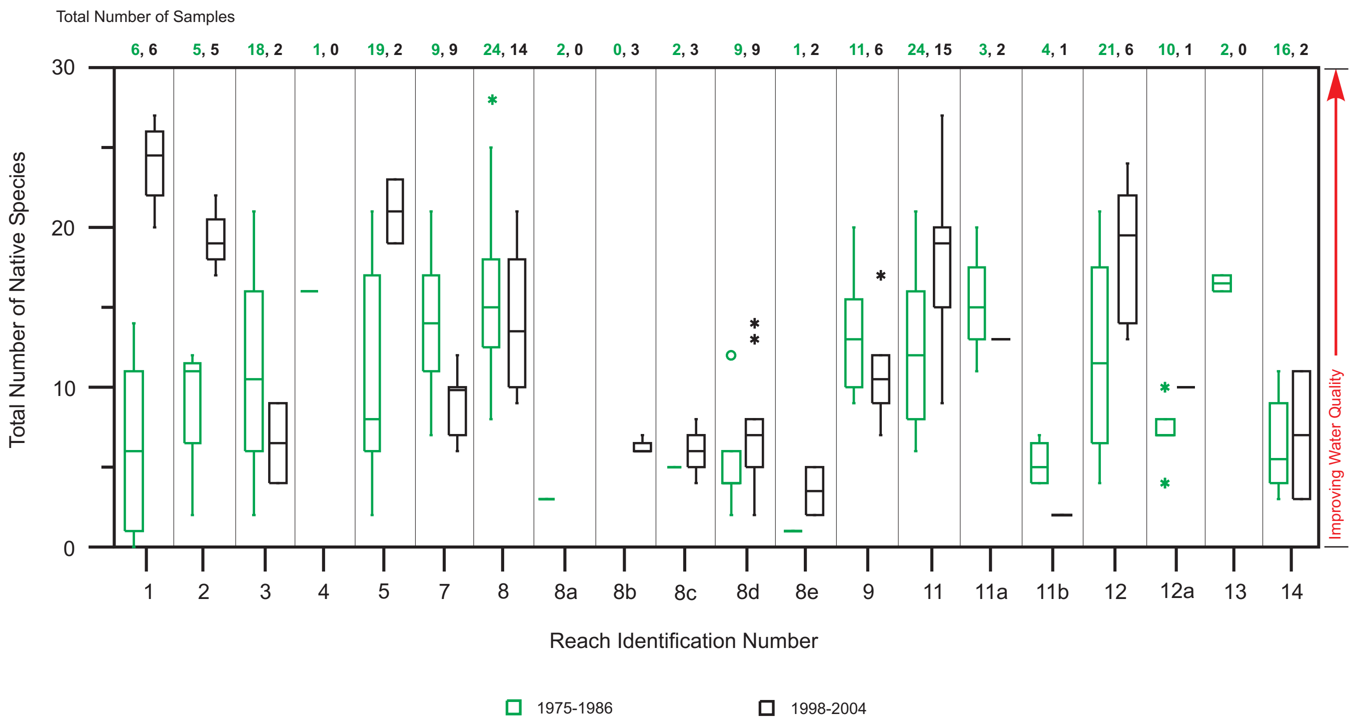
Figure 169 shows the total number of native fishes within the 1975-1986 time period versus the 1998-2004 time period among reaches as identified on Map 53. The mainstem reaches of the Milwaukee River are numbered in increasing order from downstream to upstream. The headwater tributary reaches are labeled according to which reach they flow into on the mainstem (e.g. 8a and 8b flow into Reach 8 on the mainstem). Both time periods on Figure 169 generally show the upstream headwater reaches, including Reaches 8a, 8b, 8c, 8d, 8e, 11b, 12a, and 14 as being much less diverse than the reaches on the mainstem. This is expected given that the smaller, upstream tributaries have much less volume of discharge, tend to be much flashier and shallower, tend to be more likely to go dry, and contain fewer types of available habitat than larger streams. In addition, headwater tributaries are typically coldwater streams, which naturally contain fewer species of fishes compared to the warmwater mainstem streams. Reaches 8b, 8c, 8d, 8e, and 11b are coldwater stream systems, which explain the low number of native species in 1975-1986 and 1998-2004. Although headwater tributaries do not generally contain many species of fishes on an annual basis, these resources are key spawning areas for fishes usually in the spring or fall time periods and they serve as key habitats for maintenance of forage fishes year round. Both of those functions help sustain fishery stocks on the mainstem into which the tributaries flow.

In comparing the 1975-1986 time period to the 1998-2004 time period, Figure 169 shows that some reaches have improved in diversity, some have decreased, and some have stayed the same. Reaches 1, 2, and possibly 5 seem to have increased in diversity. Most notably, Reach 1 increased from an average of five to nearly 25 species, which is due to the removal of the North Avenue dam as described below. In contrast, Reaches 3 and 7 lost species diversity, but this may be a function of sampling efforts on the tributary versus the mainstem of the Milwaukee

[40]*Wisconsin Department of Natural Resources, PUBL WT-704-2001,* op. cit.

Figure 169

TOTAL NUMBER OF NATIVE FISH SPECIES FROM ELECTROFISHING EFFORT AMONG STREAM REACHES SEPARATED BY DAMS AND DROP STRUCTURES IN THE MILWAUKEE RIVER WATERSHED: 1975-1986 AND 1998-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

River. However, the most consistently diverse fish communities within the Milwaukee River watershed are found within Reaches 8, 9, 11, and 12, which are the longest mainstem reaches and the ones with the greatest number of tributaries connected to them.

Besides blocking the upstream passage of fish, some dams as well as culverts could disrupt the normal, within-stream movements of some macroinvertebrates.[41] Aquatic macroinvertebrates are key components of these stream ecosystems. They are an important food source for fish, as well as amphibians, birds, bats, and other mammals. They also are important herbivores and detritivores, as well as predators of other invertebrates; therefore, they play a critical role in the cycling of energy and nutrients through stream ecosystems. Disruptions to the movement and dispersal of stream macroinvertebrates could reduce available habitat and lead to genetic isolation of some populations. The range size of most stream macroinvertebrates (e.g. insects) is unlikely to be affected, but dams and certain culvert types could pose problems for some mollusks and crustaceans. The separation of populations and subsequent reduction in genetic diversity may be especially important for relatively long-lived and highly threatened taxa such as the freshwater mussels. The Hilsenhoff Biotic Index[42] (HBI) was used to compare the

[41]*D. Mace Vaughan,* Potential Impact of Road-Stream Crossings (Culverts) on the Upstream Passage of Aquatic Macroinvertebrates*, The Xerces Society, Portland, OR, Report submitted to the United States Forest Service, San Dimas Technology and Development Center, March, 2002.*

[42]*William L. Hilsenhoff,* Rapid Field Assessment of Organic Pollution with Family-Level Biotic Index*, University of Wisconsin-Madison, 1988.*

abundance and diversity of macroinvertebrates among streams in the Milwaukee River watershed. The results indicated that the majority of the reaches contained a good to very good community in both 1975-1986 and 1998-2004, with the exception of a fair community in headwater Reach 14 as shown in Figure 170. This indicates that the fisheries in these areas are not food-limited and the changes in the fish community diversity are most likely due to other factors.

Figure 171 shows the fisheries IBI scores among reaches that contained the best available data to assess changes in the fishery community over time in the Milwaukee River watershed. In general, the shorter reaches and the reaches with fewer tributaries tended to show much larger fluctuations in fishery quality from year to year than the larger reaches with many tributaries (see Figure 171). A second pattern that seems to be evident is that several of the reaches have some of the lowest IBI scores in the most recent years of record including Reaches 3, 7, 8, and 8d. In addition, the fishery in the downstream reaches seems to be improving.

Removal of the North Avenue dam and major habitat improvements near the dam site were completed in 1996 on the Milwaukee River. Figure 172 shows that the total number of native fish species dramatically improved after dam removal.[43] Removal of this dam reconnected a section of the Milwaukee River from the former dam site upstream to the Estabrook dam, creating an unimpeded connection to Lake Michigan. The area below the Estabrook dam changed from a very poor to excellent fishery within a few years and the data collected by the Wisconsin Department of Natural Resources also indicates that the number of exotic fish species did not change significantly in the areas above the North Avenue dam after this reach was reconnected to Lake Michigan. The smallmouth bass, which is an intolerant fish species, has also dramatically increased in abundance within the Milwaukee River and Harbor area.

Walleye abundances have also increased, but this increase is probably indicative of the WDNR stocking efforts conducted pursuant to walleye population restoration efforts in the Lower Milwaukee River and Harbor since 1995. Radiotelemetry technology was used to track the movements of stocked walleye and it was found that there was a distinct seasonal movement pattern by the adult walleye according to water temperature and food availability. During the summer, they moved from the rivers to cooler and deeper harbor waters. In winter they moved to the warmer waters of the Menomonee River canals which receive warmwater discharges from a nearby power plant. This was also associated with a significant increase in angling effort targeted towards walleye in recent years along the Menomonee River canals, Summerfest Lagoon, and the Milwaukee River upstream of the former North Avenue dam to Kletzsch Park. In a continued effort to restore the overall fishery community in the Milwaukee River, the WDNR has also begun stocking and tracking lake sturgeon in this system. Lake sturgeons were historically an integral part of the Milwaukee River and Lake Michigan fishery.

This dam removal project demonstrates how the potential of the fishery can be enhanced through removal of a dam, as well as the dependence of the fishery on the connection with Lake Michigan and the Estuary.

Lakes and Ponds

There are 20 major lakes (i.e. lakes greater than 50 acres in size) within the Milwaukee River watershed, but there are more than 80 lakes and ponds less than 50 acres in size within the watershed as listed in Table 92.

The last recorded fishery surveys for many of the lakes and ponds were completed in the late 1970s and early 1980s. The surveys indicate that that these waterbodies contained a typical urban fish species mixture mostly dominated by tolerant species of green sunfish, black bullhead, carp, and white sucker. However, largemouth bass, northern pike, and yellow perch were also recorded to occur in several of these waterbodies. Additional information from WDNR staff indicate that the majority of the lakes and ponds listed in Table 107 provide various recreational fishing opportunities for gamefish and/or panfish species, however, some of these waterbodies are stocked to supplement these fisheries (see Table 106).

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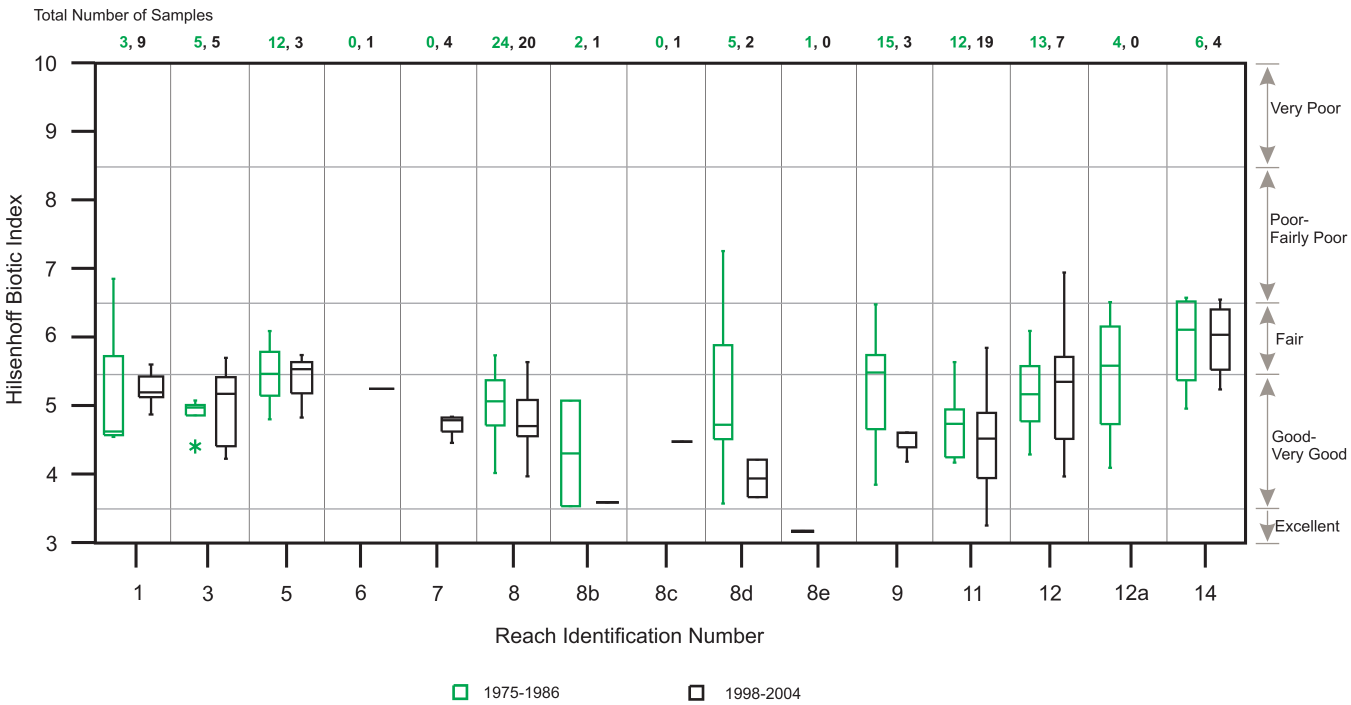
[43]*Pradeep S. Hirethota, Thomas E. Burzynski, and Bradley T. Eggold,* Changing Habitat and Biodiversity of the Lower Milwaukee River and Estuary, *PUB-FH-511-2005, August 2005.*

Figure 170

HILSENHOFF BIOTIC INDEX IN RIFFLE HABITAT AMONG STREAM REACHES SEPARATED BY DAMS AND DROP STRUCTURES IN THE MILWAUKEE RIVER WATERSHED: 1975-1986 AND 1998-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

More-recent comprehensive fisheries surveys completed by the WDNR for Erler, Little Cedar, Long (Fond du Lac County), and Random Lakes are summarized below.[44]

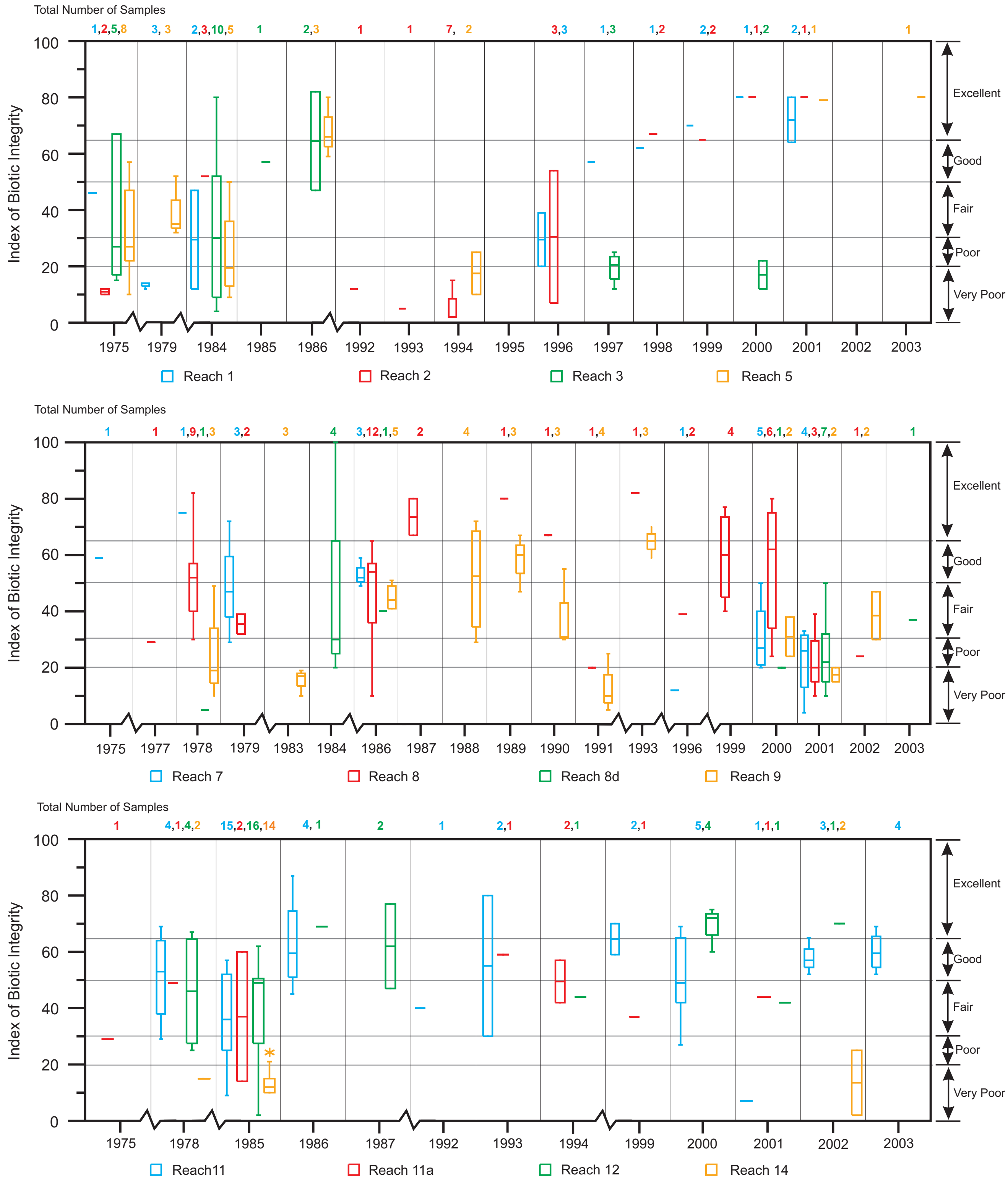
A comprehensive fish population survey of the 37-acre Erler Lake was conducted in the spring and fall of 2003. Fyke nets and electrofishing were used to collect fish samples. Eleven fish species were captured, with bluegill and largemouth bass being the predominant species. Bluegills exhibited an unusually high average size, length-frequency distribution and growth rate. Largemouth bass were generally small with an average length of 10 inches despite an average growth rate. Yellow perch were fairly common and had above average growth rates. Carp were present but, not abundant. More restrictive fishing regulations on panfish and bass were proposed to protect the populations from collapse when public access is developed.

In general, fish habitat conditions in Little Cedar Lake were good to very good during 1999. Natural shoreline is found in several areas, most of which front large wetlands. Those areas are primarily located on the southern end and western ends of the lake. Water quality is generally good and healthy stands of vegetation are found throughout the lake. No recent fishery data are available for Little Cedar Lake due to the fact that it had no public access until 1998 when Washington County bought the former Ackerman Resort located at the southeastern part

[44] *John Nelson, Senior Fisheries Biologist, Wisconsin Department of Natural Resources,* Long Lake, Comprehensive Fish Community Survey, Fond Du Lac County, 2004; Random Lake Electrofishing Report, 2004; Comprehensive Fish Community Survey, Little Cedar Lake, Washington County, 1999*, and;* Erler Lake Fish Community Survey, Washington County, 2003.

Figure 171

FISHERIES INDEX OF BIOTIC INTEGRITY AMONG STREAM REACHES SEPARATED BY DAMS AND DROP STRUCTURES IN THE MILWAUKEE RIVER WATERSHED: 1975-2003



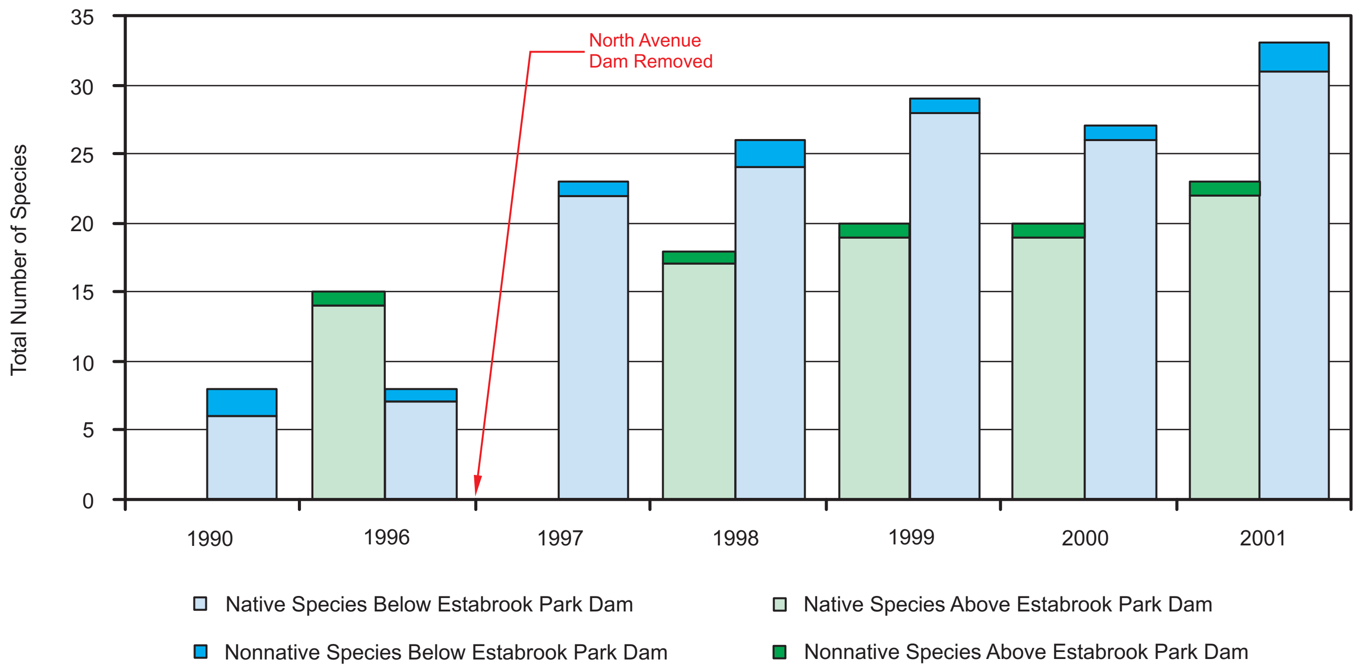
NOTES: See Figure 109 for description of symbols.

Years are not plotted on a continuous scale.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 172

COMPARISON OF THE NUMBER OF SPECIES RECORDED AT TWO SITES BEFORE AND AFTER THE REMOVAL OF THE NORTH AVENUE DAM



Source: Wisconsin Department of Natural Resources and SEWRPC.

of the lake. The lake was historically noted for fairly good northern pike, largemouth bass, and panfish fishing. The WDNR used fyke nets, mini-fyke nets, electrofishing, and seines to collect data on the fish community. Northern pike appeared to be abundant, with few legal sized fish present. Largemouth bass were abundant and had a very good size structure. Bluegills were abundant, but generally small in size. Small crappies were present. Yellow perch did not appear to be abundant and bluntnose minnow were common. Walleye were present and produced a natural population until recently when natural reproduction apparently failed to sustain healthy numbers of fish. Carp are present and concern some residents, especially in spring when they congregate at the shallow southern end of the lake to spawn. The Department tried several times around 1960 to reduce carp numbers by trapping and removing carp, but that effort was soon abandoned.

A comprehensive fish community survey of the 417-acre Long Lake in eastern Fond du Lac County was conducted during 2004. Northern pike, largemouth bass, bluegill and yellow perch were the most common fish found during the survey. Only a remnant population of walleye was present. The northern pike population estimate of 3,563 in 2004 was much reduced compared to an estimate of 8,075 in 1986. The walleye population was small with no signs of natural reproduction. A naturally reproducing population was present in the 1960s and 1970s with a 1974 estimate of 4.8 walleye/acre. The Long Lake largemouth bass population was in exceptional condition and was likely the best overall population in Fond du Lac and surrounding counties. Bluegills were abundant and had a very good size structure; however, total annual mortality estimates were high indicating excessive harvest once the fish reached six inches in size. Yellow perch were common. Yellow bullhead were abundant and had a very good size structure. Seining at four locations found 15 native species.

An electrofishing survey of the shoreline of Random Lake in Sheboygan County was conducted during the fall of 2004. The most abundant gamefish captured during the electrofishing survey was largemouth bass, however, size structure was poor and growth rates of bass in the lake were generally below the statewide average for the species. Bluegills were the most abundant panfish species caught. The population of bluegill has always been dominated

Table 107

FISH AND EXOTIC SPECIES IN LAKES AND PONDS IN THE MILWAUKEE RIVER WATERSHED

Name	Muskellunge	Northern Pike	Walleye	Largemouth Bass	Smallmouth Bass	Panfish	Trout	Catfish	Carp	Zebra Mussel	Eurasian Water Milfoil	Curly-Leaf Pondweed
Allis Lake	- -	Present	- -	Present	Present	Abundant	- -	- -	- -	- -	- -[a]	- -[a]
Auburn Lake (Lake Fifteen)	- -	Common	Present	Common	- -	Common	- -	Present	Present	- -	- -[a]	- -[a]
Barton Pond	- -	Common	--	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Batavia Pond	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Beechwood Lake	- -	Common	- -	Common	- -	Common	- -	Present	- -	- -	Present	- -[a]
Big Cedar Lake	- -	Common	Present	Abundant	- -	Common	Present	- -	Present	Present	Present	- -[a]
Birchwood Lake	- -	- -	- -	- -	- -	Present	- -	- -	Present	- -	- -[a]	- -[a]
Boltonville Pond	Present	- -	Present	- -	Common	Present	- -	- -	- -	- -	- -[a]	- -[a]
Brickyard Lake	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Brown Deer Park Pond[b]	- -	- -	- -	Present	- -	Present	Common	- -	- -	- -	- -[a]	- -[a]
Butler Lake	- -	Present	- -	Common	- -	Present	Common	Present	- -	- -	- -[a]	- -[a]
Buttermilk Lake	- -	- -	- -	- -	-	Present	- -	- -	- -	- -	- -[a]	- -[a]
Butzke Lake	- -	- -	- -	- -	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Cambellsport Millpond	- -	Present	- -	- -	- -	Present	- -	Present	- -	- -	- -[a]	- -[a]
Cascade Millpond	- -	Present	- -	Common	- -	Present	Common	- -	- -	- -	- -[a]	- -[a]
Cedar Lake (Fond du Lac County)	- -	Present	- -	Common	- -	Common	- -	Present	- -	- -	- -[a]	- -[a]
Cedar Lake (Sheboygan County)	- -	- -	- -	Abundant	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Cedarburg Pond	- -	Present	- -	Common	- -	Common	- -	Present	- -	- -	- -[a]	- -[a]
Cedarburg Stone Quarry	- -	- -	- -	Present	- -	Common	Present	- -	- -	- -	- -[a]	- -[a]
Chair Factory Millpond	- -	Present	- -	- -	Present	Present	- -	- -	- -	- -	- -[a]	- -[a]
Columbia Pond	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Crooked Lake	- -	Common	- -	Common	- -	Common	Present	Present	Present	- -	Present	- -[a]
Daly Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Dickman Lake	- -	- -	- -	- -	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Dineen Park Pond[b]	- -	Present	- -	- -	- -	Present	Common	- -	Present	- -	- -[a]	- -[a]
Donut Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Drzewiceki Lake	- -	- -	- -	Common	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Ehne Lake	- -	- -	- -	Common	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Erler Lake	- -	- -	- -	Common	- -	Common	- -	- -	- -	- -	Present	- -[a]
Estabrook Park Lagoon[b]	- -	- -	- -	Present	- -	Common	Present	- -	- -	- -	- -[a]	- -[a]
Forest Lake	- -	Present	Present	Common	- -	Abundant	- -	Present	Present	- -	Present	- -[a]
Fromm Pit	- -	- -	- -	Present	- -	Abundant	Present	- -	- -	- -	- -[a]	- -[a]
Gilbert Lake	- -	Common	- -	Common	- -	Common	- -	- -	Present	- -	Present	- -[a]
Gooseville Millpond	- -	Abundant	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Gough Lake	- -	Present	- -	Common	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Grafton Millpond	- -	Present	Present	Common	Abundant	Common	- -	Present	Present	- -	- -[a]	- -[a]
Green Lake	- -	Present	Present	Common	- -	Common	- -	Present	Present	- -	Present	- -[a]
Haack Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Hamilton Pond	- -	- -	- -	Common	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Hanneman Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Hansen Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Hasmer Lake		Common	- -	Abundant	- -	Present	- -	- -	Present	- -	- -[a]	- -[a]

Table 107 (continued)

Name	Muskellunge	Northern Pike	Walleye	Largemouth Bass	Smallmouth Bass	Panfish	Trout	Catfish	Carp	Zebra Mussel	Eurasian Water Milfoil	Curly-Leaf Pondweed
Hawthorn Lake	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Hawthorne Hills Pond	- -	- -	- -	Present	- -	Present	- -	Present	- -	- -	- -[a]	- -[a]
Horn Lake	- -	Common	- -	Common	- -	Abundant	- -	- -	- -	- -	- -[a]	- -[a]
Huiras Lake	- -	Present	- -	Common	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Juneau Park Lagoon[b]	- -	- -	- -	Common	- -	Present	Common	- -	- -	- -	Present	- -[a]
Kelling Lakes #1	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Kelling Lakes #2	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Kelling Lakes #3	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Keowns Pond	- -	- -	- -	Present	- -	Present	Present	- -	- -	- -	- -[a]	- -[a]
Kettle Moraine Lake	- -	Common	Present	Common	- -	Abundant	- -	Present	- -	- -	Present	- -[a]
Kewaskum Millpond	- -	Present	- -	Present	- -	Present	Present	Present	Present	- -	- -[a]	- -[a]
Kilbourn Lake Pond	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Lake Bernice	- -	Abundant	- -	Common	- -	Common	- -	Present	Present	- -	- -[a]	- -[a]
Lake Ellen	- -	Common	Common	Common	- -	Common	Present	Present	Present	Present	- -[a]	- -[a]
Lake Lenwood	- -	Present	- -	Common	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Lake Seven	- -	Present	- -	Common	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Lake Sixteen	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Lake Twelve	- -	Present	- -	Common	- -	Abundant	- -	- -	- -	- -	- -[a]	- -[a]
Lehner Lake	- -	- -	- -	Common	- -	Abundant	Present	- -	- -	- -	- -[a]	- -[a]
Lent Lake	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Lime Kiln Millpond	- -	Present	Present	Present	Abundant	Present	- -	- -	- -	- -	- -[a]	- -[a]
Lincoln Park Lagoon	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Linden Pond	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Little Cedar Lake	- -	Present	Common	Abundant	- -	Common	- -	Present	- -	Present	Present	- -[a]
Little Drickens Lake	- -	Present	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Little Mud Lake	- -	Present	- -	- -	- -	Abundant	- -	- -	- -	- -	- -[a]	- -[a]
Long Lake (Ozaukee County)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Long Lake (Fond du Lac County)	- -	Common	Common	Common	- -	Abundant	- -	Present	Present	Present	Present	- -[a]
Lucas Lake	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	Present	- -[a]
Mallard Hole Lake	- -	- -	- -	- -	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Mauthe Lake	- -	Present	Present	Common	- -	Common	- -	Present	Present	- -	Present	- -[a]
McGovern Park Pond[b]	- -	- -	- -	Common	- -	Present	Common	- -	Present	- -	- -[a]	- -[a]
Mee-Quon Park Pond	- -	- -	Present	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Miller Lake	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Moldenhauer Lake	- -	- -	- -	Common	- -	Abundant	Present	- -	- -	- -	- -[a]	- -[a]
Mud Lake (Ozaukee County)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Mud Lake (Fond du Lac County)	- -	- -	- -	- -	- -	Abundant	- -	- -	- -	- -	- -[a]	- -[a]
New Fane Millpond	- -	Present	Present	Present	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Newburg Pond	- -	Present	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Paradise Valley Lake	- -	Present	- -	Common	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Pit Lake	- -	Present	- -	Present	Present	Common	- -	- -	- -	- -	Present	- -[a]
Proschinger Lake	- -	Present	- -	Common	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Quaas Lake	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Radtke Lake	- -	- -	- -	Common	- -	Abundant	- -	- -	- -	- -	- -[a]	- -[a]

Table 107 (continued)

Name	Muskellunge	Northern Pike	Walleye	Largemouth Bass	Smallmouth Bass	Panfish	Trout	Catfish	Carp	Zebra Mussel	Eurasian Water Milfoil	Curly-Leaf Pondweed
Random Lake	Common	Common	Present	Common	- -	Common	- -	Present	Present	- -	Present	- -[a]
Roeckl Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Ruck Pond	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Schwietzer Pond	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Senn Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Silver Lake	- -	Abundant	Present	Abundant	- -	- -	- -	- -	- -	- -	Present	- -[a]
Smith Lake	- -	Common	- -	Abundant	- -	Abundant	- -	- -	Present	- -	- -[a]	- -[a]
Spring Lake (Fond du Lac County)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Spring Lake (Ozaukee County)	- -	Present	- -	Common	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Spruce Lake	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Thiensville Millpond	- -	Present	Present	Present	Present	Common	- -	Present	Present	- -	- -[a]	- -[a]
Tilly Lake	- -	Present	- -	Common	- -	Abundant	Common	- -	Present	- -	- -[a]	- -[a]
Tittle Lake	- -	Common	Common	Common	- -	Abundant	- -	- -	- -	- -	- -[a]	- -[a]
Uihlein Pond	- -	- -	- -	- -	- -	Common	- -	- -	- -	- -	- -[a]	- -[a]
Unnamed Lake (T11 R21 E17)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Wallace Lake	- -	- -	- -	Present	- -	Present	- -	- -	- -	- -	- -[a]	- -[a]
Washington Park Pond	- -	Present	- -	Common	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Wire and Nail Pond	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Zeunert Pond	- -	- -	- -	- -	- -		- -	- -	- -	- -	- -[a]	- -[a]

[a] *These aquatic exotic, invasive plant species are known to occur in the counties that these lakes are found, but there is no data to confirm their presence in the waterbody.*

[b] *These ponds are stocked by Wisconsin Department of Natural Resources and Milwaukee County as part of the Urban Fishing Program.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

by small fish that are slow growing. Scale samples from the bluegills confirmed the slow growth rate, as the rates were well below the state average rate for bluegills. Black crappies and yellow perch were also fairly abundant in the catch. The perch catch indicated that a few quality size perch were present. The crappies were generally small. WDNR also caught four muskellunge, and this species continues to be the most popular fishery in the lake. The walleye fishery of Random Lake has continued to improve in recent years. The walleye in the lake are generally plump, an indication that they are feeding well on the abundant panfish in the lake.

Brown Deer Park Pond, Dineen Park Pond, Estabrook Park Lagoon, Juneau Park Lagoon, and McGovern Park Pond are enrolled in the WDNR Urban Fishing Program in partnership with Milwaukee County (see Table 107). That program was initiated in 1983 for the metropolitan Milwaukee area and is still active today. The program provides fishing in urban ponds for anglers who do not have opportunities to leave the urban environment. The program stocks rainbow trout and other species to provide seasonal and year-round fishing (see Table 106).

Table 107 also shows that exotic invasive species have been recorded in 28, or nearly 30 percent, of the lakes and ponds within the Milwaukee River watershed. Carp are found in Barton Pond, Big Cedar Lake, Birchwood Lake, Crooked Lake, Dineen Park Pond, Estabrook Park Pond, Forest Lake, Gilbert Lake, Green Lake, Grafton Millpond, Hasmer Lake, Kettle Moraine Lake, Kewaskum Millpond, Lake Bernice, Lake Ellen, Long Lake (Fond du Lac County), Mauthe Lake, McGovern Park Pond, Random Lake, Smith Lake, Thiensville Millpond, Tilly Lake, and West Bend Pond. Zebra mussels have only been recorded in Big Cedar Lake, Lake Ellen, Little Cedar Lake, and Long Lake (Fond du Lac County). While data on aquatic plant communities are limited (see Table 108), Eurasian water milfoil is known to exist in Beechwood Lake, Big Cedar Lake, Crooked Lake, Erler Lake, Estabrook Park Pond, Forest Lake, Gilbert Lake, Green Lake, Juneau Park Lagoon, Kettle Moraine Lake, Little Cedar Lake, Long Lake (Fond du Lac County), Lucas Lake, Mauthe Lake, Pit Lake, Random Lake, and Silver Lake. Curly-leaf pondweed is known to exist in each of the Counties within the Milwaukee River watershed, but there is no data to confirm its presence in any particular waterbody.

Macroinvertebrates

The Hilsenhoff Biotic Index[45] (HBI) and percent EPT (percent of families comprised of Ephemeroptera, Plecoptera, and Trichoptera) were used to classify the historic and existing macroinvertebrate and environmental quality in this stream system using survey data from various sampling locations in the Milwaukee River watershed.

When applying the HBI that is used to measure the amount of organic pollution in warmwater streams of Wisconsin, it is recommended that a similar type of gear be used as well as similar type of habitat be sampled. Analysis of the macroinvertebrate data in the Milwaukee River watershed indicates that a D-Frame kick net was the only gear type used to sample these organisms, which indicates that there is sampling consistency among all sites. There have been a variety of habitat types sampled within the Milwaukee River watershed as shown in Figure 173. Figure 173 shows that riffle habitats contain the highest quality macroinvertebrate communities compared to pool, run, snag, or lake habitats in the Milwaukee River watershed. Habitat types such as lakes, pools, riffles, and runs generally contain very different compositions of substrates, water depths, and flows, which greatly affects the abundance and diversity of the associated macroinvertebrate community. Hence, the HBI procedures recommend that macroinvertebrate communities be sampled from shallow fast flowing riffle habitats, and that samples from pools or under the stream banks should not be used.[46] Therefore, only samples from riffle habitats were used to assess the macroinvertebrate community in the Milwaukee River watershed as summarized below.

[45] *William L. Hilsenhoff,* Rapid Field Assessment of Organic Pollution with Family-Level Biotic Index*, University of Wisconsin-Madison, 1988.*

[46] *William L. Hilsenhoff, "An Improved Biotic Index of Organic Stream Pollution,"* The Great Lakes Entomologist*, Volume 20, 19887.*

Table 108

FREQUENCY OF OCCURRENCE OF AQUATIC PLANT SPECIES IN BIG AND LITTLE CEDAR LAKES, AND SILVER LAKE: 2005

Plant Genus and Species	Plant Common Name	Relative Frequency of Occurrence (percent)[a] Big Cedar Lake	Relative Frequency of Occurrence (percent) Little Cedar Lake	Relative Frequency of Occurrence (percent) Silver Lake	Ecological Significance[b]
Ceratophyllum demersum	Coontail	- -	31.1	- -	Provides good shelter for young fish and supports insects valuable as food for fish and ducklings
Chara vulgaris	Muskgrass	Present	63.3	95.5	Excellent producer of fish food, especially for young trout, bluegills, small and largemouth bass, stabilizes bottom sediments, and has softening effect on the water by removing lime and carbon dioxide
Elodea canadensis	Waterweed	- -	18.9	1.5	Provides shelter and support for insects which are valuable as fish food
Lemna minor	Lesser duckweed[c]	Present	Present	Present	A nutritious food source for ducks and geese, also provides food for muskrat, beaver, and fish, while rafts of duckweed provide shade and cover for insects; in addition, extensive mats of duckweed can inhibit mosquito breeding
Lythrum salicaria	Purple loosestrife[c,d]	- -	- -	Present	Exotic invasive plant species that can lead to a decrease in native aquatic plant community abundance and diversity
Myriophyllum spicatum	Eurasian water milfoil[d]	Present	81.1	33.3	Exotic invasive plant species that can lead to a decrease in native aquatic plant community abundance and diversity, but it can provide cover for invertebrates and forage fish species
Myriophyllum sp.	Native milfoil	- -	13.3	- -	Provides valuable food and shelter for fish; fruits eaten by many wildfowl
Najas flexilis	Bushy Pondweed	Present	12.2	0.5	Stems, foliage, and seeds important wildfowl food and produces good food and shelter for fish
Najas marina	Spiny naiad	- -	10.0	- -	Provides good food and shelter for fish and food for ducks
Nuphar sp.	Yellow water lily[c]	Present	Present	Present	Leaves, stems, and flowers are eaten by deer; roots eaten by beaver and porcupine; seeds eaten by wildfowl; leaves provide harbor to insects, in addition to shade and shelter for fish
Nymphaea tuberosa	White water lily[c]	Present	Present	Present	Provides shade and shelter for fish; seeds eaten by wildfowl; rootstocks and stalks eaten by muskrat; roots eaten by beaver, deer, moose, and porcupine
Potamogeton americanus	Long-leaf pondweed	- -	- -	4.6	Offers shade, shelter, and foraging for fish; valuable food for waterfowl
Potamogeton amplifolius	Large-leaf pondweed	Present	5.6	Present	Provides cover for panfish, largemouth bass, muskellunge, and northern pike; nesting grounds for bluegill; supports insects valuable as food for fish and ducklings
Potamogeton crispus	Curly-leaf pondweed[d]	- -	13.3	- -	Provides food, shelter, and shade for some fish and food for waterfowl
Potamogeton foliosus	Leafy pondweed	- -	- -	- -	Provides valuable food for geese and ducks; grazed by muskrat, deer, beaver, and moose; good surface area for invertebrates and cover for young fish
Potamogeton gramineus	Variable pondweed	- -	5.6	12.1	Provides habitat for fish and food for waterfowl, muskrat, beaver, and deer
Potamogeton natans	Floating-leaf pondweed	- -	- -	- -	Provides valuable grazing for ducks and geese. Portions eaten by muskrat, beaver, deer, and moose; provides shade and food for fish
Potamogeton pectinatus	Sago pondweed	Present	8.9	10.6	This plant is the most important pondweed for ducks, in addition to providing food and shelter for young fish
Potamogeton richardsonii	Clasping-leaf pondweed	Present	3.3	- -	Provides good food and cover for fish and supports insects eaten by fish

Table 108 (continued)

Plant Genus and Species	Plant Common Name	Relative Frequency of Occurrence (percent)[a] Big Cedar Lake	Relative Frequency of Occurrence (percent) Little Cedar Lake	Relative Frequency of Occurrence (percent) Silver Lake	Ecological Significance[b]
Potamogeton robbinsii	Robbins pondweed	- -	1.1	- -	Provides habitat for invertebrates, in addition to providing food and shelter for young fish
Potamogeton zosteriformis	Flat-stemmed pondweed	- -	22.2	10.6	Provides some cover for bluegills, perch, northern pike, and muskellunge; food for waterfowl; supports insects valuable as food for fish and ducklings
Ranunculus longirostris	Stiff water crowfoot	- -	7.8	- -	Provides food for trout, upland game birds, and wildfowl
Scirpus subterminalis	Water bulrush	- -	2.2	- -	Supports insects; provides food for a variety of ducks and muskrats and provides cover for wildfowl
Typha augustafolia	Cattail[c]	- -	- -	- -	Supports insects; stalks and roots important food for muskrat and beaver; attracts marsh birds, wildfowl, and songbirds, in addition to being used as spawning grounds by sunfish and shelter for young fish
Utricularia vulgaris	Common bladderwort	Present	- -	30.3	Free floating plant that can provide needed fish habitat in areas not easily colonized by rooted plants; provides food and cover for fish
Vallisneria americana	Eel grass	- -	16.7	19.7	Provides good shade and shelter, supports insects, and is valuable fish food
Zosterella dubia	Water stargrass	- -	18.9	Present	Provides food and shelter for fish, locally important food for waterfowl

[a]*Maximum equals 100 percent.*

[b]*Information obtained from Norman C. Fassett, A Manual of Aquatic Plants, Wisconsin Department of Natural Resources,* Guide to Wisconsin Aquatic Plants, *and Wisconsin Lakes Partnership,* Through the Looking Glass…A Field Guide to Aquatic Plants*, 1997.*

[c]*Not measurable using the Jesson and Lound Survey Technique for Submersed Aquatic Plants.*

[d]*Section NR 109.07, "Designated Invasive and Nonnative Aquatic Plant."*

Source: SEWRPC.

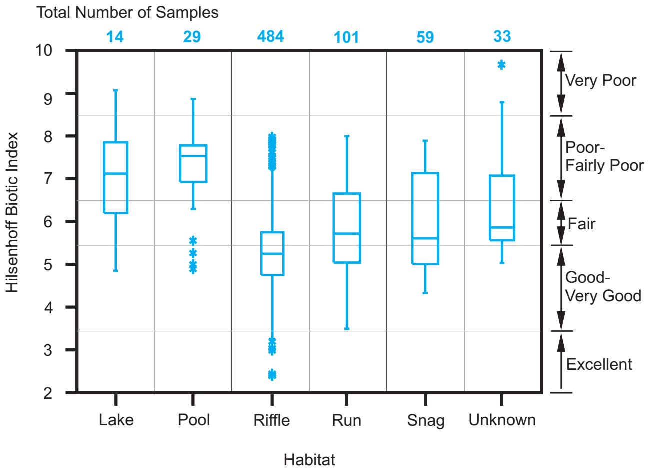
Macroinvertebrate surveys conducted by the WDNR from 1975 through 2004 show that HBI scores generally range from fair (HBI score 5.51-6.5) to good-very good (HBI score 3.51-5.5) in the Milwaukee River watershed (see Figure 174 and Maps 59 and 60). Figure 174 also shows that, based on 117 samples that were collected from 1998 through 2004 and were well distributed throughout the Milwaukee River watershed, the macroinvertebrate community quality has generally remained fairly constant from 1975 to 2004. Results generally indicate that current macroinvertebrate diversity and abundances are indicative of fair to good-very good water quality in the watershed. From 1975 to the present, the average total number of genera has increased, and the number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) genera has slightly increased, as shown in Figure 175. This indicates that the diversity of macroinvertebrates has been improved by the addition of organisms not within the EPT genera. In addition, over the long term, percent dominance of the top five families has been decreasing as shown in Figure 176. This is another indication that there is a long-term improvement in the abundance and diversity of macroinvertebrates.[47]

Results of the proportions of EPT genera and HBI scores by individual subwatersheds in the Milwaukee River indicate that the data are limited to assess the current macroinvertebrate community conditions within seven of the

[47]*M.T. Barbour, J. Gerritsen, B.D. Snyder, and J.B. Stribling,* Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish*, Second Edition, EPA 841-B-99-002, U.S. Environmental Protection Agency, Office of Water, Washington, D.C., 1999.*

Figure 173

HILSENHOFF BIOTIC INDEX (HBI) MACROINVERTEBRATE SCORES AMONG HABITAT TYPES IN THE MILWAUKEE RIVER WATERSHED: 1975-2004

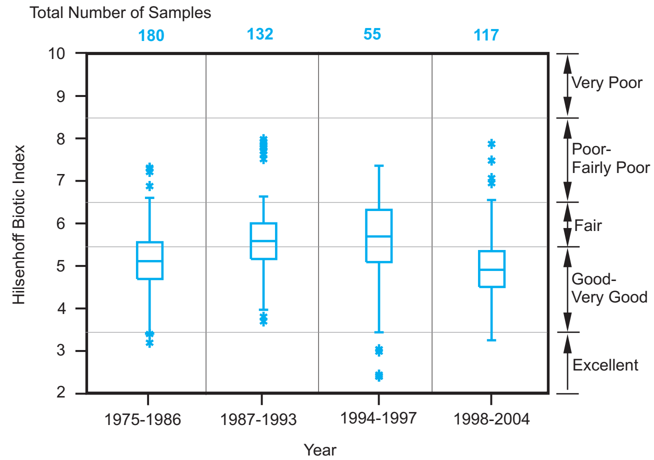


NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 174

HILSENHOFF BIOTIC INDEX (HBI) MACROINVERTEBRATE SCORES WITHIN RIFFLE HABITATS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



NOTE: See Figure 109 for description of symbols.

Sorted by riffle habitat and gear type (D-Frame Net).

Source: Wisconsin Department of Natural Resources and SEWRPC.

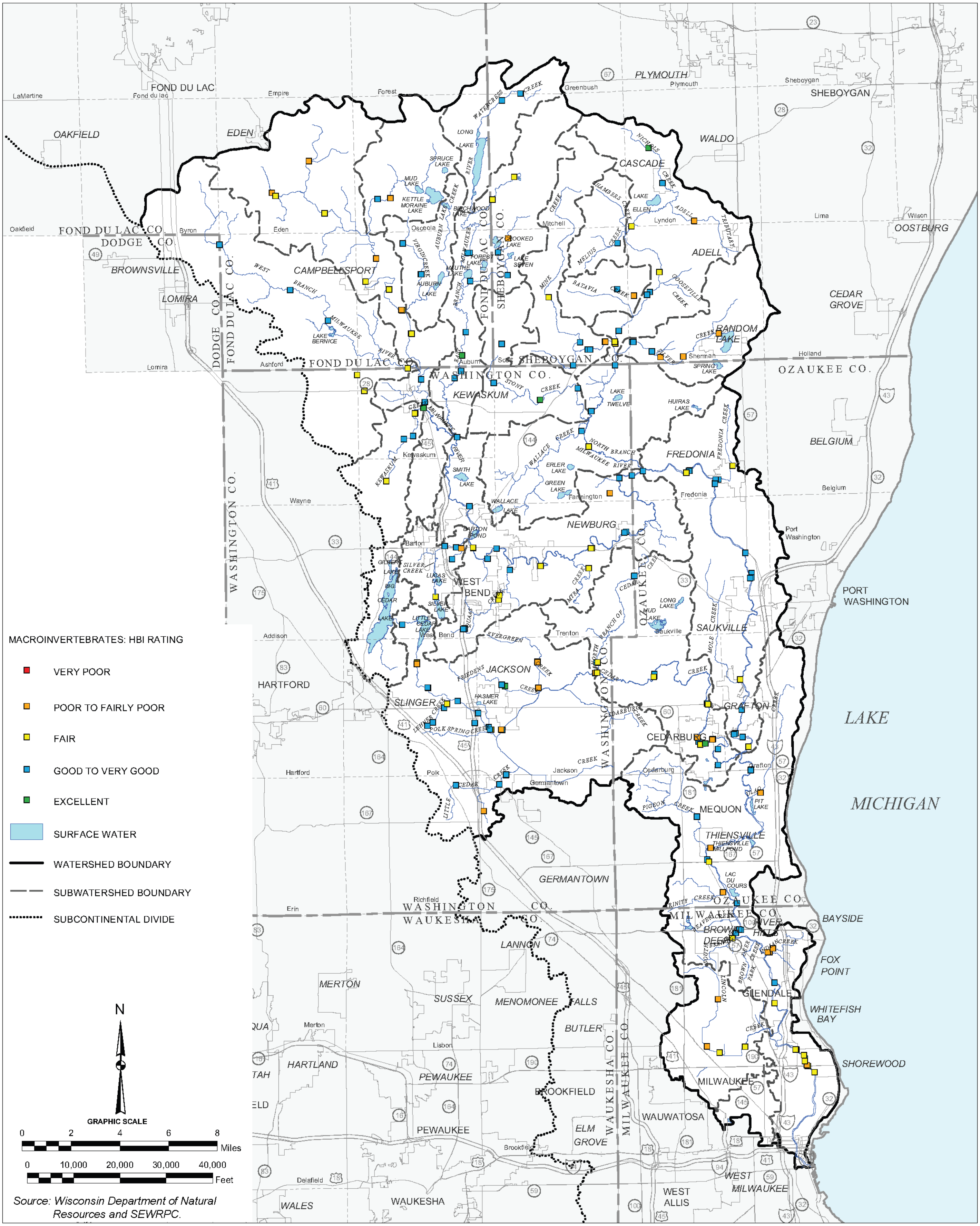
subwatersheds during the 1998 through 2004 period, as shown in Figures 177 and 178. For example, the Lake Fifteen, Watercress Creek, Chambers Creek, Lower Cedar Creek, Lincoln Creek, and Silver Creek (West Bend) subwatersheds either have only one survey record or no data in that time period. The EPT results as shown in Figure 177 for the remaining subwatersheds generally indicate that the majority of sites have a relatively moderate to high proportion of EPT genera, which is indicative of fair to good water quality conditions. In addition, most of the subwatersheds do not seem to have changed appreciably in the proportion of EPT genera from the historical records, which is supported by the HBI results in Figure 178. Figure 178 shows that the macroinvertebrate community quality has generally remained in the good-very good HBI rating from 1975 to the present within most of the subwatersheds. However, eight, or nearly 40 percent, of the subwatersheds contained sites that ranked in the fair HBI classification, which indicates some level of potential impairment to the macroinvertebrate abundance and diversity. Figure 178 demonstrates that, except for the Lincoln Creek subwatershed, most of the subwatersheds throughout the Milwaukee River watershed continue to sustain a fair to good-very good macroinvertebrate community. It should be noted that any effects on macroinvertebrates from the recently completed MMSD Lincoln Creek environmental restoration and flood control project would not be reflected in the data, which only extend through 2004.

Further analysis of the East Branch of the Milwaukee River and Lower Milwaukee River subwatersheds indicates that the proportions of collectors have not changed significantly from 1979 to 2004, as shown in Figure 179.[48] The proportion of collectors in the East Branch of the Milwaukee River subwatershed is significantly less than the Lower Milwaukee River subwatershed. This difference in the trophic structure between these subwatersheds implies that streams in the East Branch of the Milwaukee River subwatershed are potentially less disturbed or have better water quality than streams in the Lower Milwaukee River subwatershed. Similarly, as shown in

[48]*A description of the collectors, scrapers, and shredders can be found in Chapter II of this report.*

Map 59

MACROINVERTEBRATE SAMPLE LOCATIONS AND CONDITIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 1979-1997



Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 60

MACROINVERTEBRATE SAMPLE LOCATIONS AND CONDITIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 1998-2004

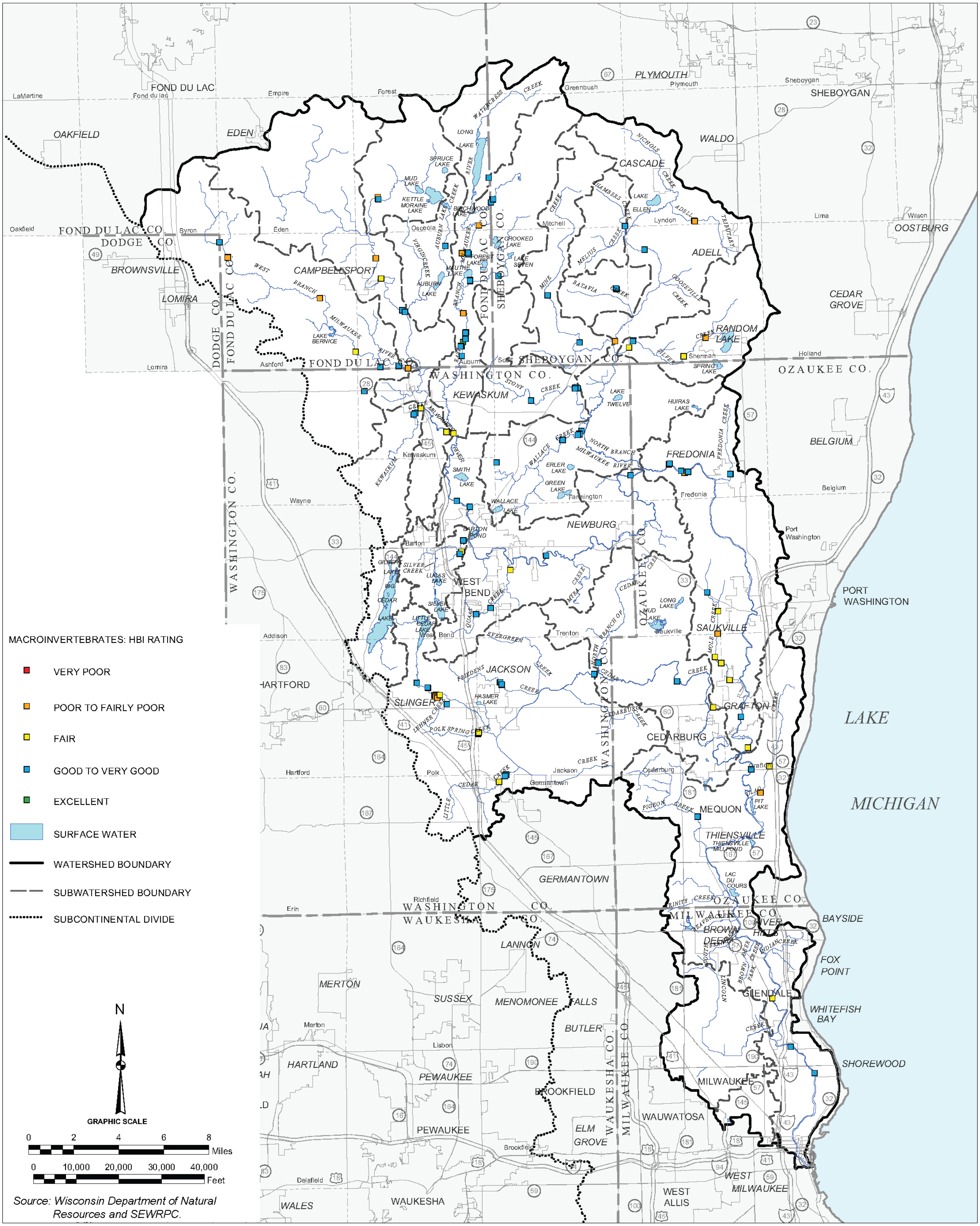
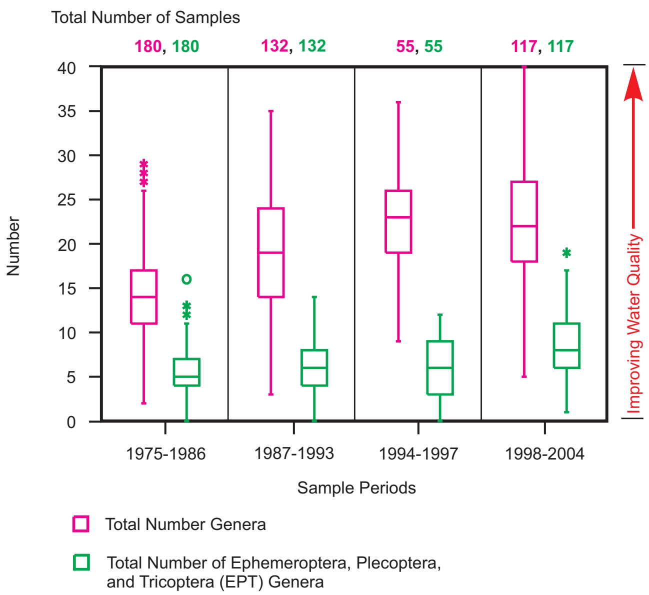


Figure 175

TOTAL NUMBER OF GENERA AND EPHEMEROPTERA, PLECOPTERA, AND TRICHOPTERA (EPT) GENERA IN RIFFLE HABITAT IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 180, the high proportion of scrapers in the East Branch of the Milwaukee River subwatershed and the loss of scrapers in the Lower Milwaukee River subwatershed from 1979 to the present also indicates that the former subwatershed contains a higher quality macroinvertebrate community trophic structure. Each of these patterns are consistent with improvement in water quality in the East Branch of the Milwaukee River subwatershed and a decline in water quality in the Lower Milwaukee River subwatershed. Water quality improvement may be related to a decrease in organic or inorganic pollution, decrease in nutrients, improvements in dissolved oxygen concentrations, decreases in heavy metals or other toxic contaminants. This trophic difference between the East Branch of the Milwaukee River subwatershed and the Lower Milwaukee River subwatershed is also consistent with the fishery community differences and water quality differences between these subwatersheds as summarized above.

Wisconsin researchers have generally found that as the amount of human land disturbance increases, such as in the Milwaukee River watershed, the subsequent macroinvertebrate community diversity and abundance decreases, which is generally supported by the data for this watershed.[49] In addition, this fairly high quality of macroinvertebrates found throughout most of the Milwaukee River watershed may also be a function of the integrity and continuity of riparian buffers greater than 75 feet adjacent to the streams and lake systems (see the "Habitat and Riparian Corridor Conditions" section below). Effective buffers help reduce pollutant loadings and other human disturbances.

Synthesis

Except for some areas within the Upper Milwaukee River, West Branch of the Milwaukee River, East Branch of the Milwaukee River, Middle Milwaukee River, Upper Lower Milwaukee River, and Lower Milwaukee River subwatersheds that contain good and in some cases excellent fishery quality, the watershed of the Milwaukee River in general contains a poor to fair fishery. The fish community contains a high abundance of both warmwater and coldwater species of fishes, seems trophically balanced in the highest quality areas, contains a good percentage of top carnivores (except for those species stocked), and is not dominated by tolerant fishes. Macroinvertebrate communities are classified as fair to good-very good at present. The macroinvertebrate community is also generally trophically balanced and not dominated by tolerant taxa. Overall, the fish and macroinvertebrate communities in the Milwaukee River watershed are of a better quality than those communities in the other watersheds in the study area.

The habitat quality was shown to largely be limited by siltation, as well as reduced amounts and quality of instream cover throughout the watershed. In addition, although there have been some water quality improvements in the downstream areas in the watershed, those areas also continue to be impaired due to sediment toxicity

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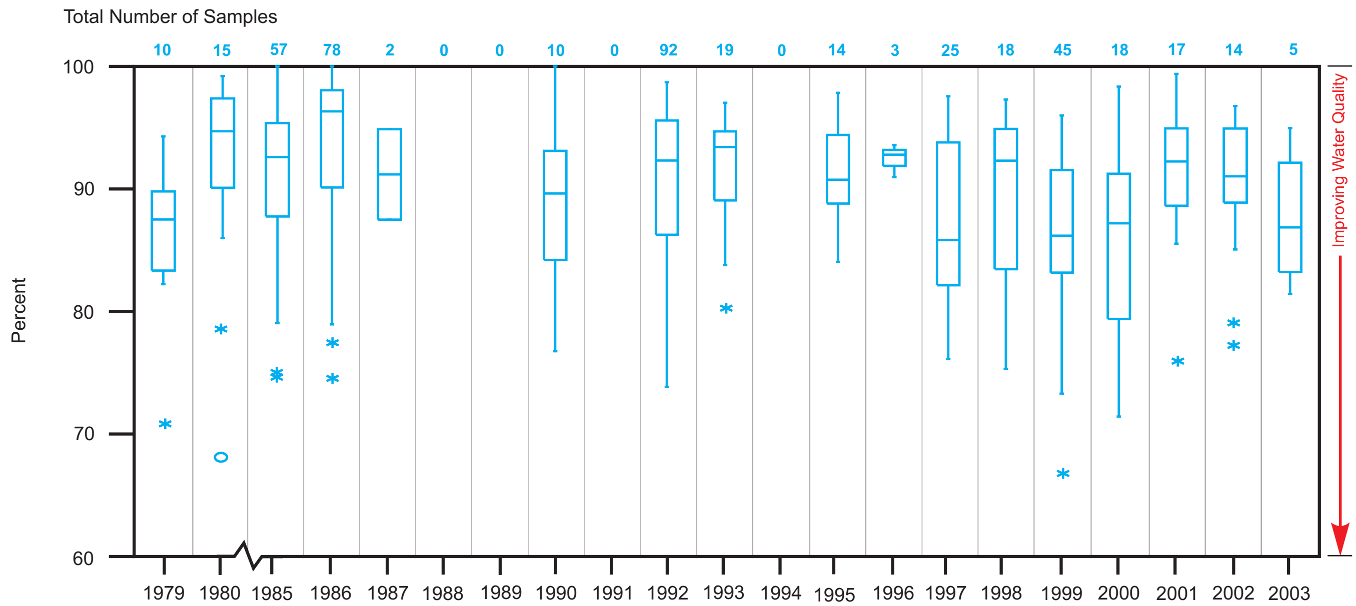
[49] *J. Masterson and R. Bannerman,* Impact of Stormwater Runoff on Urban Streams in Milwaukee County, Wisconsin*, Wisconsin Department of Natural Resources, Madison, Wisconsin, 1994.*

Figure 176

PERCENT DOMINANCE OF TOP FIVE MACROINVERTEBRATE FAMILIES IN RIFFLE HABITAT IN THE MILWAUKEE RIVER WATERSHED: 1975-2003



NOTES: See Figure 109 for description of symbols.

Years are not plotted on a continuous scale.

Source: Wisconsin Department of Natural Resources and SEWRPC.

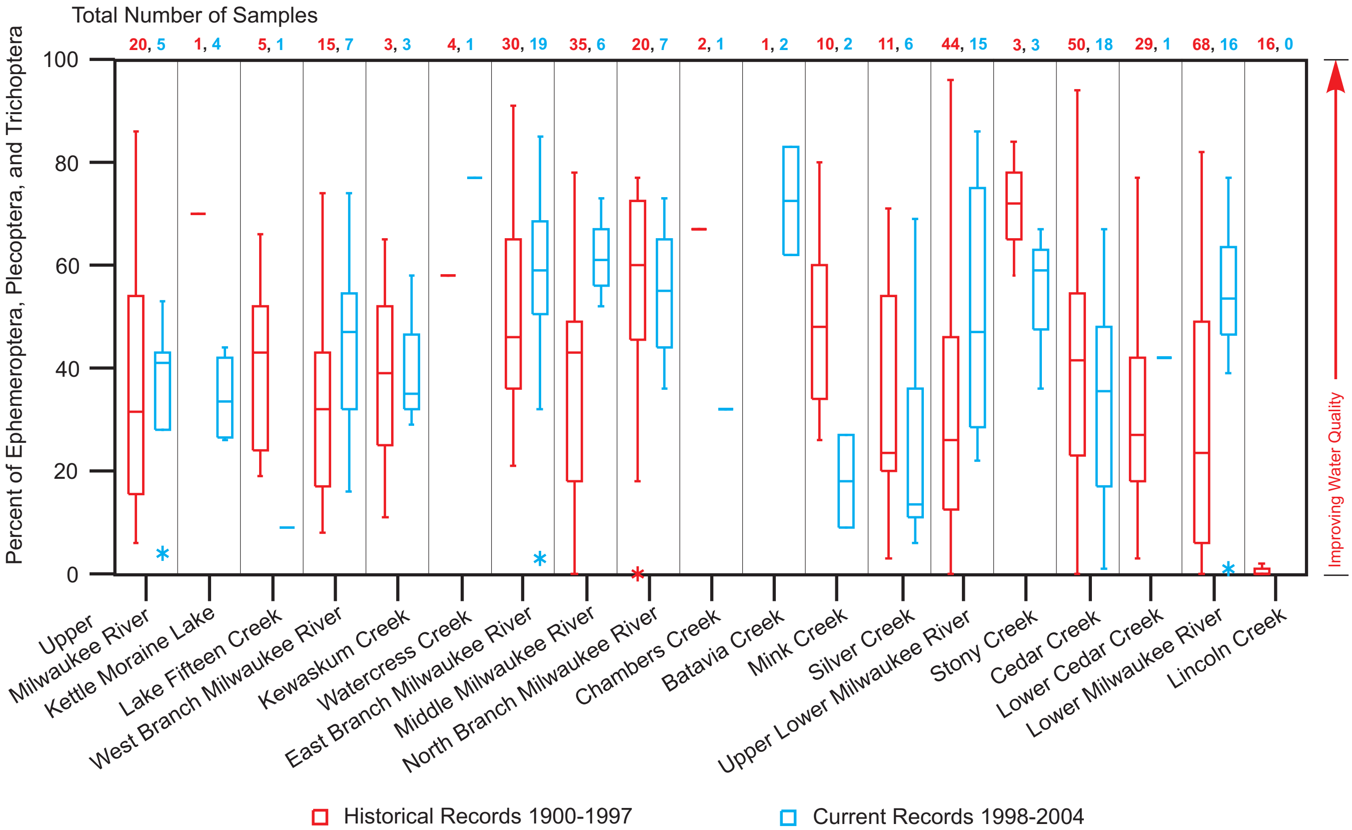
problems. Therefore, in differing degrees throughout the watershed, water, sediment, and habitat quality are important factors limiting both the fishery and macroinvertebrate community. There are several other factors that are likely to be limiting the aquatic community, including, but not limited to, 1) periodic stormwater loads and sediment toxicity; 2) decreased base flows; 3) continued fragmentation due to dams, drop structures, culverts, concrete lined channels, and enclosed conduits; 4) past channelization; 5) cropland erosion, and/or 5) increased water temperatures due to urbanization.

Other Wildlife

Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of this study, it is possible, by polling naturalists and wildlife managers familiar with the area, to compile lists of amphibians, reptiles, birds, and mammals which may be expected to be found in the area under existing conditions. The technique used in compiling the wildlife data involved obtaining lists of those amphibians, reptiles, birds, and mammals known to exist, or known to have existed, in the Milwaukee River watershed area, associating these lists with the historic and remaining habitat areas in the area as inventoried, and projecting the appropriate amphibian, reptile, bird, and mammal species into the watershed area. The net result of the application of this technique is a listing of those species which were probably once present in the watershed area, those species which may be expected to still be present under currently prevailing conditions, and those species which may be expected to be lost or gained as a result of agricultural and urban land development within the area. It is important to note that this inventory was conducted on a countywide basis for each of the aforementioned major groups of organisms. Some of the organisms listed as occurring in Milwaukee, Washington, Ozaukee, Fond du Lac, Sheboygan and Dodge Counties may only infrequently occur within the Milwaukee River watershed.

Figure 177

HISTORICAL AND BASE PERIOD PERCENT EPHEMEROPTERA, PLECOPTERA, AND TRICHOPTERA (EPT) MACROINVERTEBRATE GENERA IN RIFFLE HABITAT IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



NOTES: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

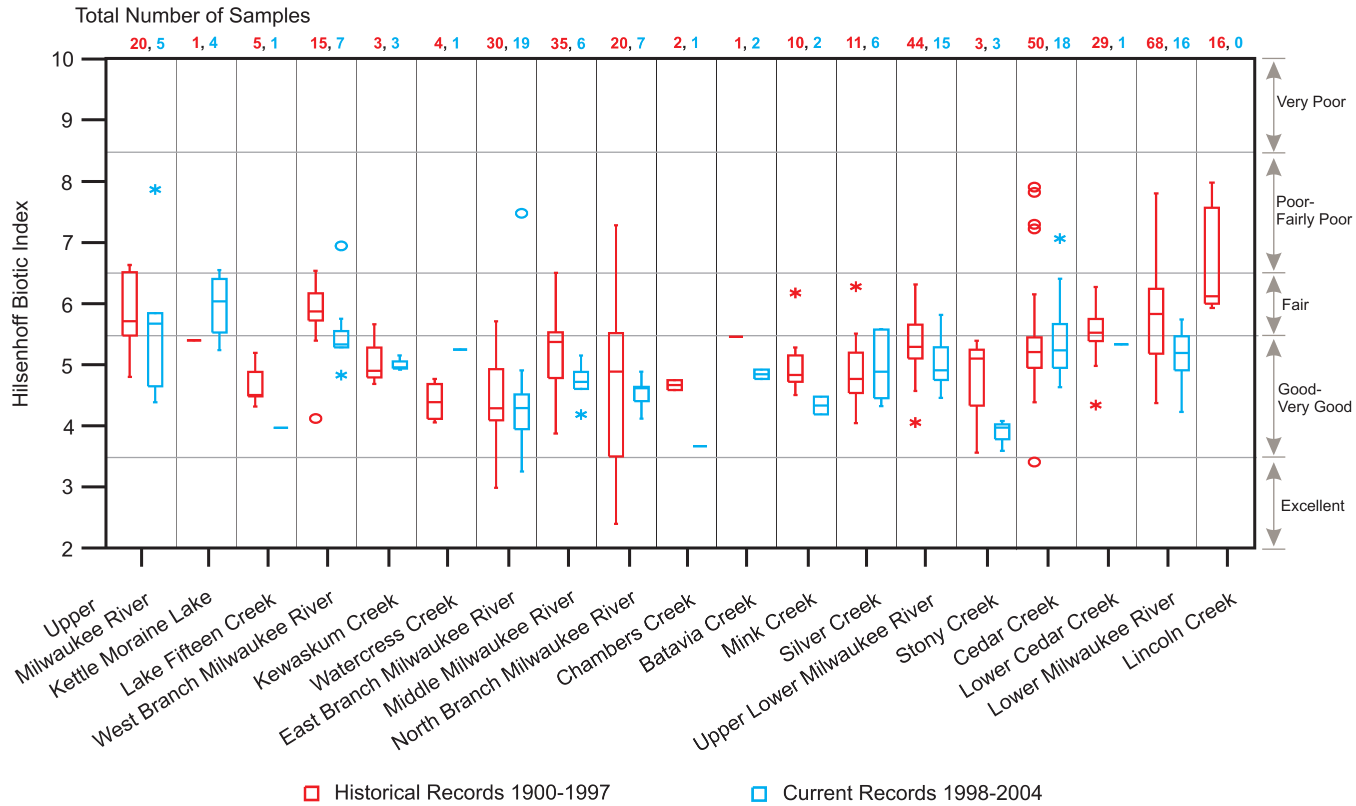
A variety of mammals, ranging in size from large animals like the white-tailed deer, to small animals like the meadow vole, are likely to be found in the vicinity of the Milwaukee River watershed. Muskrat, white-tailed deer, gray squirrel, and cottontail rabbit are mammals reported to occur in the area. Appendix D lists the mammals whose ranges historically extended into the watershed.

A large number of birds, ranging in size from large game birds to small songbirds, are found in the Milwaukee River watershed. Appendix E lists those birds that normally occur in the watershed. Each bird is classified as to whether it breeds within the area, visits the area only during the annual migration periods, or visits the area only on rare occasions. The Milwaukee River watershed also supports a significant population of waterfowl, including mallards and Canada geese. Larger numbers of various waterfowl likely move through the watershed area during the annual migrations when most of the regional species may also be present. Many game birds, songbirds, waders, and raptors also reside or visit the watershed.

Amphibians and reptiles are vital components of the ecosystem within an environmental unit like that of the Milwaukee River watershed. Examples of amphibians native to the area include frogs, toads, and salamanders. Turtles and snakes are examples of reptiles common to the Milwaukee River area. Appendix F lists the amphibian and reptile species normally expected to be present in the Milwaukee River watershed under present conditions. Most amphibians and reptiles have specific habitat requirements that are adversely affected by agricultural

Figure 178

HISTORICAL AND BASE PERIOD HILSENHOFF BIOTIC INDEX (HBI) SCORES IN RIFFLE HABITAT IN STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1975-2004



NOTES: See Figure 109 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

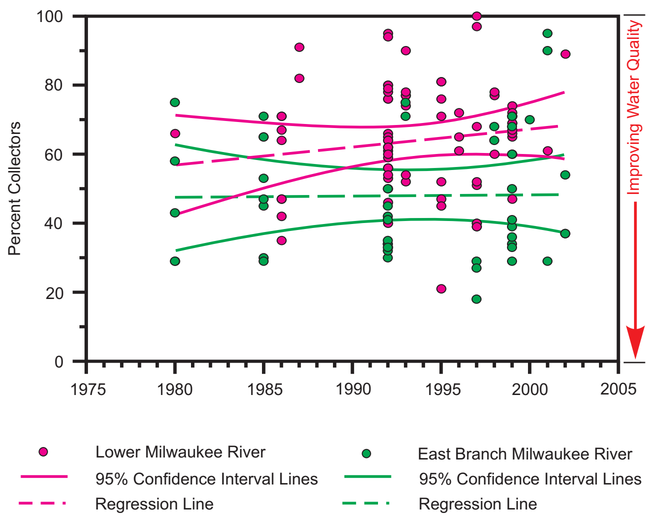
disturbances and advancing urban development. The major detrimental factors affecting the maintenance of amphibians in a changing environment is the draining or destruction of breeding ponds, urban development occurring in migration routes, and changes in food sources brought about by urbanization.

A total of 88 Endangered and threatened species and species of special concern were identified to be present within the vicinity of the Milwaukee River watershed, including 47 species of plants, 10 species of birds, 11 species of fish, four species of herptiles, and 16 species of invertebrates from Wisconsin Department of Natural Resources records dating back to the late 1800s (see Table 109). Since 1975, there have been observed 24 species of plants, 10 species of birds, 10 species of fish, three species of herptiles, and 15 species of invertebrates, totaling to an apparent loss of 26 total species.

The complete spectrum of wildlife species originally native to the watershed, along with their habitat, has undergone significant change in terms of diversity and population size since the European settlement of the area. This change is a direct result of the conversion of land by the settlers from its natural state to agricultural and urban uses, beginning with the clearing of the forest and prairies, the draining of wetlands, and ending with the development of urban land in some areas. Successive cultural uses and attendant management practices, primarily urban, have been superimposed on the land use changes and have also affected the wildlife and wildlife habitat. In urban areas, cultural management practices that affect wildlife and their habitat include the use of fertilizers, herbicides, and pesticides; road salting for snow and ice control; heavy motor vehicle traffic that produces disruptive noise levels and air pollution and nonpoint source water pollution; and the introduction of domestic pets.

Figure 179

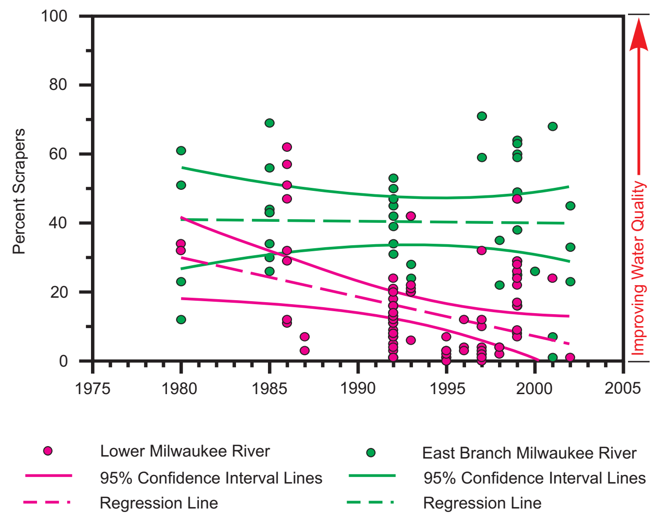
PERCENT COLLECTOR MACROINVERTEBRATE TROPHIC GROUPS IN THE EAST BRANCH MILWAUKEE RIVER AND LOWER MILWAUKEE RIVER SUBWATERSHEDS: 1979-2003



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 180

PERCENT SCRAPER MACROINVERTEBRATE TROPHIC GROUPS IN THE EAST BRANCH MILWAUKEE RIVER AND LOWER MILWAUKEE RIVER SUBWATERSHEDS: 1979-2003



Source: Wisconsin Department of Natural Resources and SEWRPC.

CHANNEL CONDITIONS AND STRUCTURES

The conditions of the bed and bank of a stream are greatly affected by the flow of water through the channel. The great amount of energy possessed by flowing water in a stream channel is dissipated along the stream length by turbulence, streambank and streambed erosion, and sediment resuspension. Sediments and associated substances delivered to a stream may be stored, at least temporarily, on the streambed, particularly where obstructions or irregularities in the channel decrease the flow velocity or act as particle traps or filters. On an annual basis or a long-term basis, streams may exhibit net deposition, net erosion, or no net change in internal sediment transport, depending on tributary land uses, watershed hydrology, precipitation, and geology. From 3 to 11 percent of the annual sediment yield in a watershed in southeastern Wisconsin may be contributed by streambank erosion.[50] In the absence of mitigative measures, increased urbanization in a watershed may be expected to result in increased streamflow rates and volumes, with potential increases in streambank erosion and bottom scour, and flooding problems. In many of the communities in the downstream portion of the Milwaukee River watershed, the requirements of MMSD Chapter 13, "Surface Water and Storm Water," are applied to mitigate instream increases in peak rates of flow that could occur due to new urban development without runoff controls. In communities outside of the MMSD service area, local ordinances provide for varying degrees of control of runoff from new development. Also, where soil conditions allow, the infiltration standards of Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* are applied to limit increases in runoff volume from new development.

Milwaukee County commissioned an assessment of stability and fluvial geomorphic character of streams within four watersheds in the County including the Milwaukee River watershed.[51] This study, conducted in fall 2003,

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[50]*SEWRPC Technical Report No. 21,* Sources of Water Pollution in Southeastern Wisconsin: 1975*, September 1978.*

[51]*Inter-Fluve, Inc.,* op. cit.

Table 109

ENDANGERED AND THREATENED SPECIES AND SPECIES OF SPECIAL CONCERN IN THE MILWAUKEE RIVER WATERSHED: 2004

Common Name	Scientific Name	Status under the U.S. Endangered Species Act	Wisconsin Status
Insects			
A Common Netspinner Caddisfly	*Hydropsyche bidens*	Not listed	Special concern
A Side-Swimmer	*Crangonyx gracilis*	Not listed	Special concern
Amber-Winged Spreadwing	*Lestes eurinus*	Not listed	Special concern
Aurora Damselfly	*Chromagrion conditum*	Not listed	Special concern
Broad-Winged Skipper	*Poanes viator*	Not listed	Special concern
Dion Skipper	*Euphyes dion*	Not listed	Special concern
Elegant Spreadwing	*Lestes inaequalis*	Not listed	Special concern
Ellipse	*Venustaconcha ellipsiformis*	Not listed	Threatened
Green-Striped Darner	*Aeshna verticalis*	Not listed	Special concern
Mulberry Wing	*Poanes massasoit*	Not listed	Special concern
Prairie Crayfish[a]	*Procambarus gracilis*	Not listed	Special concern
Slaty Skimmer	*Libellula incesta*	Not listed	Special concern
Slender Bluet	*Enallagma traviatum*	Not listed	Special concern
Swamp Metalmark	*Calephelis muticum*	Not listed	Endangered
Swamp Spreadwing	*Lestes vigilax*	Not listed	Special concern
Unicorn Clubtail	*Arigomphus villosipes*	Not listed	Special concern
Fish			
American Eel[a]	*Anguilla rostrata*	Not listed	Special concern
Banded Killifish	*Fundulus diaphanus*	Not listed	Special concern
Bloater[b]	*Coregonus hoyi*	Not listed	Special concern
Greater Redhorse	*Moxostoma valenciennesi*	Not listed	Threatened
Lake Chubsucker	*Erimyzon sucetta*	Not listed	Special concern
Least Darter	*Etheostoma microperca*	Not listed	Special concern
Longear Sunfish	*Lepomis megalotis*	Not listed	Threatened
Pugnose Shiner	*Notropis anogenus*	Not listed	Threatened
Redfin Shiner	*Lythrurus umbratilis*	Not listed	Threatened
Striped Shiner	*Luxilus chrysocephalus*	Not listed	Endangered
Weed Shiner	*Notropis Texanus*	Not listed	Special concern
Reptiles and Amphibians			
Butler's Garter Snake	*Thamnophis butleri*	Not listed	Threatened
Blanchard's Cricket Frog[a]	*Acris crepitans blanchardi*	Not listed	Endangered
Blanding's Turtle	*Emydoidea blandingii*	Not listed	Threatened
Queen Snake	*Regina septemvittata*	Not listed	Endangered
Birds			
Acadian Flycatcher	*Empidonax virescens*	Not listed	Threatened
Cerulean Warbler	*Dendroica cerulea*	Not listed	Threatened
Common Tern	*Sterna hirundo*	Not listed	Endangered
Dickcissel	*Spiza americana*	Not listed	Special concern
Hooded Warbler	*Wilsonia citrina*	Not listed	Threatened
Kentucky Warbler	*Oporornis formosis*	Not listed	Threatened
Northern Pintail	*Anas acuta*	Not listed	Special concern
Orchard Oriole	*Icterus spurius*	Not listed	Special concern
Red-Shouldered Hawk	*Buteo lineatus*	Not listed	Threatened
White-Eyed Vireo	*Vireo griseus*	Not listed	Special concern
Plants			
American Gromwell	*Lithospermum latifolium*	Not listed	Special concern
American Sea-Rocket	*Cakile edentula*	Not listed	Special concern
Autumn Coral-Root	*Corallorhiza odontorhiza*	Not listed	Special concern
Christmas Fern	*Polystichum acrostichoides*	Not listed	Special concern
Clustered Broomrape[a]	*Orobanche fasciculata*	Not listed	Threatened
Common Bog Arrow-Grass[a]	*Triglochim maritima*	Not listed	Special concern
Cooper's Milkvetch[a]	*Astragalus neglectus*	Not listed	Endangered
Cuckooflower	*Cardamine pratensis*	Not listed	Special concern
Downy Willow-Herb	*Epilobium strictum*	Not listed	Special concern

Table 109 (continued)

Common Name	Scientific Name	Status under the U.S. Endangered Species Act	Wisconsin Status
Plants (continued)			
Forked Aster	*Aster furcatus*	Not listed	Threatened
Giant Pinedrops	*Pterospora andromedea*	Not listed	Endangered
Great Indian-Plantain[a]	*Cacalia muehlenbergii*	Not listed	Special concern
Hairy Beardtongue[a]	*Penstemon hirsutus*	Not listed	Special concern
Handsome Sedge	*Carex formosa*	Not listed	Threatened
Harbinger-of-Spring[a]	*Erigenia bulbosa*	Not listed	Endangered
Hemlock Parsley[a]	*Conioselinum chinense*	Not listed	Endangered
Heart-Leaved Plantain	*Plantago cordata*	Not listed	Endangered
Hooker Orchis[a]	*Platanthera hookeri*	Not listed	Special concern
Large Roundleaf Orchid	*Platanthera orbiculata*	Not listed	Special concern
Lesser Fringed Gentain	*Gentianopsis procera*	Not listed	Special concern
Marsh Blazing Star[a]	*Liatris spicata*	Not listed	Special concern
Many-Headed Sedge	*Carex sychnocephala*	Not listed	Special concern
Marbleseed[a]	*Onosmodium molle*	Not listed	Special concern
Narrow-Leaved Vervain[a]	*Verbena simplex*	Not listed	Special concern
Ohio Goldenrod	*Solidago ohioensis*	Not listed	Special concern
One-Flowered Broomrape[a]	*Orobanche uniflora*	Not listed	Special concern
Pale-Green Orchid[a]	*Platanthera flava var. herbiola*	Not listed	Threatened
Purple Milkweed[a]	*Asclepias purpurascens*	Not listed	Endangered
Ram's-Head Lady's Slipper[a]	*Cypripedium arietinum*	Not listed	Threatened
Reflexed Trillium	*Trillium recurvatum*	Not listed	Special concern
Round-Leaved Orchis[a]	*Amerorchis rotundifolia*	Not listed	Threatened
Seaside Spurge[a]	*Euphorbia polygonifolia*	Not listed	Special concern
Showy Lady's Slipper[a]	*Cypripedium reginae*	Not listed	Special concern
Slender Sedge[a]	*Carex gracilescens*	Not listed	Special concern
Slim-Stem Small Reedgrass	*Calamagrostis stricta*	Not listed	Special concern
Small White Lady's Slipper[a]	*Cypripedium candidum*	Not listed	Threatened
Small Yellow Lady's Slipper	*Cypripedium calceolus*	Not listed	Special concern
Snow Trillium	*Trillium nivale*	Not listed	Threatened
Sparse-Flowered Sedge	*Carex tenuiflora*	Not listed	Special concern
Sticky False Asphodel	*Tofieldia glutinosa*	Not listed	Threatened
Twinleaf	*Jeffersonia diphylla*	Not listed	Special concern
Tufted Hairgrass[a]	*Deschampsia cespitosa*	Not listed	Special concern
Variegated Horsetail[a]	*Equisetum variegatum*	Not listed	Special concern
Wafer-Ash	*Ptelea trifoliata*	Not listed	Special concern
Waxleaf Meadowrue	*Thalictrum revolutum*	Not listed	Special concern
White Adder's-Mouth[a]	*Malaxis brachypoda*	Not listed	Special concern
Yellow Gentain	*Gentiana alba*	Not listed	Threatened

[a] *Species observed prior to year 1975.*

[b]*Unknown when species was observed.*

Source: Wisconsin Department of Natural Resources, Wisconsin State Herbarium, Wisconsin Society of Ornithology, and SEWRPC.

examined channel stability in about 24 miles of stream channel along the mainstem of the Milwaukee River and several of its tributaries. A major goal of this study was to create a prioritized list of potential project sites related to mitigation of streambank erosion and channel incision, responses to channelization, and maintenance of infrastructure integrity. In addition, the SEWRPC staff has evaluated the condition of the streambanks and associated erosion 1) along an unnamed Tributary to the Milwaukee River as part of the reconstruction of the USH 45 roadway improvement project in cooperation with the Wisconsin Department of Transportation and 2) in the Quaas Creek subwatershed as part of the development of a watershed protection plan in cooperation with Washington County Land Conservation Department.[52]

[52]*Wisconsin Department of Transportation and SEWRPC Letter Agreement, USH 45—Stream Relocation Project (Project ID# 4070-01-02), August 2001; SEWRPC Memorandum Report No. 151,* Stream Channel Stability and Biological Assessment of Quaas Creek: 2002*, Washington County Wisconsin, July 2002.*

Map 61 shows the types of channel bed lining in streams within the Milwaukee River watershed. Reaches within Polk Spring Creek, Beaver Creek, Southbranch Creek, an unnamed tributary to Southbranch Creek, Brown Deer Park Creek, and an unnamed tributary to Indian Creek in the lower portions of the Milwaukee River watershed are enclosed in approximately 3.3 miles of underground conduit. Enclosed channel represents less than 1 percent of the stream length assessed. Reaches within Beaver Creek, Lincoln Creek, Southbranch Creek, Brown Deer Park Creek, and Indian Creek are lined with concrete over a total length of approximately 3.7 miles. The stream network has been substantially modified over much of the watershed, with many stretches having been channelized. However, there are some areas within the upper portions of the watershed where stream channel modification has not been as significant, such as the designated exceptional water resources areas in the East Branch of the Milwaukee River and Lake Fifteen Creek subwatersheds.

Bed and Bank Stability

Alluvial streams within urbanizing watersheds often experience rapid channel enlargement. As urbanization occurs, the fraction of the watershed covered by impervious surfaces increases. This can result in profound changes in the hydrology in the watershed. As a result of runoff being conveyed over impervious surfaces to storm sewers which discharge directly to streams, peak flows become higher and more frequent and streams become "flashier," with flows increasing rapidly in response to rainfall events. The amount of sediment reaching the channel often declines. Under these circumstances and in the absence of armoring, the channel may respond by incising. This leads to an increase in the height of the streambank, which continues until a critical threshold for stability is exceeded. When that condition is reached, mass failure of the bank occurs, leading to channel widening. Typically, incision in an urbanizing watershed proceeds from the mouth to the headwaters.[53] Lowering of the downstream channel bed increases the energy gradient upstream and in the tributaries. This contributes to further destabilization. Once it begins, incision typically follows a sequence of channel bed lowering, channel widening, and deposition of sediment within the widened channel. Eventually, the channel returns to a stable condition characteristic of the altered channel geometry.

It is also important to note that most of the agricultural lands in the Milwaukee River watershed contain drain tiles that are designed specifically to convey water out of the soils and into the adjacent streams that have generally been channelized. As a result of runoff being conveyed via drain tiles, relative to undrained conditions, peak flows become somewhat higher and more frequent with flows increasing more rapidly in response to rainfall events. Similar to urban development conditions, agricultural activities in a watershed can also lead to localized bank scour, channel incision, and bank failure.

Map 62 summarizes bank stability for the Milwaukee River and several of its tributaries.[54] Photographs of typical bank stability conditions throughout the watershed are shown in Figure 181. About 43 miles of channel were inventoried for stability as shown on Map 62, including about 31 miles of channel in Milwaukee County and about 2.4 miles of channel in the unnamed tributary to the Milwaukee River and Quaas Creek systems. Approximately half of the alluvial reaches that were examined appeared to be degrading and actively eroding. About 9.5 percent of the stream length assessed was observed to be stable. The stable reaches are located in Lincoln Creek, Lower Milwaukee River, an unnamed tributary to the Milwaukee River, and portions of the Brown Deer Park Creek and Quaas Creek systems (see Map 62). These assessments represent about 9 percent of the approximately 511 total miles of stream length that exist throughout the Milwaukee River watershed area. It should be noted that the assessment of Lincoln Creek was conducted prior to the completion of the MMSD environmental restoration and flood control project. That project was designed to promote bank stability and the conclusion of stable banks along Lincoln Creek is still valid under post-project conditions.

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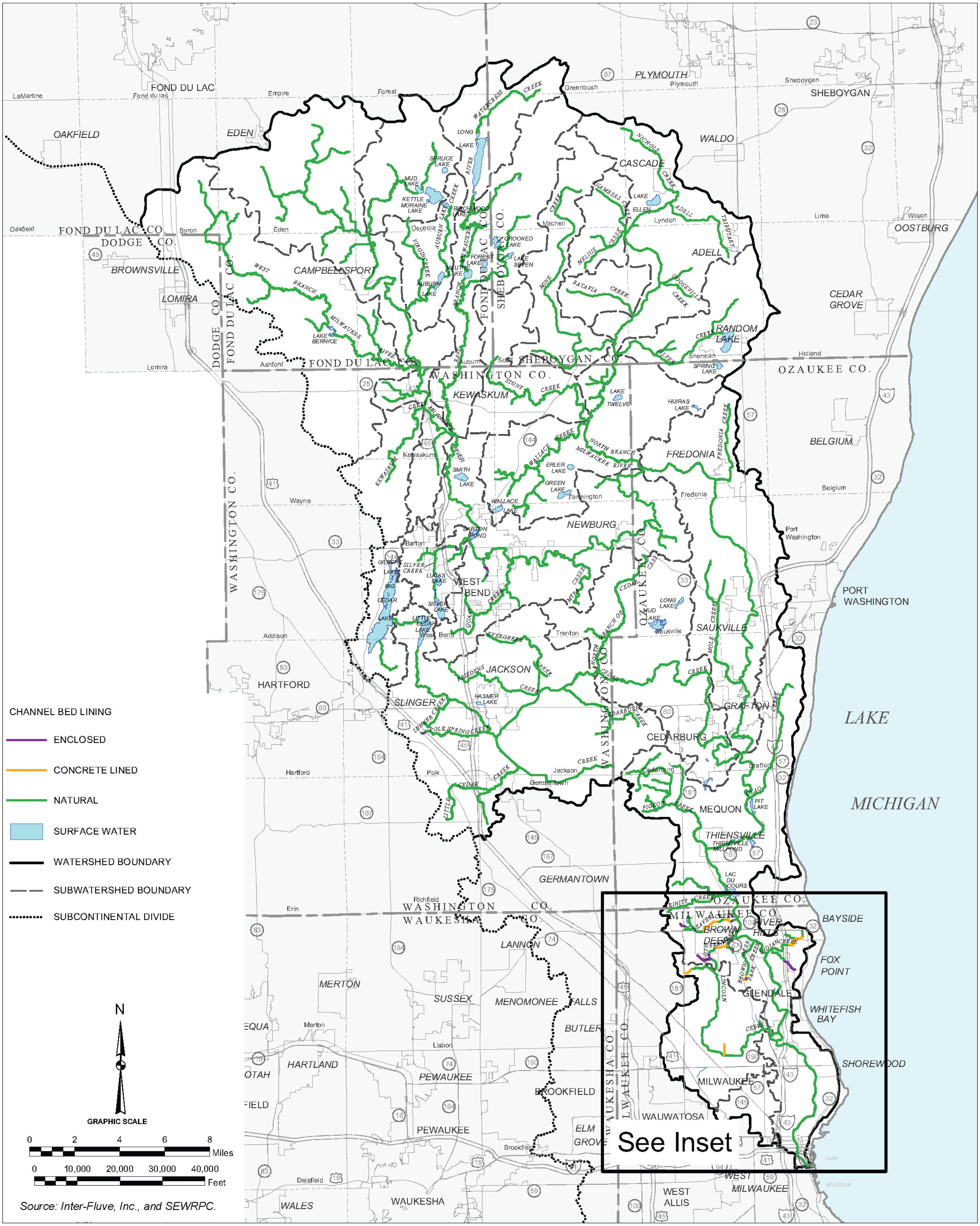
[53]*S.A. Schumm, "Causes and Controls of Channel Incision," In: S. E. Darby and A. Simon (eds.),* Incised River Channels: Processes, Forms, Engineering and Management, *John Wiley & Sons, New York, 1999.*

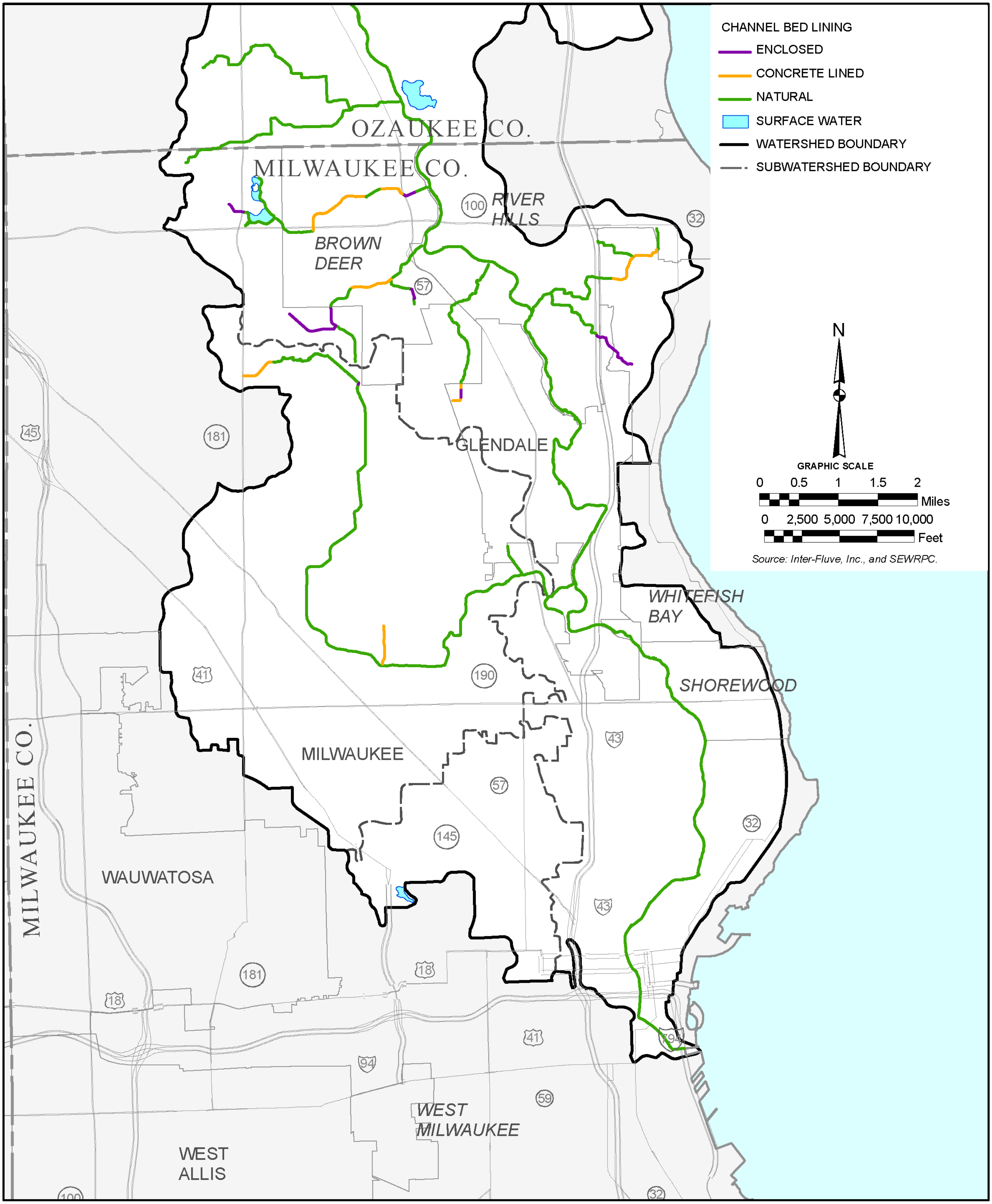
[54]*Inter-Fluve, Inc.,* op. cit.; *Wisconsin Department of Transportation and SEWRPC Letter Agreement,* op. cit.; *SEWRPC Memorandum Report No. 151,* op. cit.

Map 61

CHANNEL BED CONDITIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000



INSET to Map 61



Map 62

STREAMBANK STABILITY CONDITIONS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000

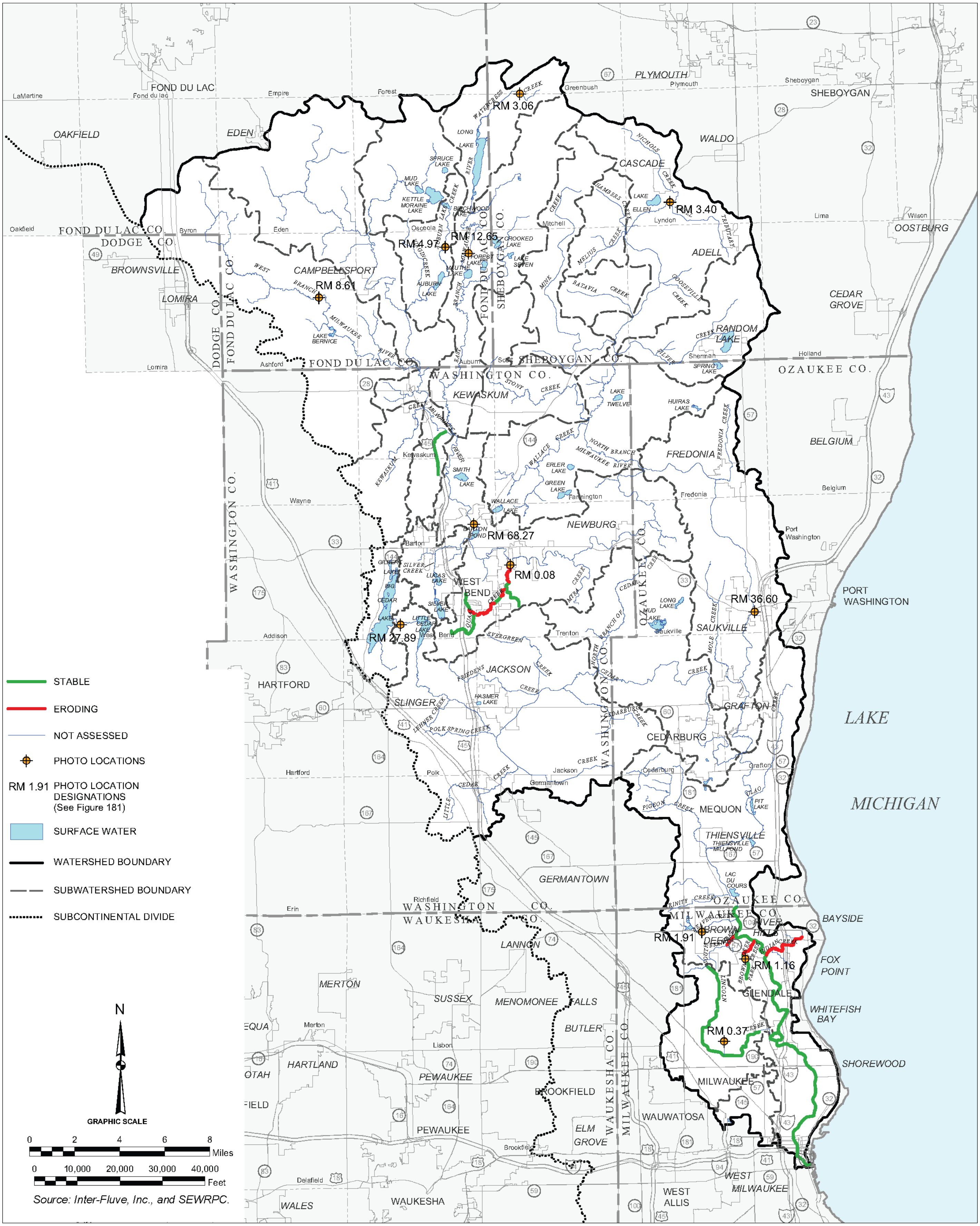


Figure 181

STREAMBANK STABILITY CONDITIONS AMONG REACHES WITHIN THE MILWAUKEE RIVER WATERSHED: 2003, 2005

WATERCRESS CREEK AT RIVER MILE 3.06

EAST BRANCH MILWAUKEE RIVER AT RIVER MILE 12.65

NICHOLS CREEK AT RIVER MILE 3.40

WEST BRANCH MILWAUKEE RIVER AT RIVER MILE 8.61

AUBURN LAKE CREEK AT RIVER MILE 4.97

MILWAUKEE RIVER AT RIVER MILE 68.27

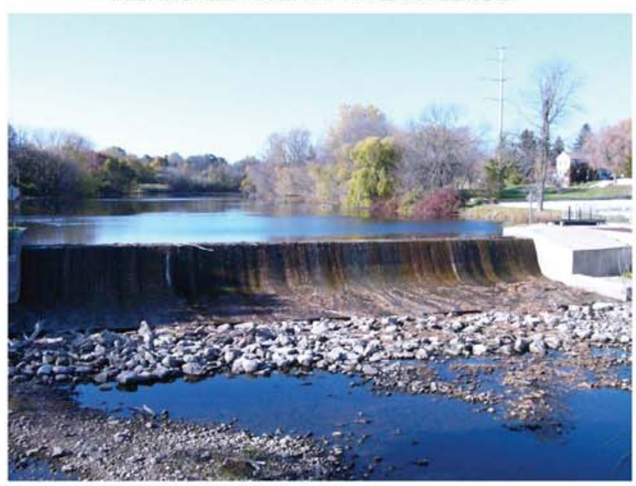


Figure 181 (continued)

QUAAS CREEK AT RIVER MILE 0.08

BEAVER CREEK AT RIVER MILE 1.91

CEDAR CREEK AT RIVER MILE 27.89

BROWN DEER CREEK AT RIVER MILE 1.16

MILWAUKEE RIVER AT RIVER MILE 36.60

WAHL CREEK AT RIVER MILE 0.37

Source: Inter-Fluve, Inc., and SEWRPC.

Dams
There are currently about 70 dams and about 6 drop structures within the Milwaukee River watershed. As shown on Map 63, the dams are located throughout the watershed, along the mainstem and tributaries of the Milwaukee River. Most of these dams form impoundments. In addition, a small number of drop structures are located in Beaver Creek and Brown Deer Park Creek. Dams and drop structures can disrupt sediment transport and limit aquatic organism passage, fragmenting populations in the reaches shown on Map 53. Those factors can lead to a reduction in overall abundance and diversity of aquatic organisms as summarized in the "Influence of Dams/Dam Removal" subsection above.

HABITAT AND RIPARIAN CORRIDOR CONDITIONS

One of the most important tasks undertaken by the Commission as part of its regional planning effort was the identification and delineation of those areas of the Region having high concentrations of natural, recreational, historic, aesthetic, and scenic resources and which, therefore, should be preserved and protected in order to maintain the overall quality of the environment. Such areas normally include one or more of the following seven elements of the natural resource base which are essential to the maintenance of both the ecological balance and the natural beauty of the Region: 1) lakes, rivers, and streams and the associated undeveloped shorelands and floodlands; 2) wetlands; 3) woodlands; 4) prairies; 5) wildlife habitat areas; 6) wet, poorly drained, and organic soils; and 7) rugged terrain and high-relief topography. While the foregoing seven elements constitute integral parts of the natural resource base, there are five additional elements which, although not a part of the natural resource base per se, are closely related to or centered on that base and therefore are important considerations in identifying and delineating areas with scenic, recreational, and educational value. These additional elements are: 1) existing outdoor recreation sites; 2) potential outdoor recreation and related open space sites; 3) historic, archaeological, and other cultural sites; 4) significant scenic areas and vistas; and 5) natural and scientific areas.

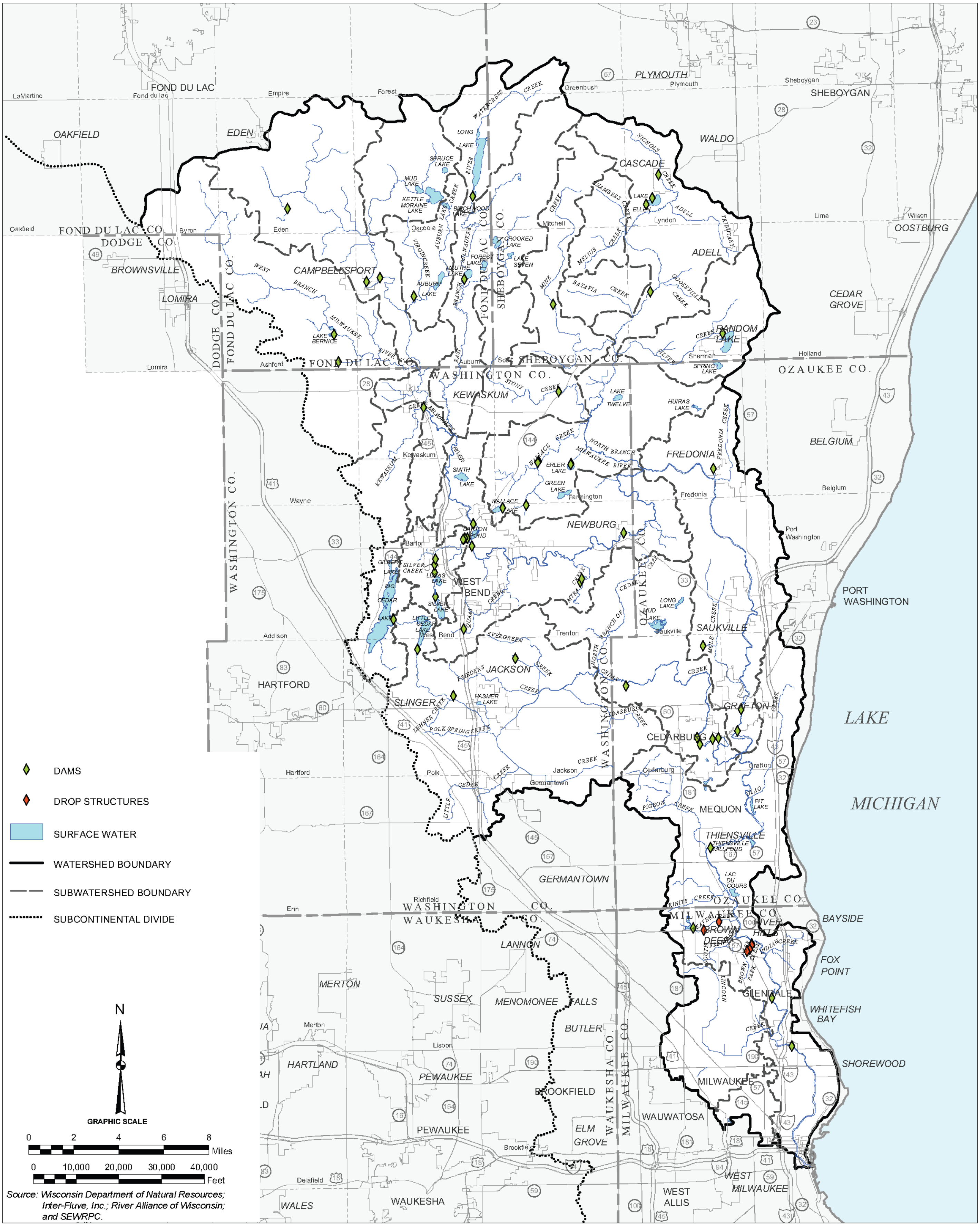
The delineation of these 12 natural resource and natural resource-related elements on a map results in an essentially linear pattern of relatively narrow, elongated areas which have been termed "environmental corridors" by the Commission. Primary environmental corridors include a wide variety of the abovementioned important resource and resource-related elements and are at least 400 acres in size, two miles in length, and 200 feet in width. Secondary environmental corridors generally connect with the primary environmental corridors and are at the least 100 acres in size and one-mile long. In addition, smaller concentrations of natural resource features that have been separated physically from the environmental corridors by intensive urban or agricultural land uses have also been identified. These areas, which are at least five acres in size, are referred to as isolated natural resource areas.

It is important to point out that, because of the many interlocking and interacting relationships between living organisms and their environment, the destruction or deterioration of any one element of the total environment may lead to a chain reaction of deterioration and destruction among the others. The drainage of wetlands, for example, may have far-reaching effects, since such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas of interconnecting lake and stream systems. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater. Groundwater serves as a source of domestic, municipal, and industrial water supply and provides a basis for low flows in rivers and streams. Similarly, the destruction of woodland cover, which may have taken a century or more to develop, may result in soil erosion and stream siltation and in more rapid runoff and increased flooding, as well as destruction of wildlife habitat. Although the effects of any one of these environmental changes may not in and of itself be overwhelming, the combined effects may lead eventually to the deterioration of the underlying and supporting natural resource base, and of the overall quality of the environment for life. The need to protect and preserve the remaining environmental corridors within the watershed area directly tributary to the Milwaukee River system thus becomes apparent.

Primary Environmental Corridors
The primary environmental corridors in southeastern Wisconsin generally lie along major stream valleys and around major lakes, and contain almost all of the remaining high-value woodlands, wetlands, and wildlife habitat

Map 63

DAMS AND DROP STRUCTURES WITHIN THE MILWAUKEE RIVER WATERSHED: 2005



areas, and all of the major bodies of surface water and related undeveloped floodlands and shorelands. As shown on Map 64, in the year 2000 primary environmental corridors in the Milwaukee River watershed area encompassed about 94,500 acres, or about 21 percent of the watershed area. The major environmental corridor lands within the watershed lie along the Kettle Moraine and trend in a north-south direction in the west central portions of the drainage area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of primary environmental corridors within the watershed. Primary environmental corridors may be subject to urban encroachment because of their desirable natural resource amenities. Unplanned or poorly planned intrusion of urban development into these corridors, however, not only tends to destroy the very resources and related amenities sought by the development, but tends to create severe environmental and development problems as well. These problems include, among others, water pollution, flooding, wet basements, failing foundations for roads and other structures, and excessive infiltration of clear water into sanitary sewerage systems.

Secondary Environmental Corridors

Secondary environmental corridors are located generally along intermittent streams or serve as links between segments of primary environmental corridors. As shown on Map 64, secondary environmental corridors in the Milwaukee River watershed area encompassed about 9,500 acres, or about 2 percent of the watershed area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of secondary environmental corridors within the watershed. Secondary environmental corridors contain a variety of resource elements, often remnant resources from primary environmental corridors which have been developed for intensive agricultural purposes or urban land uses, and facilitate surface water drainage, maintain "pockets" of natural resource features, and provide for the movement of wildlife, as well as for the movement and dispersal of seeds for a variety of plant species.

Isolated Natural Resource Areas

In addition to the primary and secondary environmental corridors, other small concentrations of natural resource base elements exist within the watershed area. These concentrations are isolated from the environmental corridors by urban development or agricultural lands and, although separated from the environmental corridor network, have important natural values. These isolated natural resource areas may provide the only available wildlife habitat in a localized area, provide good locations for local parks and nature study areas, and lend a desirable aesthetic character and diversity to the area. Important isolated natural resource area features include a variety of isolated wetlands, woodlands, and wildlife habitat. These isolated natural resource area features should also be protected and preserved in a natural state whenever possible. Such isolated areas five or more acres in size within the Milwaukee River watershed area also are shown on Map 64 and total about 11,200 acres, or about 3 percent of the watershed area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of isolated natural resource areas within the watershed.

Natural Areas and Critical Species Habitat

The regional natural areas and critical species habitat protection and management plan[55] ranked natural resource features based upon a system that considered areas to be of statewide or greater significance, NA-1; countywide or regional significance, NA-2; or local significance, NA-3. In addition, certain other areas were identified as critical species habitat sites. Within the Milwaukee River watershed area, as shown on Map 65 and Table 110, 113 such sites were identified, 26 of which were identified as critical species habitat sites. Eight sites totaling about 2,600 acres were identified as being of statewide or great significance (NA-1), about 75 percent of which are already in public ownership. There were 29 sites identified as natural areas of countywide or regional significance (NA-2) totaling 6,860 acres; about 2,315 acres or about 35 percent of which are already in public ownership and the remaining lands are proposed to be acquired. A further approximately 55 sites, totaling about 5,345 acres of natural area of local significance (NA-3), were identified. Of the approximately 5,340 acres of

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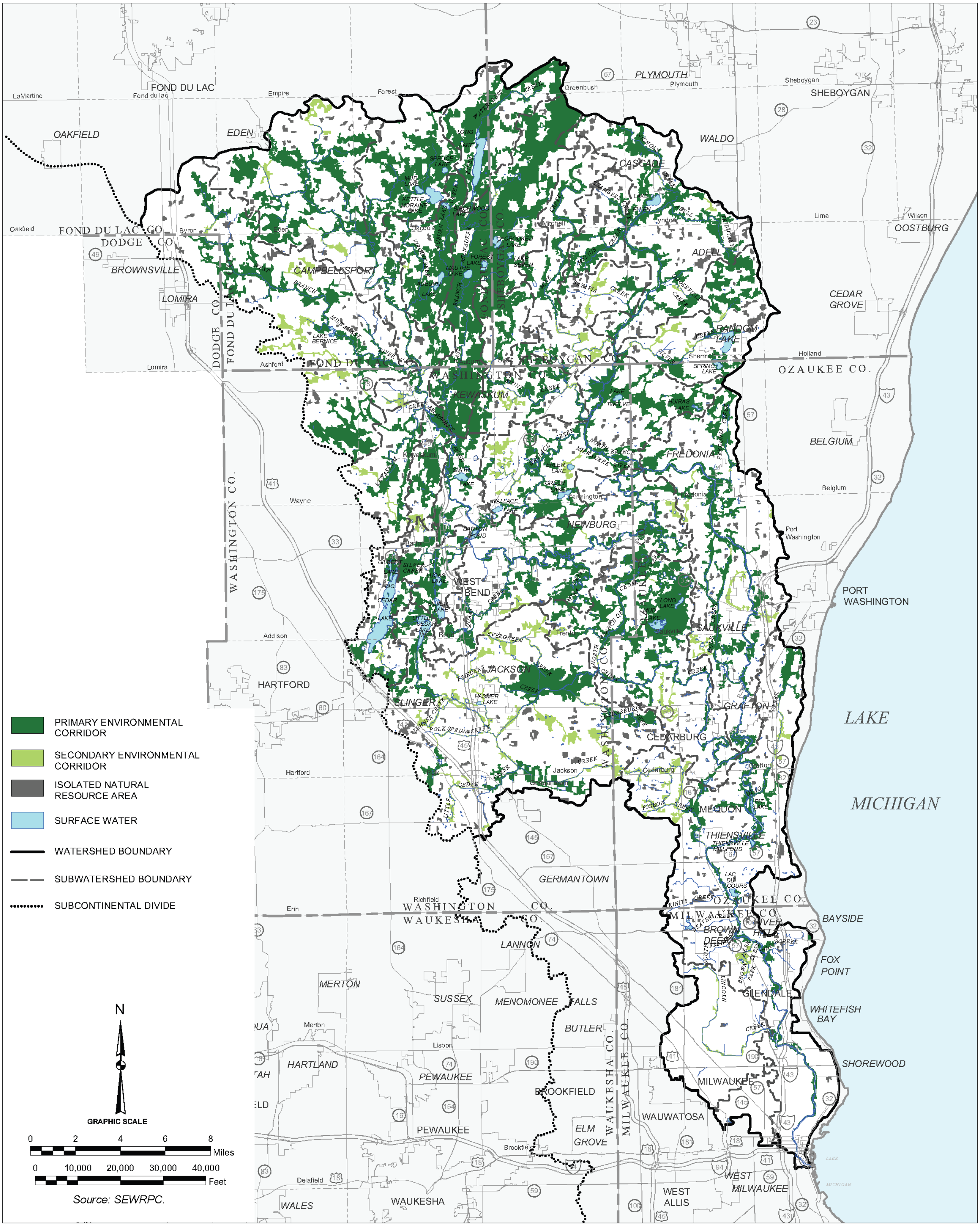
[55]*SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*, September 1997.*

Map 64

ENVIRONMENTAL CORRIDORS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000



Source: SEWRPC.

Map 65

KNOWN NATURAL AREAS AND CRITICAL SPECIES HABITAT SITES WITHIN THE MILWAUKEE RIVER WATERSHED: 1994

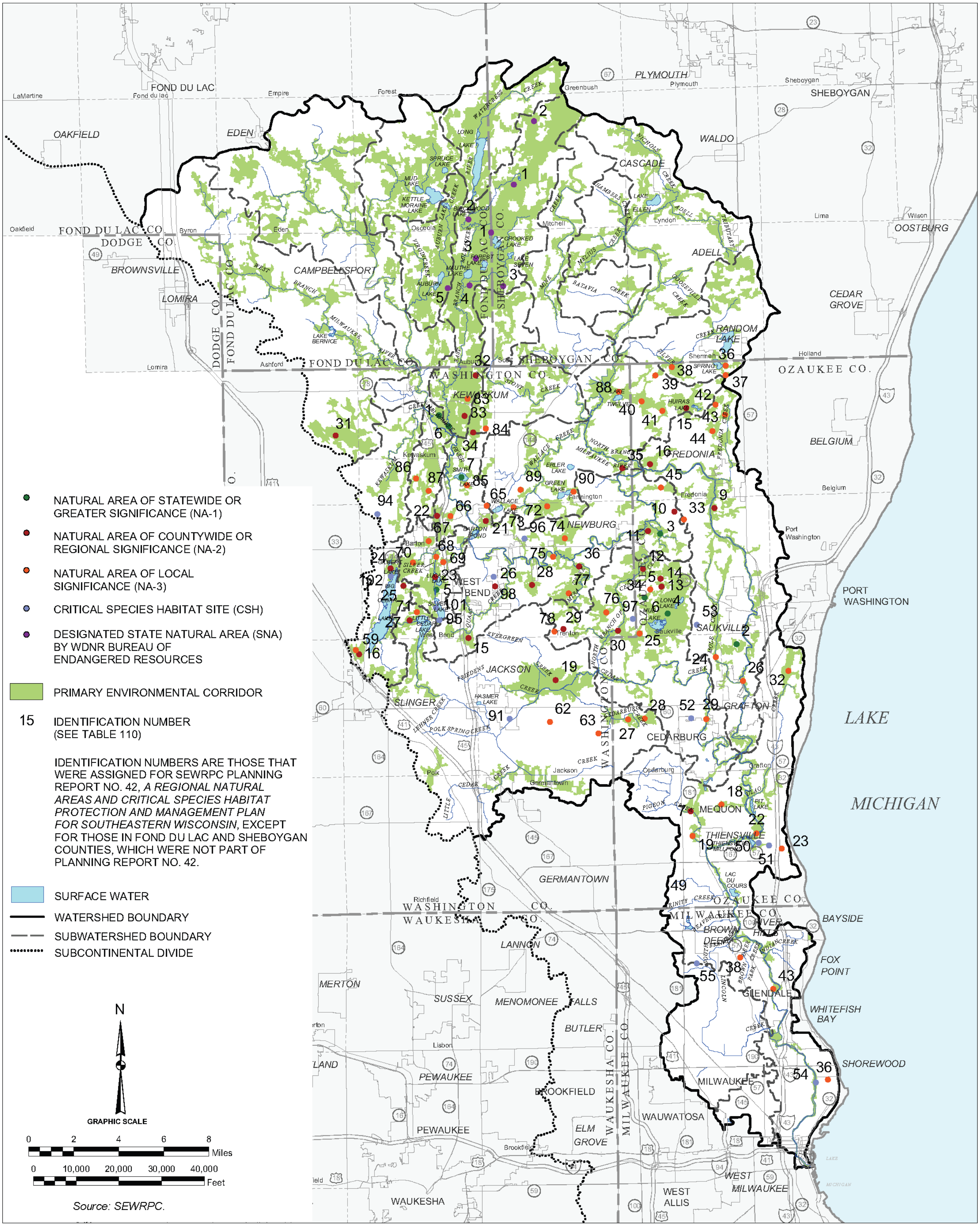


Table 110

NATURAL AREAS AND CRITICAL SPECIES HABITAT SITES IN THE MILWAUKEE RIVER WATERSHED

Number on Map 65	Name	Type of Area	Location	Owned (acres)	Proposed to Be Acquired[a] (acres)	Total (acres)	Proposed Acquisition Agency
	Natural Areas						
1	Crooked Lake Wetlands	SNA	Fond du Lac County	- -[b]	- -	- -	- -
1	Kewaskum Maple-Oak Woods State Natural Area	NA-1, CSH	Town of Kewaskum	46	40	86	Wisconsin Department of Natural Resources
1	Butler Lake Flynn's Spring	SNA	Sheboygan County	- -[c]	- -	- -	- -
2	Milwaukee River Tamarack Lowlands & Dundee Kame	SNA	Fond du Lac County	- -	- -	- -	- -
2	Kurtz Woods State Natural Area	NA-1	Town of Grafton	31	39	70	The Nature Conservancy
2	Johnson Hill Kame	SNA	Sheboygan County	- -[c]	- -	- -	- -
3	Kettle Hole Woods	SNA	Sheboygan County	- -[c]	- -	- -	- -
3	Haskell Noyes Woods	SNA	Fond du Lac County	- -[b]	- -	- -	- -
3	Riveredge Creek and Ephemeral Pond State Natural Area	NA-1, CSH	Town of Saukville	75	22	97	Riveredge Nature Center
4	Milwaukee River and Swamp	SNA	Fond du Lac County	- -[b]	- -	- -	- -
4	Cedarburg Bog State Natural Area	NA-1, CSH	Town of Saukville	1,572	437	2,009	Wisconsin Department of Natural Resources
5	Spring Lake	SNA	Fond du Lac County	- -[b]	- -	- -	- -
5	Sapa Spruce Bog State Natural Area	NA-1	Town of Saukville	22	37	59	University of Wisconsin-Milwaukee
5	Paradise Lake Fen	NA-1	Town of West Bend	11	11	22	Wisconsin Department of Natural Resources
6	Cedarburg Beech Woods State Natural Area	NA-2, CSH	Town of Saukville	87	43	130	University of Wisconsin-Milwaukee
6	Milwaukee River Floodplain Forest State Natural Area	NA-1	Town of Kewaskum	130	5	135	Wisconsin Department of Natural Resources
7	Pigeon Creek Low and Mesic Woods	NA-2	City of Mequon	- -	81	81	Ozaukee County
7	Smith Lake and Wetlands	NA-1	Town of Barton	85	45	130	Wisconsin Department of Natural Resources
9	Milwaukee River Mesic Woods	NA-2	Village of Fredonia, Town of Saukville, Town of Fredonia	67	315	382	Ozaukee County
10	Duck's Limited Bog	NA-2	Town of Saukville	13	8	21	Ducks Limited
11	Riveredge Mesic Woods	NA-2, CSH	Town of Saukville	158	54	212	Riveredge Nature Center
12	Kinnamon Conifer Swamp	NA-2	Town of Saukville	- -	382	382	Ozaukee County
13	South Conifer Swamp	NA-2	Town of Saukville	3	49	52	Wisconsin Department of Natural Resources
14	Max's Bog	NA-2	Town of Saukville	5	8	13	Private conservancy organization
15	Mud Lake Swamp	NA-2	Town of Polk, Town of West Bend	7[d]	179	188	Washington County
15	Huiras Lake Woods and Bog	NA-2	Town of Fredonia	22	413	435	Ozaukee County
16	Janik's Woods	NA-2	Town of Fredonia	- -	163	163	Ozaukee County
16	Big Cedar Lake Bog	NA-2	Town of Polk	- -	89	89	Washington County
18	Highland Road Woods	NA-3	City of Mequon	- -	83	83	City of Mequon
19	Pigeon Creek Maple Woods	NA-3	City of Mequon	- -	13	13	Ozaukee County
19	Jackson Swamp	NA-2, CSH	Town of Jackson	1,221	350	1,571	Wisconsin Department of Natural Resources
21	Lac Lawrann Conservancy Upland Woods and Wetlands	NA-2	City of West Bend	78	23	101	City of West Bend
22	Blue Hills Woods	NA-2, CSH	City of West Bend, Town of Barton	105	161	266	City of West Bend
22	Ville de Parc Riverine Forest	NA-3	City of Mequon	49	62	111	City of Mequon
23	Mequon Wetland	NA-3	City of Mequon	- -[e]	- -[e]	77	- -
23	Silverbrook Lake Woods	NA-2	Town of West Bend	148	256	404	Wisconsin Department of Natural Resources
24	Mole Creek Swamp	NA-3	Town of Cedarburg	22	67	89	Town of Cedarburg
24	Gilbert Lake Tamarack Swamp	NA-2, CSH	Town of West Bend	54	76	130	Cedar Lakes Conservation Foundation
25	Cedar-Sauk Low Woods	NA-3	Town of Cedarburg, Town of Saukville, Town of Trenton	- -	218	218[f]	Private conservancy organization

Table 110 (continued)

Number on Map 65	Name	Type of Area	Location	Owned (acres)	Proposed to Be Acquired[a] (acres)	Total (acres)	Proposed Acquisition Agency
	Natural Areas (continued)						
25	Hacker Road Bog	NA-2	Town of West Bend	25	- -	25	Wisconsin Department of Natural Resources
26	Muth Woods	NA-2	City of West Bend	- -	30	30	City of West Bend
26	Grafton Woods	NA-3	Town of Grafton	- -	18	18	Ozaukee County
27	Little Cedar Lake Wetlands	NA-2	Town of West Bend	126	11	137	Cedar Lakes Conservation Foundation
27	Sherman Road Woods	NA-3	Town of Cedarburg	- -	72	72	Private conservancy organization
28	Schoenbeck Woods	NA-2	Town of Trenton	- -	195	195	Washington County
28	Five Corners Swamp	NA-3	Town of Cedarburg	19	154	173	Wisconsin Department of Natural Resources
29	Bellin Bog	NA-2	Town of Trenton	2	15	17	Washington County
29	Cedar Creek Forest	NA-3	Town of Cedarburg	- -	23	23	City of Cedarburg
30	Reinartz Cedar Swamp	NA-2	Town of Trenton	9	110	119	Washington County
31	Wayne Swamp	NA-2	Town of Wayne, Town of Kewaskum	- -	1,126	1,126	Washington County
32	Ulao Lowland Forest	NA-3	Town of Grafton	- -	347	347	Private conservancy organization
32	Kettle Moraine Drive Bog	NA-2	Town of Kewaskum	29	10	39	Wisconsin Department of Natural Resources
33	Hanson Lake Wetland	NA-3	Town of Saukville	5	8	13	Private conservancy organization
33	Glacial Trail Forest	NA-2, CSH	Town of Kewaskum	212	11	223	Wisconsin Department of Natural Resources
34	St. Michael's Woods	NA-2, CSH	Town of Kewaskum	81	3	84	Wisconsin Department of Natural Resources
34	Knollwood Road Bog	NA-3	Town of Saukville	4	5	9	Private conservancy organization
35	Hawthorne Drive Forest	NA-3	Town of Port Washington	- -[e]	- -	54	- -
35	North Branch Woods	NA-2	Town of Farmington	- -	96	96	Washington County
36	Spring Lake Marsh	NA-3	Town of Fredonia	3	16	19	Private conservancy organization
36	Myra Wetlands	NA-2	Town of Trenton	- -	69	69	Washington County
36	Downer Woods	NA-3	City of Milwaukee	13	- -	13	University of Wisconsin-Milwaukee
37	Spring Lake Beech Forest	NA-3	Town of Fredonia	- -	65	65	Private conservancy organization
38	County Line Low Woods	NA-3	Sheboygan County	- -[c]	- -	- -	- -
38	Brown Deer Park Woods	NA-3	Village of Brown Deer	40	- -	40	Milwaukee County
39	Beekeeper Bog	NA-3	Town of Fredonia	9	6	15	Ozaukee County
40	Department of Natural Resources Lowlands	NA-3	Town of Fredonia	45	141	186	Wisconsin Department of Natural Resources
41	Pioneer Road Lowlands	NA-3	Town of Fredonia	- -	94	94	Private conservancy organization
42	Cedar Valley Swamp	NA-3	Town of Fredonia	- -	141	141	Private conservancy organization
43	Kletzsch Park Woods	NA-3	City of Glendale	13	- -	13	Milwaukee County
43	Evergreen Road Bog	NA-3	Town of Fredonia	5	39	44	Private conservancy organization
44	Kohler Road Woods	NA-3	Town of Fredonia	- -	124	124	Private conservancy organization
45	Waubeka Low Woods	NA-3	Town of Fredonia	21	140	161	Ozaukee County
59	Mueller Woods	NA-3, CSH	Town of Polk	4	93	97	Private conservancy organization
60	Slinger Upland Woods	NA-3	Town of Polk	- -	196	196	Wisconsin Department of Natural Resources
62	Kowalske Swamp	NA-3	Town of Jackson	- -[e]	- -	83	- -
63	Sherman Road Swamp	NA-3	Town of Jackson	- -[e]	- -	96	- -
65	Newark Road Wetland	NA-3	Town of Barton	- -[e]	- -	9	- -
66	Sunset Park Wetlands	NA-3	City of West Bend	- -	85	85	City of West Bend
67	Albecker Park Wetlands	NA-3	City of West Bend	31	60	91	City of West Bend
68	Silver Creek Marsh	NA-3	City of West Bend	10	17	27	Washington County
69	University Fen	NA-3	City of West Bend	1	- -	1	City of West Bend
70	CTH Z Upland Woods and Wetlands	NA-3	Town of West Bend	41	240	281	Cedar Lakes Conservation Foundation
71	Ziegler Woods	NA-3	Town of West Bend	- -	170	170	Wisconsin Department of Natural Resources
72	Sandy Knoll Swamp	NA-3	Town of Trenton, Town of Farmington	70	269	339	Washington County

Table 110 (continued)

Number on Map 65	Name	Type of Area	Location	Owned (acres)	Proposed to Be Acquired[a] (acres)	Total (acres)	Proposed Acquisition Agency
	Natural Areas (continued)						
73	Sandy Knoll Wetlands	NA-3	Town of Trenton	17	30	47	Washington County
74	Poplar Road Lacustrine Forest	NA-3	Town of Trenton	- -	177	177	Private conservancy organization
75	Fellenz Hardwood Swamp	NA-3	Town of Trenton	- -	58	58	Washington County
76	Paradise Drive Tamarack Swamp	NA-3	Town of Trenton	- -	81	81	Private conservancy organization
77	Camp Wowitan Wetlands	NA-3	Town of Trenton	10	99	109	Private conservancy organization
78	Schalla Tamarack Swamp	NA-3	Town of Trenton	- -	- -[e]	16	- -
81	Stockcar Swamp	NA-3, CSH	Town of Wayne	- -	240	240	Private conservancy organization
83	Kettle Moraine Driver Woods	NA-3	Fond du Lac County	- -[b]	- -	- -	- -
84	STH 28 Woods	NA-3	Town of Kewaskum	- -	145	145	Private conservancy organization
85	Smith Lake Swamp	NA-3	Town of Barton	- -	38	38	Wisconsin Department of Natural Resources
86	Lange Hardwoods	NA-3	Town of Barton	- -	53	53	Wisconsin Department of Natural Resources
87	Wildwood Hardwood Swamp	NA-3	Town of Barton	- -	98	98	Wisconsin Department of Natural Resources
88	Milwaukee River Swamp	NA-3	Town of Farmington	72	474	546	Private conservancy organization
89	Lizard Mound Woods	NA-3	Town of Farmington	22	6	28	Washington County
90	Green Lake Bog	NA-3	Town of Farmington	- -	19	19	Green Lake Association
	Critical Species Habitat						
54	Cambridge Bluff Woods	CSH	City of Milwaukee	12	- -	12	Milwaukee County
55	Brynwood Country Club Woods	CSH	City of Milwaukee	- -[e]	- -	7	- -
50	Pecard Sedge Meadow	CSH	City of Mequon	- -	13	13	City of Mequon
51	Eastbrook Road Woods	CSH	City of Mequon	- -	8	8	City of Mequon
52	Cedarburg Road West	CSH	Town of Cedarburg	- -[e]	- -	6	- -
53	Cedar-Sauk Upland Woods	CSH	Town of Saukville	- -[e]	- -	38	- -
91	Jackson Woods	CSH	Village of Jackson	3	21	24	Village of Jackson
94	Riesch Woods	CSH	Town of Barton	- -[e]	- -	34	- -
95	Silver Lake Swamp	CSH	Town of West Bend	- -	10	10	City of West Bend
96	Cameron Property	CSH	Town of Trenton	- -	12	12	City of West Bend
97	Fechters Woods	CSH	Town of Trenton	- -[e]	- -	6	- -
98	High School Woods	CSH	City of West Bend	7	- -	7	West Bend School District
101	Silver Lake	CSH	Town of West Bend	- -	7	7	City of West Bend
102	Gilbert Lake	CSH	Town of West Bend	- -[g]	10[g]	10[g]	Cedar Lake Conservation Foundation

[a]*Acquisition is recommended in SEWRPC Planning Report No. 42 (PR No. 42),* Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*, September 1997.*

[b]*Fond du Lac County.*

[c]*Sheboygan County.*

[d]*The seven acres of this Natural Area in existing protective ownership are within the right-of-way of USH 41 and owned by the Wisconsin Department of Transportation.*

[e]*Not proposed for acquisition.*

[f]*Includes 204 acres in Ozaukee County and 14 acres in Washington County. SEWRPC PR No. 42 recommends that the entire Natural Area be acquired by a private conservancy organization.*

[g]*Does not include 100 acres of this Critical Species Habitat site located within the Gilbert Lake Tamarack Swamp Natural Area.*

Source: SEWRPC.

critical species habitat identified in the regional natural areas and critical species habitat protection and management plan, about 3,640 acres at 14 sites are already in public ownership and the remaining lands are proposed to be acquired, as shown in Table 110.

In addition to these lands within the Southeastern Wisconsin Region, certain lands inside of the Milwaukee River watershed, but outside of the Region have been acquired by the State of Wisconsin and designated as State Natural Areas. Eight such areas are identified on Map 65 and tabulated in Table 110.

Endangered and threatened species and species of special concern present within the Milwaukee River drainage area include: 47 species of plants, 10 species of birds, 11 species of fish, four species of herptiles, one invertebrate, and 15 species of insect, as shown in Table 109.

Measures for Habitat Protection

Varying approaches to the protection of stream corridor have been adopted within the Milwaukee River basin. In Milwaukee County, stream corridor protection has been focused on public acquisition of the lands adjacent to the stream banks and their preservation as river parkways. These lands are frequently incorporated into public parks and other natural areas. In Washington County, the City of West Bend has also acquired some lands adjacent to the mainstem of the Milwaukee River, at the site of the former Woolen Mills dam site, and has preserved it as a park. The Washington County comprehensive shoreland and floodland protection ordinance requires setbacks of principal structures and places limits upon removal of shoreland vegetative cover, excavation of shoreland, and encroachment into shorelands by structures based upon a lake and stream classification system designed to protect those waters most sensitive to human encroachment. While most of the Milwaukee River system within the County is classified as Class III waters, which are subject to statewide minima with respect to these parameters, the East and West Branch of the Milwaukee River, Silver Creek (West Bend), and Stony Creek within Washington County are classified as a Class I streams, and Kewaskum Creek within the County is classified as a Class II stream. These waterways are subjected to greater setbacks and other more stringent performance standards designed to protect and preserve sensitive instream habitat and water quality. Of the lakes within the Milwaukee River watershed in Washington County, most of the larger, historically developed lakes are classified as Class III waters, subject to statewide minimum standards for shoreland protection. Erler, Hasmer, Lucas, Mud (in the Village of Slinger and the Town of Polk), and Smith Lakes are classified as Class II waters and are subject to greater setbacks and other more stringent performance standards designed to protect and preserve sensitive habitat and water quality.

The provision of buffer strips around waterways represents an important intervention that addresses anthropogenic sources of contaminants, with even the smallest buffer strip providing environmental benefit.[56] Map 66 shows the current status of riparian buffers along the Milwaukee River and its major tributary streams. As noted above, Chapter 23 of the Washington County Code of Ordinances has established, among other provisions, buffer requirements and setback distances from both stream banks and lake shores based upon the likelihood of ecosystem disturbance from land-based human activities. These requirements provide for enhanced setbacks in excess of the statewide minima within three Classes, Class III of which is equal to the 75-foot statewide minimum standards for lakeshore setbacks. The enhanced setbacks are applicable to both lakes and streams. Buffers greater than 75 feet in width are often associated with adjacent recreational and park lands within the Milwaukee River watershed. This is especially the case in the portions of the watershed within Milwaukee County.

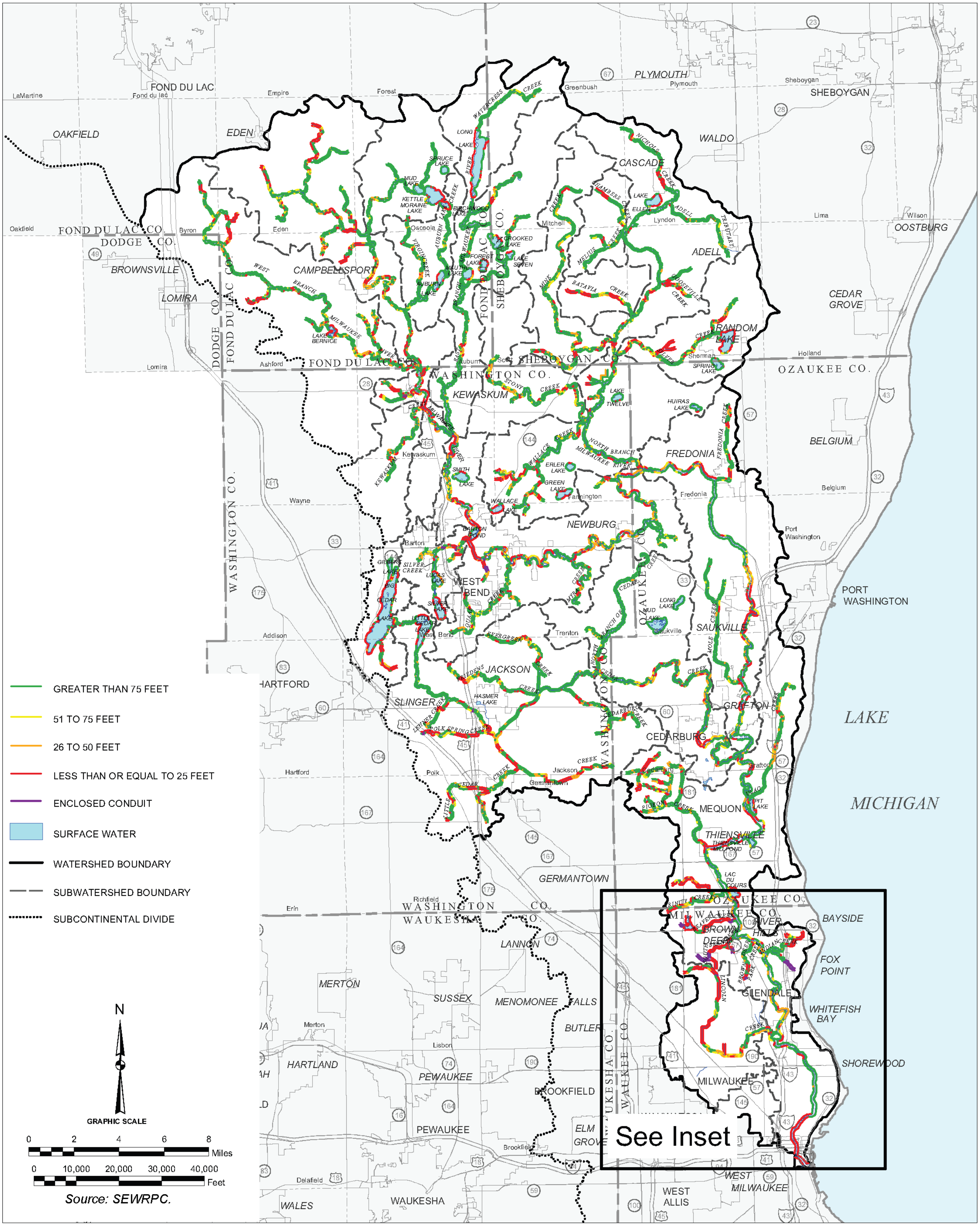
Enclosed conduits, which comprise less than three miles of the Milwaukee River watershed stream system, offer limited opportunity for installation of buffers. These enclosures are located largely within Beaver Creek, Brown Deer Park Creek, Southbranch Creek, an unnamed tributary to Southbranch Creek, and an unnamed tributary to Indian Creek, all in Milwaukee County.

Figure 182 shows the current status of buffer widths around streams among each of the major Milwaukee River subwatersheds, ranging from less than 25 feet, 25 to 50 feet, 50 to 75 feet, and greater than 75 feet. Buffers of greater than 75 feet in width were the most common category of buffer, accounting for between about 30 and 95 percent of the buffer widths observed in the subwatersheds. Buffer widths less than 25 feet were the next most common category of buffer, accounting for between about 5 and 55 percent of the buffer widths observed in the subwatersheds. Similarly, around the lakes within the Milwaukee River watershed, buffers of greater than 75 feet in width were observed on a majority of lakes studied, with the smaller waterbodies having a somewhat

[56] *A. Desbonnet, P. Pogue, V. Lee, and N. Wolff, "Vegetated Buffers in the Coastal Zone – A Summary Review and Bibliography,"* CRC Technical Report No. 2064. *Coastal Resources Center, University of Rhode Island, 1994.*

Map 66

RIPARIAN CORRIDOR WIDTHS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000



Source: SEWRPC.

INSET to Map 66

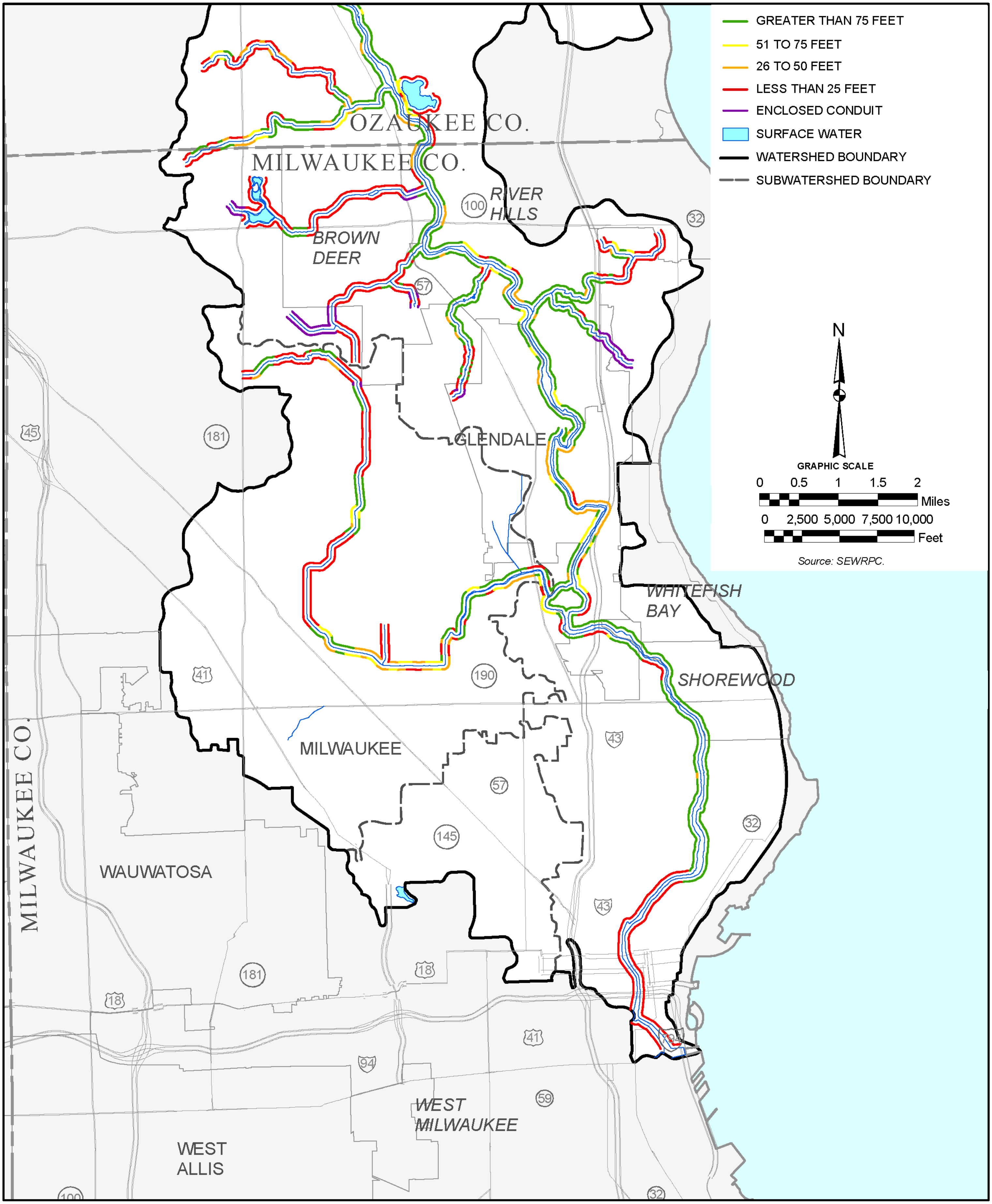


Figure 182

RIPARIAN CORRIDOR BUFFER WIDTHS IN STREAMS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000

PERCENT OF BUFFER WIDTH CATEGORIES WITHIN EACH SUBWATERSHED

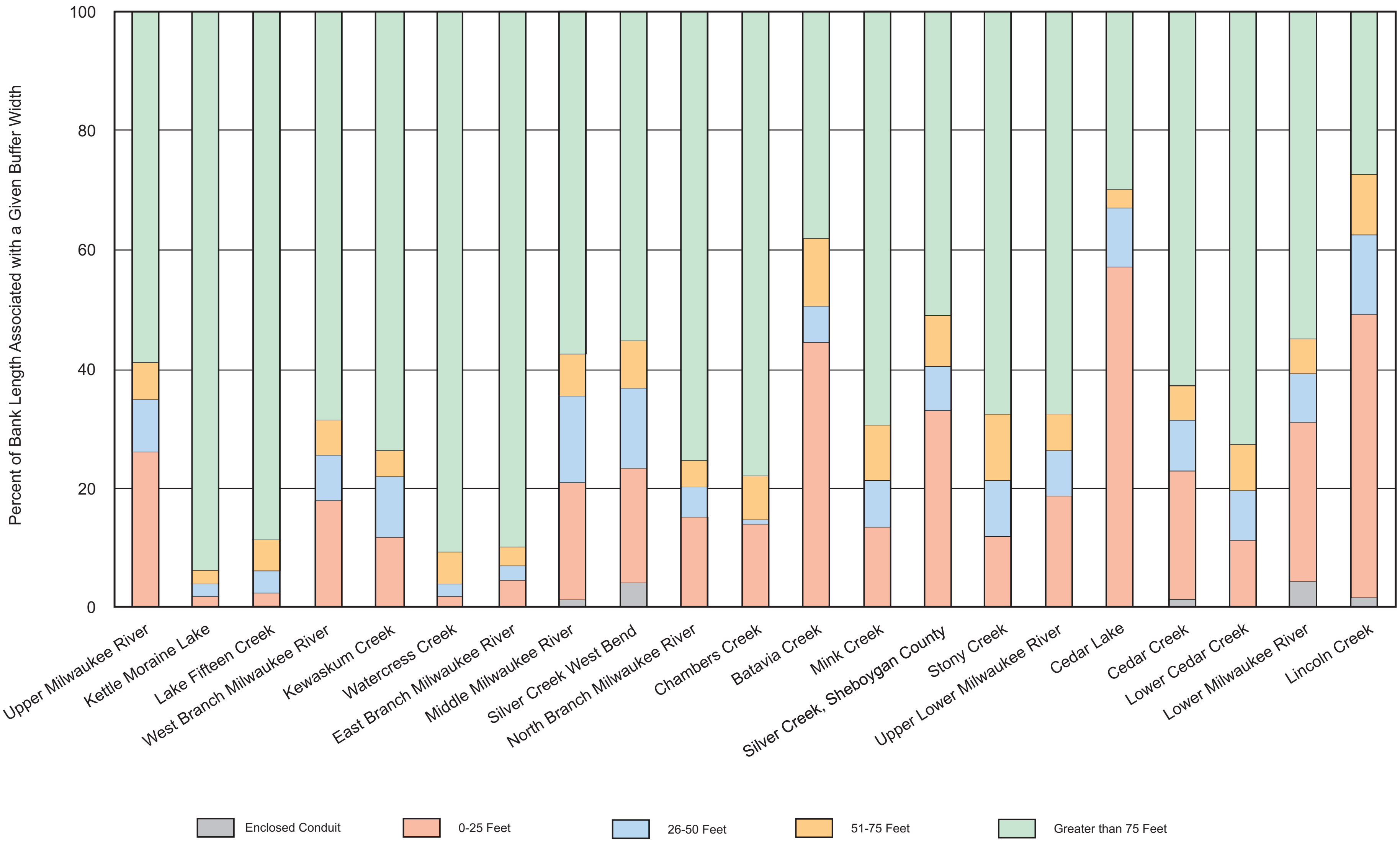
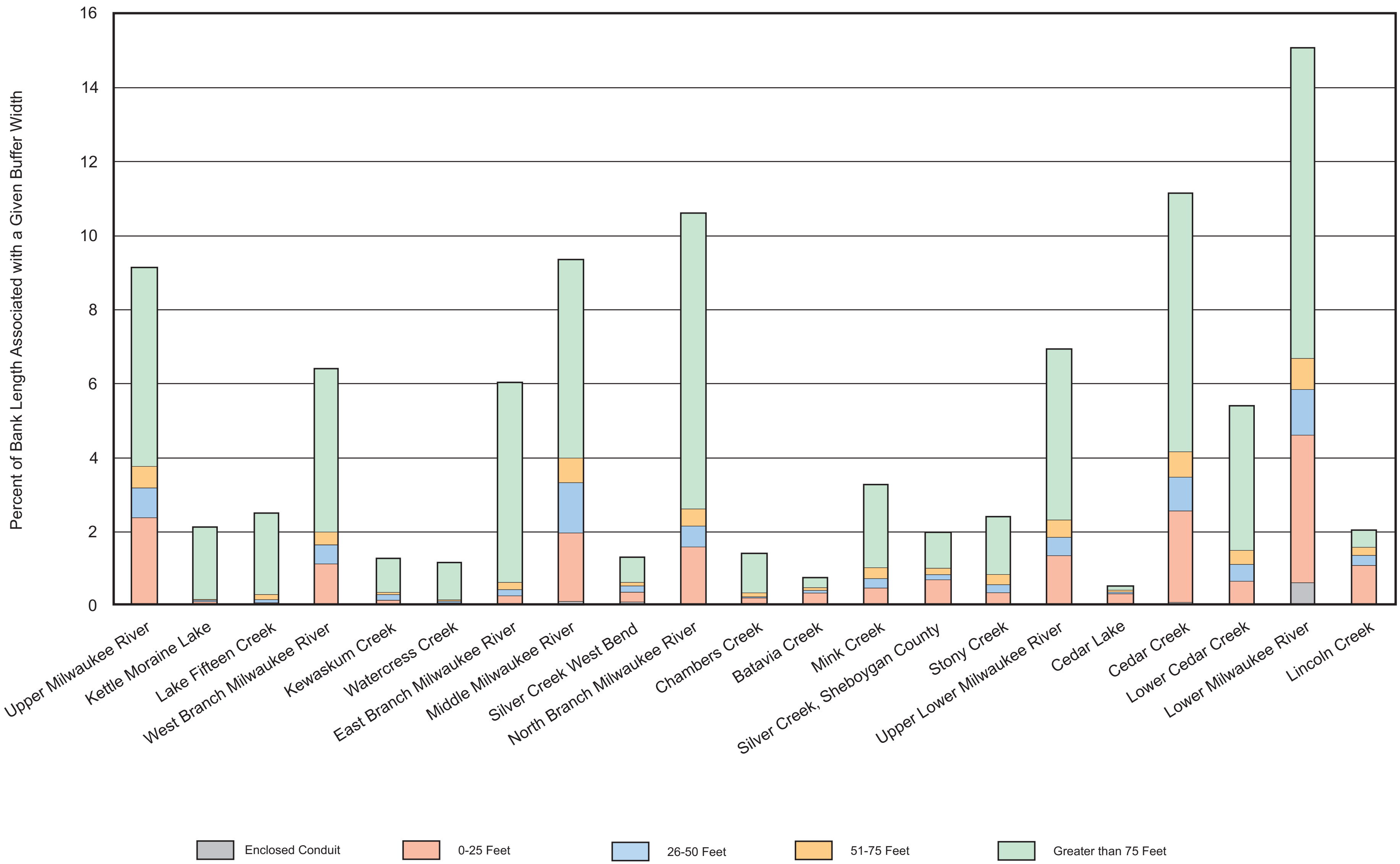


Figure 182 (continued)

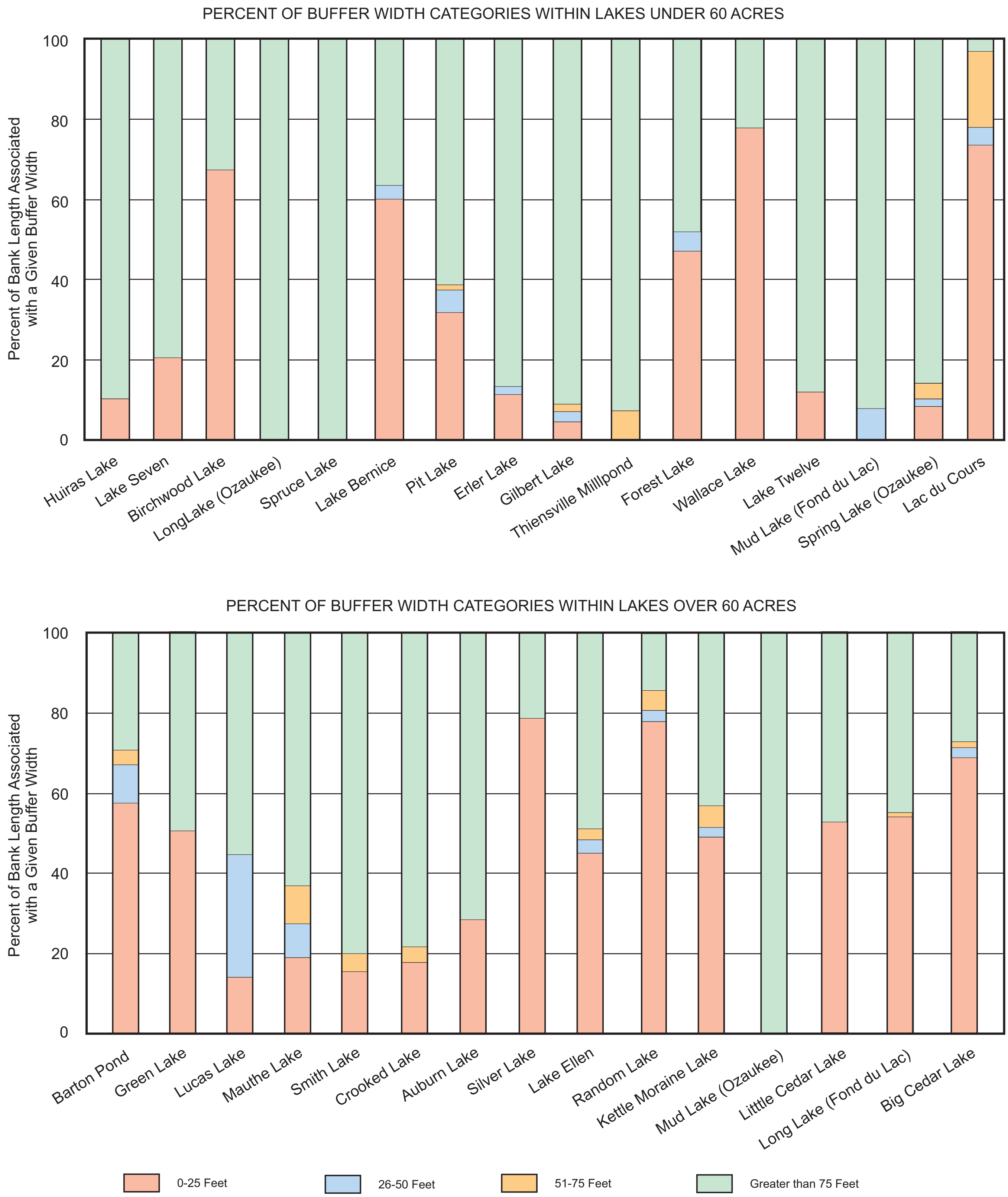
PERCENT OF BUFFER WIDTH CATEGORIES WITHIN THE ENTIRE MILWAUKEE RIVER WATERSHED



Source: SEWRPC.

Figure 183

RIPARIAN CORRIDOR BUFFER WIDTH AROUND LAKES WITHIN THE MILWAUKEE RIVER WATERSHED: 2004



Source: SEWRPC.

greater percentage of wider buffers than the larger lakes, as shown in Figure 183. This is consistent with the findings reported from Washington County, where the adoption of Ordinance provisions setting forth a 75 feet minimum shoreland buffer width for both lakes and streams was determined to create few additional nonconforming lots.[57]

SUMMARY AND STATUS OF IMPLEMENTATION OF ELEMENTS OF THE REGIONAL WATER QUALITY MANAGEMENT PLAN IN THE MILWAUKEE RIVER WATERSHED

The initial water quality management plan for the Southeastern Wisconsin Region, which was adopted in 1979, had five elements: a land use element, a point source pollution abatement element, a nonpoint source pollution abatement element, a sludge management element, and a water quality monitoring element.[58] For the purposes of documenting current conditions and trends in water quality and pollution sources, it is deemed important to redocument the point source and nonpoint source pollution abatement elements of the regional water quality management plan as amended. This section provides that redocumentation and describes actions taken to implement that plan. Those two specific elements of the plan as they relate to the Milwaukee River watershed and actions taken to implement them are described below for those components of the plan elements most directly related to water quality conditions.

Point Source Pollution Abatement Plan Element

The point source pollution abatement element of the initial plan made several recommendations regarding sewerage service in the Milwaukee River watershed. The plan recommended the abandonment of one public sewage treatment plant, located in the Village of Thiensville that was operating in the watershed in 1975. By 1987, this plant had been abandoned. The plan recommended that the attendant service area for this plant be connected to the Milwaukee Metropolitan Sewerage District's sewerage system for treatment purposes. The plan also recommended construction of a new sewage treatment plant for the Village of Jackson. The construction of that plant was complete by 1987. The initial plan also recommended upgrading or upgrading and expanding each of the remaining plants. These upgrades were subsequently completed. To facilitate connection of the Village of Thiensville sewer service area to MMSD's system, the plan recommended the construction of an intercommunity trunk sewer to connect the City of Mequon and the Village of Thiensville to MMSD's system. Construction of this trunk sewer was completed in 1987. In addition, the construction of four additional intercommunity trunk sewers within the MMSD service area was recommended to provide additional capacity to convey wastewater to MMSD's system. Three of these trunk sewers were completed over the period 1981-1994. The Northridge trunk sewer was not constructed. Outside of the area served by MMSD, the initial plan recommended the construction of two intercommunity trunk sewers. One of these was to facilitate the relocation of the Village of Jackson sewage treatment plant. This trunk sewer was completed in 1981. Another was to convey wastewater from the Waubeka sewer service area to the Village of Fredonia sewage treatment plant. This trunk sewer was not constructed. A recommendation for the construction of an additional intercommunity trunk sewer to convey sewage from the Silver Lake Sanitary District to the City of West Bend sewage treatment plant was added to the regional water quality management plan in a March 1992 plan amendment. Construction of this trunk sewer was completed in 1993.

A preliminary recommendation to abate separate sanitary sewer overflows and combined sewer overflows through the provision of large conveyance and storage facilities to contain separate and combined sewer peak flows in excess of sewerage system capacity was originally made in the comprehensive plan for the Milwaukee

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[57]*See SEWRPC Memorandum Report No. 139,* Surface Water Resources of Washington County, Wisconsin: Lake and Stream Classification Project: 2000*, September 2001.*

[58]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume One,* Inventory Findings, *September 1978; Volume Two,* Alternative Plan, *February 1979; Volume Three,* Recommended Plan, *June 1979.*

River watershed.[59] The initial regional water quality management plan deferred recommendation on adoption of this alternative pending completion of the facility planning related to MMSD's Water Pollution Abatement Program. This planning effort, documented in a series of reports by MMSD,[60] recommended construction of a deep tunnel inline storage system in conjunction with construction of a shallow relief sewer system. These recommendations were adopted as an amendment to the regional water quality management plan as part of the water resources management plan for the Milwaukee Harbor estuary.[61] This system was subsequently constructed and began operation in 1994.

The initial regional water quality management plan recommended that one private sewage treatment plant, the Cedar Lake Home Campus in the Town of West Bend, be maintained. A 1988 amendment to the plan recommended that this plant be abandoned. The plant was abandoned in 1988. Finally the initial plan recommended the refinement of sanitary sewer service areas for all sewer service areas in the watershed. As of 2005, the refinement of all service areas in the watershed had been completed, except for the MMSD area, which, in the Milwaukee River watershed, is almost entirely served by sewers.

In 1975, there were 61 combined sewer outfalls and 127 known sanitary sewer overflow relief devices located in the portion of the Milwaukee River watershed within the Southeastern Wisconsin Region. Overflows typically occurred over 50 times per year. Currently combined sewer overflows have been reduced to less than three per year. Likewise, the number of sanitary sewer overflows has been markedly reduced from the 1975 conditions.

In 1975, there were 68 point sources of wastewater other than public and private sewage treatment plants. These sources discharged industrial cooling, process, rinse, and wash waters through 118 outfalls directly, or indirectly, to the surface water system. The initial regional water quality management plan included a recommendation that these industrial point sources of waste water be monitored, and discharges limited to levels determined on a case-by-case basis under the Wisconsin Pollutant Discharge Elimination System (WPDES) permit process. Currently, this recommendation has been nearly fully implemented for the point sources that currently exist in the watershed, the only exception being an unplanned discharge or spill.

Due to the dynamic nature of permitted point sources, it is recognized that the number of wastewater sources changes as industries and other facilities change locations or processes and as decisions are made with regard to the connection of such sources to public sanitary sewer systems. Many of the historical discharges are now connected to the public sanitary sewer system.

Nonpoint Source Pollution Abatement Plan Element

The nonpoint source element of the original plan described a variety of methods and practices for abatement of nonpoint source pollution in urban and rural areas and estimated the percent reduction of released pollutants that could be achieved through implementation of these methods and practices. It identified biochemical oxygen demand as a pollutant requiring nonpoint source control in the Milwaukee River watershed. For urban areas, it recommended septic system management, construction site erosion control, and implementation of urban land

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[59]*SEWRPC Planning Report No. 13,* A Comprehensive Plan for the Milwaukee River Watershed, *Volume One,* Inventory Findings and Forecasts, *December 1970; Volume Two,* Alternative Plans and Recommended Plan, *October 1971.*

[60]*Milwaukee Metropolitan Sewerage District,* Combined Sewer Overflows, *June 1980; Milwaukee Metropolitan Sewerage District,* Inline Storage Facilities Plan, *February 1982; Milwaukee Metropolitan Sewerage District,* Combined Sewer Overflow Advanced Facilities Plan, *December 1983.*

[61]*SEWRPC Planning Report No. 37,* A Water Resources Management Plan for the Milwaukee Harbor Estuary, *Volume One,* Inventory Findings, *March 1987; Volume Two,* Alternative and Recommended Plans, *December 1987.*

practices sufficient to produce a 25 percent reduction in pollutants released to the streams of the watershed. For rural areas in the watershed, it recommended livestock waste control and conservation practices sufficient to produce a 25 percent reduction in pollutants released to the streams of the watershed. The plan also recommended that additional nonpoint source controls sufficient to produce a 75 percent reduction in pollutants be provided in the area tributary to Lake Twelve. No nonpoint source controls were recommended in the portions of the watershed served by combined sewers in the City of Milwaukee and the Village of Shorewood, since the plan assumed the provision of a deep tunnel conveyance, storage, and treatment system through which stormwater runoff would be treated.

In 1984, four portions of the Milwaukee River watershed comprising the entire watershed were designated priority watersheds under the Wisconsin Nonpoint Source Priority Watershed Pollution Abatement Program.[62] The priority watershed plans for these watersheds identified the need for reductions in total pollutant loadings, phosphorus loadings, and sediment loadings to the streams of the watersheds in order to meet water quality objectives. In addition, they recommended a number of management actions and practices to be implemented for both urban and rural lands and provided funding for a variety of activities related to abatement of nonpoint source pollution. In addition, these plans recommended that comprehensive stormwater management plans be prepared and adopted for urban areas in the priority watersheds. The implementation periods were 1989-1997 for the North Branch Milwaukee River and East and West Branch Milwaukee River Priority Watersheds, 1991-1999 for the Milwaukee River South Priority Watershed, and 1992-2000 for the Cedar Creek Priority Watershed. The plan recommendations for nonpoint source pollution control were partially implemented as of completion of the projects.[63]

During the 1980s and 1990s a stormwater management plan was developed for the City of West Bend.[64] This plan refined and detailed the recommendations of the initial regional water quality management plan. This plan recommended implementation of several measures related to water quality. The recommended measures included construction of 38 wet detentions basins, conversion of two dry detention basins to wet detention basins, maintenance of some existing basins, intensive street sweeping in selected portions of the City, catch basin cleaning, infiltration of runoff from parking lots in selected areas, leaf collection, and continued enforcement of the City's construction site erosion control ordinances. As of 2007, the recommendations of the plan have been partially implemented. The City has constructed several of the recommended detention basins and has performed maintenance on existing basins. They have ongoing programs of street sweeping, catch basin cleaning, and leaf collection and continue to enforce their construction erosion control ordinance.

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[62]*Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the East and West Branches of the Milwaukee River Priority Watershed Project, *PUBL WR-255-90, February 1989; Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the North Branch Milwaukee River Priority Watershed Project, *PUBL WR-253-90, July 1989; Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the Milwaukee River South Priority Watershed Project, *PUBL WR-246-91, December 1991; Wisconsin Department of Natural Resources,* A Nonpoint Source Control Plan for the Cedar Creek Priority Watershed Project, *PUBL WR-336-93, August 1993.*

[63]*M. Miller, J. Ball, and R. Kroner,* An Evaluation of Water Quality in the Milwaukee River Priority Watershed, *Wisconsin Department of Natural Resources PUBL WR-298-92, 1992.*

[64]*SEWRPC Community Assistance Planning Report No. 173,* A Stormwater Management Plan for the City of West Bend, Washington County, Wisconsin, *Volume One,* Inventory Findings, Forecasts, Objectives, and Design Criteria, *October 1989; Volume Two,* Alternatives and Recommended Plan for the Silver Creek Subwatershed, *June, 1990; Volume Three,* Alternatives and Recommended Plan for the Milwaukee River Drainage Area, *June 1995; Volume Four,* Alternatives and Recommended Plan for the Quaas Creek Subwatershed*, July 1996.*

In 2001, a water quality protection plan and stormwater management plan for Big Cedar Lake was prepared.[65] This plan also refined and detailed the recommendations of the initial regional water quality management plan. As a part of this plan, the subbasin boundaries within the area tributary to Big Cedar Lake were delineated and stormwater management plans were prepared for three pilot subbasins. In addition, the plan recommended the preparation and implementation of stormwater management plans for the other 17 subbasins delineated in the tributary area. Specific recommendations in the stormwater management plans for the pilot subbasins included the construction of four wet detention basins, preservation of an existing wooded depression, installation of two culverts, raising the elevation of a road, and provision of grassed swales along road sides. With some modifications, the recommendations for the pilot subbasins have been largely implemented. As of 2007 stormwater management plans have not been prepared for any of the other subbasins.

Several additional measures to abate nonpoint source pollution have been instituted since adoption of the initial regional water quality management plan. Facilities engaged in certain activities have been required to apply for and obtain stormwater discharge permits under the WPDES and to develop and follow stormwater pollution prevention plans. Many of the communities in the watershed have applied for WPDES discharge permits, and have adopted construction site erosion control ordinances. All of the communities, except the Towns of Cedarburg, Fredonia, Port Washington, and Saukville and the Villages of Adell, Campbellsport, Cascade, Eden, Lomira, Newburg, Random Lake, and Slinger, have adopted stormwater management plans or ordinances or are covered under stormwater management ordinances administered by their respective counties. The communities with permits will be required to develop new stormwater management ordinances, or update existing ordinances, to be consistent with the standards of Chapter NR 151 of the *Wisconsin Administrative Code*. Stormwater management measures are described more fully in the section on nonpoint source pollution in this chapter.

SOURCES OF WATER POLLUTION

An evaluation of water quality conditions in the Milwaukee River watershed must include an identification, characterization, and where feasible, quantification of known pollution sources. This identification, characterization, and quantification are intended to aid in determining the probable causes of water pollution problems.

Point Source Pollution

Point source pollution is defined as pollutants that are discharged to surface waters at discrete locations. Examples of such discrete discharge points include sanitary sewerage system flow relief devices, sewage treatment plant discharges, and industrial discharges.

Sewage Treatment Plants

The status of implementation in regard to the abandonment of public and private sewage treatment plants in the Milwaukee River watershed, as recommended in the initial regional water quality management plan, is summarized in Table 111. In 1975, there were nine public sewage treatment facilities located in or discharging to the portion of the Milwaukee River watershed within the Southeastern Wisconsin Region. The plants for the City of Cedarburg and the Village Jackson discharged effluent to Cedar Creek; the plants for the City of West Bend, the Village of Fredonia, the Village of Grafton, the Village of Kewaskum, the Village of Newburg, and the Village of Saukville discharged effluent to the mainstem of the Milwaukee River; and the Village of Thiensville plant discharged effluent to Pigeon Creek. One of these plants, the Village of Thiensville plant, was abandoned in 1987 and the attendant service area was connected to the MMSD system for treatment purposes, as recommended in the initial regional water quality management plan. As also recommended in the initial regional water quality

[65]*SEWRPC Memorandum Report No. 137,* A Water Quality Protection and Stormwater Management Plan for Big Cedar Lake Washington County, Wisconsin, *Volume One,* Inventory Findings, Water Quality Analyses, and Recommended Management Measures, *August 2001; Volume 2,* Stormwater Management Plans for Three Pilot Subbasins, *August 2001.*

Table 111

IMPLEMENTATION STATUS OF THE INITIAL REGIONAL WATER QUALITY MANAGEMENT PLAN RECOMMENDATIONS FOR PUBLIC SEWAGE TREATMENT PLANTS IN THE MILWAUKEE RIVER WATERSHED: 2004

Plant	Receiving Water	Plan Recommendation	Implementation Status	Year of Implementation
Public				
Cedarburg	Cedar Creek	Upgrade and expand plant	Completed	1990
Fredonia	Milwaukee River	Upgrade and expand plant	Completed	1982
Grafton	Milwaukee River	Upgrade and expand plant	Completed	1984
Jackson	Cedar Creek	Construct new plant	Completed	1981
Kewaskum	Milwaukee River	Upgrade plant	Completed	After 1995
Newburg	Milwaukee River	Upgrade and expand plant	Completed	1997
Saukville	Milwaukee River	Upgrade and expand plant	Completed	1981
Thiensville	Pigeon Creek	Abandon plant	Plant abandoned	1987
West Bend	Milwaukee River	Upgrade and expand plant	Completed	1980
Private				
Cedar Lake Home Campus	Soil absorption	Maintain plant[a]	Plant abandoned	1988

[a]*The initial regional water quality management plan recommended maintaining the Cedar Lake Home Campus sewage treatment plant. A 1988 amendment to the plan recommended that this plant be abandoned and the area served be connected to the City of West Bend sewage treatment plant.*

Source: SEWRPC.

Table 112

WASTEWATER TREATMENT FACILITIES IN THE MILWAUKEE RIVER WATERSHED: 2004

Number on Map 68	Facility Name	Address	Municipality	Ownership
1	Campbellsport Wastewater Treatment Facility	110 Columbus Park Court	Campbellsport	Public
2	Cascade Wastewater Treatment Facility	N3191 Bates Road	Cascade	Public
3	Cedarburg Wastewater Treatment Facility	W54 N370 Park Lane	Cedarburg	Public
4	Fredonia Municipal Sewer and Water Utility	210 Park Avenue	Fredonia	Public
5	Grafton Water and Wastewater Utility	1900 9th Avenue	Grafton	Public
6	Jackson Wastewater Treatment Plant	W194 N16658 Eagle Drive	Jackson	Public
7	Kettle Moraine Correctional Institution	W9071 Forest Road	Mitchell	Private
8	Kewaskum	204 First Street	Kewaskum	Public
10	Long Lake Recreational Area	N1765 Highway G	Campbellsport	Private
11	Newburg	P.O. Box 50	Newburg	Public
12	Random Lake Sewage Treatment Plant	96 Russell Drive	Random Lake	Public
13	Saukville Village Sewer Utility	1600 Cottontail Lane	Saukville	Public
14	West Bend	512 Municipal Drive	West Bend	Public
15	Town of Scott Sanitary District No. 1	N1614 Highway 28	Adell	Public

Source: SEWRPC.

management plan, a new plant was constructed to serve the Village of Jackson. The initial plan recommended upgrading or upgrading and expanding each of the remaining plants. Dates of implementation of these recommendations are given in Table 111. In addition, two plants have received additional upgrades since the implementation of the initial plan. The Village of Jackson plant was subsequently expanded and upgraded, with modifications being completed around 1997. The Village of Saukville plant was subsequently expanded and upgraded, with modifications being completed in 2002 (see Table 112).

In 1975, there were four publicly owned sewage treatment plants located in or discharging to the portion of the Milwaukee River watershed outside of the Southeastern Wisconsin Region. The Village of Adell plant discharged to a soil absorption system, the Village of Campbellsport plant discharged to the mainstem of the Milwaukee

River, the Village of Cascade plant discharged to a tributary of the North Branch of the Milwaukee River, and the Village of Random Lake plant discharged to Silver Creek (Sheboygan County). One of these plants, the Village of Adell plant, was abandoned in 1992 and the attendant service area was connected to the Onion River Wastewater Commission sewage treatment plant. This plant discharges into the Onion River, outside of the Milwaukee River watershed. One additional public sewage treatment plant in the Milwaukee River watershed, serving the Town of Scott Sanitary District, was completed in 1985.

In 1975, there were two private sewage treatment facilities located in, or discharging to, the Milwaukee River watershed, the Cedar Lake Home Campus in the Town of West Bend and the Kettle Moraine Correctional Institution in the Town of Mitchell. Both of these plants discharged effluent to soil for absorption. The initial regional water quality management plan recommended that the Cedar Lake Home Campus plant be maintained. In 1988, an amendment to the plan recommended that this plant be abandoned. This plant was abandoned in 1988 and its service area connected to the City West Bend sewage treatment plant. One additional private plant, serving the Long Lake Recreational Area in the Town of Osceola was completed and began operation in 1998. Several other private wastewater treatment plants listed in the initial plan are either currently permitted and regulated as industrial dischargers and not as sewage treatment plants or are not in operation. These include plants belonging to the Federal Food Company, the Justo Feed Company, the Level Valley Dairy, the S & R Cheese Corporation, and the Seneca Food Company.

The initial regional water quality management plan recommended that all of the sanitary sewer service areas identified in the plan be refined and detailed in cooperation with the local units of government concerned. There were 12 sewer service areas identified within, or partially within, the Milwaukee River watershed: Cedarburg, Fredonia, Grafton, Jackson, Kewaskum, Mequon, the Milwaukee Metropolitan Sewerage District, Newburg, Saukville, Thiensville, Waubeka, and West Bend. As of 2005, all of these areas with the exception of the Milwaukee Metropolitan Sewerage District service area had undergone refinements as recommended. In addition, the Port Washington and Slinger sewer service areas, which initially did not extend into the Milwaukee River watershed, were subsequently refined to incorporate portions of the watershed. Also, six sanitary sewer service areas in portions of the Milwaukee River watershed outside of the Southeastern Wisconsin Region were refined by the relevant State and local authorities. Table 113 lists the plan amendment prepared for each initial refinement, the date the Commission adopted the document as an amendment to the regional water quality management plan, and the date the Commission adopted the most recent refinement to the sewer service area. Table 113 also identifies the original service area names and the relationship of these service areas to the service area names following the refinement process. The planned sewer service areas in the Milwaukee River watershed, as refined through June 2005, total about 86.7 square miles, or about 12 percent of the total watershed area. Planned sewer service areas in the Milwaukee River watershed are shown on Map 67.

Sanitary Sewer Overflow (SSO) Sites in the Watershed

By 1993, work was completed by MMSD on its Water Pollution Abatement Program, including construction of the Inline Storage System and major relief sewers. As a result of this project, many flow relief devices within the watershed were eliminated. Those which remain include combined sewer overflows and sanitary sewer overflows. During the period from August 1995 to August 2002, separate sanitary sewer overflows were reported at 54 locations in the Milwaukee River watershed. Table 114 gives the locations of sanitary sewer overflow locations in the Milwaukee River watershed for MMSD and 14 communities. Table 114 indicates the number of days during which overflows were reported as occurring at each location during the period from August 1995 to August 2002. The SSO sites which are being incorporated into the water quality model are indicated on Map 68.

Combined Sewer Overflows (CSOs)

Combined sewer overflows are potential sources of pollution within the watershed. MMSD has 65 combined sewer overflow outfalls that discharge to streams in the Milwaukee River watershed. These outfalls can convey diluted sewage from the combined sewer system to the surface water system of the watershed as a result of high water volume from stormwater, meltwater, and infiltration and inflow of clear water during wet weather conditions. This conveyance to surface waters occurs to prevent damage to buildings or the mechanical elements

Table 113

PLANNED SANITARY SEWER SERVICE AREAS IN THE MILWAUKEE RIVER WATERSHED: 2005

Name of Initially Defined Sanitary Sewer Service Area	Planned Sewer Service Area (square miles)	Name of Refined and Detailed Sanitary Sewer Service Area(s)	Initial Plan Amendment Document	Date of SEWRPC Adoption of Initial Plan Amendment	Date of SEWRPC Adoption of Most Recent Plan Amendment
Refined Sanitary Sewer Area					
Adell	0.6	Adell	- -[a]	- -[a]	- -[a]
Batavia	0.5	Batavia	- -[a]	- -[a]	- -[a]
Campbellsport	1.1	Campbellsport	- -[a]	- -[a]	- -[a]
Cascade	0.8	Cascade	- -[a]	- -[a]	- -[a]
Cedarburg	8.3	Cedarburg	SEWRPC CAPR No. 91, *Sanitary Sewer Service Areas for the City of Cedarburg and the Village of Grafton, Ozaukee County Wisconsin*	June 15, 1987	June 19, 1996
Fredonia	1.9	Fredonia	SEWRPC CAPR No. 96, *Sanitary Sewer Service Area for the Village of Fredonia, Ozaukee County, Wisconsin*	September, 13, 1984	March 3, 2004
Grafton	8.6	Grafton	SEWRPC CAPR No. 91, *Sanitary Sewer Service Areas for the City of Cedarburg and the Village of Grafton, Ozaukee County Wisconsin*	June 15, 1987	June 19, 1996
Jackson	6.9	Jackson	SEWRPC CAPR No. 124, *Sanitary Sewer Service Area for the Village of Jackson and Environs, Washington County, Wisconsin*	June 17, 1984	June 16, 2004
Kewaskum	4.3	Kewaskum	SEWRPC CAPR No. 161, *Sanitary Sewer Service Area for the Village of Kewaskum, Washington County, Wisconsin*	March 7, 1988	December 7, 2005
Lomira	0.2	Lomira	- -[a]	- -[a]	- -[a]
Mequon	16.4	Mequon	SEWRPC CAPR No. 188, *Sanitary Sewer Service Area for the City of Mequon and the Village of Thiensville, Ozaukee County, Wisconsin*	January 15, 1992	June 21, 1995
Newburg	2.2	Newburg	SEWRPC CAPR No. 205, *Sanitary Sewer Service Area for the Village of Newburg, Ozaukee and Washington Counties, Wisconsin*	March 3, 1993	- -
Port Washington	0.3	Port Washington	SEWRPC CAPR No. 95, *Sanitary Sewer Service Area for the City of Port Washington, Ozaukee County, Wisconsin*	December 1, 1983	December 3, 2003
Random Lake	1.7	Random Lake	- -[a]	- -[a]	- -[a]
Saukville	4.7	Saukville	SEWRPC CAPR No. 90, *Sanitary Sewer Service Area for the Village of Saukville, Washington County, Wisconsin*	December 1, 1993	March 6, 2002
Slinger	1.0	Slinger	SEWRPC CAPR No. 128, *Sanitary Sewer Service Area for the Village of Slinger and Environs, Washington County, Wisconsin*	December 2, 1985	September 10, 2003
Thiensville	1.1	Thiensville	SEWRPC CAPR No. 188, *Sanitary Sewer Area for the City of Mequon and the Village of Thiensville, Ozaukee County, Wisconsin*	January 15, 1992	June 21, 1995

Table 113 (continued)

Name of Initially Defined Sanitary Sewer Service Area	Planned Sewer Service Area (square miles)	Name of Refined and Detailed Sanitary Sewer Service Area(s)	Initial Plan Amendment Document	Date of SEWRPC Adoption of Initial Plan Amendment	Date of SEWRPC Adoption of Most Recent Plan Amendment
Refined Sanitary Sewer Area (continued)					
Waubeka	0.7	Waubeka	SEWRPC CAPR No. 96, *Sanitary Sewer Service Area for the Village of Fredonia, Ozaukee County, Wisconsin*	September, 13, 1984	- -
West Bend	25.5	West Bend	SEWRPC CAPR No. 35, *Sanitary Sewer Service Area for the City of West Bend and Environs, Washington County, Wisconsin*	December 2, 1982	June 17, 1998
Subtotal	86.7	- -	- -	- -	- -
Unrefined Sanitary Sewer Service Areas					
Milwaukee Metropolitan Sewerage District	57.7	- -	- -	- -	- -
Subtotal	57.7	- -	- -	- -	- -
Total	144.4	- -	- -	- -	- -

[a]*Adell, Batavia, Campbellsport, Cascade, Lomira, and Random Lake are outside of the Southeastern Wisconsin Region.*

Source: SEWRPC.

Map 67

PLANNED SANITARY SEWER SERVICE AREAS WITHIN THE MILWAUKEE RIVER WATERSHED: 2005

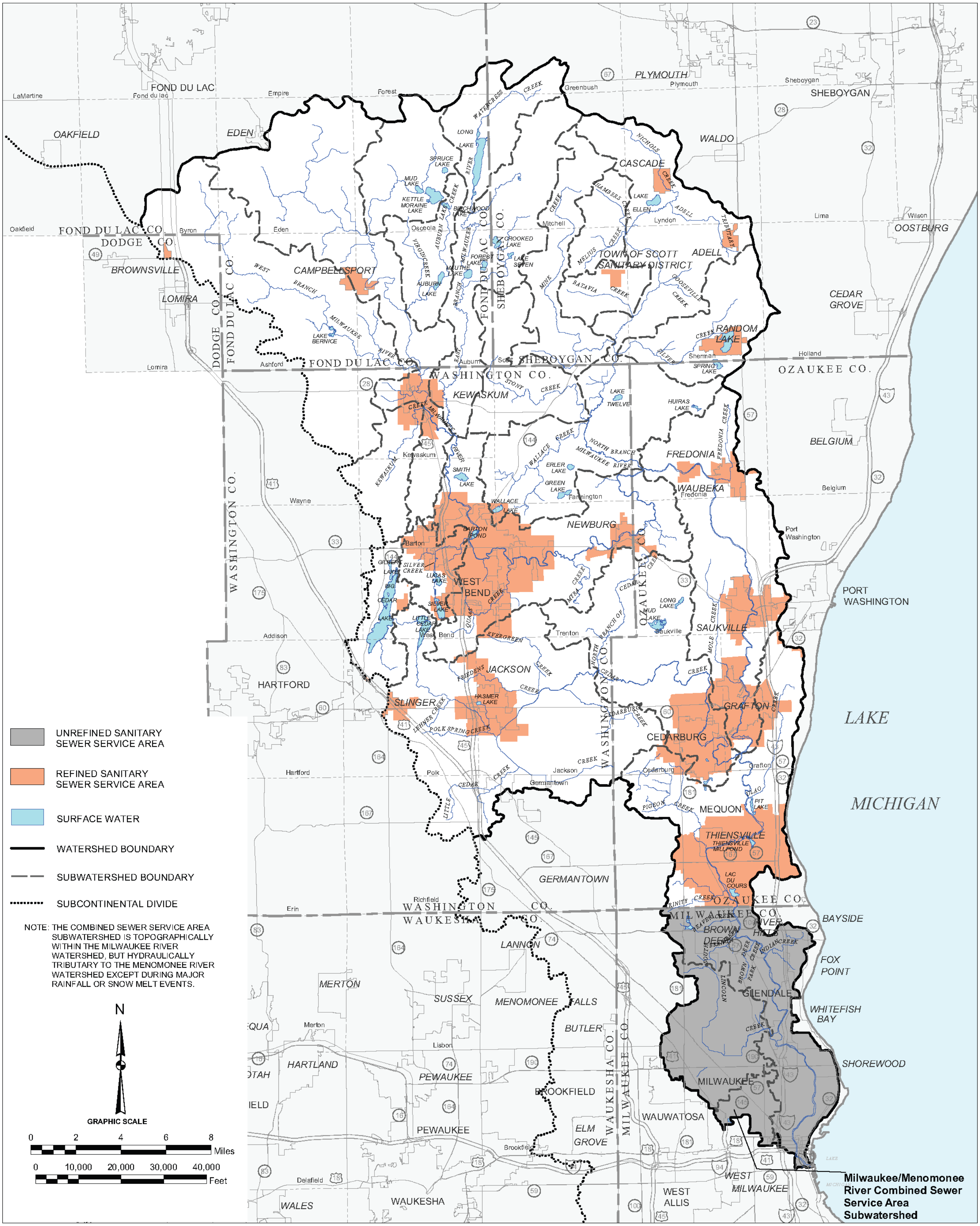


Table 114

SEPARATE SANITARY SEWER OVERFLOW LOCATIONS IN THE MILWAUKEE RIVER WATERSHED

Identification Number	Location	Community or Agency	Number of Days with Overflow: August 1995 to August 2002
205	W. Roosevelt Drive and W. Scranton Place	MMSD	2
207	N. 31st Street and W. Fairmount Avenue	MMSD	18
208	N. 31st Street on north side of Lincoln Creek	MMSD	5
209	N. 27th Street and W. Silver Spring Drive	MMSD	8
212	W. Hampton Avenue and N. Green Bay Road, West	MMSD	6
213	W. Hampton Avenue and N. Green Bay Road, East	MMSD	6
214	N. Lydell Avenue and W. Hampton Avenue	MMSD	16
223	N. 27th Street and W. Villard Avenue	MMSD	6
224	W. Hampton Avenue and N. 32nd Street	MMSD	10
226	N. 35th Street and W. Marion Street	MMSD	17
230	N. Richards Street	MMSD	21
231	N. Range Line Road	MMSD	18
244	N. Lydell Avenue and W. Lancaster Avenue	MMSD	14
245	N. Lydell Avenue and W. Montclair Avenue	MMSD	4
250	S. Water Street and E. Bruce Street	MMSD	1
BD02	N. 61st Street and W. Darnel Avenue	Brown Deer	1
BD03	N. 61st Street and Arch Avenue	Brown Deer	2
BD04	N. 61st Street	Brown Deer	2
BD05	N. 61st Street and W. Tower Avenue	Brown Deer	2
BD06	S. 57th Street and Brown Deer Road	Brown Deer	1
FP01	N. Seneca Road and Indian Creek Parkway	Fox Point	2
FP02	E. Indian Court and Indian Creek Parkway	Fox Point	2
FP03	N. Mohawk Avenue and Indian Creek Parkway	Fox Point	1
FP04	N. Navajo Road and Cherokee Circle	Fox Point	1
MQ02	Center Drive at Island Drive Lift Station	Mequon	3
MQ03	11330 N. Oriole Lane	Mequon	1
MI01	N. 31st Street and W. Capitol Drive	Milwaukee	5
MI02	N. 31st Street and W. Capitol Drive	Milwaukee	1
MI04	5384 N. 60th Street	Milwaukee	2
MI08a	N. 20th Street and W. Hampton Avenue	Milwaukee	4
MI08b	N. 20th Street and W. Hampton Avenue	Milwaukee	9
MI09	N. 20th Street (680 feet South of W. Hampton Avenue)	Milwaukee	1
MI10	N. 21st Street and W. Hampton Avenue	Milwaukee	4
MI11	N. 24th Street and W. Villard Avenue	Milwaukee	2
MI12	N. 24th Place and W. Villard Avenue	Milwaukee	2
MI13	N. 27th Street and W. Villard Avenue	Milwaukee	2
MI14	N. 27th Street (300 feet North of Villard Avenue)	Milwaukee	2
MI15	N. 27th Street (South of Hope Avenue)	Milwaukee	1
MI16	N. 28th Street and W. Villard Avenue	Milwaukee	2
MI17	N. 30th Street and W. Hope Avenue	Milwaukee	6
MI18	N. 31st Street and W. Villard Avenue	Milwaukee	2
MI19	N. 35th Street and W. Oriole Drive	Milwaukee	2
MI20	N. 36th Street and W. Toronto Street	Milwaukee	6
MI21	N. 37th Street and W. Kiley Street	Milwaukee	1
MI22a	N. 41st Street and W. Congress Street	Milwaukee	2
MI22b	N. 41st Street and W. Congress Street	Milwaukee	3
MI23	N. 49th Street and W. Rohr Avenue	Milwaukee	2
MI24	N. 55th Street and W. Custer Avenue	Milwaukee	3
MI25	N. 56th Street and W. Villard Avenue	Milwaukee	2
MI26	N. 61st Street and W Lawn Avenue	Milwaukee	1
MI27	N. 61st Street and W. Sheridan Avenue	Milwaukee	2
MI28	N. 62nd and W. Fairmount Avenue	Milwaukee	4
MI29	N. 66th Street and W. Ruby Avenue	Milwaukee	1
MI31	N. 72nd Street and W. Capitol Drive	Milwaukee	5
MI32	N. 72nd Street and W. Hope Avenue	Milwaukee	2
MI34	N. 83rd Street and W. Hope Avenue	Milwaukee	2
MI46	N. Sherman Boulevard and W. Burleigh Street	Milwaukee	0
MI47	N. Sherman Boulevard and W. Congress Street	Milwaukee	1

Table 114 (continued)

Identification Number	Location	Community or Agency	Number of Days with Overflow: August 1995 to August 2002
MI48	W. Chapman Place and W. Potomac Avenue	Milwaukee	4
MI49	W. Fairmount Avenue and N. Green Bay Avenue	Milwaukee	2
MI51	W. Milwaukee River Parkway and W. Lawn Avenue	Milwaukee	1
MI52	W. Olive Street (South of Roosevelt Drive)	Milwaukee	2
MI53	W. Potomac Avenue (North of Glendale Avenue)	Milwaukee	2
RH04	7650 N. Pheasant Lane	River Hills	5
RH05	N. Pheasant Lane	River Hills	1
SH01	Glendale Avenue and Wildwood Avenue	Shorewood	3
TH01	Vernon Avenue and Sunny Lane	Thiensville	1
TH02	Riverview Drive and Green Bay Road	Thiensville	1
WB05	Hampton Avenue and Sheffield Avenue	Whitefish Bay	1
56	Lift Station at County Highway I and County Highway A	Adell	2
57	Lift Station at 608 Tower Avenue	Adell	3
58	State Highway 57 between CTH I and CTH W	Adell	1
34	Dorchester Lift Station	Cedarburg	1
35	Doerr Way Lift Station	Cedarburg	1
- -	Cedarburg sewage treatment plant	Cedarburg	2
50	Manhole at Park Avenue	Fredonia	1
49	Manhole at Wisconsin Street	Fredonia	3
48	Manhole at Wisconsin Street and Wenzel Avenue	Fredonia	3
42	11th Avenue lift station	Grafton	1
41	14th Avenue lift station	Grafton	1
40	Manhole at 11th Avenue and Meadowbrook Court	Grafton	2
39	17th Avenue lift station	Grafton	4
38	Bridge Street lift station	Grafton	2
43	Green Bay Road lift station	Grafton	1
44	Manhole at 10th Avenue and Power Street	Grafton	1
36	Manhole at 7th Avenue and North Street	Grafton	1
37	Manhole at 13th Avenue and Veteran's Park	Grafton	1
- -	Grafton sewage treatment plant	Grafton	1
52	Manhole at Glen Brooke Drive	Jackson	1
- -	Jackson sewage treatment plant	Jackson	2
59	Manhole at Roseland Drive	Kewaskum	1
53	Manhole preceding main lift station	Kewaskum	1
54	Lift Station No. 1, Main Street	Newburg	1
- -	Kettle Moraine Correctional Institution sewage treatment plant	Mitchell	1
45	North Mill Street lift station	Saukville	1
46	Manhole at STH 33 and N. Mill Street	Saukville	3
47	Bridge Lift Station	Saukville	0
- -	Saukville sewage treatment plant	Saukville	1
51	Manhole at Main Street	West Bend	1
55	Manhole at Gadow Lane	West Bend	1
- -	West Bend sewage treatment plant	West Bend	1

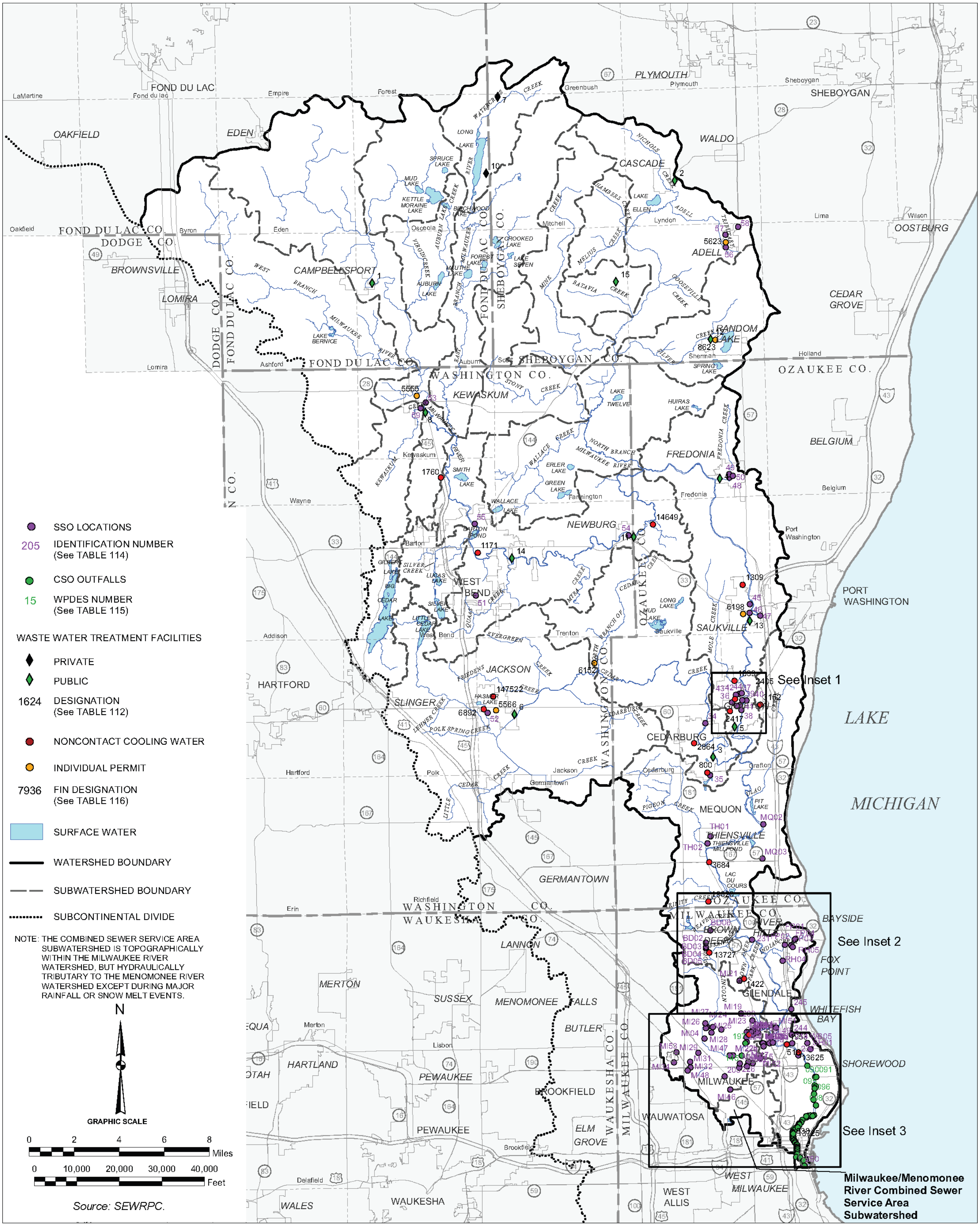
NOTE: For the MMSD Sanitary Sewer Overflow locations, the Identification Number corresponds to the WPDES permit number.

Source: Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, Triad Engineering, and SEWRPC.

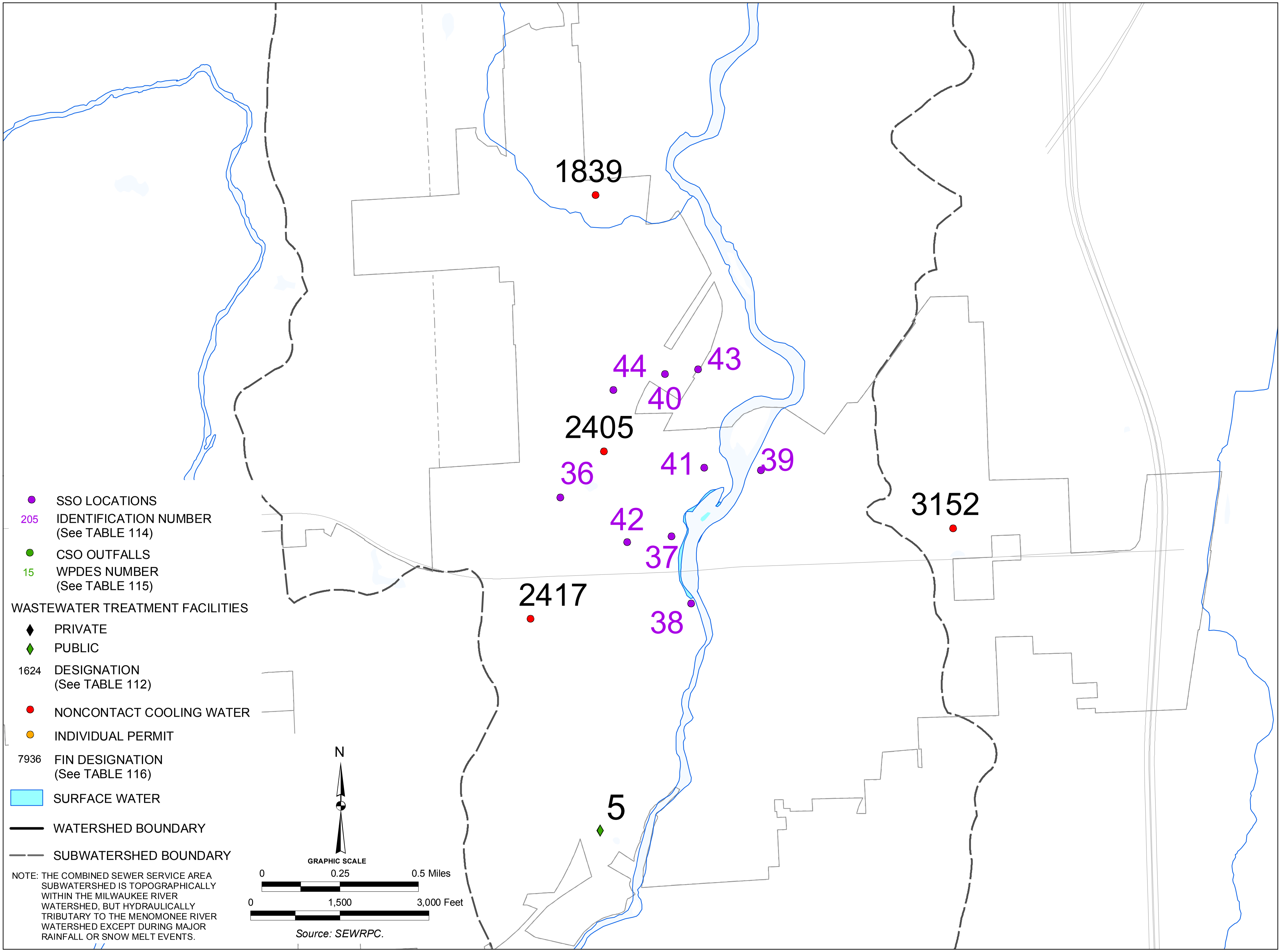
of the conveyance system during such events. The locations of these outfalls are shown on Map 68. Associated with these CSO outfalls is a set of sample collectors which obtain samples of effluent discharged during overflow events for chemical and bacteriological analysis. The assignment of collectors to outfalls is shown in Table 115. Over the period August 1995 to August 2002, the mean number of days during which individual outfalls discharged to streams in the watershed was 13.4. Associated with this mean was high variability among outfalls. There were no known discharges from several of these outfalls during this period. Other outfalls discharged over as many as 48 days. There was also variation in the number of outfalls involved in particular discharge events. Some CSO events were quite localized, consisting of discharge from only one outfall. Others occurred over a large portion of the CSO area, involving discharge from as many as 49 outfalls into the watershed. The mean number of outfalls discharging on any day that discharge occurred was 15.7.

Map 68

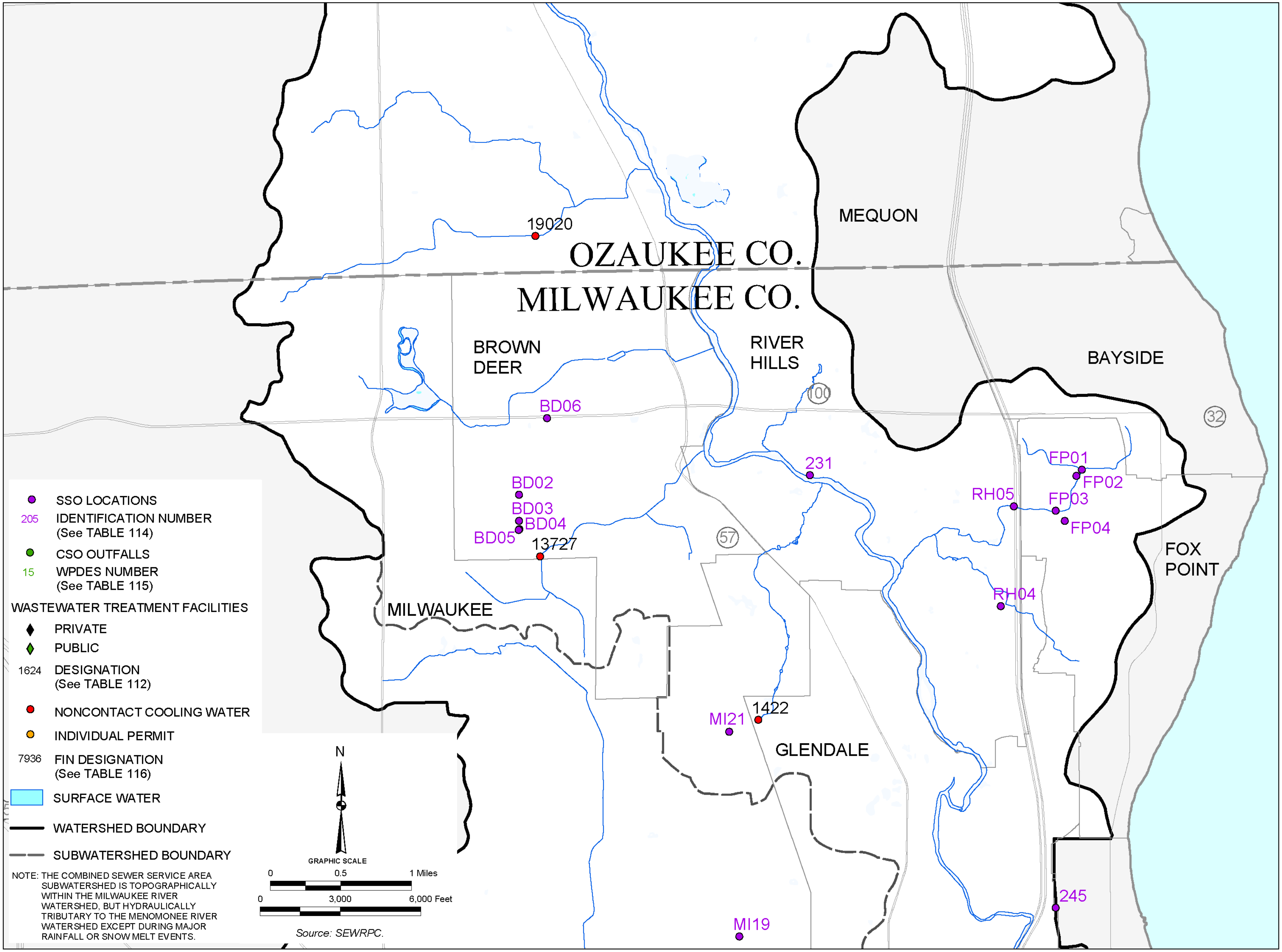
POINT SOURCES OF POLLUTION WITHIN THE MILWAUKEE RIVER WATERSHED: 2003



INSET 1 to Map 68



INSET 2 to Map 68



INSET 3 to Map 68

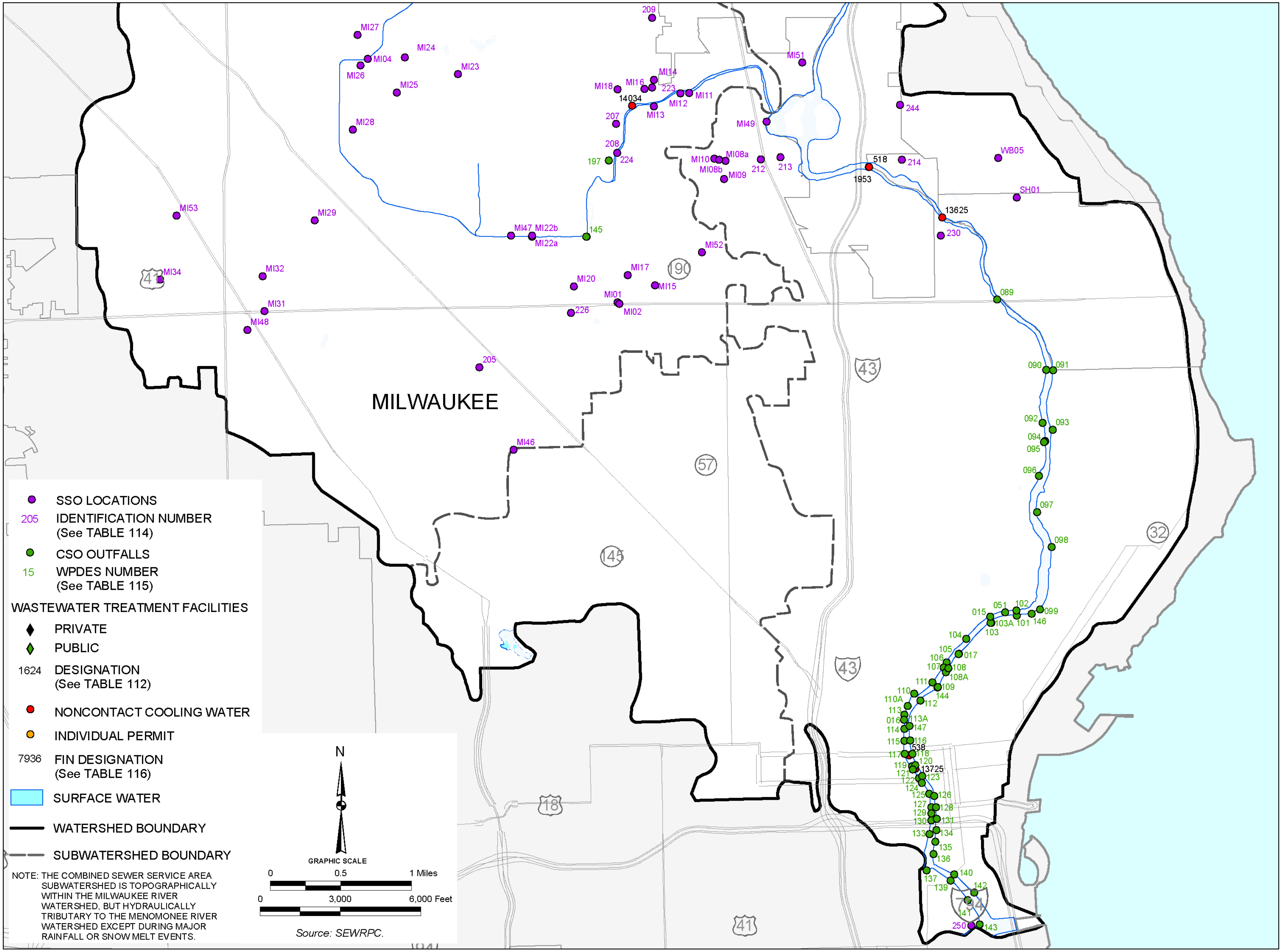


Table 115

COMBINED SEWER OVERFLOW OUTFALL LOCATIONS IN THE MILWAUKEE RIVER WATERSHED

WPDES Number	Location	Collector	Outfall Size (inches)	Number of Days with Overflow August 1995 to August 2002
15	N. Marshall Street	Unknown	30	1
16	W. Vliet Street east of N. 3rd Street	Unknown	36	6
17	N. Van Buren Street at E. Brady Street	NS 8	54	0
51	N. Commerce St. and N. Weil Street	NS 7	78	0
89	E. Capitol Drive	NS 11	72	34
90	E. Keefe Avenue	NS 4	54	42
91	E. Edgewood Avenue	NS 4	72	31
92	E. Auer Avenue	NS 5	84	6
94	E. Burleigh Street	NS 5	114 x 51[a]	20
95	E. Chambers Street	NS 5	30	22
96	E. Locust Street	NS 5	78	16
97	E. Park Place	NS 6	60	12
98	E. Park Place	NS 6	72	37
99	E. Boylston Street	NS 7	72	15
101	N. Pulaski Street	NS 7	72	3
102	N. Humboldt Avenue	NS 7	72	1
103	N. Marshall Street	NS 7	24	7
103A	N. Commerce Street	NS 7	96	48
104	N. Holton Street	NS 7	84 x 48	13
105	E. Brady Street	NS 8	30	0
106	North of E. Walnut Street	NS 8	96	31
107	E. Walnut Street	NS 8	42	0
108	E. Pleasant Street	NS 8	84 x 36	1
108A	N. Water Street and E. Pleasant Street	NS 8	96	30
109	North of W. Cherry Street	NS 8	60 x 48	0
110	W. Cherry Street	NS 8	90	0
110A	W. Cherry Street	NS 8	30	0
111	E. Lyon Street	NS 8	30	10
112	E. Ogden Avenue	NS 9	72 x 36	25
113	W. McKinley Avenue	NS 9	60	7
113A	W. Juneau Avenue	NS 9	84	10
114	W. Juneau Avenue	NS 9	52	6
115	W. Highland Avenue	NS 9	111 x 54	10
116	E. Highland Avenue	NS 9	36	11
117	W. State Street	NS 9	48	27
118	E. State Street	NS 9	60	24
119	W. Kilbourn Avenue	NS 9	54 x 72	25
120N	E. Kilbourn Avenue	NS 9	96 x 48	21
120S	E. Kilbourn Avenue	NS 9	96 x 48	20

Table 115 (continued)

WPDES Number	Location	Collector	Outfall Size (inches)	Number of Days with Overflow August 1995 to August 2002
121	North of W. Wells Street	NS 9	30	13
122	W. Wells Street	NS 9	48	14
123	E. Wells Street	NS 9	48	17
124	North of W. Wisconsin Avenue	NS 9	30	19
125	W. Wisconsin Avenue	NS 9	24	24
126	E. Wisconsin Avenue	NS 10	36	3
127	W. Michigan Street	NS 10	54	14
128	E. Michigan Street	NS 10	42	7
129	North of W. Clybourn Street	NS 10	30	13
130	W. Clybourn Street	NS 10	48	16
131	E. Clybourn Street	NS 10	48[a]	19
133	W. St. Paul Avenue	NS 10	72 X 36	15
134	E. St. Paul Avenue	NS 10	108 x 48	15
135	E. Buffalo Street	NS 10	42	13
136	E. Chicago Street	NS 10	72 x 48	9
137	S. 1st Street	CT 8	24	3
139	E. Pittsburgh Avenue	CT 8	24	14
140	N. Broadway	NS 10	30	5
141	E. Florida Street	CT 8	60	3
142	E. Polk Street	NS 10	54	16
143	E. Bruce Street	CT 8	36	5
144	E. Lyon Street	NS 8	36	0
145	N. 35th Street and W. Congress Street	NS 12	120 x 90[a]	22
146	N. Arlington Place	NS 7	120 x 48	0
147	E. Juneau Avenue	NS 9	42	21
197	W. Hampton Avenue at 32nd Street	- -	Pumps	0

[a]*Double outfall.*

Source: Milwaukee Metropolitan Sewerage District, Triad Engineering, and SEWRPC.

Other Known Point Sources

Industrial Discharges

The number of known industrial wastewater permitted dischargers in the Milwaukee River watershed has increased over time. In 1975, there were a total of 68 known industrial wastewater permitted dischargers identified in the watershed. These permitted facilities discharged industrial cooling, process, rinse, and wash waters to surface waters.[66] In 1990, 120 permitted facilities discharged wastewater to the Milwaukee River, its tributaries, or the groundwater system.[67]

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[66]*SEWRPC Planning Report No. 30,* op. cit.

[67]*SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report*, March 1995.*

Table 116 lists the industrial discharge permits in effect through the WPDES during February 2003 in the Milwaukee River watershed. At that time, 130 WPDES industrial permits were in effect in the watershed. Individual permits represent 15 of these permits, the rest are spread among 11 categories of general permits. The most common category of general permit issued in this watershed was for noncontact cooling water which regulates the discharge of noncontact cooling water, boiler blowdown, and air conditioning condensate. There were 46 facilities in the watershed covered by permits in this category. Other common categories of permits were for the discharge from contaminated groundwater remedial actions and nonmetallic mining operations and the discharge of hydrostatic test water. These types of facilities represented 16, 13, and 15 permits, respectively. The other general permit categories were each represented by 10 or fewer facilities. Data from discharge monitoring reports for several facilities covered by individual permits or general permits for noncontact cooling water are being included in water quality modeling for the regional water quality management plan update and the MMSD 2020 Facility Plan. These sites are shown on Map 68.

Due to the dynamic nature of permitted point sources, it is recognized that the number of wastewater sources in the watershed will change as industries and other facilities change locations or processes and as decisions are made with regard to the connection of such sources to public sanitary sewer systems.

Nonpoint Source Pollution
Urban Stormwater Runoff
As shown in Table 84, as of the year 2000, about 21.2 percent of land in the Milwaukee River watershed was in urban uses. Urban land uses within the watershed were primarily residential (10.2 percent); followed by transportation, communication, and utilities (6.4 percent) and industrial and extractive, and governmental and institutional, commercial, and recreational each of which comprised less than 1.5 percent of watershed area. Chapter II of this report includes descriptions of the types of pollutants associated with specific urban nonpoint sources.

Regulation of Urban Nonpoint Source Pollution through the Wisconsin Pollutant Discharge Elimination System Permit Program
Facilities engaged in industrial activities listed in Section NR 216.21(2)(b) of Chapter NR 216 of the *Wisconsin Administrative Code* must apply for and obtain a stormwater discharge permit. The WDNR originally developed a three-tier system of industrial storm water permits. Tier 1 permits apply to facilities involved in heavy industry and manufacturing, including facilities involved in lumber and wood product manufacturing, leather tanning, and primary metal industries. Tier 2 permits apply to facilities involved in light industry and manufacturing and transportation facilities, including facilities involved in printing, warehousing, and food processing. Tier 3 permits used to be issued to facilities which have certified, with WDNR concurrence, that they have no discharges of contaminated stormwater. WDNR authority for Tier 3 permits no longer exists and the Tier 3 permits have been terminated. Facilities now submit a certificate of no exposure. In addition, the WDNR also issues separate permits for automobile parts recycling facilities and scrap recycling facilities. Associated with each category of permit are specific requirements for monitoring and inspection. For all categories of permits except Tier 3 industrial permits, the permit requires the facility to develop and follow a storm water pollution prevention plan (SWPPP). Specific requirements for the SWPPP are listed in Chapter NR 216.27 of the *Wisconsin Administrative Code*. They include provisions related to site mapping, implementation scheduling, conducting annual plan assessments, and monitoring of discharge.

As shown in Appendix G, "WPDES Permitted Stormwater Facilities," 231 industrial stormwater permits were in effect in the Milwaukee River watershed in February 2003. A total of 121 of these were Tier 2 permits, representing slightly over half of the permitted facilities in the watershed. Tier 3 permits were the next most common in the watershed. In February 2003, 54 of these were in effect. There were 20 or fewer each of Tier 1, Automobile Parts Recycling, and Scrap Recycling permits in effect in the watershed at this time.

The WDNR also issues and administers construction site stormwater permits through the WPDES General Permits program. All construction sites that disturb one acre of land or more are required to obtain coverage under the General Permit. Permitted construction sites are required to implement a construction erosion control plan,

Table 116

PERMITTED WASTEWATER DISCHARGERS UNDER THE WPDES GENERAL PERMIT AND INDIVIDUAL PERMIT PROGRAMS IN THE MILWAUKEE RIVER WATERSHED: FEBRUARY 2003

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Carriage/Interstitial Water from Dredging	Henschke Hillside County Lake Access to Silver Lake	5607 and 5630 Peters Drive	West Bend	0046558	- -	21763
Concrete Products Operations	Advance Cast Stone Company	W5104 Hwy. 144	Random Lake	0046507	460117460	16179
	Jackson Concrete Company	605 W. Pleasant Valley Road	Jackson	0046507	267115090	7936
	Schmitz Ready Mix	11050 N. Industrial Drive	Mequon	0046507	246090130	7444
	Schmitz Ready Mix	989 Ulao Road	Grafton	0046507	246106740	8027
	Schmitz Ready Mix	2707 Scenic Road	Town of Polk	0046507	267115530	10123
	Yahrs Ready Mix	1020 S. Indiana Avenue	West Bend	0046507	267115970	8186
Contaminated Groundwater Remedial Actions	Bank One Corporation	501 N. Water Street	Milwaukee	0046566	241433060	14494
	Carlson Marketing Group	3825 W. Green Tree Road	Milwaukee	0046566	241485860	14585
	Clark Station #0562	4751 N. Santa Monica Boulevard	Whitefish Bay	0046566	241574850	14470
	Deli-Food Xpress	1700 E. Washington Avenue	West Bend	0046566	267058500	14523
	Edison Street Parking Lot	1201 N. Edison Street	Milwaukee	0046566	241908370	17719
	Former Northbrook Hospital	4600 Schroeder Drive	Brown Deer	0046566	241645800	14609
	Moore Oil Company, Inc.	4033 W. Custer Avenue	Milwaukee	0046566	241174340	14591
	Pentler Property–Citgo Station	246 S. Main Street	Thiensville	0046566	246019290	14625
	Praefke Brake	133 Oak Street	West Bend	0046566	267004430	14493
	Stan and Sons Service	6030 N. Green Bay Road	Glendale	0046566	241102180	14620
	Stein Property	7425 W. Capitol Drive	Milwaukee	0046566	241581230	14619
	Superior Trucking Company	1319 Riverview Drive	Kewaskum	0046566	267122240	14497
	Teutonia Avenue Service	6811 N. Teutonia Avenue	Milwaukee	0046566	241179290	14600
	Tri Par Oil	1613 Washington Street	West Bend	0046566	246041730	14627
	University Car Wash, Inc.	4519 N. Green Bay Road	Milwaukee	0046566	241628310	14520
	Village of Shorewood	3801 N. Morris Boulevard	Shorewood	0046566	241218230	14597
Hydrostatic Test Water and Water Supply System	Adell Waterworks	P.O. Box 47	Adell	0057681	460043540	16178
	ANR Pipeline Kewaskum Loop	T11N R20E Sec 19 NE NE	Town of Trenton	0057681	- -	29927
	Brown Deer Waterworks	4800 W. Glen Brook Drive	Brown Deer	0057681	241055650	13370
	Cascade Waterworks	301 First Street	Cascade	0057681	460043650	15152
	Cedarburg Light and Water Commission	N30 W5926 Lincoln Boulevard	Cedarburg	0057681	246010820	14655
	Fredonia Water Utility	P.O. Box 159	Fredonia	0057681	246010930	18205
	Jackson Water Utility	N168 W20733 Main Street	Jackson	0057681	267011140	14673
	Kewaskum Waterworks	204 First Street	Kewaskum	0057681	267011250	14674
	Random Lake Waterworks	690 Wolf Road	Random Lake	0057681	460035510	15155
	Sanitaire Corporation	2320 Camden Road	Glendale	0057681	241522380	14102
	Saukville Water Utility	639 E. Green Bay Avenue	Saukville	0057681	246013460	14651
	Shorewood Waterworks	3930 N. Murray Avenue	Shorewood	0057681	241060710	14101
	Village of Grafton Water and Wastewater Utility	1900 9th Avenue	Grafton	0057681	246003010	5814
	West Bend Water Utility	251 Municipal Drive	West Bend	0057681	267012020	14676
	Wisconsin Gas Company	2000-4300 W. Donges Bay Road	Mequon	0057681	246013130	14653
Land Applying Liquid Industrial Wastes	Marigold Foods, Inc.	W55 N155 McKinley Boulevard	Cedarburg	0057657	246010270	12176
Landspreading Sludge	Kerry Ingredients, Inc.	N168 W21455 Main Street	Jackson	0057657	267074390	6892

Table 116 (continued)

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Noncontact Cooling Water	3M Touch Systems	7025 W. Marcia Road	Milwaukee	0044938	241684630	13393
	Brady USA, Inc–Coated Products Division	2230 W. Florist Avenue	Glendale	0044938	241029030	3150
	Brewery Works, Inc.	1555 N. River Center Drive Suite 200	Milwaukee	0044938	241283350	6884
	Carlson Tool & Manufacturing Corporation	W57 N14386 Doerr Road	Cedarburg	0044938	246067580	800
	Cedarburg Nail Factory, Inc.	4811 Columbia Road	Cedarburg	0044938	246000480	17035
	Charter Steel Division of Charter Manufacturing	1658 Cold Springs Road	Saukville	0044938	246044700	1309
	DRS Power & Control Technologies, Inc.	4201 N. 27th Street	Milwaukee	0044938	241016710	7133
	E.R. Wagner	4611 N. 32nd Street	Milwaukee	0044938	241019790	847
	Electron Bean Fusion Corporation	6510 N. 40th Street	Milwaukee	0044938	241381910	13605
	First National Bank Building	735 N. Water Street	Milwaukee	0044938	241013630	13623
	Franchise Mailing Systems	4355 N. Richards Street	Milwaukee	0044938	241373440	13625
	Fred Usinger, Inc.	1030 N. Old World Third Street	Milwaukee	0044938	241006040	538
	Gateway Plastics	5650 W. County Line Road	Mequon	0044938	246002350	19020
	Gehl Company	143 Water Street	West Bend	0044938	267003880	1171
	Great Lakes REIT, Inc.	111 E. Kilbourn Avenue	Milwaukee	0044938	241341430	13725
	Hercules, Inc.	5228 N. Hopkins Street	Milwaukee	0044938	241041900	2263
	Hydrite Chemical Company	7300 W. Bradley Road	Milwaukee	0044938	241211630	13727
	Hydro Platers, Inc.	3525 W. Kiehnau Avenue	Milwaukee	0044938	241231760	969
	Johnson Controls Battery Group, Inc.	5400 N. Teutonia Avenue	Milwaukee	0044938	241033320	12482
	Kerry Ingredients	N168 W21455 Main Street	Jackson	0044938	267074390	6892
	Lallemand Biochem International	6120 W. Douglas Avenue	Milwaukee	0044938	241316350	16680
	Leeson Electric Corporation	2100 Washington Street	Grafton	0044938	246005100	3152
	Liphatech	3101 W. Custer Avenue	Milwaukee	0044938	241050700	14034
	Mid City Foundry–United Division	460 N. 9th Street	Grafton	0044938	246096290	1839
	Milwaukee Gear Company, Inc.	5150 N. Port Washington Road	Milwaukee	0044938	241167960	1953
	Molecular Biology Resources, Inc.	6143 N. 60th Street	Milwaukee	0044938	241294020	660
	Myers Manufacturing, Inc.–Plant 2	N172 W20950 Emery Way	Jackson	0044938	267063720	24277
	Norstar Aluminum Molds, Inc.	W66 N622 Madison Avenue	Cedarburg	0044938	246066150	2864
	Pechiney Plastic Packaging, Inc.	6161 N. 64th Street	Milwaukee	0044938	241334060	1046
	Pereles Brothers	5840 N. 60th Street	Milwaukee	0044938	241016490	269
	Rexnord--Stearns Division	120 N. Broadway	Milwaukee	0044938	241256840	12483
	Ritus Rubber Corporation	7901 W. Clinton Avenue	Milwaukee	0044938	241252990	2570
	Ritus Rubber Corporation	7201 W. Bradley Road	Milwaukee	0044938	241267180	13340
	Riveredge Nature Center	4438 W. Hawthorne Drive	Newburg	0044938	246032710	14649
	Signicast Corporation–Milwaukee	9000 N. 55th Street	Milwaukee	0044938	241025510	2242
	SPX Dock Products	6720 N. Teutonia Avenue	Milwaukee	0044938	241083590	1422
	Stainless Foundry Engineering, Inc.	5150 N. 35th Street	Milwaukee	0044938	241019350	8416
	Super Steel Products Corporation–Calumet	7100 W. Calumet Road	Milwaukee	0044938	241017040	2562
	Tecumseh Power–Grafton Operations	900 North Street	Grafton	0044938	246009170	2405
	Thermoset, Inc.	6411 W. Mequon Road	Mequon	0044938	246045250	3684
	Treat All Metals, Inc	5140 N. Port Washington Road	Milwaukee	0044938	241010770	518
	Universal Strap, Inc.	W209 N17500 Industrial Drive	Jackson	0044938	267080220	14722
	Vishay Cera Mite Grafton	1327 6th Avenue	Grafton	0044938	246043820	2417
	Weasler Engineering, Inc.	7801 North Hwy 45	Barton	0044938	267019610	1760
	West Bend Division of Regal Ware, Inc.	1100 Schmidt Road	West Bend	0044938	267067900	23790
	Wisconsin Color Press	5400 W. Good Hope Road	Milwaukee	0044938	241374980	2130
Nonmetallic Mining Operations[c]	B R Amon & Sons–Garbisch Pit	Boltonville Road	Scott	0046515	460071810	24654
	B R Amon & Sons–Kraemer Pit	W7055 CTH N and High View Road	Town of Mitchell	0046515	460001850	15190
	CRM Recycling Site	7460 N. 60th Street	Milwaukee	0046515	241049270	11086
	Hartman Sand & Gravel Company, Inc.–Home Pit	N6621 Pioneer Drive	Fredonia	0046515	246057020	23164
	Hartman Sand & Gravel Company, Inc.–Spring Lake Pit	North of Jay Road, East of Random Lake Road	Fredonia	0046515	- -	23165
	Jackson Quarry	607 Pleasant Valley Road	Jackson	0046515	267098810	16958
	James Cape and Sons Cedarburg Limestone Quarry	660 Susan Lane	Cedarburg	0046515	246105310	14399

Table 116 (continued)

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Nonmetallic Mining Operations[c] (continued)	Lake Ellen Stone, Inc.	N2133 Hwy 28	Adell	0046515	460104370	867
	Ozaukee County Highway Department–Lakeland Pit	3601 Lakeland Road	Saukville	0046515	246005760	25115
	Payne & Dolan–Saukville Aggregate Site 81005	2892 Lakeland Drive	Saukville	0046515	999905280	2804
	Rowe Sand & Gravel, Inc.	1219 Hwy I	Grafton	0046515	246105750	3117
	Werner Johann & Son, Inc.	2021 W. Decorah Road	West Bend	0046515	267115750	2907
	West Bend Sand & Stone, Inc.	4246 Hwy 33	West Bend	0046515	267105960	2904
Petroleum Contaminated Water[a]	- -	- -	- -	- -	- -	- -
Pit/Trench Dredging	ANR Pipeline Kewaskum Loop	T11N R20E Sec 19 NE NE	Trenton	0049344	- -	29927
	Wondra Excavating, Inc.	- -	Washington Co.	0049344	- -	19633
Potable Water Treatment and Conditioning	Hays Brake LLC	5800 W. Donges Bay Road	Mequon	0046540	246021270	3617
	North Shore Water Commission	400 W. Bender Road	Glendale	0046540	241016820	13723
	Weasler Engineering, Inc.	7801 Hwy 45	Barton	0046540	267019610	1760
Swimming Pool Facilities	Cedaqua Swimming Pool	- -	Cedarburg	0046523	- -	1984
	Cedarburg Community Pool	W68 N851 Evergreen Boulevard	Cedarburg	0046523	246105420	14645
	Grafton High School Swimming Pool	1900 Washington Avenue	Grafton	0046523	246072200	14646
	Homestead High School	5000 W. Mequon Road	Mequon	0046523	246029190	13729
	Le Club	2001 W. Good Hope Road	Milwaukee	0046523	241519850	14033
	Mequon Public Pool	11333 Cedarburg Road	Mequon	0046523	246069550	14078
	Milwaukee County Parks and Recreation–Lincoln Park	1300 E. Glendale Avenue	Milwaukee	0046523	241520510	14059
	Milwaukee Country Club	8000 N. Range Line Road	River Hills	0046523	241088100	14079
	Ozaukee Country Club	10823 N. River Road	Mequon	0046523	246020610	14097
	Schroeder YMCA	9250 N. Green Bay Road	Brown Deer	0046523	241522600	14110
Individual Permits	Adell Corporation	627 Maine Street	Adell	- -	460032760	5623
	Badger Meter, Inc.	4545 W. Brown Deer Road	Milwaukee	0033529	241015500	6463
	Cook Composites & Polymers Company	340 Railroad Street	Saukville	0027731	246004330	6198
	ITW West Bend Company	400 Washington Street	West Bend	0027294	267004640	6178
	Johnson Controls, Inc.	5757 N. Green Bay Road	Glendale	0000108	241005160	5559
	Krier Foods, Inc.[b]	520 Wolf Road	Random Lake	0049204	460146280	10134
	Lakeside Foods, Inc.[b]	709 Allen Street	Random Lake	0032760	460034850	8623
	Level Valley Creamery, Inc.[c]	807 Pleasant Valley Road	West Bend	0026751	267030280	6152
	Milk Specialties Company, Inc.–Adell Ingredients	627 Maine Street	Adell	0001236	460032760	5623
	Northland Cranberries[d]	N168 W20701 Main Street	Jackson	- -	267003770	5566
	Osmonics Autotrol	5730 N. Glen Park Road	Milwaukee	0041351	241022210	6689
	Regal Ware, Inc.	1675 Reigle Drive	Kewaskum	0000060	267003660	5555
	Village of River Hills	7650 N. Pheasant Lane	River Hills	0032221	241088430	18595
	Wisconsin Thermoset Molding, Inc.	900 E. Vienna Avenue	Milwaukee	0042218	241440760	473
	Wisconsin Department of Natural Resources–Kettle Moraine Springs Fish Hatchery	N1929 Trout Springs Road	Adell	0026255	460033750	7297

[a] *There were no active WPDES general permits for Petroleum Contaminated Water in the Milwaukee River watershed during February 2003.*

[b] *The name of this facility has changed to Lakeside Foods, 709 Allen Street, Random Lake. Field checking indicates that this is the same building.*

[c] *Level Valley Creamery was purchased by Schreiber Foods in 2005.*

[d] *The Northland Cranberries bottling plant in Jackson closed on November 21, 2003, and was subsequently sold.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

and a post-construction stormwater management plan as required in Chapter NR 216.46 and Chapter NR 216.47 of the *Wisconsin Administrative Code*. Owners of permitted construction sites are also required to conduct inspections of their construction erosion control measures on a weekly basis and within 24 hours of a precipitation event of 0.5 inches or more. Due to the dynamic nature of construction activities, it is recognized that the number of sites requiring Construction Site Storm Water permits in the watershed will change as construction projects are completed and new projects are initiated.

The WPDES stormwater permits for municipalities within the watershed are described below and are listed in Table G-3 in Appendix G.

Chapter NR 151 of the Wisconsin Administrative Code
Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* establishes performance standards for the control of nonpoint source pollution from agricultural lands, nonagricultural (urban) lands, and transportation facilities. The standards for urban lands apply to areas of existing development, redevelopment, infill, and construction sites. In general, the construction erosion control, post-construction nonpoint source pollution control, and stormwater infiltration requirements of NR 151 apply to projects associated with construction activities that disturb at least one acre of land.

The urban standards are applied to activities covered under the WPDES program for stormwater discharges. As noted below, communities with WPDES discharge permits must adopt stormwater management ordinances that have requirements at least as stringent as the standards of Chapter NR 151. Those communities must also achieve levels of control of nonpoint source pollution from areas of existing development (as of October 1, 2004), that are specified under Chapter NR 151.

Stormwater Management Systems
Stormwater management facilities are defined, for purposes of this report, as conveyance, infiltration, or storage facilities, including, but not limited to, subsurface pipes and appurtenant inlets and outlets, ditches, streams and engineered open channels, detention and retention basins, pumping facilities, infiltration facilities, constructed wetlands for treatment of runoff, and proprietary treatment devices based on settling processes and control of oil and grease. Such facilities are generally located in urbanized areas and constructed or improved and operated for purposes of collecting stormwater runoff from tributary drainage areas and conveying, storing, and treating such runoff prior to discharge to natural watercourses. In the larger and more intensively developed urban communities, these facilities consist either of complete, largely piped, stormwater drainage systems which have been planned, designed, and constructed as systems in a manner similar to sanitary sewer and water utility systems, or of fragmented or partially piped systems incorporating open surface channels to as great a degree as possible. In the Milwaukee River watershed, the stormwater drainage systems provide the means by which a significant portion of the nonpoint sources pollutants reach the surface water system.

With the relatively recent application of the WPDES permitting program to stormwater discharges and the adoption of local stormwater management ordinances, controls on the quality of stormwater runoff prior to discharge to receiving streams have become more common. Table 117 indicates the status of stormwater management activities in each of the communities in the watershed.

Table G-3 in Appendix G indicates that Fond du Lac, Milwaukee, Ozaukee, Sheboygan, and Washington Counties; the Cities of Cedarburg, Glendale, Mequon, and Milwaukee; the Village of Bayside, Brown Deer, Fox Point, Germantown, Grafton, River Hills, Saukville, Shorewood, Thiensville, and Whitefish Bay; and the Towns of Cedarburg, Grafton, and Richfield have WPDES stormwater discharge permits. The remaining communities in the watershed do not currently have stormwater discharge permits. Thus, communities comprising 22 percent of the watershed area have been issued WPDES stormwater discharge permits. In addition to specific nonpoint source pollution control activities recommended under their WPDES permits, the permitted communities will also all be required to develop new, or update existing, stormwater management ordinances to be consistent with the standards of Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*. As part of their

Table 117

STORMWATER MANAGEMENT INFORMATION FOR CITIES, VILLAGES, AND TOWNS WITHIN THE MILWAUKEE RIVER WATERSHED

Civil Division	Stormwater Management Ordinance and/or Plan	Construction Erosion Control Ordinance	Stormwater Utility, General Fund, and/or Established Stormwater Fee Program
Dodge County[a]	- -	X	- -
Town of Lomira	- -	X[a]	- -
Village of Lomira	- -	- -	- -
Fond du Lac County[b]	X	X	- -
Town of Ashford	X[b]	X[b]	- -
Town of Auburn	X[b]	X[b]	- -
Town of Byron	X[b]	X[b]	- -
Town of Eden	X[b]	X[b]	- -
Town of Empire	X[b]	X[b]	- -
Town of Forest	X[b]	X[b]	- -
Town of Osceola	X[b]	X[b]	- -
Village of Campbellsport	- -	X	- -
Village of Eden	- -	- -	- -
Milwaukee County			
City of Glendale	X	X	X
City of Milwaukee	X	X	X
Village of Bayside	X	X	- -
Village of Brown Deer	X	X	- -
Village of Fox Point	X	X	- -
Village of River Hills	X	X	- -
Village of Shorewood	X	X	- -
Village of Whitefish Bay	X	X	- -
Ozaukee County			
City of Cedarburg	X	X	- -
City of Mequon	X	X	- -
Town of Cedarburg	- -[c]	- -[c]	- -
Town of Fredonia	- -	- -	- -
Town of Grafton	X	X	- -
Town of Port Washington	- -	- -	- -
Town of Saukville	- -	- -	- -
Village of Fredonia	X	X	- -
Village of Grafton	X	X	- -
Village of Newburg	- -	X	- -
Village of Saukville	X	X	- -
Village of Thiensville	X	X	- -
Sheboygan County			
Town of Greenbush	X[d]	X[d]	- -
Town of Holland	X[d]	X[d]	- -
Town of Lyndon	X[d]	X[d]	- -
Town of Mitchell	X[d]	X[d]	- -
Town of Scott	X[d]	X[d]	- -
Town of Sherman	X[d]	X[d]	- -
Village of Adell	- -	- -	- -
Village of Cascade	- -	- -	- -
Village of Random Lake		X	

Table 117 (continued)

Civil Division	Stormwater Management Ordinance and/or Plan	Construction Erosion Control Ordinance	Stormwater Utility, General Fund, and/or Established Stormwater Fee Program
Washington County	X	X	- -
City of West Bend	X	X	- -
Town of Addison	X[e]	X[e]	- -
Town of Barton	X[e]	X[e]	- -
Town of Farmington	X[e]	X[e]	- -
Town of Germantown	X[e]	X[e]	- -
Town of Jackson	X[e]	X[e]	- -
Town of Kewaskum	X	X	- -
Town of Polk	X[e]	X[e]	- -
Town of Richfield	X[e]	X[e]	- -
Town of Trenton	X[e]	X[e]	- -
Town of Wayne	X	X	- -
Town of West Bend	X	X	- -
Village of Germantown	X	X	- -
Village of Jackson	X	X	- -
Village of Kewaskum	X	X	- -
Village of Newburg	- -	X	- -
Village of Slinger	- -	- -	- -

[a]*The Town of Lomira is covered under the Dodge County construction erosion control ordinance.*

[b]*All towns are covered under Fond du Lac County's stormwater management and construction erosion control ordinances.*

[c]*Will adopt ordinances as required under WPDES stormwater discharge permit.*

[d]*All towns are covered under Sheboygan County's stormwater management and construction erosion control ordinances.*

[e]*In the indicated towns; Washington County administers either 1) the county stormwater management and construction erosion control (SWM & CEC) ordinance or 2) a SWM & CEC ordinance adopted by the town.*

Source: SEWRPC.

permit application, each community prepared maps of the stormwater outfalls that are part of the municipal separate stormwater system.

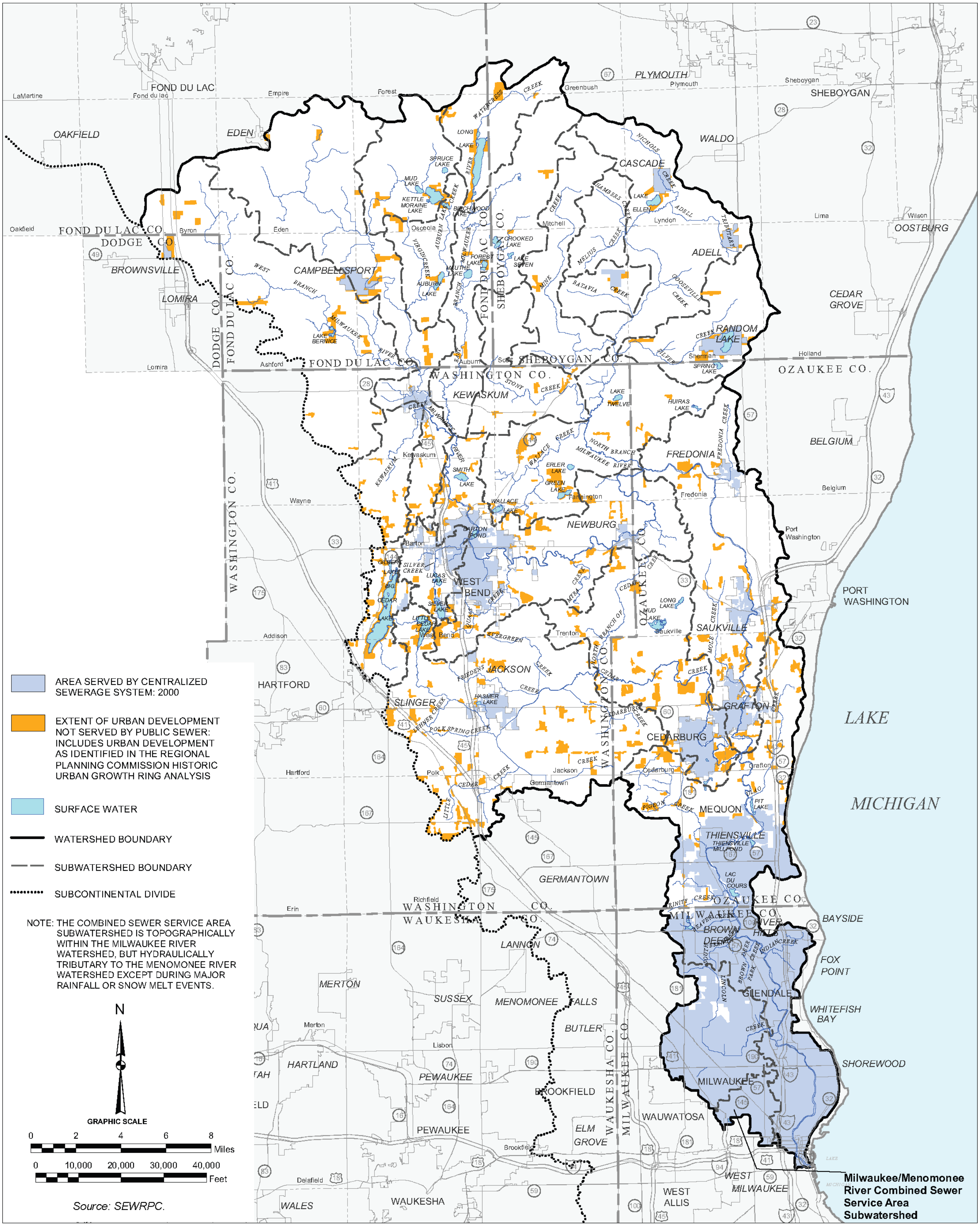
Urban Enclaves Outside Planned Sewer Service Areas

Map 69 shows areas served by centralized sanitary sewer systems in the Milwaukee River watershed in 2000. In that year, 59,932 acres of the watershed were served by sanitary sewer systems. In addition, there were about 18,105 acres of urban-density enclaves that were not served by public sanitary sewer systems. As shown on Map 70, about 11,935 acres of these enclaves are in areas served by onsite sewage disposal systems that were developed prior to 1980. These older systems may be at particular risk for malfunctioning. As described in Chapter II of this report, failure of onsite disposal systems can contribute nonpoint source pollutants to streams and groundwater.

In 1978, the State of Wisconsin established the Private Onsite Wastewater Treatment System Replacement or Rehabilitation Financial Assistance Program under the Wisconsin Fund Program. That voluntary program annually awards grants to counties, Indian tribes, and municipalities to assist homeowners and small businesses in replacing or rehabilitating failing private, onsite systems. The program is administered by the Wisconsin Department of Commerce in cooperation with the counties and communities. Grant eligibility is subject to

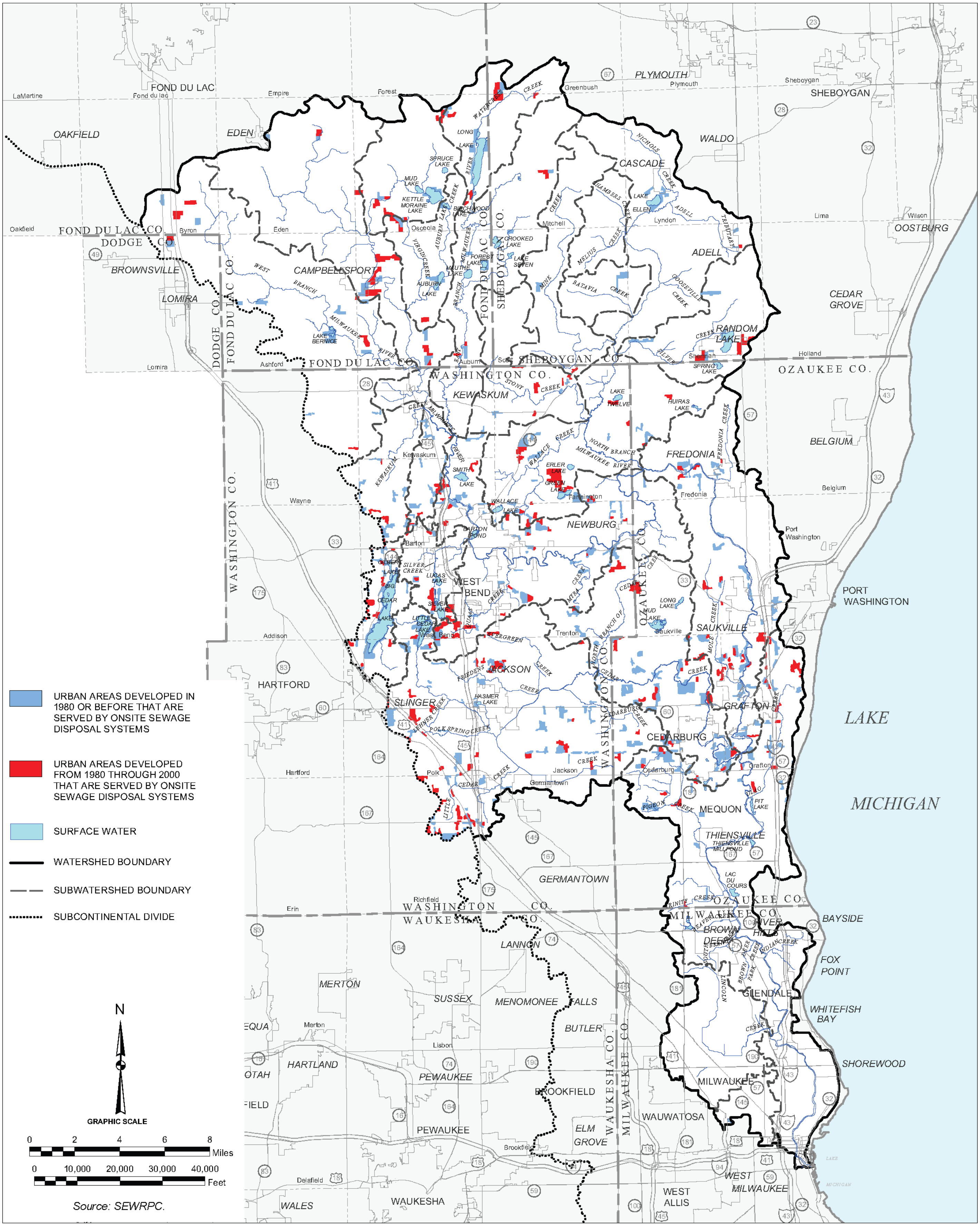
Map 69

AREAS SERVED BY CENTRALIZED SANITARY SEWERAGE SYSTEMS WITHIN THE MILWAUKEE RIVER WATERSHED: 2000



Map 70

URBAN AREAS WITHIN THE MILWAUKEE RIVER WATERSHED THAT ARE SERVED BY ONSITE SEWAGE DISPOSAL SYSTEMS: 1980 AND PRIOR AND 1981 THROUGH 2000



specific income, revenue, occupancy, and operation requirements. Onsite systems that are installed, replaced, or rehabilitated after the date on which the county or community elects to participate are required to have a maintenance program. Thus, given the 1978 date of establishment of the grant program, the determination of areas developed with onsite systems before 1980 and those developed in 1980 or later,[68] provides an indication of which systems are subject to the requirement of having formal maintenance programs and which are not. The counties, or communities in the case of Milwaukee County, are responsible for administering the maintenance program with the goal of assuring the onsite systems function properly. In the Milwaukee River watershed, Dodge, Fond du Lac, Ozaukee, Sheboygan, and Washington Counties currently participate in the program.

Solid Waste Disposal Sites

Solid waste disposal sites are a potential source of surface water, as well as groundwater, pollution. It is important to recognize, however, the distinction between a properly designed and constructed solid waste landfill and the variety of operations that are referred to as refuse dumps, especially with respect to potential effects on water quality. A solid waste disposal site may be defined as any land area used for the deposit of solid wastes regardless of the method of operation, or whether a subsurface excavation is involved. A solid waste landfill may be defined as a solid waste disposal site which is carefully located, designed, and operated to avoid hazards to public health or safety, or contamination of groundwaters or surface waters. The proper design of solid waste landfills requires careful engineering to confine the refuse to the smallest practicable area, to reduce the refuse mass to the smallest practicable volume, to avoid surface water runoff, to minimize leachate production and percolation into the groundwater and surface waters, and to seal the surface with a layer of earth at the conclusion of each day's operation or at more frequent intervals as necessary.

In order for a landfill to produce leachate, there must be some source of water moving through the fill material. Possible sources included precipitation, the moisture content of the refuse itself, surface water infiltration, groundwater migrating into the fill from adjacent land areas, or groundwater rising from below to come in contact with the fill. In any event, leachate is not released from a landfill until a significant portion of the fill material exceeds its saturation capacity. If external sources of water are excluded from the solid waste landfill, the production of leachates in a well-designed and managed landfill can be effectively minimized if not entirely avoided. The quantity of leachate produced will depend upon the quantity of water that enters the solid waste fill site minus the quantity that is removed by evapotranspiration. Studies have estimated that for a typical landfill, from 20 to 50 percent of the rainfall infiltrated into the solid waste may be expected to become leachate. Accordingly, a total annual rainfall of about 35 inches, which is typical of the Milwaukee River watershed, could produce from 190,000 to 480,000 gallons of leachates per year per acre of landfill if the facility is not properly located, designed, and operated.

As of 2005, there were two active solid waste landfills within the watershed, both located in the West Branch Milwaukee River subwatershed. As set forth in Table 118 and shown on Map 71, there are 47 inactive landfills in the watershed: 10 in the Upper Lower Milwaukee River subwatershed; six in the North Branch Milwaukee River subwatershed; four each in the Cedar Creek, Lower Milwaukee River, Middle Milwaukee River, Stony Creek, and West Branch Milwaukee River subwatersheds; three in the Lincoln Creek subwatershed; two each in the Silver Creek (West Bend) and Upper Milwaukee River subwatersheds; and one each in the Lake Fifteen Creek and Watercress Creek subwatersheds.

Rural Stormwater Runoff

Rural land uses within the Milwaukee River watershed include agricultural—mostly crop production—and woodlands, wetlands, water, and other open lands as set forth in the beginning of this chapter. As noted above, Chapter NR 151 of the *Wisconsin Administrative Code* establishes performance standards for the control of

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[68]*Since 1970, the SEWRPC land use inventory has been conducted at five-year intervals. Thus the 1980 inventory was the best available information for establishing which systems have maintenance requirements.*

Table 118

ACTIVE AND INACTIVE SOLID WASTE DISPOSAL SITES IN THE MILWAUKEE RIVER WATERSHED: 2005

Number on Map 71	Facility Name	Address	Municipality	Classification	Subwatershed	Facility Identification	Status
1	City of Glendale	5909 N. Milwaukee Parkway	Glendale	Landfill, unclassified	Lincoln Creek	241206900	Inactive
2	City of Mequon Compost/Closed Landfill Site	Bonniwell Road	Mequon	Landfill, 50,000-500,000 cubic yards	Lower Milwaukee River	246046460	Inactive
3	City of Milwaukee	- -	Milwaukee	- -	Lincoln Creek	- -	Inactive
4	City of Milwaukee, Bluehole Landfill	- -	Milwaukee	- -	Lower Milwaukee River	- -	Inactive
5	Village of Whitefish Bay	5201 W. Good Hope Road	Milwaukee	Landfill 50,000-500,000 cubic yards	Lincoln Creek	241218670	Inactive
6	Grafton, Lime Kiln Park	Green Bay Road	Grafton	Landfill, unclassified	Upper Lower Milwaukee River	246036780	Inactive
7	Freeman Chemical	- -	Saukville	- -	Upper Lower Milwaukee River	- -	Inactive
8	Village of Saukville	CTH O (South Main)	Saukville	Landfill, unclassified	Upper Lower Milwaukee River	246048770	Inactive
9	Village of Thiensville	STH 57	Thiensville	Landfill, unclassified	Lower Milwaukee River	246050200	Inactive
10	Town of Sherman Landfill	Pelishek Road	Sherman	Landfill 0-50,000 cubic yards	North Branch Milwaukee River	460020000	Inactive
11	Town of Sherman	- -	Sherman	Landfill, unclassified	North Branch Milwaukee River	460019890	Inactive
12	Town of Ashford Landfill	CTH W	Ashford	Landfill 50,000-500,000 cubic yards	West Branch Milwaukee River	420015860	Inactive
13	City of West Bend	- -	Barton	- -	Silver Creek West Bend	- -	Inactive
14	- -	- -	Barton	- -	North Branch Milwaukee River	- -	Inactive
15	Majerus Landfill	W5633 Campbell Road	Byron	Landfill >500,000 cubic yards	West Branch Milwaukee River	420014430	Inactive
16	Sadoff & Ruddy Industries	USH 41	Byron	Landfill >500,000 cubic yards	West Branch Milwaukee River	420018280	Active
17	Sadoff & Ruddy Industries	USH 41	Byron	Landfill >500,000 cubic yards	West Branch Milwaukee River	420018280	Active
18	City/Town of Cedarburg Compost Site/Old Landfill	Pleasant Valley Road	Cedarburg	Landfill 50,000-500,000 cubic yards	Upper Lower Milwaukee River	246049650	Inactive
19	Marvin Procknow	- -	Cedarburg	- -	Upper Lower Milwaukee River	- -	Inactive
20	Wisconsin Electric Power Company	Cedar Sauk Road	Cedarburg	Landfill, unclassified	Upper Lower Milwaukee River	246049210	Inactive
21	Village of Eden Landfill	- -	Eden	Landfill, unclassified	Upper Milwaukee River	420018720	Inactive
22	Town of Eden Landfill	- -	Eden	Landfill, unclassified	Upper Milwaukee River	420016190	Inactive
23	Lazy Days Camp Ground	- -	Farmington	Landfill, unclassified	North Branch Milwaukee River	267060310	Inactive
24	Town of Farmington	Paradise Road	Farmington	Landfill 0-50,000 cubic yards	Stony Creek	267061300	Inactive
25	Town of Fredonia	Hickory Grove Road	Fredonia	Landfill 0-50,000 cubic yards	Upper Lower Milwaukee River	246047890	Inactive
26	Ozaukee County Highway Department	CTH Y and CTH A	Fredonia	Landfill 50,000-500,000 cubic yards	Middle Milwaukee River	246049540	Inactive
27	Town of Grafton	Cedar Sauk Road	Grafton	Landfill 50,000-500,000 cubic yards	Upper Lower Milwaukee River	246048000	Inactive
28	Wisconsin Electric Power Company	- -	Grafton	- -	Lower Milwaukee River	- -	Inactive
29	Town of Jackson	CTH G	Jackson	Landfill, unclassified	Cedar Creek	267061410	Inactive
30	Village of Kewaskum	County Line Road	Kewaskum	Landfill 50,000-500,000 cubic yards	West Branch Milwaukee River	420017840	Inactive
31	Town of Kewaskum	Hickory Road	Kewaskum	Landfill 0-50,000 cubic yards	Stony Creek	267061520	Inactive

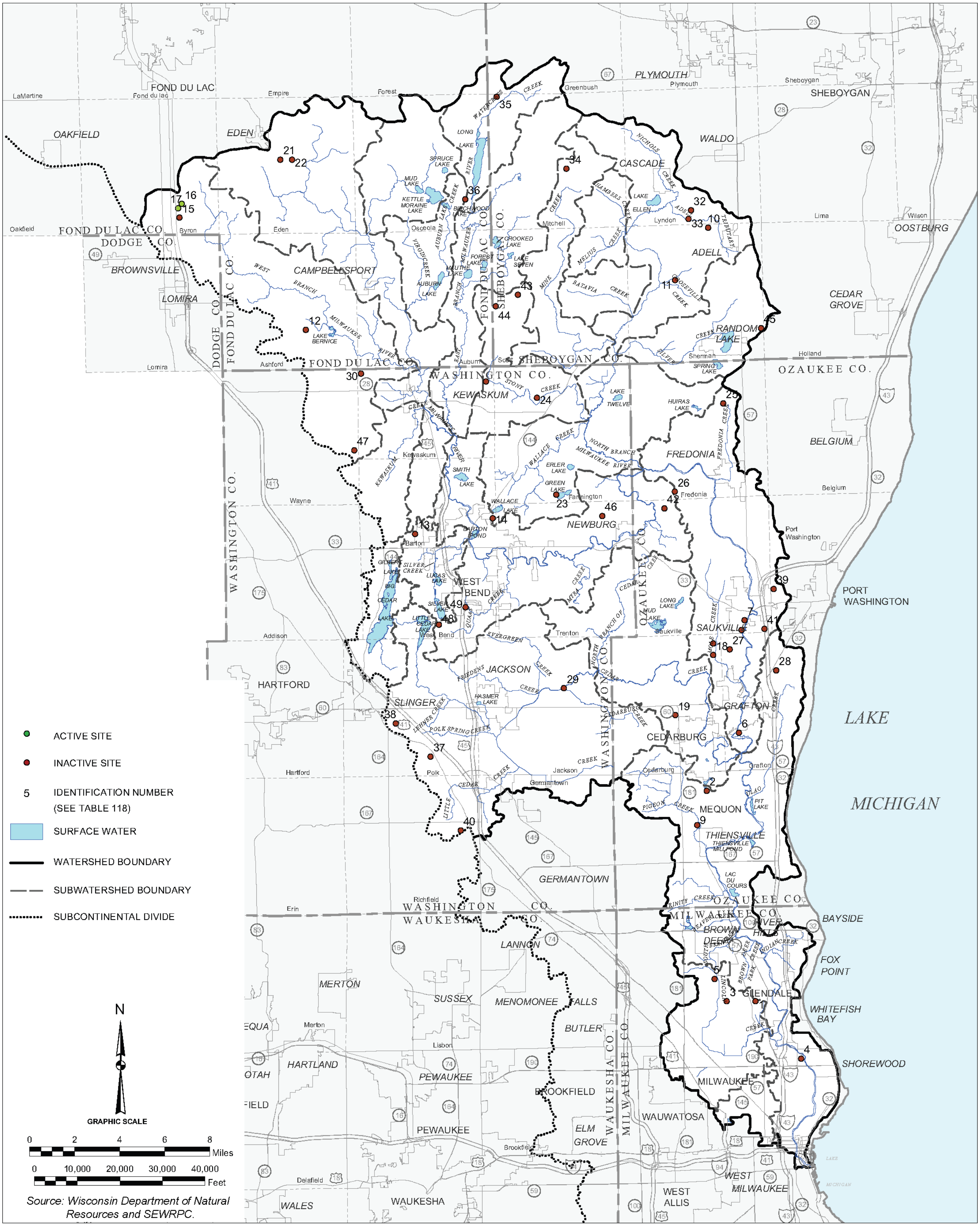
Table 118 (continued)

Number on Map 71	Facility Name	Address	Municipality	Classification	Subwatershed	Facility Identification	Status
32	Town of Lyndon and Village of Cascade Landfill	Bates Road	Lyndon	Landfill 50,000-500,000 cubic yards	North Branch Milwaukee River	460020440	Inactive
33	Sheboygan County Highway Department	- -	Lyndon	Landfill 0-50,000 cubic yards	North Branch Milwaukee River	460015600	Inactive
34	Town of Mitchell Landfill	Parnell Road	Mitchell	Landfill 50,000-500,000 cubic yards	Mink Creek	460019010	Inactive
35	WI DOC Kettle Moraine Watercress	Kettle Moraine	Mitchell	Landfill 0-50,000 cubic yards	Watercress Creek	460021760	Inactive
36	Town of Osceola Landfill	CTH F	Osceola	Landfill 50,000-500,000 cubic yards	Lake Fifteen Creek	420017070	Inactive
37	LeRoy Schmidt Dump	- -	Polk	Landfill, unclassified	Cedar Creek	267060420	Inactive
38	- -	- -	Polk	- -	Cedar Creek	- -	Inactive
39	Town of Port Washington	Northwood and Millcrest	Port Washington	Landfill, unclassified	Upper Lower Milwaukee River	246048110	Inactive
40	Town of Richfield	Mayfield Road	Richfield	Landfill 50,000-500,000 cubic yards	Cedar Creek	267063060	Inactive
41	Town of Saukville	Foster Road	Saukville	Landfill 50,000-500,000 cubic yards	Upper Lower Milwaukee River	246048220	Inactive
42	Laubenstein Sales and Service, Inc.	CTH Y	Saukville	Landfill 0-50,000 cubic yards	Middle Milwaukee River	246050090	Inactive
43	Town of Scott Landfill	CTH S	Scott	Landfill 50,000-500,000 cubic yards	Stony Creek	460019560	Inactive
44	WDNR Kettle Moraine Forest	Division Road	Scott	Landfill 0-50,000 cubic yards	Stony Creek	460021650	Inactive
45	Dimmer Disposal Operation	CTH CC	Sherman	Landfill, unclassified	Silver Creek	460021650	Inactive
46	Town of Trenton	- -	Trenton	Landfill, unclassified	Middle Milwaukee River	267061630	Inactive
47	Town of Wayne	- -	Wayne	- -	West Branch Milwaukee River	- -	Inactive
48	Town of West Bend	- -	West Bend	- -	Silver Creek West Bend	- -	Inactive
49	- -	- -	West Bend	- -	Middle Milwaukee River	- -	Inactive

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 71

ACTIVE AND INACTIVE SOLID WASTE DISPOSAL SITES WITHIN THE MILWAUKEE RIVER WATERSHED: 2005



nonpoint source pollution from agricultural lands, nonagricultural (urban) lands, and transportation facilities. Agricultural performance standards are established for soil erosion, manure storage facilities, clean water diversions, nutrient management, and manure management. Those standards must only be met to the degree that grant funds are available to implement projects designed to meet the standards.

Livestock Operations

The presence of livestock and poultry manure in the environment is an inevitable result of animal husbandry and is a major potential source of water pollutants. Animal manure composed of feces, urine, and sometimes bedding material, contributes suspended solids, nutrients, oxygen-demanding substances, bacteria, and viruses to surface waters. Animal waste constituents of pastureland and barnyard runoff, and animal wastes deposited on pastureland and cropland and in barnyards, feedlots, and manure piles, can potentially contaminate water by surface runoff, infiltration to groundwater, and volatilization to the atmosphere. During the warmer seasons of the year the manure is often scattered on cropland and pastureland where the waste material is likely to be taken up by vegetative growth composing the land cover. However, when the animal manure is applied to the land surface during the winter, the animal wastes are subject to excessive runoff and transport, especially during the spring snowmelt period.

Based on data from 2002, animal operations in the Milwaukee River watershed include 1,791 operations rearing a total of about 211,418 cattle and calves, 152 operations rearing a total of about 19,864 pigs, 119 operations rearing a total of about 3,998 sheep, and 231 operations rearing a total of about 34,899 chickens, mostly broilers. Most of these operations are in the portions of the watershed in Fond du Lac and Sheboygan Counties.

Five concentrated animal feeding operations (CAFO) are situated in the watershed. Abel Dairy in the Town of Eden rears about 1,700 cattle and calves. Clover Hill Dairy in the Town of Ashford rears about 850 cattle and calves. Opitz Dairy Farm in the Town of Saukville rears about 1,800 cattle and calves. R&J Partnership in the Town of Kewaskum rears up to 400,000 chickens. Vorpahl Farms in the Town of Sherman rears about 2,050 cattle and calves. Concentrated animal feeding operations are defined as livestock and poultry operations with more than 1,000 animal units. Animal units are calculated for each different type and size class of livestock and poultry. For example, facilities with 1,000 beef cattle, 700 milking cows, or 200,000 chickens each would be considered to have the equivalent of 1,000 animal units. Concentrated animal feeding operations are regulated by the State of Wisconsin under the WPDES permit program.

Crop Production

In the absence of mitigating measures, runoff from cropland can have an adverse effect on water quality within the Milwaukee River watershed by contributing excess sediments, nutrients, and organic matter, including pesticides to streams. Negative effects associated with soil erosion and transport to waterbodies includes reduced water clarity, sedimentation on streambeds, and contamination of the water from various agricultural chemicals and nutrients that are attached to the individual soil particles. Some of these nutrients, in particular phosphorus, and to some extent nitrogen, are directly associated with eutrophication of water resources. The extent of the water pollution from cropping practices varies considerably as a result of the soils, slopes, and crops, as well as in the numerous methods of tillage, planting, fertilization, chemical treatment, and conservation practices. Conventional tillage practices, or moldboard plowing, involve turning over the soil completely, leaving the soil surface bare of most cover or residue from the previous year's crop, and making it highly susceptible to erosion due to wind and rain. The use of conservation tillage practices has become common in the watershed in recent years within areas most susceptible to erosion and surface water impacts.

Crops grown in the Milwaukee River watershed include row crops, such as corn and soybeans; small grains, such as winter wheat; and hay such as alfalfa. Vegetables, such as snap beans and sweet corn, constitute less than 1 percent of the agricultural land cover. Row crops and vegetable crops, which have a relatively higher level of exposed soil surface, tend to contribute higher pollutant loads than do hay and pastureland, which support greater levels of vegetative cover. Crop rotations typically follow a two- or three-year sequence of corn and soybeans and occasionally winter wheat in the third year. However, hay is periodically included as part of a long-term rotation of corn, oats, and alfalfa.

Since the early 1930s, it has been a national objective to preserve and protect agricultural soil from wind and water erosion. Federal programs have been developed to achieve this objective, with the primary emphasis being on sound land management and cropping practices for soil conservation. An incidental benefit of these programs has been a reduction in the amount of eroded organic and inorganic materials entering surface waters as sediment or attached to sediment. Some practices are effective in both regards, while others may enhance the soil conditions with little benefit to surface water quality. Despite the implementation of certain practices aimed at controlling soil erosion from agricultural land, and development of soil erosion plans and/or land water resource management plans for Milwaukee,[69] Ozaukee,[70] and Washington[71] counties, such erosion and the resultant deposition of sediment in the streams of the Milwaukee River watershed remains a significant water resource problem. Soil erosion from agricultural lands is one of the major sources of sediment and nutrients in the Milwaukee River and its tributaries.

Nutrients such as phosphorus and agri-chemicals, including herbicides and pesticides, are electrostatically attracted to silt sized particles and are transported to surface waters through soil erosion. As previously mentioned, phosphorus is one of the primary nutrients associated with eutrophication of water resources, and agri-chemicals can negatively impact the life cycles of aquatic organisms. In the eutrophication process, phosphorus enhances growth of aquatic vegetation and algae, which has the effect of accelerating the aging process of a water resource. Phosphorus is usually not susceptible to downward movement through the soil profile; instead, the majority of phosphorus reaches water resources by overland flow, or erosion. Nitrogen also is a nutrient that contributes to eutrophication; however, it is most often associated with subsurface water quality contamination. Nitrogen in the form of nitrate can be associated with respiration problems in newborn infants. Nitrogen is susceptible to downward movement through the soil profile; however, due to the nature of soils in the watershed, nitrogen is not as significant a threat due to various chemical reactions that occur within the soil.[72]

Woodlands

A well-managed woodland contributes few pollutants to surface waters. Under poor management, however, woodlands may have detrimental water quality effects through the release of sediments, nutrients, organic matter, and pesticides into nearby surface waters. If trees along streams are cut, thermal pollution may occur as the direct rays of the sun strike the water. Disturbances caused by tree harvesting, livestock grazing, tree growth promotion, tree disease prevention, fire prevention, and road and trail construction are a major source of pollution from silvicultural activities. Most of these activities are seldom practiced in the Milwaukee River watershed.

Pollution Loadings

Annual Loadings

Annual average pollutant loads to the Milwaukee River watershed are set forth in Tables 119 through 125. Average annual per acre loads are set forth in Table 126. These estimates represent point and nonpoint source loads delivered to the modeled stream reaches, after accounting for any trapping factors that would retain pollutants on the surface of the land. They include loads from groundwater. It is important to note that the stream

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[69]*Milwaukee County Land Conservation Committee,* Milwaukee County Land and Water Resource Management Plan, *April 2001.*

[70]*SEWRPC Community Assistance Planning Report No. 171,* Ozaukee County Agricultural Soil Erosion Control Plan, *February 1989.*

[71]*SEWRPC Community Assistance Planning Report No. 170,* Washington County Agricultural Soil Erosion Control Plan, *March 1989.*

[72]*Soils that have a high clay content and stay wet for long periods of time, or even well-drained soils after a rainfall event, are susceptible to nitrogen losses to the atmosphere through a chemical reaction known as denitrification. This reaction converts nitrate, NO_3^-, to gaseous nitrogen, N_2, which is lost to the atmosphere.*

Table 119

AVERAGE ANNUAL TOTAL NONPOINT SOURCE POLLUTANT LOADS IN THE MILWAUKEE RIVER WATERSHED[a]

Subwatershed	Total Phosphorus (pounds)	Total Suspended Solids (pounds)	Fecal Coliform Bacteria (trillions of cells)	Total Nitrogen (pounds)	Biochemical Oxygen Demand (pounds)	Copper (pounds)
Batavia Creek	600	226,000	161.10	19,510	28,470	18
Cedar Creek	18,700	8,286,000	3,542.40	299,660	737,700	377
Cedar Lake	2,640	1,256,000	1,575.05	26,600	81,330	99
Chambers Creek	650	252,000	187.96	19,620	28,580	22
East Branch Milwaukee River	2,600	1,010,000	791.81	43,350	97,240	88
Kettle Moraine Lake	3,450	2,042,000	698.83	60,000	129,130	63
Kewaskum Creek	2,240	1,040,000	378.87	43,880	93,300	41
Lake Fifteen Creek	1,420	780,000	455.30	21,190	48,850	44
Lincoln Creek	7,940	2,826,000	4,178.52	42,920	217,940	381
Lower Cedar Creek	8,410	4,350,000	2,488.74	112,010	270,700	229
Lower Milwaukee River	21,520	8,268,000	8,496.57	188,580	623,130	785
Middle Milwaukee River	9,630	4,598,000	3,305.63	139,980	328,410	311
Mink Creek	1,440	566,000	446.95	51,040	66,800	49
North Branch Milwaukee River	7,720	3,198,000	2,438.55	177,620	317,620	237
Silver Creek (Sheboygan County)	2,180	824,000	895.02	48,230	89,990	79
Silver Creek (West Bend)	2,010	996,000	932.76	17,270	59,770	81
Stony Creek	1,400	534,000	460.50	41,210	61,730	48
Upper Lower Milwaukee River	8,600	4,322,000	2,954.41	141,400	303,230	277
Upper Milwaukee River	10,230	5,294,000	1,629.27	200,930	417,620	179
Watercress Creek	2,660	1,522,000	925.66	41,630	96,970	73
West Branch Milwaukee River	10,310	5,278,000	1,521.16	224,550	415,580	176
Total	126,350	57,468,000	38,465.06	1,961,180	4,514,090	3,657

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

channel pollutant loads may be expected to be different from the actual transport from the watershed, because physical, chemical, and biological processes may retain or remove pollutants or change their form during transport over the land surface or within the stream system. These processes include particle deposition or entrapment on the land surface or in floodplains, stream channel deposition or aggradation, biological uptake, and chemical transformation and precipitation. The total pollutant loads set forth in Table 119 are representative of potential pollutants moved from the Milwaukee River watershed into stream channels, but are not intended to reflect the total amount of pollutants moving from those sources through the entire hydrologic-hydraulic system.

Point Source Loadings

Annual average total point source pollutant loads of six pollutants in the Milwaukee River watershed are set forth in Tables 120 through 125. Contributions of most of these pollutants by point sources represent a minor portion of the combined total average loads from point and nonpoint sources, generally about 15 percent or less, except for the phosphorus load, which is split about evenly between point and nonpoint sources.

Average annual point source loads of total phosphorus in the Milwaukee River watershed are shown in Table 120. The total average annual point source load of total phosphorus is about 148,150 pounds. Most of this is contributed by the Lower Milwaukee River subwatershed. Industrial dischargers and sewage treatment plants account for almost all of the contributions of total phosphorus from point sources, with relatively small contributions from combined sewer overflows and separate sanitary sewer overflows.

Table 120

AVERAGE ANNUAL LOADS OF TOTAL PHOSPHORUS IN THE MILWAUKEE RIVER WATERSHED[a]

Subwatershed	Point Sources					Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Batavia Creek	0	0	0	0	0	120	480	600	600
Cedar Creek	<10	0	0	7,400	7,400	3,310	15,390	18,700	26,100
Cedar Lake	0	0	0	0	0	390	2,250	2,640	2,640
Chambers Creek	0	0	0	0	0	150	500	650	650
East Branch Milwaukee River	0	0	0	0	0	460	2,140	2,600	2,600
Kettle Moraine Lake	0	0	0	0	0	270	3,180	3,450	3,450
Kewaskum Creek	0	0	0	0	0	370	1,870	2,240	2,240
Lake Fifteen Creek	0	0	0	0	0	220	1,200	1,420	1,420
Lincoln Creek	4,260	200	80	0	4,540	7,870	70	7,940	12,480
Lower Cedar Creek	10	10	0	5,730	5,750	3,200	5,210	8,410	14,160
Lower Milwaukee River	73,470	540	1,710	0	75,720	14,780	6,740	21,520	97,240
Middle Milwaukee River	10	0	0	14,740	14,750	3,480	6,150	9,630	24,380
Mink Creek	0	0	0	0	0	320	1,120	1,440	1,440
North Branch Milwaukee River	15,870	<10	0	6,580	22,450	1,480	6,240	7,720	30,170
Silver Creek (Sheboygan County)	0	0	0	900	900	830	1,350	2,180	3,080
Silver Creek (West Bend)	0	0	0	0	0	1,280	730	2,010	2,010
Stony Creek	0	0	0	0	0	310	1,090	1,400	1,400
Upper Lower Milwaukee River	140	30	0	12,850	13,020	3,480	5,120	8,600	21,620
Upper Milwaukee River	80	0	0	3,540	3,620	1,400	8,830	10,230	13,850
Watercress Creek	0	0	0	0	0	300	2,360	2,660	2,660
West Branch Milwaukee River	0	0	0	0	0	1,270	9,040	10,310	10,310
Total	93,840	780	1,790	51,740	148,150	45,290	81,060	126,350	274,500
Percent of Total Load	34.2	0.3	0.7	18.8	54.0	16.5	29.5	46.0	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

Average annual point source loads of total suspended solids in the Milwaukee River watershed are shown in Table 121. The total average annual point source load of total suspended solids is about 915,650 pounds. Most of this is contributed by the Lower Milwaukee River and Upper Lower Milwaukee River subwatersheds. Industrial dischargers, sewage treatment plants, and combined sewer overflows represent the major sources of TSS, contributing about 50 percent, 32 percent, and 16 percent, respectively, of the total load from point sources. Separate sanitary sewer overflows contribute a relatively small amount.

Average annual point source loads of fecal coliform bacteria in the Milwaukee River watershed are shown in Table 122. The total average annual point source load of fecal coliform bacteria is about 2,361.60 trillion cells per year. Most of this is contributed by the Lower Milwaukee River subwatershed. Combined sewer overflows and separate sanitary sewer overflows account for 80 percent and 18 percent, respectively, of the total load from point sources, with a relatively small contribution from sewage treatment plants.

Average annual point source loads of total nitrogen in the Milwaukee River watershed are shown in Table 123. The total average annual point source load of total nitrogen is about 219,930 pounds. Most of this is contributed by the Lower Milwaukee River and Upper Lower Milwaukee River subwatersheds. Sewage treatment plants and industrial dischargers account for 56 percent and 34 percent, respectively, of the total load from point sources, with smaller contributions from combined sewer overflows and separate sanitary sewer overflows.

Table 121

AVERAGE ANNUAL LOADS OF TOTAL SUSPENDED SOLIDS IN THE MILWAUKEE RIVER WATERSHED[a]

Subwatershed	Point Sources					Nonpoint Sources			
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	Total (pounds)
Batavia Creek	0	0	0	0	0	40,000	186,000	226,000	226,000
Cedar Creek	0	0	0	24,000	24,000	1,504,000	6,782,000	8,286,000	8,310,000
Cedar Lake	0	0	0	0	0	186,000	1,070,000	1,256,000	1,256,000
Chambers Creek	0	0	0	0	0	52,000	200,000	252,000	252,000
East Branch Milwaukee River	0	0	0	0	0	150,000	860,000	1,010,000	1,010,000
Kettle Moraine Lake	0	0	0	0	0	126,000	1,916,000	2,042,000	2,042,000
Kewaskum Creek	0	0	0	0	0	162,000	878,000	1,040,000	1,040,000
Lake Fifteen Creek	0	0	0	0	0	94,000	686,000	780,000	780,000
Lincoln Creek	28,000	6,000	4,000	0	38,000	2,778,000	48,000	2,826,000	2,864,000
Lower Cedar Creek	0	0	0	46,000	46,000	1,256,000	3,094,000	4,350,000	4,396,000
Lower Milwaukee River	370,000	16,000	139,650	0	525,650	5,236,000	3,032,000	8,268,000	8,793,650
Middle Milwaukee River	0	0	0	44,000	44,000	1,510,000	3,088,000	4,598,000	4,642,000
Mink Creek	0	0	0	0	0	106,000	460,000	566,000	566,000
North Branch Milwaukee River	54,000	0	0	8,000	62,000	532,000	2,666,000	3,198,000	3,260,000
Silver Creek (Sheboygan County)	0	0	0	16,000	16,000	292,000	532,000	824,000	840,000
Silver Creek (West Bend)	0	0	0	0	0	526,000	470,000	996,000	996,000
Stony Creek	0	0	0	0	0	100,000	434,000	534,000	534,000
Upper Lower Milwaukee River	0	2,000	0	130,000	132,000	1,748,000	2,574,000	4,322,000	4,454,000
Upper Milwaukee River	2,000	0	0	26,000	28,000	580,000	4,714,000	5,294,000	5,322,000
Watercress Creek	0	0	0	0	0	134,000	1,388,000	1,522,000	1,522,000
West Branch Milwaukee River	0	0	0	0	0	596,000	4,682,000	5,278,000	5,278,000
Total	454,000	24,000	143,650	294,000	915,650	17,708,000	39,760,000	57,468,000	58,383,650
Percent of Total Load	0.8	<0.1	0.3	0.5	1.6	30.3	68.1	98.4	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

Average annual point source loads of BOD in the Milwaukee River watershed are shown in Table 124. The total average annual point source load of BOD is about 719,070 pounds. Most of this is contributed by the Lower Milwaukee River and Middle Milwaukee River subwatersheds. Sewage treatment plants and industrial dischargers contribute 56 percent and 40 percent, respectively, of the total load from point sources.

Average annual point source loads of copper in the Milwaukee River watershed are shown in Table 125. The total average annual point source load of copper is about 689 pounds per year. Most of this is contributed by the Middle Milwaukee River subwatershed. Sewage treatment plants represent 92 percent of the total load from point sources.

Nonpoint Source Loads

Because nonpoint source pollution is delivered to streams in the watershed through many diffuse sources, including direct overland flow, numerous storm sewer and culvert outfalls, and swales and engineered channels, it would be prohibitively expensive and time-consuming to directly measure nonpoint source pollution loads to streams. Thus, the calibrated water quality model was applied to estimate average annual nonpoint source pollutant loads delivered to the streams in the watershed. The results of that analysis are set forth in Tables 119 through 125 and depicted graphically on Maps H-25 through H-36 in Appendix H. General water quality modeling procedures are described in Chapter V of SEWRPC Planning Report No. 50, *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds.*

Table 119 shows the average annual total nonpoint source pollutant loads for subwatersheds of the Milwaukee River watershed. Average annual per acre nonpoint source pollution loads for subwatersheds of the Milwaukee River watershed are shown in Table 126.

Table 122

AVERAGE ANNUAL LOADS OF FECAL COLIFORM BACTERIA IN THE MILWAUKEE RIVER WATERSHED[a]

	Point Sources					Nonpoint Sources			
Subwatershed	Industrial Point Sources (trillions of cells)	SSOs (trillions of cells)	CSOs (trillions of cells)	Sewage Treatment Plants (trillions of cells)	Subtotal (trillions of cells)	Urban (trillions of cells)	Rural (trillions of cells)	Subtotal (trillions of cells)	Total (trillions of cells)
Batavia Creek	0.00	0.00	0.00	0.00	0.00	73.50	87.60	161.10	161.10
Cedar Creek	0.01	0.00	0.00	0.20	0.21	1,664.36	1,878.04	3,542.40	3,542.61
Cedar Lake	0.00	0.00	0.00	0.00	0.00	212.84	1,362.21	1,575.05	1,575.05
Chambers Creek	0.00	0.00	0.00	0.00	0.00	82.08	105.88	187.96	187.96
East Branch Milwaukee River	0.00	0.00	0.00	0.00	0.00	270.07	521.74	791.81	791.81
Kettle Moraine Lake	0.00	0.00	0.00	0.00	0.00	157.94	540.89	698.83	698.83
Kewaskum Creek	0.00	0.00	0.00	0.00	0.00	198.48	180.39	378.87	378.87
Lake Fifteen Creek	0.00	0.00	0.00	0.00	0.00	114.69	340.61	455.30	455.30
Lincoln Creek	0.79	111.29	57.96	0.00	170.04	4,178.24	0.28	4,178.52	4,348.56
Lower Cedar Creek	0.00	2.78	0.00	1.67	4.45	1,637.71	851.03	2,488.74	2,493.19
Lower Milwaukee River	9.84	296.62	1,820.95	0.00	2,127.41	7,522.97	973.60	8,496.57	10,623.98
Middle Milwaukee River	0.02	0.00	0.00	27.70	27.72	1,909.21	1,396.42	3,305.63	3,333.35
Mink Creek	0.00	0.00	0.00	0.00	0.00	183.01	263.94	446.95	446.95
North Branch Milwaukee River	0.67	1.77	0.00	8.19	10.63	814.80	1,623.75	2,438.55	2,449.18
Silver Creek (Sheboygan County)	0.05	0.00	0.00	0.82	0.87	599.28	295.74	895.02	895.89
Silver Creek (West Bend)	0.00	0.00	0.00	0.00	0.00	722.20	210.56	932.76	932.76
Stony Creek	0.00	0.00	0.00	0.00	0.00	188.85	271.65	460.50	460.50
Upper Lower Milwaukee River	0.62	16.58	0.00	1.75	18.95	1,849.48	1,104.93	2,954.41	2,973.36
Upper Milwaukee River	0.11	0.00	0.00	1.21	1.32	820.18	809.09	1,629.27	1,630.59
Watercress Creek	0.00	0.00	0.00	0.00	0.00	201.89	723.77	925.66	925.66
West Branch Milwaukee River	0.00	0.00	0.00	0.00	0.00	697.12	824.04	1,521.16	1,521.16
Total	12.11	429.04	1,878.91	41.54	2,361.60	24,098.90	14,366.16	38,465.06	40,826.66
Percent of Total Load	<0.1	1.1	4.6	0.1	5.8	59.0	35.2	94.2	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

The average annual nonpoint load of total phosphorus is estimated to be 126,350 pounds per year. About 16 percent of the total point and nonpoint source load is from urban nonpoint sources and about 30 percent is from rural nonpoint sources (see Table 120). The distribution of total load among the subwatersheds is shown on Map H-25 in Appendix H. Map H-26 shows the annual per acre loads of total phosphorus from the subwatersheds. Contributions of total phosphorus vary among the subwatersheds (see Table 120) from about 600 pounds per year from the Batavia Creek subwatershed to about 21,520 pounds per year from the Lower Milwaukee River subwatershed. The highest loads of total phosphorus are contributed by the Lower Milwaukee River and Cedar Creek subwatersheds. This reflects both the relatively high unit area load (pounds per acre) contributed by the Lower Milwaukee River subwatershed (see Table 121) and the large area of these subwatersheds. The highest unit area loads occur in the Lincoln Creek and Lower Milwaukee River subwatersheds.

The average annual nonpoint load of total suspended solids is estimated to be 57,468,000 pounds per year. About 30 percent of the total point and nonpoint source load is from urban nonpoint sources and about 68 percent is from rural nonpoint sources (see Table 121). The distribution of this load among the subwatersheds is shown in Map H-27 in Appendix H. Map H-28 shows the annual per acre loads of total suspended solids for the subwatersheds. Contributions of total suspended solids vary among the subwatersheds (see Table 121) from about 226,000 pounds per year from the Batavia Creek subwatershed to about 8,286,000 pounds per year from the Cedar Creek subwatershed. The highest loads of total suspended solids are contributed by the Lower Milwaukee River and the Cedar Creek subwatersheds. For both of these subwatersheds, this reflects the relatively large subwatershed areas and the relatively high unit area loads. The highest unit area loads occur in the Lincoln Creek, Cedar Lake, and Lower Milwaukee River subwatersheds.

Table 123

AVERAGE ANNUAL LOADS OF TOTAL NITROGEN IN THE MILWAUKEE RIVER WATERSHED[a]

Subwatershed	Point Sources					Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Batavia Creek	0	0	0	0	0	560	18,950	19,510	19,510
Cedar Creek	40	0	0	4,580	4,620	13,420	286,240	299,660	304,280
Cedar Lake	0	0	0	0	0	1,610	24,990	26,600	26,600
Chambers Creek	0	0	0	0	0	650	18,970	19,620	19,620
East Branch Milwaukee River	0	0	0	0	0	2,080	41,270	43,350	43,350
Kettle Moraine Lake	0	0	0	0	0	1,220	58,780	60,000	60,000
Kewaskum Creek	0	0	0	0	0	1,780	42,100	43,880	43,880
Lake Fifteen Creek	0	0	0	0	0	920	20,270	21,190	21,190
Lincoln Creek	3,530	850	960	0	5,340	42,420	500	42,920	48,260
Lower Cedar Creek	<10	20	0	950	970	16,910	95,100	112,010	112,980
Lower Milwaukee River	64,010	2,270	16,950	0	83,230	79,020	109,560	188,580	271,810
Middle Milwaukee River	10	0	0	27,930	27,940	16,190	123,790	139,980	167,920
Mink Creek	0	0	0	0	0	1,420	49,620	51,040	51,040
North Branch Milwaukee River	7,560	10	0	9,530	17,100	6,410	171,210	177,620	194,720
Silver Creek (Sheboygan County)	0	0	0	350	350	3,680	44,550	48,230	48,580
Silver Creek (West Bend)	0	0	0	0	0	6,410	10,860	17,270	17,270
Stony Creek	0	0	0	0	0	1,440	39,770	41,210	41,210
Upper Lower Milwaukee River	350	130	0	77,920	78,400	17,730	123,670	141,400	219,800
Upper Milwaukee River	30	0	0	1,950	1,980	6,740	194,190	200,930	202,910
Watercress Creek	0	0	0	0	0	1,480	40,150	41,630	41,630
West Branch Milwaukee River	0	0	0	0	0	5,390	219,160	224,550	224,550
Total	75,530	3,280	17,910	123,210	219,930	227,480	1,733,700	1,961,180	2,181,110
Percent of Total Load	3.5	0.2	0.8	5.6	10.1	10.4	79.5	89.9	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

The average annual nonpoint source load of fecal coliform bacteria is estimated to be 38,465.06 trillion cells per year. About 59 percent of the total point and nonpoint source load is from urban nonpoint sources and about 35 percent is from rural nonpoint sources (see Table 122). The distribution of this load among the subwatersheds is shown in Map H-29 in Appendix H. Map H-30 shows the annual per acre loads of fecal coliform bacteria for the subwatersheds. Contributions of fecal coliform bacteria vary among the subwatersheds (see Table 122) from about 161.10 trillion cells per year from the Batavia Creek subwatershed to about 8,496.57 trillion cells per year from the Lower Milwaukee River subwatershed. The highest loads of fecal coliform bacteria are contributed by the Lower Milwaukee River and Lincoln Creek subwatersheds. This reflects the high unit area loads contributed by these subwatersheds and the relatively large area of the Lower Milwaukee River subwatershed.

The average annual nonpoint load of total nitrogen is estimated to be 1,961,180 pounds per year. About 10 percent of the total point and nonpoint source load is from urban nonpoint sources and about 80 percent is from rural nonpoint sources (see Table 123) The distribution of this load among the subwatersheds is shown in Map H-31 in Appendix H. Map H-32 shows the annual per acre loads of total nitrogen for the subwatersheds. Contributions of total nitrogen vary among the subwatersheds (see Table 123) from about 17,270 pounds per year from the Silver Creek (West Bend) subwatershed to about 299,660 pounds per year from the Cedar Creek subwatershed. The highest loads of total nitrogen are contributed by the Cedar Creek and the West Branch Milwaukee River subwatersheds. This is due to both the relatively large area of these subwatersheds and to those subwatersheds having the highest unit area loads. The highest unit area loads occur in the Cedar Creek and West Branch Milwaukee River subwatersheds.

Table 124

AVERAGE ANNUAL LOADS OF BIOCHEMICAL OXYGEN DEMAND IN THE MILWAUKEE RIVER WATERSHED[a]

Subwatershed	Point Sources					Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Batavia Creek	0	0	0	0	0	4,000	24,470	28,470	28,470
Cedar Creek	60	0	0	10,370	10,430	105,650	632,050	737,700	748,130
Cedar Lake	0	0	0	0	0	12,700	68,630	81,330	81,330
Chambers Creek	0	0	0	0	0	5,140	23,440	28,580	28,580
East Branch Milwaukee River	0	0	0	0	0	15,060	82,180	97,240	97,240
Kettle Moraine Lake	0	0	0	0	0	8,880	120,250	129,130	129,130
Kewaskum Creek	0	0	0	0	0	11,340	81,960	93,300	93,300
Lake Fifteen Creek	0	0	0	0	0	7,770	41,080	48,850	48,850
Lincoln Creek	15,210	1,440	720	0	17,370	216,100	1,840	217,940	235,310
Lower Cedar Creek	20	40	0	20,080	20,140	85,590	185,110	270,700	290,840
Lower Milwaukee River	259,990	3,830	22,550	0	286,370	388,570	234,560	623,130	909,500
Middle Milwaukee River	20	0	0	296,770	296,790	108,290	220,120	328,410	625,200
Mink Creek	0	0	0	0	0	10,490	56,310	66,800	66,800
North Branch Milwaukee River	7,020	20	0	6,080	13,120	50,380	267,240	317,620	330,740
Silver Creek (Sheboygan County)	4,330	0	0	2,990	7,320	26,810	63,180	89,990	97,310
Silver Creek (West Bend)	0	0	0	0	0	36,060	23,710	59,770	59,770
Stony Creek	0	0	0	0	0	10,240	51,490	61,730	61,730
Upper Lower Milwaukee River	2,770	210	0	52,690	55,670	103,450	199,780	303,230	358,900
Upper Milwaukee River	1,030	0	0	10,830	11,860	44,460	373,160	417,620	429,480
Watercress Creek	0	0	0	0	0	10,130	86,840	96,970	96,970
West Branch Milwaukee River	0	0	0	0	0	42,450	373,130	415,580	415,580
Total	290,450	5,540	23,270	399,810	719,070	1,303,560	3,210,530	4,514,090	5,233,160
Percent of Total Load	5.6	0.1	0.4	7.6	13.7	24.9	61.4	86.3	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

The average annual nonpoint load of BOD is estimated to be 4,514,090 pounds per year. About 25 percent of the total point and nonpoint source load is from urban nonpoint sources and about 61 percent is from rural nonpoint sources (see Table 124). The distribution of this load among the subwatersheds is shown in Map H-33 in Appendix H. Map H-34 shows the annual per acre loads of BOD for the subwatersheds. Contributions of BOD vary among the subwatersheds (see Table 124) from a low of about 28,470 pounds per year from the Batavia Creek subwatershed to about 737,700 pounds per year from the Cedar Creek subwatershed. The highest loads of BOD are contributed by the Cedar Creek and the Lower Milwaukee River subwatersheds. This is due to both the relatively large area of these subwatersheds and to those subwatersheds having high unit area loads. The highest unit area loads occur in the Lincoln Creek and Cedar Creek subwatersheds.

The average annual nonpoint load of copper is estimated to be 3,657 pounds per year. About 53 percent of the total point and nonpoint source load is from urban nonpoint sources and about 31 percent is from rural nonpoint sources (see Table 125). The distribution of this load among the subwatersheds is shown in Map H-35 in Appendix H. Map H-36 shows the annual per acre loads of copper for the subwatersheds. Contributions of copper vary among the subwatersheds (see Table 125) from 18 pounds per year from the Batavia Creek subwatershed to 785 pounds per year from the Lower Milwaukee River subwatershed. The highest loads of copper are contributed by the Lower Milwaukee River, Lincoln Creek, and Cedar Creek subwatersheds. In the cases of the Lincoln Creek and Lower Milwaukee River subwatersheds, this reflects relatively large unit area loads, and in the cases of the Lower Milwaukee River and Cedar Creek subwatersheds this reflects relatively large subwatershed areas. The highest unit area loads occur in the Lincoln Creek, Lower Milwaukee River, and Cedar Lake subwatersheds. The overall average urban unit area load of copper is 0.016 pound per acre per year and the average rural unit area load is 0.006 pound per acre per year.

Table 125

AVERAGE ANNUAL LOADS OF COPPER IN THE MILWAUKEE RIVER WATERSHED[a]

	Point Sources					Nonpoint Sources			
Subwatershed	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	Total (pounds)
Batavia Creek	0	0	0	0	0	7	11	18	18
Cedar Creek	0	0	0	46	46	190	187	377	423
Cedar Lake	0	0	0	0	0	23	76	99	99
Chambers Creek	0	0	0	0	0	9	13	22	22
East Branch Milwaukee River	0	0	0	0	0	27	61	88	88
Kettle Moraine Lake	0	0	0	0	0	16	47	63	63
Kewaskum Creek	0	0	0	0	0	20	21	41	41
Lake Fifteen Creek	0	0	0	0	0	14	30	44	44
Lincoln Creek	0	1	2	0	3	380	1	381	384
Lower Cedar Creek	0	0	0	97	97	146	83	229	326
Lower Milwaukee River	0	2	50	0	52	684	101	785	837
Middle Milwaukee River	0	0	0	307	307	192	119	311	618
Mink Creek	0	0	0	0	0	19	30	49	49
North Branch Milwaukee River	0	0	0	18	18	93	144	237	255
Silver Creek (Sheboygan County)	0	0	0	15	15	49	30	79	94
Silver Creek (West Bend)	0	0	0	0	0	62	19	81	81
Stony Creek	0	0	0	0	0	18	30	48	48
Upper Lower Milwaukee River	0	0	0	113	113	181	96	277	390
Upper Milwaukee River	0	0	0	38	38	80	99	179	217
Watercress Creek	0	0	0	0	0	18	55	73	73
West Branch Milwaukee River	0	0	0	0	0	77	99	176	176
Total	0	3	52	634	689	2,305	1,352	3,657	4,346
Percent of Total Load	0	0.1	1.2	14.6	15.9	53.0	31.1	84.1	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Wet-Weather and Dry-Weather Loads

It is important to distinguish between instream water quality during dry weather conditions and during wet weather conditions. Differences between wet-weather and dry-weather instream water quality reflect differences between the dominant sources and loadings of pollutants associated with each condition. Dry-weather instream water quality reflects the quality of ground water discharge to the stream plus the continuous or intermittent discharge of various point sources, for example industrial cooling or process waters, and leakage or other unplanned dry-weather discharges from sanitary sewers or private process water systems. While instream water quality during wet weather conditions includes the above discharges, and in extreme instances discharges from separate and/or combined sanitary sewer overflows, the dominant influence, particularly during major rainfall or snowmelt runoff events, is likely to be the soluble or insoluble substances carried into streams by direct land surface runoff. That direct runoff moves from the land surface to the surface waters by overland routes, such as drainage swales, street and highway ditches, and gutters, or by underground storm sewer systems.

Daily average loads of six pollutants—total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, biochemical oxygen demand, and copper, were estimated for both wet-weather and dry-weather conditions for two sites along the Milwaukee River—the Port Washington Road station (River Mile 6.91) and the Pioneer Road station near Cedarburg (River Mile 26.25)—based upon flow and water quality data. To facilitate comparison of the estimates for these two stations, flow duration curves were developed for the same period: 1981-2004. In addition, daily average loads of total phosphorus were estimated for wet weather and dry weather conditions for one tributary, the East Branch of the Milwaukee River at New Fane (River Mile 5.71). A water quality sample was assumed to represent wet-weather conditions when daily mean flow was in the upper 20th percentile of the flow duration curve for the relevant flow gauge. This includes flows that are high due to rainfall events, runoff from snowmelt, or a combination of rainfall and snowmelt. The flow duration curves for

Table 126

AVERAGE ANNUAL PER ACRE NONPOINT SOURCE POLLUTANT LOADS IN THE MILWAUKEE RIVER WATERSHED[a]

Subwatershed	Total Phosphorus (pounds per acre)	Total Suspended Solids (pounds per acre)	Fecal Coliform Bacteria (trillions of cells per acre)	Total Nitrogen (pounds per acre)	Biochemical Oxygen Demand (pounds per acre)	Copper (pounds per acre)
Batavia Creek	0.12	45	0.03	3.92	5.72	0.004
Cedar Creek	0.39	174	0.07	6.29	15.48	0.008
Cedar Lake	0.41	197	0.25	4.17	12.74	0.016
Chambers Creek	0.11	45	0.03	3.47	5.05	0.004
East Branch Milwaukee River	0.12	45	0.04	1.95	4.38	0.004
Kettle Moraine Lake	0.30	178	0.06	5.22	11.24	0.005
Kewaskum Creek	0.30	139	0.05	5.85	12.43	0.005
Lake Fifteen Creek	0.18	99	0.06	2.69	6.21	0.006
Lincoln Creek	0.62	220	0.33	3.34	16.95	0.030
Lower Cedar Creek	0.31	162	0.09	4.16	10.06	0.009
Lower Milwaukee River	0.49	189	0.19	4.32	14.28	0.018
Middle Milwaukee River	0.29	140	0.10	4.25	9.97	0.009
Mink Creek	0.11	43	0.03	3.92	5.13	0.004
North Branch Milwaukee River	0.16	68	0.05	3.79	6.78	0.005
Silver Creek (Sheboygan County)	0.17	65	0.07	3.82	7.13	0.006
Silver Creek (West Bend)	0.33	165	0.15	2.86	9.89	0.013
Stony Creek	0.11	43	0.04	3.29	4.92	0.004
Upper Lower Milwaukee River	0.27	134	0.09	4.38	9.39	0.009
Upper Milwaukee River	0.28	147	0.05	5.60	11.63	0.005
Watercress Creek	0.25	141	0.09	3.85	8.98	0.007
West Branch Milwaukee River	0.28	143	0.04	6.10	11.28	0.005

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

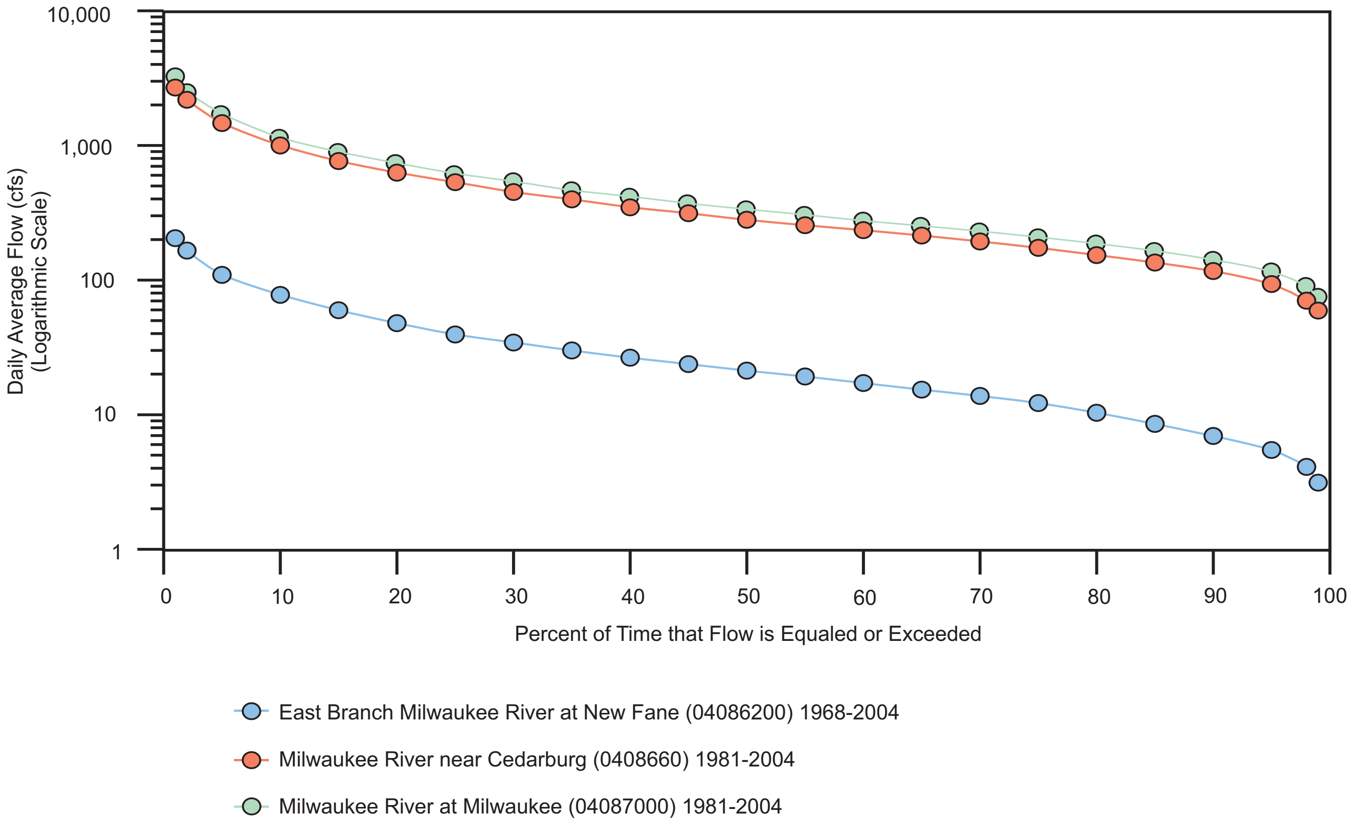
Source: Tetra Tech, Inc.

the Milwaukee River at Estabrook Park (River Mile 6.65), the gauge nearest Port Washington Road, the Milwaukee River near Cedarburg, and the East Branch of the Milwaukee River at New Fane are shown in Figure 184. For the Port Washington Road station along the Milwaukee River, water quality samples were considered to reflect wet-weather conditions when daily mean flow at Estabrook Park for the corresponding date equaled or exceeded 730 cubic feet per second (cfs). For the Pioneer Road station along the Milwaukee River, water quality samples were considered to reflect wet-weather conditions when daily mean flow at the gauge near Cedarburg equaled or exceeded 628 cfs. For the New Fane station along the East Branch of the Milwaukee River, water quality samples were considered to reflect wet-weather conditions when daily mean flow at the gauge at New Fane equaled or exceeded 48 cfs. On dates when daily mean flow was less than these thresholds, the corresponding water quality samples were considered to reflect dry-weather conditions. Daily average pollutant loads were estimated by appropriately combining daily average flow and pollutant ambient concentration.

Figure 185 shows the daily average pollutant loads for total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, and biochemical oxygen demand from the Milwaukee River at the Port Washington Road sampling station. In all cases, the estimated loads occurring during wet-weather periods were considerably higher than the estimated loads occurring during dry-weather periods. For the 1998 through 2004 baseline period, the mean estimated daily average wet-weather load of total phosphorus was about 1,863 pounds, which is slightly over eight times the mean estimated daily average dry-weather load of about 230 pounds. For the baseline period, the mean estimated daily average wet-weather load of total suspended solids was about 761,300 pounds, about 22 times the mean estimated daily average dry-weather load of about 35,130 pounds. For the baseline period, the mean estimated daily average wet-weather load of fecal coliform bacteria was about 135 trillion cells, about 1.5 times the mean estimated daily average dry-weather load of 83 trillion cells. For the baseline period, the mean

Figure 184

FLOW DURATION CURVES FOR USGS STREAM GAUGES IN THE MILWAUKEE RIVER WATERSHED



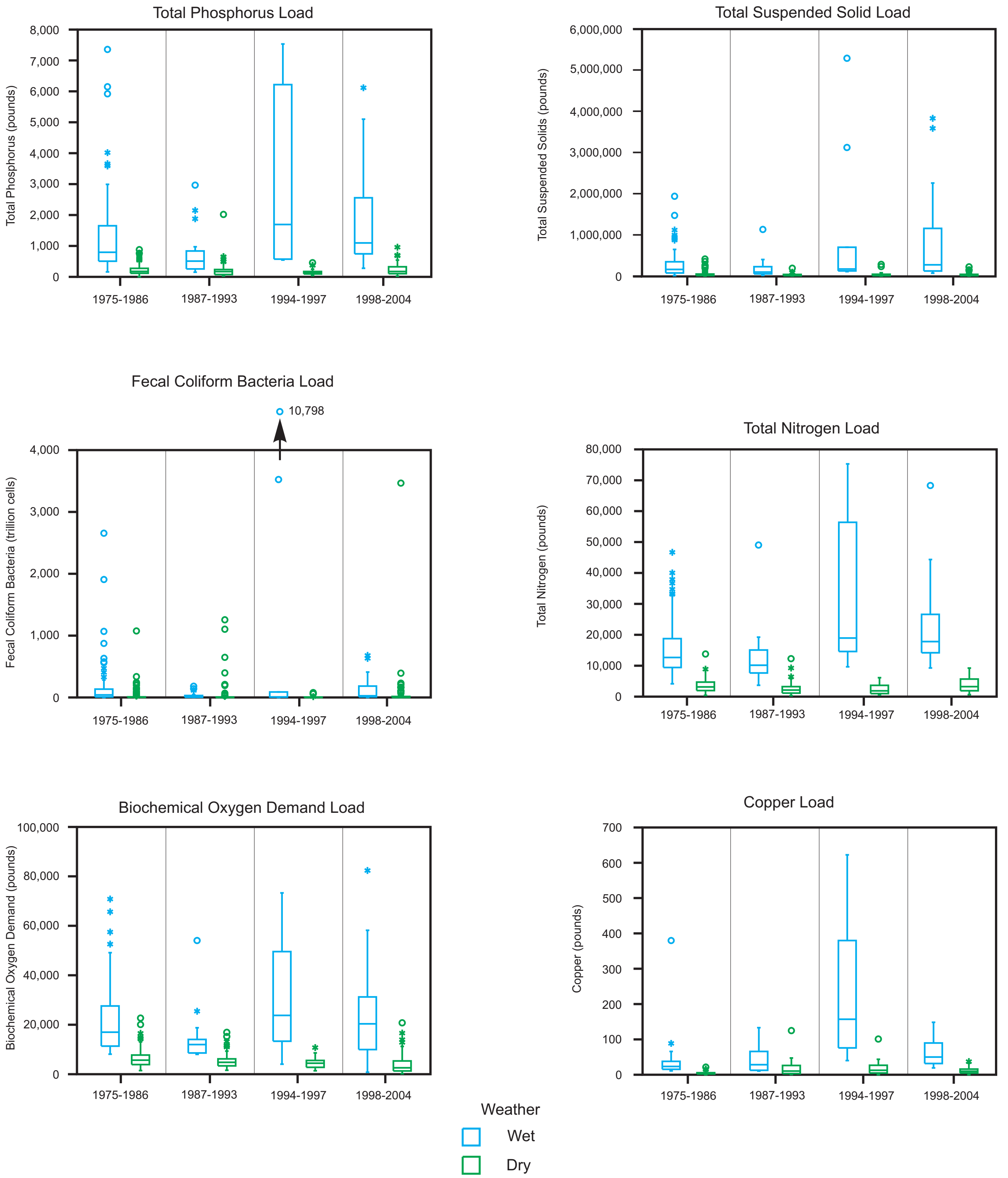
Source: U.S. Geological Survey and SEWRPC.

estimated daily average wet-weather load of total nitrogen was 23,400 pounds, nearly six times the mean estimated daily average dry-weather load of 3,983 pounds. For the baseline period, the mean estimated daily average wet-weather load of BOD was about 23,600 pounds, over five times the mean estimated daily average dry-weather load of about 4,170 pounds. For the baseline period, the mean estimated daily wet-weather load of copper was about 64.2 pounds, almost five times the mean estimated daily dry-weather load of about 13.2 pounds.

Figure 186 shows the daily average pollutant loads for total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, and biochemical oxygen demand from the Milwaukee River at the Pioneer Road sampling station. In all cases, the estimated loads occurring during wet-weather periods were considerably higher than the estimated loads occurring during dry-weather periods. For the 1998 through 2004 baseline period, the mean estimated daily average wet-weather load of total phosphorus was about 1,640 pounds, which is almost eight times the mean estimated daily average dry-weather load of about 208 pounds. For the baseline period, the mean estimated daily average wet-weather load of total suspended solids was about 415,400 pounds, about 21 times the mean estimated daily average dry-weather load of about 20,240 pounds. For the baseline period, the mean estimated daily average wet-weather load of fecal coliform bacteria was about 128 trillion cells, about 14 times the mean estimated daily average dry-weather load of 9.1 trillion cells. For the baseline period, the mean estimated daily average wet-weather load of total nitrogen was 22,300 pounds, over five times the mean estimated daily average dry-weather load of 4,090 pounds. For the baseline period, the mean estimated daily average wet-weather load of BOD was about 20,000 pounds, over eight times the mean estimated daily average dry-weather load of 2,420 pounds. For the baseline period, the mean estimated daily wet-weather load of copper was about 74.5 pounds, almost seven times the mean estimated daily dry-weather load of about 11.1 pounds.

Figure 185

DAILY AVERAGE POLLUTION LOADS IN THE MILWAUKEE RIVER AT PORT WASHINGTON ROAD (RIVER MILE 6.91): 1975-2004

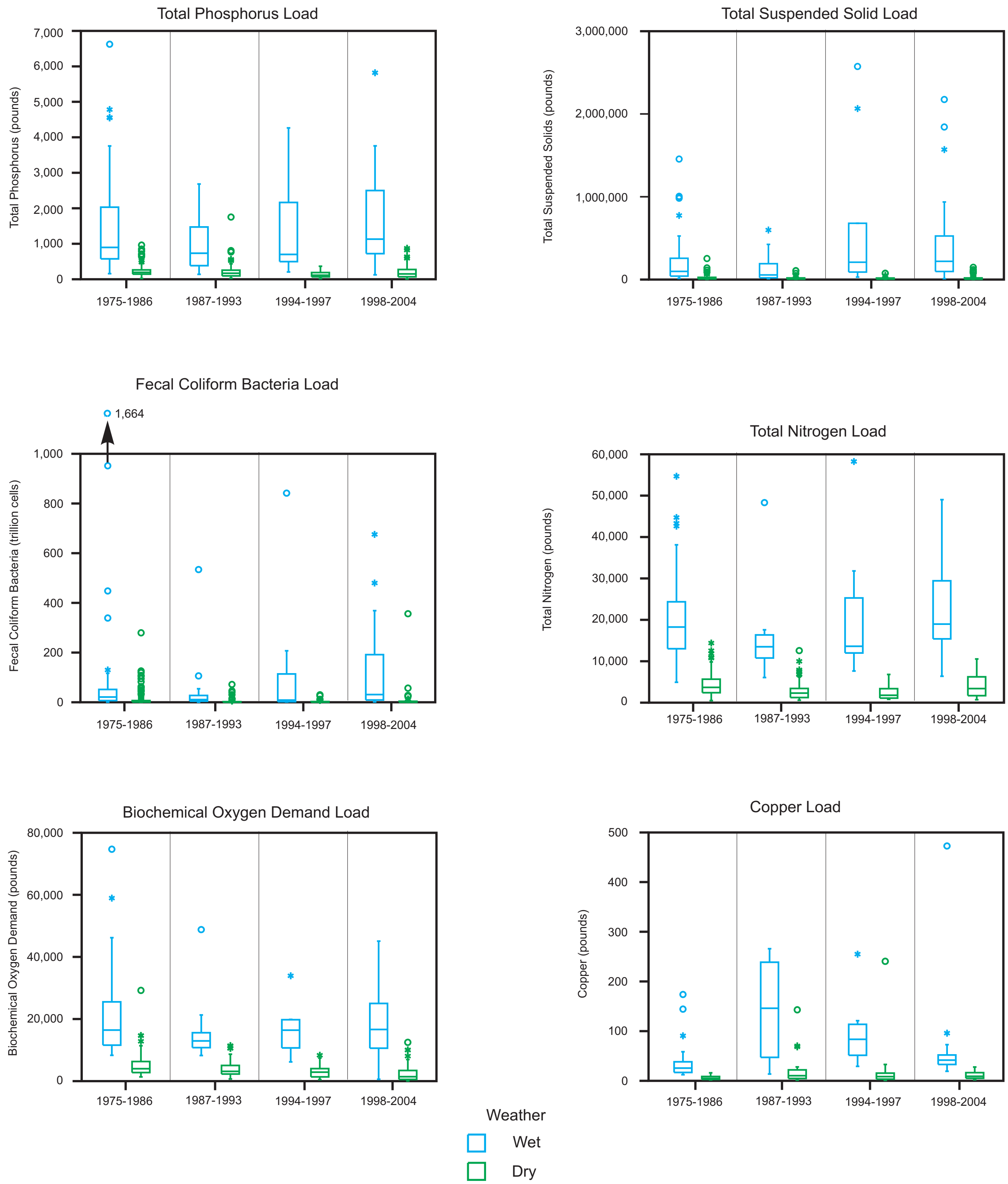


NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 186

DAILY AVERAGE POLLUTION LOADS IN THE MILWAUKEE RIVER AT PIONEER ROAD (RIVER MILE 26.25): 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

For most of the pollutants examined, the estimated mean dry-weather loads at the Pioneer Road station represented about 85 to 96 percent of the estimated mean dry-weather loads at the Port Washington Road station. There were three exceptions to this. The estimated mean dry-weather loads of TSS and BOD at Pioneer Road represented about 58 percent of the estimated mean dry-weather loads of TSS and BOD at Port Washington Road. There was an even greater difference between the estimated mean dry-weather loads of fecal coliform bacteria from these two stations. The estimated mean dry-weather load of fecal coliform bacteria at Pioneer Road represented about 11 percent of the estimated mean dry-weather load of fecal coliform bacteria at Port Washington Road. The estimated mean wet-weather loads at the Pioneer Road station also represented about 85 to 96 percent of the estimated mean wet-weather loads at the Port Washington Road station. There were two exceptions to this. The estimated mean wet-weather load of TSS at Pioneer Road represented about 55 percent of the estimated mean wet-weather load of TSS at Port Washington Road, and the estimated mean wet-weather load of copper at Pioneer Road was about 16 percent higher than the estimated mean wet-weather load at Port Washington Road. This was due to the presence of a single exceptionally high outlier in the wet-weather data from the Pioneer Road station (see Figure 186). When this outlier was removed from the data set, the estimated mean wet-weather load of copper at Pioneer Road represented about 68 percent of the estimated mean wet-weather load at Port Washington Road.

Figures 185 and 186 also show the occurrence of individual wet-weather events during which the estimated daily average pollutant load was many times higher than typical wet-weather loads. The presence of these outliers indicates that individual wet-weather events can contribute a substantial fraction of the annual pollutant load to the River. For example, Figure 185 shows that the maximum estimated daily average wet-weather load of total suspended solids detected at the Port Washington Road station during the baseline period of 1998-2004 was about 3.8 million pounds. Comparing this to Table 121 shows that this single day's load represents about 7 percent of the estimated average annual load of total suspended solids in the entire watershed. Similarly, Figure 186 shows that the maximum daily estimated wet-weather load of copper detected at the Pioneer Road station along the mainstem during the baseline period of 1998-2004 was about 473 pounds. Comparing this to Table 125 shows that this single day's load represents about 11 percent of the estimated average annual load of copper in the entire watershed. While these two examples may represent extreme cases, they do indicate that a large fraction of the annual pollutant load to the watershed can be contributed by a small number of wet-weather events.

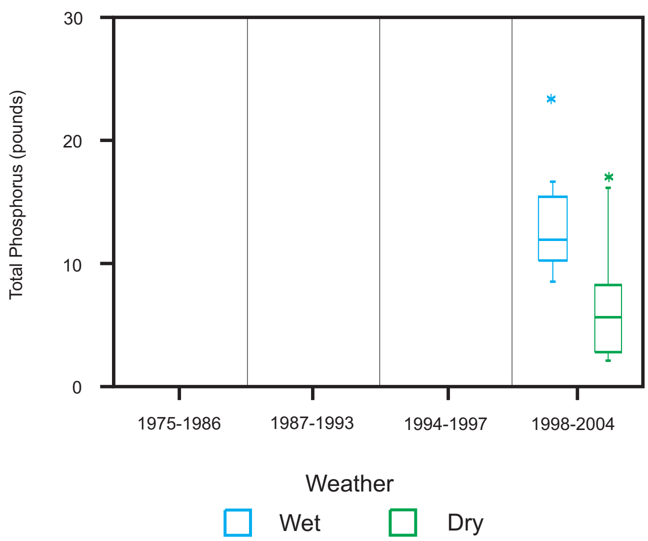
For most tributaries, there were not sufficient data to estimate average daily dry-weather and wet-weather loads of pollutants. Sufficient data were available to estimate loads of total phosphorus for the East Branch Milwaukee River at New Fane. Figure 187 shows the daily average pollutant loads for total phosphorus from the East Branch Milwaukee River at the New Fane sampling station. For the 1998 through 2004 baseline period, the mean estimated daily average wet-weather load of total phosphorus was about 13.1 pounds, which is about twice the mean estimated daily average dry-weather load of about 6.4 pounds.

ACHIEVEMENT OF WATER USE OBJECTIVES IN THE MILWAUKEE RIVER AND ITS TRIBUTARIES

The water use objectives and the supporting water quality standards and criteria for the Milwaukee River watershed are documented in Chapter IV of this report. Most of the stream reaches in the Milwaukee River watershed are recommended for fish and aquatic life and full recreational uses. A few are recommended for coldwater uses. Auburn Lake Creek upstream from Auburn Lake, Chambers Creek, Gooseville Creek, Melius Creek, Nichols Creek, and Watercress Creek are all considered coldwater streams and subject to standards under which dissolved oxygen concentrations are not to be less than 7.0 mg/l during spawning and 6.0 mg/l during the rest of the year. The other exceptions to the fish and aquatic life and full recreational use designations are subject to variances under Chapter NR 104 of the *Wisconsin Administrative Code*. Silver Creek (Sheboygan County) downstream from the Random Lake sewage treatment plant to the first crossing of Creek Road is recommended for limited forage fish and is subject to a variance under which dissolved oxygen concentrations are not to be less than 3.0 mg/l. Indian Creek, Lincoln Creek, and the mainstem of the Milwaukee River downstream from the site of the former North Avenue dam are subject to special variances under which dissolved oxygen concentrations are

Figure 187

DAILY AVERAGE TOTAL PHOSPHORUS LOADS IN THE EAST BRANCH OF THE MILWAUKEE RIVER AT NEW FANE ROAD (RIVER MILE 5.71): 1975-2004



NOTE: See Figure 109 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC.

not to be less than 2.0 mg/l and concentrations of fecal coliform bacteria are not to exceed 1,000 cells per 100 ml as a geometric mean based on not less than five samples per month.

Based upon the available data for sampling stations in the watershed, the mainstem of the Milwaukee River and its major tributaries did not fully meet the water quality standards associated with the recommended water use objectives during and prior to 1975, the base year of the initial regional water quality management plan. Review of subsequent data indicated that as of 1995, the recommended water use objectives were only being partially achieved in the majority of the streams in the watershed.[73]

During the 1998-2004 extended baseline period, the recommended water use objectives were only being partially achieved in much of the Milwaukee River watershed. Table 127 shows the results of comparisons of water quality data from the baseline period to supporting water quality standards. Review of data from 1998 to 2004 shows the following:

- Ammonia concentrations in all but one sample taken along the mainstem and all samples from 15 tributaries were under the acute toxicity criterion for fish and aquatic life for ammonia, indicating compliance with the standard.

- Dissolved oxygen concentrations from stations along the mainstem of the Milwaukee River at Port Washington Road and at the site of the former North Avenue dam were occasionally below the relevant standard. Dissolved oxygen concentrations at stations along the mainstem of the River above the dam at Kewaskum were sometimes below the relevant standard indicating more-frequent violations of the standard. Dissolved oxygen concentrations from all of the samples from 11 tributaries were above the relevant standard, indicating compliance with the standard. In three additional tributaries, Lincoln Creek, Quaas Creek, and Southbranch Creek, dissolved oxygen concentrations were occasionally below the relevant standard. Dissolved oxygen concentrations in two tributaries, the North Branch Milwaukee River and the West Branch Milwaukee River, were commonly below the relevant standard, indicating more-frequent violations of the standard.

- Water temperatures in all samples taken from the mainstem of the Milwaukee River and from 16 tributaries were at or below the relevant standard, indicating compliance with the standard. The water temperature in one of 127 samples taken from Cedar Creek was above the relevant standard, indicating an isolated incidence of violation of the standard.

[73]*SEWRPC Memorandum Report No. 93,* op. cit.

Table 127

CHARACTERISTICS OF STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1998-2004

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a]					Fish Biotic Index Rating[a,b]	Macroinvertebrate Biotic Index Rating (HBI)[a,b]	303(d) Impairments[e]
		Dissolved Oxygen	Temperature	NH_3[c]	Total Phosphorus[d]	Fecal Coliform Bacteria			
Mainstem									
Milwaukee River above Dam at Kewaskum	22.9	84.0 (144)	100.0 (191)	- -	63.8 (58)	60.0 (10)	Very poor to excellent (3)	Poor to good (12)	- -
Milwaukee River between Dam at Kewaskum and CTH M near Newburg	20.5	100.0 (117)	100.0 (121)	- -	74.5 (51)	72.7 (11)	Fair to excellent (4)	Fair to good (4)	- -
Milwaukee River between CTH M near Newburg and Waubeka	12.3	100.0 (95)	100.0 (110)	- -	78.6 (42)	100.0 (9)	Fair to excellent (5)	Poor to good (10)	- -
Milwaukee River between Waubeka and Pioneer Road near Cedarburg	19.2	100.0 (95)	100.0 (95)	98.9 (90)	38.4 (112)	41.1 (90)	Good to excellent (5)	Fair to good (3)	Bacteria, fish consumption advisory[f]
Milwaukee River between Pioneer Road near Cedarburg and Brown Deer Road	11.3	100.0 (87)	100.0 (88)	100.0 (70)	44.8 (87)	30.7 (88)	- -	- -	Bacteria, fish consumption advisory
Milwaukee River between Brown Deer Road and Silver Spring Drive	6.5	100.0 (81)	100.0 (81)	100.0 (64)	42.5 (80)	38.3 (81)	Excellent (4)	Fair to good (3)	Bacteria, fish consumption advisory
Milwaukee River between Silver Spring Drive and Port Washington Road	1.6	94.1 (85)	100.0 (85)	100.0 (69)	42.9 (84)	30.6 (85)	- -	- -	Bacteria, fish consumption advisory
Milwaukee River between Port Washington Road and Estabrook Park	0.3	100.0 (75)	100.0 (76)	100.0 (76)	42.4 (92)	54.5 (11)	- -	Poor to good (3)	Bacteria, fish consumption advisory
Milwaukee River between Estabrook Park and former North Avenue Dam	3.6	98.6 (71)	100.0 (71)	100.0 (62)	37.1 (70)	19.7 (71)	Good to excellent (5)	Fair to good (9)	Bacteria, fish consumption advisory
Milwaukee River between former North Avenue Dam and Walnut Street	0.9	100.0 (87)	100.0 (87)	100.0 (74)	39.5 (86)	65.1 (83)	Very poor (1)	- -	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory
Milwaukee River between Walnut Street and Wells Street	0.8	100.0 (84)	100.0 (84)	100.0 (75)	38.6 (83)	69.9 (83)	- -	- -	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory
Milwaukee River between Wells Street and Water Street	0.6	100.0 (88)	100.0 (88)	100.0 (86)	37.5 (88)	68.2 (88)	- -	- -	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory
Milwaukee River between Water Street and Union Pacific Railroad	0.3	100.0 (76)	100.0 (76)	100.0 (73)	64.5 (76)	77.3 (75)	- -	- -	Aquatic toxicity, bacteria, dissolved oxygen, fish consumption advisory
Milwaukee River between Union Pacific Railroad and confluence with Lake Michigan	0.4	100.0 (2)	100.0 (2)	100.0 (2)	75.0 (4)	100.0 (3)	- -	- -	Aquatic toxicity, bacteria, dissolved oxygen consumption advisory

Table 127 (continued)

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a]					Fish Biotic Index Rating[a,b]	Macroinvertebrate Biotic Index Rating (HBI)[a,b]	303(d) Impairments[e]
		Dissolved Oxygen	Temperature	NH_3[c]	Total Phosphorus[d]	Fecal Coliform Bacteria			
Tributaries									
Upper Milwaukee River Subwatershed									
Unnamed Creek (T14N R18E NW SE 22)	1.3	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E NW SW 14)	1.9	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E SW NE 28)	1.0	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E NW NE 27)	5.7	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E SE NW 36)	0.4	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E SE SE 36)	0.7	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E NW SE 6)	2.0	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E NW NE 06)	10.9	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E SE SW 34)	1.2	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R19E NW NE 9)	1.2	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R19E SE NE 4)	1.7	- -	- -	- -	- -	- -	- -	- -	- -
Lake Fifteen Creek Subwatershed									
Auburn Lake Creek[g]	7.4	- -	- -	- -	- -	- -	Fair to good (2)	Good (1)	- -
Unnamed Creek (T13N R19E SW NE 10) (Virgin Creek)	4.5	- -	- -	- -	- -	- -	- -	- -	- -
West Branch Milwaukee River Subwatershed									
West Branch Milwaukee River	20.1	60.0 (5)	100.0 (6)	100.0 (5)	61.5 (39)	- -	Poor to excellent (4)	Poor to good (10)	- -
Unnamed Creek (T14N R17E SE NE 36)	1.6	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E SE NE 16)	1.0	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R18E NW NE 26)	1.7	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E NW SE 33)	0.4	- -	- -	- -	- -	- -	- -	- -	- -
Kewaskum Creek Subwatershed									
Kewaskum Creek	6.4	- -	- -	- -	70.6 (34)	- -	Fair (1)	Fair to good (5)	- -
Watercress Creek Subwatershed									
Watercress Creek	6.5	- -	- -	- -	- -	- -	Fair (1)	- -	- -
East Branch Milwaukee River Subwatershed									
East Branch Milwaukee River from Long Lake to STH 28	15.9	100.0 (125)	100.0 (139)	100.0 (6)	98.4 (62)	100.0 (10)	Fair to excellent (11)	Poor to excellent (17)	- -

Table 127 (continued)

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a]					Fish Biotic Index Rating[a,b]	Macroinvertebrate Biotic Index Rating (HBI)[a,b]	303(d) Impairments[e]
		Dissolved Oxygen	Temperature	NH_3[c]	Total Phosphorus[d]	Fecal Coliform Bacteria			
Tributaries (continued)									
East Branch Milwaukee River Subwatershed (continued)									
East Branch Milwaukee River from STH 28 to Confluence with West Branch Milwaukee River	2.3	- -	- -	- -	- -	- -	Good (1)	Fair (1)	- -
Unnamed Creek (T14N R19E SE NW 36) (Parnell Creek)	7.8	100.0 (6)	100.0 (6)	100.0 (7)	66.7 (6)	- -	- -	Good (5)	- -
Crooked Lake Creek	5.1	100.0 (6)	100.0 (6)	100.0 (6)	100.0 (6)	- -	Poor to very poor (2)	Fair to good (7)	- -
Lake Seven Outlet	0.4	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E SW NE 14)	8.3	- -	- -	- -	- -	- -	- -	- -	- -
Middle Milwaukee River Subwatershed									
Unnamed Creek (T11N R20E SW SE 17)	2.2	- -	- -	- -	- -	- -	- -	- -	- -
Quaas Creek	5.9	99.1 (856)	100.0 (856)	- -	79.4 (34)	- -	Fair to very poor (5)	Fair to good (4)	- -
Myra Creek	2.6	- -	- -	- -	- -	- -	- -	- -	- -
Riveredge Creek	2.2	- -	100.0 (131)	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R20E NE SW 36)	1.5	- -	- -	- -	- -	- -	- -	- -	- -
Silver Creek West Bend Subwatershed									
Unnamed Creek (T11N R19E NE NW 14) (Engmon Creek)	1.5	- -	- -	- -	- -	- -	Very poor (1)	Good to poor (5)	- -
Silver Creek	4.0	- -	- -	- -	- -	- -	Very poor (3)	Good (1)	- -
North Branch Milwaukee River Subwatershed									
North Branch Milwaukee River	30.0	83.6 (140)	100.0 (197)	100.0 (12)	56.3 (64)	44.4 (9)	Fair (1)	Poor to good (3)	- -
Nichols Creek	3.3	- -	- -	- -	- -	- -	Poor to fair (4)	- -	- -
Unnamed Creek (T13N R21E NE NW 11)	0.5	- -	- -	- -	- -	- -	- -	- -	- -
Adell Tributary	5.1	- -	- -	- -	- -	- -	- -	Poor to fair (4)	Degraded habitat
Unnamed Creek (T14N R21E SW NE 31)	0.5	- -	- -	- -	- -	- -	- -		- -
Gooseville Creek	1.8	- -	- -	- -	- -	- -	Poor to fair (2)	- -	- -
Unnamed Creek (T12N R20E SE SE 2)	0.8	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R20E SW SW 3)	2.6	- -	- -	- -	- -	- -	- -	- -	- -
Wallace Creek	8.6	100.0 (5)	100.0 (6)	100.0 (5)	33.3 (6)	- -	Poor to fair (2)	Good (7)	- -

Table 127 (continued)

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a]					Fish Biotic Index Rating[a,b]	Macroinvertebrate Biotic Index Rating (HBI)[a,b]	303(d) Impairments[e]
		Dissolved Oxygen	Temperature	NH_3[c]	Total Phosphorus[d]	Fecal Coliform Bacteria			
Tributaries (continued)									
Chambers Creek Subwatershed									
Chambers Creek	2.9	- -	- -	- -	- -	- -	Poor (2)	Good (1)	- -
Unnamed Creek (T13N R20E NW NE 11)	0.9	- -	- -	- -	- -	- -	- -	- -	- -
Melius Creek	3.3	- -	- -	- -	- -	- -	Poor (2)	- -	- -
Batavia Creek Subwatershed									
Batavia Creek	5.0	- -	- -	- -	65.8 (32)	- -	- -	- -	- -
Mink Creek Subwatershed									
Mink Creek	17.3	- -	- -	- -	- -	- -	Poor to good (5)	Good (2)	- -
Unnamed Creek (T13N R20E SE NE 34)	3.6	- -	- -	- -	- -	- -	- -	- -	- -
Silver Creek Subwatershed									
Unnamed Creek (T13N R21E SE NE 23)	1.4	- -	- -	- -	- -	- -	- -	- -	- -
Silver Creek	10.5	- -	- -	- -	- -	- -	Poor (2)	Poor to good (6)	- -
Unnamed Creek (T13N R21E NE NW 32)	0.4	- -	- -	- -	- -	- -	- -	- -	- -
Stony Creek Subwatershed									
Stony Creek	10.0	100.0 (6)	100.0 (6)	100.0 (6)	100.0 (6)	- -	Poor to fair (3)	Good (6)	- -
Unnamed Creek (T12N R20E SW NW 8)	0.4	- -	- -	- -	- -	- -	- -	- -	- -
Upper Lower Milwaukee River Subwatershed									
Fredonia Creek	4.1	- -	- -	- -	- -	- -	- -	Poor to good (4)	- -
Mole Creek	4.0	100.0 (5)	100.0 (6)	100.0 (5)	100.0 (6)	- -	Very poor to fair (9)	Poor to good (11)	- -
Cedar Lake Subwatershed									
Unnamed Creek (T10N R19E NW NE 5)	1.7	- -	- -	- -	- -	- -	- -	- -	- -
Cedar Creek Subwatershed									
Cedar Creek	31.5	100.0 (124)	99.2 (127)	100.0 (6)	94.9 (59)	92.9 (14)	Good (3)	Fair to good (4)	Fish consumption advisory
Kressin Creek	4.7	- -	- -	- -	- -	- -	- -	- -	- -
Little Cedar Creek	6.0	- -	- -	- -	- -	- -	Fair (1)	Fair to good (5)	- -
Little Cedar Lake Outlet	1.7	- -	- -	- -	- -	- -	Very poor to fair (9)	Poor to good (12)	- -
Lehner Creek	0.3	- -	- -	- -	- -	- -	Very poor (2)	Good (1)	Degraded habitat, temperature

Table 127 (continued)

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a]					Fish Biotic Index Rating[a,b]	Macroinvertebrate Biotic Index Rating (HBI)[a,b]	303(d) Impairments[e]
		Dissolved Oxygen	Temperature	NH_3[c]	Total Phosphorus[d]	Fecal Coliform Bacteria			
Tributaries (continued)									
Cedar Creek Subwatershed (continued)									
Unnamed Creek (T10N R20E SW SE 19) (Jackson Creek)	1.3	- -	- -	- -	- -	- -	- -	- -	Degraded habitat
Polk Springs Creek	1.9	100.0 (161)	100.0 (167)	100.0 (89)	48.7 (39)	- -	Very poor to poor (3)	Poor to good (6)	- -
Friedens Creek	3.8	100.0 (5)	100.0 (6)	100.0 (5)	83.3 (6)	- -	Very poor (2)	Fair to good (6)	- -
Evergreen Creek	4.9	- -	- -	- -	- -	- -	- -	- -	Degraded habitat
Cedarburg Creek	3.0	- -	- -	- -	- -	- -	- -	- -	- -
Lower Cedar Creek Subwatershed									
Unnamed Creek (T10N R20E NE NE 1)	1.0	- -	- -	- -	- -	- -	- -	- -	- -
North Branch Cedar Creek	7.3	- -	- -	- -	- -	- -	Very poor to poor (2)	Poor to good (4)	- -
Lower Milwaukee River Subwatershed									
Ulao Creek	8.6	- -	- -	- -	- -	- -	Excellent (1)	Poor to fair (3)	- -
Pigeon Creek	2.4	100.0 (5)	100.0 (6)	100.0 (5)	100.0 (6)	- -	Poor (1)	Good (3)	- -
Trinity Creek	3.1	- -	- -	- -	- -	- -	- -	- -	- -
Beaver Creek	2.6	- -	- -	- -	- -	- -	- -	- -	Aquatic toxicity
Southbranch Creek above Bradley Road	0.1	100.0 (30)	100.0 (30)	100.0 (32)	3.3 (30)	38.7 (31)	- -	- -	- -
Southbranch Creek between Bradley Road and 55th Street	0.2	100.0 (39)	100.0 (34)	100.0 (32)	12.1 (33)	32.4 (34)	- -	- -	- -
Southbranch Creek between 55th Street and 47th Street	0.5	100.0 (36)	100.0 (36)	100.0 (30)	11.4 (35)	22.2 (36)	- -	- -	- -
Southbranch Creek between 47th Street and Teutonia Avenue	0.5	91.4 (35)	100.0 (35)	100.0 (28)	29.4 (34)	8.6 (35)	- -	- -	- -
Brown Deer Park Creek	2.2	- -	- -	- -	- -	- -	- -	- -	- -
Indian Creek	1.9	100.0 (32)	100.0 (32)	100.0 (28)	75.0 (28)	71.9 (32)	Very poor (1)	- -	Aquatic toxicity, degraded habitat, dissolved oxygen, temperature[h]
Lincoln Creek Subwatershed									
Wahl Creek	0.5	- -	- -	- -	- -	- -	- -	- -	- -
Lincoln Creek above 60th Street	0.9	100.0 (81)	100.0 (81)	100.0 (74)	57.5 (80)	76.3 (80)	- -	- -	Aquatic toxicity, degraded habitat, dissolved oxygen, temperature

Table 127 (continued)

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a]					Fish Biotic Index Rating[a,b]	Macroinvertebrate Biotic Index Rating (HBI)[a,b]	303(d) Impairments[e]
		Dissolved Oxygen	Temperature	NH_3[c]	Total Phosphorus[d]	Fecal Coliform Bacteria			
Tributaries (continued)									
Lincoln Creek Subwatershed (continued)									
Lincoln Creek between 60th Street and 51st Street	1.5	100.0 (79)	100.0 (80)	100.0 (65)	77.2 (79)	47.5 (80)	- -	- -	Aquatic toxicity, degraded habitat, dissolved oxygen, temperature
Lincoln Creek between 51st Street and 55th Street	1.1	100.0 (61)	100.0 (61)	100.0 (56)	81.7 (60)	73.3 (60)	- -	- -	Aquatic toxicity, degraded habitat, dissolved oxygen, temperature
Lincoln Creek between 55th Street and 47th Street	2.5	100.0 (100)	100.0 (100)	100.0 (83)	37.6 (93)	34.5 (84)	Very poor (1)	- -	Aquatic toxicity, degraded habitat, dissolved oxygen, temperature
Lincoln Creek between 47th Street and Green Bay Avenue	2.9	97.6 (83)	100.0 (422)	100.0 (78)	14.6 (82)	37.3 (83)	Very poor (2)	- -	Aquatic toxicity, degraded habitat, dissolved oxygen, temperature

[a]*Number in parentheses shows number of samples.*

[b]*The State of Wisconsin has not promulgated water quality standards or criteria for biotic indices.*

[c]*Based upon the acute toxicity criterion for ammonia.*

[d]*Total phosphorus is compared to the concentration recommended in the regional water quality management plan.*

[e]*As listed in the Approved Wisconsin 303(d) Impaired Waters List.*

[f]*The section of the Milwaukee River between Pioneer Road near Cedarburg and the Village of Grafton are listed as impaired due to fish consumption advisories and bacteria. The section of the River upstream from the Village of Grafton is not listed as impaired.*

[g]*Referred to as Lake Fifteen Creek in some reports.*

[h]*The natural channel downstream of Interstate Highway 43 is considered impaired. Reaches upstream from Interstate Highway 43 are not considered impaired.*

Source: SEWRPC.

- Fecal coliform bacteria standards were commonly exceeded at stations along the mainstem of the Milwaukee River, Indian Creek, Lincoln Creek, the North Branch Milwaukee River, and Southbranch Creek, indicating frequent violations of the standard. Fecal coliform bacteria standards were exceeded in one of 14 samples taken at one station along Cedar Creek, indicating an isolated incidence of violation of the standard. Fecal coliform bacteria concentrations along the East Branch Milwaukee River were at or below the relevant standard, indicating compliance with the standard.

- Concentrations of total phosphorus in the mainstem of the Milwaukee River and 12 tributaries commonly exceeded the planning levels recommended in the original regional water quality management plan. Concentrations of total phosphorus in two additional tributaries occasionally exceeded the recommended levels in the regional water quality management plan. Concentrations of total phosphorus in four tributaries were at or below the recommended levels in the regional water quality management plan.

Thus, during the baseline period, the stream reaches for which data are available substantially met the standards for ammonia, dissolved oxygen, and water temperature, but less frequently met the regulatory standard for fecal coliform bacteria and the planning standard for phosphorus. The streams only partially achieved the recommended water use objectives.

An additional issue to consider when examining whether stream reaches are achieving water use objectives is whether toxic substances are present in water, sediment, or tissue of aquatic organisms in concentrations sufficient to impair beneficial uses. Table 128 summarizes the data from 1998 to 2004 regarding toxic substances in water, sediment, and tissue from aquatic organisms for the Milwaukee River watershed. For toxicants, the baseline period was extended to 2004 in order to take advantage of results from sampling conducted by the USGS specifically for the regional water quality management plan update.

Pesticides were detected in water from three stations along the mainstem of the River and from stations along two tributary streams: Lincoln Creek and the North Branch of the Milwaukee River. The concentrations detected did not exceed water quality standards. Pesticides were detected in tissue from aquatic organisms at one station during the baseline period.

The concentrations of PCBs in tissue from all aquatic organisms examined during the baseline period from the mainstem of the Milwaukee River downstream from Pioneer Road were above the threshold used by the WDNR for issuing fish consumption advisories. Upstream from Pioneer Road, this threshold was exceeded in over 20 percent of fish tissue samples. In addition, concentrations of PCBs in tissue from the majority of aquatic organisms collected from Cedar Creek were above this threshold. High concentrations of PCBs were detected in sediment in the Milwaukee River in the Estabrook Impoundment, several impoundments along Cedar Creek in the City of Cedarburg, and in Zeunert Pond in Cedarburg. Release of PCBs from these deposits appears to account for a substantial portion of PCB mass transport in the lower Milwaukee River.

Water samples from 11 stations along the mainstem of the Milwaukee River showed detectable concentrations of several PAH compounds. These compounds were also detected in water samples collected at several stations along Lincoln Creek and Southbranch Creek. PAHs were also detected in sediment collected from Cedar Creek, the East Branch of the Milwaukee River, and the North Branch of the Milwaukee River.

Limited sampling for other organic compounds showed detectable concentrations of several compounds in water from the mainstem of the Milwaukee River and from Lincoln Creek. Compounds detected included pharmaceutical and personal care products such as the stimulant caffeine, industrial solvents such as isophorone, dye components such as carbazole, aroma and flavoring agents such as acetophenone and camphor, flame retardants, insect repellants such as DEET, and metabolites of nonionic detergents. Where water quality criteria have been promulgated, the concentrations of these substances were below the relevant criteria.

Table 128

TOXICITY CHARACTERISTICS OF STREAMS IN THE MILWAUKEE RIVER WATERSHED: 1998-2004[a]

	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
Stream Reach	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
Mainstem															
Milwaukee River above Dam at Kewaskum	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	E-50 (2)	- -	- -
Milwaukee River between Dam at Kewaskum and CTH M near Newburg	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	D (1)	- -	- -
Milwaukee River between CTH M near Newburg and Waubeka	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	D (1)	- -	- -
Milwaukee River between Waubeka and Pioneer Road near Cedarburg	D (3)	- -	- -	E-15 (13)	- -	E-22 (9)	D (13)	- -	- -	D (3)	- -	- -	E-77 (53)	- -	- -
Milwaukee River between Pioneer Road near Cedarburg and Brown Deer Road	- -	- -	- -	E-8 (13)	- -	E-100 (33)	D (13)	- -	- -	- -	- -	- -	E-70 (53)	- -	E-100 (9)
Milwaukee River between Brown Deer Road and Silver Spring Drive	- -	- -	- -	E-9 (11)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-72 (53)	- -	- -
Milwaukee River between Silver Spring Drive and Port Washington Road	- -	- -	- -	E-25 (12)	- -	- -	D (13)	- -	- -	D (6)	- -	- -	E-77 (53)	- -	- -
Milwaukee River between Port Washington Road and Estabrook Park	D (49)	D (2)	- -	- -	D (91)	- -	D (3)	- -	- -	- -	- -	- -	D (2)	D (4)	- -
Milwaukee River between Estabrook Park and former North Avenue Dam	- -	- -	- -	E-42 (12)	- -	- -	D (12)	- -	- -	- -	- -	- -	E-2 (46)	- -	- -
Milwaukee River between former North Avenue Dam and Walnut Street	- -	- -	D (3)	E-31 (13)	- -	E-100 (24)	D (12)	- -	- -	- -	- -	- -	E-23 (52)	- -	E-100 (9)
Milwaukee River between Walnut Street and Wells Street	- -	- -	- -	E-31 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-24 (49)	- -	- -
Milwaukee River between Wells Street and Water Street	- -	- -	- -	E-31 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-9 (53)	- -	- -
Milwaukee River between Water Street and Union Pacific Railroad	- -	- -	- -	E-23 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-3 (63)	- -	- -
Milwaukee River between Union Pacific Railroad and Confluence with Lake Michigan	D (3)	- -	- -	- -	- -	- -	D (3)	- -	- -	D (3)	- -	- -	- -	- -	- -

Table 128 (continued)

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
Upper Milwaukee River Subwatershed															
Unnamed Creek (T14N R18E NW SE 22)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E NW SW 14)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E SW NE 28)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E NW NE 27)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E SE NW 36)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R18E SE SE 36)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E NW SE 6)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E NW NE 06)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E SE SW 34)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R19E NW NE 9)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R19E SE NE 4)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Lake Fifteen Creek Subwatershed															
Auburn Lake Creek[c]	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E SW NE 10) Virgin Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
West Branch Milwaukee River Subwatershed															
West Branch Milwaukee River	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R17E SE NE 36)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E SE NE 16)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R18E NW NE 26)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E NW SE 33)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Kewaskum Creek Subwatershed															
Kewaskum Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Watercress Creek Subwatershed															
Watercress Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Table 128 (continued)

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
East Branch Milwaukee River Subwatershed															
East Branch Milwaukee River from Long Lake to STH 28	- -	N (4)	- -	- -	N (4)	- -	- -	D (4)	- -	- -	- -	- -	- -	D (4)	- -
East Branch Milwaukee River from STH 28 to Confluence with West Branch Milwaukee River	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R19E SE NW 36) Parnell Creek	N (3)	- -	- -	- -	- -	- -	N (3)	- -	- -	- -	- -	- -	- -	- -	- -
Crooked Lake Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Lake Seven Outlet	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R19E SW NE 14)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Middle Milwaukee River Subwatershed															
Unnamed Creek (T11N R20E SW SE 17)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Quaas Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Myra Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Riveredge Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R20E NE SW 36)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Silver Creek (West Bend) Subwatershed															
Unnamed Creek (T11N R19E NE NW 14) Engmon Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Silver Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
North Branch Milwaukee River Subwatershed															
North Branch Milwaukee River	D (6)	N (4)	- -	- -	D (4)	- -	- -	D (4)	- -	- -	- -	- -	- -	D (4)	- -
Nichols Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R21E NE NW 11)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Adell Tributary	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T14N R21E SW NE 31)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Gooseville Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R20E SE SE 2)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R20E SW SW 3)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Wallace Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Table 128 (continued)

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
Chambers Creek Subwatershed		- -													
Chambers Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R20E NW NE 11)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Melius Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Batavia Creek Subwatershed															
Batavia Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Mink Creek Subwatershed															
Mink Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T13N R20E SE NE 34)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Silver Creek (Sheboygan) Subwatershed															
Unnamed Creek (T13N R21E SE NE 23)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Silver Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R20E SW NW 8)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Stony Creek Subwatershed															
Stony Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T12N R20E SW NW 8)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Upper Lower Milwaukee River Subwatershed															
Fredonia Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Mole Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Cedar Lake Subwatershed															
Unnamed Creek (T10N R19E NW NE 5)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Cedar Creek Subwatershed															
Cedar Creek	- -	- -	- -	E-91 (22)	D (50)	E-80 (66)	- -	D (22)	- -	- -	- -	- -	N (1)	D (10)	D (4)
Kressin Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Little Cedar Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Little Cedar Lake Outlet	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Lehner Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Creek (T10N R20E SW SE 19) Jackson Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Polk Springs Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Friedens Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Evergreen Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Cedarburg Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Table 128 (continued)

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
Lower Cedar Creek Subwatershed															
Unnamed Creek (T10N R20E NE NE 1)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
North Branch Cedar Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Lower Milwaukee River Subwatershed															
Ulao Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pigeon Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Trinity Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Beaver Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Southbranch Creek above Bradley Road	- -	- -	- -	N (3)	- -	- -	D (3)	- -	- -	- -	- -	- -	E-7 (28)	- -	- -
Southbranch Creek between Bradley Road and 55th Street	- -	- -	- -	N (4)	- -	- -	D (5)	- -	- -	- -	- -	- -	E-25 (28)	- -	- -
Southbranch Creek between 55th Street and 47th Street	- -	- -	- -	N (5)	- -	- -	D (5)	- -	- -	- -	- -	- -	E-7 (29)	- -	- -
Southbranch Creek between 47th Street and Teutonia Avenue	- -	- -	- -	N (6)	- -	- -	D (5)	- -	- -	- -	- -	- -	E-40 (30)	- -	- -
Brown Deer Park Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Indian Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	E-13 (8)	- -	- -
Lincoln Creek Subwatershed															
Wahl Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Lincoln Creek above 60th Street	- -	- -	- -	E-8 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-12 (66)	- -	- -
Lincoln Creek between 60th Street and 51st Street	- -	- -	- -	N (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-8 (49)	- -	- -
Lincoln Creek between 51st Street and 55th Street	- -	- -	- -	E-11 (13)	- -	- -	D (9)	- -	- -	- -	- -	- -	D (54)	- -	- -
Lincoln Creek between 55th Street and 47th Street	D (13)	N (1)	- -	N (12)	- -	- -	D (14)	- -	- -	D (11)	- -	- -	E-9 (67)	- -	- -
Lincoln Creek between 47th Street and Green Bay Avenue	- -	- -	- -	E-31 (13)	- -	- -	D (13)	- -	- -	- -	- -	- -	E-57 (54)	- -	- -
Lincoln Creek between Green Bay Avenue and the Confluence with the Milwaukee River	- -	- -	- -	- -	D (17)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

NOTE: E-X denotes exceedence of a water quality standard in X percent of the samples, D denotes detection of a substance in this class in at least one sample, N denotes that no substances in this class were detected in any sample.

[a]*Number in parentheses indicates sample size.*

[b]*Metals sampled were arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. Sample sizes are shown for most metals. Mercury was sampled less frequently. For mercury, exceedances were determined based on the wildlife criterion of 1.3 nanograms per liter.*

[c]*Referred to as Lake Fifteen Creek in some reports.*

Source: SEWRPC.

Water samples from the long-term stations along the mainstem of the Milwaukee River and a few tributaries were examined for concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. While the sample sizes given in Table 128 are representative of sampling for most of these metals, it is important to note that mercury was sampled less intensively. The number of samples analyzed for mercury was about two-thirds the number analyzed for other metals. Detectable concentrations of each of these metals were present in samples from most of the stations tested. Several of these metals were present at times in concentrations that exceeded water quality standards. Concentrations of mercury in water commonly exceeded both the human threshold concentration for public health and welfare and the wildlife criterion for surface water quality. The percent of samples exceeding the lower of these two concentrations, which is the wildlife criterion, is given in Table 128. In addition, concentrations of copper in water samples occasionally exceeded the EPA's criterion maximum concentration (CMC) for copper and concentrations of cadmium, chromium, lead, nickel, and zinc occasionally exceeded the chronic toxicity criteria for aquatic life, and more rarely, the acute criteria for aquatic life. Concentrations of mercury in the tissue from aquatic organisms collected from two stations along the mainstem of the River during the baseline period were above the threshold used by the WDNR for issuing fish consumption advisories.

The summary above suggests that some beneficial uses are being impaired by the presence of contaminants, especially PCBs and mercury. The fish consumption advisories in effect for the Milwaukee River shown in Table 100 reflect this.

Section 303(d) of the Clean Water Act requires that the states periodically submit a list of impaired waters to the USEPA for approval. Wisconsin most recently submitted this list in 2004.[74] This list was subsequently approved by the USEPA. Table 127 and Map 72 indicate stream reaches in the Milwaukee River watershed that are classified as being impaired waters. Three sections of the mainstem of the Milwaukee River are listed as impaired. The section of the River upstream of the Lime Kiln dam in the Village of Grafton is considered impaired due to fish consumption advisories necessitated by high concentrations of PCBs in the tissue of fish collected from this reach. A 25-mile section of the Milwaukee River between the City of Grafton and site of the former North Avenue dam is considered impaired due to bacterial contamination and fish consumption advisories necessitated by high concentrations of PCBs in the tissue of fish collected from this reach. The 3.1-mile reach of variance water between the confluence with Lake Michigan and the site of the former North Avenue dam is considered impaired due to aquatic toxicity, bacterial contamination, fish consumption advisories necessitated by high concentrations of PCBs in the tissue of fish collected from this reach, and lack of compliance with standards for dissolved oxygen concentration. Bacteria, metals, phosphorus, and PCBs from contaminated sediment and a combination of point and nonpoint sources are cited as factors contributing to the impairment of this section of the River. Several tributary streams are also listed as impaired. Adell Tributary, Evergreen Creek, Jackson Creek, and Lehner Creek are considered impaired due to habitat degradation from sedimentation related to nonpoint source pollution. Lehner Creek is also considered impaired due to high water temperatures. Beaver Creek is considered impaired due to aquatic toxicity related to nonpoint source pollution. A five-mile section of Cedar Creek between Bridge Road in the City of Cedarburg and the confluence with the Milwaukee River is considered impaired due to fish consumption advisories necessitated by high concentrations of PCBs in the tissue of fish collected from this reach. PCBs from contaminated sediments are cited as factors contributing to the impairment of this section of Cedar Creek. Indian Creek downstream from IH 43, which is classified as a variance water, is considered impaired due to aquatic toxicity, degraded habitat, lack of compliance with standards for dissolved oxygen concentration, and high temperatures. Metals, phosphorus, and sedimentation related to nonpoint source pollution are cited as contributing to the impairment of this section of stream. Lincoln Creek, which is classified as a variance water, is considered impaired due to aquatic toxicity, degraded habitat, lack of compliance with standards for dissolved oxygen concentration, and high temperatures. Metals, PAHs, phosphorus, and sedimentation from undetermined sources are cited as factors contributing to the impairment of this stream.

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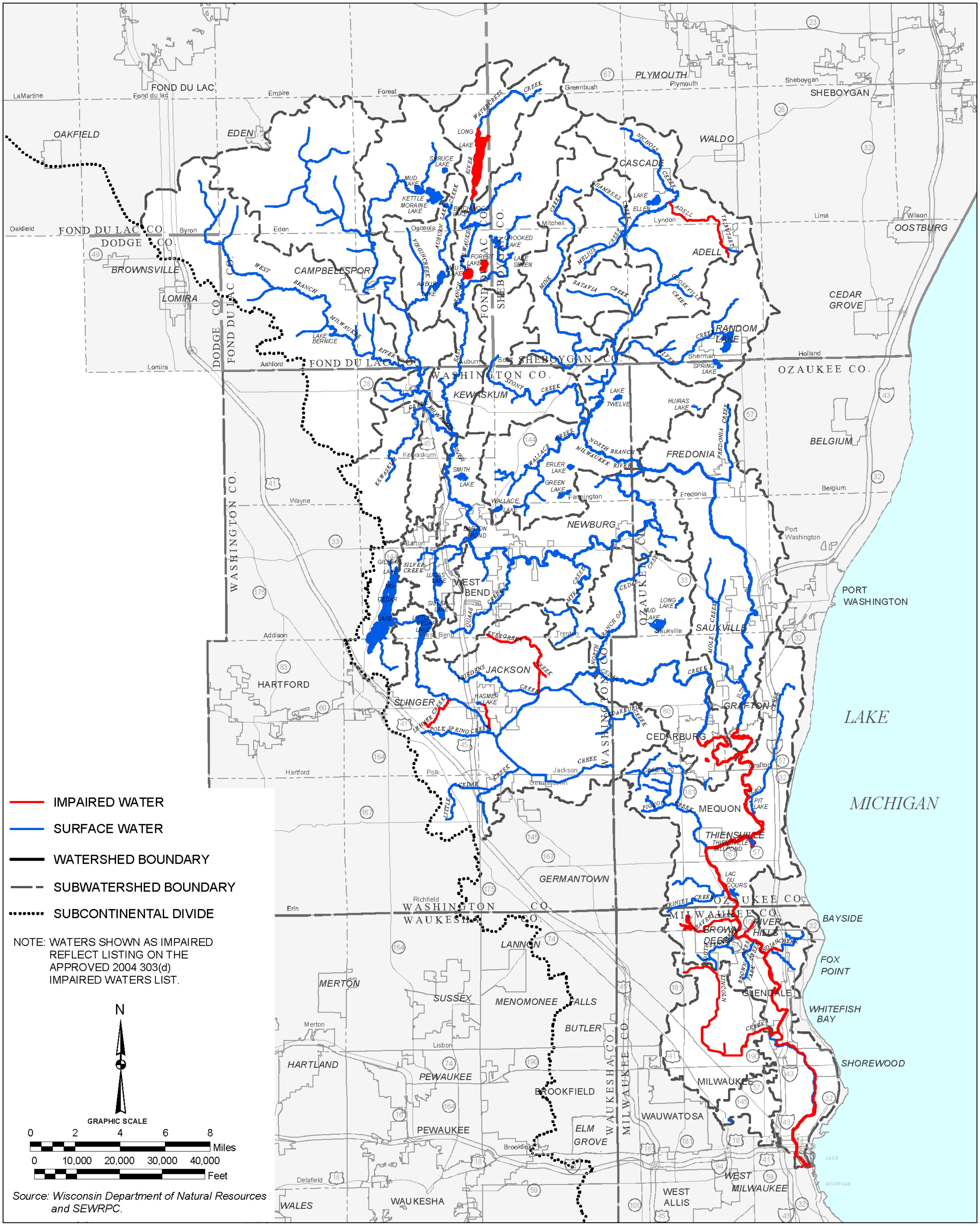
[74] *Wisconsin Department of Natural Resources,* Approved 2004 Wisconsin 303(d) Impaired Waters List, *August 2004.*

Map 72

IMPAIRED WATERS WITHIN THE MILWAUKEE RIVER WATERSHED: 2004



Two lakes and one pond in the Milwaukee River watershed are also listed as being impaired. Forest Lake and Mauthe Lake are considered impaired due to fish consumption advisories necessitated by high concentrations of mercury in the tissue of fish collected from these lakes. Atmospheric deposition of mercury is cited as contributing to these impairments. Zeunert Pond in the City of Cedarburg is also considered impaired due to fish consumption advisories necessitated by high concentrations of mercury in the tissue of fish collected from this pond. Mercury in contaminated sediment is cited as contributing to this impairment.

SUMMARY

The water quality and pollution sources inventory for the Milwaukee River system has been summarized by answering five basic questions. This chapter provided detailed information needed to answer the questions. The information is presented below.

How Have Water Quality Conditions Changed Since 1975?

Water quality conditions in the Milwaukee River watershed have both improved in some respects and declined in other respects since 1975.

Improvements in Water Quality

Concentrations of several pollutants associated with combined sewer overflows such as BOD, fecal coliform bacteria, total phosphorus, and ammonia have decreased along much of the length of the Milwaukee River. These reductions in nutrients and oxygen-demanding wastes have produced some improvements in concentrations of chlorophyll-*a* and dissolved oxygen at some sampling stations, especially in the estuary during the summer. Decreases in the concentrations of some pollutants have also been detected in some tributaries to the Milwaukee River. These include decreases in concentrations of ammonia, BOD, and total phosphorus which have resulted in some improvements in chlorophyll-*a* concentrations in Cedar Creek and dissolved oxygen concentrations at some stations along Cedar Creek and Lincoln Creek. Improvements have also occurred in the concentrations of several toxic metals detected in the Milwaukee River and Lincoln Creek. These improvements likely reflect both changes in the types of industries present in the watershed, the connection of most process wastewaters to the sanitary sewerage systems, and the implementation of treatment requirements for all industrial discharges.

No Change or Reductions in Water Quality

Concentrations of suspended and dissolved pollutants typically associated with stormwater runoff and other nonpoint source pollution, such as chloride, copper, total suspended solids, and zinc have increased along much of the mainstem of the River. Increases in chloride concentration have also been observed in tributaries and lakes in the watershed for which sufficient data exist to assess trends. Concentrations of some nutrients, such as nitrate, total nitrogen, and dissolved phosphorus during the summer have also increased at several stations along the mainstem of the River. In addition, specific conductance has increased at most stations along the mainstem of the River, suggesting that the total concentration of dissolved material in the water has increased.

How Have Toxicity Conditions Changed Since 1975?

In some respects, toxicity conditions in the Milwaukee River watershed have improved since 1975; in other respects, they have declined or not changed.

Improvements in Toxicity Conditions

The concentrations of PCBs in water in Cedar Creek have declined. In addition, examinations of PCB congener composition indicate that the percentage of PCB congeners of greatest environmental concern in PCB samples in water has decreased over time at some sites along Cedar Creek. As part of remediation efforts, sediments contaminated with PCBs have been removed from Ruck Pond along Cedar Creek and from the banks of the former Hamilton Pond along Cedar Creek. This should reduce the toxic effects related to contaminated sediments in the Cedar Creek and the mainstem of the Milwaukee River.

No Change in Toxicity Conditions
Transport of PCBs from upstream is contributing about 15 kg per year of PCBs to the estuary sections of the Milwaukee River. In addition, fish consumption advisories remain in effect for portions of the watershed due to PCB contamination.

Inconclusive Toxicity Data
In some cases the available data are not adequate to assess changes. For example, pesticides continue to be detected in water samples in the mainstem of the Milwaukee River and several tributaries; however, methodological differences in the collection and analysis of historical and recent samples prevent assessment of trends in concentration. Similarly, PAHs continue to be detected in downstream sections of the mainstem of the Milwaukee River and in Lincoln Creek, but methodological differences in the collection and analysis of historical and recent samples prevent assessment of trends in concentration.

Sediment Conditions
The removal of sediments contaminated with PCBs from Ruck Pond and the banks of the former Hamilton Pond along Cedar Creek should reduce the toxicity of sediments in Cedar Creek and the mainstem of the Milwaukee River below the confluence with Cedar Creek; however, deposits of PCBs remain in sediment in impoundments along Cedar Creek, in the mainstem of the Milwaukee River at Thiensville Millpond and Estabrook Impoundment, in Lincoln Creek, and in Zeunert Pond in Cedarburg.

In the available data on sediment toxicity, the expected incidence of toxicity to benthic organisms ranges from less than 1 percent up to 100 percent at sites along the mainstem of the Milwaukee River. Most reaches along the mainstem with high toxicity are downstream from the confluence with Cedar Creek. In reaches along the mainstem upstream from Cedar Creek, the expected incidence of toxicity to benthic organisms is less than about 5 percent.

Data on sediment toxicity is available for only a few tributary streams. In Lincoln Creek and Cedar Creek, the expected incidence of toxicity to benthic organisms ranges from 20 to 100 percent and 9 to 100 percent, respectively. By contrast, the expected incidences of toxicity to benthic organisms in samples from the East Branch of the Milwaukee River are below 20 percent and the expected incidences of toxicity to benthic organisms from samples in the North Branch of the Milwaukee River and from Gooseville Creek are below 10 percent. The overall quality of sediment, as measured by mean PEC-Q, remains poor. Sediment at locations in the Milwaukee River watershed contains concentrations of PAHs arsenic, cadmium, chromium, copper, manganese, mercury, nickel, and zinc high enough to likely produce some toxic effects in benthic organisms and concentrations of PCBs high enough to pose substantial risks of toxicity to benthic organisms

What Are the Sources of Water Pollution?
The Milwaukee River watershed contains several potential sources of water pollution. These fall into two broad categories: point sources and nonpoint sources.

Point Sources
Twelve public sewage treatment plants and two private plants currently discharge into streams of the Milwaukee River watershed. MMSD has 65 combined sewer overflow outfalls that discharge to the streams of the Milwaukee River watershed. These outfalls convey a combination of stormwater runoff and sanitary sewage from the combined sewer system to the surface water system as a result of high water volume from stormwater, meltwater, and infiltration and inflow of clear water during wet weather conditions. Prior to 1994, overflows from these sites typically occurred around 50 times per year. Since MMSD's inline storage system came online in 1994, the number of combined sewer overflows per year has declined to about three. Since 1995, separate sanitary sewer overflows have been reported at 54 locations: 15 within MMSD's SSO area and 39 within local communities. The number of SSO events occurring per year has also declined compared to the time period prior to completion of the MMSD Water Pollution Abatement Program facilities in 1993. As of February 2003, 130 industrial dischargers

and other point sources were permitted through the WPDES program to discharge wastewater to streams in the Milwaukee River watershed. About one third of the permitted facilities discharged noncontact cooling water. The remaining discharges are of a nature which typically meets or exceeds the WPDES permit levels which are designed to meet water quality standards.

Nonpoint Sources

The Milwaukee River watershed is comprised of combinations of urban land uses and rural land uses. As of 2000, about 79 percent of the watershed was in rural and other open land uses. About 21 percent of the watershed is contained within planned sewer service areas: 8 percent within MMSD's planned service area, 3 percent within the sanitary sewer service areas of local communities that are connected to MMSD's conveyance and treatment systems, 4 percent within the City of West Bend's planned sewer service area, about 1 percent within each of the City of Cedarburg and Villages of Grafton and Jackson's planned sewer service areas, and less than 1 percent each within the City of Port Washington, the Villages of Adell, Campbellsport, Cascade, Fredonia, Kewaskum, Lomira, Newburg, Random Lake, and Slinger and Waubeka's planned sewer service areas. The status of adoption of stormwater management ordinances and/or plans and of construction erosion control ordinances in each community and county in the watershed is set forth in Table 117. That table also indicates which communities have established either stormwater utilities, general funds, or stormwater fee programs. As of 2005, there were two active solid waste landfills within the watershed, both located in the West Branch Milwaukee River subwatershed. As set forth in Table 118 and shown on Map 71, there are 47 inactive landfills in the watershed: 10 in the Upper Lower Milwaukee River subwatershed; six in the North Branch Milwaukee River subwatershed; four each in the Cedar Creek, Lower Milwaukee River, Middle Milwaukee River, Stony Creek, and West Branch Milwaukee River subwatersheds; three in the Lincoln Creek subwatershed; two each in the Silver Creek (West Bend) and Upper Milwaukee River subwatersheds; and one each in the Lake Fifteen Creek and Watercress Creek subwatersheds.

Quantification of Pollutant Loads

The annual average load of BOD to streams of the Milwaukee River watershed is estimated to be 5,233,160 pounds per year. Sewage treatment plants, combined sewer overflows, and separate sanitary sewer overflows contribute about 7.6 percent, 0.4 percent, and 0.1 percent, respectively, of this load. Industrial discharges contribute about 5.6 percent of this load. The rest of BOD load to streams in the Milwaukee River watershed, about 86.3 percent, is contributed by nonpoint sources, with 61.4 percent coming from rural sources and 24.9 percent from urban sources.

The annual average load of TSS to streams of the Milwaukee River watershed is estimated to be 58,383,650 pounds per year. Sewage treatment plants, combined sewer overflows, separate sanitary sewer overflows, and industrial discharges contribute 0.5 percent, 0.3 percent, less than 0.1 percent, and 0.8 percent, respectively, of this load. The rest of the TSS load to streams in the Milwaukee River watershed, about 98.4 percent, is contributed by nonpoint sources, with 68.1 percent coming from rural sources and 30.3 percent from urban sources.

The annual average load of fecal coliform bacteria to streams of the Milwaukee River watershed is estimated to be 40,826.66 trillion cells per year. Combined sewer overflows, sewage treatment plants, and separate sanitary sewer overflows contribute 4.6 percent, 0.1 percent and about 1.1 percent, respectively, of this load. Industrial discharges contribute less than 0.1 percent of this load. The rest of the fecal coliform bacteria load to streams in the Milwaukee River watershed, about 94.2 percent, is contributed by nonpoint sources, with 35.2 percent coming from rural sources and 59.0 percent from urban sources.

The annual average load of total phosphorus to streams of the Milwaukee River watershed is estimated to be 274,500 pounds per year. Industrial discharges and sewage treatment plants contribute about 34.2 percent and 18.8 percent, respectively, of this load. Combined sewer overflows and separate sanitary sewer overflows contribute about 0.7 percent and 0.3 percent, respectively, of this load. The rest of total phosphorus loadings to streams in the Milwaukee River watershed, about 46.0 percent, are contributed by nonpoint sources, with 29.5 percent coming from rural sources and 16.5 percent from urban sources.

What is the Current Condition of the Fishery?
Except for some areas within the Upper Milwaukee River, West Branch of the Milwaukee River, East Branch of the Milwaukee River, Middle Milwaukee River, Upper Lower Milwaukee River, and Lower Milwaukee River subwatersheds that contain good and in some cases excellent fishery quality, the watershed of the Milwaukee River in general contains a poor to fair fishery. The fish community contains a high abundance of both warmwater and coldwater species of fishes, seems trophically balanced in the highest quality areas, contains a good percentage of top carnivores (except for those species stocked), and is not dominated by tolerant fishes. Macroinvertebrate communities are classified as fair to good-very good at present. The macroinvertebrate community is also generally trophically balanced and not dominated by tolerant taxa. Overall, the fish and macroinvertebrate communities in the Milwaukee River watershed are of a better quality than those communities in the other watersheds in the study area.

The habitat quality was shown to largely be limited by siltation, as well as reduced amounts and quality of instream cover throughout the watershed. In addition, although there have been some water quality improvements in the downstream areas in the watershed, those areas also continue to be impaired due to sediment toxicity problems. Therefore, in differing degrees throughout the watershed, water, sediment, and habitat quality are important factors limiting both the fishery and macroinvertebrate community. There are several other factors that are likely to be limiting the aquatic community, including, but not limited to, 1) periodic stormwater loads and sediment toxicity; 2) decreased base flows; 3) continued fragmentation due to dams, drop structures, culverts, concrete lined channels, and enclosed conduits; 4) past channelization; 5) cropland erosion, and/or 5) increased water temperatures due to urbanization.

To What Extent Are Water Use Objectives and Water Quality Standards Being Met?
During the 1998 to 2004 extended study baseline period, the Milwaukee River partially met the water quality criteria supporting its recommended water use classification. In all of the samples taken from the mainstem of the River, temperatures were in compliance with the relevant water quality standards. In almost all of the samples taken from the mainstem of the River, concentrations of ammonia were in compliance with the relevant water quality standards. In all samples at stations below the site of the former North Avenue dam, dissolved oxygen concentrations equaled or exceeded the 2.0 mg/l special variance standard applying to the estuary. At most stations above the estuary, concentrations of dissolved oxygen in all samples equaled or exceeded the 5.0 mg/l standard for fish and aquatic life. There were three exceptions to this: concentrations of dissolved oxygen occasionally fell below 5.0 mg/l in the sections of the River above the dam at Kewaskum in Washington and Fond du Lac Counties, between Silver Spring Drive and Port Washington Road in Milwaukee County, and between Estabrook Park and the site of the North Avenue dam, also in Milwaukee County. In the estuary, concentrations of fecal coliform bacteria in the Milwaukee River were usually less than or equal to the variance standard of 1,000 cells per 100 ml. While the rate of compliance varied among stations, it was generally between 65 percent and 77 percent. In the section of the River upstream from the estuary, concentrations of fecal coliform bacteria usually exceeded the recreational use standard of 200 cells per 100 ml. Between Pioneer Road in Cedarburg and the site of the former North Avenue dam, concentrations of fecal coliform bacteria exceeded 200 cells per ml in the majority of samples. Depending upon the station, the percentage of samples in this section of the River that complied with the standard ranged between about 20 and 55 percent. Upstream from Pioneer Road, fecal coliform bacteria concentrations met, or exceeded, the standard in the majority of samples at the stations at Waubeka, Newburg, and above the dam at Kewaskum, although, at Newburg and Kewaskum, concentrations occasionally exceeded the standard. Compliance with the planning standard for total phosphorus recommended in the original regional water quality management plan was also low with the number of samples showing total phosphorus below the 0.1 mg/l planning standard ranging from 37 to 79 percent at stations along the mainstem. At most stations along the mainstem of the River, concentrations of total phosphorus were below the standard in about 37 percent to 45 percent of the samples. The exception to this generalization occurred at the downstream stations nearest to the confluence with Lake Michigan and the three stations farthest upstream. At the two stations downstream from Water Street, dissolved phosphorus concentrations were below 0.1 mg/l in 65 to 75 percent of the samples. This may reflect the influence of Lake Michigan on the water chemistry of the River. At the three stations farthest upstream dissolved phosphorus concentrations were below the recommended standard in about 64 to 78 percent of samples.

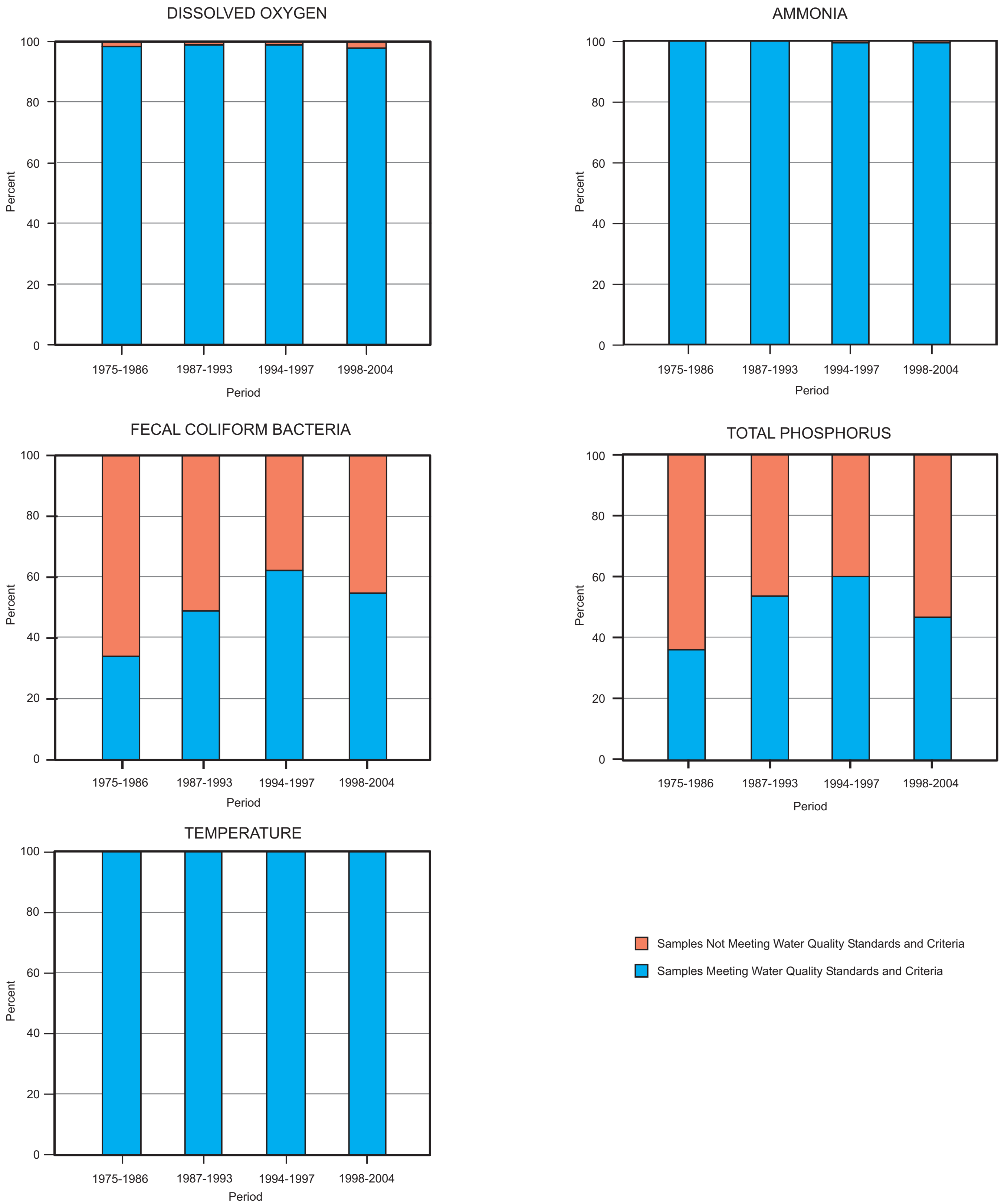
Figure 188 shows changes over time in the proportions of samples showing compliance with applicable water quality standards for the Milwaukee River. Over the entire study period of 1975-2004, water temperatures were in compliance with the applicable water quality standards in all of the samples. Over that same period, concentrations of ammonia were in compliance with the applicable water quality standards in almost all of the samples. A very small percentage of samples in each period had concentrations of dissolved oxygen that were not in compliance with the applicable water quality standard. By contrast, a significant percentage of samples collected in each period had concentrations of fecal coliform bacteria or total phosphorus that were not in compliance with the applicable water quality standard. During each period, dissolved oxygen concentrations in about 99 percent of the samples collected from the mainstem of the River were in compliance with the applicable standard. The rate of compliance with the planning standard recommended for total phosphorus in the original regional water quality management plan increased over much of the study period, but showed a decrease in the 1998-2004 baseline period. During the period 1975-1986, total phosphorus concentrations were less than or equal to 0.1 mg/l in about 36 percent of the samples collected. By the period 1994-1997, this rate of compliance had increased to 60 percent. During the baseline period of 1998-2004, the rate of compliance with the recommended total phosphorus standard decreased to 47 percent. The rate of compliance with the applicable standards for fecal coliform bacteria followed a different pattern. The percentage of samples in which the concentrations of fecal coliform bacteria were equal to or below the applicable standard increased from about 34 percent during the period 1975-1986 to about 64 percent during the period 1994-1997. During the 1998-2004 baseline period this rate of compliance decreased to about 55 percent.

Relatively few data are available for assessing whether streams tributary to the Milwaukee River are meeting water use objectives and water quality standards. Data were available to evaluate whether one or more standard was met for 19 of 76 tributary streams. In 16 tributary streams, temperatures in all samples were at or below the 31.7ºC fish and aquatic life standard. In one other tributary, Cedar Creek, temperatures were at or below the standard in the vast majority of samples. In the 15 tributary streams for which data were available, ammonia concentrations were at or below the applicable standard in all samples. Dissolved oxygen concentrations in 11 tributaries equaled or exceeded the applicable standard in all samples, indicating compliance with the standard. In four tributaries, Lincoln Creek, the North Branch Milwaukee River, Quaas Creek, and Southbranch Creek, dissolved oxygen concentrations occasionally dropped below the standard. In only one tributary, the West Branch Milwaukee River, were dissolved oxygen concentrations frequently below the standard. Fecal coliform concentrations frequently exceeded the applicable standard in four tributaries: Indian Creek, Lincoln Creek, the North Branch Milwaukee River, and Southbranch Creek. In the North Branch Milwaukee River and Southbranch Creek, concentrations of fecal coliform bacteria were out of compliance with the standard in the majority of samples. By contrast, concentrations of fecal coliform bacteria only occasionally exceeded the applicable standard in Cedar Creek. Concentrations of fecal coliform bacteria in the East Branch Milwaukee River were at or below the applicable standard in all samples collected. Total phosphorus concentrations exceeded the 0.1 mg/l planning standard recommended in the original regional water quality management plan in most tributaries for which data were available. In three tributaries, Polk Springs Creek, Southbranch Creek, and Wallace Creek, total phosphorus concentrations exceeded the recommended planning standard in the majority of samples. In eight more tributaries, Batavia Creek, Indian Creek, Kewaskum Creek, Lincoln Creek, the North Branch Milwaukee River, Parnell Creek, Quaas Creek, and the West Branch Milwaukee River, total phosphorus concentrations frequently exceeded the recommended standard. In three more tributaries, Cedar Creek, the East Branch Milwaukee River, and Friedens Creek, total phosphorus concentrations occasionally exceeded the recommended standard. In only four tributaries, Crooked Lake Creek, Mole Creek, Pigeon Creek, and Stony Creek, were total phosphorus concentrations at or below the recommended standard in all samples.

Two sections of stream in the Milwaukee River are listed as impaired pursuant to Section 303(d) of the Clean Water Act. The mainstem of the Milwaukee River below the site of the former North Avenue dam is considered impaired due to aquatic toxicity, bacterial contaminations, concentrations of dissolved oxygen which do not meet the applicable water quality standard, and fish consumption advisories necessitated by the concentrations of PCBs in the tissue of fish collected in this reach. The mainstem of the Milwaukee River in Milwaukee and Ozaukee Counties is considered impaired due to bacterial contamination and fish consumption advisories necessitated by

Figure 188

PROPORTION OF SAMPLES MEETING WATER QUALITY STANDARDS AND CRITERIA FOR SEVERAL CONSTITUENTS IN THE MAINSTEM OF THE MILWAUKEE RIVER: 1975-2004



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

the concentrations of PCBs in the tissue of fish collected in this reach. Reaches in several tributary streams are also considered impaired. Adell Tributary, Evergreen Creek, Jackson Creek, and Lehner Creek are considered impaired due to habitat degradation. Lehner Creek is also considered impaired due to high water temperatures. Beaver Creek is considered impaired due to aquatic toxicity. A five-mile section of Cedar Creek between Bridge Road in the City of Cedarburg and the confluence with the Milwaukee River is considered impaired due to fish consumption advisories necessitated by high concentrations of PCBs in the tissue of fish collected from this reach. PCBs from contaminated sediments are cited as factors contributing to the impairment of this section of Cedar Creek. Indian Creek downstream from IH 43, which is classified as a variance water, is considered impaired due to aquatic toxicity, degraded habitat, lack of compliance with standards for dissolved oxygen concentration, and high temperatures. Lincoln Creek, which is classified as a variance water, is considered impaired due to aquatic toxicity, degraded habitat, lack of compliance with standards for dissolved oxygen concentration, and high temperatures.

Some toxic substances have been detected in the Milwaukee River watershed at concentrations that may impair beneficial uses. Concentrations of mercury in water samples taken from the Milwaukee River often exceeded both the human threshold concentration for public health and welfare and the wildlife criterion for surface water quality. In addition, concentrations of copper in water samples occasionally exceeded the USEPA's criterion maximum concentration. Concentrations of mercury and copper in water occasionally exceeded both of these standards in Lincoln Creek and in Southbranch Creek. Concentrations of PCBs in water samples collected from the mainstem of the Milwaukee River below the confluence with Cedar Creek and from Lincoln Creek exceeded the wildlife criterion for surface water quality occasionally to often, depending upon the sampling station. Concentrations of PCBs in almost all water samples collected from Cedar Creek exceeded the wildlife criterion for surface water quality. Concentrations of PCBs in tissue of several species of fish collected from the mainstem of the Milwaukee River below Grafton and Cedar Creek below Bridge Road in Cedarburg are high enough that special consumption advisories have been issued. The statewide consumption advisory for mercury also applies to the watershed.

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Chapter VIII

SURFACE WATER QUALITY CONDITIONS AND SOURCES OF POLLUTION IN THE OAK CREEK WATERSHED

INTRODUCTION AND SETTING WITHIN THE STUDY AREA

A basic premise of the Commission watershed studies is that the human activities within a watershed affect, and are affected by, surface and groundwater quality conditions. This is especially true in the urban and urbanizing areas of the Oak Creek watershed, where the effects of human activities on water quality tend to overshadow natural influences. The hydrologic cycle provides the principal linkage between human activities and the quality of surface and ground waters in that the cycle transports potential pollutants from human activities to the environment and from the environment into the sphere of human activities.

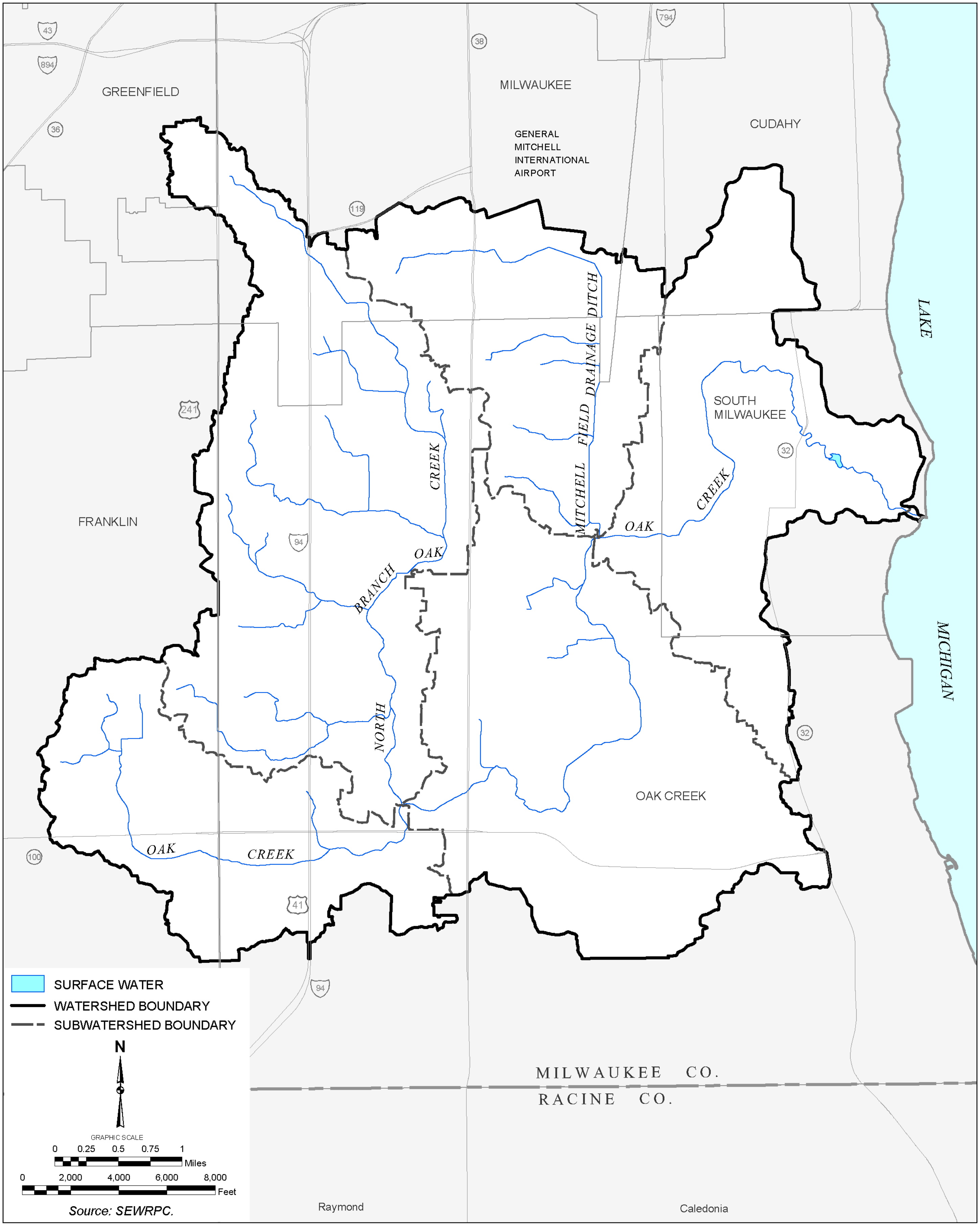
Comprehensive water quality planning efforts such as the regional water quality management plan update, should include an evaluation of historical, present, and anticipated water quality conditions and the relationship of those conditions to existing and probable future land and water uses. The purpose of this chapter is to determine the extent to which surface waters in the Oak Creek watershed have been and are polluted, and to identify the probable causes for, or sources of, that pollution. More specifically, this chapter documents current surface water pollution problems in the watershed utilizing field data from a variety of water quality studies, most of which were conducted during the past 30 years; indicates the location and type of the numerous and varied sources of wastewater, industrial, stormwater runoff, and other potential pollutants discharged to the surface water system of the watershed; describes the characteristics of the discharges from those sources; and, to the extent feasible, quantifies the pollutant contribution of each source. The information presented herein provides an important basis for the development and testing of the alternative water quality control plan elements under the regional water quality management plan update.

DESCRIPTION OF THE WATERSHED

The Oak Creek watershed is located in the east central portion of the Southeastern Wisconsin Region and covers an area of approximately 27 square miles. The Oak Creek originates in southern Milwaukee County and flows approximately 14 miles in a northeasterly direction to its confluence with Lake Michigan. Rivers and streams in the watershed are part of the Lake Michigan drainage system as the watershed lies east of the subcontinental divide. The boundaries of the basin, together with the locations of the main channels of the Oak Creek watershed and its principal tributaries, are shown on Map 73. The Oak Creek watershed contains no lakes with a surface area of 50 acres or more.

Map 73

SURFACE WATER WITHIN THE OAK CREEK WATERSHED: 2000



Source: SEWRPC.

Civil Divisions
Superimposed on the watershed boundary is a pattern of local political boundaries. As shown on Map 74, the watershed lies entirely within Milwaukee County. Six civil divisions lie in part or entirely within the Oak Creek watershed, as also shown on Map 74 and Table 129. Geographic boundaries of the civil divisions are an important factor which must be considered in the regional water quality management plan update since the civil divisions form the basic foundation of the public decision making framework within which intergovernmental, environmental, and developmental problems must be addressed.

LAND USE

This section describes the changes in land use which have occurred within the Oak Creek watershed since 1970, the approximate base year of the initial regional water quality management plan, and indicates the changes in such land uses since 1990, the base year of the initial plan update (see Table 130). Although the watershed is largely urbanized, 39 percent of the watershed was still in rural and other open space land uses in 2000. These rural and open space uses included about 14 percent of the total area of the watershed in unused and other open lands and about 1.2 percent in surface water and wetlands. Most of the rural and open spaces remaining in the watershed are located in Milwaukee County scattered throughout the City of Oak Creek. The remaining approximately 61 percent of the total watershed was devoted to urban uses, as shown on Map 75.

Urban development exists throughout almost the entire Oak Creek watershed. Urban land use in the watershed increased from about 14.0 square miles in 1990 to about 16.9 square miles in 2000, an increase of about 21 percent. As shown in Table 130, residential land represents the largest urban land use in the watershed. Since 1990, most, though not all, of the urban growth in the watershed has occurred in the southern portion of the watershed in the Cities of Franklin, Oak Creek, and South Milwaukee. The historic urban growth within the Oak Creek watershed is summarized on Map 76 and Table 131.

The 2020 land use plan discourages scattered, low density urban development.[1] Much of the changes in urban lands within the Oak Creek watershed are due to new development of rural lands.

The changes in land use reflect changes in population and population distribution within the watershed. Several trends are apparent in the data. Over the long term the number of persons living in the watershed has increased. From 1970 through 1990, the population in the watershed increased from 38,162 to 43,301, representing an additional 5,139 persons, or a 13 percent increase. Over the same time period the number of households increased from 10,456 to 16,526, an increase of 6,070, or about 58 percent. Between 1990 and 2000, the size of the population in the watershed grew more quickly, increasing by 7,732 to a total of 51,033 persons, which is an increase of 18 percent. During that decade of increasing population numbers, the number of households in the watershed increased by 4,425 units to 20,951, which is an increase of about 27 percent.

QUANTITY OF SURFACE WATER

Since 1963, measurements of discharge have been taken at one location along Oak Creek: a U.S. Geological Survey (USGS) stream gauge station at 15th Avenue in the City of South Milwaukee. Figure 189 shows historical and baseline period discharge for this station. Mean monthly streamflow rises to a peak in March associated with spring snowmelt and rains. It then declines relatively rapidly through the spring and more slowly during summer to reach its annual minimum in September. Following this, it increases slightly through the autumn. Considerable variability is associated with these patterns, but some of this variability is more likely attributed to sampling conditions rather than actual changes in discharge.

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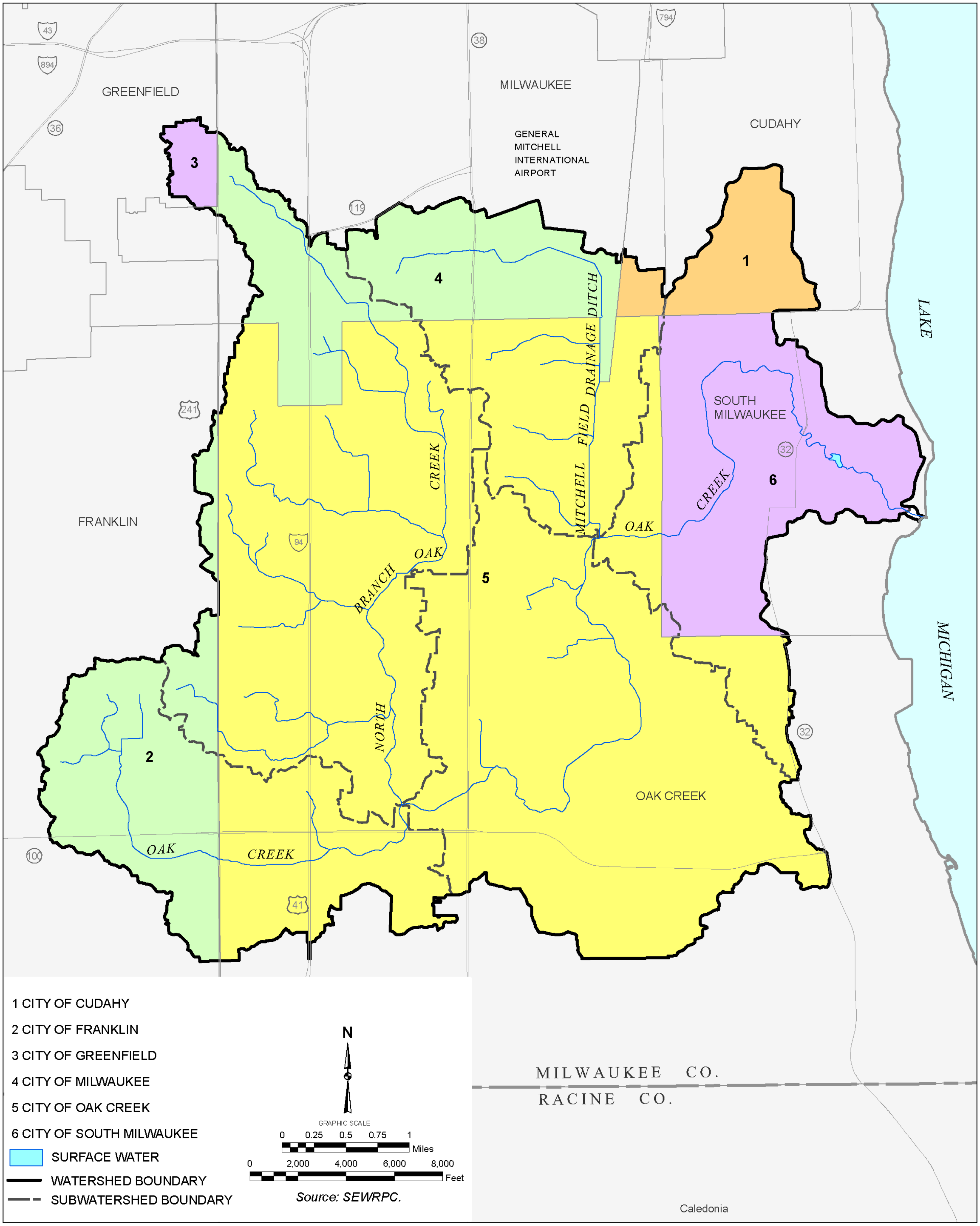
[1]*SEWRPC Planning Report No. 45,* A Regional Land Use Plan for Southeastern Wisconsin: 2020, *December 1997.*

Map 74

CIVIL DIVISIONS WITHIN THE OAK CREEK WATERSHED: 2000



Source: SEWRPC.

Table 129

AREAL EXTENT OF COUNTIES, CITIES, VILLAGES, AND TOWNS WITHIN THE OAK CREEK WATERSHED

Civil Division	Area (square miles)	Percent of Total
Milwaukee County		
City of Cudahy	0.99	3.60
City of Franklin	2.59	9.45
City of Greenfield	0.23	0.85
City of Oak Creek	17.44	63.61
City of Milwaukee	2.90	10.58
City of South Milwaukee	3.26	11.91
Total	27.41	100.00

Source: SEWRPC.

Table 130

LAND USE IN THE OAK CREEK WATERSHED: 1970-2000[a,b]

Category	1970		1990		2000		Change 1970-2000	
	Square Miles	Percent of Total	Square Miles	Percent of Total	Square Miles	Percent of Total	Square Miles	Percent
Urban								
Residential	4.7	17.0	6.0	21.7	7.3	26.4	2.6	55.3
Commercial	0.4	1.4	0.7	2.5	1.0	3.6	0.6	150.0
Industrial and Extractive	0.8	2.9	1.2	4.3	1.4	5.1	0.6	75.0
Transportation, Communication, and Utilities[c]	3.8	13.7	4.5	16.2	5.3	19.1	1.5	39.5
Governmental and Institutional	0.6	2.2	0.8	2.9	1.0	3.6	0.4	66.7
Recreational	0.8	2.9	0.8	2.9	0.9	3.2	0.1	12.5
Subtotal	11.1	40.1	14.0	50.5	16.9	61.0	5.8	52.3
Rural								
Agricultural and Related	10.7	38.6	7.6	27.4	4.6	16.6	-6.1	-57.0
Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wetlands	0.8	2.9	0.8	2.9	1.2	4.2	0.4	50.0
Woodlands	1.4	5.1	1.3	4.7	1.2	4.2	-0.2	-14.3
Unused and Other Open Lands	3.7	13.3	4.0	14.5	3.9	14.0	0.2	5.4
Subtotal	16.6	59.9	13.7	49.5	10.8	39.0	-5.8	-34.9
Total	27.7	100.0	27.7	100.0	27.7	100.0	0.0	- -

[a]*As approximated by whole U.S. Public Land Survey one-quarter sections.*

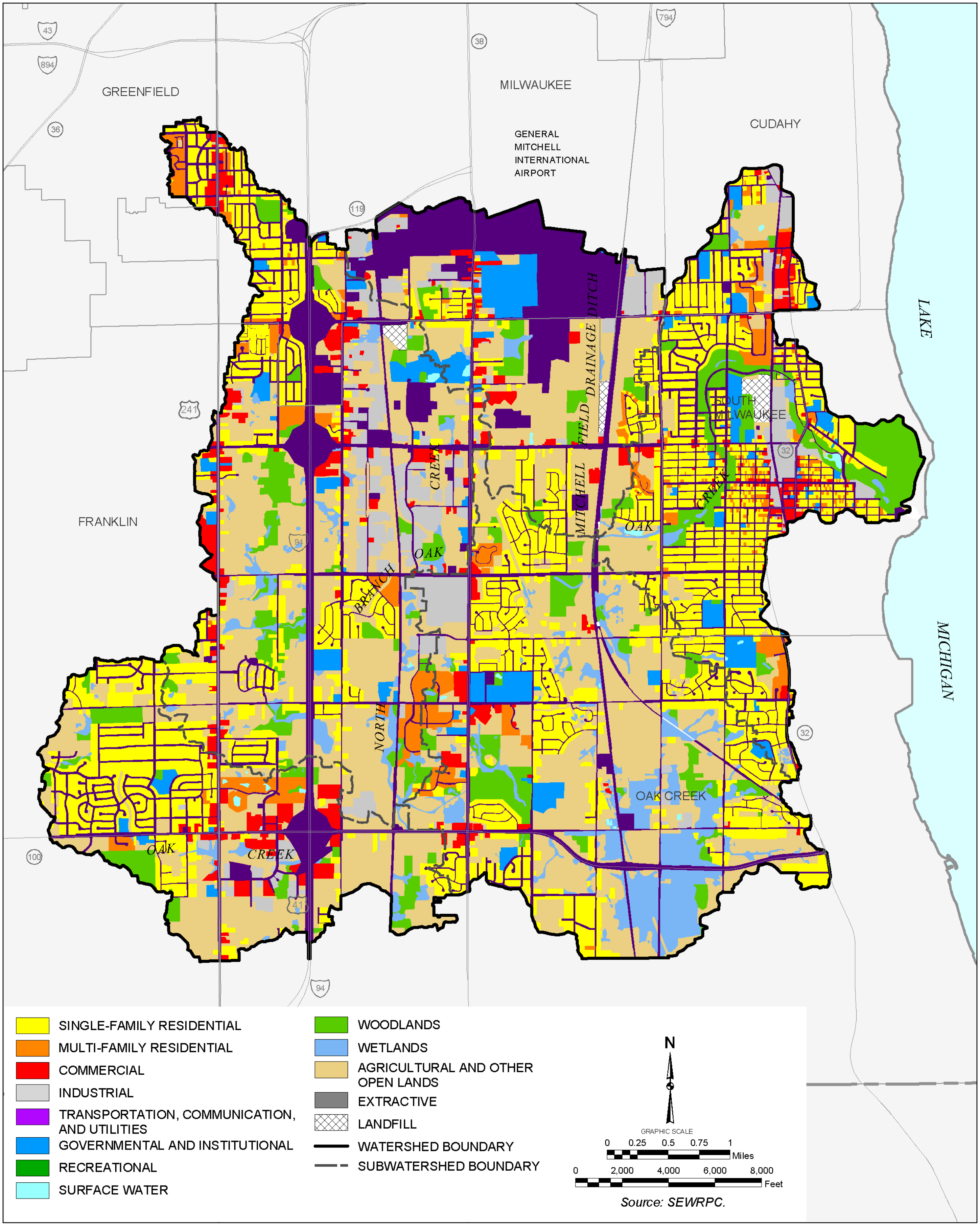
[b]*As part of the regional land use inventory for the year 2000, the delineation of existing land use was referenced to real property boundary information not available for prior inventories. This change increases the precision of the land use inventory and makes it more usable to public agencies and private interests throughout the Region. As a result of the change, however, year 2000 land use inventory data are not strictly comparable with data from the 1990 and prior inventories. At the county and regional level, the most significant effect of the change is to increase the transportation, communication, and utilities category, the result of the use of narrower estimated right-of-ways in prior inventories. The treatment of streets and highways generally diminishes the area of adjacent land uses traversed by those streets and highways in the 2000 land use inventory relative to prior inventories.*

[c]*Off-street parking of more than 10 spaces are included with the associated land use.*

Source: SEWRPC.

Map 75

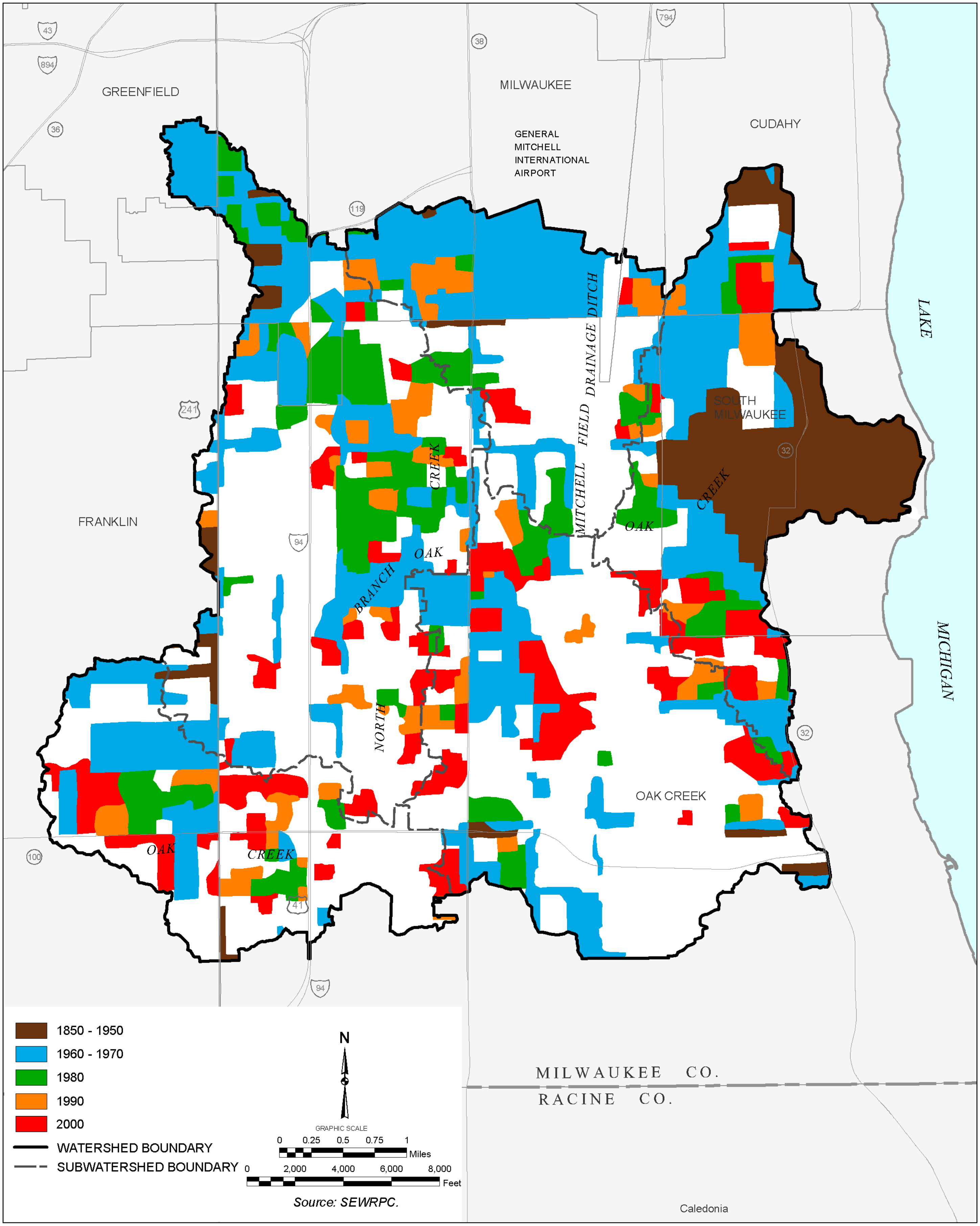
EXISTING LAND USE WITHIN THE OAK CREEK WATERSHED: 2000



Source: SEWRPC.

Map 76

HISTORICAL URBAN GROWTH WITHIN THE OAK CREEK WATERSHED: 1850-2000



Source: SEWRPC.

Table 131

EXTENT OF URBAN GROWTH WITHIN THE OAK CREEK WATERSHED: 1850-2000

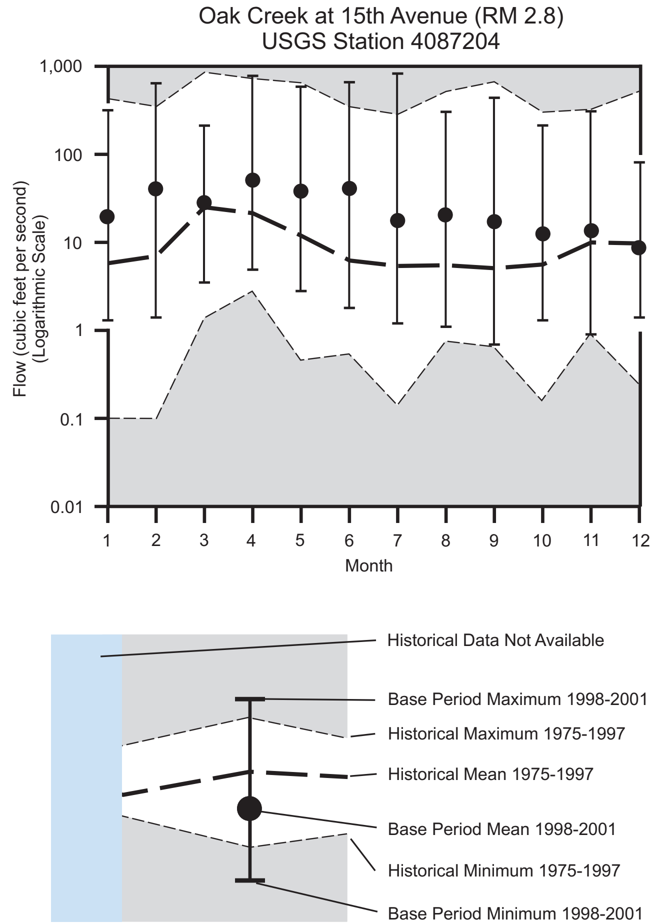
Year	Extent of New Urban Development Occurring Since Previous Year (acres)[a]	Cumulative Extent of Urban Development (acres)[a]	Cumulative Extent of Urban Development (percent)[a]
1850	8	8	0.0
1880	10	18	0.1
1900	72	90	0.5
1920	550	640	3.5
1940	139	779	4.3
1950	678	1,458	8.1
1963	2,918	4,375	24.3
1970	1,562	5,938	32.9
1975	687	6,625	36.7
1980	851	7,476	41.4
1985	436	7,912	43.9
1990	510	8,422	46.7
1995	796	9,218	41.1
2000	763	9,981	55.3

[a]*Urban development, as defined for the purposes of this discussion, includes those areas within which houses or other buildings have been constructed in relatively compact groups, thereby indicating a concentration of urban land uses. Scattered residential developments were not considered in this analysis.*

Source: U.S. Bureau of the Census and SEWRPC.

Figure 189

HISTORICAL AND BASE PERIOD FLOW ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



Source: U.S. Geological Survey and SEWRPC.

Baseline period stream flow in Oak Creek tended to be higher than that seen during the historical period. While the range of baseline period stream flow was generally within historical ranges, during most months mean stream flow during the baseline period was higher than mean stream flow during the historical period. Monthly minimum stream flow during most months of the baseline period was higher than the historical monthly minima, in some months by about a factor of eight. In June and July, monthly maximum stream flows during the base period were higher than historical maxima. These trends suggest that baseflow has increased in Oak Creek.

Because data were available from only one station, flow fractions were not calculated for the Oak Creek watershed.

SURFACE WATER QUALITY OF THE OAK CREEK WATERSHED: 1975-2001

The earliest systematic collection of water quality data in the Oak Creek watershed occurred in the mid-1960s.[2] Data collection after that was sporadic until the 1970s. Since then, considerable data have been collected, especially on the mainstem of Oak Creek. The major sources of data include the Milwaukee Metropolitan

[2]*SEWRPC Technical Report No. 4,* Water Quality and Flow of Streams in Southeastern Wisconsin*, April 1964.*

Sewerage District (MMSD), the Wisconsin Department of Natural Resources (WDNR), the USGS, and the U.S. Environmental Protection Agency's (USEPA) STORET legacy and modern databases (see Map 77). In addition, Commission staff reviewed data collected by citizen monitoring programs including the Testing the Waters Program. These data are presented in Appendix B. The largest portion of data was collected by MMSD. Most of these data were obtained from sampling stations along the mainstem of the Creek. In addition, sufficient data were available for the Mitchell Field Drainage Ditch to assess baseline period water quality for some water quality parameters. The data record for the other tributary streams in the watershed is fragmentary.

For analytical purposes, data from four time periods were examined: 1975-1986, 1987-1993, 1994-1997, and 1998-2001. Continuous bimonthly data records exist from one of MMSD's long-term monitoring stations beginning in 1975. After 1986, MMSD no longer conducted sampling during the winter months. In 1994, the Inline Storage System (ISS), or Deep Tunnel, came online. The remaining period from 1998-2001 defines the baseline water quality conditions of the river system, developed since the ISS came online. These periods were chosen to facilitate comparisons between water quality trends in the Oak Creek watershed and the other watersheds in the regional water quality management plan update study area. While operation of the ISS would not be expected to have as direct an effect on instream water quality in the Oak Creek watershed as it does in the Kinnickinnic River, Menomonee River, and Milwaukee River watersheds, the ISS and the related MMSD water pollution abatement program and local sewerage system improvements have reduced separate sanitary sewer overflows in the Oak Creek watershed.

Under this plan update, baseline water quality conditions were graphically compared to historical conditions on a monthly basis. For each water quality parameter examined, the background of the graph summarizes the historical conditions. The white area in the graphs shows the range of values observed during the period 1975-1997. The upper and lower boundaries between the white and gray areas show historical maxima and minima, respectively. A blue background indicates months for which no historical data were available. The black dash line plots the monthly mean value of the parameter for the historical period. Overlaid on this background is a summary of baseline conditions from the period 1998-2001. The black dots show the monthly mean value of the parameter for that period. The black bars show the monthly ranges of parameter for the same period.

In addition to this summarization, water quality parameters from Oak Creek were examined for the presence of several different types of trends: changes along the length of the Creek, changes at individual sampling stations over time, and seasonal changes throughout the year. Because Oak Creek does not discharge into the Milwaukee River estuary, comparisons between the means at upstream and estuary sites were not appropriate and were not done. Map 77 and Table 132 show the seven MMSD sampling stations on Oak Creek, designated by their River Mile locations, which had sufficiently long periods of sampling to be used for this analysis. Figure 190 shows photographs of selected river sampling stations along the mainstem of Oak Creek. Trends were examined along a section of Oak Creek from the confluence with Lake Michigan to a station 10.06 miles upstream. Changes over time were assessed both on an annual and on a seasonal basis as set forth in Appendix C. It is important to note that only limited data were available to assess baseline water quality conditions for tributary streams.

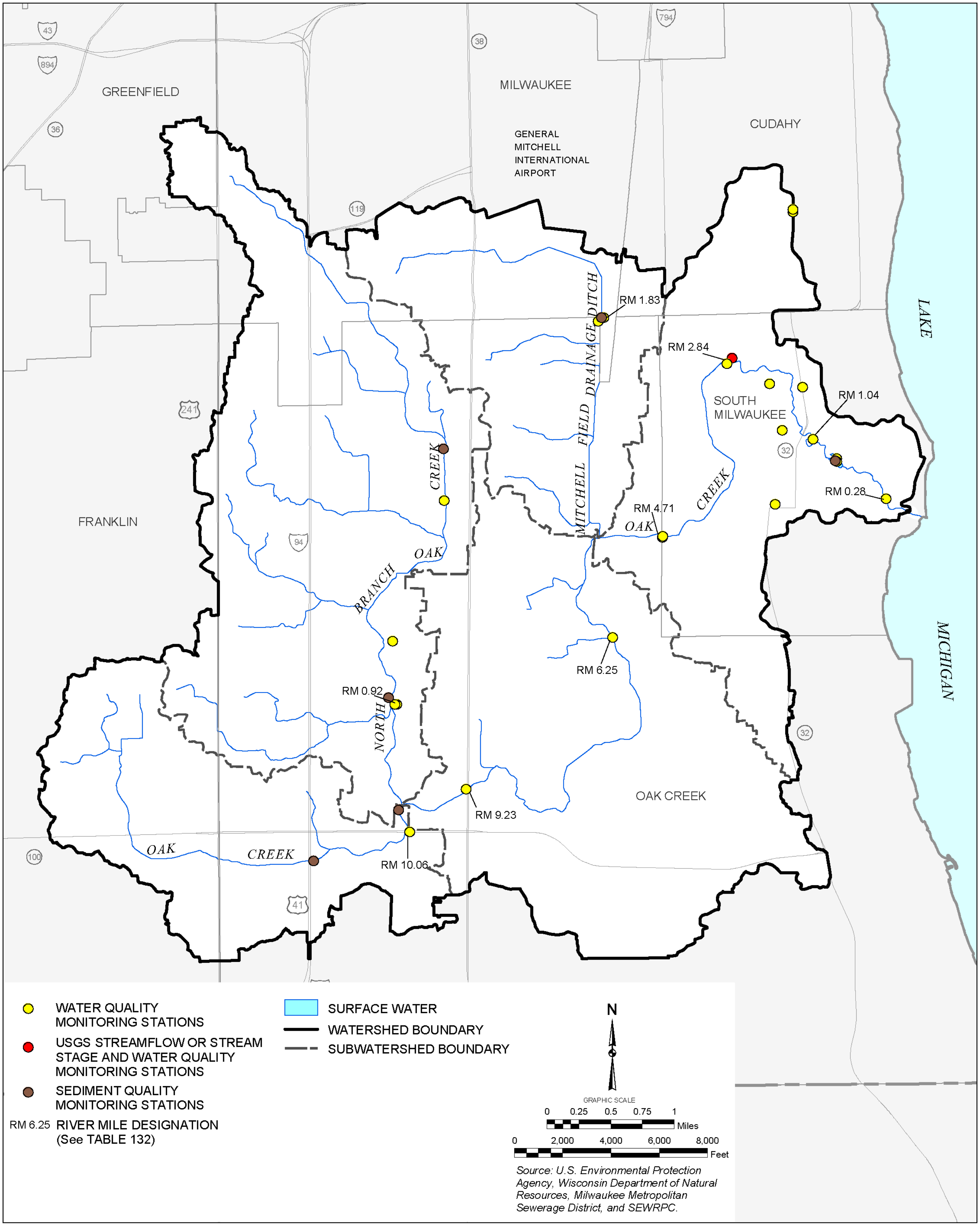
Bacterial and Biological Parameter*s*

Bacteria

As shown in Figure 191, median concentrations of fecal coliform bacteria in Oak Creek ranged from about 430 to 930 cells per 100 milliliters (ml). Fecal coliform counts in the Creek varied over five orders of magnitude, ranging from as low as one cell per 100 ml to 93,000 cells per 100 ml. The range of variability appears to be higher during the summer and fall as shown in Figure 192, although it is important to note that this may reflect the larger numbers of samples that were taken during the summer and fall than during the spring and winter. During the spring and fall, baseline period monthly mean concentrations of fecal coliform bacteria at most sampling stations are greater than the historical monthly means. During the summer, baseline period monthly mean concentrations of fecal coliform bacteria are near or below historical monthly means. It is important to note that counts in most samples exceed the standard for full recreational use of 200 cells per 100 ml.

Map 77

WATER AND SEDIMENT QUALITY MONITORING STATIONS WITHIN THE OAK CREEK WATERSHED: 1975-2001



Source: U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Table 132

SAMPLE SITES USED FOR ANALYSIS OF WATER QUALITY TRENDS IN OAK CREEK

Location	River Mile	Period of Record	Data Sources
Tributaries			
Mitchell Field Drainage Ditch at College Avenue	1.8[a]	1998-2001	USGS, USEPA
North Branch of Oak Creek at Puetz Road	0.9[a]	1975-1976, 1990, 1996	USEPA
Mainstem			
Oak Creek at Ryan Road	10.1[b]	1985-2001	MMSD
Oak Creek at STH 38	9.2[b]	1985-2001	MMSD
Oak Creek at Forest Hill Road	6.3[b]	1985-2001	MMSD
Oak Creek at Pennsylvania Avenue	4.7[b]	1975-1976, 1985-2001	MMSD, USEPA
Oak Creek at 15th Avenue	2.8[b]	1972-1982, 1984-2001, 2004	MMSD, USGS
Oak Creek at Oak Creek Parkway East of STH 32	1.0[b]	1985-2001	MMSD
Oak Creek at Oak Creek Parkway East of Lake Drive	0.3[b]	1995-2001	MMSD

[a]*River Mile is measured at a distance upstream from the confluence with Oak Creek.*

[b]*River Mile is measured at a distance upstream from the confluence with Lake Michigan.*

Source: SEWRPC.

As shown in Table C-4 in Appendix C, few time-based trends in fecal coliform bacteria concentrations were detected in Oak Creek. When analyzed on an annual basis, only one long-term sampling station experienced a trend toward increasing fecal coliform concentrations. No statistically significant trends were detected at any station when the data were examined by season. This suggests that few changes have occurred in fecal coliform concentrations in Oak Creek. As shown in Table 133, no trends were detected in fecal coliform bacteria concentrations along the length of the Creek. At most sites along the Creek, fecal coliform concentrations tend to be positively correlated with concentrations of both total nitrogen and total phosphorus. In addition, positive correlations are seen at some sites with concentrations of dissolved phosphorus and inorganic nitrogen compounds. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the Creek.

Few samples for *E. coli* are available for the Oak Creek watershed. During 2004, three samples were taken at the 15th Avenue station. Concentrations of *E. coli* in these samples ranged from 93 cells per 100 ml to 1,300 cells per 100 ml with a mean concentration of 574 cells per 100 ml. These data are not sufficient to assess trends through regression analysis or to determine whether there are seasonal patterns to the numbers of these bacteria in the Creek (see Table C-4 in Appendix C of this report).

*Chlorophyll-*a

Over the period of record, the mean concentration of chlorophyll-*a* in Oak Creek was 4.67 micrograms per liter (μg/l). Individual samples of this parameter ranged from 0.020 μg/l to 178.9 μg/l. In addition, each station had samples with concentrations in excess of 25 μg/l. Figure 193 shows that chlorophyll-*a* concentrations at most stations along Oak Creek increased after 1993, and then concentrations decreased slightly after 1997. As shown in Table C-4 in Appendix C of this report, statistically significant increasing trends in chlorophyll-*a* concentration were detected at three stations. In addition, chlorophyll-*a* concentrations in the Creek tend to increase from upstream to downstream (see Table 133). Chlorophyll-*a* concentrations in Oak Creek are negatively correlated with alkalinity at most stations. This reflects the role of carbon dioxide in both photosynthesis and the activity of carbon dioxide dissolved in water. When carbon dioxide dissolves in water, it combines with water to form carbonic acid. This can dissociate to release bicarbonate and carbonate ions. Alkalinity is a measure of these forms of inorganic carbon in water. During photosynthesis algae and plants remove carbon dioxide from the water, reducing alkalinity. At two stations, chlorophyll-*a* concentrations are also positively correlated with water temperatures. Since chlorophyll-*a* in the water strongly reflects algal productivity, this probably reflects the

Figure 190

SAMPLING LOCATIONS ALONG THE MAINSTEM OF OAK CREEK: 2003

OAK CREEK AT RIVER MILE 12.02

OAK CREEK AT RIVER MILE 2.85

OAK CREEK AT RIVER MILE 7.48

OAK CREEK AT RIVER MILE 1.04

OAK CREEK AT RIVER MILE 5.18

OAK CREEK AT RIVER MILE 0.28

Source: Milwaukee County and Inter-Fluve, Inc.

higher growth rates that photosynthetic organisms are able to attain at higher temperature. The increases in chlorophyll-*a* concentrations at three stations represent a reduction in water quality over time.

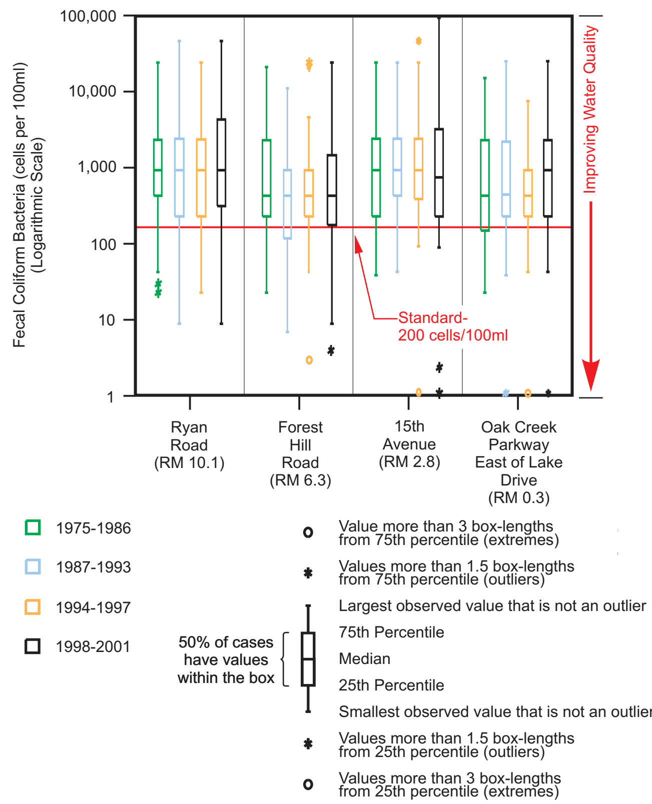
Chemical and Physical Parameters

Temperature

As shown in Figure 194, the annual median water temperature in Oak Creek during the period 1998-2001 ranged from 13.0 degrees Celsius (ºC) at the sampling station at Ryan Road up to 15.7ºC at the station at the Oak Creek Parkway site east of Lake Drive. As shown in Table 133, temperatures in Oak Creek show a statistically significant trend toward increasing from upstream to downstream. Figure 195 shows that while water temperatures from the baseline period tend to be within historical ranges, monthly mean baseline period water temperatures generally tend to be the same or somewhat higher than historical monthly means. With the higher temperatures occurring during the summer and fall. The apparent increases may not represent a significant difference given that few trends over time were detected in temperatures along the Creek (see Table C-4 in Appendix C).

Figure 191

FECAL COLIFORM BACTERIA CONCENTRATIONS ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



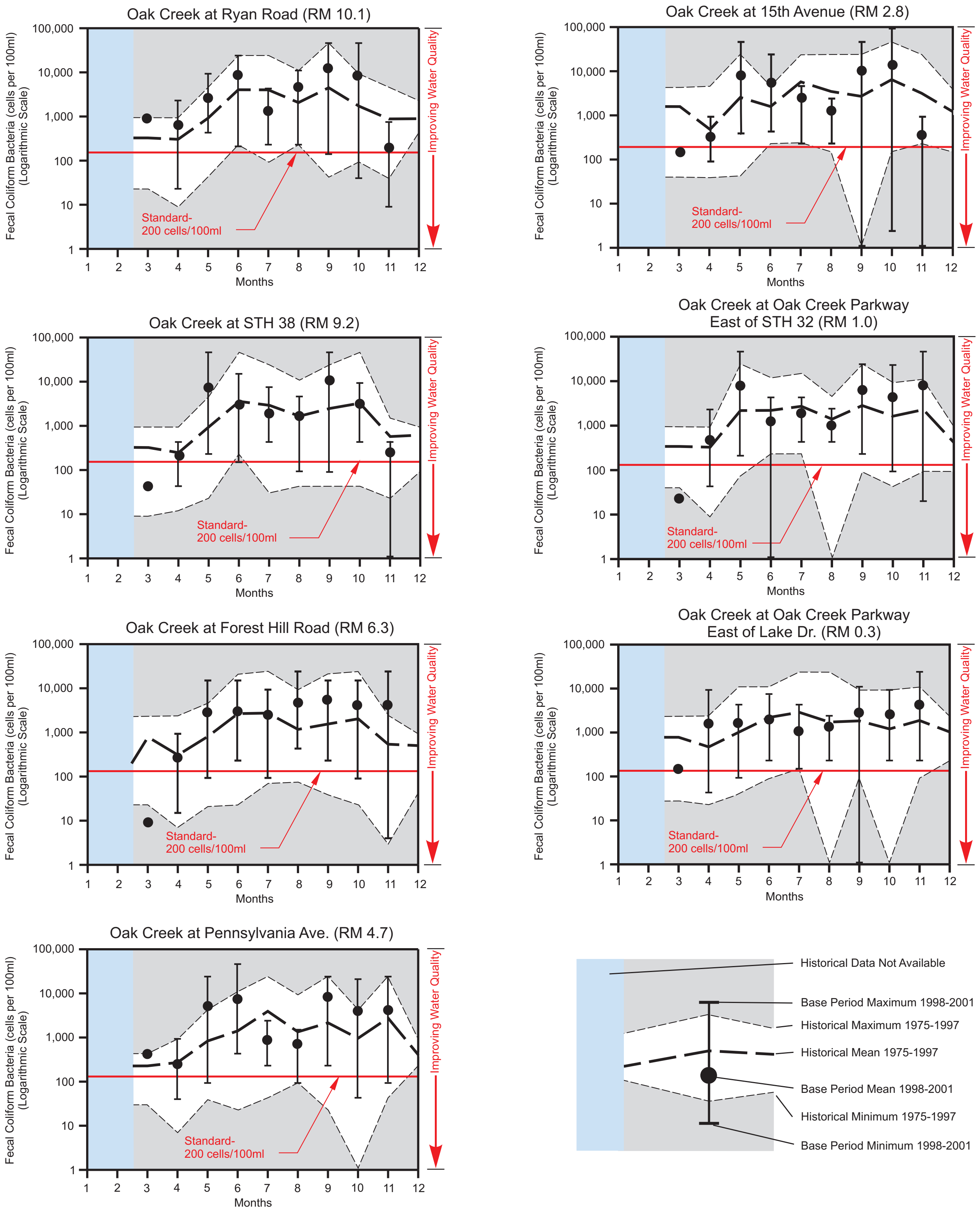
Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Due to the complexity of these temperature trends, they were further analyzed using a three-factor analysis of variance. This type of analysis tests for statistically significant differences among mean temperatures based upon three different factors which may account for any differences. In addition, it tests for significant effects on mean temperatures of any interactions between the factors. In this instance, the independent factors examined were sampling station, the time periods 1975-1986, 1987-1993, 1994-1997, and 1998-2001, and season. Data from winter months were not included in this analysis because of the small number of samples taken during the winter. The results of this analysis suggest that water temperature at the sampling station farthest upstream, the Ryan Road station, are significantly cooler than those at the other stations. The analysis did not detect any differences among the time periods.

Figure 196 shows continuously recorded water temperature data that were collected during late summer and early fall 2004 at two sites in the Oak Creek watershed: the mainstem of Oak Creek near CTH V and the Mitchell Field Drainage Ditch just upstream from the confluence with Oak Creek. There are several noteworthy features in the patterns of variation shown. The overall pattern of temperature variation is similar at both sites. At both sites there are strong daily cycles in water temperature that are driven by changes in air temperature and solar heating over the course of the day. The range of these daily fluctuations varies from about 0.6ºC to 6.1ºC. The average range in water temperature at the site along Oak Creek was 3.2ºC. The average range in water temperature at the site along the Mitchell Field Drainage Ditch was 2.5ºC. This diurnal cycle is overlaid upon longer period fluctuations and trends. The longest period trend that is apparent in the data is cooling of the water temperature as part of the seasonal cycle. Intermediate period fluctuations associated with weather systems are also present. During August, water temperatures tend to be similar at both sites. During September, warmer water temperatures and a narrower range of daily temperature variations were recorded at the site along the Mitchell Field Drainage Ditch.

Figure 192

HISTORICAL AND BASE PERIOD FECAL COLIFORM BACTERIA ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Table 133

UPSTREAM TO DOWNSTREAM TRENDS IN WATER QUALITY PARAMETERS FROM SITES ALONG THE MAINSTEM OF OAK CREEK 1975-2001[a]

Constituent	Trend	Slope	Intercept	R^2
Bacteria and Biological				
Fecal Coliform[b]	0	- -	- -	- -
E. coli	- -	- -	- -	- -
Chlorophyll-*a*[b]	⬆	-0.38	0.64	0.10
Chemical				
Alkalinity	0	- -	- -	- -
Biochemical Oxygen Demand[b]	0	- -	- -	- -
Chloride[b]	⬇	0.01	2.08	0.03
Dissolved Oxygen	⬆	-0.26	9.62	0.11
Hardness	0	- -	- -	- -
pH	⬆	-0.04	7.92	0.15
Specific Conductance	⬇	15.30	1,045.70	0.03
Temperature	⬆	-0.13	15.10	0.01
Suspended Material				
Total Suspended Sediment	- -	- -	- -	- -
Total Suspended Solid	⬆	-1.02	14.40	<0.01
Nutrients				
Ammonia[b]	⬇	0.01	-1.01	0.01
Kjeldahl Nitrogen[b]	0	- -	- -	- -
Nitrate[b]	⬆	<-0.01	-0.41	<0.01
Nitrite[b]	0	- -	- -	- -
Organic Nitrogen[b]	0	- -	- -	- -
Total Nitrogen[b]	0	- -	- -	- -
Dissolved Phosphorus[b]	⬇	0.01	-1.76	0.01
Total Phosphorus[b]	0	- -	- -	- -
Metals				
Arsenic[b]	0	- -	- -	- -
Cadmium[b]	0	- -	- -	- -
Chromium[b]	0	- -	- -	- -
Copper[b]	0	- -	- -	- -
Lead[b]	0	- -	- -	- -
Mercury[b]	0	- -	- -	- -
Nickel[b]	0	- -	- -	- -
Zinc[b]	0	- -	- -	- -

NOTE: The following symbols were used:

⬆ indicates a statistically significant increase from upstream to downstream.

⬇ indicates a statistically significant decrease from upstream to downstream.

0 indicates that no trend was detected.

R^2 indicates the fraction of variance accounted for by the regression.

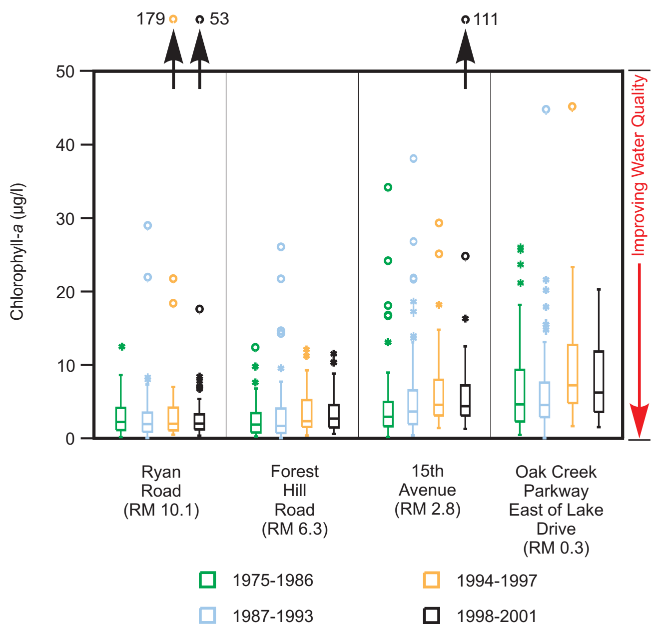
[a]*Trends were assessed through linear regression analysis. Values of water quality parameters were regressed against River Mile. A trend was considered significant if the regression showed a significant slope at P = 0.05 or less. Higher R^2 values indicate that higher portions of the variation in the data are attributable to the trend. Lower R^2 values indicate that more of the variation is due to random factors.*

[b]*These data were log-transformed before being entered into regression analysis.*

Source: SEWRPC.

Figure 193

CHLOROPHYLL-*a* CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF OAK CREEK: 1975-2001

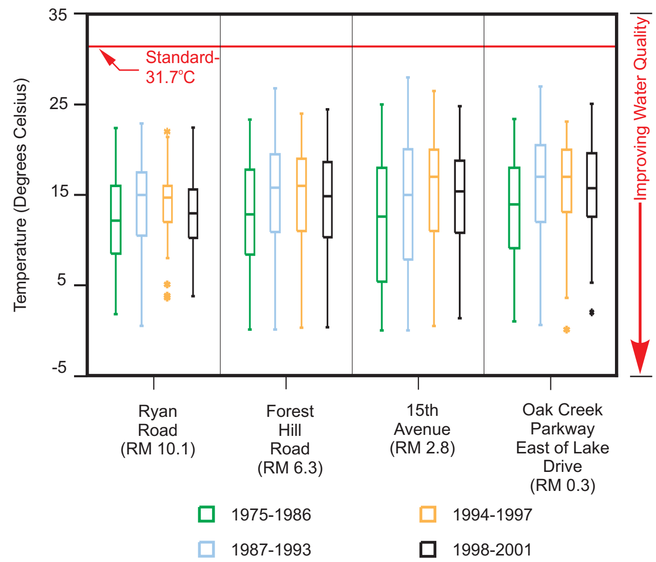


NOTE: See Figure 191 for description of symbols.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 194

WATER TEMPERATURE AT SITES ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



NOTE: See Figure 191 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Alkalinity

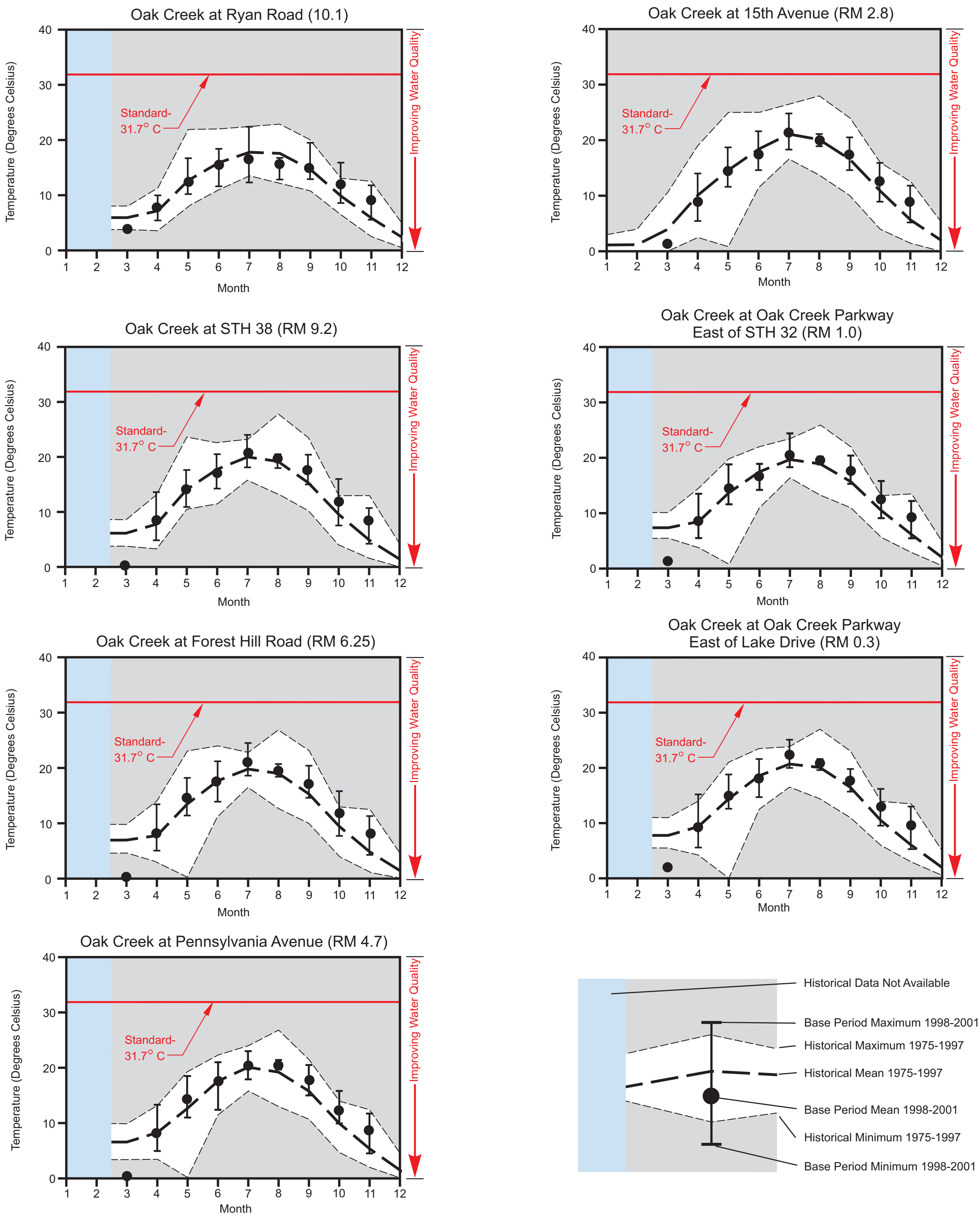
The mean value of alkalinity in Oak Creek over the period of record was 247.3 milligrams per liter expressed as the equivalent concentration of calcium carbonate (mg/l as $CaCO_3$). The data show moderate variability, ranging from 7.0 to 401 milligrams per liter (mg/l). The analyses in Table 133 show no evidence of upstream to downstream trends in alkalinity along the mainstem of the Creek. Few stations showed any evidence of trends in alkalinity over time (see Table C-4 in Appendix C). A strong seasonal pattern in alkalinity is apparent at all stations. Alkalinity concentrations in the Creek are low in late winter or early spring. They increase to a peak that occurs in late spring. Following this they rapidly decline to a low point in mid summer. This is followed by a gradual increase during late summer and fall months to a second peak in late fall. There is moderate variation around this pattern. Alkalinity concentrations in Oak Creek are strongly positively correlated with hardness, specific conductance, and concentrations of chloride, all parameters which, like alkalinity, measure amounts of dissolved material in water.

Biochemical Oxygen Demand (BOD)

The mean concentration of BOD in Oak Creek during the period of record was 2.24 mg/l. Individual samples varied from below the limit of detection to 8.4 mg/l. As shown in Figure 197, the concentrations of BOD declined after 1994 at most sampling stations along the Creek. Figure 198 shows a monthly comparison of baseline and historical concentrations of BOD at two sites along the Creek: STH 38, an upstream station, and 15th Avenue, a downstream station. At the STH 38 station, baseline monthly mean concentrations of BOD are below the historical monthly mean concentrations and often near or below historical minimum concentrations. At 15th Avenue, baseline monthly mean BOD concentrations are generally below the historical monthly mean concentrations. Where they are not, they are near historical monthly mean concentrations. At both stations, baseline period monthly minimum concentrations are below the historical monthly minimum concentrations and

Figure 195

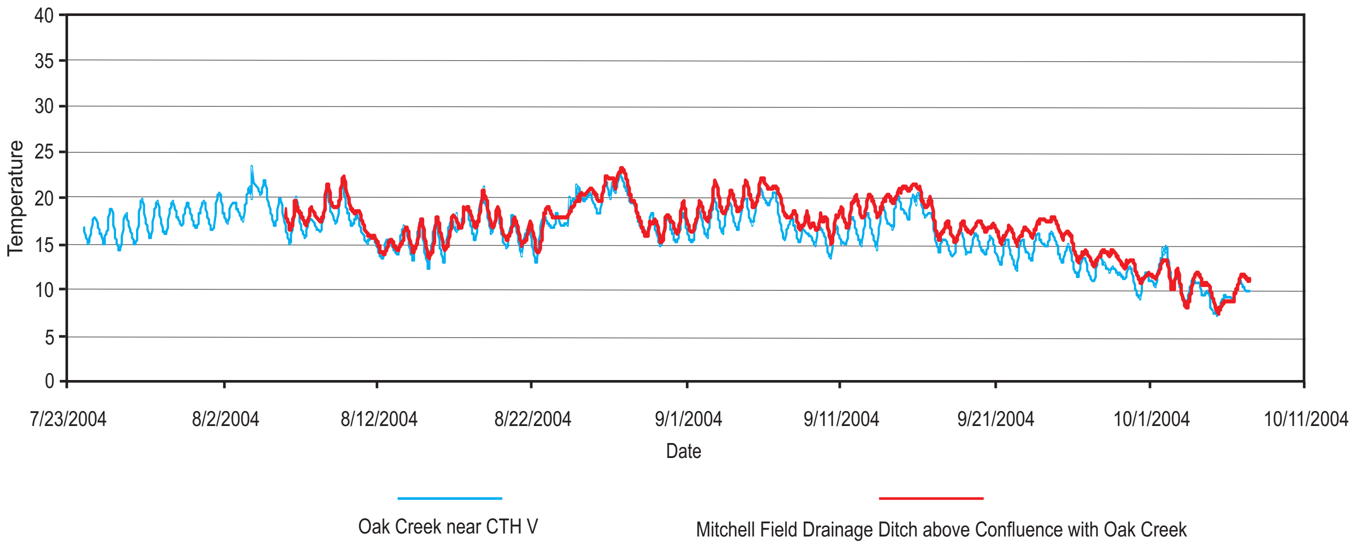
HISTORICAL AND BASE PERIOD WATER TEMPERATURE ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 196

CONTINUOUSLY RECORDED WATER TEMPERATURE FROM STREAMS IN THE OAK CREEK WATERSHED



Source: Wisconsin Department of Natural Resources.

are often near or below the limit of detection. Monthly maximum concentrations during the baseline period, however, occasionally exceed historical monthly maximum concentrations. Similar relationships between baseline and historical concentrations of BOD are seen at the other five long-term sampling stations. All stations show significant declining trends in BOD concentration over time (see Table C-4 in Appendix C of this report).

Several other factors may influence BOD concentrations in Oak Creek. BOD concentrations in the Creek are positively correlated at some stations with concentrations of fecal coliform bacteria. This correlation may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the Creek. In some parts of the Creek, decomposition of organic material in the sediment may act as a source of BOD to the overlying water.

The declining trend in BOD concentrations over time detected at stations along the mainstem of the Creek represents an improvement in water quality.

Data for BOD from 12 samples were also available for the years 1998-2001 from one station along the Mitchell Field Drainage Ditch at College Avenue (see Map 77). BOD concentrations detected in this tributary ranged from 10 mg/l to 200 mg/l with a mean concentration of 82 mg/l. These concentrations are high relative to those observed in the mainstem of Oak Creek. Deicing compounds used at General Mitchell International Airport were shown to represent a major source of BOD to Wilson Park Creek in the Kinnickinnic River watershed (see Chapter V of this report) and they may also represent a source of BOD to the Mitchell Field Drainage Ditch. It is important to note that ethylene glycol, a compound commonly used in airport deicing operations, was not detected in water from Mitchell Field Drainage Ditch in three samples collected during 1999-2000. However, these samples were not analyzed for propylene glycol, another deicing compound, known to create high oxygen demands in waters.

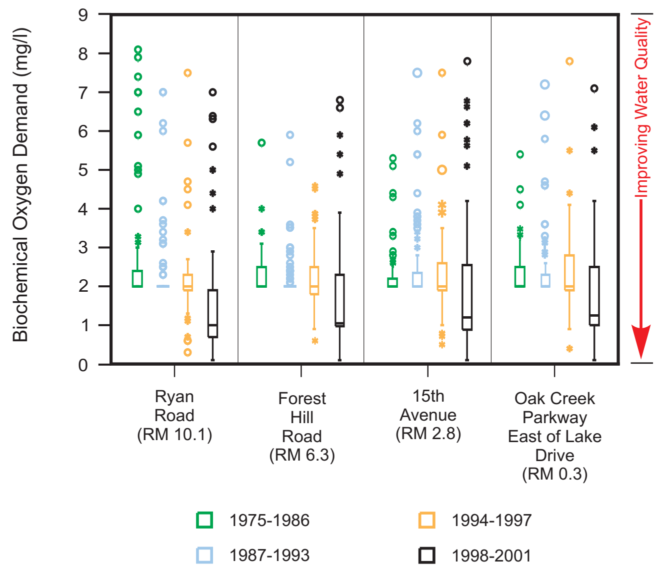
Chloride

The mean chloride concentration in Oak Creek for the period of record was 158.6 mg/l. All sites show wide variations between minimum and maximum values. Figure 199 shows, that from 1994 to 1997, the mean concentrations of chloride at all stations increased relative to the 1975-1993 period. In the period from 1998-2001, mean chloride concentrations decreased at all of the stations. Table C-4 in Appendix C of this report shows that, despite this recent decline, mean chloride concentrations at most stations along the Creek have been increasing over time. On an annual basis, statistically significant increases have been detected at five of the sampling stations along the mainstem of the Creek. Chloride concentrations show a strong seasonal pattern. For the period during which winter data are available, mean chloride concentrations were highest in winter or early spring. This is likely to be related to the use of deicing salts on streets and highways. These concentrations declined through the spring to reach lows during summer and fall. As shown in Table 133, chloride concentrations in Oak Creek showed a significant trend toward decreasing from upstream to downstream.

Observed instream chloride concentrations in Oak Creek rarely approached the planning standard of 1,000 milligrams per liter (mg/l) that was adopted under the original regional water quality management plan. Observed instream concentrations frequently exceeded the 250 mg/l secondary drinking water standard.[3] Instream concentrations occasionally exceeded the chronic toxicity criterion of 395 mg/l, but rarely exceeded the acute toxicity criterion of 757 mg/l as set forth in Chapter NR 105, "Surface Water Quality Criteria and Secondary Values for Toxic Substances," of the *Wisconsin Administrative Code*.

Figure 197

BIOCHEMICAL OXYGEN DEMAND AT SITES ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



NOTE: See Figure 191 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Chloride concentrations in Oak Creek show strong positive correlations with alkalinity, hardness, and specific conductance, all parameters which, like chloride, measure amounts of dissolved material in water. The increase in chloride concentrations in Oak Creek represents a decline in water quality.

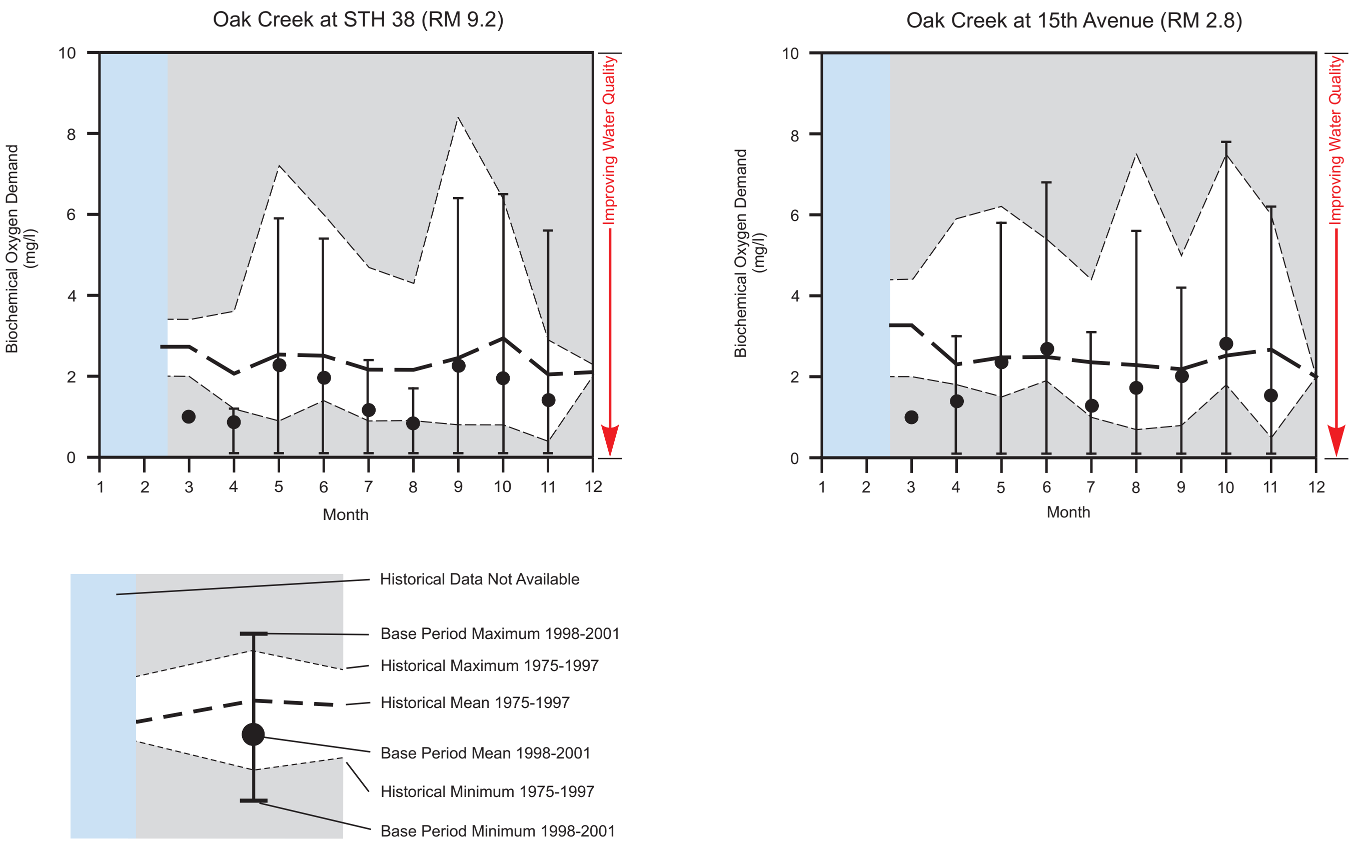
Dissolved Oxygen

Over the period of record, the mean concentration of dissolved oxygen in Oak Creek was 8.4 mg/l. The data ranged from concentrations that were undetectable to concentrations in excess of saturation. As shown in Figure 200, this variability is present at individual sample sites. Over the baseline period, mean dissolved oxygen concentrations in the Creek tended to increase from upstream to downstream. There was one exception to this pattern: where mean oxygen concentrations decreased by over 1 mg/l between the sampling station at Forest Hill Road and the sampling station at Pennsylvania Avenue. High concentrations of BOD entering Oak Creek from the Mitchell Field Drainage Ditch may be one factor contributing to this decline in dissolved oxygen concentration (see above). Despite the decrease between these two stations, there is a statistically significant trend toward dissolved oxygen concentrations increasing from upstream to downstream in Oak Creek (see Table 133). Figure 200 also shows that dissolved oxygen concentrations have declined over time in Oak Creek. It is important to note that because dissolved oxygen concentration is greatly affected by water temperature, and the data prior to 1987 include samples taken during winter, this change between 1975-1986 and 1987-1993 may be more reflective

[3]*Section 809.60 of Chapter NR 809, "Safe Drinking Water," of the* Wisconsin Administrative Code, *establishes a secondary standard for chloride of 250 mg/l and notes that, while that concentration is not considered hazardous to health, it may be objectionable to an appreciable number of persons.*

Figure 198

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF BIOCHEMICAL OXYGEN DEMAND ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



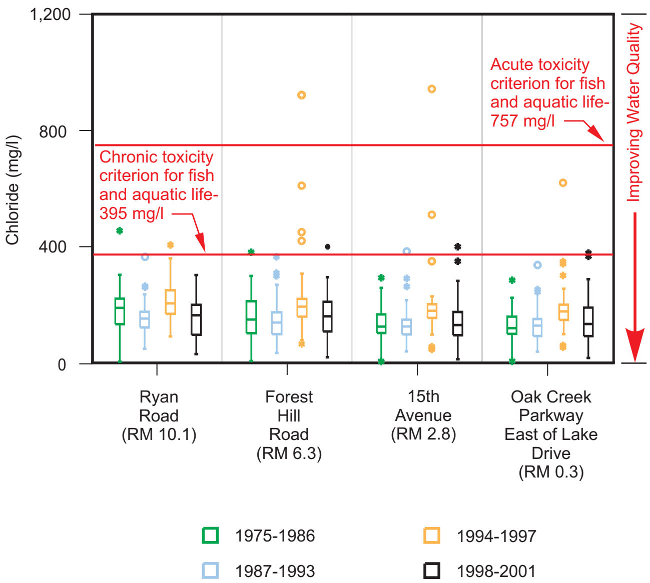
Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

of a change in methodology than any change in the concentration of dissolved oxygen in the Creek. Still, statistical analysis detected significant trends toward declining dissolved oxygen concentration at three sampling stations (see Table C-4 in Appendix C of this report).

Figure 201 compares monthly baseline period concentrations of dissolved oxygen to historical concentrations at three sampling stations. At Ryan Road, an upstream site, baseline period monthly mean dissolved oxygen concentrations were generally below historical monthly mean concentrations. The lowest concentrations detected at this station during the base period were often lower than the historical minima. During the late spring, summer, and early fall dissolved oxygen concentrations at this station often fell below the standard for fish and aquatic life of 5.0 mg/l. A slightly different pattern was seen at the station at Pennsylvania Avenue. At this station, baseline period monthly mean dissolved oxygen concentrations were generally near or below historical means. In addition, monthly minimum dissolved oxygen concentrations during the baseline period approached historical minima. Just as at Ryan Road, dissolved oxygen concentrations at this station often fell below the standard during the late spring through mid fall. A third pattern was observed at the station at 15th Avenue. Here monthly mean dissolved oxygen concentrations during the baseline period were below historical means. While the monthly minimum dissolved oxygen concentrations were generally near historical minimum concentrations, baseline period maximum concentrations of dissolved oxygen were near the historical monthly mean concentrations and below historical monthly maximum concentrations. Dissolved oxygen concentrations at this station during the baseline period were generally above the standard.

Figure 199

CHLORIDE CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF OAK CREEK: 1975-2001

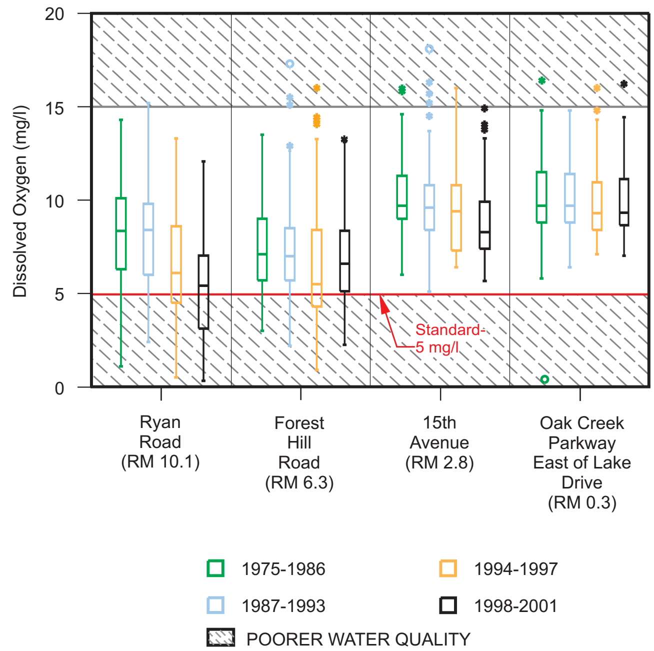


NOTE: See Figure 191 for description of symbols.

Source: *U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

Figure 200

DISSOLVED OXYGEN CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



NOTES: See Figure 191 for description of symbols.

140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

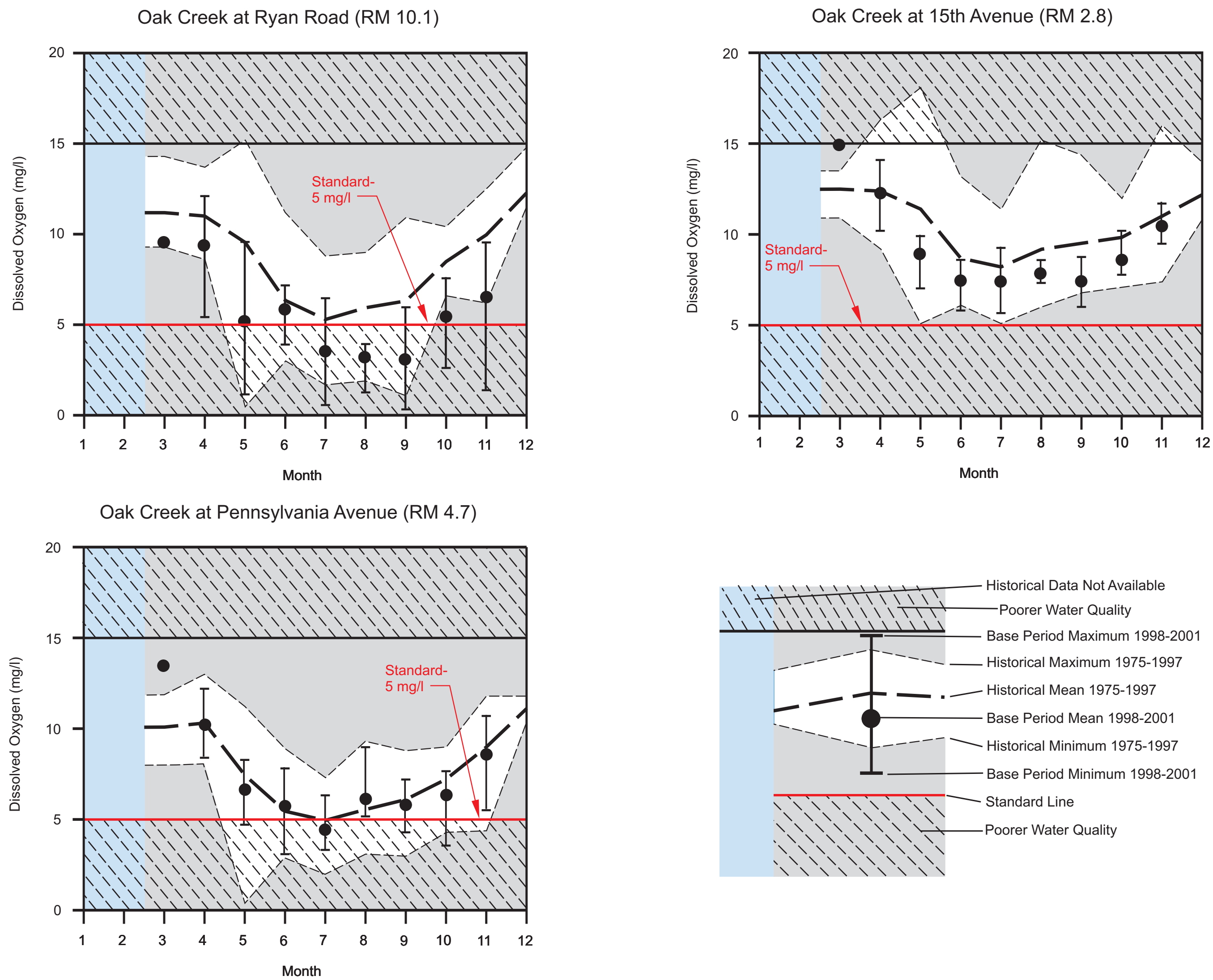
Source: *U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.*

The data show strong seasonal patterns to the mean concentrations of dissolved oxygen (see Figure 201). The mean concentration of dissolved oxygen is highest during the winter. It declines through spring to reach a minimum during the summer. It then rises through the fall to reach maximum values in winter. This seasonal pattern is driven by changes in water temperature. The solubility of oxygen in water decreases with increasing temperature. In addition, the metabolic demands and oxygen requirements of most aquatic organisms, including bacteria, tend to increase with increasing temperature. Higher rates of bacterial decomposition when the water is warm may contribute to the declines in the concentration of dissolved oxygen observed during the summer. In addition to the reasons mentioned above, dissolved oxygen concentrations can also be affected by a variety of other factors including the presence of aquatic plants, sunlight, turbulence in the water, and the amount and type of sediment as summarized in the Water Quality Indicators section in Chapter II of this report.

Several other factors can affect dissolved oxygen concentrations in Oak Creek. First, settling of suspended material in portions of the Creek can transfer material from the water column to the sediment. Decomposition of organic matter contained in this material, through chemical and especially biological processes, removes oxygen from the overlying water, lowering the dissolved oxygen concentration. Second, as noted above, decomposition of oxygen demanding materials in water entering the mainstem of the Creek from the Mitchell Field Drainage Ditch may be lowering dissolved oxygen concentrations in the reaches below the confluence with this tributary. Third, dissolved oxygen concentrations in Oak Creek are positively correlated with pH. This reflects the effect of photosynthesis on both of these parameters. During photosynthesis, algae and plants remove carbon dioxide from

Figure 201

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF DISSOLVED OXYGEN ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



NOTE: 140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

the water. This tends to raise the water's pH. At the same time, oxygen is released as a byproduct of the photosynthetic reactions.

The decreases in concentrations of dissolved oxygen in Oak Creek represent a reduction in water quality over time.

Hardness

Over the period of record, the mean hardness in Oak Creek was 372.4 mg/l as $CaCO_3$. On a commonly used scale, this is considered to be very hard water.[4] The range of the data runs from 0.41 to 1,208.1 mg/l as $CaCO_3$,

[4] *E. Brown, M.W. Skougstad, and M.J. Fishman,* Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, *U.S. Department of Interior, U.S. Geological Survey, 1970.*

showing considerable variability. Some of this variability probably results from inputs of relatively soft water during storm events. Hardness concentrations in Oak Creek show strong positive correlations with alkalinity, chloride, and specific conductance, all parameters which, like hardness, measure amounts of dissolved material in water. Hardness does not vary significantly along the length of the Creek (see Table 133). No trends or seasonal patterns in hardness were detected (Table C-4 in Appendix C). In summary, hardness concentrations were generally shown to have remained unchanged among stations during the time period examined from 1975 to 2001.

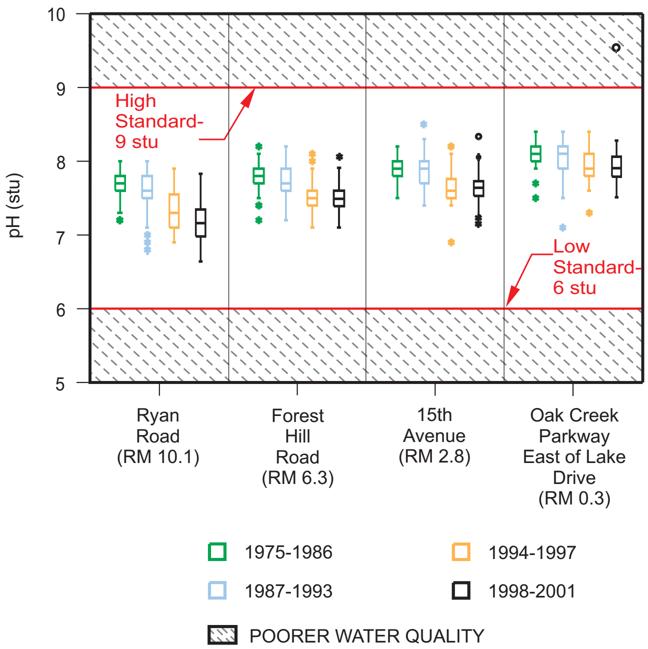
pH
The mean pH in Oak Creek over the period of record was 7.7 standard units. The mean values at individual sampling stations along the mainstem of the Creek ranged from 7.5 to 8.0 standard units. At most stations, pH varied only by $\pm$ 1.0 standard unit from the stations' mean values. Variability in pH was very similar among stations, with coefficients of variation ranging from 0.03 to 0.07. As shown in Figure 202, two trends were detected in pH in Oak Creek. First, pH in the Creek tends to increase from upstream to downstream. Table 133 shows that this trend is statistically significant. Second, as shown in Table C-4 in Appendix C, there is a significant trend toward pH at all stations along the Creek decreasing over time. The causes of this decrease is unknown. Positive correlations are seen between pH and alkalinity, hardness, and specific conductance at some stations but they are neither as common nor as strong as the correlations detected among alkalinity, hardness, and specific conductance. At all stations, dissolved oxygen concentrations are positively correlated with pH. This reflects the effect of photosynthesis on both of these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the water's pH. At the same time, oxygen is released as a byproduct of the photosynthetic reactions. Summer and fall values of pH in Oak Creek tend to be slightly lower than spring and winter values. In summary, pH concentrations were generally shown to have decreased at all of the stations during the time period examined from 1975 to 2001.

Specific Conductance
The mean value for specific conductance in Oak Creek over the period of record was 1,138.4 microSiemens per centimeter (μS/cm). Considerable variability was associated with this mean. Specific conductance ranged from 0.05 to 5,500.0 μS/cm. Some of this variability may reflect the discontinuous nature of inputs of dissolved material into the Creek. Runoff associated with storm events can have a major influence on the concentration of dissolved material in the Creek. The first runoff from a storm event transports a large pulse of salts and other dissolved material from the watershed into the Creek. This will tend to raise specific conductance. Later runoff associated with the event will be relatively dilute. This will tend to lower specific conductance. Table 133 shows that in Oak Creek, specific conductance decreases from upstream to downstream. This suggests that concentrations of dissolved material decrease from upstream to downstream in the Creek. Trend analysis results show that specific conductance has not changed over time in the Creek (Table C-4 in Appendix C). The data show a seasonal pattern of variation in specific conductance. For those years in which data were available, specific conductance was highest during the early spring. It then declined during the spring to reach lower levels in the summer and fall. Specific conductance in Oak Creek shows strong positive correlations with alkalinity, chloride, and hardness, all parameters which, like specific conductance, measure amounts of dissolved material in water. In summary, specific conductance has not changed in Oak Creek over the period of record indicating that the concentrations of dissolved materials in water in the Creek have not changed.

Suspended Material
The mean value for total suspended solids (TSS) concentration in Oak Creek over the period of record was 30.9 mg/l. Considerable variability was associated with this mean, with values ranging from 1.2 to 970.0 mg/l. As shown in Figure 203, concentrations of TSS show a seasonal pattern with highest mean concentrations generally occurring in late spring or early summer. There is a trend toward TSS concentrations increasing from upstream to downstream along the Creek (see Table 133). Few time-based trends were detected in TSS concentrations in the Creek (Table C-4 in Appendix C). TSS concentrations showed strong positive correlations with total phosphorus concentrations, reflecting the fact that total phosphorus concentrations include a large particulate fraction. TSS concentrations were also positively correlated with concentrations of fecal coliform bacteria, BOD, and nutrients.

Figure 202

pH SITES ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



NOTE: See Figure 191 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

TSS concentrations were negatively correlated with some measures of dissolved materials, such as alkalinity, chloride, hardness, and specific conductance.

Nutrients

Nitrogen Compounds

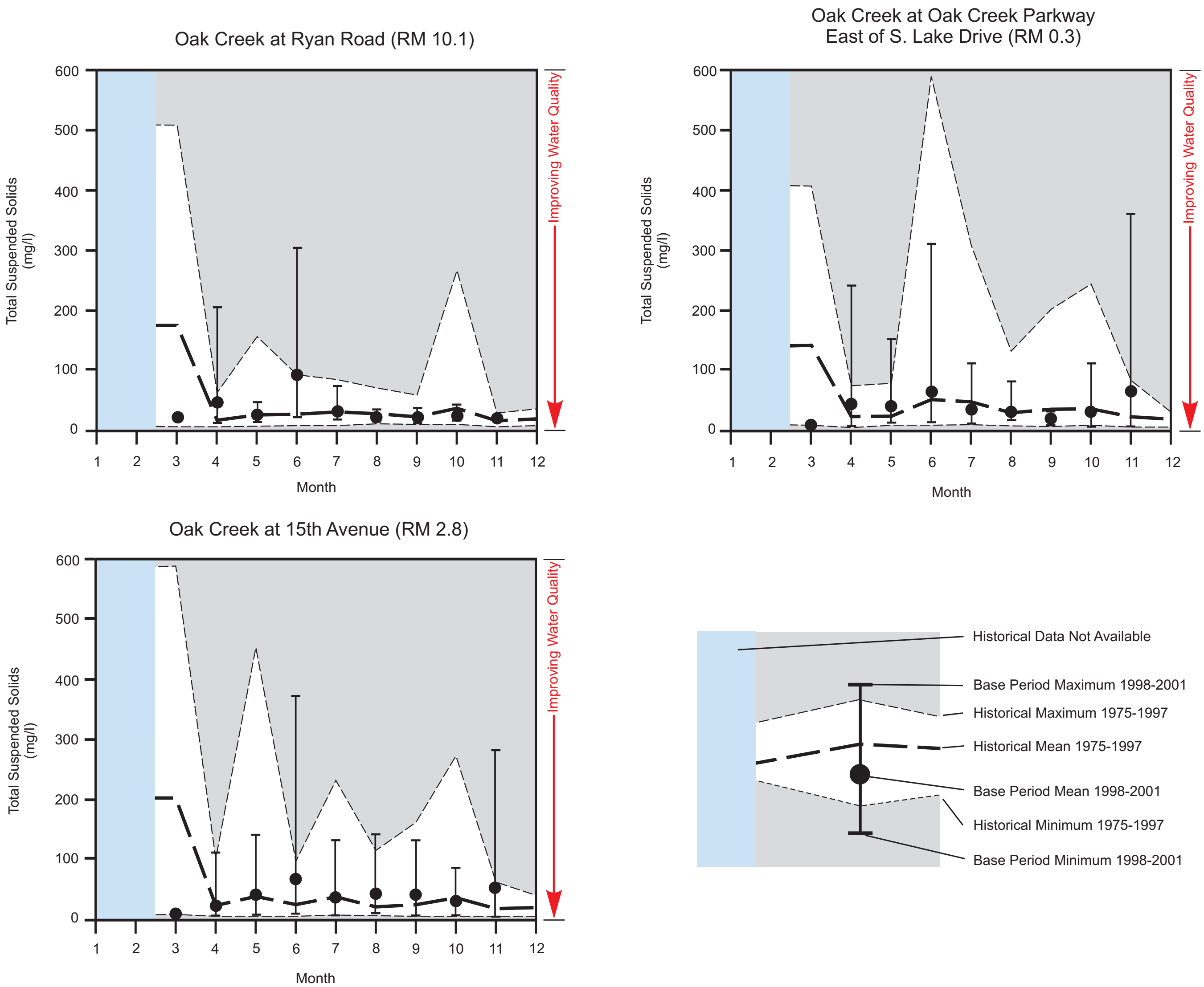
The mean concentration of total nitrogen in Oak Creek over the period of record was 1.19 milligrams per liter measured as nitrogen (mg/l as N). Concentrations at the seven sampling stations along the mainstem varied over two orders of magnitude, ranging from 0.1 to 7.1 mg/l as N. As shown in Figure 204, at all stations total nitrogen concentrations during the period 1987-1994 were lower than during the period 1975-1986. At most stations, total nitrogen concentrations experienced an increase during the period 1994-1997 and 1998-2001. By contrast, during 1994-1997 total nitrogen concentrations at the Ryan Road station continued to decline. After that, they increased. The baseline monthly mean concentrations of total nitrogen at most stations were generally near or slightly higher than the historical monthly mean concentrations. The major exception to this occurred at the station that is farthest upstream, at Ryan Road. At this station baseline period monthly mean total nitrogen concentrations during the spring were higher than the historical monthly means. As shown in Table 133, no significant trends were detected in the concentrations of total nitrogen along the length of the Creek. In addition, no significant time-based trends were detected in total nitrogen concentrations (Table C-4 in Appendix C). The concentration of total nitrogen in Oak Creek is moderately positively correlated with the concentration of total phosphorus. This probably reflects the nitrogen and phosphorus contained in particulate organic matter in the water, including live material such as plankton and detritus.

Total nitrogen is a composite measure of several different compounds which vary in their availability to algae and aquatic plants and vary in their toxicity to aquatic organisms. Common constituents of total nitrogen include ammonia, nitrate, and nitrite. In addition a large number of nitrogen-containing organic compounds, such as amino acids, nucleic acids, and proteins commonly occur in natural waters. These compounds are usually reported as organic nitrogen.

The mean concentration of ammonia in Oak Creek was 0.19 mg/l as N. Over the period of record, ammonia concentrations varied between 0.002 and 2.220 mg/l as N. Figure 205 shows that at most stations ammonia concentrations have decreased since 1975. For the most part, baseline period monthly mean concentrations of ammonia are generally near or above historical monthly means during the spring and below the historical monthly means during summer and fall. When examined on an annual basis, there is a statistically significant trend toward ammonia concentrations at all stations declining over time (Table C-4 in Appendix C). Examination on a seasonal basis shows that these decreasing trends in ammonia concentrations are occurring during the summer and fall. In addition, Table 133 shows that there is a trend toward ammonia concentrations decreasing from upstream to downstream. There were no clear patterns of seasonal variation in ammonia concentrations in Oak Creek.

Figure 203

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF TOTAL SUSPENDED SOLIDS ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



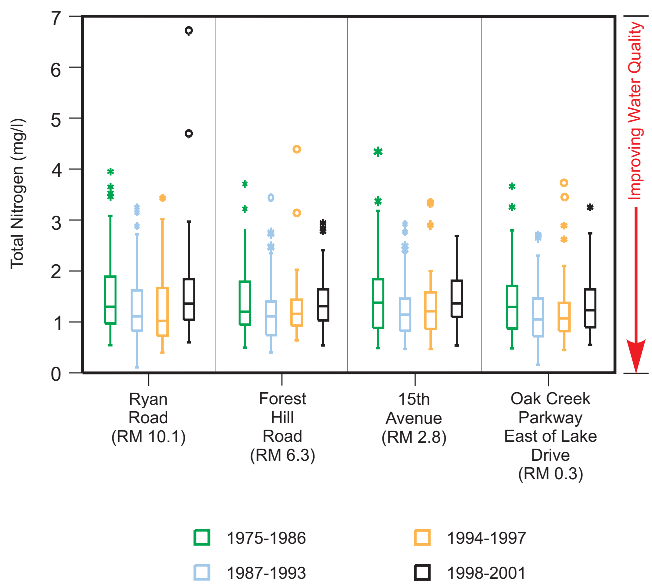
Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

The mean concentration of nitrate in Oak Creek for the period of record was 0.51 mg/l as N. During this time, concentrations in the Creek varied between 0.005 and 3.420 mg/l as N. Nitrate concentrations declined at all stations after 1986. At most stations, nitrate concentrations experienced an increase during the periods 1994-1997 and 1998-2001. By contrast, during 1994-1997 nitrate concentrations at the Ryan Road station continued to decline. After this, they increased. Table 133 indicates that there is a trend for nitrate to increase from upstream to downstream along the Creek. No statistically significant trends were detected in nitrate concentration over time (Table C-4 in Appendix C). The data show evidence of seasonal variations in nitrate concentration. Nitrate concentration was highest in the early spring and late fall. It declined through spring to reach lower levels in the summer. In the fall, the concentration began to climb again.

The mean concentration of nitrite in Oak Creek was 0.028 mg/l as N over the period of record. Nitrite concentrations showed more variability than nitrate. This probably reflects the fact that nitrite in oxygenated water tends to oxidize to nitrate fairly quickly. No trends were detected in nitrite concentrations along the length of the

Figure 204

TOTAL NITROGEN CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF OAK CREEK: 1975-2001

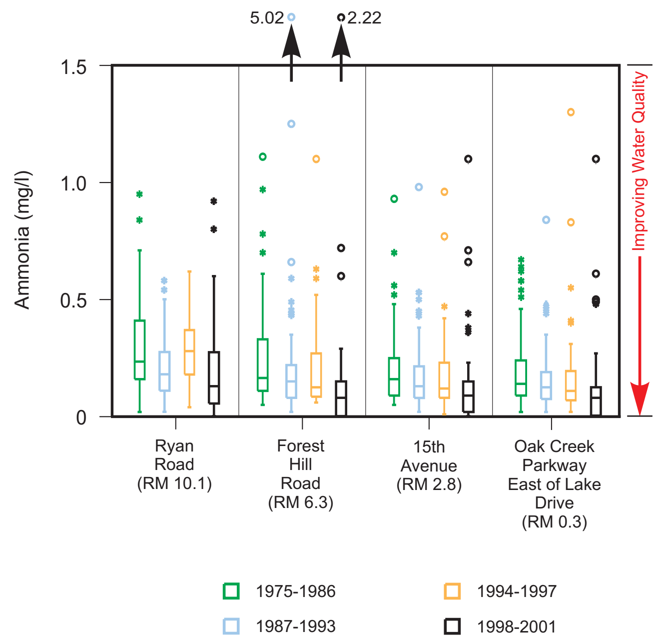


NOTE: See Figure 191 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 205

AMMONIA CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



NOTES: See Figure 191 for description of symbols.

Standard is dependent upon ambient temperature and pH which indicate ammonia concentrations did not exceed those toxicity standards.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Creek (see Table 133). In addition, there were few trends in nitrite concentration over time see (Table C-4 in Appendix C). Mean monthly nitrite concentrations in Oak Creek tend to be highest during the summer.

During the period of record the mean concentration of organic nitrogen in Oak Creek was 0.63 mg/l as N. This parameter showed considerable variability with concentrations ranging from undetectable to 6.28 mg/l as N. When examined on an annual basis, four stations along the Creek show trends toward increasing concentrations of organic nitrogen over time. This reflects trends toward higher organic nitrogen concentrations during the fall (Table C-4 in Appendix C). Monthly mean organic nitrogen concentrations tend to be highest during the early spring. Other than that, there were no clear patterns in seasonal variation of organic nitrogen.

Several processes can influence the concentrations of nitrogen compounds in a waterbody. Primary production by plants and algae will result in ammonia and nitrate being removed from the water and incorporated into cellular material. This effectively converts the nitrogen to forms which are detected only as total nitrogen. Decomposition of organic material in sediment can release nitrogen compounds to the overlying water. Bacterial action may convert some nitrogen compounds into others.

Several observations can be made based on this analysis of nitrogen chemistry in Oak Creek:

- The relative proportions of different nitrogen compounds in Oak Creek seem to be changing with time.

- Throughout the Creek ammonia concentrations have been declining over time. This represents an improvement in water quality.

- Where trends exist, the concentrations of organic nitrogen compounds seem to be increasing over time. This represents a decrease in water quality.

- From upstream to downstream, nitrate concentrations tend to increase. At the same time, ammonia concentrations tend to decrease from upstream to downstream along the Creek.

Total and Dissolved Phosphorus
Two forms of phosphorus are commonly sampled in surface waters: dissolved phosphorus and total phosphorus. Dissolved phosphorus represents the form that can be taken up and used for growth by algae and aquatic plants. Total phosphorus represents all the phosphorus contained in material dissolved or suspended within the water, including phosphorus contained in detritus and organisms.

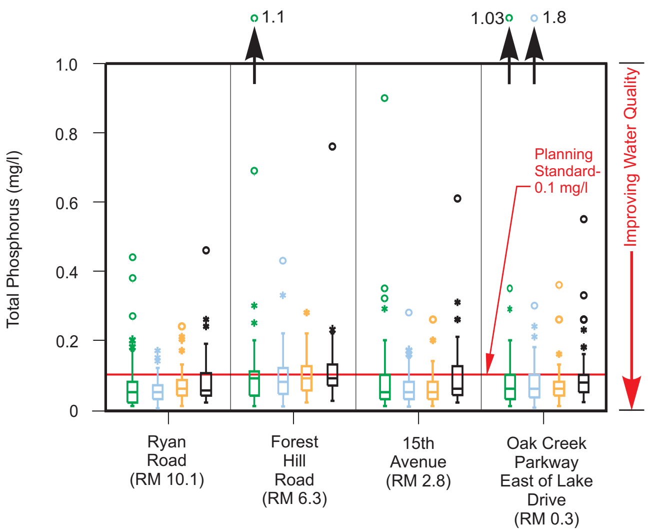
The mean concentration of total phosphorus in Oak Creek during the period of record was 0.085 mg/l and the mean concentration of dissolved phosphorus in Oak Creek over the period of record was 0.030 mg/l. Phosphorus concentrations varied over four orders of magnitude, with concentrations of total phosphorus in the Creek ranging from 0.003 to 1.760 mg/l, and of dissolved phosphorus ranging from 0.003 to 1.150 mg/l. At most sampling sites, the data showed moderate variability. Figure 206 shows that concentrations of total phosphorus have increased at some stations along the Creek. The upstream stations show a continual increase over all four periods. The downstream stations, by contrast, show a more rapid increase after 1997. Table C-4 in Appendix C shows that significant trends were detected toward increasing total phosphorus concentration over time at three stations and significant trends toward increasing dissolved phosphorus concentration over time were detected at four stations. As shown in Table 133, there was a significant trend toward dissolved concentrations decreasing from upstream to downstream. This may reflect uptake and incorporation into cellular material of dissolved phosphorus by algae, plants, and other organisms in the Creek. At some stations, total phosphorus concentrations were positively correlated with concentrations of temperature and total nitrogen. These correlations reflect the roles of phosphorus and nitrogen as nutrients for algal growth. During periods of high algal productivity, algae remove dissolved phosphorus and nitrogen compounds from the water and incorporate them into cellular material. Because the rates of biological reactions are temperature dependent, these periods tend to occur when water temperatures are warmer. At most stations, concentrations of total phosphorus were also positively correlated with concentrations of fecal coliform bacteria. This correlation may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the Creek.

Figure 207 shows a monthly comparison of the historical and baseline concentrations of total phosphorus at two sampling stations along the mainstem of Oak Creek, one upstream site and one downstream site. At Ryan Road, the upstream station, mean monthly total phosphorus concentrations during the baseline period were generally near the historical monthly means, except during the spring when they were higher. During the spring months, the maximum monthly concentrations observed at this station exceeded the historical monthly maxima. At 15th Avenue, the downstream station, monthly mean total phosphorus concentrations from the baseline period were generally above historical monthly means. At both stations, concentrations of total phosphorus often exceeded the planning standard of 0.1 mg/l recommended in the regional water quality management plan.

Figure 208 shows the annual mean total phosphorus concentrations of phosphorus in Oak Creek for the years 1985 to 2001. For the most part, mean annual total phosphate concentrations from the years 1996-2001 were within the range of variation from previous years. In the Kinnickinnic River and Menomonee River watersheds, annual average total phosphorus concentrations increased sharply after 1996. One possible factor in this increase was phosphorus loads from facilities discharging noncontact cooling water drawn from municipal water utilities. The City of Milwaukee, for example, treats its municipal water with orthophosphate to inhibit release of copper and lead from pipes in the water system and private residences. The City of Greenfield is a retail customer of the Milwaukee Water Works, so its municipal water also contains orthophosphate. In addition, the water utilities of

Figure 206

TOTAL PHOSPHORUS CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



NOTE: See Figure 191 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

the Cities of Cudahy and South Milwaukee both add polyphosphate to their municipal water supply for the same purpose as the City of Milwaukee. The water utilities of the Cities of Franklin and Oak Creek do not treat their municipal water with orthophosphate or polyphosphate. As of 2003, there were no permitted noncontact cooling water dischargers to Oak Creek in the Cities of Cudahy, Franklin, or Greenfield; there was one in Milwaukee, and there were two in South Milwaukee. There was also one discharger in the City of Oak Creek operating under an individual permit. Based on the foregoing, it is concluded that orthophosphate or polyphosphate in cooling water discharges represents a relatively small contribution of phosphorus to the streams of the watershed.

The trends toward increasing dissolved and total phosphorus over time at some stations along Oak Creek represent a decline in water quality.

Metals

Arsenic

The mean value for the concentration of arsenic in the water of Oak Creek over the period of record was 1.56 μg/l. Concentrations ranged from 0.95 μg/l to 9.1 μg/l. Table 133 shows that there is no evidence of trends in arsenic concentration along the length of the Creek. Table C-4 in Appendix C reveals a trend at all sampling stations toward arsenic concentrations declining when examined on an annual basis. In addition, when trends in arsenic concentrations were assessed on a seasonal basis, all stations showed declines during the spring and some stations showed declines during the summer. These declines may reflect changes in the amount and types of industry within the Oak Creek watershed, as well as reductions due to treatment of industrial discharges. In addition, sodium arsenate has not been used in herbicides since the 1960s. Arsenic concentrations in Oak Creek show no evidence of seasonal variation. The reductions in arsenic concentration in Oak Creek represent an improvement in water quality.

Cadmium

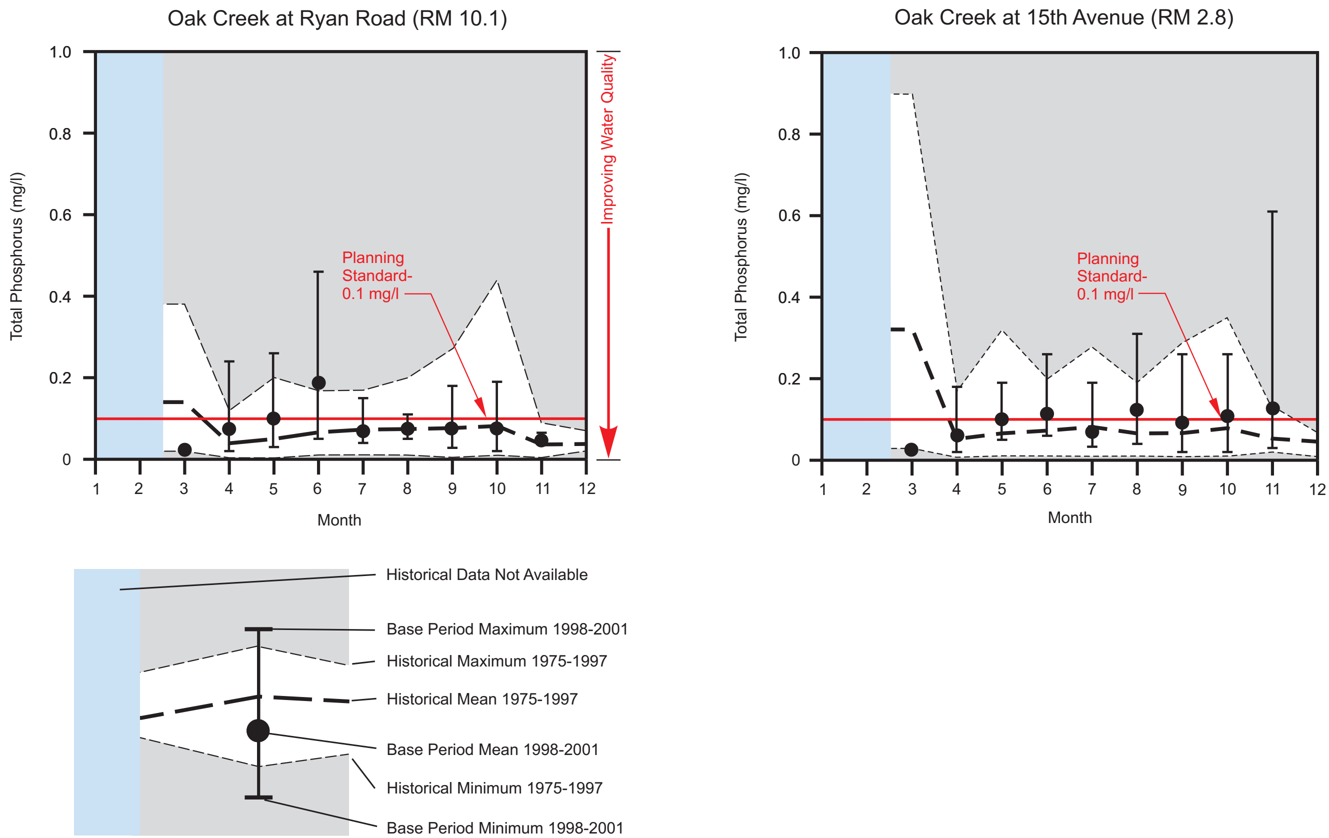
The mean concentration of cadmium in Oak Creek over the period of record was 1.92 μg/l. A moderate amount of variability was associated with this mean. Individual sample concentrations ranged from 0.05 to 14.0 μg/l. There were few differences among the stations in the amount of variability. Table C-4 in Appendix C also shows the presence of a strong decreasing trend in cadmium concentrations at all stations on an annual basis and nearly all stations on a seasonal basis. These declines in cadmium concentration may reflect changes in the number and types of industry present in the watershed, reductions due to treatment of industrial discharges, and reductions in airborne deposition of cadmium to the Great Lakes region. Cadmium concentrations in the Creek showed no evidence of seasonal variation or variation along the length of the Creek. The reduction in cadmium concentrations in Oak Creek represents an improvement in water quality.

Chromium

The mean concentration of chromium in Oak Creek over the period of record was 7.66 μg/l. Chromium concentration showed moderate variability, with individual sample concentrations ranging from 1.5 to 40.0 μg/l. As shown in Table C-4 in Appendix C, analysis of time-based trends on an annual basis suggests that chromium concentrations are declining at two stations. When analyzed on a seasonal basis, decreasing trends were detected

Figure 207

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF TOTAL PHOSPHORUS ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

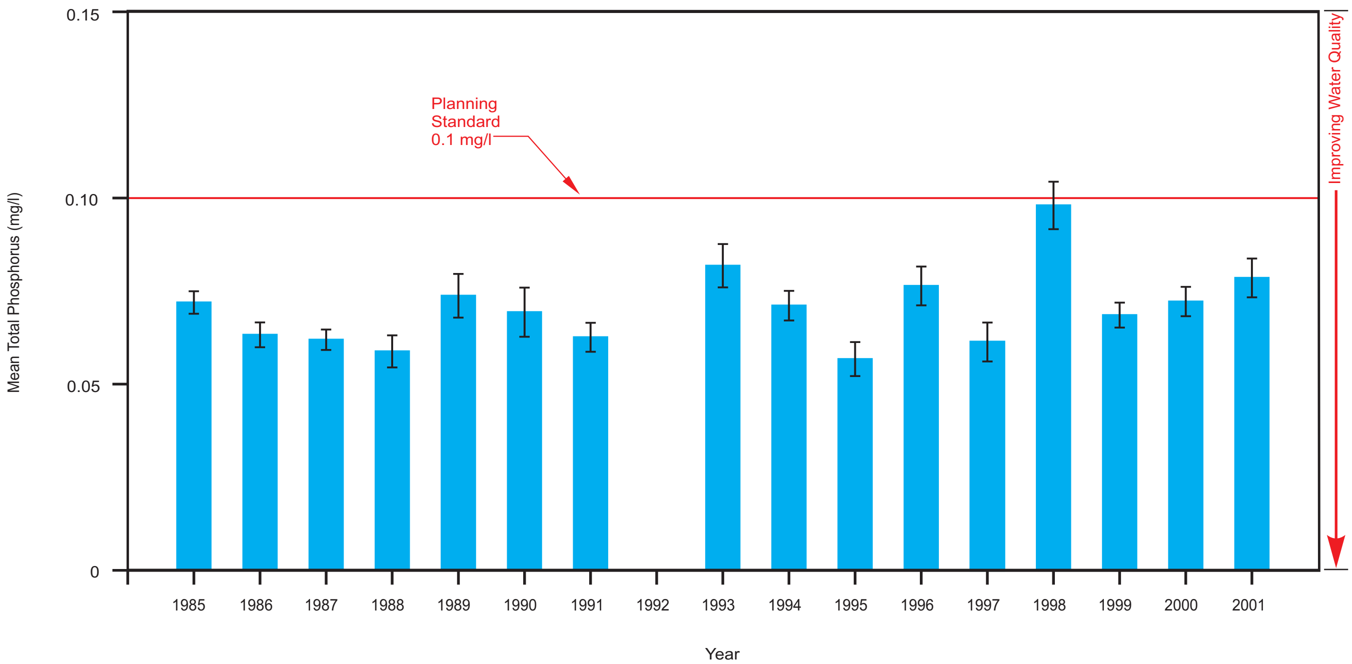
at five stations during the spring. The decline in chromium concentration at some stations in the Creek may reflect the loss of industry in some parts of the watershed and the decreasing importance of the metal plating industry in particular, as well as the establishment of treatment of discharges instituted for the remaining and new industries since the late 1970s. The treatment/pretreatment requirements instituted did result in many discharges which previously went to the Creek being removed and connected to the public sewer system. There is no evidence of seasonal variation in chromium concentrations in Oak Creek. In addition, Table 133 indicates that there is no evidence of trends in chromium concentration along the length of the Creek. The decline in chromium concentrations at some sites along Oak Creek represents an improvement in water quality.

Copper

The mean concentration of copper in Oak Creek during the period of record was 8.24 μg/l. Moderate variability was associated with this mean. Figure 209 shows that prior to 1987, the median concentrations of copper increased over time at all stations. This increase in median copper concentrations continued through the period 1994-1997. During the period 1998-2001, the median concentration of copper declined at all sampling stations along the Creek except for the 15th Avenue station. At this station the median copper concentration during 1998-2001 was similar to the median from 1994-1997. In general, mean copper concentrations followed the pattern described for median, except at the 15th Avenue station where the mean copper concentration from the period 1998-2001 was slightly higher than the mean copper concentration from the period 1994-1997. Nearly all stations showed that monthly mean copper concentrations are generally near or below the historical monthly means. Despite this recent decline, all stations show significant increasing trends in copper concentrations (Table C-4 in

Figure 208

MEAN ANNUAL CONCENTRATIONS OF TOTAL PHOSPHORUS IN OAK CREEK: 1975-2001



NOTE: Error bars (I) represent one standard error or the mean.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

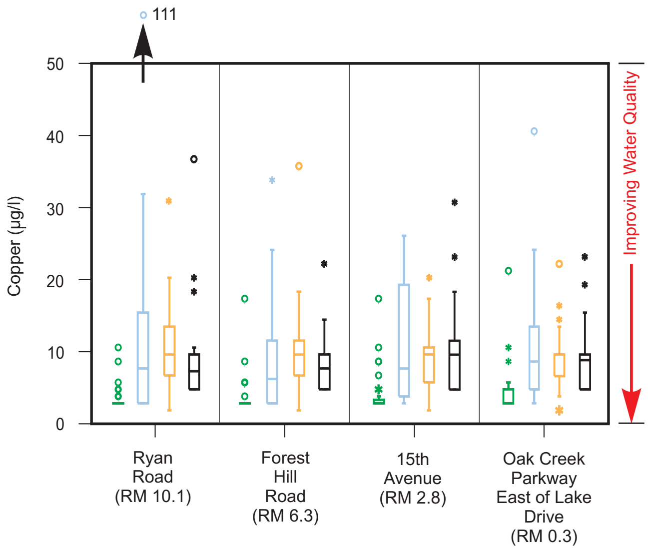
Appendix C). Table 133 shows that no trends were detected in copper concentration along the length of the Creek. Wear and tear of brake pads and other metal components of vehicles is a major source of copper to the environment. Once deposited on impervious surfaces, stormwater runoff may carry this metal into the Creek. While copper compounds are also used in lake management for algae control, the Oak Creek watershed contains no major lakes and few ponds. This makes it unlikely that algicides constitute a major source of copper to Oak Creek. There is no evidence of seasonal variation in copper concentrations in Oak Creek. At all stations, copper concentrations showed moderately strong positive correlations with zinc concentrations in Oak Creek. This reflects the fact that many of the same sources release these two metals to the environment. In addition, at most stations, copper concentrations showed negative correlations with pH, reflecting the fact that the solubility of copper increases with decreasing pH. The trend toward increasing copper concentration in Oak Creek represents a decline of water quality.

Lead

The mean concentration of lead in Oak Creek over the period of record was 41.8 μg/l. This mean is not representative of current conditions because lead concentrations in the water of the Creek have been declining since the late 1980s, as shown in Figure 210. At all sampling stations, the baseline ranges of lead concentrations are below the historical mean concentrations. Baseline monthly mean lead concentrations are quite low when compared to the historical means and ranges. This pattern is seen at all of the sampling stations. A major factor causing the decline in lead concentrations has been the phasing out of use of lead as a gasoline additive. From 1983-1986, the amount of lead in gasoline in the United States was reduced from 1.26 grams per gallon (g/gal) to 0.1 g/gal. In addition lead was completely banned for use in fuel for on-road vehicles in 1995. The major drop in lead in water in Oak Creek followed this reduction in use. In freshwater, lead has a strong tendency to adsorb to

Figure 209

COPPER CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



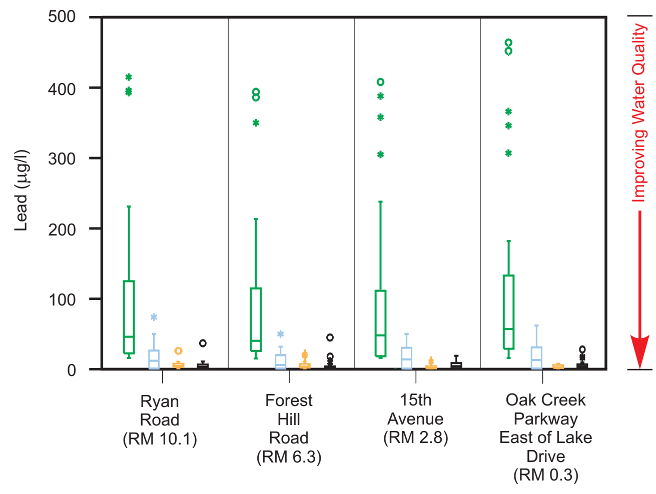
NOTES: See Figure 191 for description of symbols.

Copper acute and chronic toxicity standards depend upon ambient hardness which indicate that copper concentrations exceeded these toxicity standards in about 5 to 10 percent of samples.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 210

LEAD CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



NOTES: See Figure 191 for description of symbols.

The human threshold criteria for public health and welfare for lead is 140 μg/l.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

particulates suspended in the water.[5] As these particles are deposited, they will carry the adsorbed lead into residence in the sediment. Because of this, the lower concentrations of lead in the water probably reflect the actions of three processes: reduction of lead entering the environment, washing out of lead in the water into Lake Michigan, and deposition of adsorbed lead in the sediment. Lead concentrations in Oak Creek show no evidence of patterns of seasonal variation. The reductions in lead concentration in Oak Creek represent an improvement in water quality.

Mercury

Few historical data on the concentration of mercury in the water of Oak Creek exist. Though a few samples were taken during the mid-1970s, most sampling for mercury in water in the Creek was taken during or after 2000. The mean concentration of mercury in the Creek over the period of record was 0.079 μg/l. Mercury concentrations showed moderate variability, with a range from 0.02 to 0.61 μg/l. For the period 2000-2001, the mean concentration of mercury in the Creek was 0.059 μg/l. The means at individual stations during this period ranged from 0.058 μg/l at STH 38 to 0.118 μg/l at 15th Avenue. Table 133 shows that no trends in mercury concentration

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[5] *H.L. Windom, T. Byrd, R.G. Smith, and F. Huan, "Inadequacy of NASQUAN Data for Assessing Metal Trends in the Nation's Rivers,"* Environmental Science and Technology, *Volume 25, 1991, pp. 1137-1142.*

were detected along the length of the Creek. Table C-4 in Appendix C shows that few time-based trends were detected in Oak Creek; however, it is important to note that the data record for this metal at most stations is very short. There is no evidence of seasonal variation of mercury concentrations in Oak Creek.

Nickel
The mean concentration of nickel in Oak Creek over the period of record was 11.2 μg/l. While some sites had outliers, variability was generally low. No trends in nickel concentrations were detected along the length of the Creek (see Table 133). When examined on an annual basis, no time-based trends were detected in nickel concentration (Table C-4 in Appendix C). When the data were analyzed for the presence of time-based trends on a seasonal basis, several stations showed significant decreasing trends in nickel concentration during either the fall or spring. By contrast, only one station shows trend toward increasing nickel concentrations over time when analyzed on a seasonal basis. There was no evidence of seasonal variation in nickel concentration in Oak Creek. The trends toward decreasing nickel concentrations at some stations in Oak Creek during the spring and fall represent an improvement in water quality.

Zinc
The mean concentration of zinc in Oak Creek during the period of record was 20.8 μg/l. Zinc concentrations showed moderate variability. Concentrations in individual samples ranged from 2.15 to 212.00 μg/l. Figure 211 shows that zinc concentrations in Oak Creek have been increasing. This is supported by the detection of trends toward increasing zinc concentrations at all stations (Table C-4 in Appendix C). Table 133 shows that no significant trends in zinc concentration along the length of the Creek were detected. Figure 212 compares monthly mean zinc concentrations from the baseline period to historical monthly mean zinc concentrations at three sampling stations. Baseline period mean monthly zinc concentrations during most months are higher than historical concentrations. In addition, in many months at these sites, the maximum zinc concentrations reported during the baseline period exceed the historical maxima. These increases in zinc may be caused by an increased amount of vehicle traffic in the watershed. Zinc can be released to stormwater by corrosion of galvanized gutters and roofing materials. In addition, wear and tear on automobile brake pads and tires are major sources of zinc to the environment. Stormwater runoff can carry zinc from these sources into the Creek. There is no evidence of seasonal variation in the concentration of zinc in Oak Creek. The trend toward increasing zinc concentrations in the estuary represents a reduction in water quality.

Organic Compounds
Between February and June 2004, samples were collected by the USGS on three dates from the Oak Creek at 15th Avenue and examined for the presence and concentrations of several organic compounds dissolved in water. Bromoform, a disinfectant byproduct, was detected in one sample at a concentration of 0.1 μg/l. As shown in Table 18 in Chapter IV of this report, this concentration is below Wisconsin's human threshold criterion for public heath and welfare for fish and aquatic life waters. Dissolved isophorone, a solvent, was detected in one sample at a concentration of 0.1 μg/l. This concentration is also below Wisconsin's human threshold criterion for public heath and welfare for fish and aquatic life waters. Carbazole, a component of dyes, lubricants, and pesticides, was detected in two samples at a concentration of 0.1 μg/l. The plasticizer triphenyl phosphate was found in two samples at a concentration of 0.1 μg/l. Three flame retardant chemicals were detected in samples from Oak Creek. Tri(2-chloroethyl) phosphate and tri(dichloroisopropyl) phosphate were each detected in two samples at concentrations of 0.1 μg/l. Tributyl phosphate was found in all three samples at concentrations ranging between 0.1 and 0.5 μg/l. Finally, two compounds which are metabolites of nonionic detergents were detected in these samplings. Diethoxynonylphenol was detected in two samples at concentrations ranging from 2.0 to 4.0 μg/l and *p*-nonylphenol was detected in one sample at a concentration of 2.0 μg/l. Both of these compounds are known to be endocrine disruptors.

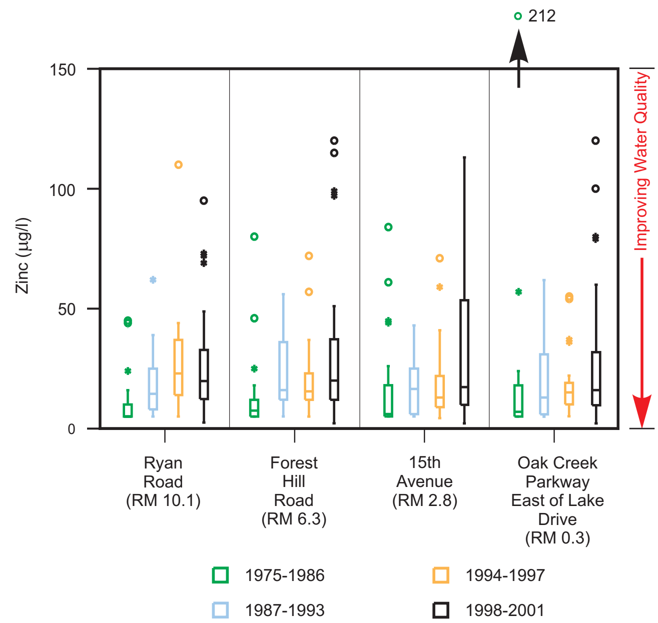
During 1999 and 2000, the Mitchell Field Drainage Ditch was sampled on three dates for ethylene glycol, a compound used in airport deicing operations. This compound can create high oxygen demands in waters and is toxic to some organisms. Ethylene glycol was not detected in any of these samples.

Pharmaceuticals and Personal Care Products

In February, March, and May 2004, the USGS sampled water from Oak Creek at 15th Avenue for the presence of several compounds found in pharmaceuticals and personal care products. The concentration of triclosan, an antibacterial agent commonly found in such personal care products as toothpaste, mouthwash, hand soaps, deodorants, and cosmetics, was below the limit of detection in all of the samples. Caffeine, a stimulant found in beverages and analgesics, was detected in all three samples at concentrations ranging between 0.1 μg/l and 0.3 μg/l. Cotinine, a metabolite of nicotine, was detected in two samples at concentrations ranging between 0.18 μg/l and 0.36 μg/l. Camphor and menthol, fragrance and flavoring agents, were detected in one and two samples respectively at concentrations of 0.1 μg/l. The sources of these compounds to Oak Creek are not known.

Figure 211

ZINC CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



NOTES: See Figure 191 for description of symbols.

Acute and chronic toxicity standards for zinc depend upon ambient hardness which indicate zinc concentrations did not exceed these toxicity standards.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

TOXICITY CONDITIONS OF OAK CREEK

Toxic Substances in Water

Pesticides

Since the 1970s, the Oak Creek watershed has been sampled for the presence of pesticides in water on several occasions. There have been four sampling years: 1975, 1982, 1993 and 2004. It is important to note that the results from the samples taken in 2004 are not directly comparable to those from the early periods. The data from the earlier periods were derived from unfiltered samples which included both pesticides dissolved in water and pesticides contained in and adsorbed to particulates suspended in the water. The data from 2004 were derived from filtered samples and measure only the fraction of pesticides dissolved in water. Since most pesticides are poorly soluble in water, the data from 2004 may underestimate ambient pesticide concentrations relative to the earlier data. Sampling during 1975 focused heavily on the insecticides dieldrin, lindane, and DDT and on the metabolites of DDT. The concentrations of these substances were below the limits of detection. Single samples from sites on the mainstem of Oak Creek were taken in 1982 and 1993 and tested for toxaphene. In both cases, the concentration of this insecticide was below the limit of detection. During the 2004 sampling, the insecticides diazinon, dieldrin, and malathion were below the limit of detection. The insecticide carbaryl was detected in one sample as were the herbicide atrazine and its metabolite deethylatrazine. The concentration of atrazine reported, was found to be below the USEPA draft aquatic life criteria.

Polycyclic Aromatic Hydrocarbons (PAHs)

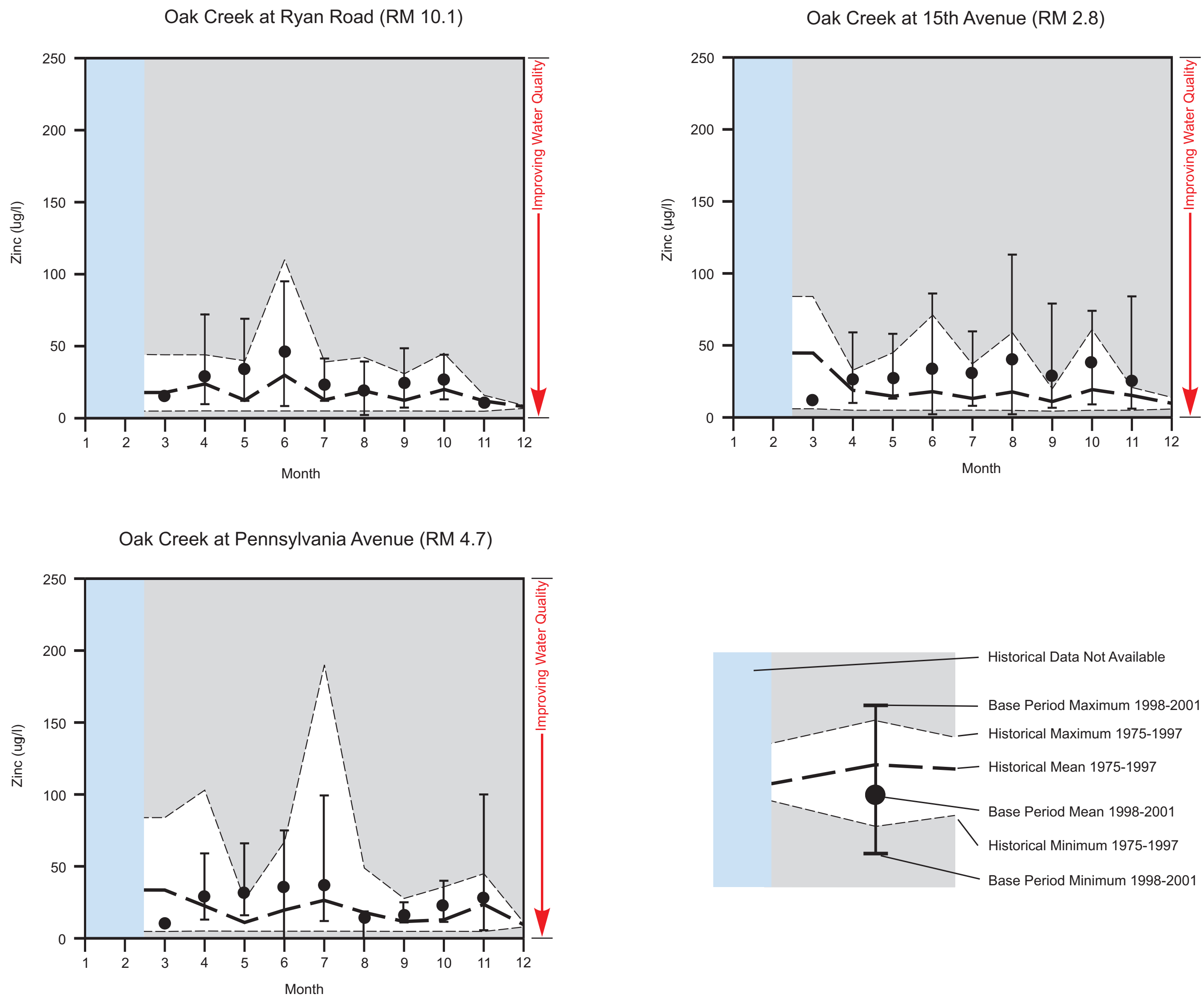
In 2004, one site along the mainstem of Oak Creek was sampled on three dates for six PAH compounds dissolved in water. The mean concentration of PAHs detected in these samples was 0.07 μg/l.

Polychlorinated Biphenyls (PCBs)

In 1975, three sites in the Oak Creek watershed were sampled for the presence and concentrations of PCBs in whole water, two sites on three dates and one site on one date. The concentrations of PCBs in all of these samples were below the limit of detection. Since then, Oak Creek has not been sampled for PCBs in water.

Figure 212

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF ZINC ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



NOTE: Acute and chronic toxicity standards for zinc depend upon ambient hardness which indicate zinc concentrations did not exceed these toxicity standards.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Toxic Contaminants in Aquatic Organisms

The WDNR periodically surveys tissue from fish and other aquatic organisms for the presence of toxic and hazardous contaminants. Surveys were conducted at sites within the Oak Creek watershed between 1987 and 1993. These surveys screened for the presence and concentrations of several contaminants including metals, PCBs, and organochloride pesticides. Because of potential risks posed to humans by consumption of fish containing high levels of contaminants, the WDNR has issued fish consumption advisories for several species of fish taken from the Oak Creek watershed. The statewide fish consumption advisory for mercury applies to fish in the Oak Creek watershed. In addition, a special consumption advisory has been issued for several species in portions of Oak Creek due to tissue concentrations of PCBs (see Table 134).

Table 134

FISH CONSUMPTION ADVISORIES FOR THE OAK CREEK WATERSHED[a]

Species	Consumption Advisory Level			
	One Meal per Week	One Meal per Month	One Meal per Two Months	Do Not Eat
Oak Creek Up to First Dam				
Brown Trout	- -	Less than 22 inches	Larger than 22 inches	- -
Chinook Salmon	- -	Less than 32 inches	Larger than 32 inches	- -
Chubs	- -	All sizes	- -	- -
Coho Salmon	- -	All sizes	- -	- -
Lake Trout	- -	Less than 23 inches	23 to 27 inches	Larger than 27 inches
Rainbow Trout	Less than 22 inches	Larger than 22 inches	- -	- -
Smelt	All sizes	- -	- -	- -
Whitefish	- -	All sizes	- -	- -
Yellow Perch	All sizes	- -	- -	- -

[a]*The statewide general fish consumption advisory applies to other fish species not listed in this table.*

Source: Wisconsin Department of Natural Resources.

It is important to note that some samples collected from the Oak Creek watershed consisted of whole organism homogenates and others consisted of fillets of skin and muscle tissue. These types of samples are not directly comparable. Consumption advisory determinations are based on fillet samples. In both cases, a single sample may represent tissue from several fish of the same species.

Mercury

Between 1988 and 1993 the WDNR examined tissue from one sample each of carp, crayfish, and green sunfish from Oak Creek for mercury contamination. Fillet samples were examined for green sunfish and whole organism samples were examined for carp and crayfish. The concentration of mercury reported in the fillet sample from green sunfish was 0.2 μg per gram tissue. The concentrations of mercury reported in the whole organism samples from carp and crayfish were 0.08 μg per gram tissue and 0.014 μg per gram tissue, respectively.

It is important to recognize that the number of individual organisms and the range of species taken from this watershed that have been screened for the presence of mercury contamination are quite small. Because of this, these data may not be completely representative of the body burdens of mercury carried by aquatic organisms in the Creek and its tributaries.

PCBs

Between 1987 and 1993 the WDNR sampled tissue from three species of aquatic organisms from Oak Creek for contamination with PCBs. Fillet samples were examined for green sunfish and carp. The concentration of PCBs in the fillet sample from green sunfish was 0.20 μg per gram tissue. The concentrations of PCBs in the fillet samples from carp ranged between 0.95 μg per gram tissue and 0.97 μg per gram tissue. Whole organism samples were examined for carp and crayfish. The concentrations of PCBs in the whole organism samples from carp ranged between 0.27 μg per gram tissue and 1.80 μg per gram tissue. The concentration of PCBs in the whole organism sample from crayfish was 0.10 μg per gram tissue.

The number of individual organisms and the range of species taken from this watershed that have been screened for the presence of PCB contamination are quite small. Because of this, these data may not be completely representative of the body burdens of PCBs carried by aquatic organisms in the Creek and its tributaries.

Pesticides
Between 1987 and 1993 the WDNR examined fillet samples of green sunfish and whole organism samples of carp and crayfish from Oak Creek for contamination by historically used, bioaccumulative pesticides and their breakdown products. Many of these compounds are no longer in use. For example, crop uses of most of these compounds were banned in the United States between 1972 and 1983. While limited uses were allowed after this for some of these substances, by 1988 the uses of most had been phased out. Measurable concentrations of o,p'-DDT and p,p'-DDT were not detected in tissue of fish or crayfish collected from Oak Creek during this period. Measurable concentrations of the DDT breakdown products of o,p'-DDD, p,p'-DDD, o,p'-DDE, and p,p'-DDE were detected in whole organism samples of carp.

During the same period, fillet samples of green sunfish and whole organism samples of carp and crayfish from Oak Creek were examined for the presence of several other pesticides. Concentrations of chlordane isomers, 2,4,5-trichlorophenol, 2,4,6-trichlorophenol, aldrin, dieldrin, endrin, α-BHC, γ-BHC, hexachlorobenzene, pentachlorophenol, and toxaphene-like compounds were below the limit of detection in all the samples that were examined.

The number of individual organisms and the range of species taken from this watershed that have been screened for the presence of pesticide contamination are quite small. Because of this, these data may not be completely representative of the body burdens of pesticides carried by aquatic organisms in the Creek and its tributaries.

Toxic Contaminants in Sediment
Most of the data on contaminants in sediments of the Oak Creek watershed are from the mainstem of Oak Creek. Toxicants that have been sampled for include metals and PAHs. Sediment samples taken from Oak Creek during 1997 showed detectable concentrations of arsenic, cadmium, chromium, copper, lead, nickel, and zinc (see Table 135). Mean concentrations of arsenic, copper, lead, and zinc in these samples were between the Threshold Effect Concentrations (TEC) and the Probable Effect Concentrations (PECs), indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms (see Table 13 in Chapter III of this report).

The amount of organic carbon in sediment can exert considerable influence on the toxicity of nonpolar organic compounds such as PAHs, PCBs, and certain pesticides to benthic organisms. While the biological responses of benthic organisms to nonionic organic compounds has been found to differ across sediments when the concentrations are expressed on a dry weight basis, they have been found to be similar when the concentrations have been normalized to a standard percentage of organic carbon.[6] Because of this, the concentrations of PAHs, PCBs, and pesticides are generally normalized to 1 percent organic carbon prior to analysis. Data from measurements of organic carbon were not available for sediment samples from the Oak Creek watershed. Because of this, data on PAHs were not normalized and PAH data was not used in the calculation of mean PEC-Q values (see below).

Concentrations of PAHs in six sediment samples collected in 1997 ranged between about 5,050 micrograms PAH per kilogram (μg PAH/kg) sediment and about 89,090 μg PAH/kg sediment with a mean value of 27,100 μg PAH/kg sediment. Total organic carbon data were not available for these samples.

No data were available regarding concentrations of PCBs or pesticides in sediment from the Oak Creek watershed.

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[6]*U.S. Environmental Protection Agency,* Technical Basis for the Derivation of Equilibrium Partitioning Sediment Guidelines (ESGs) for the Protection of Benthic Organisms: Nonionic Organics*, USEPA Office of Science and Technology, Washington, D.C., 2000.*

Table 135

CONCENTRATIONS OF TOXIC METALS IN SEDIMENT SAMPLES FROM OAK CREEK: 1997[a]

Statistic	Metals							
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Mean	12.12	0.90	30.2	40.8	114.5	- -	21.5	188.5
Standard Deviation	5.31	0.53	11.4	18.9	171.9	- -	5.4	85.2
Minimum	4.69	0.31	17.0	18.0	15.0	- -	16.0	91.0
Maximum	20.00	1.50	44.0	63.0	460.0	- -	30.0	290.4
Number of Samples	6	6	6	6	6	0	6	6

[a]*All concentrations in mg/kg based on dry weight.*

Source: Wisconsin Department of Natural Resources.

The combined effects of several toxicants in sediments of Oak Creek were estimated using the methodology described in Chapter III of this report. Figure 213 shows that for sediments in Oak Creek overall mean PEC-Q values, a measure that integrates the effects of multiple toxicants on benthic organisms, range between 0.28 and 0.53. These PEC-Q levels suggest that benthic organisms in Oak Creek are experiencing incidences of toxic effects, as indicated in Figure 214. In these samples, the estimated incidence of toxicity ranges between 25 and 42 percent. Sampling on the North Branch of Oak Creek and the Mitchell Field Drainage Ditch suggest that benthic organisms in these streams are experiencing similar incidences of toxicity, with estimated incidences ranging between 17 and 58 percent.

Sediment from Oak Creek Park Pond has also been sampled for the presence of toxic contaminants. Toxicants that have been sampled for include metals, PAHs, and PCBs. Sediment samples taken from Oak Creek Park Pond between 1997 and 2001 showed detectable concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc (see Table 136). Mean concentrations of copper, lead, nickel, and zinc in the samples were between the TECs and PECs, indicating that these toxicants are likely to be producing some level of toxic effects in benthic organisms.

Concentrations of PAHs in four sediment samples collected between 1997 and 2001 ranged between 18,150 μg PAH/kg sediment and 22,730 μg PAH/kg sediment with a mean value of 20,000 μg PAH/kg sediment. Total organic carbon data were available for three of these samples. Concentrations of total PCBs in three sediment samples collected in 2001 ranged between 42 μg PCB/kg sediment and 230 μg PCB/kg sediment with a mean value of 118 μg PCB/kg sediment. Total organic carbon data were available for all of these samples.

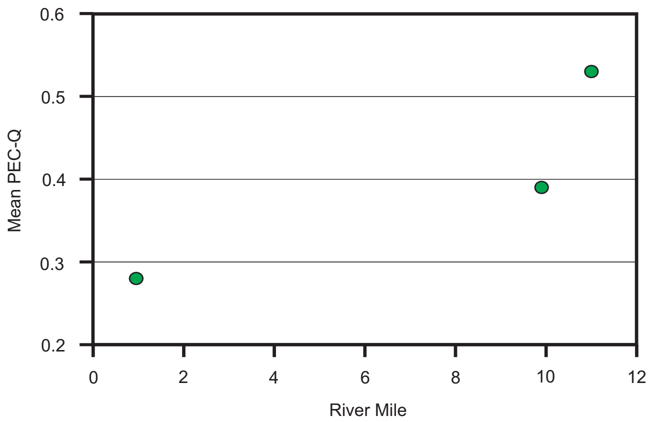
The combined effects of several toxicants in the sediment of Oak Creek Park Pond were estimated using the methodology described in Chapter III of this report. For sediments in Oak Creek Park Pond, overall mean PEC-Q values ranged between 0.23 and 0.34. These values suggest that benthic organisms in Oak Creek Park Pond are experiencing incidences of toxicity ranging between about 21 and 27 percent.

BIOLOGICAL CONDITIONS OF THE OAK CREEK AND ITS TRIBUTARIES

Aquatic and terrestrial wildlife communities have educational and aesthetic values, perform important functions in the ecological system, and are the basis for certain recreational activities. The location, extent, and quality of fishery and wildlife areas and the type of fish and wildlife characteristic of those areas are, therefore, important determinants of the overall quality of the environment in the Oak Creek watershed.

Figure 213

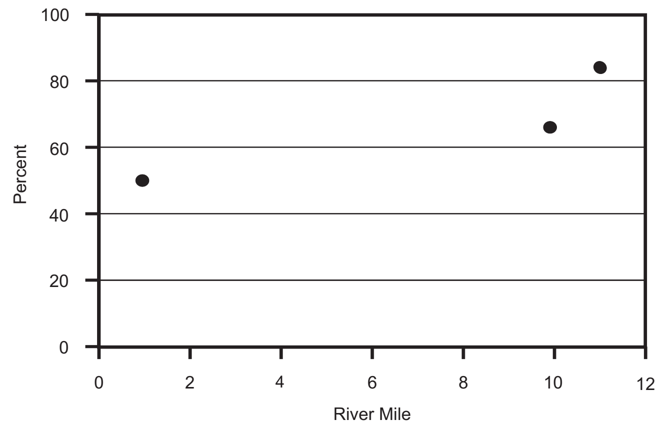
MEAN PROBABLE EFFECT CONCENTRATION QUOTIENTS (PEC-Q) FOR SEDIMENT ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 214

ESTIMATED INCIDENCE OF TOXICITY TO BENTHIC ORGANISMS ALONG THE MAINSTEM OF OAK CREEK: 1975-2001



Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 136

CONCENTRATIONS OF TOXIC METALS IN SEDIMENT SAMPLES FROM OAK CREEK PARK POND: 1997-2001[a]

Statistic	Metals							
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Mean	4.0	0.34	36.8	44.0	68.2	0.074	25.8	180.0
Standard Deviation	4.9	0.40	8.6	6.3	24.9	0.010	4.6	26.0
Minimum	0.0	0.00	27.0	36.0	43.0	0.065	20.0	150.0
Maximum	10.0	0.80	48.0	50.0	96.0	0.083	30.0	210.0
Number of Samples	4	4	4	4	4	3	4	4
Date of Earliest Sample	1997	1997	1997	1997	1997	2001	1997	1997
Date of Latest Sample	2001	2001	2001	2001	2001	2001	2001	2001

[a]*All concentrations in mg/kg based on dry weight.*

Source: Wisconsin Department of Natural Resources.

Fisheries

Streams

Review of the fishery data collected in the Oak Creek basin between 1902 and 2004 indicates an apparent loss of multiple species throughout the watershed during this time period. This apparent decrease does not seem to be due to decreased sampling effort compared with earlier time periods as shown in Table 137. Table 137 also shows that the historical and current numbers of species have been, and continue to be, very low. The time period of 1987-1993 contained only nine species of fish, which was the lowest number recorded for the Oak Creek watershed. However, since the 1987-1993 time period, the fishery has more than doubled in the number of recorded species to a maximum of 20 for the most recent time period, which is the highest ever recorded in this watershed. Despite the increase in species diversity noted above, there have been notable losses of several species of fishes that have not been observed since 1986 that include the brassy minnow, common shiner, emerald shiner, Iowa darter, sand shiner, blacknose shiner, and least darter, which is a species of special concern in the State of Wisconsin.

Table 137

FISH SPECIES COMPOSITION IN THE OAK CREEK WATERSHED: 1902-2004

Species According to Their Relative Tolerance to Pollution	Percent Occurrence[a]				
	1902-1974	1975-1986	1987-1993	1994-1997	1998-2004
Intolerant					
Blacknose Shiner	40.0	0.0	0.0	0.0	0.0
Least Darter[b]	20.0	0.0	0.0	0.0	0.0
Tolerant					
Black Bullhead	20.0	11.8	60.0	83.3	25.0
Blacknose Dace	20.0	0.0	0.0	0.0	12.5
Bluntnose Minnow	20.0	0.0	0.0	0.0	12.5
Central Mudminnow	40.0	58.8	100.0	83.3	75.0
Common Carp	0.0	11.8	0.0	33.3	12.5
Creek Chub	80.0	88.3	100.0	83.3	100.0
Fathead Minnow	60.0	82.4	40.0	83.3	75.0
Golden Shiner	20.0	0.0	0.0	16.7	0.0
Goldfish	0.0	29.4	0.0	33.3	25.0
Green Sunfish	60.0	82.4	100.0	100.0	100.0
White Sucker	80.0	82.4	100.0	66.7	75.0
Intermediate					
Bluegill	0.0	0.0	0.0	0.0	25.0
Brassy Minnow	20.0	0.0	0.0	0.0	0.0
Brook Stickleback	40.0	58.8	40.0	50.0	62.5
Channel Catfish	0.0	0.0	0.0	0.0	12.5
Common Shiner	20.0	0.0	0.0	0.0	0.0
Emerald Shiner	0.0	11.8	0.0	0.0	0.0
Gizzard Shad	0.0	0.0	0.0	0.0	12.5
Grass Carp	0.0	0.0	0.0	16.7	0.0
Iowa Darter	20.0	0.0	0.0	0.0	0.0
Johnny Darter	50.0	0.0	0.0	0.0	25.0
Lake Chub	0.0	0.0	0.0	0.0	12.5
Largemouth Bass	0.0	5.9	40.0	50.0	12.5
Longnose Dace	0.0	0.0	0.0	0.0	12.5
Pumpkinseed	0.0	11.8	100.0	33.3	12.5
Rock Bass	0.0	0.0	0.0	0.0	12.5
Sand Shiner	0.0	11.8	0.0	0.0	0.0
Total Number of Samples	5	17.0	5	6.0	8.0
Total Number of Samples per Year	<1	1.4	<1	1.5	1.3
Total Number of Species	16	13	9	13	20

[a]*Values represent percent occurrence, which equals the number of sites where each species was found divided by the total number of sites within a given time period.*

[b]*Designated species of special concern.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

It is important to note that in addition to the species listed in Table 137 the following species have also been reported from the estuary area near Lake Michigan: coho salmon, chinook salmon, rainbow trout, brown trout, brook trout, and longnose sucker.[7] Some of these species periodically also migrate upstream of Oak Creek as far up as the dam,[8] which is approximately one mile from the confluence of Lake Michigan, which precludes any fish

[7]*SEWRPC Planning Report No. 36,* A Comprehensive Plan for the Oak Creek Watershed*, August 1986.*

[8]*James Thompson, Wisconsin Department of Natural Resources, Personal Communication to SEWRPC, 2004.*

migration further upstream. This dam also prevents migration from upstream areas on Oak Creek to the lower reaches of Oak Creek and Lake Michigan, and is contributing to the maintenance of the poor abundance and diversity of this fishery over time. This dam limits the Oak Creek fishery by preventing both upstream and downstream immigration and emigration of fishes to and from Lake Michigan; preventing the ability of fishes to reach feeding areas, spawning areas, juvenile rearing habitat, and/or overwintering sites; and increasing the vulnerability of fishes to predation, especially in the downstream area spillway.

In Wisconsin, high-quality warmwater streams are characterized by many native species, darters, suckers, sunfish, and intolerant species (species that are particularly sensitive to water pollution and habitat degradation). Within such environments, tolerant fish species also occur that are capable of persisting under a wide range of degraded conditions and are also typically present within high-quality warmwater streams, but they do not dominate. Insectivores (fish that feed primarily on small invertebrates) and top carnivores (fish that feed on other fish, vertebrates, or large invertebrates) are generally common. Omnivores (fish that feed on both plant and animal material) are also generally common, but do not dominate. Simple lithophilous spawners which are species that lay their eggs directly on large substrate, such as clean gravel or cobble, without building a nest or providing parental care for the eggs are also generally common.

The Oak Creek watershed fishery has been and continues to be largely dominated by a high proportion of low dissolved oxygen tolerant fishes and low numbers of native fish species, which are indicative of a poor fishery (see Table 137 and Figure 215). The proportions of such tolerant fish species have all generally increased since 1975 as shown in Table 137. Most notable are the high dominance of the central mudminnow, creek chub, fathead minnow, white sucker, and green sunfish, which are a typical "urban" tolerant fishery assemblage.[9] Carp, an exotic invasive species, have been shown to be present, but have generally not dominated the fishery within this watershed to date. Nonetheless, carp are likely to be having a negative effect on overall fishery in this watershed by destroying habitat and competing for food and spawning areas of native fish species.

Index of Biotic Integrity (IBI) results indicate that there has not been any significant change in the quality of the fishery of the Oak Creek watershed compared to the historical conditions (see Figure 216 and Map 78). Although a few of the samples over time achieved a poor community IBI rating score of 20 to 30, in the majority of the sites over all years, samples have generally remained in the very poor (IBI score 0-20) classification. Figure 217 indicates that the entire watershed has historically contained a low abundance and diversity of fishes. Although the data are limited to assess the current fishery conditions within each of the subwatersheds during the 1998 through 2004 period, Figure 217 demonstrates that it is very likely that each of these subwatersheds will continue to sustain a limited fishery.

Urbanization can cause numerous changes to streams that have the potential to alter aquatic biodiversity that include but are not limited to the following factors which have been observed to varying degrees in the Oak Creek watershed:[10]

- Increased flow volumes and channel-forming storms—These alter habitat complexity, change availability of food organisms related to timing of emergence and recovery after disturbance, reduce prey availability, increase scour related mortality, deplete large woody debris for cover in the channel, and accelerate streambank erosion;

- Decreased base flows—These lead to increased crowding and competition for food and space, increased vulnerability to predation, and increased sediment deposition;

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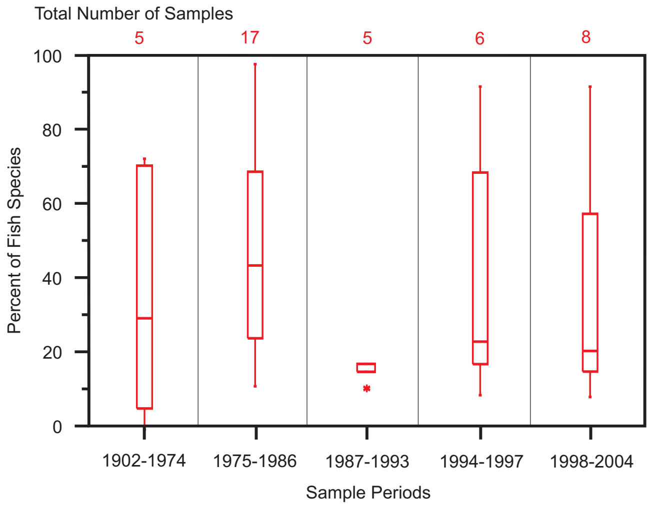
[9]*William Wawrzyn, Wisconsin Department of Natural Resources, Personal Communication to SEWRPC, 2004.*

[10]*Center for Watershed Protection, "Impacts of Impervious Cover on Aquatic Systems,"* Watershed Protection Research Monograph No. 1*, March 2003.*

Figure 215

PROPORTIONS OF DISSOLVED OXYGEN TOLERANT FISHES IN THE OAK CREEK WATERSHED: 1902-2004

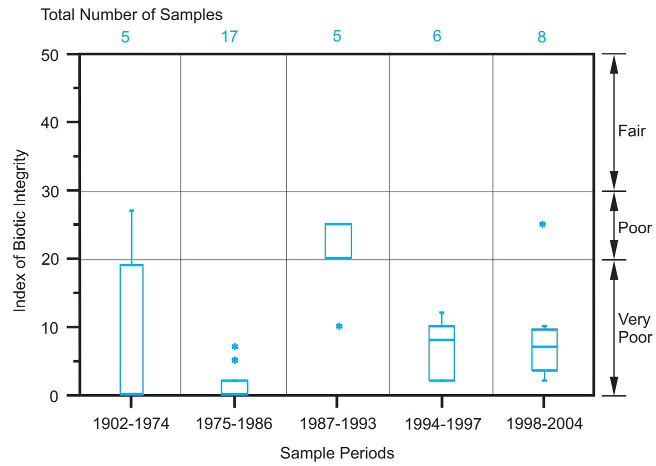


NOTE: See Figure 191 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 216

FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION IN THE OAK CREEK WATERSHED: 1902-2004



NOTE: See Figure 191 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

- Increased sediment transport—This leads to reduced survival of eggs, loss of habitat due to deposition, siltation of pool areas, and reduced macroinvertebrate reproduction;
- Loss of pools and riffles—This leads to a loss of deep water cover and feeding areas causing a shift in balance of species due to habitat changes;
- Changed substrate composition—This leads to reduced survival of eggs, loss of inter-gravel cover refuges for early life stages for fishes, and reduced macroinvertebrate production;
- Loss of large woody debris—This leads to loss of cover from large predators and high flows, reduced sediment and organic matter storage, reduced pool formation, and reduced organic substrate for macroinvertebrates;
- Increased temperatures due to runoff from pavement versus natural landscapes–This leads to changes in migration patterns, increased metabolic activity, increased disease and parasite susceptibility, and increased mortality of sensitive fishes and macroinvertebrates;
- Creation of fish blockages by road crossings, culverts, drop structures, and dams—This leads to loss of spawning habitat, inability to reach feeding areas and/or overwintering sites, loss of summer rearing habitat, and increased vulnerability to predation;
- Loss of vegetative rooting systems—This leads to decreased channel stability, loss of undercut banks, and reduced streambank integrity;
- Channel straightening or hardening—This leads to increased stream scour and loss of habitat complexity through disruption of sediment transport ability;

Map 78

FISHERIES (1902-2004) AND MACROINVERTEBRATE (1979-2003) SAMPLE LOCATIONS AND CONDITIONS WITHIN THE OAK CREEK WATERSHED

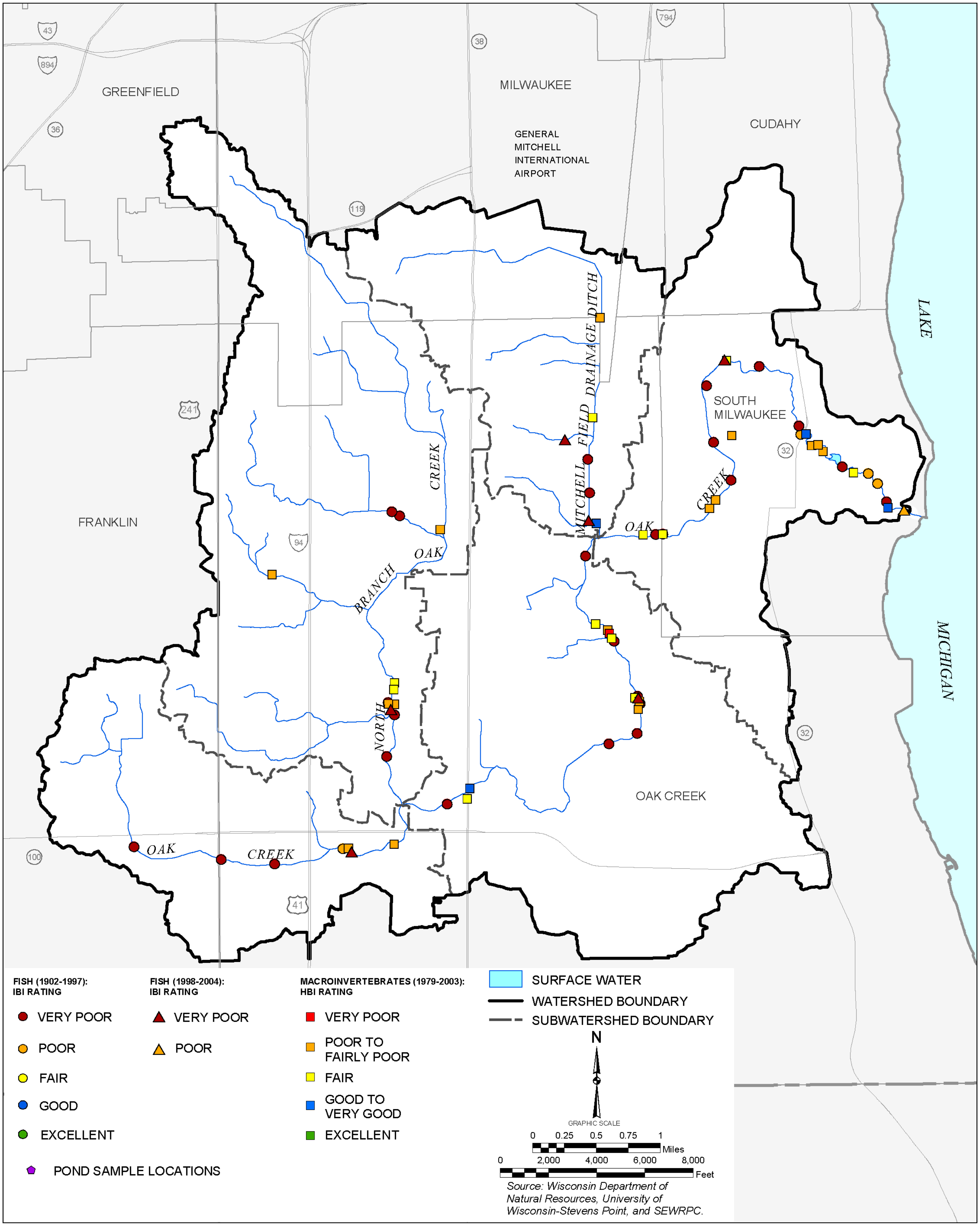
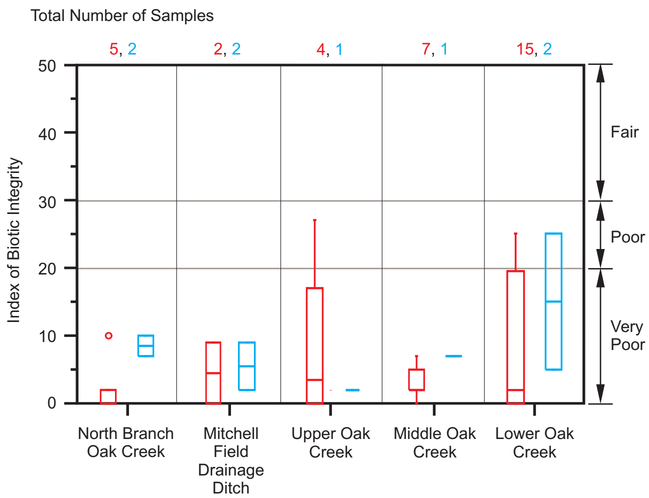


Figure 217

HISTORICAL AND BASE PERIOD FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION IN STREAMS IN THE OAK CREEK WATERSHED: 1902-2004



NOTE: See Figure 191 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

- Reduced water quality—This leads to reduced survival of eggs and juvenile fishes, acute and chronic toxicity to juveniles and adult fishes, and increased physiological stress;

- Increased turbidity—This leads to reduced survival of eggs, reduced plant productivity, and increased physiological stress on aquatic organisms; and

- Increased algae blooms—These lead to oxygen depletion causing fish kills due to chronic algae blooms and increased eutrophication of standing waters.

The apparent stagnation of the fishery community within the Oak Creek watershed can be attributed to habitat loss and degradation as a consequence of human activities primarily related to the historic and current development that has occurred within the watershed.

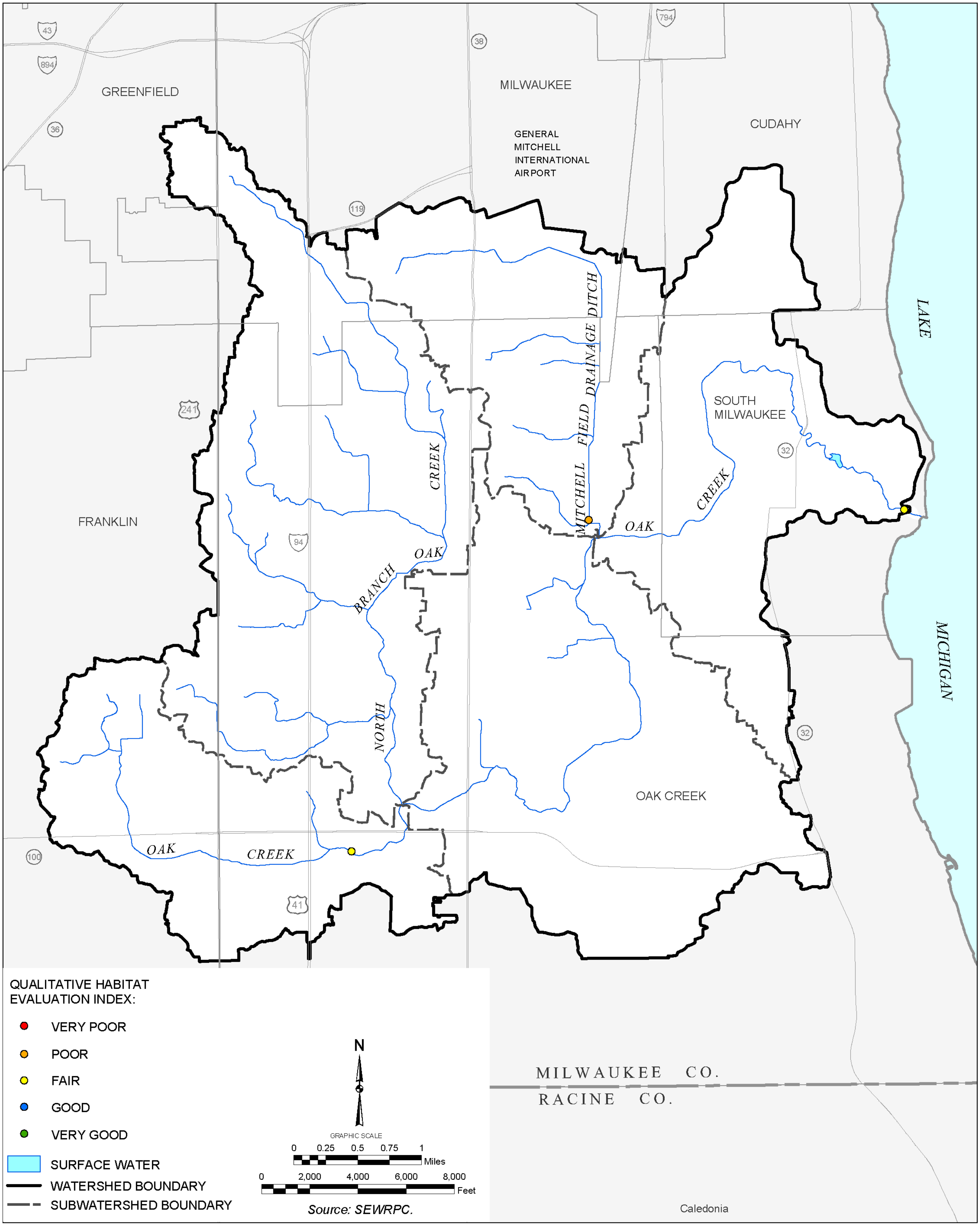
Chapter II of this report includes a description of the correlation between urbanization in a watershed and the quality of the aquatic biological resources. The amount of imperviousness in a watershed that is directly connected to the stormwater drainage system can be used as a surrogate for the combined impacts of urbanization in the absence of mitigation. The Oak Creek watershed included about 30 percent urban land use by 1970, which approximately corresponds to about 10 percent directly connected imperviousness in the watershed, and, as of 2000, it has about 55 percent urban land overall (approximately 20 percent directly connected imperviousness). That level of directly connected imperviousness is beyond the threshold level of 10 percent at which previously cited studies indicate that negative biological impacts have been observed. As also described in Chapter II of this report, studies have indicated that the amount of agricultural land in a watershed can also be correlated with negative instream biological conditions. Agricultural land use has dominated the upper and middle portions of the Oak Creek watershed, whereas the lower portions of the watershed have been dominated by urban development. Based upon the amount of agricultural and urban lands in the watershed and, in the past, a lack of measures to mitigate the adverse effects of those land uses, the resultant poor to very poor IBI scores observed throughout this watershed are not surprising. The standards and requirements of Chapter NR 151 "Runoff Management," and Chapter NR 216, "Storm Water Discharge Permits," of the *Wisconsin Administrative Code* are intended to mitigate the impacts of existing and new urban development and agricultural activities on surface water resources through control of peak flows in the channel-forming range, promotion of increased baseflow through infiltration of stormwater runoff, and reduction in sediment loads to streams and lakes. The implementation of those rules is intended to mitigate, or improve, water quality and instream/inlake habitat conditions.

As shown on Map 79, limited habitat data have been collected as part of the WDNR baseline monitoring program in the Oak Creek watershed. These data were analyzed using the Qualitative Habitat Evaluation Index (QHEI),[11]

[11]*Edward T. Rankin, The Quality Habitat Evaluation Index [QHEI]: Rationale, Methods, and Application, State of Ohio Environmental Protection Agency, November 1989.*

Map 79

STREAM HABITAT SAMPLE LOCATIONS AND CONDITIONS WITHIN THE OAK CREEK WATERSHED: 2000



Source: SEWRPC.

which integrates the physical parameters of the stream and adjacent riparian features to assess potential habitat quality. This index is designed to provide a measure of habitat that generally corresponds to those physical factors that affect fish communities and which are important to other aquatic life (i.e. macroinvertebrates). This index has been shown to correlate well with fishery IBI scores. The results suggest that fisheries habitat is poor to fair throughout the Oak Creek watershed. Comparing these results with previous data and habitat assessments suggests that habitat quality has not improved, and is largely a result of the past channelization and ongoing urbanization that has occurred and is continuing to occur throughout this watershed.[12]

Lakes and Ponds

There are no major lakes (i.e. lakes greater than 50 acres in size) within the Oak Creek watershed, but there is one pond named Oak Creek Parkway Pond located behind the dam near Mill Road on the mainstem of Oak Creek approximately one mile upstream of the confluence with Lake Michigan.

The only recorded fishery survey was completed for Oak Creek Parkway Pond in 1981. The survey indicated that this pond contained a typical urban fish species mixture mostly dominated by tolerant species of green sunfish, central mudminnow, goldfish, carp, fathead minnow, and white sucker. However, largemouth bass and pumpkinseed were also reported to occur in this pond, which indicates that it may support some limited natural fishery. No other surveys have been completed on this pond to date.

Oak Creek Parkway Pond is enrolled in the Wisconsin Department of Natural Resources' Urban Fishing Program in partnership with Milwaukee County. That program was initiated in 1983 for the metropolitan Milwaukee area and is still active today. The program provides fishing in urban ponds for anglers who don't have opportunities to leave the urban environment. The program stocks rainbow trout and other species to provide seasonal and year-round fishing.

Macroinvertebrates

The Hilsenhoff Biotic Index[13] (HBI) and percent EPT (percent of families comprised of Ephemeroptera, Plecoptera, and Trichoptera) were used to classify the historic and existing macroinvertebrate and environmental quality in this stream system using survey data from various sampling locations in the Oak Creek watershed.

Macroinvertebrate surveys conducted from 1979 through 2004 by the WDNR show that HBI scores generally range from poor to fair in the Oak Creek watershed (see Figure 218 and Map 78). Figure 218 also shows that there has not been any substantial change in the macroinvertebrate community quality over time. Results generally indicate that current macroinvertebrate diversity and abundances are indicative of fair water quality in the Oak Creek watershed; however, this was based only upon four samples collected during the 1998 through 2004 time period and may not be indicative of overall quality in this watershed. In more than half of the samples taken within this watershed, more than 50 percent of the total number of organisms was comprised within one family of organisms. This high dominance by a single taxon is associated with low abundance and diversity of macroinvertebrates at these sample sites and is indicative of disturbed and/or degraded conditions within a stream.[14]

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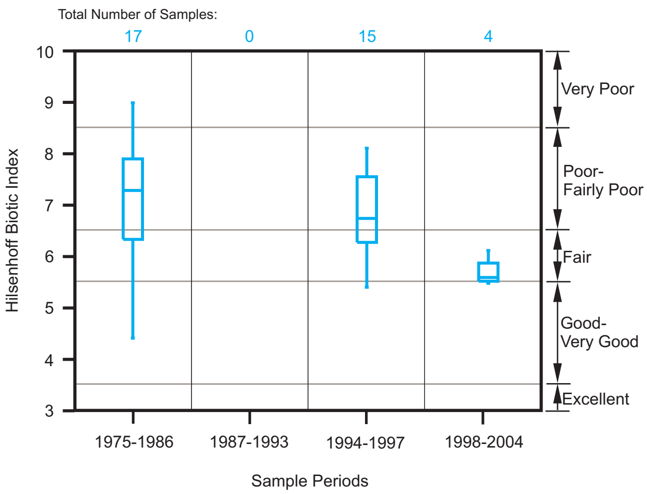
[12]*SEWRPC Planning Report No. 36,* A Comprehensive Plan for the Oak Creek Watershed*, August, 1986.*

[13]*William L. Hilsenhoff,* Rapid Field Assessment of Organic Pollution with Family-Level Biotic Index*, University of Wisconsin- Madison, 1988.*

[14]*M.T. Barbour, J. Gerritsen, B.D. Snyder, and J.B. Stribling, Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition, EPA 841-B-99-002, U.S. Environmental Protection Agency, Office of Water, Washington, D.C., 1999.*

Figure 218

HILSENHOFF BIOTIC INDEX (HBI) MACROINVERTEBRATE SCORES IN OAK CREEK: 1975-2004



NOTE: See Figure 191 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Macroinvertebrate community conditions seem to be equally poor in the North Branch of Oak Creek subwatershed, Mitchell Field Drainage Ditch subwatershed, and Lower Oak Creek subwatershed as demonstrated by both HBI and percent EPT as shown in Figure 219. However, the recent records are based upon a limited number of samples, which makes interpretation difficult based upon a lack of comparability. If the recent records do represent current conditions within the Oak Creek watershed, the data suggest that both the North Branch of Oak Creek subwatershed and Lower Oak Creek subwatershed show potential limited improvements in macroinvertebrate abundance and diversity. This, however, would have to be verified with additional sampling. Due to the lack of recent data, current macroinvertebrate community quality conditions are not available for the Upper Oak Creek subwatershed or Middle Oak Creek subwatershed, but they are not likely to be different from the historical conditions because of the degraded habitat within this watershed. As noted above, implementation of the standards and requirements of Chapter NR 151 and Chapter NR 216 of the *Wisconsin Administrative Code* are intended to mitigate the impacts of existing and new urban development and agricultural activities on surface water resources. Such implementation could have a positive effect on macroinvertebrates.

Wisconsin researchers have generally found that as the amount of urban lands increase, such as in the Oak Creek watershed, the subsequent macroinvertebrate community diversity and abundance decreases, which is supported by the data for this watershed.[15]

Synthesis

The Oak Creek watershed currently contains a very poor fishery and poor to fair macroinvertebrate communities. The fish community contains relatively few species of fishes, is trophically unbalanced, contains few or no top carnivores, and is dominated by tolerant fishes. The macroinvertebrate community is equally depauperate and dominated by tolerant taxa. Since water quality has either not improved or has generally been decreasing in the watershed for most constituents, water quality and habitat are potentially the most important factors limiting both the fishery and macroinvertebrate community. It is also important to note there are several other factors that are likely limiting the aquatic community, including but not limited to 1) periodic stormwater loads; 2) decreased base flows; 3) continued fragmentation due to culverts, drop structures, and concrete lined channels, enclosed conduits, and a dam; 4) past channelization; and/or 5) increased water temperatures due to urbanization.

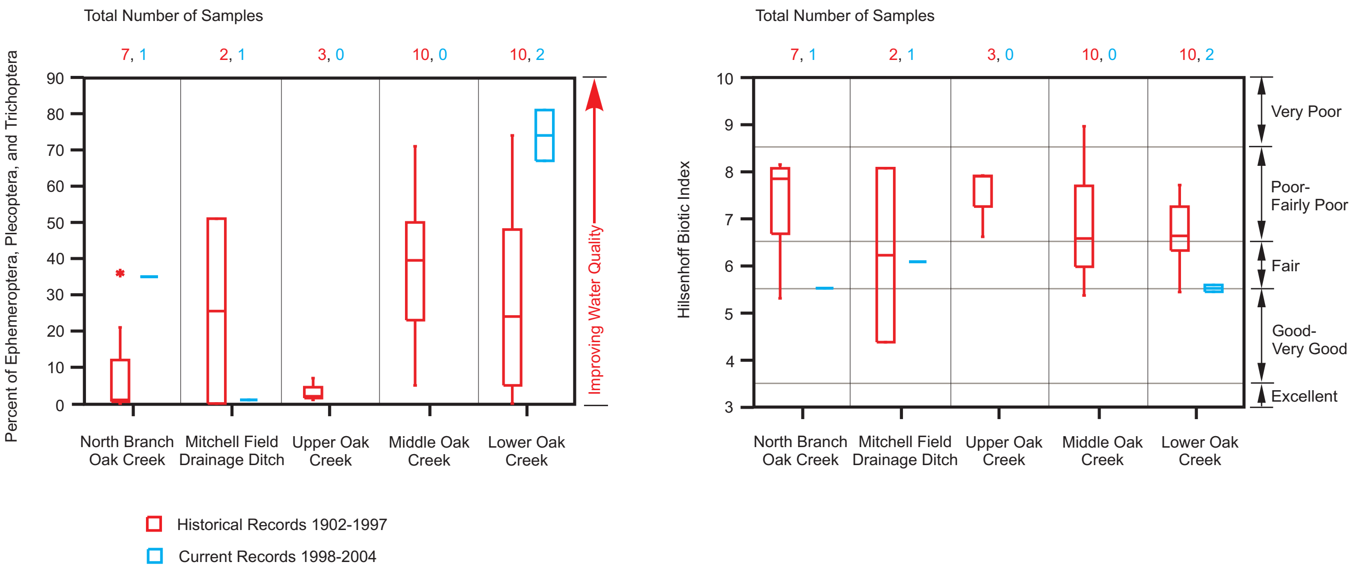
Other Wildlife

Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of this study, it is possible, by polling naturalists and wildlife managers familiar with the area, to compile lists of amphibians, reptiles, birds, and mammals which may be expected to be found in the area under existing conditions. The technique used in compiling the wildlife data involved obtaining lists of those amphibians,

[15] *J. Masterson and R. Bannerman, "Impact of Stormwater Runoff on Urban Streams in Milwaukee County, Wisconsin," Wisconsin Department of Natural Resources, Madison, Wisconsin, 1994.*

Figure 219

HISTORICAL AND BASE PERIOD PERCENT EPHEMEROPTERA, PLECOPTERA, AND TRICHOPTERA (EPT) MACROINVERTEBRATE GENERA AND HILSENHOFF BIOTIC INDEX (HBI) SCORES IN STREAMS IN THE OAK CREEK WATERSHED: 1975-2004



NOTE: See Figure 191 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

reptiles, birds, and mammals known to exist, or known to have existed, in the Oak Creek watershed area, associating these lists with the historic and remaining habitat areas in the area as inventoried, and projecting the appropriate amphibian, reptile, bird, and mammal species into the watershed area. The net result of the application of this technique is a listing of those species which were probably once present in the watershed, those species which may be expected to still be present under currently prevailing conditions, and those species which may be expected to be lost or gained as a result of urbanization within the area. It is important to note that this inventory was conducted on a countywide basis for Milwaukee County for each of the aforementioned major groups of organisms. Some of the organisms listed as occurring in Milwaukee County may only infrequently occur within the Oak Creek watershed.

A variety of mammals, ranging in size from large animals like the white-tailed deer, to small animals like the meadow vole, are likely to be found in the Oak Creek watershed. Muskrat, white-tailed deer, gray squirrel, and cottontail rabbit are mammals reported to occur in the area. Appendix D lists the mammals whose ranges historically extended into the watershed.

A large number of birds, ranging in size from large game birds to small songbirds, are found in the Oak Creek watershed (Appendix E). Each bird is classified as to whether it breeds within the area, visits the area only during the annual migration periods, or visits the area only on rare occasions. The Oak Creek watershed also supports a significant population of waterfowl, including mallards and Canada geese. Larger numbers of various waterfowl likely move through the drainage area during the annual migrations when most of the regional species may also be present. Many game birds, songbirds, waders, and raptors also reside or visit the watershed.

Amphibians and reptiles are vital components of the ecosystem within an environmental unit like that of the Oak Creek watershed. Examples of amphibians native to the area include frogs, toads, and salamanders. Turtles and snakes are examples of reptiles common to the Oak Creek watershed area. Appendix F lists the amphibian and reptile species normally expected to be present in the Oak Creek watershed area under present conditions. Most amphibians and reptiles have specific habitat requirements that are adversely affected by advancing urban development. The major detrimental factors affecting the maintenance of amphibian diversity in a changing environment is water level fluctuations in urban wetlands that occur as a result of increased stormwater discharges,[16] the destruction of breeding ponds, urban development occurring in migration routes, and changes in food sources brought about by urbanization.

Endangered and threatened species and species of special concern present within the Oak Creek watershed include 15 species of plants, two species of birds, two species of fish, one species of herptiles, and two species of invertebrates from Wisconsin Department of Natural Resources records dating back to the late 1800s (see Table 138). Since 1975, there have only been observed five species of plants, two species of fish, and two species of birds totaling to an apparent loss of 13 species.

The complete spectrum of wildlife species originally native to the watershed, along with their habitat, has undergone significant change in terms of diversity and population size since the European settlement of the area. This change is a direct result of the conversion of land by the settlers from its natural state to agricultural and urban uses, beginning with the clearing of the forest and prairies, the draining of wetlands, and ending with the development of extensive urban areas. Successive cultural uses and attendant management practices, primarily urban, have been superimposed on the land use changes and have also affected the wildlife and wildlife habitat. In urban areas, cultural management practices that affect wildlife and their habitat include the use of fertilizers, herbicides, and pesticides; road salting for snow and ice control; heavy motor vehicle traffic that produces disruptive noise levels and air pollution and nonpoint source water pollution; and the introduction of domestic pets.

CHANNEL CONDITIONS AND STRUCTURES

The conditions of the bed and bank of a stream are greatly affected by the flow of water through the channel. The great amount of energy possessed by flowing water in a stream channel is dissipated along the stream length by turbulence, streambank and streambed erosion, and sediment resuspension. Sediments and associated substances delivered to a stream may be stored, at least temporarily, on the streambed, particularly where obstructions or irregularities in the channel decrease the flow velocity or act as particle traps or filters. On an annual basis or a long-term basis, streams may exhibit net deposition, net erosion, or no net change in internal sediment transport, depending on tributary land uses, watershed hydrology, precipitation, and geology. From 3 to 11 percent of the annual sediment yield in a watershed in southeastern Wisconsin may be contributed to streambank erosion.[17] In the absence of mitigative measures, increased urbanization in a watershed may be expected to result in increased streamflow rates and volumes, with potential increases in streambank erosion and bottom scour, and flooding problems. In the communities in the Oak Creek watershed, the requirements of MMSD Chapter 13, "Surface Water and Storm Water," are applied to mitigate instream increases in peak rates of flow that could occur due to new urban development without runoff controls. In the City of South Milwaukee, which is the only community in the watershed outside the MMSD service area, local ordinances provide for control of runoff from new development. Also, where soil conditions allow, the infiltration standards of Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* are applied to limit increases in runoff volume from new development.

Milwaukee County commissioned an assessment of stability and fluvial geomorphic character of streams within four watersheds in the County including the Oak Creek watershed.[18] This study, conducted in fall 2003, examined

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[16]*Center for Watershed Protection,* op. cit.

[17]*SEWRPC Technical Report No. 21,* Sources of Water Pollution in Southeastern Wisconsin: 1975, *September 1978.*

[18]*Inter-Fluve, Inc.,* op. cit.

Table 138

ENDANGERED AND THREATENED SPECIES AND SPECIES OF SPECIAL CONCERN IN THE OAK CREEK WATERSHED: 2004

Common Name	Scientific Name	Status under the U.S. Endangered Species Act	Wisconsin Status
Crustacea			
Prairie Crayfish	*Procambarus gracilis*	Not listed	Special concern
Dragonflies and Damselflies			
Lemon-faced Emerald	*Somatochlora ensigera*	Not listed	Special concern
Fish			
Least Darter[a]	*Etheostoma microperca*	Not listed	Special concern
Redfin Shiner[a]	*Lythrurus umbratilis*	Not listed	Threatened
Reptiles and Amphibians			
Butler's Garter Snake	*Thamnophis butleri*	Not listed	Threatened
Birds			
Black Crowned Night Heron[a]	*Nycticorax nycticorax*	Not listed	Special concern
Red-Shouldered Hawk[a]	*Buteo Lineatus*	Not listed	Threatened
Plants			
American Sea Rocket	*Cakile edentula*	Not listed	Special concern
Bluestem Goldenrod	*Solidago caesia*	Not listed	Endangered
Downy Willow-herb	*Epilobium strictum*	Not listed	Special Concern
False Hop Sedge	*Carex lupuliformis*	Not listed	Endangered
Handsome Sedge	*Carex formosa*	Not listed	Threatened
Hooker Orchis[a]	*Platanthera hookeri*	Not listed	Special concern
Indian Cucumber Root[a]	*Medeola virginiana*	Not listed	Special concern
Ohio Goldenrod	*Solidago ohioensis*	Not listed	Special concern
Purple Milkweed[a]	*Asclepias purpurascens*	Not listed	Endangered
Ravenfoot Sedge	*Carex crus-corvi*	Not listed	Endangered
Reflexed Trillium	*Trillium recurvatum*	Not listed	Special concern
Small Yellow Lady's-Slipper[a]	*Cypripedium calceolus*	Not listed	Special concern
Smooth Black-haw	*Viburnum prunifolium*	Not listed	Special concern
Sticky False Asphodel	*Tofieldia glutinosa*	Not listed	Threatened
Waxleaf Meadowrue[a]	*Thalictrum revolutum*	Not listed	Special concern

[a]*Species observed prior to year 1975.*

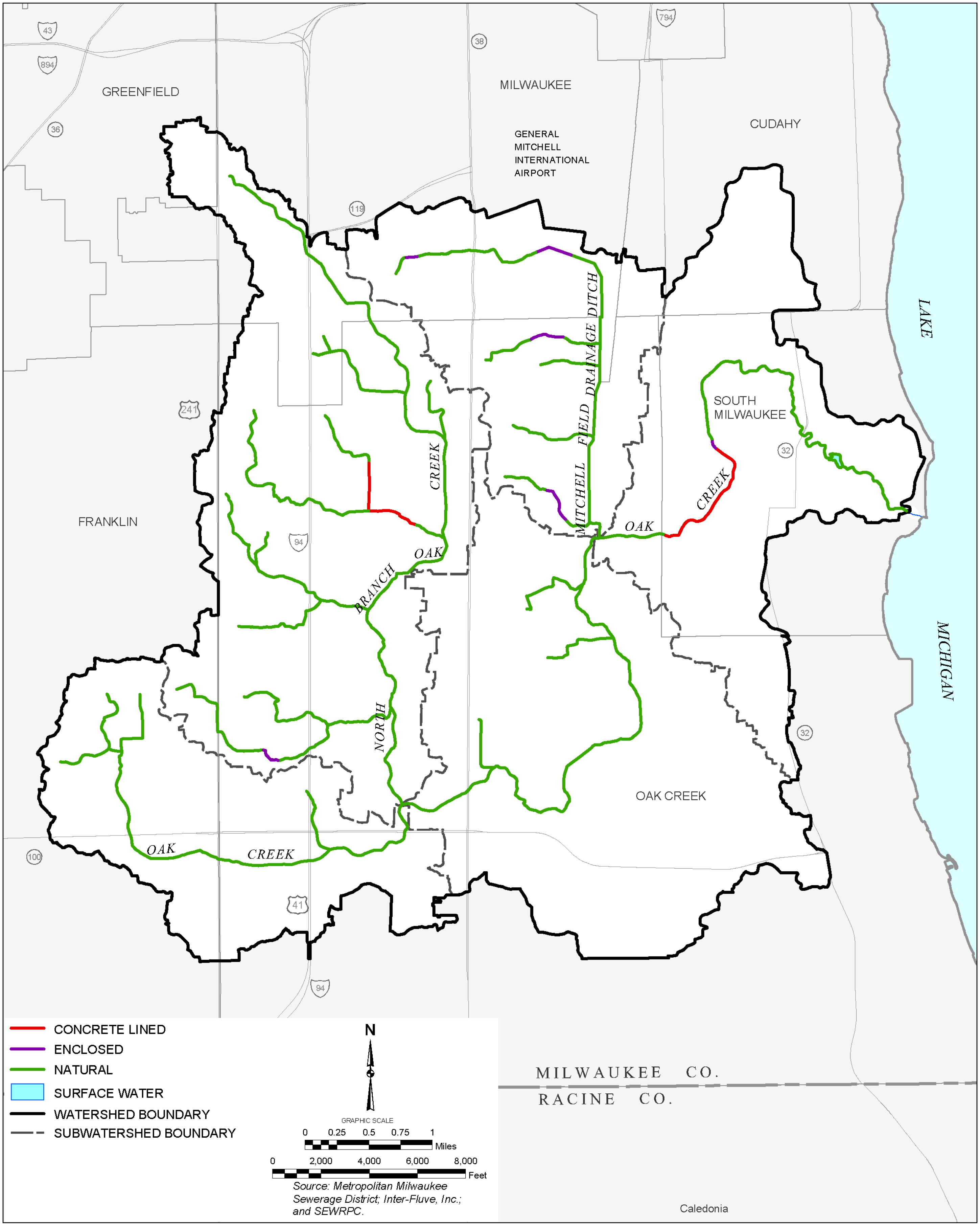
Source: *Wisconsin Department of Natural Resources, Wisconsin State Herbarium, Wisconsin Society of Ornithology, and SEWRPC.*

channel stability in about 24 miles of stream channel along the mainstem of Oak Creek and several of its tributaries. In addition, a major goal of the study was to create a prioritized list of potential project sites related to mitigation of streambank erosion and channel incision, responses to channelization, and maintenance of infrastructure integrity. The impacts of development on streamflow rates and volumes can be mitigated to some degree by properly installed and maintained stormwater management practices. Some level of control is required by current regulations. The effectiveness of such regulations is, in part, dependent upon the level of compliance with, and enforcement of, the regulations.

Map 80 shows the types of channel bed lining in streams within the Oak Creek watershed. The majority channel bed lining in the watershed, about 93 percent, is natural. A small portion of the mainstem of Oak Creek downstream from the confluence with the Mitchell Field Drainage Ditch is concrete-lined as is a portion of a tributary to the North Branch of Oak Creek. In addition, small reaches of the mainstem of Oak Creek, a tributary to the North Branch of Oak Creek, and the Mitchell Field Drainage Ditch and its tributaries are enclosed in conduit.

Map 80

CHANNEL BED CONDITIONS WITHIN THE OAK CREEK WATERSHED: 2000



Source: Metropolitan Milwaukee Sewerage District; Inter-Fluve, Inc.; and SEWRPC.

The stream network has been substantially modified over much of the watershed. With the exception of the lower 5,000 feet, almost the entire length of the mainstem of Oak Creek is channelized and straightened, with a trapezoidal cross-section. The lower reaches, though not straightened, have significant hard armoring from riprap and stonewalls. The North Branch of Oak Creek is also channelized. The upstream reaches are extremely incised, especially through Copernicus Park. The remainder of the channel is trapezoidal with mainly grass-lined slopes. A railroad bridge upstream from the confluence with the mainstem of Oak Creek is preventing at least three feet of head cut from moving upstream through the system.[19] About half the course of the Mitchell Field Drainage Ditch consists of either grass-lined ditch or conduit running through General Mitchell International Airport. Downstream from the airport, this tributary has also been channelized. Near the airport, historical incision has lowered the channel bed by as much as five feet.

Bed and Bank Stability

Alluvial streams within urbanizing watersheds often experience rapid channel enlargement. As urbanization occurs, the fraction of the watershed covered by impervious materials increases. This can result in profound changes in the hydrology in the watershed. As a result of runoff being conveyed over impervious surfaces to storm sewers which discharge directly to streams, peak flows become higher and more frequent and streams become "flashier" with flows increasing rapidly in response to rainfall events. The amount of sediment reaching the channel often declines. Under these circumstances and in the absence of armoring, the channel may respond by incising. This leads to an increase in the height of the streambank, which continues until a critical threshold for stability is exceeded. When that condition is reached, mass failure of the bank occurs, leading to channel widening. Typically, incision in an urbanizing watershed proceeds from the mouth to the headwaters.[20] Lowering of the channel bed downstream increases the energy gradient upstream and in the tributaries. This contributes to further destabilization. Once it begins, incision typically follows a sequence of channel bed lowering, channel widening, and deposition of sediment within the widened channel. Eventually, the channel returns to a stable condition characteristic of the altered channel geometry.

Map 81 summarizes bank stability for Oak Creek and its tributaries.[21] About 24 miles of channel were inventoried for stability as shown on Map 81. Most alluvial reaches that were examined appeared to be degrading and actively eroding (see Figure 220). Less than 8 percent of the lengths of bank assessed were observed to be stable. The stable reaches are located on the Lower Oak Creek, Middle Oak Creek, Upper Oak Creek and Mitchell Field Drainage Ditch as shown on Map 81. All of the rest of the reaches assessed within the watershed were observed to be eroding (see Figure 220).

Dams

There is currently one dam within the Oak Creek watershed. It is located on Oak Creek in the Oak Creek Parkway, as shown on Map 82, and is used to control the water level in the pond upstream. In addition, a total of six drop structures are located in Oak Creek and the North Branch of Oak Creek. Three other drop structures, two on the North Branch and one on the main stem of Oak Creek, were removed by MMSD in 2004. Drop structures can disrupt sediment transport and limit aquatic organism passage in these systems, which serve to fragment these populations reducing overall abundance and diversity.

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[19]Ibid.

[20]*S.A. Schumm, "Causes and Controls of Channel Incision," In: S. E. Darby and A. Simon (eds.),* Incised River Channels: Processes, Forms, Engineering and Management, *John Wiley & Sons, New York, 1999.*

[21]*Inter-Fluve, Inc.,* op. cit.

Map 81

STREAMBANK STABILITY CONDITIONS WITHIN THE OAK CREEK WATERSHED: 2000

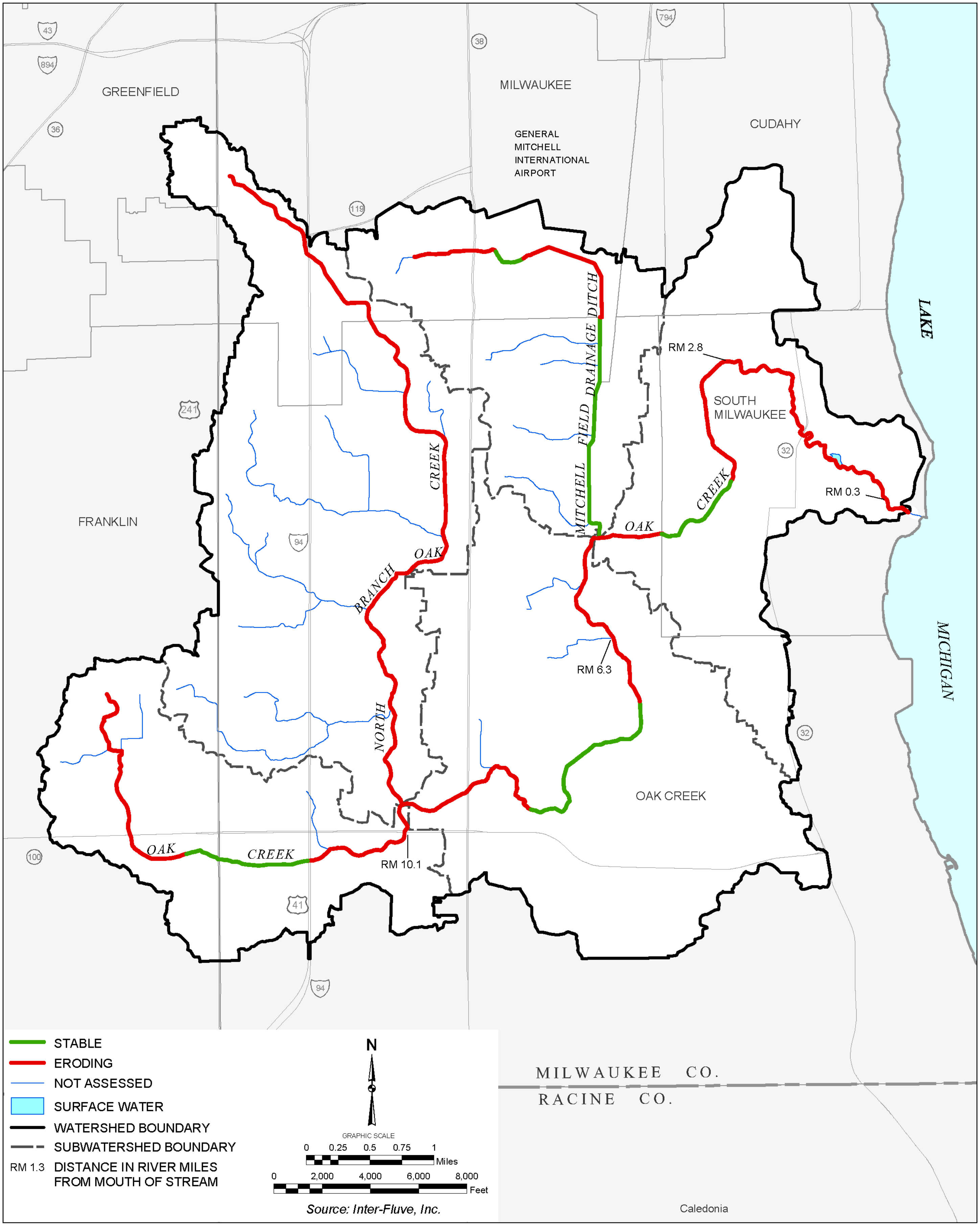


Figure 220

STREAMBANK STABILITY CONDITIONS ALONG REACHES WITHIN THE OAK CREEK WATERSHED: 2003

NORTH BRANCH OAK CREEK (RM 6.0)

OAK CREEK (RM 7.0)

MITCHELL FIELD DRAINAGE DITCH (RM 1.3)

OAK CREEK (RM 3.7)

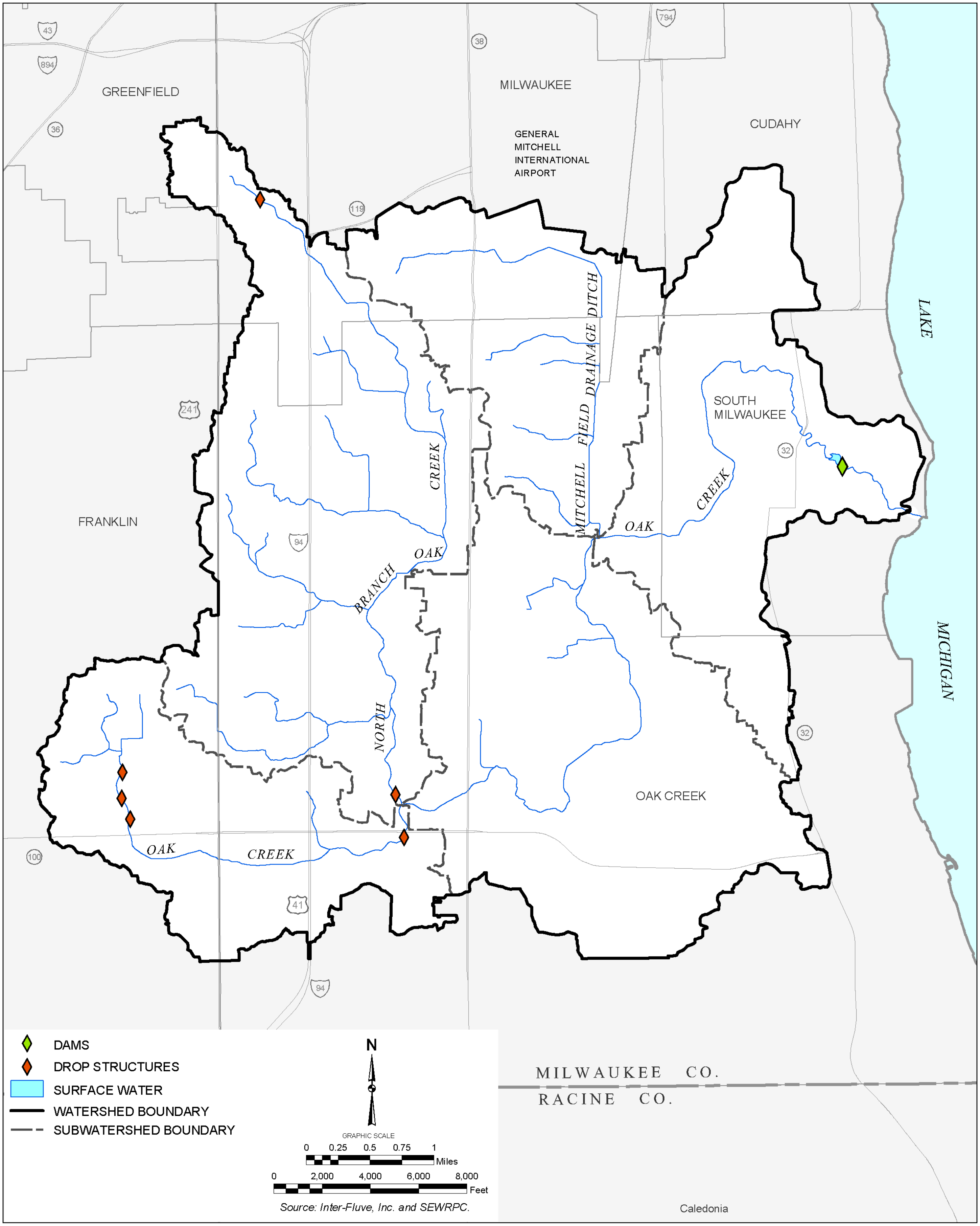
OAK CREEK (RM 11.4)

OAK CREEK (RM 0.3)

Source: Milwaukee County and Inter-Fluve, Inc.

Map 82

DAMS AND DROP STRUCTURES WITHIN THE OAK CREEK WATERSHED: 2005



Source: Inter-Fluve, Inc. and SEWRPC.

HABITAT AND RIPARIAN CORRIDOR CONDITIONS

One of the most important tasks undertaken by the Commission as part of its regional planning effort was the identification and delineation of those areas of the Region having high concentrations of natural, recreational, historic, aesthetic, and scenic resources and which, therefore, should be preserved and protected in order to maintain the overall quality of the environment. Such areas normally include one or more of the following seven elements of the natural resource base which are essential to the maintenance of both the ecological balance and the natural beauty of the Region: 1) lakes, rivers, and streams and the associated undeveloped shorelands and floodlands; 2) wetlands; 3) woodlands; 4) prairies; 5) wildlife habitat areas; 6) wet, poorly drained, and organic soils; and 7) rugged terrain and high-relief topography. While the foregoing seven elements constitute integral parts of the natural resource base, there are five additional elements which, although not a part of the natural resource base per se, are closely related to or centered on that base and therefore are important considerations in identifying and delineating areas with scenic, recreational, and educational value. These additional elements are 1) existing outdoor recreation sites; 2) potential outdoor recreation and related open space sites; 3) historic, archaeological, and other cultural sites; 4) significant scenic areas and vistas; and 5) natural and scientific areas.

The delineation of these 12 natural resource and natural resource-related elements on a map results in an essentially linear pattern of relatively narrow, elongated areas which have been termed "environmental corridors" by the Commission. Primary environmental corridors include a wide variety of the abovementioned important resource and resource-related elements and are at least 400 acres in size, two miles in length, and 200 feet in width. Secondary environmental corridors generally connect with the primary environmental corridors and are at the least 100 acres in size and one mile long. In addition, smaller concentrations of natural resource features that have been separated physically from the environmental corridors by intensive urban or agricultural land uses have also been identified. These areas, which are at least five acres in size, are referred to as isolated natural resource areas.

It is important to point out that, because of the many interlocking and interacting relationships between living organisms and their environment, the destruction or deterioration of any one element of the total environment may lead to a chain reaction of deterioration and destruction among the others. The drainage of wetlands, for example, may have far-reaching effects, since such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas of interconnecting lake and stream systems. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater. Groundwater serves as a source of domestic, municipal, and industrial water supply and provides a basis for low flows in rivers and streams. Similarly, the destruction of woodland cover, which may have taken a century or more to develop, may result in soil erosion and stream siltation and in more rapid runoff and increased flooding, as well as destruction of wildlife habitat. Although the effects of any one of these environmental changes may not in and of itself be overwhelming, the combined effects may lead eventually to the deterioration of the underlying and supporting natural resource base, and of the overall quality of the environment for life. The need to protect and preserve the remaining environmental corridors within the drainage area directly tributary to the Oak Creek system thus becomes apparent.

Primary Environmental Corridors

The primary environmental corridors in Southeastern Wisconsin generally lie along major stream valleys and around major lakes, and contain almost all of the remaining high-value woodlands, wetlands, and wildlife habitat areas, and all of the major bodies of surface water and related undeveloped floodlands and shorelands. As shown on Map 83, in the year 2000 primary environmental corridors in the Oak Creek drainage area encompassed about 684 acres, or about 4 percent of the drainage area. In the period from the initial inventory in 1980 through 2000, there was an increase of about 237 acres in the area of primary environmental corridors within the watershed.[22]

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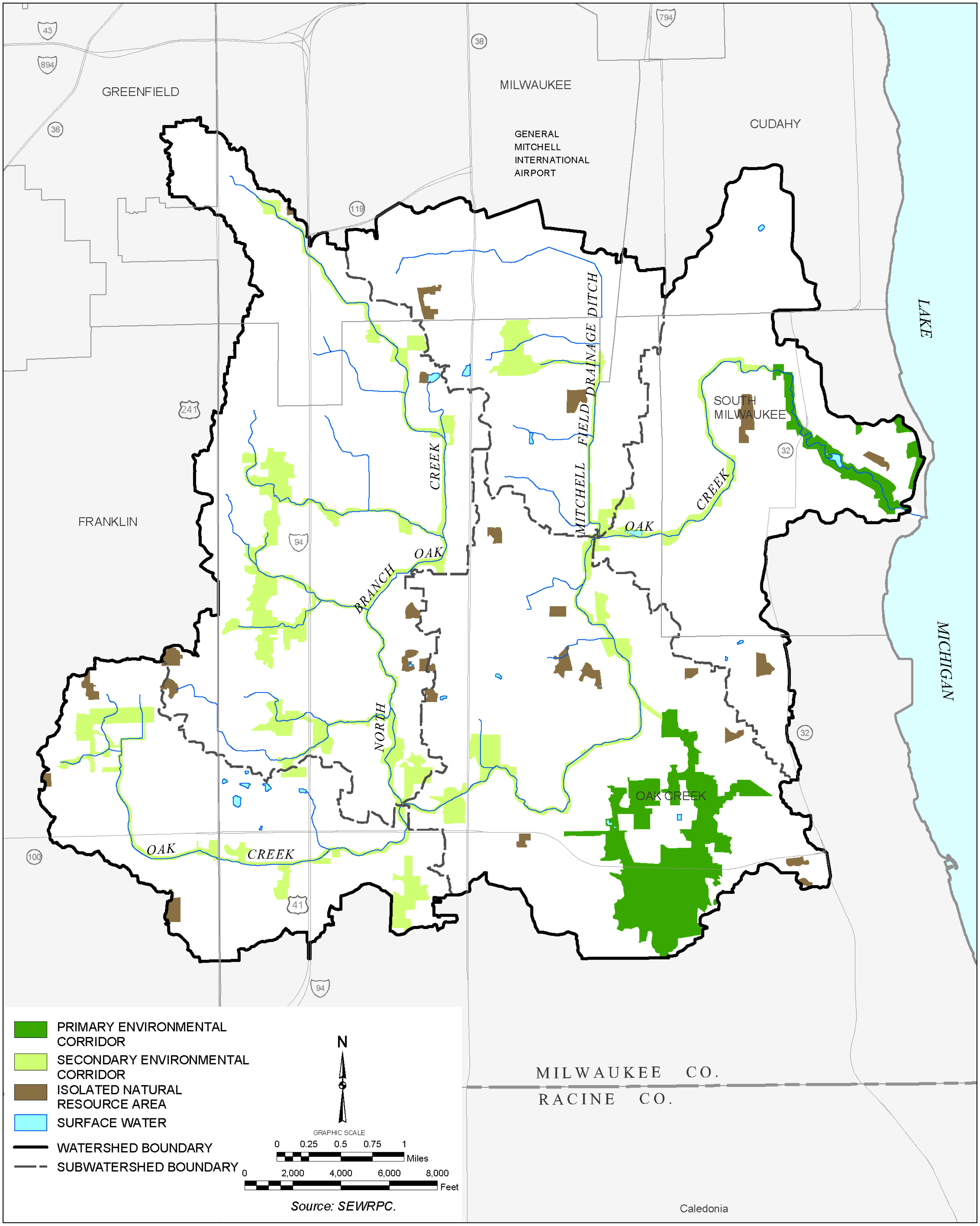
[22]*This increase in the primary environmental corridor area is primarily due to an increase in the area of delineated 100-year recurrence interval floodlands. Those lands are either Milwaukee County park lands or would be anticipated to revegetate since development would be restricted within the flood plain.*

Map 83

ENVIRONMENTAL CORRIDORS WITHIN THE OAK CREEK WATERSHED: 2000



Source: SEWRPC.

Primary environmental corridors may be subject to urban encroachment because of their desirable natural resource amenities. Unplanned or poorly planned intrusion of urban development into these corridors, however, not only tends to destroy the very resources and related amenities sought by the development, but tends to create severe environmental and development problems as well. These problems include, among others, water pollution, flooding, wet basements, failing foundations for roads and other structures, and excessive infiltration of clear water into sanitary sewerage systems.

Secondary Environmental Corridors

Secondary environmental corridors are located generally along intermittent streams or serve as links between segments of primary environmental corridors. As shown on Map 83, secondary environmental corridors in the Oak Creek drainage area encompassed about 1,160 acres, or about 7 percent of the drainage area. In the period from the initial inventory in 1980 through 2000, there was an increase of about 8 acres in the area of secondary environmental corridors within the watershed. Secondary environmental corridors contain a variety of resource elements, often remnant resources from primary environmental corridors which have been developed for intensive agricultural purposes or urban land uses, and facilitate surface water drainage, maintain "pockets" of natural resource features, and provide for the movement of wildlife, as well as for the movement and dispersal of seeds for a variety of plant species.

Isolated Natural Resource Areas

In addition to primary and secondary environmental corridors, other small concentrations of natural resource base elements exist within the drainage area. These concentrations are isolated from the environmental corridors by urban development or agricultural lands and, although separated from the environmental corridor network, have important natural values. These isolated natural resource areas may provide the only available wildlife habitat in a localized area, provide good locations for local parks and nature study areas, and lend a desirable aesthetic character and diversity to the area. Important isolated natural resource area features include a variety of isolated wetlands, woodlands, and wildlife habitat. These isolated natural resource area features should also be protected and preserved in a natural state whenever possible. Such isolated areas five or more acres in size within the Oak Creek drainage area also are shown on Map 83 and total about 202 acres, or about 1 percent of the drainage area. In the period from the initial inventory in 1980 through 2000, there was a loss of about 20 acres in the area of isolated natural resource areas within the watershed.

Natural Areas and Critical Species Habitat

The regional natural areas and critical species habitat protection and management plan[23] ranked natural resource features based upon a system that considered areas to be of statewide or greater significance, NA-1; countywide or regional significance, NA-2; or local significance, NA-3. In addition, certain other areas were identified as critical species habitat sites. Within the Oak Creek drainage area, as shown on Map 84, 12 such sites were identified, two of which were identified as critical species habitat sites. No sites were identified as being of statewide or great significance (NA-1). Of the natural areas of countywide or regional significance (NA-2), portions of the Cudahy Woods and Falk Park Woods are currently under protective ownership by local government units, with additional portions proposed for acquisition. These areas, together with the other areas already under protective ownership and proposed for acquisition by Milwaukee County, total approximately 147 acres in areal extent. A further approximately 309 acres of natural area of local significance (NA-3) were identified. Of the approximately 24 acres of critical species habitat identified in the regional natural areas and critical species habitat protection and management plan, none of the area at these two sites are proposed for acquisition by state and county government, as shown in Table 139. For a summary of the endangered and threatened species and species of special concern present within the Oak Creek drainage area see the Other Wildlife section above.

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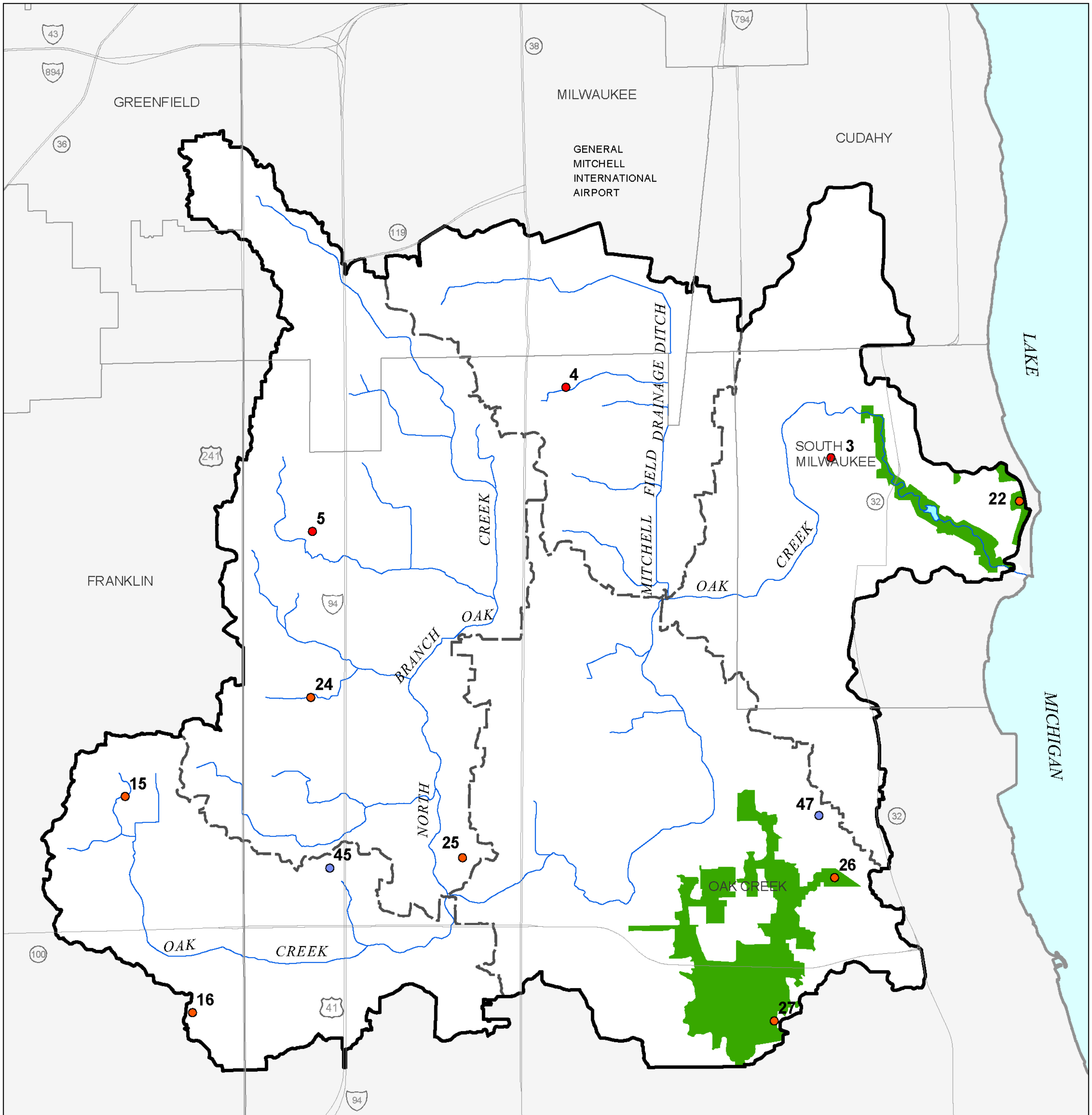
[23]*SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*, September 1997.*

Map 84

KNOWN NATURAL AREAS AND CRITICAL SPECIES HABITAT SITES WITHIN THE OAK CREEK WATERSHED: 2000



- NATURAL AREA OF STATEWIDE OR GREATER SIGNIFICANCE (NA-1)(NONE)
- NATURAL AREA OF COUNTYWIDE OR REGIONAL SIGNIFICANCE (NA-2)
- NATURAL AREA OF LOCAL SIGNIFICANCE (NA-3)
- CRITICAL SPECIES HABITAT SITE
- PRIMARY ENVIRONMENTAL CORRIDOR
- SURFACE WATER

15 IDENTIFICATION NUMBER (SEE TABLE 139)

IDENTIFICATION NUMBERS ARE THOSE THAT WERE ASSIGNED FOR SEWRPC PLANNING REPORT NO. 42, *A REGIONAL NATURAL AREAS AND CRITICAL SPECIES HABITAT PROTECTION AND MANAGEMENT PLAN FOR SOUTHEASTERN WISCONSIN.*

- WATERSHED BOUNDARY
- SUBWATERSHED BOUNDARY

N

GRAPHIC SCALE

0 0.25 0.5 0.75 1 Miles

0 2,000 4,000 6,000 8,000 Feet

Source: SEWRPC.

Table 139

NATURAL AREAS AND CRITICAL SPECIES HABITAT AREAS IN THE OAK CREEK WATERSHED

Number on Map 84	Name	Type of Area	Location	Owned (acres)	Proposed to Be Acquired[a] (acres)	Total (acres)	Proposed Acquisition Agency
	Natural Areas						
3	Rawson Park Woods	NA-2	City of South Milwaukee	23	- -	23	Milwaukee County
4	Cudahy Woods	NA-2	City of Oak Creek	41	6	47	Milwaukee County
5	Falk Park Woods	NA-2	City of Oak Creek	71	6	77	Milwaukee County
15	Franklin (Puetz Road) Woods	NA-3	City of Franklin	28	- -	28	City of Franklin
16	Fitzsimmons Road Woods	NA-3	City of Franklin	14	28	42	City of Franklin
22	Grant Park Woods-South	NA-3	City of South Milwaukee	45	- -	45	Milwaukee County
24	Esch-Honadel Woods	NA-3	City of Oak Creek	- -	72	72	Milwaukee County
25	Wood Creek Woods	NA-3	City of Oak Creek	- -	35	35	City of Oak Creek[b]
26	Wedge Woods	NA-3	City of Oak Creek	- -	19	19	City of Oak Creek
27	Oak Creek Low Woods	NA-3	City of Oak Creek	31	37	68	Milwaukee County
	Critical Species Habitat						
45	Meyers Woods	CSH	City of Oak Creek	- -	- -[c]	18	- -
47	Fittshur Wetland	CSH	City of Oak Creek	- -	- -[c]	6	- -

[a]*Acquisition is recommended in SEWRPC Planning Report No. 42 (PR No. 42),* Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*, September 1997.*

[b]*Area planned for urban development and removed from planned environmental corridor by SEWRPC Community Assistance Planning Report No. 213*, Sanitary Sewer Service Area for the City of Oak Creek*, Milwaukee County, Wisconsin*, *July 1994.*

[c]*Not proposed for acquisition.*

Source: SEWRPC.

Measures for Habitat Protection

Within the Oak Creek basin, as in the rest of Milwaukee County, stream corridor protection has been focused on public acquisition of the lands adjacent to the stream banks and their preservation as river parkways. These lands are frequently incorporated into public parks and other natural areas.

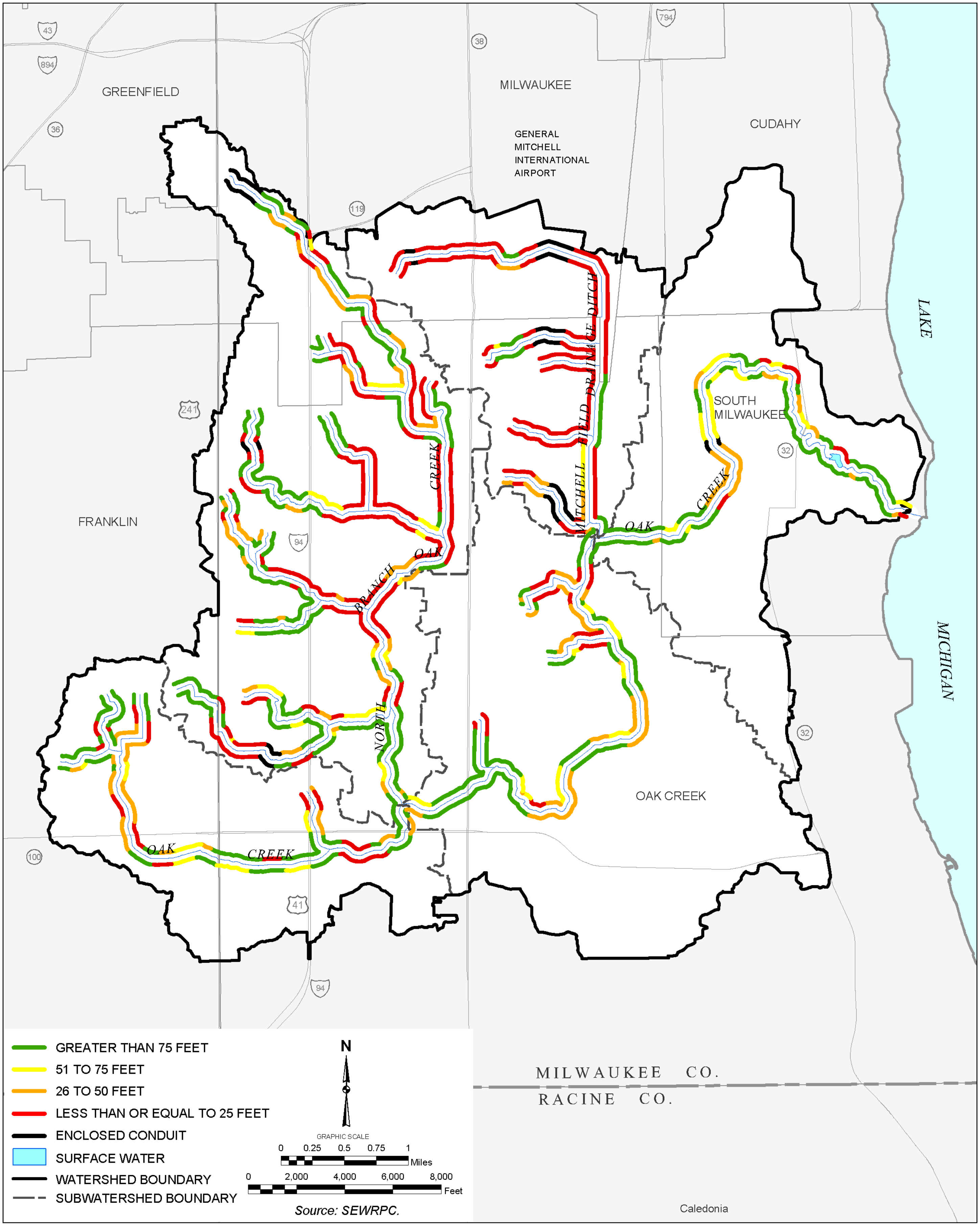
The provision of buffer strips along waterways represents an important intervention that addresses anthropogenic sources of contaminants, with even the smallest buffer strip providing environmental benefit.[24] Map 85 shows the current status of riparian buffers along Oak Creek and its major tributary streams. Approximately 3.4 miles of the Oak Creek stream network, mostly concentrated within the Mitchell Field Drainage Ditch subbasin, are enclosed conduits, and offer limited opportunity for installation of such buffers as shown on Map 85. In general, buffers greater than 75 feet in width are widely distributed throughout the entire area of the Oak Creek watershed except for the Mitchell Field Drainage Ditch subwatershed area.

Figure 221 shows the current status of buffer widths ranging from less than 25 feet, 25 to 50 feet, 50 to 75 feet, and greater than 75 feet among each of the major Oak Creek subwatersheds. The Mitchell Field Drainage Ditch subwatershed is the only one dominated by buffers less than 25 feet in width, which accounts for about 65 percent of the buffer widths in the subwatershed. On a subwatershed basis, buffers from 25 to 50 feet wide occurred along an average of 18 percent of the total stream length and buffers from 50 to 75 feet wide occurred along an average of 11 percent of the stream length. Except for the Mitchell Field Drainage Ditch subwatershed, buffers greater than 75 feet in width occur along between 40 percent and 52 percent of the total stream lengths in individual subwatersheds, which is the greatest proportion compared to all of the other buffer width categories and indicates a greater level of protection in these subwatersheds.

[24]*A. Desbonnet, P. Pogue, V. Lee, and N. Wolff, "Vegetated Buffers in the Coastal Zone - a summary review and bibliography,"* CRC Technical Report No. 2064. *Coastal Resources Center, University of Rhode Island, 1994.*

Map 85

RIPARIAN CORRIDOR WIDTHS WITHIN THE OAK CREEK WATERSHED: 2000

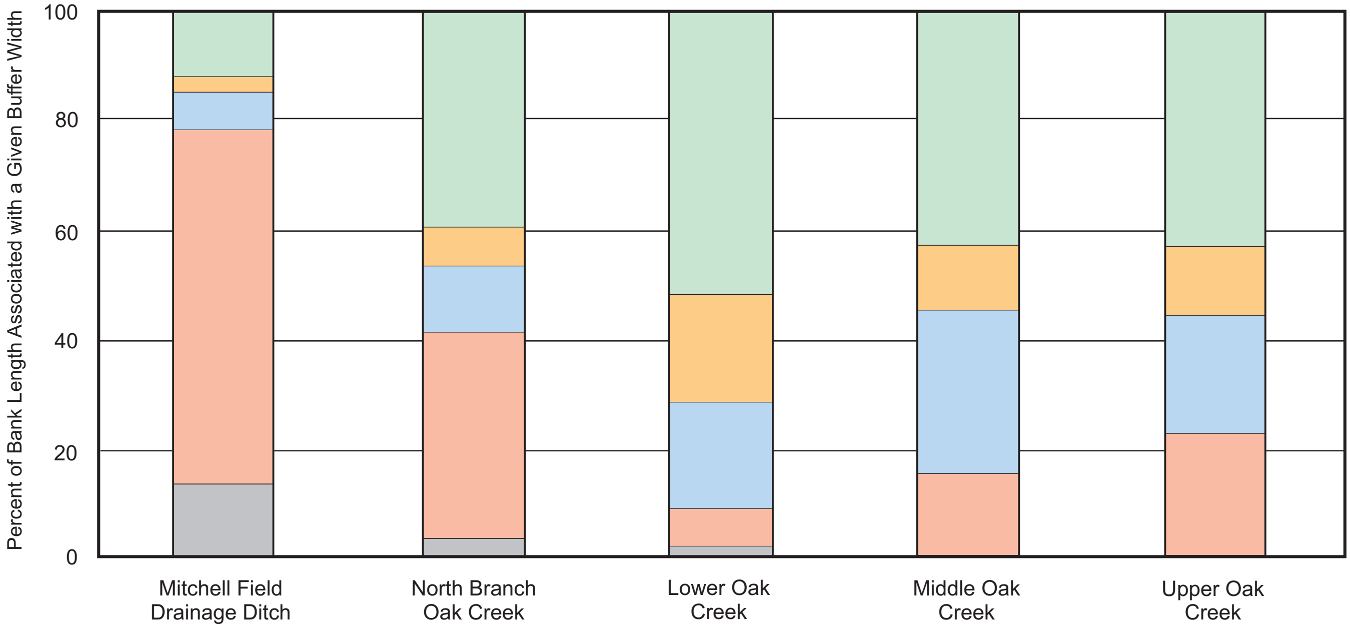


Source: SEWRPC.

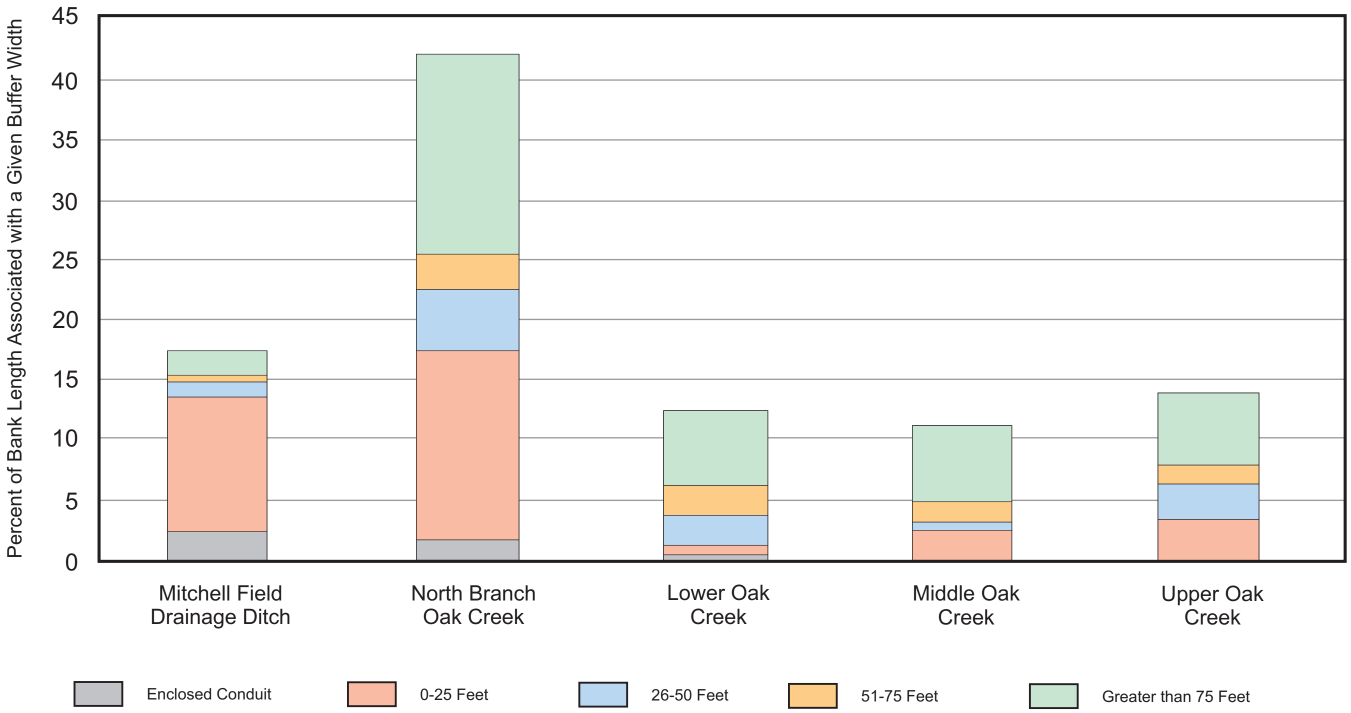
Figure 221

RIPARIAN BUFFER WIDTHS WITHIN THE OAK CREEK WATERSHED: 2000

PERCENT OF BUFFER WIDTH CATEGORIES WITHIN EACH SUBWATERSHED



PERCENT OF BUFFER WIDTH CATEGORIES WITHIN THE ENTIRE OAK CREEK WATERSHED



Source: SEWRPC.

SUMMARY AND STATUS OF IMPLEMENTATION OF ELEMENTS OF THE REGIONAL WATER QUALITY MANAGEMENT PLAN IN THE OAK CREEK WATERSHED

The initial regional water quality management plan for the Southeastern Wisconsin Region, which was adopted in 1979, had five elements: a land use element, a point source pollution abatement element, a nonpoint source pollution abatement element, a sludge management element, and a water quality monitoring element.[25] For the purposes of documenting current conditions and trends in water quality and pollution sources, it is deemed important to redocument the point source and nonpoint source pollution abatement elements of the regional water quality management plan as amended. This section provides that redocumentation and describes the action taken to implement that plan. Those two specific elements of the plan as they relate to the Oak Creek watershed and actions taken to implement them are described below for those components of the plan elements most directly related to water quality conditions.

Point Source Pollution Abatement Plan Element

In 1975, there were no combined sewer outfalls and three known separate sanitary sewer overflow relief devices located in the Oak Creek watershed. One of these flow relief devices was abated in 1984.

In 1975, there were eight industrial point sources of wastewater. These sources discharged industrial cooling, process, rinse, and wash waters through 13 outfalls directly, or indirectly, to the surface water system. The initial regional water quality management plan included a recommendation that these industrial point sources of wastewater be monitored, and discharges limited to levels determined on a case-by-case basis under the Wisconsin Pollutant Discharge Elimination System (WPDES) permit process. Currently, this recommendation has been nearly fully implemented for the point sources that currently exist in the watershed, the only exception being an unplanned discharge or spill.

Due to the dynamic nature of permitted point sources, it is recognized that the number of wastewater sources changes as industries and other facilities change locations or processes and as decisions are made with regard to the connection of such sources to public separate sanitary sewer systems. Many of the historical dischargers are now connected to the public separate sanitary sewer system.

Nonpoint Source Pollution Abatement Plan Element

The nonpoint source element of the original plan described a variety of methods and practices for abatement of nonpoint source pollution in urban and rural areas and estimated the percent reduction of released pollutants that could be achieved through implementation of these methods and practices. It identified ammonia-nitrogen, phosphorus, and fecal coliform bacteria as pollutants requiring nonpoint source control in the Oak Creek watershed. For urban areas, it recommended construction site erosion control and implementation of urban land practices sufficient to produce a 50 percent reduction in pollutants released to the streams of the watershed. For rural areas, it recommended conservation practices sufficient to produce a 50 percent reduction in pollutants released to the streams of the watershed.

Several additional measures to abate nonpoint source pollution have been instituted since adoption of the initial plan. Facilities engaged in certain industrial activities have been required to apply for and obtain stormwater discharge permits under the WPDES and to develop and follow storm water pollution prevention plans. All the communities in the watershed have applied for, or obtained, WPDES discharge permits, and have adopted construction site erosion control ordinances. All of the communities have adopted stormwater management plans or ordinances. These communities will be required to develop new or update existing stormwater management

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[25]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume One,* Inventory Findings, *September 1978; Volume Two,* Alternative Plans, *February 1979; Volume Three,* Recommended Plan*, June 1979.*

ordinances to be consistent with the standards of Chapter NR 151 of the *Wisconsin Administrative Code.* Stormwater management measures are described more fully in the section on nonpoint source pollution in this chapter.

SOURCES OF WATER POLLUTION

An evaluation of water quality conditions in the Oak Creek watershed must include an identification, characterization, and where feasible, quantification of known pollution sources. This identification, characterization, and quantification is intended to aid in determining the probable causes of water pollution problems.

Point Source Pollution

Point source pollution is defined as pollutants that are discharged to surface waters at discrete locations. Examples of such discrete discharge points include sanitary sewerage system flow relief devices, sewage treatment plant discharges, and industrial discharges.

Sewage Treatment Plants

In 1975, there were no public sewage treatment facilities located in or discharging to the Oak Creek watershed. Currently, the City of South Milwaukee's sewage treatment plant and the Milwaukee Metropolitan Sewerage District's Jones Island and South Shore treatment plants serve the existing sewered portions of the Oak Creek watershed. In 1975, the base year of the initial plan, and in 1990, there were no privately owned sewage treatment plants discharging to the stream system of the Oak Creek watershed. There are currently no privately owned sewage treatment plants in the Oak Creek watershed.

The initial regional water quality management plan recommended that all of the sanitary sewer service areas identified in the plan be refined and detailed in cooperation with the local units of government concerned. There were four sewer service areas identified within, or partially within, the Oak Creek watershed: Franklin, Oak Creek, South Milwaukee, and the Milwaukee Metropolitan Sewerage District. Currently all of the sewer service areas within the watershed have undergone refinements as recommended, with the exceptions of the City of South Milwaukee and the Milwaukee Metropolitan Sewerage District which are currently almost entirely served by sewer. Table 140 lists the plan amendment prepared for each initial refinement, the date the Commission adopted the document as an amendment to the regional water quality management plan, and the date the Commission adopted the amendment to the regional water quality management plan for the most recent refinement to the sewer service area. The planned sewer service area includes the entire 27.4-square-mile watershed. Planned sanitary sewer service areas in the Oak Creek watershed are shown on Map 86.

Sanitary Sewer Overflow (SSO) Sites in the Watershed

During the period from August 1995 to August 2002, sanitary sewer overflows were reported at seven locations, all within the City of South Milwaukee. Table 141 gives the locations of sanitary sewer overflow locations in the watershed and indicates the number of days during which overflow occurred at each location during the period from August 1995 to August 2002. The SSO sites which are being incorporated into the water quality model are indicated on Map 87.

Combined Sewer Overflows (CSOs)

Because the area served by combined sewers does not extend into the Oak Creek watershed, combined sewer overflows are not a potential source of pollution to Oak Creek or its tributaries.

Other Known Point Sources

Industrial Discharges

The number of known industrial wastewater permitted dischargers in the Oak Creek watershed has increased over time. In 1975, there were a total of eight known industrial wastewater permitted dischargers identified in the watershed. These permitted facilities discharged industrial cooling, process, rinse, and wash waters to surface

Table 140

PLANNED SANITARY SEWER SERVICE AREAS IN THE OAK CREEK WATERSHED: 2004

Name of Initially Defined Sanitary Sewer Service Area	Planned Sewer Service Area (square miles)	Name of Refined and Detailed Sanitary Sewer Service Area(s)	Initial Plan Amendment Document	Date of SEWRPC Adoption of Initial Plan Amendment	Date of SEWRPC Adoption of Most Recent Plan Amendment
Refined Sanitary Sewer Area					
Milwaukee Metropolitan Sewerage District (portion)	2.59	Franklin	SEWRPC CAPR No. 176, *Sanitary Sewer Service Area for the City of Franklin, Milwaukee County, Wisconsin*	December 5, 1990	December 5, 1990
Milwaukee Metropolitan Sewerage District (portion)	17.44	Oak Creek	SEWRPC CAPR No. 213, *Sanitary Sewer Service Area for the City of Oak Creek, Milwaukee County, Wisconsin*	September 7, 1994	September 7, 1994
Subtotal	20.03	- -	- -	- -	- -
Unrefined Sanitary Sewer Service Areas					
Milwaukee Metropolitan Sewerage District	4.12	- -	- -	- -	- -
South Milwaukee	3.26				
Subtotal	7.38	- -	- -	- -	- -
Total	27.41	- -	- -	- -	- -

Source: SEWRPC.

waters.[26] In 1990, 12 permitted facilities discharged wastewater to Oak Creek, its tributaries, or the groundwater system.[27]

Table 142 lists the industrial discharge permits in effect through the WPDES in the watershed in February 2003. At that time, 12 WPDES industrial permits were in effect in the watershed. One of these was an individual permit, the rest were spread among six categories of general permits. The most common categories of general permit issued in this watershed were for the discharge of noncontact cooling water and for the discharge of petroleum contaminated water. There were three facilities in the watershed in each of these categories. The other general permit categories were each represented by two or fewer facilities. Data from discharge monitoring reports for several facilities covered by individual permits or general permits for noncontact cooling water are being included in water quality modeling for the regional water quality management plan update and the MMSD 2020 Facility Plan. These sites are shown on Map 87.

Due to the dynamic nature of permitted point sources, it is recognized that the number of wastewater sources in the watershed will change as industries and other facilities change locations or processes and as decisions are made with regard to the connection of such sources to public sanitary sewer systems.

Nonpoint Source Pollution

Urban Stormwater Runoff

As shown in Table 130, as of the year 2000, urban land uses within the Oak Creek watershed were primarily residential (26.4 percent), followed by transportation, communication, and utilities (19.1 percent); industrial (5.1 percent); governmental and institutional (3.6 percent), commercial (3.6 percent), and recreational (3.2 percent).

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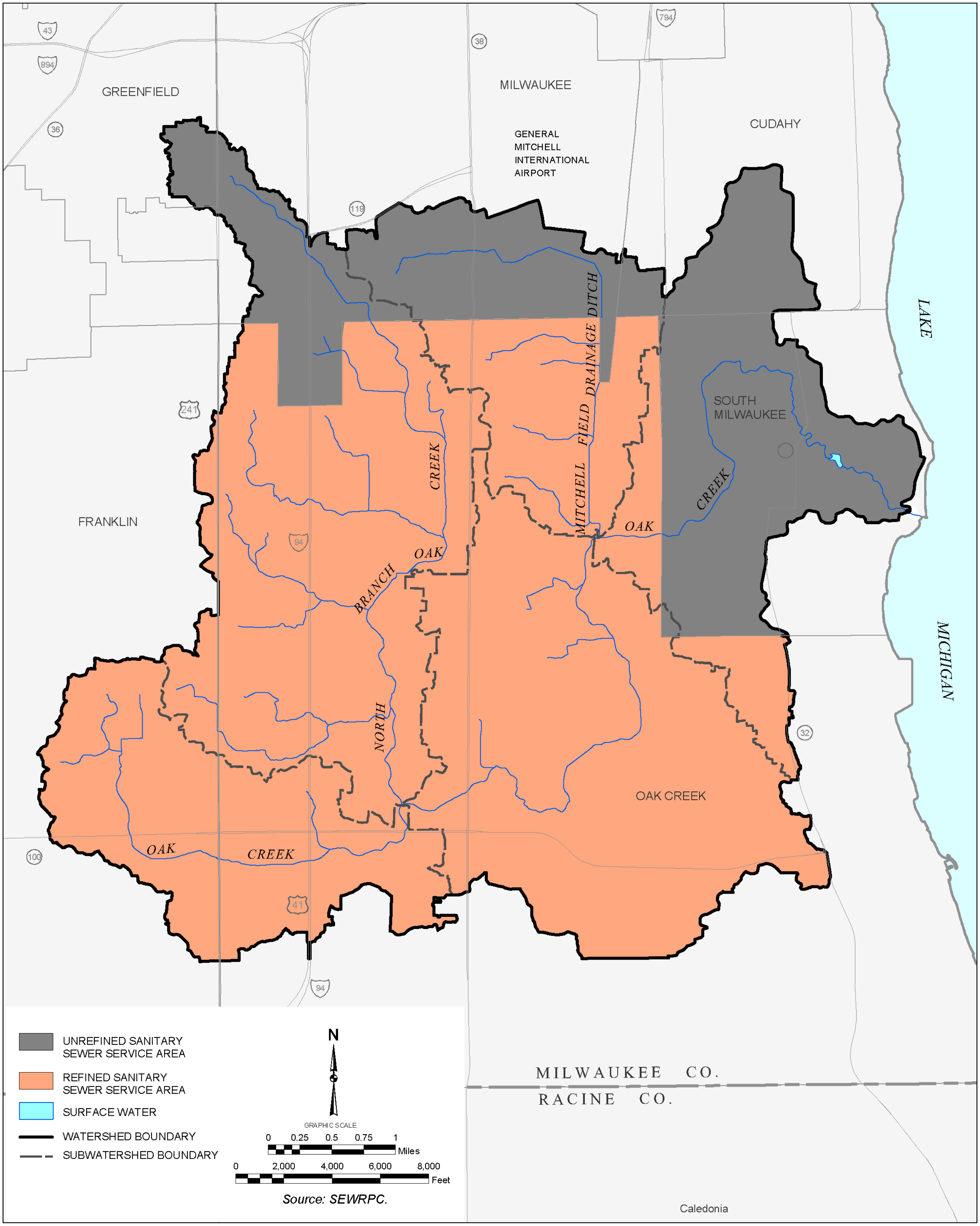
[26]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *September 1978.*

[27]*SEWRPC Memorandum Report No. 93,* op. cit.

Map 86

PLANNED SANITARY SEWER SERVICE AREAS WITHIN THE OAK CREEK WATERSHED: 2004



Source: SEWRPC.

Table 141

SEPARATE SANITARY SEWER OVERFLOW LOCATIONS IN THE OAK CREEK WATERSHED

Identification Number	Location	Community	Number of Days with Overflow: August 1995 to August 2002
1	Ravine Lift Station at 3rd Avenue and Marquette/Michigan Avenues	South Milwaukee	2
2	Marquette Relief Station at 16th Avenue and Marquette Avenue	South Milwaukee	2
3	Oak Relief Station at 17th Avenue and Oak Street	South Milwaukee	1
4	3rd Avenue SSO at 3rd Avenue 84 feet south of Marquette Avenue	South Milwaukee	0
5	Mackinac Avenue SSO at 14th Avenue and Mackinac Avenue	South Milwaukee	1
6	Marion Avenue SSO at 16th Avenue and Marion Avenue	South Milwaukee	1
7	Maple Avenue SSO at 16th Avenue and Maple Avenue	South Milwaukee	2
8	Menomonee Avenue SSO at 16th Avenue and Menomonee Avenue	South Milwaukee	1

Source: Wisconsin Department of Natural Resources and SEWRPC.

Chapter II of this report includes descriptions of the types of pollutants associated with specific urban nonpoint sources.

Chapter NR 216, "Storm Water Discharge Permits," of the *Wisconsin Administrative Code* establishes the requirements for the stormwater discharge permitting program for industries, municipalities, and construction sites. The rule was promulgated in November of 1994.

Regulation of Urban Nonpoint Source Pollution through the Wisconsin Pollutant Discharge Elimination System Permit Program

Facilities engaged in industrial activities listed in Section NR 216.21(2)(b) of Chapter NR 216 of the *Wisconsin Administrative Code* must apply for and obtain a stormwater discharge permit. The WDNR originally developed a three-tier system of industrial storm water permits. Tier 1 permits apply to facilities involved in heavy industry and manufacturing, including facilities involved in lumber and wood product manufacturing, leather tanning, and primary metal industries. Tier 2 permits apply to facilities involved in light industry and manufacturing and transportation facilities, including facilities involved in printing, warehousing, and food processing. Tier 3 permits used to be issued to facilities which have certified, with WDNR concurrence, that they have no discharges of contaminated stormwater. WDNR authority for Tier 3 permits no longer exists and the Tier 3 permits have been terminated. Facilities now submit a certificate of no exposure. In addition, the WDNR also issues separate permits for automobile parts recycling facilities and scrap recycling facilities. Associated with each category of permit are specific requirements for monitoring and inspection. For all categories of permits except Tier 3 industrial permits, the permit requires the facility to develop and follow a storm water pollution prevention plan (SWPPP). Specific requirements for the SWPPP are listed in Chapter NR 216.27 of the *Wisconsin Administrative Code*. They include provisions related to site mapping, implementation scheduling, conducting annual plan assessments, and monitoring of discharge.

Map 87

POINT SOURCES OF POLLUTION WITHIN THE OAK CREEK WATERSHED: 2003

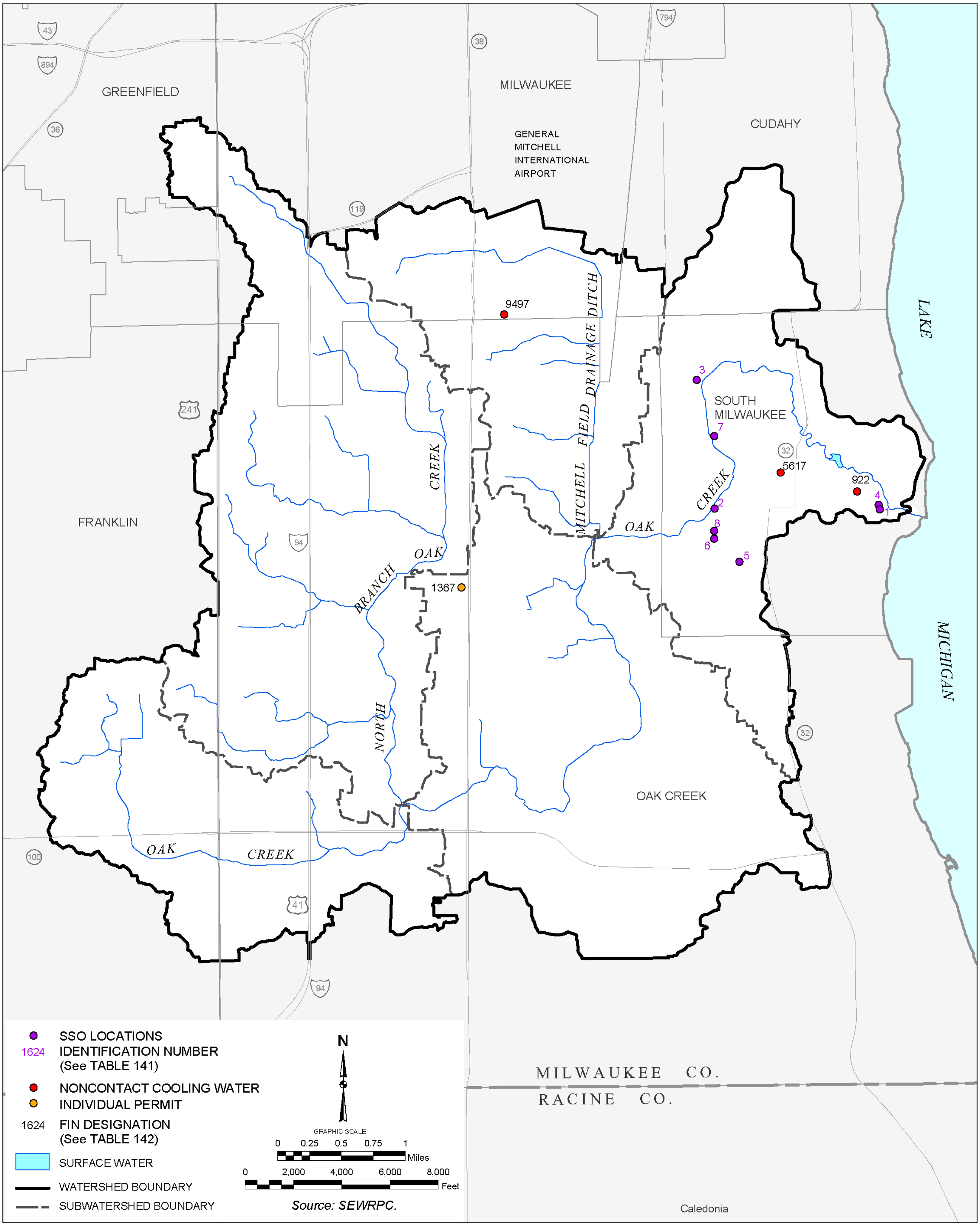


Table 142

PERMITTED WASTEWATER DISCHARGERS UNDER THE WPDES GENERAL PERMIT AND INDIVIDUAL PERMIT PROGRAMS IN THE OAK CREEK WATERSHED: FEBRUARY 2003

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Carriage/Interstitial Water from Dredging[a]	- -	- -	- -	- -	- -	- -
Concrete Products Operations[b]	- -	- -	- -	- -	- -	- -
Contaminated Groundwater Remedial Actions[c]	Bel-Aire Enterprises	6100 S. Howell Avenue	Oak Creek	0046566	241653720	12778
Hydrostatic Test Water and Water Supply System	Equilon Enterprises, LLC.	1701 E. College Avenue	Milwaukee	0057681	241017810	13348
Land Applying Liquid Industrial Wastes[d]						
Noncontact Cooling Water	Bucyrus International, Inc. EGS Electrical Group—Appleton US Air Force 440th Air Refueling Group	1100 Milwaukee Avenue 2105 5th Avenue 300 E. College Avenue	South Milwaukee South Milwaukee Milwaukee	0044938 0044938 0044938	241008130 241015390 241196980	5617 922 9497
Nonmetallic Mining Operations[e]	- -	- -	- -	- -	- -	- -
Petroleum Contaminated Water	Equilon Enterprises, LLC Pilot Travel Centers, LLC #40 US Air Force 440th Air Refueling Group	1701 E. College Avenue 2031 W. Ryan Road 300 E. College Avenue	Milwaukee Oak Creek Milwaukee	0046531 0046531 0046531	241017810 - - 241176980	13348 16484 9497
Pit/Trench Dredging[f]	- -	- -	- -	- -	- -	- -
Potable Water Treatment and Conditioning	Delphi Automotive Systems	7929 S. Howell Avenue	Milwaukee	0046540	241045750	1367
Swimming Pool Facilities	Milwaukee County Parks and Recreation Department—Grobschmidt Pool YMCA—South Shore	2500 16th Avenue 3244 E. College Avenue	South Milwaukee Cudahy	0046523 0046523	241520950 241522820	12851 14109
Individual Permits	Delphi Automotive Systems	7929 S. Howell Avenue	Oak Creek	61581	241045750	1367

[a] *There were no active WPDES general permits for Carriage/Interstitial Water from Dredging in the Oak Creek watershed during February 2003.*

[b] *There were no active WPDES general permits for Concrete Products Operations in the Oak Creek watershed during February 2003.*

[c] *There were no active WPDES general permits for Contaminated Groundwater Remedial Action in the Oak Creek watershed during February 2003.*

[d] *There were no active WPDES general permits for Land Applying of Liquid Industrial Wastes in the Oak Creek watershed during February 2003.*

[e] *There were no active WPDES general permits for Nonmetallic Mining Operations in the Oak Creek watershed during February 2003.*

[f] *There were no active WPDES general permits for Pit/Trench Dredging in the Oak Creek watershed during February 2003.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

As shown in Appendix G, "WPDES Permitted Stormwater Facilities," 22 industrial stormwater permits were in effect in the Oak Creek watershed in February 2003. Most of these were Tier 2 permits. With 12 of these permits in effect, this category represented slightly over half of the permitted facilities in the watershed. There were three or fewer each of Tier 1, Tier 3, Automobile Parts Recycling, and Scrap Recycling permits in effect in the watershed at that time.

The WDNR also issues and administers construction site stormwater permits through the WPDES General Permits program. All construction sites that disturb one acre of land or more are required to obtain coverage under the General Permit. Permitted construction sites are required to implement a construction erosion control plan, and a post-construction stormwater management plan as required in Chapter NR 216.46 and Chapter NR 216.47 of the *Wisconsin Administrative Code*. Owners of permitted construction sites are also required to conduct inspections of their construction erosion control measures on a weekly basis and within 24 hours of a precipitation event of 0.5 inches or more. Due to the dynamic nature of construction activities, it is recognized that the number of sites requiring Construction Site Storm Water permits in the watershed will change as construction projects are completed and new projects are initiated.

The WPDES stormwater permits for municipalities within the watershed are described below.

Chapter NR 151 of the Wisconsin Administrative Code

Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*, which was promulgated in September 2002, establishes performance standards for the control of nonpoint source pollution from agricultural lands, nonagricultural (urban) lands, and transportation facilities. The standards for urban lands apply to areas of existing development, redevelopment, infill, and construction sites. In general, the construction erosion control, post-construction nonpoint source pollution control, and stormwater infiltration requirements of Chapter NR 151 apply to projects associated with construction activities that disturb at least one acre of land.

The urban standards are applied to activities covered under the WPDES program for stormwater discharges. As noted below, communities with WPDES stormwater discharge permits must adopt stormwater management ordinances that have requirements at least as stringent as the standards of Chapter NR 151. Those communities must also achieve levels of control of nonpoint source pollution from areas of existing development (as of October 1, 2004) that are specified under Chapter NR 151.

Stormwater Management Systems

Stormwater management facilities are defined, for purposes of this report, as conveyance, infiltration, or storage facilities, including, but not limited to, subsurface pipes and appurtenant inlets and outlets, ditches, streams and engineered open channels, detention and retention basins, pumping facilities, infiltration facilities, constructed wetlands for treatment of runoff, and proprietary treatment devices based on settling processes and control of oil and grease. Such facilities are generally located in urbanized areas and constructed or improved and operated for purposes of collecting stormwater runoff from tributary drainage areas and conveying, storing, and treating such runoff prior to discharge to natural watercourses. In the larger and more intensively developed urban communities, these facilities consist either of complete, largely piped, stormwater drainage systems which have been planned, designed, and constructed as systems in a manner similar to sanitary sewer and water utility systems, or of fragmented or partially piped systems incorporating open surface channels to as great a degree as possible. In the Oak Creek watershed, the stormwater drainage systems have historically provided the means by which a significant portion of the nonpoint sources pollutants reach the surface water system.

With the relatively recent application of the WPDES permitting program to stormwater discharges and the adoption of local stormwater management ordinances, controls on the quality of stormwater runoff prior to discharge to receiving streams have become more common. Table 143 indicates the status of stormwater management activities in each of the communities in the watershed.

Table 143

STORMWATER MANAGEMENT INFORMATION FOR CITIES, VILLAGES, AND TOWNS WITHIN THE OAK CREEK WATERSHED

Civil Division	Stormwater Management Ordinance and/or Plan	Construction Erosion Control Ordinance	Stormwater Utility, General Fund, and/or Established Stormwater Fee Program
Milwaukee County			
City of Cudahy	X	X	X
City of Franklin	X	X	- -
City of Greenfield	X	X	- -
City of Milwaukee	X	X	X
City of Oak Creek..........................	X	X	X
City of South Milwaukee................	X	X	- -

Source: SEWRPC.

All of the communities in the watershed, the Cities of Cudahy, Franklin, Milwaukee, Oak Creek, and South Milwaukee have WPDES stormwater discharge permits. In addition to specific nonpoint source pollution control activities recommended under their WPDES permits, these communities will also all be required to develop new, or update existing, stormwater management ordinances to be consistent with the standards of Chapter NR 151 of the *Wisconsin Administrative Code*. As part of their permit application, each community prepared maps of the stormwater outfalls that are part of the municipal separate stormwater system.

Urban Enclaves Outside the Current Sewer Service Areas

Map 88 shows areas served by centralized sanitary sewer systems within the Oak Creek watershed in 2000. In that year 11,240 acres of the watershed were served by sanitary sewer systems. In addition, there are about 100 acres of urban-density enclaves that were not served by public sewer sanitary systems. As shown on Map 89, about 70 acres of these enclaves are in areas served by onsite sewage disposal systems that were developed prior to 1980. These older systems may be at particular risk for malfunctioning. As described in Chapter II of this report, failure of onsite disposal systems can contribute nonpoint source pollutants to streams and groundwater.

In 1978, the State of Wisconsin established the Private Onsite Wastewater Treatment System Replacement or Rehabilitation Financial Assistance Program under the Wisconsin Fund Program. That voluntary program annually awards grants to counties, Indian tribes, and municipalities to assist homeowners and small businesses in replacing or rehabilitating failing private, onsite systems. The program is administered by the Wisconsin Department of Commerce in cooperation with the counties and communities. Grant eligibility is subject to specific income, revenue, occupancy, and operation requirements. Onsite systems that are installed, replaced, or rehabilitated after the date on which the county or community elects to participate are required to have a maintenance program. Thus, given the 1978 date of establishment of the grant program, the determination of areas developed with onsite systems before 1980 and those developed in 1980 or later,[28] provides an indication of which systems are subject to the requirement of having formal maintenance programs and which are not. The counties, or communities in the case of Milwaukee County, are responsible for administering the maintenance program with the goal of assuring the onsite systems function properly. The City of Franklin is the only community in the Oak Creek watershed that currently participates in the program.

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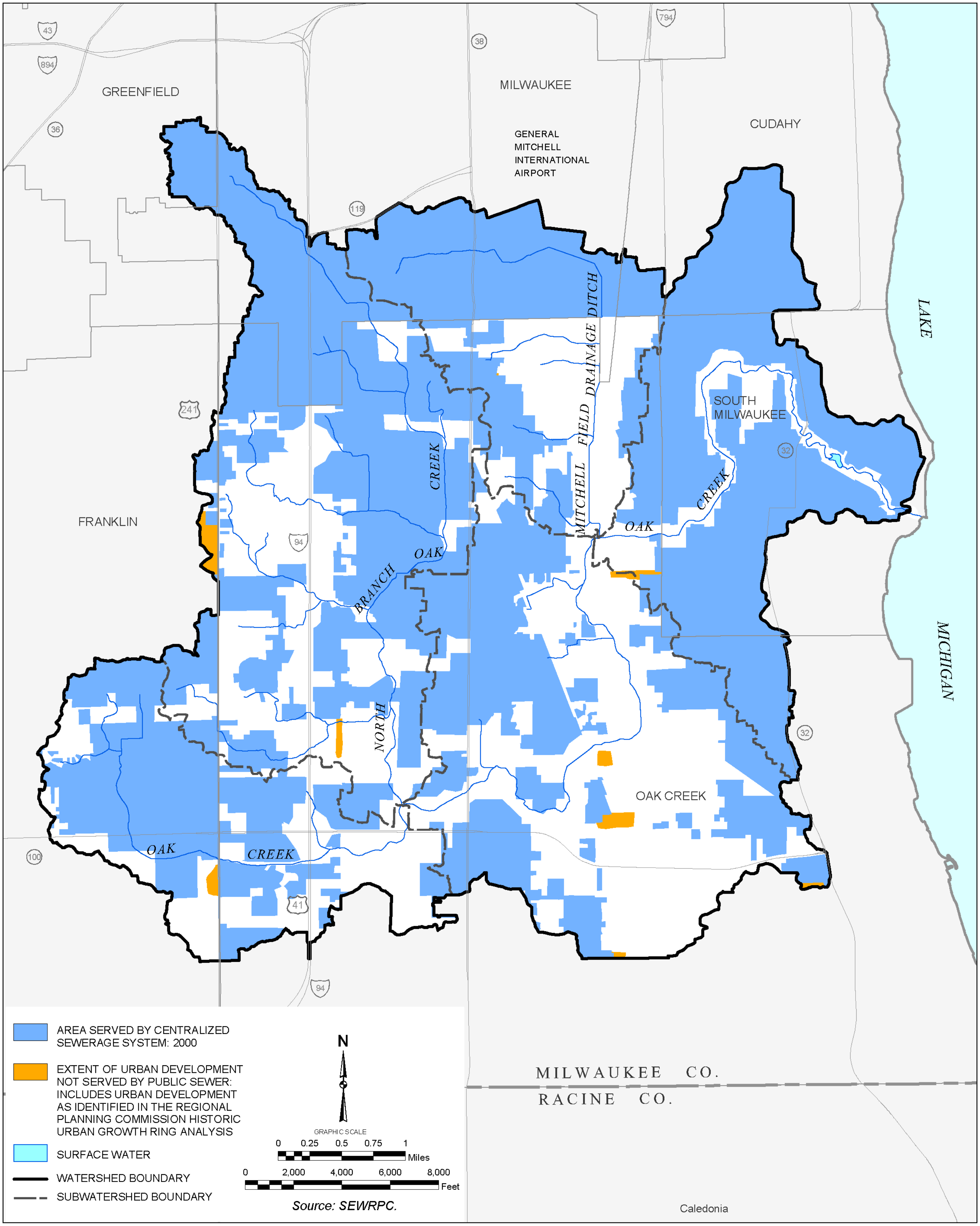
[28]*Since 1970, the SEWRPC land use inventory has been conducted at five-year intervals. Thus the 1980 inventory was the best available information for establishing which systems have maintenance requirements.*

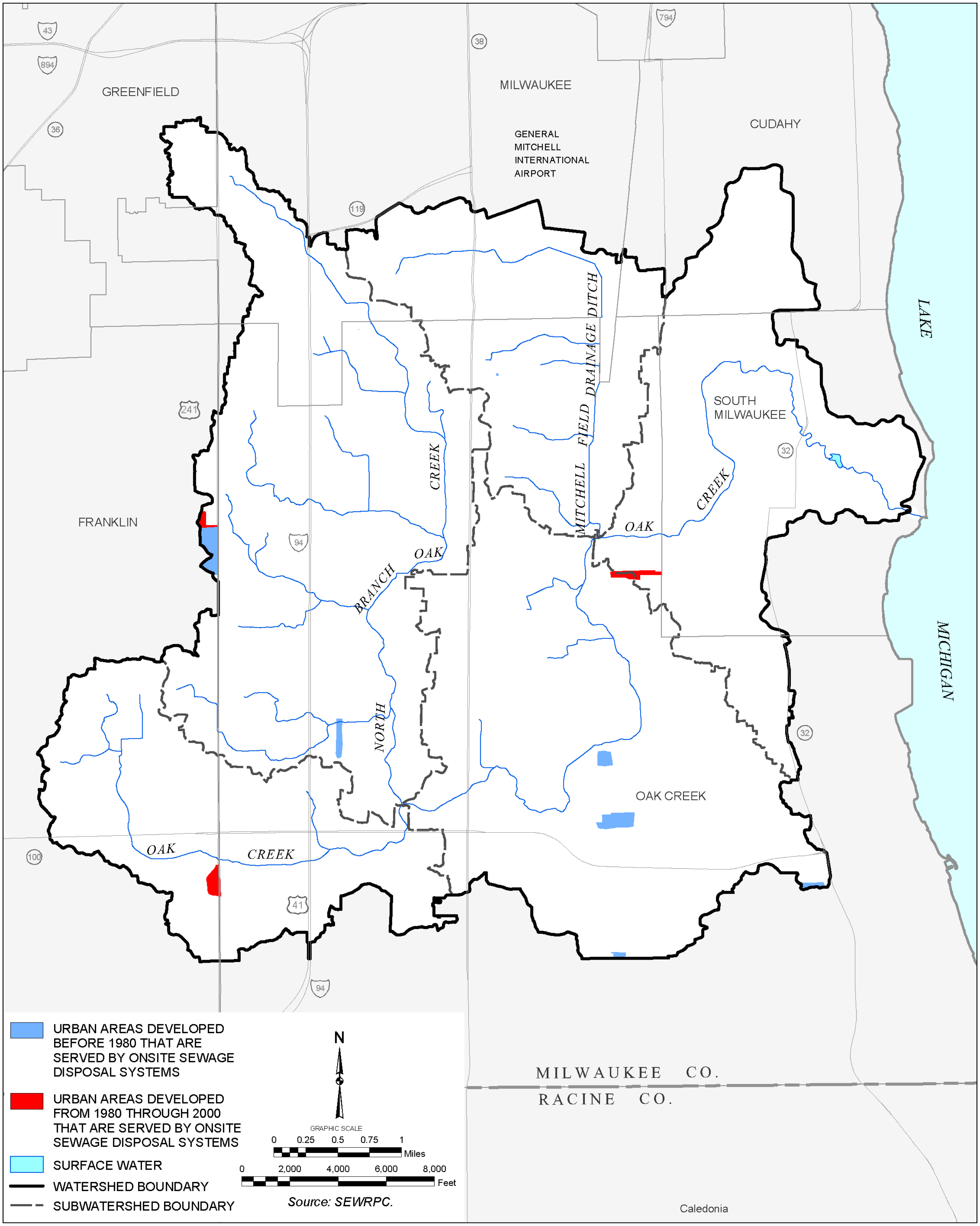
Map 88

AREAS SERVED BY CENTRALIZED SANITARY SEWERAGE SYSTEMS WITHIN THE OAK CREEK WATERSHED: 2000



Map 89

URBAN AREAS WITHIN THE OAK CREEK WATERSHED THAT ARE SERVED BY ONSITE SEWAGE DISPOSAL SYSTEMS: PRIOR TO 1980 AND 1980 THROUGH 2000



Solid Waste Disposal Sites
Solid waste disposal sites are a potential source of surface water, as well as groundwater, pollution. It is important to recognize, however, the distinction between a properly designed and constructed solid waste landfill and the variety of operations that are referred to as refuse dumps, especially with respect to potential effects on water quality. A solid waste disposal site may be defined as any land area used for the deposit of solid wastes regardless of the method of operation, or whether a subsurface excavation is involved. A solid waste landfill may be defined as a solid waste disposal site which is carefully located, designed, and operated to avoid hazards to public health or safety, or contamination of groundwaters or surface waters. The proper design of solid waste landfills requires careful engineering to confine the refuse to the smallest practicable area, to reduce the refuse mass to the smallest practicable volume, to avoid surface water runoff, to minimize leachate production and percolation into the groundwater and surface waters, and to seal the surface with a layer of earth at the conclusion of each day's operation or at more frequent intervals as necessary.

In order for a landfill to produce leachate, there must be some source of water moving through the fill material. Possible sources included precipitation, the moisture content of the refuse itself, surface water infiltration, groundwater migrating into the fill from adjacent land areas, or groundwater rising from below to come in contact with the fill. In any event, leachate is not released from a landfill until a significant portion of the fill material exceeds its saturation capacity. If external sources of water are excluded from the solid waste landfill, the production of leachates in a well-designed and managed landfill can be effectively minimized if not entirely avoided. The quantity of leachate produced will depend upon the quantity of water that enters the solid waste fill site minus the quantity that is removed by evapotranspiration. Studies have estimated that for a typical landfill, from 20 to 50 percent of the rainfall infiltrated into the solid waste may be expected to become leachate. Accordingly, a total annual rainfall of about 35 inches, which is typical of the Oak Creek watershed, could produce from 190,000 to 480,000 gallons of leachates per year per acre of landfill if the facility is not properly located, designed, and operated.

As of 2005, there was one active solid waste landfill within the watershed, located in the Lower Oak Creek subwatershed. As set forth in Table 144 and shown on Map 90, there seven inactive landfills in the watershed: three each in the Mitchell Field Drainage Ditch and Lower Oak Creek subwatersheds and one in the Middle Oak Creek watershed.

Rural Stormwater Runoff
Rural land uses within the Oak Creek watershed include agricultural—mostly crop production—and woodlands, wetlands, water, and other open lands as set forth in the beginning of this chapter. As noted above, Chapter NR 151 of the *Wisconsin Administrative Code* establishes performance standards for the control of nonpoint source pollution from agricultural lands, nonagricultural (urban) lands, and transportation facilities. Agricultural performance standards are established for soil erosion, manure storage facilities, clean water diversions, nutrient management, and manure management. Those standards must only be met to the degree that grant funds are available to implement projects designed to meet the standards.

Livestock Operations
The presence of livestock and poultry manure in the environment is an inevitable result of animal husbandry and is a major potential source of water pollutants. Animal manure composed of feces, urine, and sometimes bedding material, contributes suspended solids, nutrients, oxygen-demanding substances, bacteria, and viruses to surface waters. Presently in the watershed, there are few animal operations. Animal waste constituents of pastureland and barnyard runoff, and animal wastes deposited on pastureland and cropland and in barnyards, feedlots, and manure piles, can potentially contaminate water by surface runoff, infiltration to groundwater, and volatilization to the atmosphere. During the warmer seasons of the year the manure is often scattered on cropland and pastureland where the waste material is likely to be taken up by vegetative growth composing the land cover. However, when the animal manure is applied to the land surface during the winter, the animal wastes are subject to excessive runoff and transport, especially during the spring snowmelt period.

Table 144

ACTIVE AND INACTIVE SOLID WASTE DISPOSAL SITES IN THE OAK CREEK RIVER WATERSHED: 2004

Number on Map 90	Facility Name	Address	Municipality	Classification	Subwatershed	Facility ID	Status
1	Ladish Corporation	- -	Cudahy	- -	Lower Oak Creek	241008130	Inactive
2	WEPCo Embk Airport Spur, Wisconsin Department of Transportation	Airport Spur Freeway	Milwaukee	Landfill, unclassified	Mitchell Field Drainage Ditch	241219220	Inactive
3	Milwaukee County Landfill College Avenue	1800 E. College Avenue	Milwaukee	Landfill> 500,000 cubic yards	Mitchell Field Drainage Ditch	241107780	Inactive
4	Milwaukee City College Avenue Unlic.	1600 E. College Avenue-south side	Milwaukee	Landfill, unclassified	Mitchell Field Drainage Ditch	241687050	Inactive
5	Bucyrus- Erie Corporation	1100 Milwaukee Avenue	South Milwaukee	- -	Lower Oak Creek	241006920	Inactive
6	Falk Corporation Landfill	13th Avenue north of Rawson Avenue	South Milwaukee	Landfill> 500,000 cubic yards-monofil	Lower Oak Creek	241514790	Active
7	Oak Creek City	1700 E. Drexel Avenue	Oak Creek	Landfill 50,000 - 500,000 cubic yards	Lower Oak Creek	241208550	Inactive
8	Derosso Landfill Co. Inc.	- -	Oak Creek	Landfill> 500,000 cubic yards-monofil	Middle Oak Creek	241410090	Inactive

Source: Wisconsin Department of Natural Resources and SEWRPC.

Crop Production

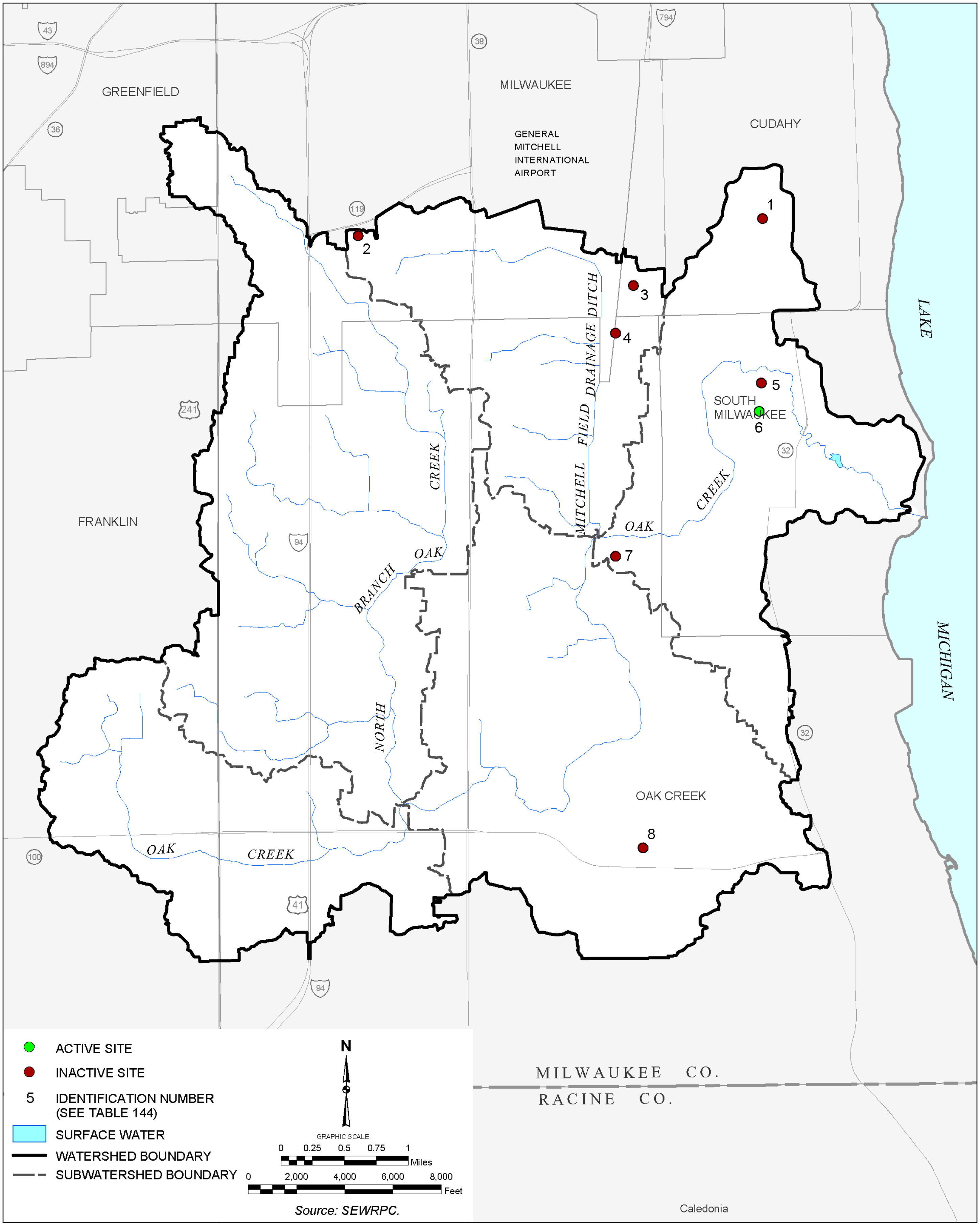
In the absence of mitigating measures, runoff from cropland can have an adverse effect upon water quality within the Oak Creek watershed by contributing excess sediments, nutrients, and organic matter, including pesticides to streams. Negative effects associated with soil erosion and transport to waterbodies includes reduced water clarity, sedimentation on streambeds, and contamination of the water from various agricultural chemicals and nutrients that are attached to the individual soil particles. Some of these nutrients, in particular phosphorus, and to some extent nitrogen, are directly associated with eutrophication of water resources. The extent of the water pollution from cropping practices varies considerably as a result of the soils, slopes, and crops, as well as in the numerous methods of tillage, planting, fertilization, chemical treatment, and conservation practices. Conventional tillage practices, or moldboard plowing, involve turning over the soil completely, leaving the soil surface bare of most cover or residue from the previous year’s crop, and making it highly susceptible to erosion due to wind and rain. The use of conservation tillage practices has become common in the watershed in recent years within areas most susceptible to erosion and surface water impacts.

Crops grown in the Oak Creek watershed include row crops, such as corn and soybeans; small grains, such as wheat and oats; hay, such as alfalfa; and vegetables, such as snap beans and sweet corn. Row crops and vegetable crops, which have a relatively higher level of exposed soil surface, tend to contribute higher pollutant loads than do hay and pastureland, which support greater levels of vegetative cover. Crop rotations typically follow a two- or three-year sequence of corn and soybeans and occasionally winter wheat in the third year. However, hay is periodically included as part of a long-term rotation of corn, oats, and alfalfa.

Since the early 1930s, it has been a national objective to preserve and protect agricultural soil from wind and water erosion. Federal programs have been developed to achieve this objective, with the primary emphasis being on sound land management and cropping practices for soil conservation. An incidental benefit of these programs has been a reduction in the amount of eroded organic and inorganic material entering surface waters as sediment or attached to sediment. Some practices are effective in both regards, while others may enhance the soil

Map 90

ACTIVE AND INACTIVE SOLID WASTE DISPOSAL SITES WITHIN THE OAK CREEK WATERSHED: 2004



Source: SEWRPC.

conditions with little benefit to surface water quality. Despite the implementation of certain practices aimed at controlling soil erosion from agricultural land, and development of a soil erosion plan for Milwaukee County,[29] such erosion and the resultant deposition of sediment in the streams of the Oak Creek watershed remains a significant water resource problem. Soil erosion from agricultural lands is one of the major sources of sediment and nutrients in Oak Creek and its tributaries.

Nutrients such as phosphorus and agri-chemicals, including herbicides and pesticides, are electrostatically attracted to silt sized particles and are transported to surface waters through soil erosion. As previously mentioned, phosphorus is one of the primary nutrients associated with eutrophication of water resources, and agri-chemicals can negatively impact the life cycles of aquatic organisms. In the eutrophication process, phosphorus enhances growth of aquatic vegetation and algae, which has the effect of accelerating the aging process of a water resource. Phosphorus is usually not susceptible to downward movement through the soil profile; instead, the majority of phosphorus reaches water resources by overland flow, or erosion. Nitrogen also is a nutrient that contributes to eutrophication; however, it is most often associated with subsurface water quality contamination. Nitrogen in the form of nitrate can be associated with respiration problems in newborn infants. Nitrogen is susceptible to downward movement through the soil profile; however, due to the nature of soils in the watershed, nitrogen is not as significant a threat due to various chemical reactions that occur within the soil.[30]

Woodlands

A well-managed woodland contributes few pollutants to surface waters. Under poor management, however, woodlands may have detrimental water quality effects through the release of sediments, nutrients, organic matter, and pesticides into nearby surface waters. If trees along streams are cut, thermal pollution may occur as the direct rays of the sun strike the water. Disturbances caused by tree harvesting, livestock grazing, tree growth promotion, tree disease prevention, fire prevention, and road and trail construction are a major source of pollution from silvicultural activities. Most of these activities are seldom practiced in the Oak Creek watershed.

Pollution Loadings

Annual Loadings

Annual average point and/or nonpoint pollution loads to the Oak Creek watershed are set forth in Tables 145 through 151. Average annual per acre nonpoint source pollution loads are set forth in Table 152. The nonpoint source pollution load estimates represent loads delivered to the modeled stream reaches after accounting for any trapping factors that would retain pollutants on the surface of the land. They include loads from groundwater. It is important to note that the stream channel pollutant loads may be expected to be different from the actual transport from the watershed, because physical, chemical, and/or biological processes may retain or remove pollutants or change their form during transport within the stream system. These processes include particle deposition or entrapment in floodplains, stream channel deposition or aggradation, biological uptake, and chemical transformation and precipitation. The total nonpoint source pollution loads set forth in Table 145 are representative of the total annual quantities of potential pollutants moved from the Oak Creek watershed into stream channels, but are not intended to reflect the total amount of the pollutants moving from those sources through the entire hydrologic-hydraulic system.

Tables 146 through 151 indicate that nonpoint source pollution comprises almost all of the total pollution load.

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[29]*Milwaukee County Land Conservation Committee,* Milwaukee County Land and Water Resource Management Plan, *April 2001.*

[30]*Soils that have a high clay content and stay wet for long periods of time, or even well-drained soils after a rainfall event are susceptible to nitrogen losses to the atmosphere through a chemical reaction known as denitrification. This reaction converts nitrate,* NO_3^-*, to gaseous nitrogen,* N_2*, which is lost to the atmosphere.*

Table 145

AVERAGE ANNUAL TOTAL NONPOINT SOURCE POLLUTANT LOADS IN THE OAK CREEK WATERSHED[a]

Subwatershed	Total Phosphorus (pounds)	Total Suspended Solids (pounds)	Fecal Coliform Bacteria (trillions of cells)	Total Nitrogen (pounds)	Biochemical Oxygen Demand (pounds)	Copper (pounds)
Lower Oak Creek	2,240	997,810	613.00	16,290	58,360	105
Middle Oak Creek	2,290	1,073,450	490.86	23,050	64,490	95
Mitchell Field Drainage Ditch	1,390	641,430	541.40	16,940	38,010	67
North Branch Oak Creek	3,160	1,770,590	775.08	26,380	94,770	161
Upper Oak Creek	1,530	819,300	362.22	14,090	43,270	69
Total	10,610	5,302,580	2,782.56	96,750	298,900	497

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Table 146

AVERAGE ANNUAL LOADS OF TOTAL PHOSPHORUS IN THE OAK CREEK WATERSHED[a]

Subwatershed	Point Sources			Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Lower Oak Creek	10	10	20	2,200	40	2,240	2,260
Middle Oak Creek	0	0	0	1,310	980	2,290	2,290
Mitchell Field Drainage Ditch	<10	0	<10	980	410	1,390	1,390
North Branch Oak Creek	0	0	0	2,650	510	3,160	3,160
Upper Oak Creek	0	0	0	1,360	170	1,530	1,530
Total	10	10	20	8,500	2,110	10,610	10,630
Percent of Total	0.1	0.1	0.2	80.0	19.8	99.8	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Annual average pollutant loads of six pollutants to the Oak Creek watershed are set forth in Tables 145 through 151. Average annual per acre loads are set forth in Table 152. These estimates represent point and nonpoint source loads delivered to the modeled stream reaches, after accounting for any trapping factors that would retain pollutants on the surface of the land. They include loads from groundwater. It is important to note that the stream channel pollutant loads may be expected to be different from the actual transport from the watershed, because physical, chemical, and/or biological processes may retain or remove pollutants or change their form during transport over the land surface or within the stream system. These processes include particle deposition or entrapment on the land surface or in floodplains, stream channel deposition or aggradation, biological uptake, and chemical transformation and precipitation. The total pollutant loads set forth in Table 145 are representative of the total annual quantities of potential pollutants moved from the Oak Creek watershed into stream channels, but are not intended to reflect the total amount of the pollutants moving from those sources through the entire hydrologic-hydraulic system.

Table 147

AVERAGE ANNUAL LOADS OF TOTAL SUSPENDED SOLIDS IN THE OAK CREEK WATERSHED[a]

Subwatershed	Point Sources			Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Lower Oak Creek	1,930	500	2,430	974,250	23,560	997,810	1,000,240
Middle Oak Creek	0	0	0	685,780	387,670	1,073,450	1,073,450
Mitchell Field Drainage Ditch	<10	0	<10	532,620	108,810	641,430	641,430
North Branch Oak Creek	0	0	0	1,558,560	212,030	1,770,590	1,770,590
Upper Oak Creek	0	0	0	663,060	156,240	819,300	819,300
Total	1,930	500	2,430	4,414,270	888,310	5,302,580	5,305,010
Percent of Total	<0.1	<0.1	<0.1	83.2	16.7	99.9	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Table 148

AVERAGE ANNUAL LOADS OF FECAL COLIFORM BACTERIA IN THE OAK CREEK WATERSHED[a]

Subwatershed	Point Sources			Nonpoint Sources			Total (trillions of cells)
	Industrial Point Sources (trillions of cells)	SSOs (trillions of cells)	Subtotal (trillions of cells)	Urban (trillions of cells)	Rural (trillions of cells)	Subtotal (trillions of cells)	
Lower Oak Creek	0	9.55	9.55	612.67	0.33	613.00	622.55
Middle Oak Creek	0	0.00	0.00	394.77	96.09	490.86	490.86
Mitchell Field Drainage Ditch	0	0.00	0.00	505.12	36.28	541.40	541.40
North Branch Oak Creek	0	0.00	0.00	735.48	39.60	775.08	775.08
Upper Oak Creek	0	0.00	0.00	354.83	7.39	362.22	362.22
Total	0	9.55	9.55	2,602.87	179.69	2,782.56	2,792.11
Percent of Total	0.0	0.3	0.3	93.2	6.5	99.7	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Point Source Loadings

Annual average total point source pollutant loads of six pollutants in the Oak Creek watershed are set forth in Tables 146 through 151. Contributions of these pollutants by point sources represent a minor portion of the total average annual loads, generally about 1 percent or less.

Average annual point source loads of total phosphorus in the Oak Creek watershed are shown in Table 146. The total average annual point source load of total phosphorus is about 20 pounds. Most of this is contributed by the Lower Oak Creek subwatershed, with a small amount contributed by the Mitchell Field Drainage Ditch subwatershed. Industrial dischargers and separate sanitary sewer overflows representing approximately equal proportions of the contributions of total phosphorus.

Table 149

AVERAGE ANNUAL LOADS OF TOTAL NITROGEN IN THE OAK CREEK WATERSHED[a]

Subwatershed	Point Sources: Industrial Point Sources (pounds)	Point Sources: SSOs (pounds)	Point Sources: Subtotal (pounds)	Nonpoint Sources: Urban (pounds)	Nonpoint Sources: Rural (pounds)	Nonpoint Sources: Subtotal (pounds)	Total (pounds)
Lower Oak Creek	340	20	360	15,280	1,010	16,290	16,650
Middle Oak Creek	0	0	0	9,240	13,810	23,050	23,050
Mitchell Field Drainage Ditch	<10	0	<10	9,360	7,580	16,940	16,940
North Branch Oak Creek	0	0	0	17,590	8,790	26,380	26,380
Upper Oak Creek	0	0	0	9,180	4,910	14,090	14,090
Total	340	20	360	60,650	36,100	96,750	97,110
Percent of Total	0.4	<0.1	0.4	62.4	37.2	99.6	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Table 150

AVERAGE ANNUAL LOADS OF BIOCHEMICAL OXYGEN DEMAND IN THE OAK CREEK WATERSHED[a]

Subwatershed	Point Sources: Industrial Point Sources (pounds)	Point Sources: SSOs (pounds)	Point Sources: Subtotal (pounds)	Nonpoint Sources: Urban (pounds)	Nonpoint Sources: Rural (pounds)	Nonpoint Sources: Subtotal (pounds)	Total (pounds)
Lower Oak Creek	3,440	120	3,560	56,390	1,970	58,360	61,920
Middle Oak Creek	0	0	0	37,820	26,670	64,490	64,490
Mitchell Field Drainage Ditch	<10	0	<10	28,860	9,150	38,010	38,010
North Branch Oak Creek	0	0	0	79,090	15,680	94,770	94,770
Upper Oak Creek	0	0	0	35,580	7,690	43,270	43,270
Total	3,440	120	3,560	237,740	61,160	298,900	302,460
Percent of Total	1.1	<0.1	1.2	78.6	20.2	98.8	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Average annual point source loads of total suspended solids in the Oak Creek watershed are shown in Table 147. The total average annual point source load of total suspended solids is about 2,430 pounds. Most of this is contributed by the Lower Oak Creek subwatershed, with a small amount contributed by the Mitchell Field Drainage Ditch subwatershed. Industrial dischargers represent about 79 percent of the total load, and separate sanitary sewer overflows comprise the remaining 21 percent.

Average annual point source loads of fecal coliform bacteria in the Oak Creek watershed are shown in Table 148. The total average annual point source loads of fecal coliform bacteria is about 9.55 trillion cells per year, which is contributed by separate sanitary sewer overflows in the Lower Oak Creek subwatershed.

Average annual point source loads of total nitrogen in the Oak Creek watershed are shown in Table 149. The total average annual point source load of total nitrogen is about 360 pounds. Most of this is contributed by the Lower

Table 151

AVERAGE ANNUAL LOADS OF COPPER IN THE OAK CREEK WATERSHED[a]

Subwatershed	Point Sources			Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Lower Oak Creek	0	<1	<1	105	<1	105	105
Middle Oak Creek	0	0	0	70	25	95	95
Mitchell Field Drainage Ditch	0	0	0	56	11	67	67
North Branch Oak Creek	0	0	0	148	13	161	161
Upper Oak Creek	0	0	0	66	3	69	69
Total	0	<1	<1	445	52	497	497
Percent of Total	0.0	0.0	0.0	89.5	10.5	100.0	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Table 152

AVERAGE ANNUAL PER ACRE NONPOINT SOURCE POLLUTANT LOADS IN THE OAK CREEK WATERSHED[a]

Subwatershed	Total Phosphorus (pounds)	Total Suspended Solids (pounds)	Fecal Coliform Bacteria (trillions of cells)	Total Nitrogen (pounds)	Biochemical Oxygen Demand (pounds)	Copper (pounds)
Lower Oak Creek	0.69	309	0.19	5.05	18.10	0.033
Middle Oak Creek	0.50	232	0.11	4.99	13.97	0.021
Mitchell Field Drainage Ditch	0.57	265	0.22	6.99	15.69	0.028
North Branch Oak Creek	0.62	346	0.15	5.15	18.49	0.031
Upper Oak Creek	0.60	323	0.14	5.56	17.08	0.027

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Oak Creek subwatershed, with a small amount contributed by the Mitchell Field Drainage Ditch subwatershed. Industrial dischargers represent about 94 percent of the total load, and separate sanitary sewer overflows comprising the remaining 6 percent.

Average annual point source loads of BOD in the Oak Creek watershed are shown in Table 150. The total average annual point source load of BOD is about 3,560 pounds. Most of this is contributed by the Lower Oak Creek subwatershed, with a small amount contributed by the Mitchell Field Drainage Ditch subwatershed. Industrial dischargers represent about 97 percent of the total load, with separate sanitary sewer overflows comprising the remaining 3 percent.

Average annual point source loads of copper in the Oak Creek watershed are shown in Table 151. The total average annual point source load of copper is less than one pound per year, which is contributed by separate sanitary sewer overflows in the Lower Oak Creek subwatershed.

Nonpoint Source Loads
Because nonpoint source pollution is delivered to streams in the watershed through many diffuse sources, including direct overland flow, numerous storm sewer and culvert outfalls, and swales and engineered channels, it would be prohibitively expensive and time-consuming to directly measure nonpoint source pollution loads to streams. Thus, the calibrated water quality model was applied to estimate average annual nonpoint source pollution loads delivered to the streams in the watershed. The results of that analysis are set forth in Tables 145 through 151 and depicted graphically on Maps H-37 through H-48 in Appendix H. General water quality modeling procedures are described in Chapter V of SEWRPC Planning Report No. 50, *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds.*

Table 145 shows the average annual total nonpoint source pollution loads for subwatersheds of the Oak Creek watershed. Average annual per acre nonpoint source pollution loads for the subwatersheds are shown in Table 152.

The average annual nonpoint load of total phosphorus is estimated to be 10,610 pounds per year. About 80 percent of the total point and nonpoint source load is from urban nonpoint sources and 19.8 percent is from rural nonpoint sources (see Table 146). The distribution of the total load among the subwatersheds is shown on Map H-37 in Appendix H. Map H-38 shows the annual per acre loads of total phosphorus for the subwatersheds. Contributions of total phosphorus vary among the subwatersheds (see Table 145) from a low of 1,390 pounds per year from the Mitchell Field Drainage Ditch subwatershed to 3,160 pounds per year from the North Branch Oak Creek subwatershed. The highest loads of total phosphorus are contributed by the North Branch Oak Creek, Middle Oak Creek, and Lower Oak Creek subwatersheds. In the Middle Oak Creek subwatershed, this reflects the relatively large subwatershed area, and, in the cases of the Lower Oak Creek and North Branch subwatersheds, it is a reflection of the highest unit area loads (pounds per acre) occurring in those subwatersheds.

The average annual nonpoint load of total suspended solids is estimated to be 5,302,580 pounds per year. About 83.2 percent of the total point and nonpoint source load is from urban nonpoint sources and 16.7 percent is from rural nonpoint sources (see Table 147). The distribution of this load among the subwatersheds is shown on Map H-39 in Appendix H. Map H-40 shows the annual per acre loads of total suspended solids for the subwatersheds. Contributions of total suspended solids vary among the subwatersheds (see Table 145) from a low of 641,430 pounds per year from the Mitchell Field Drainage Ditch subwatershed to 1,770,590 pounds per year from the North Branch Oak Creek subwatershed. The highest loads of total suspended solids are contributed by the North Branch Oak Creek and Middle Oak Creek subwatersheds. In the Middle Oak Creek subwatershed, this reflects the relatively large subwatershed area, and, in the case of the North Branch of Oak Creek subwatershed, it reflects a relatively high unit area load. The highest unit area loads occur in the Upper Oak Creek and North Branch Oak Creek subwatersheds.

The average annual nonpoint load of fecal coliform bacteria is estimated to be 2,782.56 trillion cells per year. About 93.2 percent of the total point and nonpoint source load is from urban nonpoint sources and 6.5 percent is from rural nonpoint sources (see Table 148). The distribution of this load among the subwatersheds is shown on Map H-41 in Appendix H. Map H-42 shows the annual per acre loads of fecal coliform bacteria for the subwatersheds. Contributions of fecal coliform bacteria vary among the subwatersheds (see Table 145) from a low of 362.22 trillion cells per year from the Upper Oak Creek subwatershed to 775.08 trillion cells per year from the North Branch Oak Creek subwatershed. The highest loads of fecal coliform bacteria are contributed by the North Branch Oak Creek and the Lower Oak Creek subwatersheds. In part, this reflects relatively high average unit area loads generated by these subwatersheds (see Table 152), although the Mitchell Field Drainage Ditch subwatershed has the highest unit area load.

The average annual nonpoint load of total nitrogen in the watershed is estimated to be 96,750 pounds per year. About 62.4 percent of the total point and nonpoint source load is from urban nonpoint sources and 37.2 percent from rural nonpoint sources (see Table 149). The distribution of this load among the subwatersheds is shown on Map H-43 in Appendix H. Map H-44 shows the annual per acre loads of total nitrogen for the subwatersheds.

Contributions of total nitrogen vary among the subwatersheds (see Table 145) from a low of 14,090 pounds per year from the Upper Oak Creek subwatershed to 26,380 pounds per year from the North Branch Oak Creek subwatershed. The highest loads of total nitrogen are contributed by the North Branch Oak Creek and the Middle Oak Creek subwatersheds. This is largely due to the size of these subwatersheds, since their unit area loads are in the lower range. The Mitchell Field Drainage Ditch subwatershed has the highest unit area load.

The average annual nonpoint load of BOD in the Oak Creek watershed is estimated to be 298,900 pounds per year (see Table 150). About 78.6 percent of the total point and nonpoint source load is from urban nonpoint sources and 20.2 percent from rural nonpoint sources (see Table 150). The distribution of this load among the subwatersheds is shown on Map H-45 in Appendix H. Map H-46 shows the annual per acre loads of BOD for the subwatersheds. Contributions of BOD vary among the subwatersheds (see Table 145) from a low of 38,010 pounds per year from the Mitchell Field Drainage Ditch subwatershed to 94,770 pounds per year from the North Branch Oak Creek subwatershed. The highest loads of BOD are contributed by the North Branch Oak Creek and the Middle Oak Creek subwatersheds. In the Middle Oak Creek subwatershed, this reflects the relatively large subwatershed area, and, in the case of the North Branch of Oak Creek subwatershed, it reflects a high unit area load.

The average annual nonpoint load of copper in the Oak Creek watershed is estimated to be 497 pounds per year (see Table 151). About 89.5 percent of the total point and nonpoint source load is from urban nonpoint sources and 10.5 percent from rural nonpoint sources (see Table 151). The distribution of this load among the subwatersheds is shown on Map H-47 in Appendix H. Map H-48 in Appendix H shows the annual per acre loads of copper for the subwatersheds. Contributions of copper vary among the subwatersheds (see Table 145) from a low of 67 pounds per year from the Mitchell Field Drainage Ditch subwatershed to 161 pounds per year from the North Branch Oak Creek subwatershed. The highest loads of copper are contributed by the North Branch Oak Creek and the Lower Oak Creek subwatersheds. This reflects higher unit area loads generated by these subwatersheds (see Table 152).

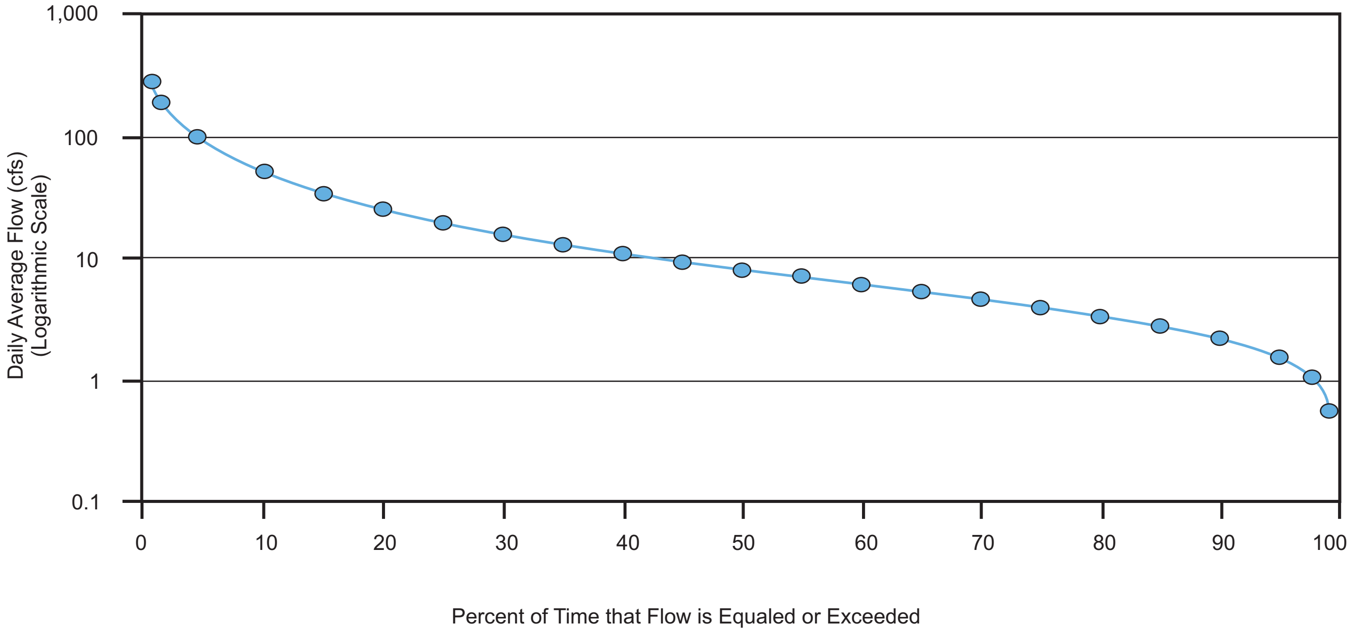
Wet-Weather and Dry-Weather Loads

It is important to distinguish between instream water quality during dry weather conditions and during wet weather conditions. Differences between wet-weather and dry-weather instream water quality reflect differences between the dominant sources and loadings of pollutants associated with each condition. Dry weather instream water quality reflects the quality of the groundwater discharge to the stream plus the continuous or intermittent discharge of various point sources, for example industrial cooling or process waters, and leakage or other unplanned dry-weather discharges from sanitary sewers or private process water piping systems. While instream water quality during wet weather conditions includes the above discharges, and in extreme instances discharges from separate and/or combined sanitary sewer overflows, the dominant influence, particularly during major rainfall or snowmelt runoff events, is likely to be the soluble or insoluble substances carried into streams by direct land surface runoff. That direct runoff moves from the land surface to the surface waters by overland routes, such as drainage swales, street and highway ditches, and gutters, or by underground storm sewer systems.

Daily average loads of six pollutants—total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, biochemical oxygen demand, and copper—were estimated for both wet-weather and dry-weather conditions for Oak Creek based on flow and water quality data from the 15th Avenue station. A water quality sample was assumed to represent wet-weather conditions when daily mean flow was in the upper 20th percentile of the flow duration curve. This includes flows that are high due to rainfall events, runoff from snowmelt, or a combination of rainfall and snowmelt. The flow duration curve for Oak Creek at the 15th Avenue station is shown in Figure 222. For this station, water quality samples were considered to reflect wet-weather conditions when daily mean flow for the corresponding date equaled or exceeded 24.35 cfs. On dates when daily mean flow was less than this, the corresponding water quality samples were considered to reflect dry-weather conditions. Daily average pollutant loads were estimated by appropriately combining daily average flow and pollutant ambient concentration.

Figure 222

FLOW DURATION CURVE FOR OAK CREEK AT 15TH AVENUE, SOUTH MILWAUKEE (USGS GAUGE 0408720): 1963-2004



Source: U.S. Geological Survey and SEWRPC.

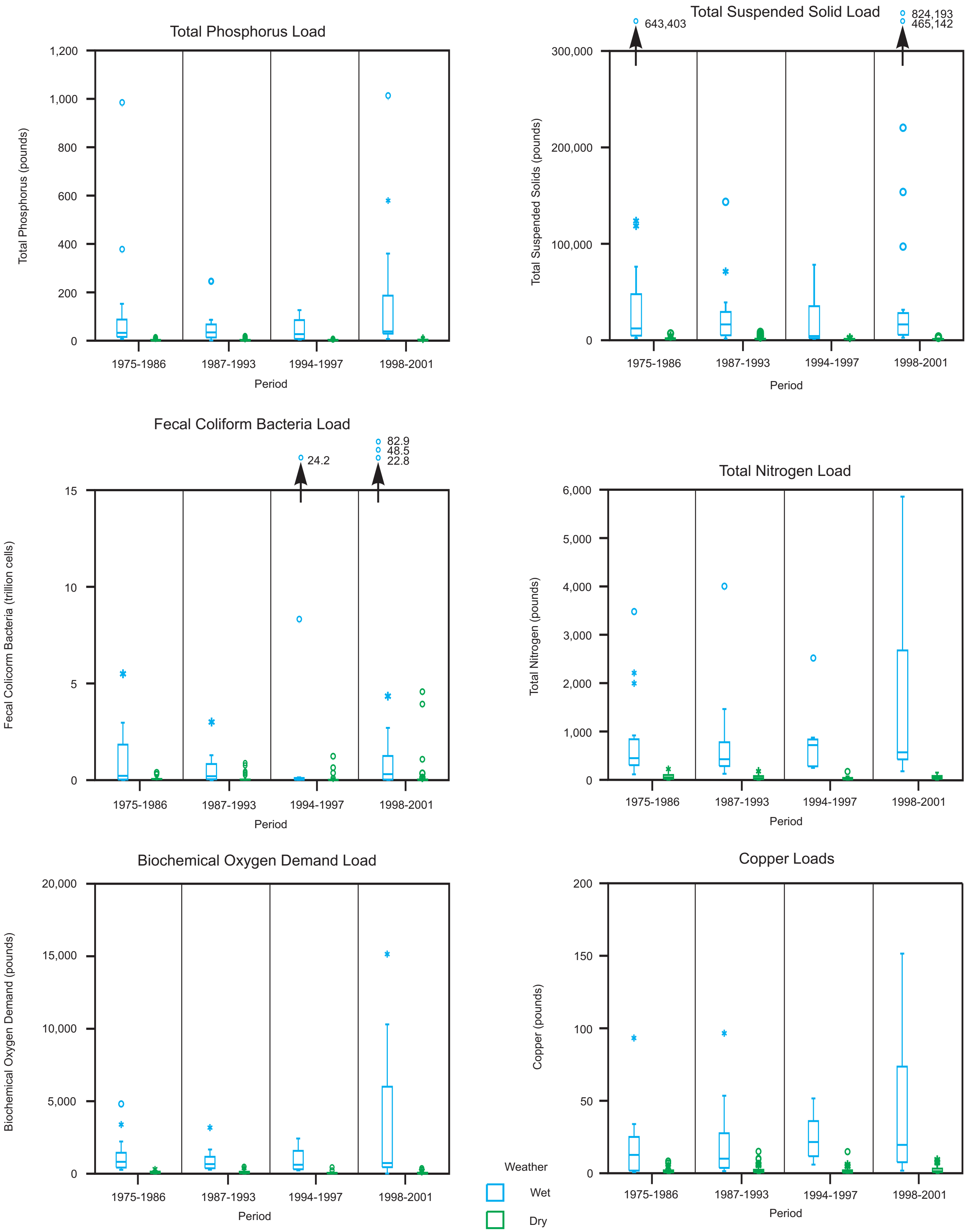
Figure 223 shows the daily average pollutant loads for total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, biochemical oxygen demand, and copper from Oak Creek at the 15th Avenue sampling station. In all cases, the loads detected during wet-weather periods were considerably higher than the loads detected during dry-weather periods. For the 1998 through 2001 baseline period:

- The mean estimated daily average wet-weather load of total phosphorus was about 164.50 pounds, which is about 57 times the mean estimated daily average dry-weather load of about 2.88 pounds.
- The mean estimated daily average wet-weather load of total suspended solids was about 17,210 pounds, about 31 times the mean estimated daily average dry-weather load of about 552 pounds.
- The mean estimated daily average wet-weather load of fecal coliform bacteria was about 9.80 trillion cells, about 35 times the mean estimated daily average dry-weather load of 0.28 trillion cells.
- The mean estimated daily average wet-weather load of total nitrogen was 1,560 pounds, about 27 times the mean estimated daily average dry-weather load of 57 pounds.
- The mean estimated daily average wet-weather load of BOD was 3,080 pounds, about 51 times the mean estimated daily average dry-weather load of about 60 pounds.
- The mean estimated daily average wet-weather load of total copper was 46.7 pounds, almost 20 times the mean estimated daily average dry-weather load of 2.4 pounds.

Figure 223 also shows the occurrence of individual wet-weather events during which the estimated daily average pollutant load was many times higher than typical wet-weather loads. The presence of these outliers indicates that individual wet-weather events can contribute a substantial fraction of the annual pollutant load to the stream. For example, Figure 223 shows that the maximum estimated daily average wet-weather load of total phosphorus

Figure 223

DAILY AVERAGE POLLUTANT LOADS IN OAK CREEK AT 15TH AVENUE (RIVER MILE 2.84): 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

detected at the 15th Avenue station during the baseline period of 1998-2001 was about 1,000 pounds. Comparing this to Table 146 shows that this single day's load represents about 10 percent of the estimated average annual load of total phosphorus in the entire watershed. Similarly, Figure 223 shows that the maximum estimated daily average wet-weather load of copper detected during the baseline period of 1998-2001 was about 150 pounds. Comparing this to Table 151 shows that this single day's load represents about 30 percent of the estimated average annual load of copper in the entire watershed. While these two examples may represent extreme cases, they do indicate that a large fraction of the annual pollutant load to the watershed is contributed by a small number of wet-weather events.

ACHIEVEMENT OF WATER USE OBJECTIVES IN THE OAK CREEK AND ITS TRIBUTARIES

The water use objectives and the supporting water quality standards and criteria for the Oak Creek watershed are discussed in Chapter IV of this report. All of the stream reaches in the Oak Creek watershed are recommended for fish and aquatic life and full recreational uses.

Based upon the available data for sampling stations in the watershed, the mainstem of Oak Creek and its major tributaries did not fully meet the water quality standards associated with the recommended water use objectives during and prior to 1975, the base year of the initial plan. Review of subsequent data indicated that as of 1995, the recommended water use objectives were only being partially achieved in the majority of the streams in the watershed.[31]

During the 1998-2001 baseline period, the recommended water use objectives were only being partially achieved in much of the Oak Creek watershed. Table 153 shows the results of comparisons of water quality data from the baseline period to supporting water quality standards. Review of data from 1998 to 2001 shows the following:

- Ammonia concentrations in all samples taken along the mainstem and along the Mitchell Field Drainage Ditch were under the acute toxicity criterion for fish and aquatic life for ammonia, indicating compliance with the standard.

- Water temperatures in all samples taken from the mainstem were at or below the relevant standard, indicating compliance with the standard.

- Dissolved oxygen concentrations at most stations along the mainstem were at or above the standard for fish and aquatic life waters in the vast majority of samples, indicating substantial compliance with the standard. The major exception to this generalization occurred in the portion of the mainstem upstream from the confluence with the North Branch of Oak Creek (above Ryan Road). In this reach, dissolved oxygen concentrations were below the standard in a substantial portion of the samples, indicating substantial noncompliance with the standard.

- Fecal coliform bacteria standards are generally exceeded at stations along the mainstem of Oak Creek, indicating general violation of the standard.

- Concentrations of total phosphorus in the mainstem of Oak Creek and the Mitchell Field Drainage Ditch commonly exceeded the recommended levels in the regional water quality management plan.

Thus, during the baseline period the stream reaches for which data are available only partially achieved the recommended water use objectives.

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[31] *SEWRPC Memorandum Report No. 93,* op. cit.

Table 153

CHARACTERISTICS OF STREAMS IN THE OAK CREEK WATERSHED: 1998-2001[a]

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[b]					Fish Biotic Index Rating[b,e]	Macroinvertebrate Biotic Index Rating (HBI)[b,c]	303(d) Impairments[f]
		Dissolved Oxygen	Temperature	NH_3[c]	Total Phosphorus[d]	Fecal Coliform Bacteria			
Tributaries									
North Branch Oak Creek	3.31	- -	- -	- -	- -	- -	- -	- -	- -
Mitchell Field Drainage Ditch	5.85	- -	100.0 (1)	100.0 (10)	45.5 (11)	- -	- -	- -	- -
Mainstem									
Oak Creek above Ryan Road	3.73	56.9 (51)	100.0 (52)	100.0 (52)	75.0 (52)	15.7 (51)	- -	- -	Aquatic toxicity
Oak Creek between STH 38 and Ryan Road	0.83	98.1 (53)	100.0 (54)	100.0 (48)	79.2 (53)	15.1 (53)	- -	- -	Aquatic toxicity
Oak Creek between Forest Hill Road and STH 38	2.98	75.0 (52)	100.0 (53)	100.0 (46)	58.5 (53)	25.0 (52)	- -	- -	Aquatic toxicity
Oak Creek between Pennsylvania Avenue and Forest Hill Road	1.54	84.6 (53)	100.0 (53)	100.0 (46)	69.2 (52)	18.9 (53)	- -	- -	Aquatic toxicity
Oak Creek between 15th Avenue and Pennsylvania Avenue	1.87	100.0 (54)	100.0 (55)	100.0 (52)	63.6 (55)	14.5 (55)	- -	- -	Aquatic toxicity
Oak Creek between Oak Creek Parkway East of STH 32 and 15th Avenue	1.80	100.0 (45)	100.0 (46)	100.0 (37)	72.3 (47)	17.0 (47)	- -	- -	Aquatic toxicity
Oak Creek between Oak Creek Parkway East of Lake Drive and Oak Creek Parkway East of STH 32	0.76	100.0 (52)	100.0 (53)	100.0 (48)	75.9 (54)	13.0 (54)	- -	- -	Aquatic toxicity

[a]*Except as noted, evaluations of dissolved oxygen, temperature, ammonia, total phosphorus, and fecal coliform bacteria are based on data from 1998-2001.*

[b]*Number in parentheses shows number of samples.*

[c]*Based upon the acute toxicity criterion for ammonia.*

[d]*Total phosphorus is compared to the concentration recommended in the regional water quality management plan.*

[e]*The State of Wisconsin has not promulgated water quality standards or criteria for biotic indices.*

[f]*As listed in the Approved Wisconsin 303(d) Impaired Waters List.*

Source: SEWRPC.

An additional issue to consider when examining whether stream reaches are achieving water use objectives is whether toxic substances are present in water, sediment, or tissue of aquatic organisms in concentrations sufficient to impair beneficial uses. Table 154 summarizes the data from 1998 to 2004 regarding toxic substances in water, sediment, and tissue from aquatic organisms for the Oak Creek watershed. For toxicants, the baseline period was extended to 2004 in order to take advantage of results from phase III of the MMSD Corridor Study Project conducted by the USGS. Pesticides were detected in water from one station along the mainstem of the Creek. The concentrations detected did not exceed water quality standards. No samples were available for concentrations of pesticides in tissue from aquatic organisms or sediment during the period 1998-2004. No samples were available for concentration of PCBs in water, tissue from aquatic organisms, or sediment during the period 1998-2004. The PAH compounds fluoranthene, phenanthrene, and pyrene were detected in water samples collected at one station along the mainstem of the Creek. No other data were available on concentrations of PAHs from the period 1998-2004. Limited sampling for other organic compounds showed detectable concentrations of several compounds in water from the mainstem of the Creek. Compounds detected include pharmaceutical and personal care products such as the stimulant caffeine, industrial solvent such as isophorone, dye components such as carbazole, flame retardants, and metabolites of nonionic detergents. Where water quality criteria have been promulgated, concentrations of these substances were below the relevant criteria. Water samples from the seven long-term stations along the mainstem of the Creek were examined for concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. While the sample sizes given in Table 154 are representative of sampling for most of these metals, it is important to note that mercury was sampled less intensively. The number of samples analyzed for mercury was about two-thirds the number analyzed for other metals. Detectable concentrations of each of these metals were present in samples from each of the stations tested. Two of these metals were present at times in concentrations that exceeded water quality standards. Concentrations of mercury in water commonly exceeded both the human threshold concentration for public health and welfare and the wildlife criterion for surface water quality. The percent of samples exceeding the lower of these two concentrations is given in Table 154. Concentrations of copper in water samples occasionally exceeded the USEPA's criterion maximum concentration (CMC) for copper. About 5 to 10 percent of samples, depending on the station, had copper concentrations exceeding this standard. Finally, water samples from the Mitchell Field Drainage Ditch were examined for concentrations of cadmium, copper, lead, and zinc. While detectable concentrations of each of these metals were present in the samples, none of the concentrations detected exceeded the applicable water quality standards.

The summary above suggests that some beneficial uses are being impaired by the presence of contaminants, especially mercury.

Section 303(d) of the Clean Water Act requires that the states periodically submit a list of impaired waters to the USEPA for approval. Wisconsin most recently submitted this list in 2004.[32] This list was subsequently approved by the USEPA. Table 153 and Map 91 indicate stream reaches in the Oak Creek watershed that are classified as being impaired waters. The mainstem of Oak Creek is listed as impaired due to aquatic toxicity. Nonpoint source pollution and other undetermined factors are cited as factors contributing to these impairments.

SUMMARY

The water quality and pollution sources inventory for the Oak Creek system have been summarized by answering five basic questions. The chapter provided detailed information needed to answer the questions. The information is summarized below.

[32] *Wisconsin Department of Natural Resources,* Approved 2004 Wisconsin 303(d) Impaired Waters List, *August 2004.*

Table 154

TOXICITY CHARACTERISTICS OF STREAMS IN THE OAK CREEK WATERSHED: 1998-2004

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
Tributaries															
North Branch Oak Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Mitchell Field Drainage Ditch	- -	- -		- -	- -	- -	- -	- -	- -	- -	- -	- -	D (5)	- -	- -
Mainstem															
Oak Creek above Ryan Road	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	E-24 (38)	- -	- -
Oak Creek between STH 38 and Ryan Road	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	E-15 (38)	- -	- -
Oak Creek between Forest Hill Road and STH 38	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	E-29 (39)	- -	- -
Oak Creek between Pennsylvania Avenue and Forest Hill Road	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	E-22 (37)	- -	- -
Oak Creek between 15th Avenue and Pennsylvania Avenue	D (3)	- -	- -	- -	- -	- -	D (3)	- -	- -	D (3)	- -	- -	E-26 (39)	- -	- -
Oak Creek between Oak Creek Parkway East of STH 32 and 15th Avenue	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	E-35 (34)	- -	- -
Oak Creek between Oak Creek Parkway East of Lake Drive and Oak Creek Parkway East of STH 32	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	E-25 (40)	- -	- -

NOTE: E-X denotes exceedence of a water quality standard in X percent of the samples, D denotes detection of a substance in this class in at least one sample, N denotes that no substances in this class were detected in any sample.

[a]*Number in parentheses indicates sample size.*

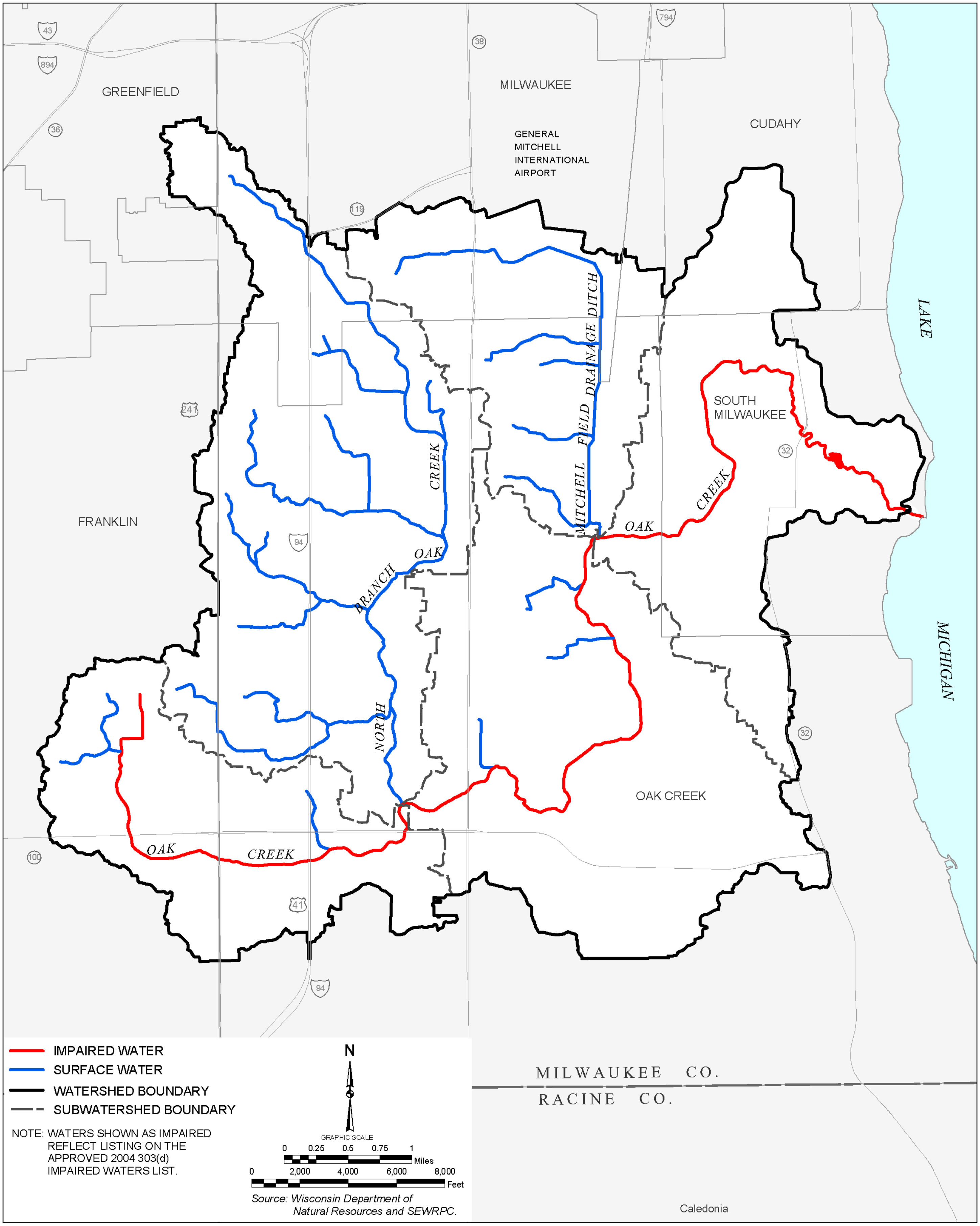
[b]*Metals sampled were arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. Sample sizes are shown for most metals. Mercury was sampled less frequently.*

[c]*These samples were taken at S. 11th Street.*

Source: SEWRPC.

Map 91

IMPAIRED WATERS WITHIN THE OAK CREEK WATERSHED: 2004



How Have Water Quality Conditions Changed Since 1975?
Water quality conditions in the Oak Creek watershed have both improved in some respects and declined in other respects since 1975.

Improvements in Water Quality
Concentrations in Oak Creek of some pollutants such as BOD and ammonia, have decreased. Improvements have also occurred in the concentrations of some toxic metals detected in Oak Creek. These improvements likely reflect both changes in the types of industries present in the watershed, the connection of most process wastewaters to the MMSD sewerage system, and the implementation of treatment requirements for all industrial discharges. Concentrations of lead have also declined, due largely to the phasing out of the use of lead as an additive to gasoline.

No Change or Reductions in Water Quality
Concentrations of suspended and dissolved pollutants typically associated with stormwater runoff and other nonpoint source pollution, such as chloride, copper, total suspended solids, and zinc have remained unchanged or increased. In addition, concentrations of some nutrients such as organic nitrogen and total and dissolved phosphorus have increased. A result of the increase in nutrients has been an increase in chlorophyll-*a* concentrations at some stations along with a decrease in the concentrations of dissolved oxygen at some stations. For some of these pollutants, such as chloride, copper, and zinc, increases in concentration have occurred in all reaches sampled along Oak Creek. For others, such as organic nitrogen, dissolved phosphorus, and total phosphorus, concentrations have increased in some reaches while remaining unchanged in others. In addition, pH has decreased in all reaches of the Creek.

How Have Toxicity Conditions Changed Since 1975?
In some respects, toxicity conditions in Oak Creek have improved since 1975; in other respects, they have declined or not changed.

Improvements in Toxicity Conditions
As described above, there have been reductions in concentrations of some toxic metals in the water column.

Worsened Toxicity Conditions
Other toxicity conditions in Oak Creek have gotten worse. In recent sampling PAHs and the pesticides carbaryl and atrazine were detected in water from Oak Creek. Also, concentrations of zinc and copper in water have increased along the entire Oak Creek mainstem.

Inconclusive Toxicity Data
In some cases, the available data are not adequate to assess changes. While there has been no recent examination of toxicant concentrations in tissue from aquatic organisms, testing from the late 1980s and early 1990s showed the presence of mercury and PCBs in tissue of aquatic organisms and consumption advisories remain in effect for portions of the Creek. Various pesticides have been detected in water in Oak Creek, but different compounds were screened for in recent samplings than were examined in historical samplings.

Sediment Conditions
In the most recent available data on sediment toxicity, the expected incidence of toxicity to benthic organisms ranges between 25 and 42 percent in Oak Creek and 17 and 58 percent in the Mitchell Field Drainage Ditch. The overall quality of sediment, as measured by mean PEC-Q, remains poor. Sediment in Oak Creek contains concentrations of arsenic, copper, lead, PAHs, and zinc high enough to pose substantial risks of toxicity to benthic organisms.

What Are the Sources of Water Pollution?
The Oak Creek watershed contains several potential sources of water pollution. These fall into two broad categories: point sources and nonpoint sources.

Point Sources
There are no public or private sewage treatment plants and no combined sewer overflow outfalls discharging into the streams of the Oak Creek watershed. Since 1995, sanitary sewer overflows have been reported at seven locations within the City of South Milwaukee. As of February 2003, 12 industrial dischargers and other point sources were permitted through the WPDES program to discharge wastewater to streams in the Oak Creek watershed. Three of the permitted facilities discharged noncontact cooling water. The remaining discharges are of several types as indicated in Table 142. All of the permitted discharges are of a nature which typically complies with the WPDES permit levels which are designed to meet water quality standards.

Nonpoint Sources
The Oak Creek watershed is comprised of combinations of urban land uses and rural land uses. As of 2000, about 39 percent of the watershed was in rural and other open land uses. The entire watershed is contained within MMSD's planned sewer service area. About 100 acres of the watershed consist of urban enclaves that are served by onsite sewage treatment systems. All communities in the watershed have adopted construction erosion control ordinances and have adopted stormwater management ordinances and/or plans. As of February 2003, 22 facilities engaged in industrial activities in the watershed had applied for and obtained WPDES stormwater discharge permits. As a condition of these permits, these facilities are required to develop and follow a stormwater pollution prevention plan. There is currently one active solid waste landfill in the watershed, located in the Lower Oak Creek watershed. The watershed contains five inactive solid waste landfills, three located in the Mitchell Field Drainage Ditch subwatershed and one located in each of the Lower Oak Creek and Middle Oak Creek watersheds.

Quantification of Pollutant Loads
The current annual average load of BOD to streams of the Oak Creek watershed is estimated to be 302,460 pounds. Separate sewer overflows contribute less than 0.1 percent of this load. Industrial discharges contribute about 1.1 percent. The rest of BOD loadings to streams in the Oak Creek watershed, about 98.8 percent, are contributed by nonpoint sources, with 78.6 percent coming from urban sources and 20.2 percent from rural sources.

The current annual average load of TSS to streams of the Oak Creek watershed is estimated to be 5,305,010 pounds. Separate sewer overflows and industrial discharges each contribute less than 0.1 percent of this load. The rest of TSS loadings to streams in the Oak Creek watershed, almost 100 percent, are contributed by nonpoint sources, with 83.2 percent coming from urban sources and 16.7 percent from rural sources.

The current annual average load of fecal coliform bacteria to streams of the Oak Creek watershed is estimated to be 2,792.11 trillion cells. Separate sewer overflows contribute about 0.3 percent of this load. The rest of fecal coliform bacteria loadings to streams in the Oak Creek watershed, about 99.7 percent, are contributed by nonpoint sources, with 93.2 percent coming from urban sources and 6.5 percent from rural sources.

The current annual average load of total phosphorus to streams of the Oak Creek watershed is estimated to be 10,630 pounds. Separate sewer overflows and industrial discharges each contribute 0.1 percent of this load. Industrial discharges contribute about 0.1 percent of this load. The rest of total phosphorus loadings to streams in the Oak Creek watershed, about 99.8 percent, are contributed by nonpoint sources, with 80 percent coming from urban sources and 19.8 percent from rural sources.

What is the Current Condition of the Fishery?
The Oak Creek watershed currently contains a very poor fishery and poor to fair macroinvertebrate communities at present. The fish community contains relatively few species of fishes, is trophically unbalanced, contains few or no top carnivores, and is dominated by tolerant fishes. The macroinvertebrate community is equally depauperate and dominated by tolerant taxa. Since water quality has either not improved or generally been decreasing in the watershed for most constituents, water quality and habitat seems to potentially be the most important factors limiting both the fishery and macroinvertebrate community.

To What Extent Are Water Use Objectives and Water Quality Standards Being Met?
During the 1998 to 2001 study baseline period, Oak Creek only partially met the water quality criteria supporting its recommended water use classification. In all of the samples taken from the mainstem of the Creek temperatures and concentrations of ammonia were in compliance with the relevant water quality standards. At most stations along the mainstem dissolved oxygen were above the standard for fish and aquatic life in the majority of samples. In the upstream reaches above Ryan Road dissolved oxygen concentrations were below the standard of 5.0 mg/l in about 43 percent of the samples. Concentrations of fecal coliform bacteria in Oak Creek usually exceed the recreational use standard of 200 cells per 100 ml which applies to the Creek. While the rate of compliance varied among stations, it was low, being below the standard in between 15 and 35 percent of the samples. Compliance with the standard for total phosphorus recommended in the regional water quality management plan was also low with the number of samples showing total phosphorus below the 0.1 mg/l standard ranging from 58 and 79 percent at stations along the mainstem.

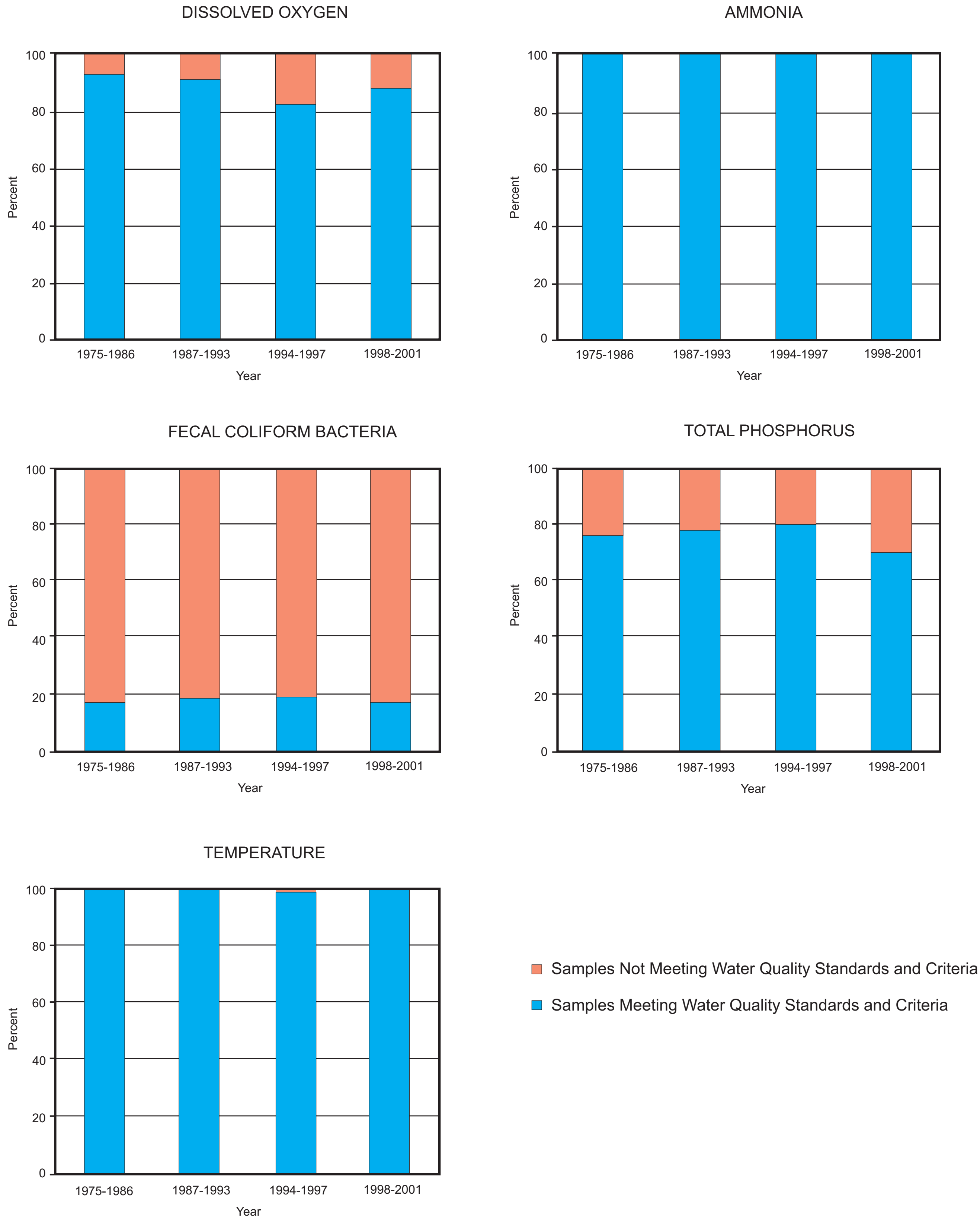
Figure 224 shows changes over time in the proportions of samples showing compliance with applicable water quality standards for Oak Creek. Over the entire study period of 1975-2001, water temperatures and concentrations of ammonia were in compliance with the applicable water quality standards in the vast majority of samples. By contrast, a significant percentage of samples collected in each period had concentrations of dissolved oxygen, fecal coliform bacteria, or total phosphorus that were not in compliance with the applicable water quality standard. In about 93 percent of the samples collected during the period 1975-1986, dissolved oxygen concentrations were in compliance with the standard. This rate of compliance decreased to about 82 percent of the samples collected during the period 1994-1997. During the period 1998-2001 the rate of compliance increased to about 88 percent of the samples collected. The rate of compliance with the standard recommended for total phosphorus in the regional water quality management plan shows the opposite pattern. It increased from about 76 percent of samples collected being in compliance with the standard during the period 1975-1986 to about 80 percent of all samples collected being in compliance with the standard during the period 1994-1997. During the period 1998-2001 the percentage of samples collected in compliance with the standard decreased to about 70 percent. During the entire study period, concentrations of fecal coliform bacteria exceeded the recreational use standard of 200 cells per 100 ml in the majority of samples collected. In each period, about 17 to 19 percent of samples collected were in compliance with the standard.

Relatively few data are available for assessing whether streams tributary to Oak Creek are meeting water use objectives and water quality standards. Based on available data, the Mitchell Field Drainage Ditch is only partially meeting its water use objectives. While ammonia concentrations in this stream were below the acute toxicity standard for fish and aquatic life for all samples, total phosphorus concentrations exceeded the recommended concentration in about 55 percent of the samples.

Some toxic substances have been detected in the Oak Creek watershed at concentrations that may impede beneficial uses. Concentrations of mercury in water samples taken from Oak Creek often exceeded both the human threshold concentration for public health and welfare and the wildlife criterion for surface water quality. Also, concentrations of copper in water samples occasionally exceeded the USEPA's criterion maximum concentration.

Figure 224

PROPORTION OF SAMPLES FOR SEVERAL CONSTITUENTS MEETING WATER QUALITY STANDARDS AND CRITERIA ALONG THE MAINSTEM OF THE OAK CREEK: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, and Milwaukee Metropolitan Sewerage District.

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Chapter IX

SURFACE WATER QUALITY CONDITIONS AND SOURCES OF POLLUTION IN THE ROOT RIVER WATERSHED

INTRODUCTION AND SETTING WITHIN THE STUDY AREA

A basic premise of the Commission watershed studies is that the human activities within a watershed affect, and are affected by, surface and groundwater quality conditions. This is especially true in the urban and urbanizing areas of the Root River watershed, where the effects of human activities on water quality tend to overshadow natural influences. The hydrologic cycle provides the principal linkage between human activities and the quality of surface and ground waters in that the cycle transports potential pollutants from human activities to the environment and from the environment into the sphere of human activities.

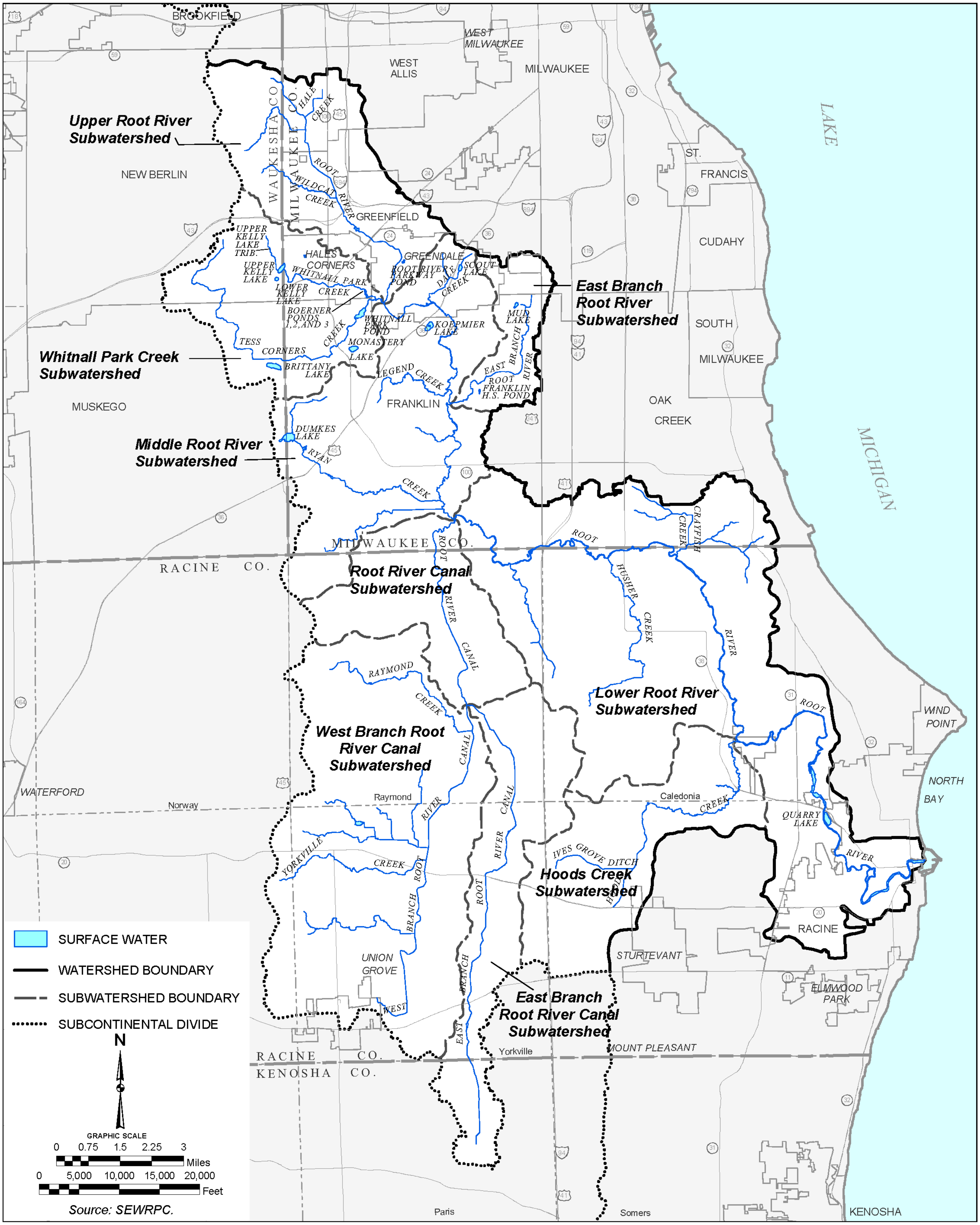
Comprehensive water quality planning efforts such as the regional water quality management plan update, should include an evaluation of historical, present, and anticipated water quality conditions and the relationship of those conditions to existing and probable future land and water uses. The purpose of this chapter is to determine the extent to which surface waters in the Root River watershed have been and are polluted, and to identify the probable causes for, or sources of, that pollution. More specifically, this chapter documents current surface water pollution problems in the watershed utilizing field data from a variety of water quality studies, most of which were conducted during the past 30 years; indicates the location and type of the numerous and varied sources of wastewater, industrial, stormwater runoff, and other potential pollutants discharged to the surface water system of the watershed; describes the characteristics of the discharges from those sources; and, to the extent feasible, quantifies the pollutant contribution of each source. The information presented herein provides an important basis for the development and testing of the alternative water quality control plan elements under the regional water quality management plan update.

DESCRIPTION OF THE WATERSHED

The Root River watershed is located in the east central portion of the Southeastern Wisconsin Region and covers an area of approximately 198 square miles. The mainstem of the Root River originates in southwestern Milwaukee County and flows approximately 44 miles in a southerly and easterly direction to its confluence with Lake Michigan in the City of Racine in Racine County. Tributaries of the Root River extend into Kenosha, Milwaukee, Racine, and Waukesha Counties. Rivers and streams in the watershed are part of the Lake Michigan drainage system as the watershed lies east of the subcontinental divide. The boundaries of the basin, together with the locations of the main channels of the Root River watershed and its principal tributaries, are shown on Map 92. While the Root River watershed contains no lakes with a surface area of 50 acres or more, it does contain several named lakes and ponds.

Map 92

SURFACE WATER WITHIN THE ROOT RIVER WATERSHED: 2000



Source: SEWRPC.

Civil Divisions
Superimposed on the watershed boundary is a pattern of local political boundaries. As shown on Map 93, the watershed lies in Kenosha, Milwaukee, Racine, and Waukesha Counties. Nineteen civil divisions lie in part or entirely within the Root River watershed, as also shown on Map 93 and Table 155. Geographic boundaries of the civil divisions are an important factor which must be considered in the regional water quality management plan update since the civil divisions form the basic foundation of the public decision making framework within which intergovernmental, environmental, and developmental problems must be addressed.

LAND USE

This section describes the changes in land use which have occurred within the Root River watershed since 1970, the approximate base year of the initial regional water quality management plan, and indicates the changes in such land uses since 1990, the base year of the initial plan update, as shown in Table 156. Although much of the watershed is urbanized, 67.2 percent of the watershed was still in rural and other open space land uses in 2000. These rural and open space uses included about 6.4 percent of the total area of the watershed in unused and other open lands and about 6.4 percent in surface water and wetlands. Most of the rural and open spaces remaining in the watershed are located in eastern Racine County and southern Milwaukee County. The remaining approximately 32.8 percent of the total watershed was devoted to urban uses, as shown on Map 94.

While urban development exists throughout much of the Root River watershed, it is especially concentrated in the northern portion of the watershed in Milwaukee and Waukesha Counties and the southeastern portion of the watershed in and around the City of Racine. Urban land use in the watershed increased from about 55.9 square miles in 1990 to about 64.6 square miles in 2000, an increase of about 15.6 percent. As shown in Table 156, residential land represents the largest urban land use in the watershed. Since 1990, much, though not all, of the urban growth in the watershed has occurred in the northern portion of the watershed in the Cities of Franklin, Greenfield, New Berlin, and Oak Creek. The historical urban growth within the Root River watershed is summarized on Map 95 and Table 157.

The changes in land use reflect changes in population and population distribution within the watershed. Several trends are apparent in the data. Over the long term the number of persons living in the watershed has increased. From 1970 through 1990, the population in the watershed increased by about 12,822, from 142,268 to 155,090; however, during that time period the number of households increased by 17,239, from 39,278 to 56,517. Between 1990 and 2000 the size of the population in the watershed continued to grow, increasing to 169,420 persons, or an increase of 14,330 persons. During this decade of increasing population, the number of households in the watershed increased by 8,470 units to 64,987.

QUANTITY OF SURFACE WATER

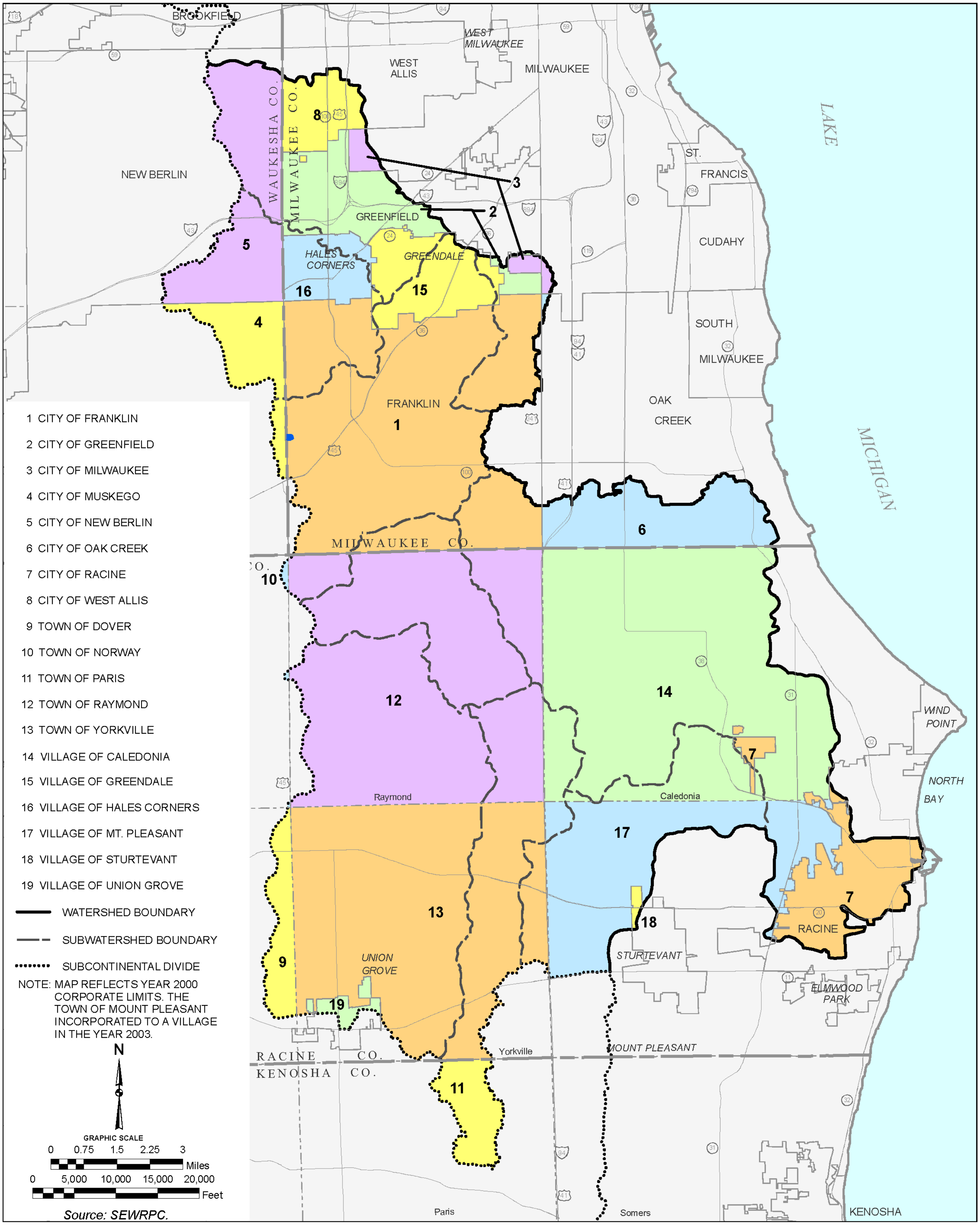
Since 1963, measurements of discharge have been taken at a number of locations along the Root River and its tributaries. The period of record for some of these stations is rather short, with data collection occurring over periods ranging from about four months to about six months. Three stations, the stations on the Root River near Franklin and below the Horlick dam in Racine and the station on the Root River Canal near Franklin, have periods of record longer than 40 years.

Figure 225 shows historical and baseline period discharge for the three stations with long-term records. Similar annual patterns are seen in the baseline period mean discharge at both sites. Mean monthly streamflow tends to reach a low point in December. Mean monthly discharge rises from this low point to a peak in April associated with spring snowmelt and rains. It then declines slightly through the spring, summer, and fall to the winter minimum. Considerable variability is associated with these patterns, but some of this variability is more likely attributed to sampling conditions rather than actual changes in discharge.

For the most part, stream flow from the baseline period is within historical ranges at all three of the stations with long-term flow data. During spring months, monthly maximum discharges during the baseline period were less, or

Map 93

CIVIL DIVISIONS WITHIN THE ROOT RIVER WATERSHED: 2000



Source: SEWRPC.

Table 155

AREAL EXTENT OF COUNTIES, CITIES, VILLAGES, AND TOWNS WITHIN THE ROOT RIVER WATERSHED

Civil Division	Area (square miles)	Percent of Total
Kenosha County		
Town of Paris	2.75	1.39
Milwaukee County		
City of Franklin	31.67	16.03
City of Greenfield	6.20	3.14
City of Milwaukee	1.07	0.54
City of Oak Creek	7.14	3.61
City of West Allis	2.96	1.50
Village of Greendale	5.46	2.76
Village of Hales Corners	3.20	1.62
Subtotal	57.70	29.20
Racine County		
City of Racine	7.03	3.55
Town of Dover	2.62	1.33
Town of Norway	0.12	0.06
Town of Raymond	34.02	17.22
Town of Yorkville	29.92	15.14
Village of Caledonia	35.85	18.14
Village of Mt. Pleasant	13.50	6.83
Village of Sturtevant	0.20	0.10
Village of Union Grove	0.73	0.37
Subtotal	123.98	62.74
Waukesha County		
City of Muskego	3.93	1.99
City of New Berlin	9.24	4.68
Subtotal	13.17	6.67
Total	197.60	100.00

Source: SEWRPC.

similar to, the historical monthly maxima. Baseline period monthly mean discharges tended to be higher than the historical means during the spring at all three stations with long-term flow data. By contrast, baseline period monthly mean discharges were lower than the historical means during the month of December at all three of these stations.

Flow fractions were calculated for all stations relative to the discharge at the Racine station below the Horlick dam using the procedure described in Chapter III of this report. These are shown on Map 96. Several generalizations emerge from this analysis:

- The magnitude of average discharge increases rapidly in the headwaters of the River. For example, average discharge increased by about a factor of five between the stations at W. Grange Avenue (River Mile 36.7) and W. Ryan Road (River Mile 28.0) on the mainstem of the River. Much of the increase in discharge represents contributions of water from Dale Creek, the East Branch of the Root River, Tess Corners Creek, and Whitnall Park Creek.

- Much of the discharge at downstream stations can be accounted for by discharge from stations upstream and from tributaries entering the River upstream. For instance, median discharge from the Root River and its tributaries upstream from the Ryan Road station (River Mile 28.0) represents about 30 percent of the median discharge at the Racine station below the Horlick dam (River Mile 5.9).

Table 156

LAND USE IN THE ROOT RIVER WATERSHED: 1970-2000[a,b]

Category	1970		1990		2000		Change 1970-2000	
	Square Miles	Percent of Total	Square Miles	Percent of Total	Square Miles	Percent of Total	Square Miles	Percent
Urban								
Residential	24.4	12.4	30.5	15.5	34.5	17.5	10.1	41.4
Commercial	1.5	0.8	2.4	1.2	2.8	1.4	1.3	86.7
Industrial and Extractive	1.6	0.8	1.8	0.9	2.6	1.3	1.0	62.5
Transportation, Communication, and Utilities[c]	13.0	6.6	14.0	7.1	16.7	8.6	3.7	28.5
Governmental and Institutional	2.4	1.2	2.7	1.4	3.0	1.5	0.6	25.0
Recreational	3.9	2.0	4.5	2.3	5.0	2.5	1.1	28.2
Subtotal	46.8	23.8	55.9	28.4	64.6	32.8	17.8	38.0
Rural								
Agricultural and Related	121.3	61.6	110.2	55.9	99.5	50.5	-21.8	-18.0
Water	1.2	0.6	1.5	0.8	1.6	0.8	0.4	33.3
Wetlands	9.4	4.7	10.3	5.2	10.9	5.6	1.5	16.0
Woodlands	8.1	4.1	8.1	4.1	7.6	3.9	-0.5	-6.2
Unused and Other Open Lands	10.2	5.2	11.0	5.6	12.7	6.4	2.5	24.5
Subtotal	150.2	76.2	141.1	71.6	132.3	67.2	-17.8	-11.9
Total	197.0	100.0	197.0	100.0	197.0	100.0	0.0	- -

[a]*As approximated by whole U.S. Public Land Survey one-quarter sections.*

[b]*As part of the regional land use inventory for the year 2000, the delineation of existing land use was referenced to real property boundary information not available for prior inventories. This change increases the precision of the land use inventory and makes it more usable to public agencies and private interests throughout the Region. As a result of the change, however, year 2000 land use inventory data are not strictly comparable with data from the 1990 and prior inventories. At the county and regional level, the most significant effect of the change is to increase the transportation, communication, and utilities category, the result of the use of narrower estimated right-of-ways in prior inventories. The treatment of streets and highways generally diminishes the area of adjacent land uses traversed by those streets and highways in the 2000 land use inventory relative to prior inventories.*

[c]*Off-street parking of more than 10 spaces are included with the associated land use.*

Source: SEWRPC.

Most of this, about 24 percent of the median discharge at the Racine station below the Horlick dam, is contributed by Dale Creek, the East Branch of the Root River, Tess Corners Creek, and Whitnall Park Creek. Similarly, median discharge at the station in the Root River Canal near Franklin and upstream from Six Mile Road (River Mile 3.5) represents about 28 percent of the median discharge at the station below the Horlick dam. This suggests that Crayfish Creek, Hoods Creek, and Husher Creek, which discharge to the Root River downstream from the Root River Canal, contribute approximately 40 percent of the discharge at the station below the Horlick dam. The remainder of the median discharge is contributed by direct runoff and direct baseflow to the Root River mainstem and runoff and baseflow from smaller tributaries.

SURFACE WATER QUALITY OF THE ROOT RIVER WATERSHED: 1975-2001

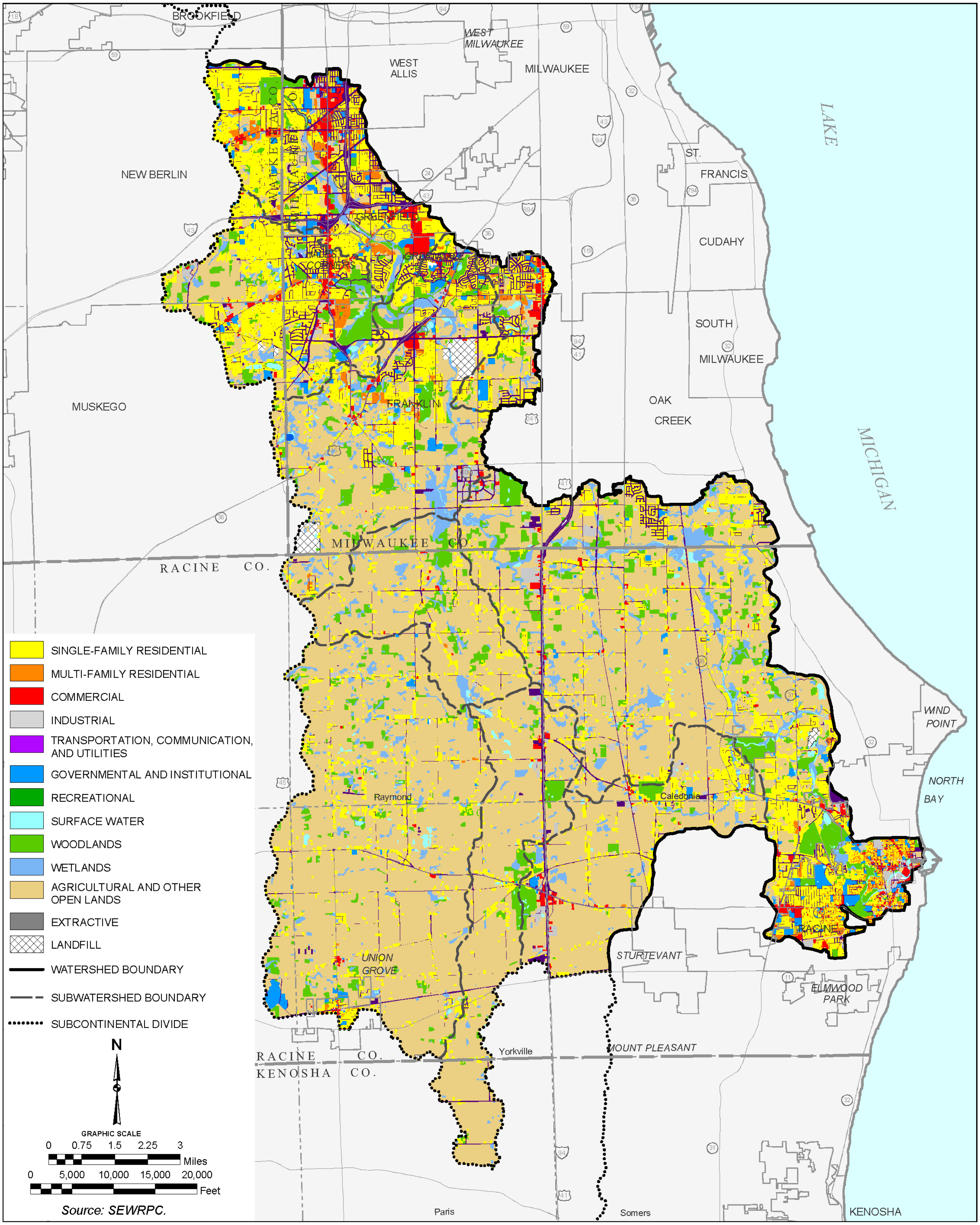
Water Quality of Streams

The earliest systematic collection of water quality data in the Root River watershed occurred in the mid-1960s.[1] Data collection after that was sporadic until the 1970s. Since then, considerable data have been collected,

[1]*SEWRPC Technical Report No. 4,* Water Quality and Flow of Streams in Southeastern Wisconsin*, April 1964.*

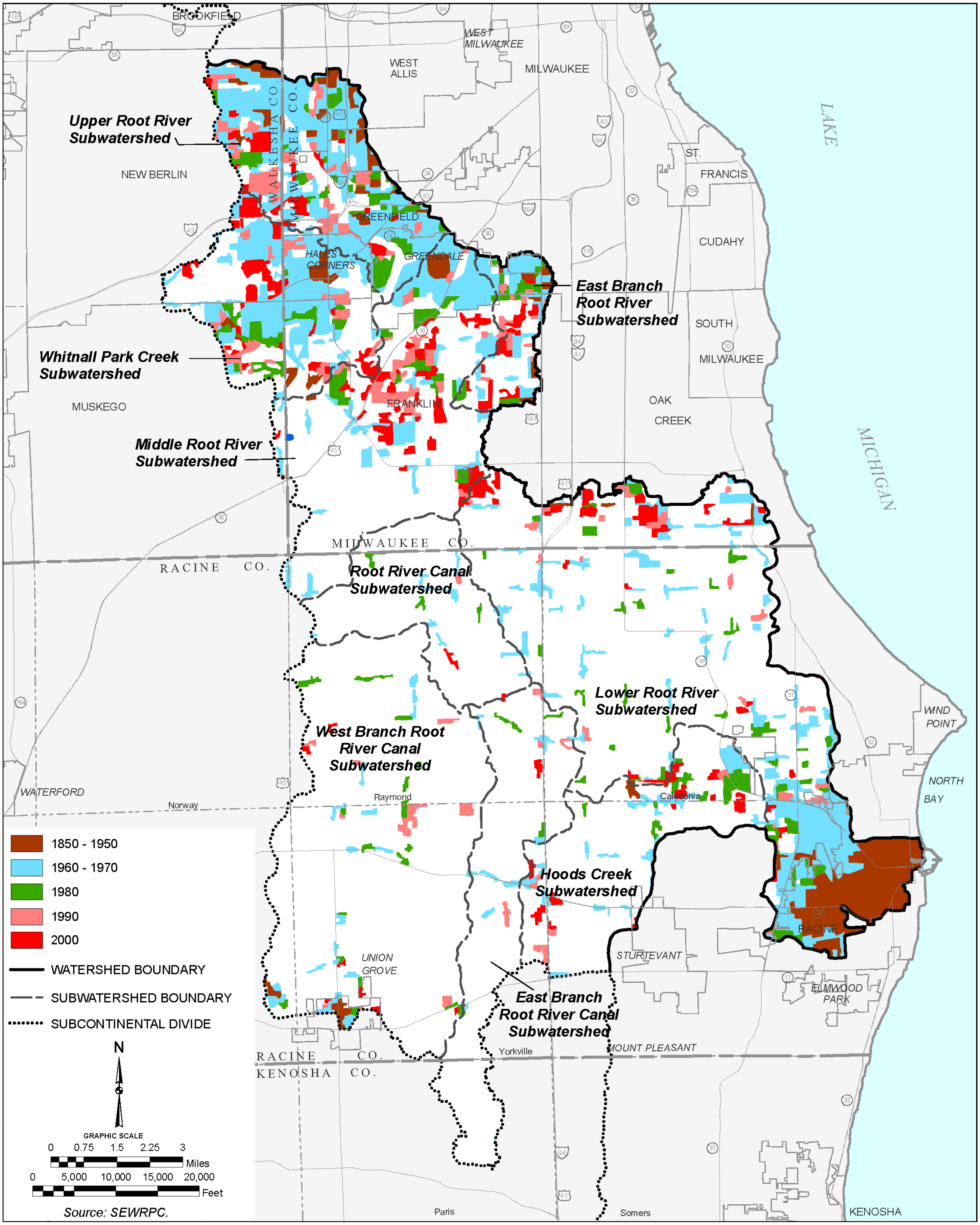
Map 94

EXISTING LAND USE WITHIN THE ROOT RIVER WATERSHED: 2000



Map 95

HISTORICAL URBAN GROWTH WITHIN THE ROOT RIVER WATERSHED: 1850-2000



Source: SEWRPC.

especially on the mainstem of the River. The major sources of data include the Milwaukee Metropolitan Sewerage District (MMSD), the Wisconsin Department of Natural Resources (WDNR), the U.S. Geological Survey (USGS), the City of Racine Health Department, and the U.S. Environmental Protection Agency's (USEPA) STORET legacy and modern databases (see Map 97). In addition, Commission staff reviewed data collected by citizen monitoring programs including the Water Action Volunteers Program. These data are presented in Appendix B. Most of these data were obtained from sampling stations along the mainstem of the River. In addition, sufficient data were available for Husher Creek and the Root River Canal to assess baseline period water quality for several water quality parameters. The data record for the other tributary streams in the watershed is fragmentary.

For analytical purposes, data from four time periods were examined: 1975-1986, 1987-1993, 1994-1997, and 1998-2004. Bimonthly data records exist from two of MMSD's long-term monitoring stations beginning in 1975. After 1986, MMSD no longer conducted sampling during the winter months. In 1994, the Inline Storage System (ISS), or Deep Tunnel, came online. The remaining period from 1998-2001 defines the baseline water quality conditions of the river system, developed since the ISS came online. These periods were chosen to facilitate comparisons between water quality trends in the Root River watershed and the other watersheds in the regional water quality management plan update study area. While operation of the ISS would not be expected to have as direct an effect on instream water quality in the Root River watershed as it does in the Kinnickinnic River, Menomonee River, and Milwaukee River watersheds, the ISS and the related MMSD water pollution abatement program and local sewerage system improvements have reduced separate sanitary sewer overflows in the Root River watershed.

Table 157

EXTENT OF URBAN GROWTH WITHIN THE ROOT RIVER WATERSHED: 1850-2000

Year	Extent of New Urban Development Occurring Since Previous Year (acres)[a]	Cumulative Extent of Urban Development (acres)[a]	Cumulative Extent of Urban Development (percent)[a]
1850	244	244	0.2
1880	396	640	0.5
1900	321	962	0.7
1920	1,043	2,004	1.6
1940	652	2,656	2.1
1950	1,926	4,582	3.6
1963	12,263	16,845	13.3
1970	5,001	21,846	17.3
1975	1,788	23,634	18.7
1980	2,446	26,080	20.6
1985	1,681	27,761	21.9
1990	1,873	29,634	23.4
1995	1,528	31,162	24.6
2000	2,435	33,697	26.6

[a]Urban development, as defined for the purposes of this discussion, includes those areas within which houses or other buildings have been constructed in relatively compact groups, thereby indicating a concentration of urban land uses. Scattered residential developments were not considered in this analysis.

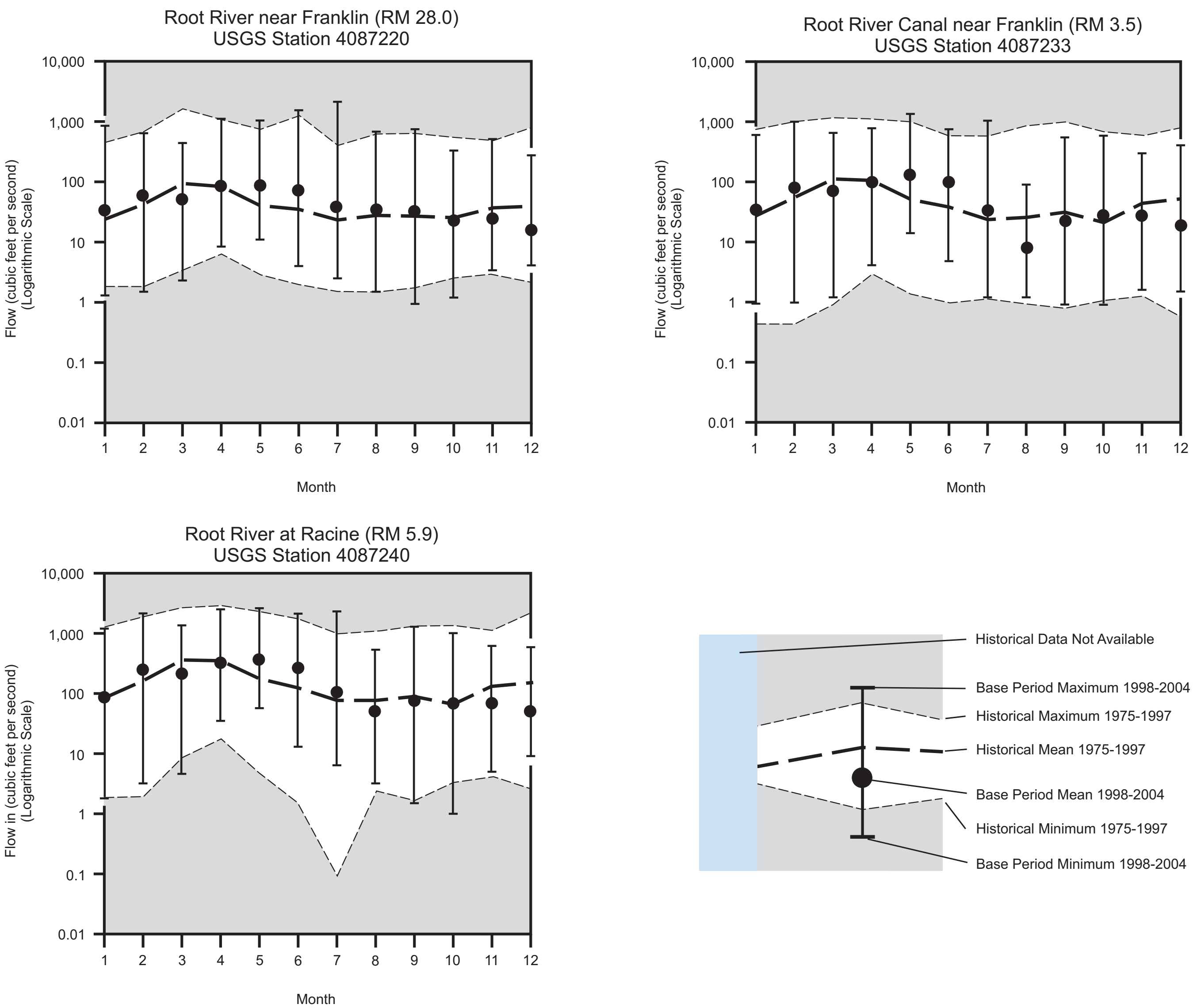
Source: U.S. Bureau of the Census and SEWRPC.

Under this plan update, baseline water quality conditions were graphically compared to historical conditions on a monthly basis. As shown in the sample graph presented in Figure 23 of Chapter III of this report, for each water quality parameter examined, the background of the graph summarizes the historical conditions. The white area in the graphs shows the range of values observed during the period 1975-1997. The upper and lower boundaries between the white and gray areas show historical maxima and minima, respectively. A blue background indicates months for which no historical data were available. The black dashed line plots the monthly mean value of the parameter for the historical period. Overlaid on this background is a summary of baseline conditions from the period 1998-2004. Relative to the Kinnickinnic River, Menomonee River, and Oak Creek watersheds, the baseline period examined for the Root River was extended to 2004 in order to take advantage of data collected specifically for the regional water quality management plan update in 2004 by the USGS and by the City of Racine Health Department during the period 1998-2005. The black dots show the monthly mean value of the parameter for that period. The black bars show the monthly ranges of parameter for the same period.

In addition to this summarization, water quality parameters from the Root River were examined for the presence of several different types of trends: changes along the length of the River, changes at individual sampling stations over time, and seasonal changes throughout the year. Because the Root River does not discharge into the Milwaukee River estuary, comparisons between the means at upstream and estuary sites were not appropriate and

Figure 225

HISTORICAL AND BASE PERIOD FLOW AT LONG-TERM STATIONS IN THE ROOT RIVER WATERSHED: 1975-2004



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

were not done. Map 97 and Table 158 show the nine sampling stations on the Root River, designated by their River Mile locations, which had sufficiently long periods of sampling to be used for this analysis. Six of these stations are MMSD stations. Figure 226 shows photographs of selected river sampling stations along the mainstem of the Root River. Trends were examined along a section of Root River from the confluence with Lake Michigan to a station 41.5 miles upstream. Changes over time were assessed both on an annual and on a seasonal basis as set forth in Appendix C. It is important to note that only limited data were available to assess baseline water quality conditions for tributary streams.

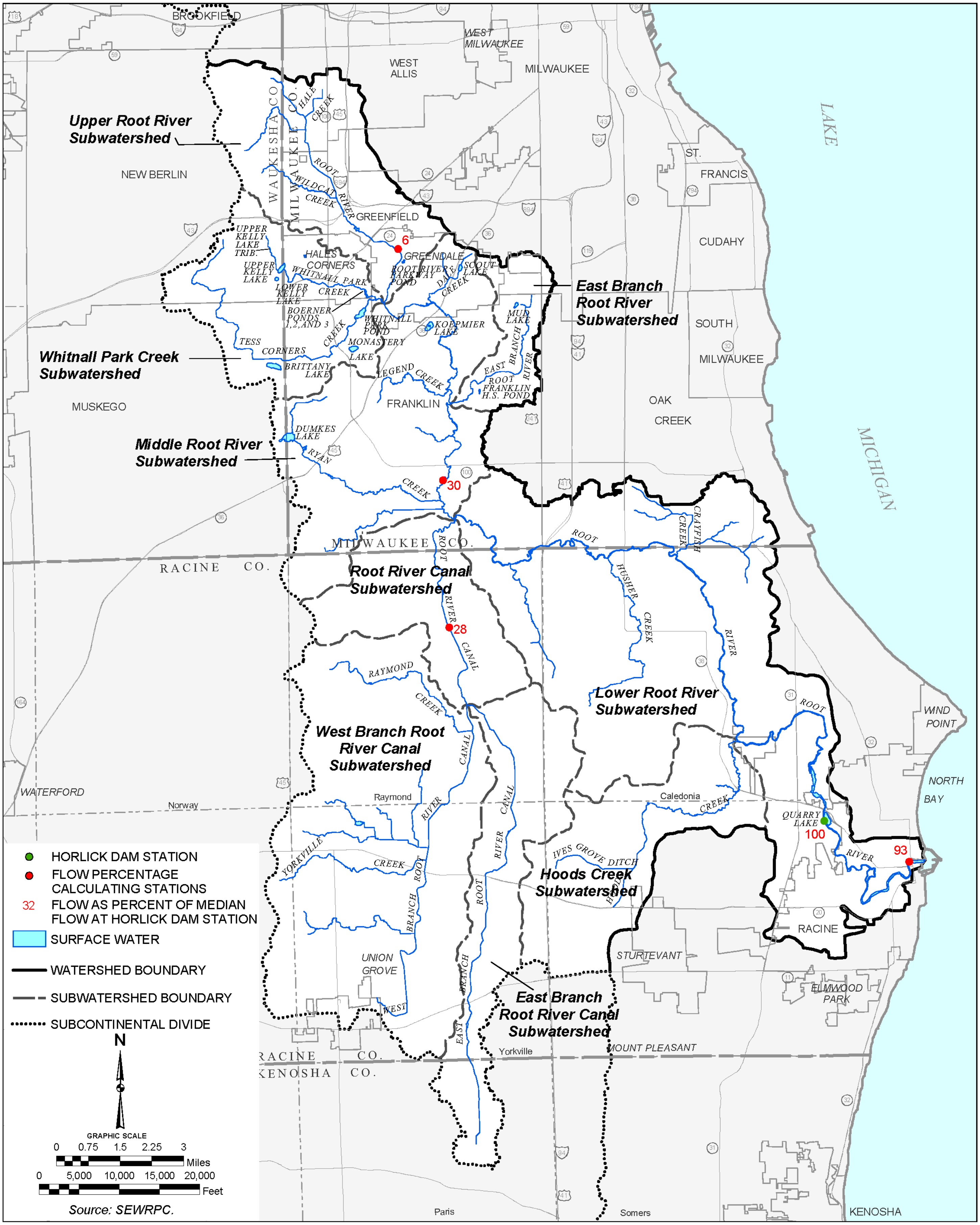
Bacterial and Biological Parameters

Bacteria

As shown in Figure 227, median concentrations of fecal coliform bacteria in the Root River during the period of record ranged from about 80 to 6,420 cells per 100 milliliters (ml). Fecal coliform counts in the River varied over

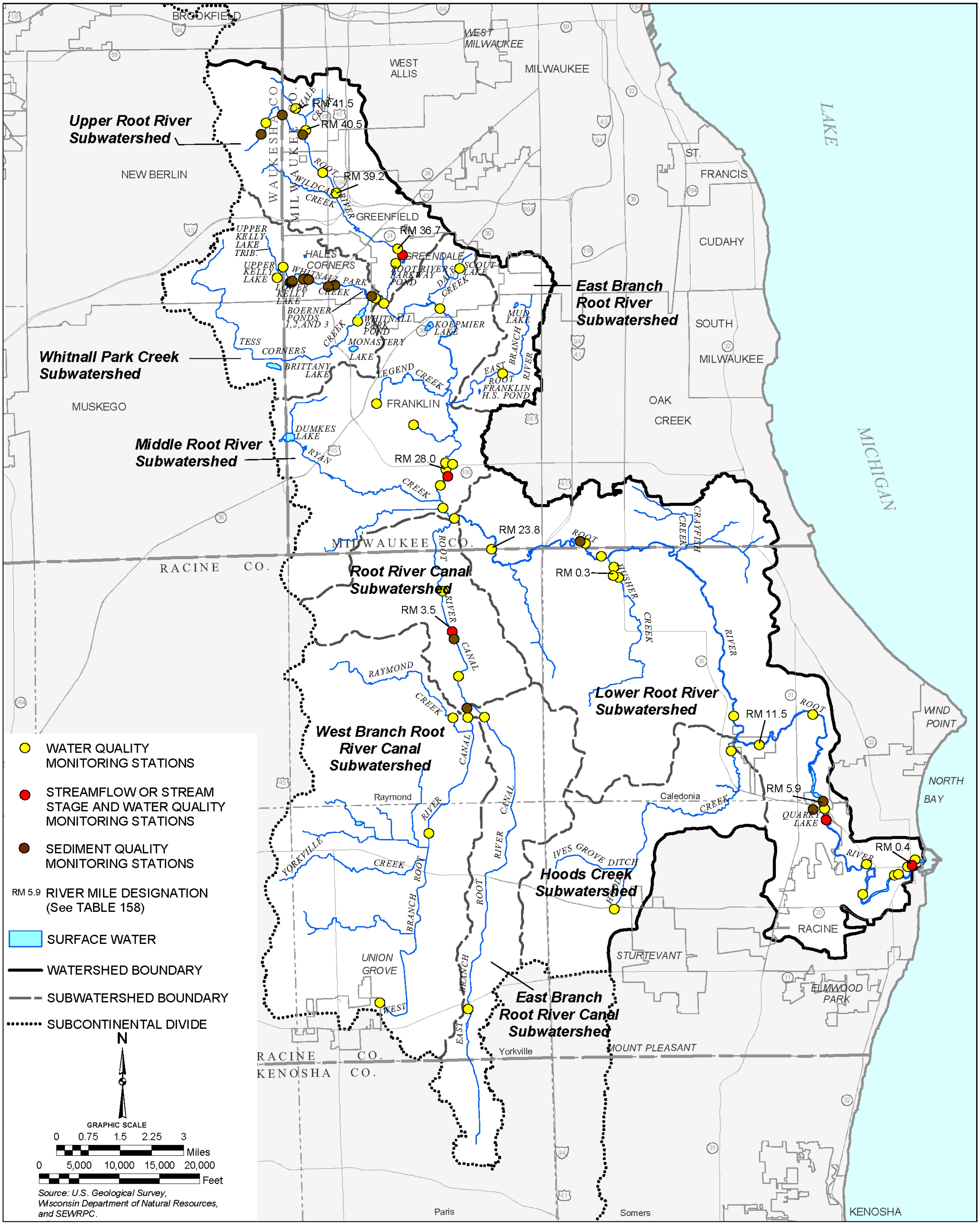
Map 96

FLOW PERCENTAGES AMONG STATIONS WITHIN THE ROOT RIVER WATERSHED: 2000



Map 97

WATER AND SEDIMENT QUALITY MONITORING STATIONS WITHIN THE ROOT RIVER WATERSHED: 1975-2001



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

Table 158

SAMPLE SITES USED FOR ANALYSIS OF WATER QUALITY TRENDS IN THE ROOT RIVER

Location	River Mile	Period of Record	Data Sources
Tributaries			
Husher Creek at 7 1/2 Mile Road	0.3[a]	1981-1982, 1996, 2001	USGS, EPA
Root River Canal near Franklin	3.5[a]	1975-1981, 1985-1994, 2001	USGS
Mainstem			
Root River at W. Cleveland Avenue	41.5[b]	1999-2001	MMSD
Root River at W. National Avenue and W. Oklahoma Avenue	41.0[b]	1999-2001	MMSD
Root River at W. Cold Spring Road	39.2[b]	1999-2001	MMSD
Root River at W. Grange Avenue	36.7[b]	1975-1976, 1981-1982, 1996,1999-2001, 2004	USGS, EPA, WDNR, MMSD
Root River at W. Ryan Road	28.0[b]	1971-1982, 1985-1994, 1996, 1999-2001, 2004	USGS, WDNR, MMSD
Root River at County Line Road	23.8[b]	1999-2001	MMSD
Root River at Johnson Park	11.5[b]	1977-1983, 1986-1990, 1992-2005	EPA, WDNR, City of Racine
Root River below Horlick Dam, Racine	5.9[b]	1975-1994, 1996-1999, 2002, 2004-2005	USGS, EPA, City of Racine
Root River near Mouth	0.4[b]	1996-1997, 1999, 2004-2005	USGS, City of Racine

[a]*River Mile is measured as distance upstream from the confluence with the mainstem of the Root River.*

[b]*River Mile is measured as distance upstream from the confluence with Lake Michigan.*

Source: SEWRPC.

six orders of magnitude, ranging from as low as one cell per 100 ml to over 240,000 cells per 100 ml. Median concentrations at the stations shown in Figure 227 during the period 1998-2005 were lower than median concentrations at these stations during the period 1994-1997. The range of variability appears to be higher during late spring, early summer, and fall as shown in Figure 228, although it is important to note that this may reflect the larger numbers of samples that were taken during these months than during other months. Counts in most samples exceed the standard for full recreational use of 200 cells per 100 ml. Table 159 shows a statistically significant trend toward concentrations of fecal coliform bacteria decreasing from upstream to downstream along the mainstem of the River. This relationship accounts for a small portion of the variation in the concentrations of fecal coliform bacteria in the River. Several factors may account for it. Water in the upstream sections of the River may be receiving more contamination from sources containing these bacteria than water in the downstream sections. This trend might also reflect settling and resuspension of bacteria in various reaches of the River. Several generalizations emerge from the comparison of baseline period fecal coliform concentrations to historical concentrations shown in Figure 228: First, fecal coliform concentrations in the Root River tend to be relatively low during the late winter and early spring. They increase sharply during the spring and early summer. This is followed by a decrease that, depending upon the station, occurs during summer or fall. Second, during spring and early summer, baseline period monthly mean concentrations of fecal coliform bacteria at the stations at W. Ryan Road and W. Grange Avenue were higher than the historical mean concentrations. A different pattern was observed at the station at Johnson Park. At this station, concentrations of fecal coliform bacteria from the baseline period were generally below the historical mean concentrations. Downstream from this station, at the stations below the Horlick dam and near the mouth of the River, monthly mean concentrations of fecal coliform bacteria were near historical mean concentrations for those months where data were available for the baseline period.

Figure 226

SAMPLING STATION LOCATIONS ALONG THE ROOT RIVER: 2003

ROOT RIVER AT RIVER MILE 41.0

ROOT RIVER AT RIVER MILE 23.8

ROOT RIVER AT RIVER MILE 39.2

ROOT RIVER AT RIVER MILE 11.5

ROOT RIVER AT RIVER MILE 28.0

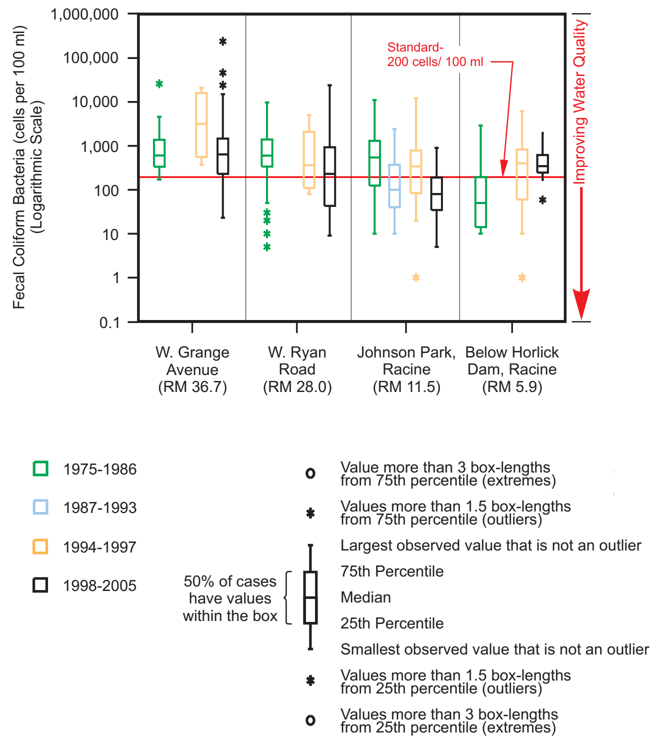
ROOT RIVER AT RIVER MILE 5.9

Source: Inter-Fluve, Inc., Wisconsin Department of Natural Resources, and SEWRPC.

As shown in Table C-5 in Appendix C of this report, few time-based trends in fecal coliform bacteria concentrations were detected in the Root River. When analyzed on an annual basis, most long-term sampling sites showed no statistically significant trends in fecal coliform concentrations. There were two exceptions to this generalization. A statistically significant trend toward decreasing fecal coliform bacteria concentrations was detected at the station at Johnson Park. Analysis of these trends by season suggests that the changes have occurred during all seasons except the summer. This trend accounts for a small fraction of the variation observed at this station. A statistically significant trend toward increasing fecal coliform bacteria concentrations was detected at the station below the Horlick dam. Again, this trend accounts for a small fraction of the variation observed at this station. Fecal coliform bacteria concentrations in the Root River tend to be positively correlated with concentrations of biochemical oxygen demand and with concentrations of several nutrients including dissolved phosphorus, total phosphorus, organic nitrogen, and total nitrogen. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the River. Fecal coliform bacteria concentrations are also strongly positively correlated with concentrations of *E. coli*, reflecting the fact that *E. coli* constitute a major component of fecal coliform bacteria. In addition, fecal coliform bacteria concentrations in the River are negatively correlated with several measures of dissolved material such as alkalinity, hardness, specific conductance, and chloride concentrations.

Figure 227

FECAL COLIFORM BACTERIA CONCENTRATIONS ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2005



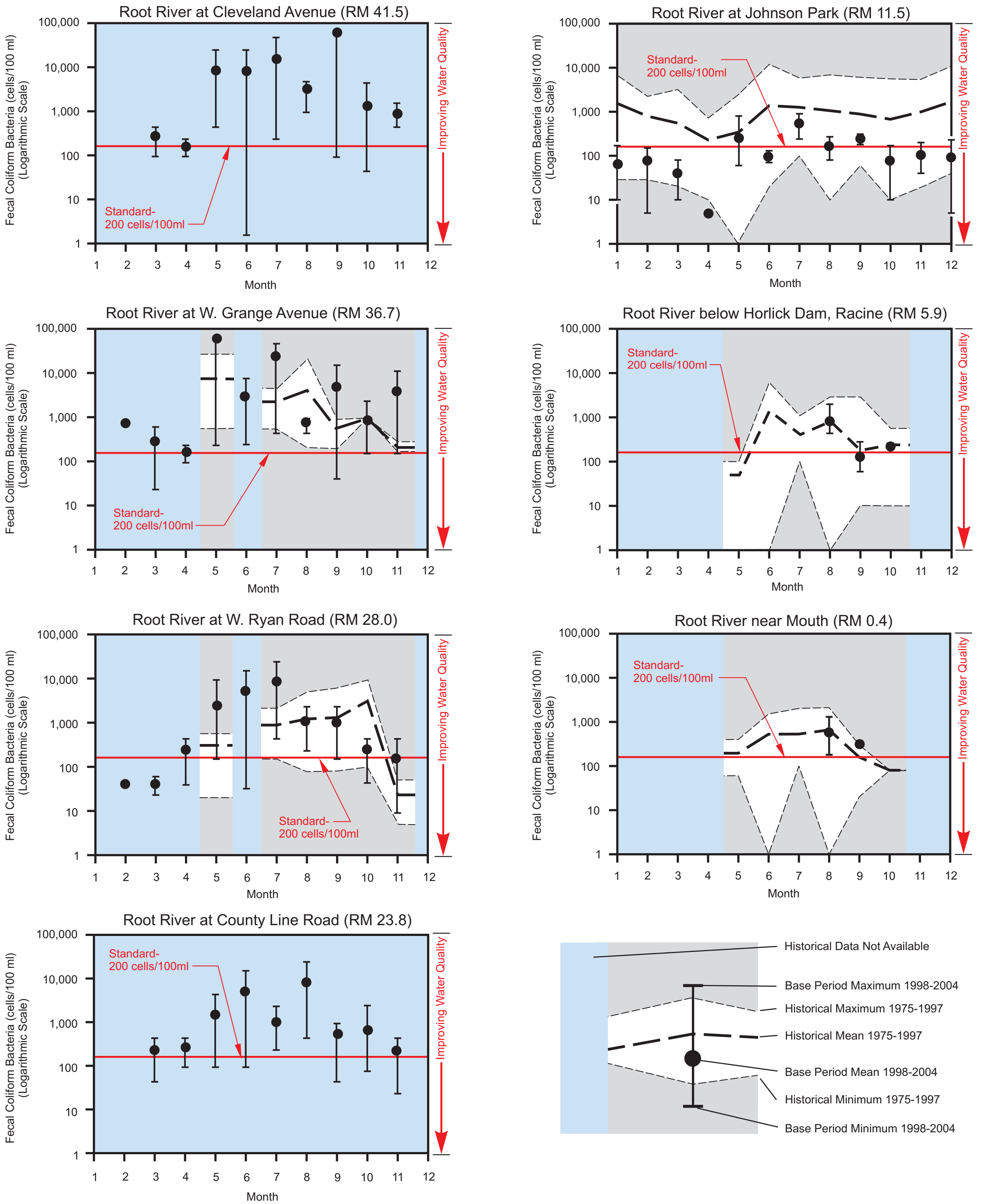
Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Health Department, and SEWRPC.

MMSD began regular sampling for *E. coli* in the Root River at two long-term sampling stations along the mainstem in 2000. In addition, the City of Racine Health Department monitors *E. coli* concentrations at several sites along the River in the City of Racine. Figure 229 shows the concentrations of *E. coli* at four sites along the Root River. Concentrations of *E. coli* in the River ranged from below the limit of detection to 130,000 cells per 100 ml. Median and mean concentrations during the baseline period were generally higher at downstream stations, though this may reflect the fact that only a small number of samples were available from MMSD's stations. In any case, no statistically significant trend in *E. coli* concentration was detected from upstream to downstream along the Root River (see Table 159). No statistically significant time-based trends were detected in *E. coli* concentrations (see Table C-5 in Appendix C). The data are insufficient for assessing whether there are seasonal patterns to the numbers of these bacteria in the River.

Figure 230 shows mean concentrations of *E. coli* in the Root River at the four stations in the City of Racine for which data from 1996-2005 were available. Analysis of variance (ANOVA) shows that mean *E. coli* concentrations at Cedar Bend Park were significantly higher than mean concentrations at the other three stations. This result has two implications. First, the higher than background mean concentrations at the Cedar Bend Park station suggest that some source or sources at or upstream from this site are contributing high loads of *E. coli* to the River. Second, the fact that the mean *E. coli* concentrations at the site near the mouth of the River are not significantly different from the mean concentrations at the stations below the Horlick dam and Johnson Park suggests that concentrations of these bacteria are returning to background levels downstream of the Cedar Bend Park station through dilution, settling to the sediment, cell death, or some other mechanism.

Figure 228

HISTORICAL AND BASE PERIOD FECAL COLIFORM BACTERIA IN THE ROOT RIVER: 1975-2004



Source: *U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Health Department and SEWRPC.*

Table 159

UPSTREAM TO DOWNSTREAM TRENDS IN WATER QUALITY PARAMETERS FROM UPSTREAM SITES ALONG THE ROOT RIVER 1975-2001[a]

Constituent	Trend	Slope	Intercept	R^2
Bacteria and Biological				
Fecal Coliform[b]	⬇	0.0181	2.216	0.08
E. coli [b]	0	- -	- -	- -
Chlorophyll-*a*[b]	⬆	-0.0271	1.296	0.03
Chemical				
Alkalinity	⬇	2.3626	194.006	0.06
Biochemical Oxygen Demand[b]	⬆	-0.0119	0.566	0.07
Chloride[b]	⬇	0.0085	1.872	0.19
Dissolved Oxygen	0	- -	- -	- -
Hardness	⬇	1.9816	311.350	0.05
pH	⬆	-0.0201	8.184	0.51
Specific Conductance	⬇	14.2615	701.381	0.32
Temperature	⬆	-0.1190	17.507	0.07
Suspended Material				
Total Suspended Sediment	0	- -	- -	- -
Total Suspended Solids	⬇	0.4746	36.540	0.16
Nutrients				
Ammonia[b]	0	- -	- -	- -
Kjeldahl Nitrogen[b]	⬆	-0.0037	0.029	0.05
Nitrate[b]	⬆	-0.0246	0.461	0.27
Nitrite[b]	⬆	-0.0286	-0.644	0.25
Organic Nitrogen[b]	⬆	-0.0048	-0.000	0.08
Total Nitrogen[b]	⬆	-0.0095	0.495	0.18
Dissolved Phosphorus[b]	⬆	-0.0053	-1.314	0.02
Total Phosphorus[b]	⬆	-0.0061	-0.824	0.12
Metals				
Arsenic[b]	- -	- -	- -	- -
Cadmium[b]	0	- -	- -	- -
Chromium[b]	⬇	0.2204	0.086	0.18
Copper[b]	⬇	0.0083	0.545	0.18
Lead[b]	⬇	0.0084	0.135	0.02
Mercury[b]	⬇	0.0320	-2.501	0.21
Nickel[b]	0	- -	- -	- -
Zinc[b]	⬇	0.0099	0.887	0.16

NOTE: The following symbols were used:

⬆ indicates a statistically significant increase from upstream to downstream.

⬇ indicates a statistically significant decrease from upstream to downstream.

0 indicates that no trend was detected.

R^2 indicates the fraction of variance accounted for by the regression.

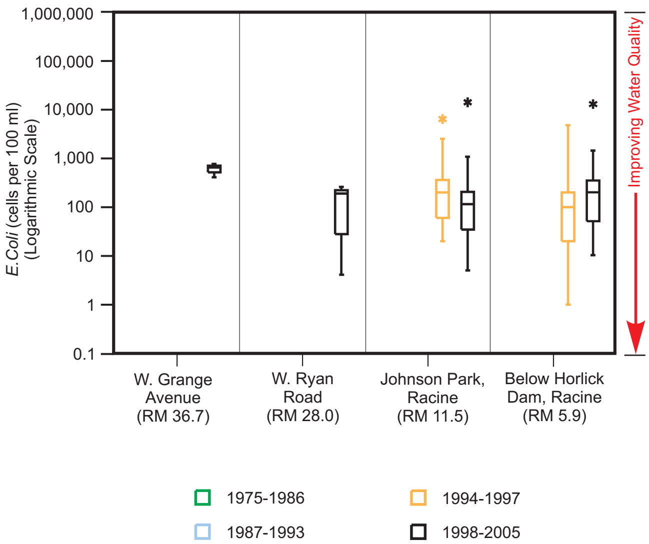
[a]*Trends were assessed through linear regression analysis. Values of water quality parameters were regressed against River Mile. A trend was considered significant if the regression showed a significant slope at P = 0.05 or less. Higher R^2 values indicate that higher portions of the variation in the data are attributable to the trend. Lower R^2 values indicate that more of the variation is due to random factors.*

[b]*These data were log-transformed before being entered into regression analysis.*

Source: SEWRPC.

Figure 229

***E. COLI* BACTERIA CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2005**

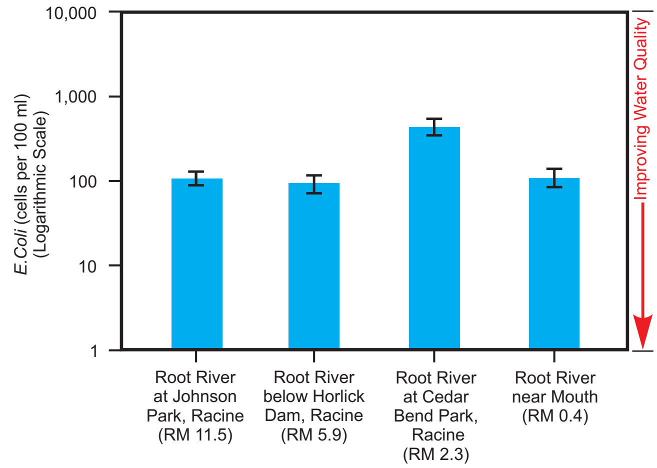


NOTE: See Figure 227 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Health Department, and SEWRPC.

Figure 230

MEAN *E. COLI* CONCENTRATIONS AT STATIONS ALONG THE ROOT RIVER IN RACINE: 1996-2005



NOTE: Error bars (I) indicate one standard error of the mean.

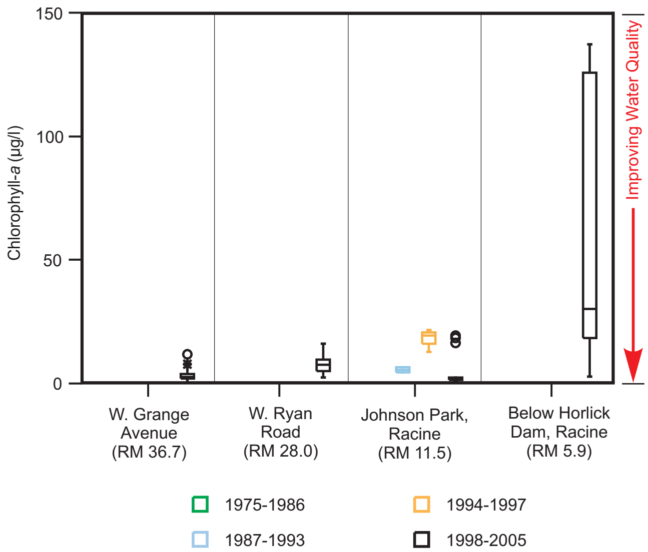
Source: City of Racine Health Department.

Chlorophyll-a

Over the period of record, the mean concentration of chlorophyll-*a* in the Root River was 8.29 micrograms per liter (μg/l). Individual samples of this parameter ranged from 0.14 μg/l to 137 μg/l. Relatively few historical data are available for chlorophyll-*a* concentrations at most long-term sampling stations along the Root River. Figure 231 shows that concentrations of chlorophyll-*a* at the Johnson Park station were higher during the period 1994-1997 than they were during the period 1987-1993. During the period 1998-2005, chlorophyll-*a* concentrations at this station were lower than during either of the previous periods. In addition, concentrations of chlorophyll-*a* at the sampling station below Horlick dam showed considerable variation during the period 1998-2004. Table 159 shows that there is a statistically significant trend toward chlorophyll-*a* increasing from upstream to downstream along the mainstem of the River. Few statistically significant time-based trends were detected in chlorophyll-*a* concentrations (see Table C-5 in Appendix C). On an annual basis, a trend toward decreasing chlorophyll-*a* concentration was detected at the Johnson Park station. This trend probably results from decreasing chlorophyll-*a* concentrations during the spring at this station. Trends toward increasing chlorophyll-*a* concentrations during summer and fall were detected at the station below Horlick dam; however, these trends are based on a small amount of data. At some stations, chlorophyll-*a* concentrations are negatively correlated with concentrations of ammonia and dissolved phosphorus. This reflects the role of these compounds as nutrients for algal growth. As algae grow, they remove these compounds from the water and incorporate them into cellular material. Chlorophyll-*a* concentrations at some stations are also negatively correlated with alkalinity. Since chlorophyll-*a* concentrations in water strongly reflect algal productivity, these correlations probably reflect lowering of alkalinity during photosynthesis through removal of inorganic carbon, mostly carbon dioxide, bicarbonate and carbonate, from the water. The trend toward decreasing chlorophyll-*a* concentration at the Johnson Park station may indicate an improvement in water quality.

Figure 231

CHLOROPHYLL-*a* CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2005

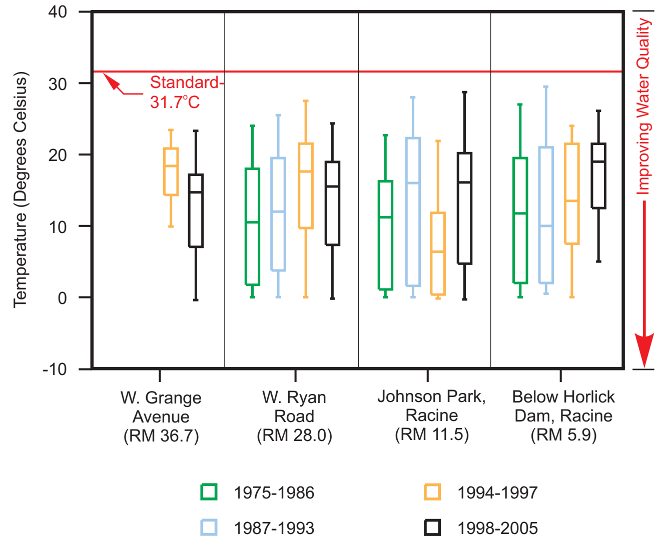


NOTE: See Figure 227 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 232

WATER TEMPERATURE AT SITES ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2005



NOTE: See Figure 227 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Health Department, and SEWRPC.

Chemical and Physical Parameters

Temperature

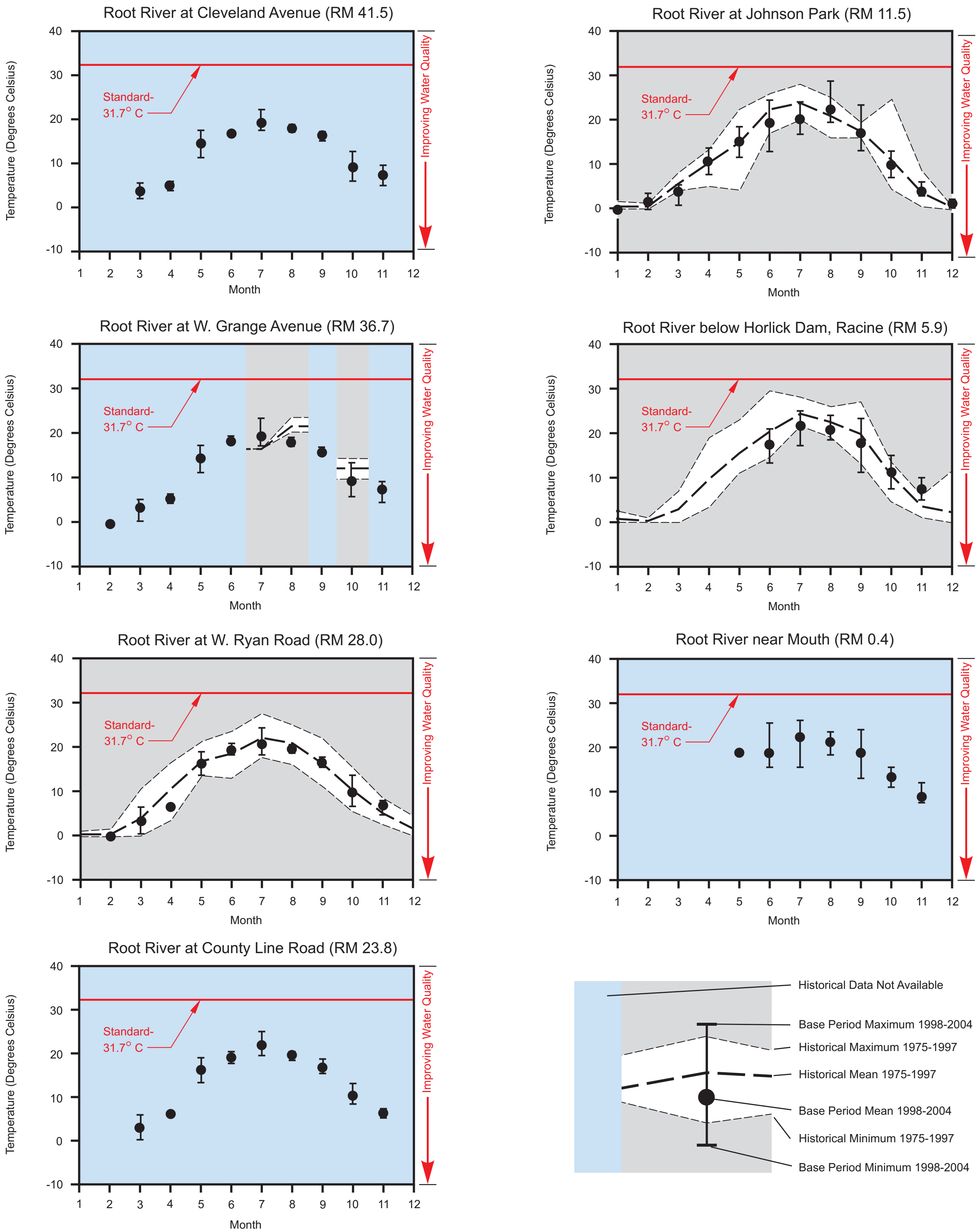
Figure 232 shows water temperature at four sites along the mainstem of the Root River. The annual median water temperature in the Root River during the period 1998-2005 ranged from 14.4 degrees Celsius (ºC) at the sampling station at the intersection of W. National Avenue and W. Oklahoma Avenue up to 19.5ºC at the station near the mouth of the River. As shown in Table 159, temperatures in the Root River show a statistically significant trend toward increasing from upstream to downstream. Figure 233 shows historical and baseline period monthly mean temperatures for seven sampling stations along the mainstem of the River. At most of the stations for which historical data were available, water temperatures from the baseline period generally tended to be within historical ranges and monthly mean baseline period water temperatures generally tended to be the same as or near historical monthly means. The differences observed at the station at W. Grange Avenue most likely reflect the limited amount of historical data available for this station. Few trends over time were detected in temperatures along the River (see Table C-5 in Appendix C). When examined on an annual basis, the data show a slight trend toward increasing water temperature at the stations below the Horlick dam and a slight trend toward decreasing water temperatures at the station near the Mouth of the River.

Alkalinity

The mean value of alkalinity in the Root River over the period of record was 271.0 milligrams per liter (mg/l) expressed as the equivalent concentration of calcium carbonate (mg/l as $CaCO_3$). The data show moderate variability, ranging from 48.7 to 469.0 mg/l as $CaCO_3$. Table 159 shows that there is a statistically significant trend toward alkalinity decreasing from upstream to downstream along the length of the River. Few stations showed any evidence of significant time-based trends when analyzed annually or seasonally, but where there were significant trends, they indicated decreasing concentrations (see Table C-5 in Appendix C). These differences and trends may reflect changes in the relative importance of groundwater and surface runoff on the chemistry of water in the River from upstream to downstream with surface runoff becoming increasingly influential downstream.

Figure 233

HISTORICAL AND BASE PERIOD WATER TEMPERATURE IN THE ROOT RIVER: 1975-2005



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Health Department and SEWRPC.

Alkalinity concentrations in the Root River are strongly positively correlated with hardness, pH, specific conductance, and concentrations of chloride, all parameters which, like alkalinity, measure amounts of dissolved material in water. At some stations, alkalinity is negatively correlated with temperature, reflecting the fact that it indirectly measures concentrations of carbon dioxide in water and that solubility of gases in water decreases with increasing temperature.

Biochemical Oxygen Demand (BOD)
The mean concentration of BOD in the Root River during the period of record was 3.05 mg/l. Individual samples varied from below the limit of detection to 17.0 mg/l. As shown in Figure 234, the concentrations of BOD have declined at those sampling stations that have sufficiently long data records to permit comparison. Figure 235 shows a monthly comparison of baseline and historical concentrations of BOD at three sites along the River: W. Grange Avenue, W. Ryan Road, and below the Horlick dam. At all stations, baseline period minimum monthly mean concentrations are often below the historical monthly minimum concentrations and are often near or below the limit of detection. In most months where both historical and baseline period data are available, baseline period mean concentrations of BOD were below the historical means and occasionally below historical minima. There is a statistically significant trend toward BOD concentrations increasing from upstream to downstream (see Table 159). Three stations show significant declining trends in BOD concentration over time (see Table C-5 in Appendix C).

Several factors may influence BOD concentrations in the Root River. BOD concentrations in the River are positively correlated at most stations with concentrations of fecal coliform bacteria and some nutrients such as organic nitrogen, dissolved phosphorus, and total phosphorus. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the River. In addition, aerobic metabolism of many organic nitrogen compounds requires oxygen and thus these compounds contribute to BOD. In some parts of the River, decomposition of organic material in the sediment acts as a source of BOD to the overlying water.

The declining trend in BOD concentrations over time detected at three stations along the mainstem of the River represents an improvement in water quality.

Chloride
The mean chloride concentration in the Root River for the period of record was 148.4 mg/l. All sites show wide variations between minimum and maximum values. Figure 236 shows that mean concentrations of chloride in the River increased over time at those stations for which historical data are available. Table C-5 in Appendix C of this report shows statistically significant trends toward mean chloride concentrations increasing over time at the three most downstream sampling stations, Johnson Park, below the Horlick dam, and near the mouth. Chloride concentrations show a strong seasonal pattern. For the period during which winter data are available, mean chloride concentrations were highest in winter or early spring. This is likely to be related to the use of deicing salts on streets and highways. These concentrations declined through the spring to reach lows during summer and fall.

From 1975 through 2004, only one observed instream chloride concentration in the Root River approached the planning standard of 1,000 milligrams per liter (mg/l) that was adopted under the original regional water quality management plan. Observed instream concentrations at the sampling locations upstream of the Horlick dam frequently exceeded the 250 mg/l secondary drinking water standard.[2] Also, observed concentrations at those sampling locations occasionally exceeded the chronic toxicity criterion of 395 mg/l and rarely exceeded the acute toxicity criterion of 757 mg/l as set forth in Chapter NR 105, "Surface Water Quality Criteria and Secondary

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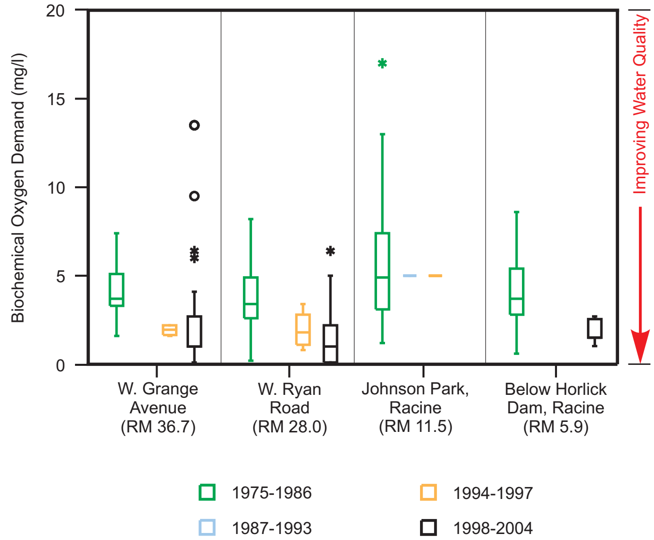
[2]*Section 809.60 of Chapter NR 809, "Safe Drinking Water," of the* Wisconsin Administrative Code, *establishes a secondary standard for chloride of 250 mg/l and notes that, while that concentration is not considered hazardous to health, it may be objectionable to an appreciable number of persons.*

Figure 234

BIOCHEMICAL OXYGEN DEMAND (BOD) AT SITES ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2004



NOTE: See Figure 227 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Values for Toxic Substances," of the *Wisconsin Administrative Code*. Observed chloride concentrations downstream of the Horlick dam never approached the secondary drinking water standard or the chronic and acute toxicity criteria.

Chloride concentrations in the Root River show strong positive correlations with alkalinity, hardness, pH, and specific conductance, all parameters which, like chloride, measure amounts of dissolved material in water. In addition, chloride concentrations at several stations along the Root River are strongly negatively correlated with temperature, reflecting the use of deicing salts on streets and highways during cold weather. The increase in chloride concentrations detected at some stations along the Root River represents a decline in water quality.

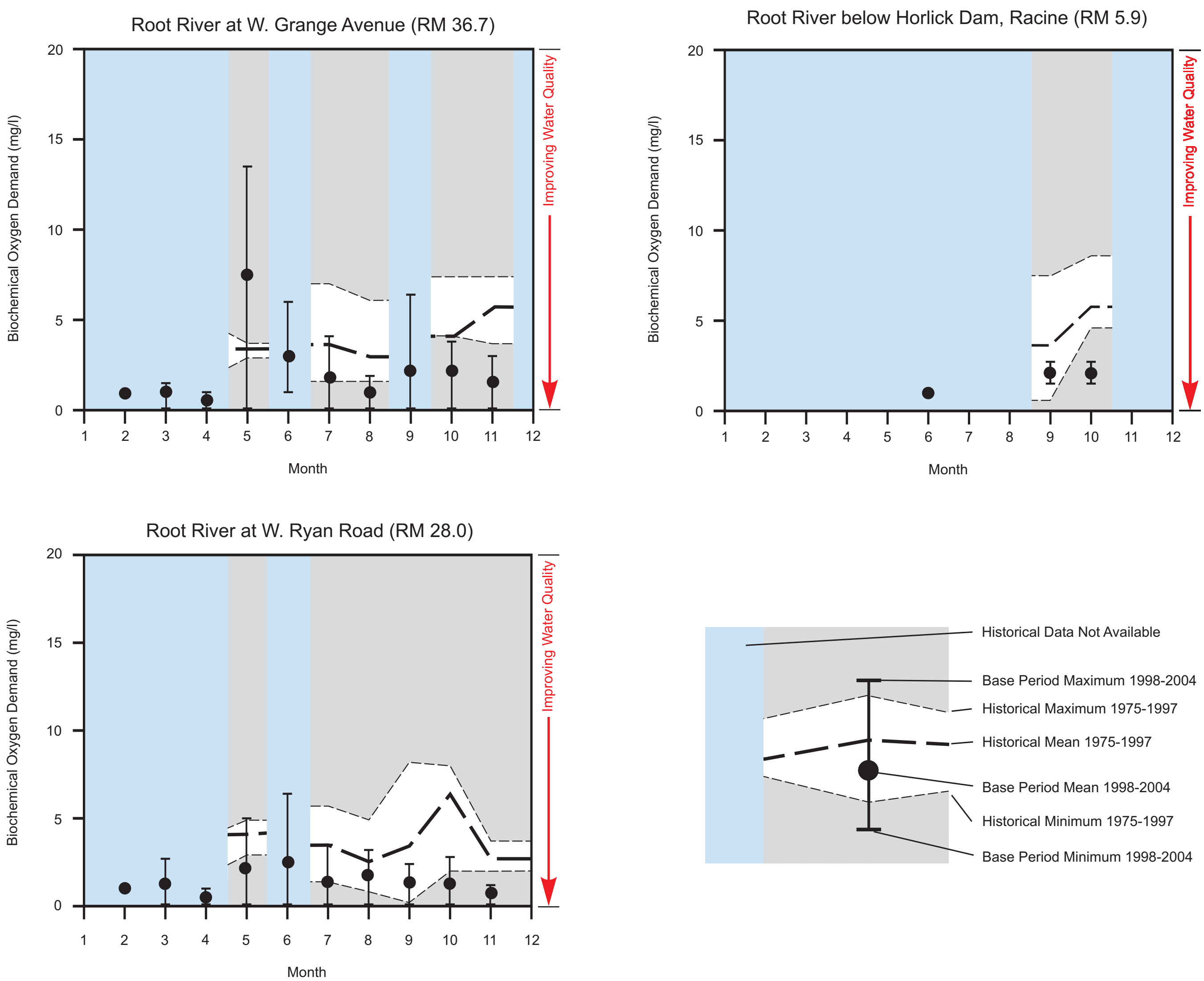
Dissolved Oxygen

Over the period of record, the mean concentration of dissolved oxygen in the Root River was 6.9 mg/l. The data ranged from concentrations that were undetectable to concentrations in excess of saturation. Figure 237 shows the distributions of dissolved oxygen concentrations at four sampling stations along the River. Considerable variability in dissolved oxygen concentration is present at individual sample sites. In the upstream reaches of the River, at the stations at W. Grange Avenue and W. Ryan Road, dissolved oxygen concentrations in the samples collected during the period 1998-2004 were higher than dissolved oxygen concentrations in the samples collected during the period 1994-1997; however, data were collected at these stations only during the summer and mid fall months during 1994-1997 (see Figure 237). Since dissolved oxygen concentrations tend to be lower during these months due to the higher water temperatures and the associated reductions in the solubility of oxygen in water, the data shown for 1994-1997 probably underestimate ambient oxygen concentrations at these stations. Similarly, the decline in oxygen concentrations shown for the station below the Horlick dam (see Figure 237) may be an artifact of the small number of samples taken at this station prior to 1998. Median concentrations of dissolved oxygen at the Johnson Park station have increased over the period of record (see Figure 237). Figure 238 shows that these increases are attributable to higher concentrations of dissolved oxygen in the early spring and late summer. Figure 238 also shows that during summer and fall months during the baseline period, dissolved oxygen concentrations at the station at the intersection of W. National and W. Oklahoma Avenues were often below the 5 mg/l standard for fish and aquatic life. To some extent, low dissolved oxygen concentrations during summer and fall occurred at several stations in the upstream portions of the Root River, including the stations at Cleveland Avenue, W. Cold Spring Road, and W. Grange Avenue. In general, low dissolved oxygen concentrations were less common at downstream stations in this section of the River. Despite this, no statistically significant trends were detected in dissolved oxygen concentrations from upstream to downstream along the mainstem of the Root River (see Table 159). Few time-based trends were detected in dissolved oxygen concentrations (see Table C-5 in Appendix C).

The data show strong seasonal patterns to the mean concentrations of dissolved oxygen (see Figure 238). The mean concentration of dissolved oxygen is highest during the winter. It declines through spring to reach a minimum during the summer. It then rises though the fall to reach maximum values in winter. This seasonal pattern is driven by changes in water temperature. (As noted above, the solubility of oxygen in water decreases

Figure 235

HISTORICAL AND BASE PERIOD BIOCHEMICAL OXYGEN DEMAND IN THE ROOT RIVER: 1975-2004



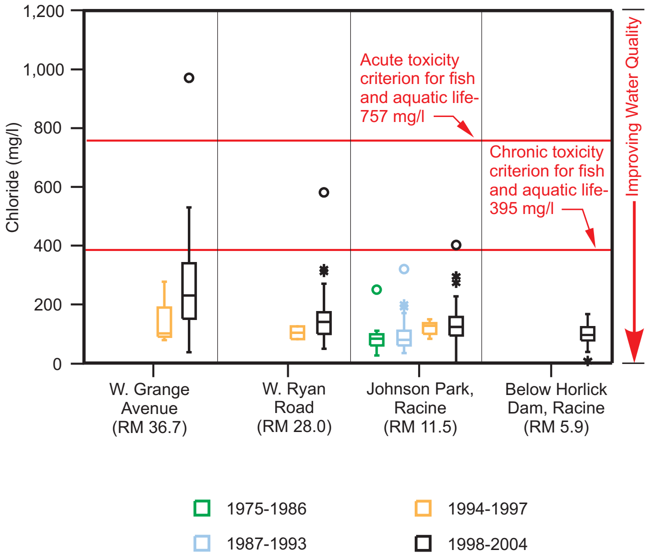
Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

with increasing temperature.) In addition, the metabolic demands and oxygen requirements of most aquatic organisms, including bacteria, tend to increase with increasing temperature. Higher rates of bacterial decomposition when the water is warm may contribute to the declines in the concentration of dissolved oxygen observed during the summer.

Several other factors can affect dissolved oxygen concentrations in the Root River. First, settling of suspended material in portions of the River can transfer material from the water column to the sediment. Decomposition of organic matter contained in this material, through chemical and especially biological processes, removes oxygen from the overlying water, lowering the dissolved oxygen concentration. Second, dissolved oxygen concentrations in the Root River are positively correlated with pH. This reflects the effect of photosynthesis on both of these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the water's pH. At the same time, oxygen is released as a byproduct of the photosynthetic reactions. Third, dissolved

Figure 236

CHLORIDE CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2004

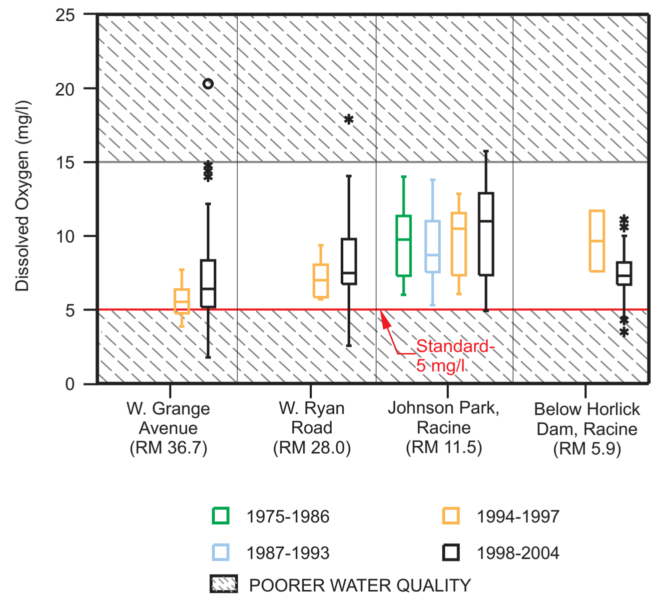


NOTE: See Figure 227 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 237

DISSOLVED OXYGEN CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2004



NOTES: See Figure 227 for description of symbols.

140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

oxygen concentrations in water can be affected by numerous other factors including the presence of aquatic plants, sunlight, and the amount of and type of sediment as summarized in the Water Quality Indicators section in Chapter II of this report.

Based on analysis of the limited historical data that are available to assess this, concentrations of dissolved oxygen appear to be unchanged in the Root River, during the time period examined from 1975-2005.

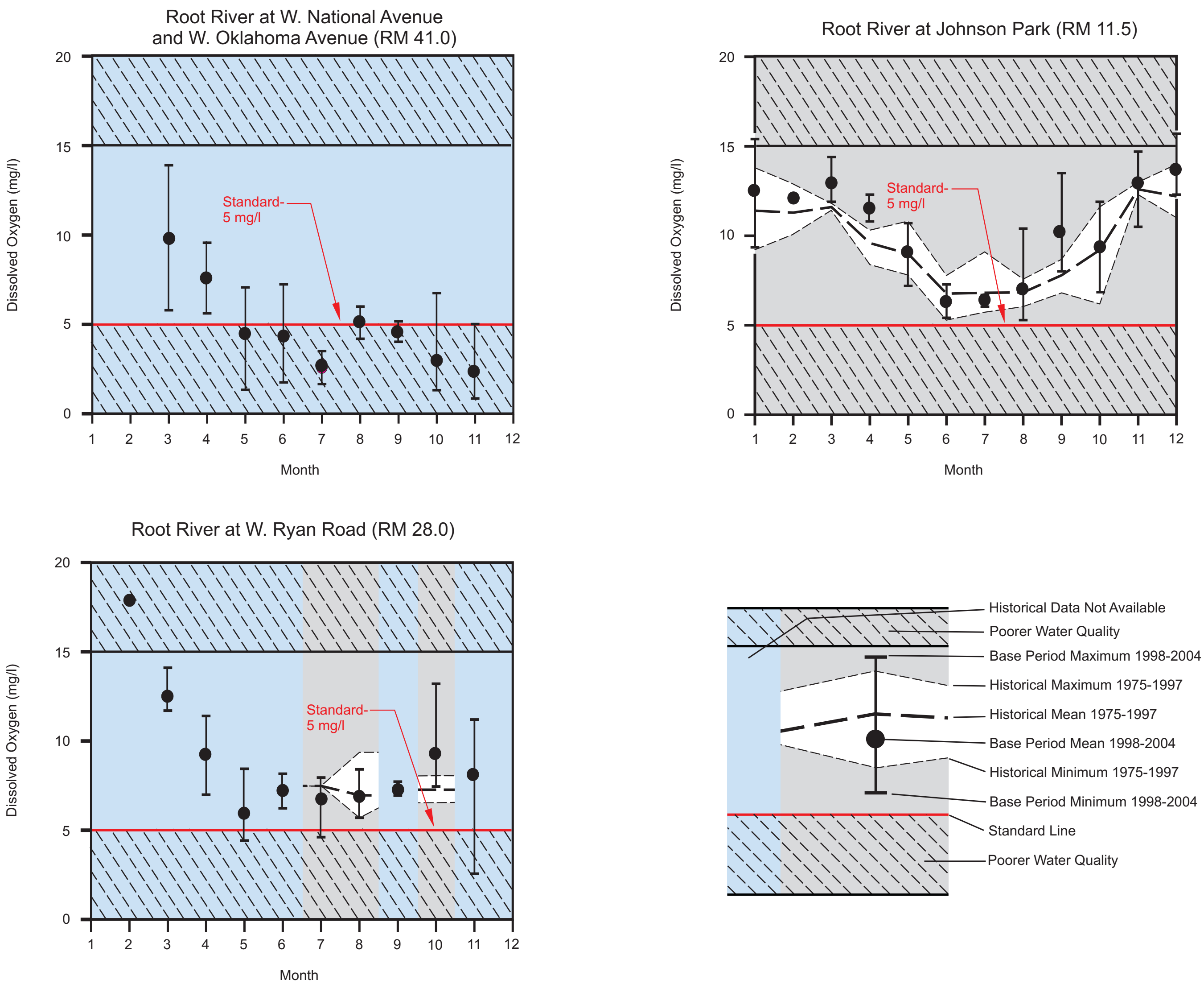
Hardness

Over the period of record, the mean hardness in the Root River was 373.6 mg/l as $CaCO_3$. On a commonly used scale, this is considered to be very hard water.[3] The range of the data runs from 93.4 to 715.0 mg/l as $CaCO_3$, showing considerable variability. Some of this variability probably results from inputs of relatively soft water during storm events. Table 159 shows that there is a statistically significant trend toward hardness decreasing from upstream to downstream in the River. While no time-based trends were detected when the data were analyzed on an annual basis, several stations show significant trends toward decreasing hardness concentrations during the spring (see Table C-5 in Appendix C). Hardness concentrations in the Root River show strong positive correlations with alkalinity, chloride, and specific conductance, all parameters which, like hardness, measure amounts of dissolved material in water.

[3]*E. Brown, M.W. Skougstad, and M.J. Fishman,* Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, *U.S. Department of Interior, U.S. Geological Survey, 1970.*

Figure 238

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF DISSOLVED OXYGEN ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2004



NOTE: 140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

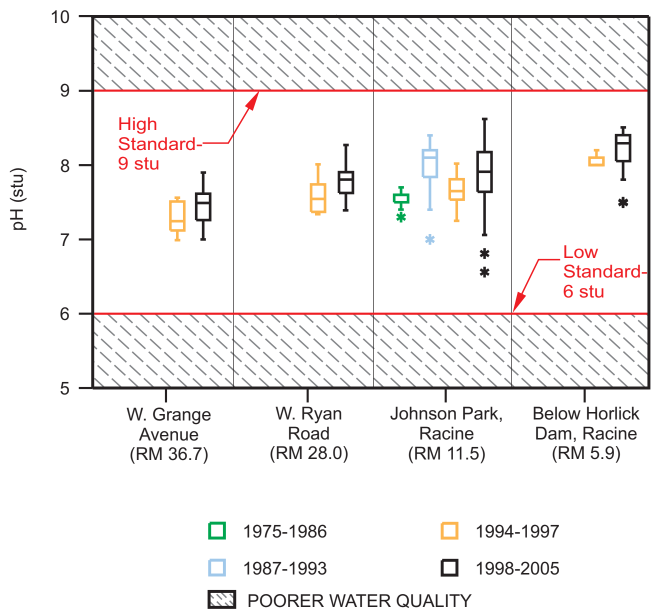
Hardness is a measure of the concentration of polyvalent metal ions, primarily calcium and magnesium, in water. Over the period of record the concentration of calcium in the Root River ranged between 39.0 mg/l and 156.0 mg/l with a mean concentration of 78.7 mg/l. The concentration of magnesium ranged between 16.0 mg/l and 78.9 mg/l with a mean concentration of 38.7 mg/l. No significant time-based trends were detected in concentrations of calcium or magnesium in the Root River.

pH

The mean pH in the Root River over the period of record was 7.8 standard units. The mean values at individual sampling stations along the mainstem of the River ranged from 7.4 to 8.0 standard units. At most stations, pH varied only by ±1.0 standard unit from the stations' mean values. Variability in pH was very similar among stations, with coefficients of variation ranging from 0.02 to 0.05. As shown in Figure 239, two trends were

Figure 239

pH AT SITES ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2005



NOTE: See Figure 227 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, City of Racine Health Department, and SEWRPC.

detected in pH in the Root River. First, pH in the River tends to increase from upstream to downstream. Table 159 shows that this trend is statistically significant. Second, pH at several stations along the River during the baseline period was higher than pH during the period 1994-1998. Table C-5 in Appendix C of this report shows that at two stations, a significant trend was detected toward pH increasing over time. The cause of this increase is unknown. Positive correlations are seen between pH and alkalinity, hardness, and specific conductance at some stations but they are neither as common nor as strong as the correlations detected among alkalinity, hardness, and specific conductance. At several stations, dissolved oxygen concentrations are positively correlated with pH. This reflects the effect of photosynthesis on both of these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the water's pH. At the same time, oxygen is released as a byproduct of the photosynthetic reactions. In summary, pH concentrations appear to have increased at some of the stations during the time period examined from 1975 to 2004.

Specific Conductance

The mean value for specific conductance in the Root River over the period of record was 979.0 microSiemens per centimeter (μS/cm). Considerable variability was associated with this mean. Specific conductance ranged from 1.0 to 4,100.0 μS/cm. Some of this variability may reflect the discontinuous nature of inputs of dissolved material into the River. Runoff associated with storm events can have a major influence on the concentration of dissolved material in the River. The first runoff from a storm event transports a large pulse of salts and other dissolved material from the watershed into the River. This will tend to raise specific conductance in the River. Later runoff associated with the event will be relatively dilute. This will tend to lower specific conductance. Table 159 shows that there was a statistically significant trend toward specific conductance decreasing from upstream to downstream in the River. Trend analysis shows several results (see Table C-5 in Appendix C). When examined on an annual basis, statistically significant trends toward specific conductance decreasing were detected at two stations: County Line Road and at the station below the Horlick dam. In addition, a statistically significant increasing trend was detected at the Johnson Park station. The data show a seasonal pattern of variation in specific conductance. For those years in which data were available, specific conductance was highest during the winter. It then declined during the spring to reach lower levels in the summer and fall. Specific conductance in the Root River show strong positive correlations with alkalinity, chloride, and hardness, all parameters which, like hardness, measure amounts of dissolved material in water. In summary, specific conductance was shown to have increased at the Johnson Park station, decreased at the Horlick dam and County Line Road stations, and remained unchanged in the rest of the Root River during the time period examined from 1975 to 2004. The increase in specific conductance at one station indicates that the concentrations of dissolved materials in water at this station is increasing and represents a decline in water quality. The decrease in specific conductance at two stations indicates that the concentrations of dissolved materials in water at these stations is decreasing and represents an improvement in water quality.

Suspended Material

The mean value for total suspended solids (TSS) concentration in the Root River over the period of record was 22.1 mg/l. Considerable variability was associated with this mean, with values ranging from below the limit of detection to 390 mg/l. During most months, mean monthly concentrations of TSS during the baseline period at the Johnson Park sampling station were near or below historical means (see Figure 240). There was a statistically significant trend toward TSS concentrations decreasing from upstream to downstream along the River (see Table 159). Few time-based trends were detected in TSS concentrations at sampling stations along the River (see Table C-5 in Appendix C). TSS concentrations in the Root River showed strong positive correlations with total phosphorus concentrations, reflecting the fact that total phosphorus concentrations include a large particulate fraction. TSS concentrations were also positively correlated with concentrations of fecal coliform bacteria. TSS concentrations were negatively correlated with some measures of dissolved materials, such as alkalinity and specific conductance.

In addition to TSS, total suspended sediment concentration was sampled at four sites along the mainstem of the Root River. The mean value for total suspended sediment concentration over the period of record was 55.6+ mg/l. Considerable variability was associated with this mean, with values ranging from 7.0 to 289.0 mg/l. Table 159 shows that no statistically significant trends were detected in total suspended sediment concentrations along the length of the River. Analysis of time-based trends show statistically significant decreases in total suspended sediment concentrations over time at two stations (see Table C-5 in Appendix C). These results should be interpreted with caution as they result from comparison of concentrations from one to two years in the mid-1970s to concentrations from 2004 and may be more reflective of changes in methodology than changes in concentration in the River. It is important to note that total suspended sediment concentrations are not comparable to TSS concentrations.[4]

Nutrients

Nitrogen Compounds

The mean concentration of total nitrogen in the Root River over the period of record was 2.38 milligrams per liter measured as nitrogen (mg/l as N). Concentrations varied over three orders of magnitude, ranging from 0.32 to 13.36 mg/l as N. As shown in Figure 241, median total nitrogen concentrations did not change much at upstream stations between the periods 1994-1997 and 1998-2004. At the station at Johnson Park, median total nitrogen concentrations for the period 1998-2004 were lower than those in the previous period. There is a statistically significant trend toward total nitrogen concentrations increasing from upstream to downstream along the River (see Table 159). Table C-5 in Appendix C of this report shows that few significant trends in total nitrogen concentration were detected in the Root River. When examined on an annual basis, there was a statistically significant trend toward total nitrogen concentrations increasing at the station at County Line Road. When examined on a seasonal basis, statistically significant trends toward decreasing concentrations of total nitrogen were detected during the fall at the stations at Johnson Park and below Horlick dam. The concentration of total nitrogen in the Root River is moderately to strongly positively correlated with the concentration of total phosphorus at some stations. This probably reflects the nitrogen and phosphorus contained in particulate organic matter in the water, including live material such as plankton and detritus.

Total nitrogen is a composite measure of several different compounds which vary in their availability to algae and aquatic plants and vary in their toxicity to aquatic organisms. Common constituents of total nitrogen include ammonia, nitrate, and nitrite. In addition a large number of nitrogen-containing organic compounds, such as amino acids, nucleic acids, and proteins commonly occur in natural waters. These compounds are usually reported as organic nitrogen.

The mean concentration of ammonia in the Root River was 0.15 mg/l as N. Over the period of record, ammonia concentrations varied between 0.002 and 1.30 mg/l as N. Figure 242 shows that ammonia concentrations experienced an increase following the period 1994-1997. It is important to note that, except at the Johnson Park

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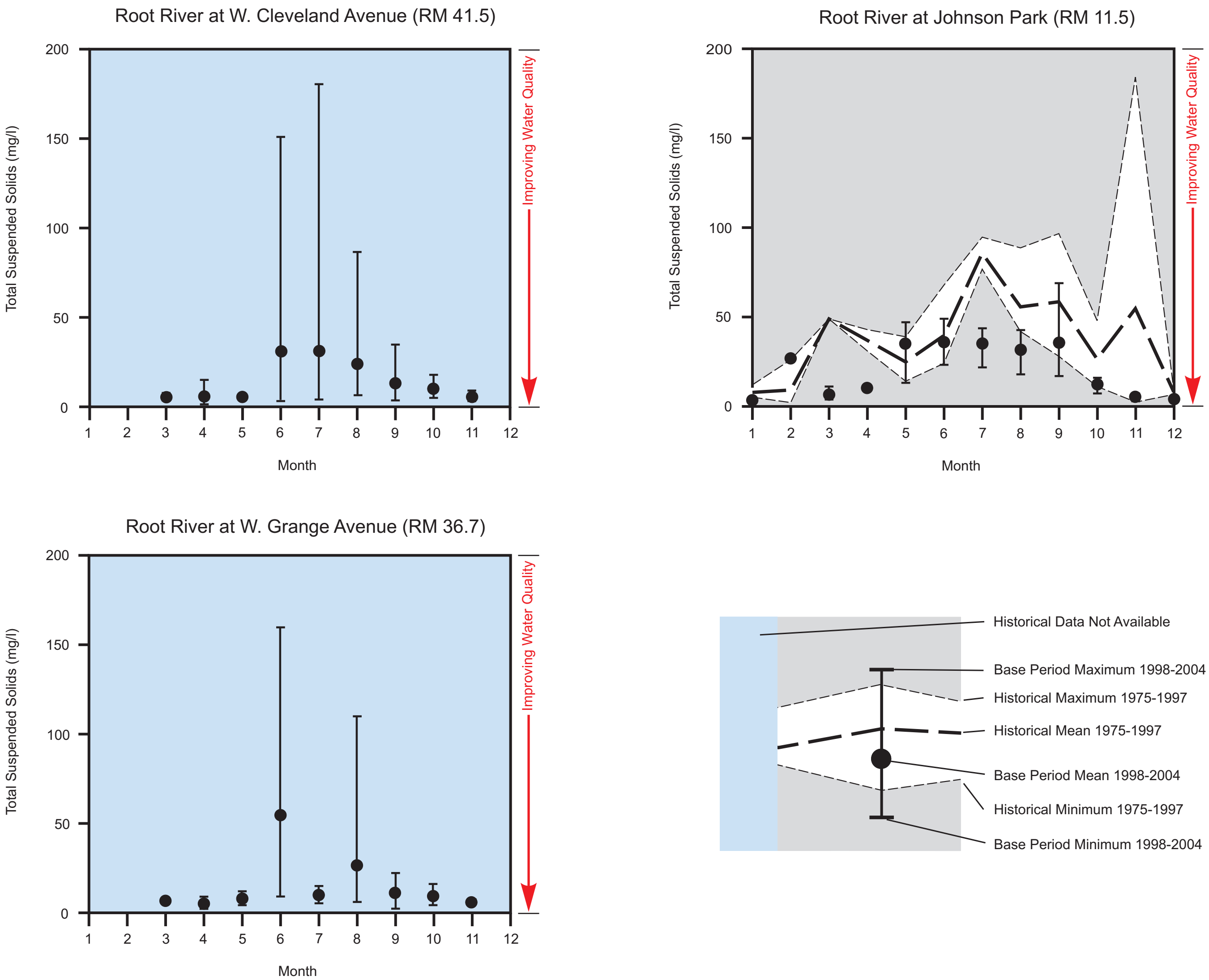
[4]*J.R. Gray, G.D. Glysson, L.M. Turcios, and G.E. Schwartz,* Comparability of Suspended-Sediment Concentration and Total Suspended Solids Data, *U. S. Geological Survey Water-Resources Investigations Report No. 00-4191, 2000.*

Figure 240

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF TOTAL SUSPENDED SOLIDS IN THE ROOT RIVER: 1975-2004



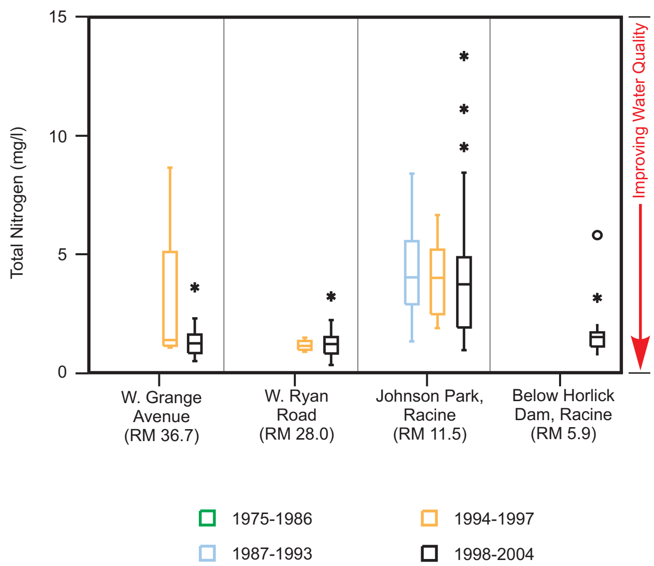
Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

station, data from 1994-1997 were available from only a few months of the year and may not represent the entire range of ammonia concentrations occurring in the River. At the Johnson Park station, baseline period monthly mean concentrations of ammonia are near or below historical monthly means during most months. When examined on an annual basis, there are statistically significant trends toward ammonia concentrations decreasing over time at four stations (see Table C-5 in Appendix C). There were no clear patterns of seasonal variation in ammonia concentrations in the Root River. No longitudinal trends were detected in ammonia concentrations along the lengths of the mainstem of the Root River.

The mean concentration of nitrate in the Root River for the period of record was 2.37 mg/l as N. During this time, concentrations in the River varied between 0.005 and 30.27 mg/l as N. There is a statistically significant trend for nitrate concentrations to increase from upstream to downstream along the mainstem of the River. Trend analysis detected few statistically significant trends in nitrate concentrations (see Table C-5 in Appendix C). The data show some evidence of seasonal variations in nitrate concentration. Nitrate concentration was highest in the late

Figure 241

TOTAL NITROGEN CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2004

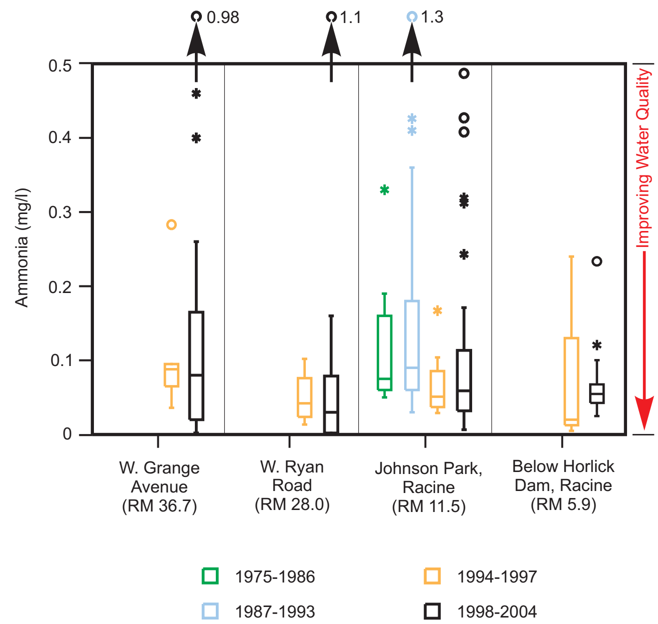


NOTE: See Figure 227 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 242

AMMONIA CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2004



NOTE: See Figure 227 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

spring and early summer. It declined through fall to reach lower levels in the winter. In the spring, the concentration began to climb again. At the Johnson Park station, baseline period monthly mean nitrate concentrations were higher than historical monthly means during the spring and summer. They were lower than the historical monthly mean during the fall.

The mean concentration of nitrite in the Root River was 0.135 mg/l as N over the period of record. Nitrite concentrations showed more variability than nitrate. This probably reflects the fact that nitrite in oxygenated water tends to oxidize to nitrate fairly quickly. Nitrite concentrations tended to increase from upstream to downstream along the length of the River (see Table 159). There were few trends in nitrite concentration over time see (see Table C-5 in Appendix C). Mean monthly nitrite concentrations in the Root River tend to be highest during the late spring and early summer.

During the period of record the mean concentration of organic nitrogen in the Root River was 0.81 mg/l as N. This parameter showed considerable variability with concentrations ranging from undetectable to 2.94 mg/l as N. Few time-based trends were detected in organic nitrogen concentrations. When examined on an annual basis, two upstream stations showed statistically significant trends toward increasing concentrations of organic nitrogen over time. One downstream station showed a significant trend toward decreasing organic nitrogen concentration over time (see Table C-5 in Appendix C). There is a statistically significant trend toward organic nitrogen concentration increasing from upstream to downstream along the length of the River (see Table 159). Organic nitrogen concentrations in the Root River tend to be high during the summer. Organic nitrogen concentrations in the Root River show a positive correlation with temperature. In addition, they show positive correlations with concentrations of BOD, fecal coliform bacteria, and total phosphorus. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the River. In addition, aerobic metabolism of many organic nitrogen compounds requires oxygen and thus these compounds contribute to BOD. The correlation with total phosphorus concentrations reflects the roles of phosphorus and nitrogen as nutrients for algal growth. During periods of high algal productivity, algae remove dissolved phosphorus and nitrogen compounds from the water and incorporate them into cellular material.

Several processes can influence the concentrations of nitrogen compounds in a waterbody. Primary production by plants and algae will result in ammonia and nitrate being removed from the water and incorporated into cellular material. This effectively converts the nitrogen to forms which are detected only as total nitrogen. Decomposition of organic material in sediment can release nitrogen compounds to the overlying water. Bacterial action may convert some nitrogen compounds into others.

Several things emerge from this analysis of nitrogen chemistry in the Root River:

- At several stations along the mainstem of the River ammonia concentrations have been declining over time. This represents an improvement in water quality.
- Concentrations of other forms of nitrogen in the River do not appear to be changing with time.
- Concentrations of all forms of nitrogen, except for ammonia, tend to increase from upstream to downstream along the length of the River.

Total and Dissolved Phosphorus

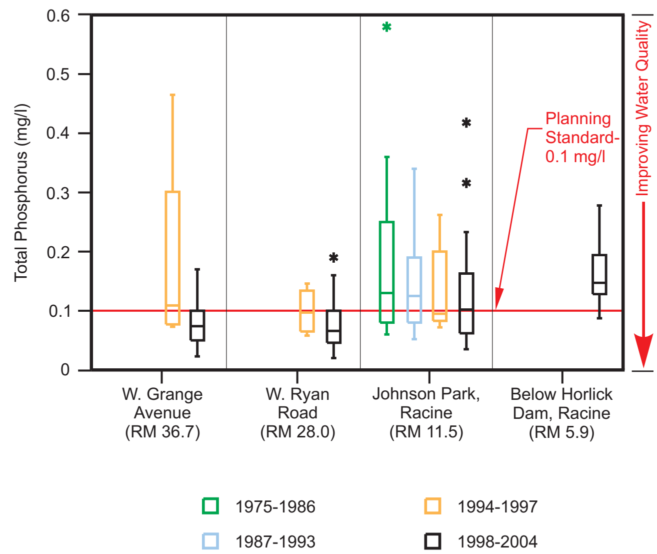
Two forms of phosphorus are commonly sampled in surface waters: dissolved phosphorus and total phosphorus. Dissolved phosphorus represents the form that can be taken up and used for growth by algae and aquatic plants. Total phosphorus represents all the phosphorus contained in material dissolved or suspended within the water, including phosphorus contained in detritus and organisms and attached to soil and sediment.

The mean concentration of total phosphorus in the Root River during the period of record was 0.127 mg/l, and the mean concentration of dissolved phosphorus in the Root River over the period of record was 0.051 mg/l. Total phosphorus concentrations varied over two orders of magnitude, ranging from 0.01 to 0.73 mg/l. Dissolved phosphorus concentrations were more variable, ranging over three orders of magnitude from 0.003 to 0.324 mg/l. At most sampling sites, the data showed moderate variability. Figure 243 shows that total phosphorus concentrations tend to increase from upstream to downstream. Statistically significant trends toward both total and dissolved phosphorus increasing from upstream to downstream were detected (see Table 159). Total phosphorus concentrations at some stations along the mainstem of the River were lower during the period 1998-2004 than during the period 1994-1997 (see Figure 243). This may not accurately represent trends in the watershed because, at some stations, data prior to 1998 were collected only during summer months when total phosphorus concentrations tend to be higher than during the fall or early spring (e.g. W. Ryan Road in Figure 244). At some stations, dissolved phosphorus concentrations were negatively correlated with concentrations of chlorophyll-*a* and total phosphorus concentration were positively correlated with concentrations of chlorophyll-*a*. This reflects the role of dissolved phosphorus as a nutrient for algal growth. During periods of high algal productivity, algae remove dissolved phosphorus from the water and incorporate it into cellular material. At some stations, total phosphorus concentrations were positively correlated with temperature and concentrations of organic nitrogen and total nitrogen. These correlations reflect the roles of phosphorus and nitrogen as nutrients for algal growth. During periods of high algal productivity, algae remove dissolved phosphorus and nitrogen compounds from the water and incorporate them into cellular material. Because the rates of biological reactions are temperature dependent, these periods tend to occur when water temperatures are warmer. At most stations, concentrations of total phosphorus were also positively correlated with concentrations of BOD and fecal coliform bacteria. This correlation may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the River.

Figure 244 shows a monthly comparison of the historical and baseline concentrations of total phosphorus at three sampling stations along the length of the mainstem of the Root River. All stations show a strong seasonal pattern in total phosphorus concentrations. Total phosphorus concentrations are highest in the summer. At upstream stations, such as W. Cold Spring Road or W. Ryan Road, this peak concentration tends to occur in June. It tends to occur later in the summer downstream. At the Johnson Park station, mean monthly total phosphorus concentrations during the baseline period were lower than historical means in most months. Few statistically significant time-based trends were detected in dissolved and total phosphorus concentrations in the Root River. On an annual basis, a trend toward decreasing total phosphorus concentrations over time was detected at the station below the Horlick dam (see Table C-5 in Appendix C). Similarly, a trend toward decreasing concentrations of dissolved phosphorus was detected at the Johnson Park station. These trends represent an improvement in water quality. When examined on a seasonal basis, statistically significant trends toward increases in dissolved phosphorus during the summer were detected at four upstream stations. These trends represent a decline in water quality.

Figure 243

TOTAL PHOSPHORUS CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2004



NOTE: See Figure 227 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 245 shows the annual mean total phosphorus concentrations of phosphorus in the Root River for the years 1986 to 2003. For the most part, mean annual total phosphorus concentrations from the years 1996-2003 were within the range of variation from previous years. In the Kinnickinnic River and Menomonee River watersheds, annual average total phosphorus concentrations increased sharply after 1996. One possible factor in this increase was phosphorus loads from facilities discharging noncontact cooling water drawn from municipal water utilities. The water utilities for the City of Milwaukee and the City of New Berlin treats their municipal water with orthophosphate or polyphosphate to inhibit release of copper and lead from pipes in the water system and private residences. This does not appear to represent a major source of phosphorus to the streams in the Root River watershed, since those are the only utilities in the watershed that apply such treatment, and they cover a relatively small portion of the watershed area.

Metals

Arsenic

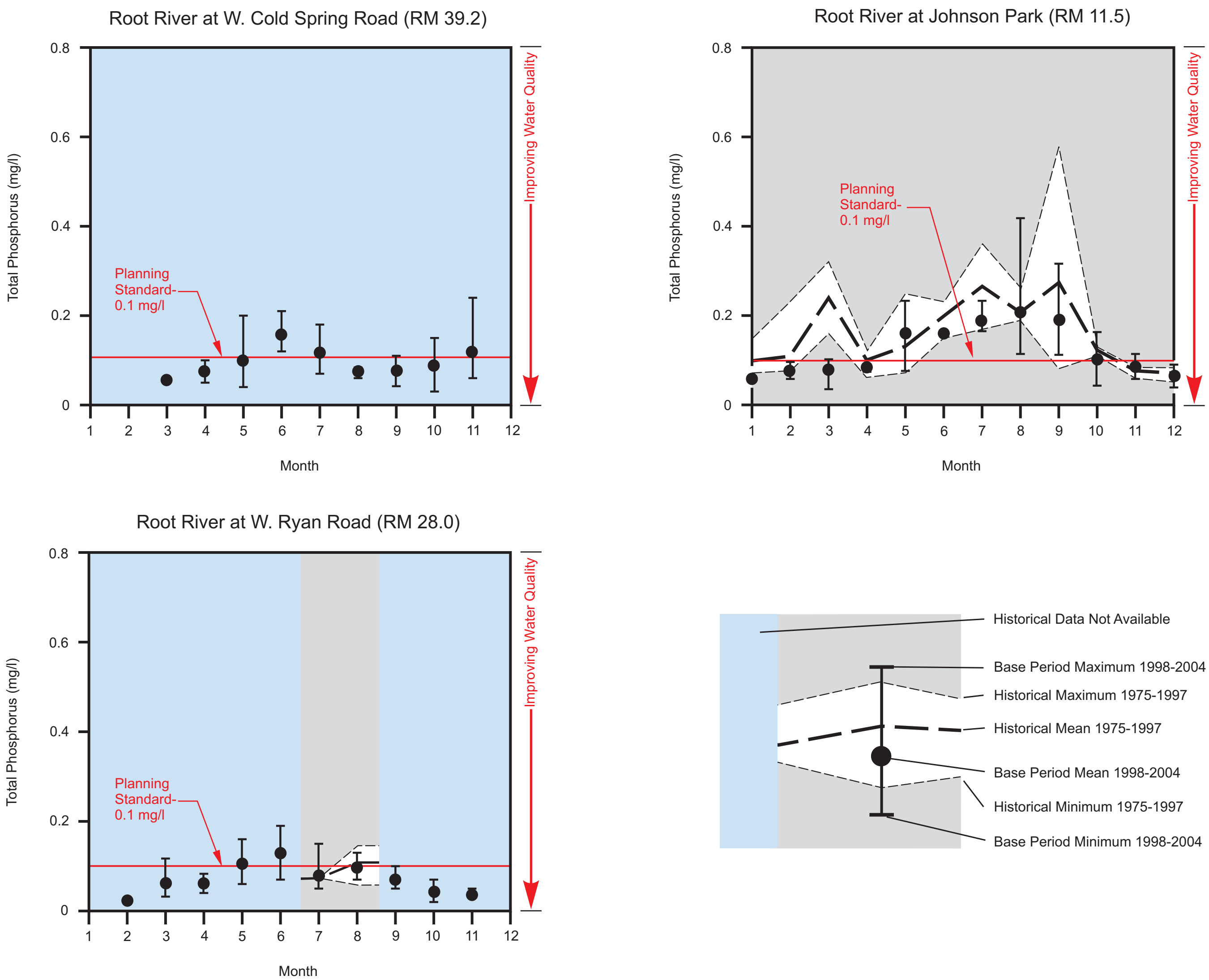
The mean value for the concentration of arsenic in the water of the Root River over the period of record was 1.57 μg/l. The data ranged from below the limit of detection to 5.5 μg/l. There were not sufficient arsenic data for the Root River to analyze for trends.

Cadmium

The mean concentration of cadmium in the Root River over the period of record was 0.083 μg/l. A moderate amount of variability was associated with this mean. Individual samples ranged from 0.015 to 0.690 μg/l. There were few differences among the stations in the amount of variability. Table C-5 in Appendix C of this report shows the presence of strong decreasing trends in cadmium concentration at nearly all stations for which data were available when the data were analyzed on an annual basis. These declines in cadmium concentration may reflect changes in the number and types of industry present in the watershed, reductions due to treatment of industrial discharges, and reductions in airborne deposition of cadmium to the Great Lakes region. Cadmium

Figure 244

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF TOTAL PHOSPHORUS ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2004



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

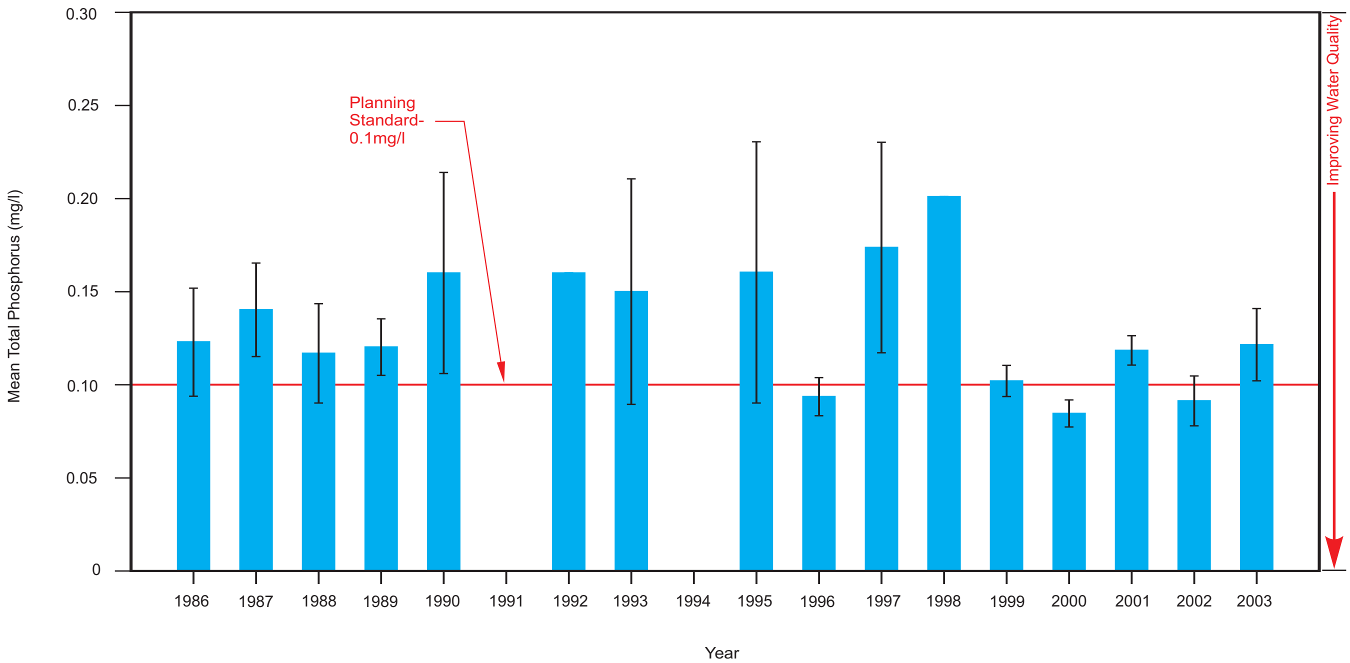
concentrations in the River showed no evidence of seasonal variation or variation along the length of the River. At several stations, cadmium concentrations are moderately negatively correlated with pH. This reflects the fact that cadmium tends to be more soluble in water under acidic conditions. The reduction in cadmium concentrations in the Root River represents an improvement in water quality.

Chromium

The mean concentration of chromium in the Root River over the period of record was 10.1 μg/l. Chromium concentration showed moderate variability, with individual sample concentrations ranging from below the limit of detection to 84.0 μg/l. There is a statistically significant trend toward chromium concentrations in the River decreasing from upstream to downstream (see Table 159). As shown in Table C-5 in Appendix C of this report, analysis of time-based trends suggests that chromium concentrations are declining within much of the River. The decline in chromium concentration in the Root River may reflect the loss of industry in some parts of the watershed and the decreasing importance of the metal plating industry in particular, as well as the establishment

Figure 245

MEAN ANNUAL CONCENTRATIONS OF TOTAL PHOSPHORUS IN THE ROOT RIVER: 1986-2003



NOTE: Error bars (I) indicate one standard error of the mean.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

of treatment of discharges instituted for the remaining and new industries since the late 1970s. There is no evidence of seasonal variation in chromium concentrations in the Root River. The decline in chromium concentrations represents an improvement in water quality.

Copper

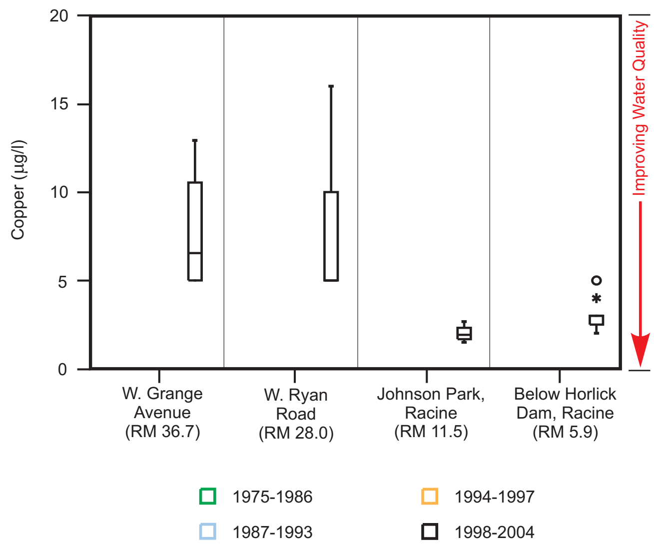
The mean concentration of copper in the Root River during the period of record was 7.4 μg/l. As shown in Figure 246, moderate variability was associated with this mean. There was a tendency for copper concentrations in the River to decrease from upstream to downstream. Table 159 shows that this trend was statistically significant. Statistically significant trends toward decreasing copper concentration over time were detected at all of the sampling stations in Milwaukee County and at the station below Horlick dam (see Table C-5 in Appendix C). No time-based trends were detected at the other two stations in Racine County. The trend toward decreasing copper concentration in the Root River represents an improvement in water quality.

Lead

The mean concentration of lead in the Root River over the period of record was 4.34 μg/l with sample concentrations ranging between 0.14 μg/l and 43.00 μg/l. Lead concentrations in the water of the River tend to be higher in upstream reaches than in downstream reaches, as shown in Figure 247. Table 159 shows that there is a statistically significant trend toward lead concentrations decreasing from upstream to downstream. With one exception, no time-based trends were detected in lead concentrations in the Root River (see Table C-5 in Appendix C). Lead concentrations at the station at W. Cleveland Avenue show a trend toward decreasing over time. The lack of detection of trends at other stations reflects the fact that the samples from most stations were examined for lead concentrations only during the period 1999-2003. The decrease in lead concentration at the W. Cleveland Avenue stations represents an improvement in water quality.

Figure 246

COPPER CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2004

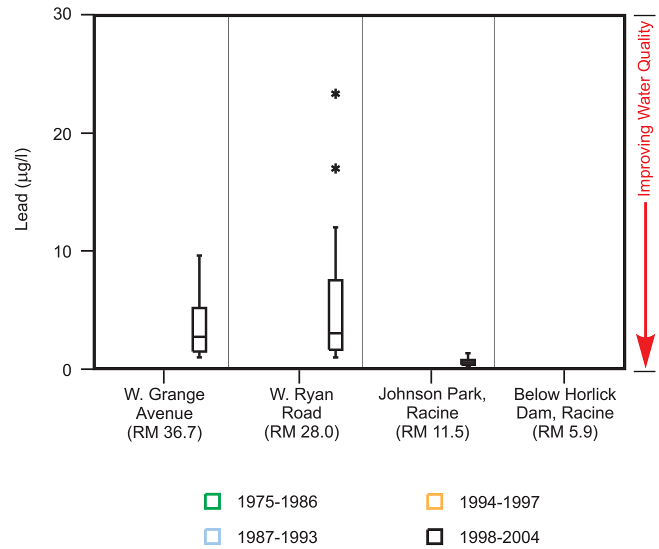


NOTE: See Figure 227 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 247

LEAD CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2004



NOTES: See Figure 227 for description of symbols.

The human threshold criteria for public health and welfare for lead is 140 µg/l.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Mercury

Few historical data on the concentration of mercury in the water of the Root River exist. Most sampling for mercury in water in the River was taken during or after 1996. The mean concentration of mercury in the River over the period of record was 0.116 μg/l. Mercury concentrations showed moderate variability, with a range from below the limit of detection to 2.84 μg/l. The means at individual stations ranged from 0.001 μg/l at the station near the River's mouth to 0.240 μg/l at W. Ryan Road. Table 159 shows that there was a statistically significant trend toward mercury concentrations decreasing from upstream to downstream. Few time-based trends were detected in mercury concentration in the Root River (see Table C-5 in Appendix C). When examined on an annual basis, there was a significant trend toward increasing mercury concentrations at the station at W. Ryan Road. There is no evidence of seasonal variation of mercury concentrations in the Root River. The increase in mercury concentrations at one station along the Root River represents a decrease in water quality.

Nickel

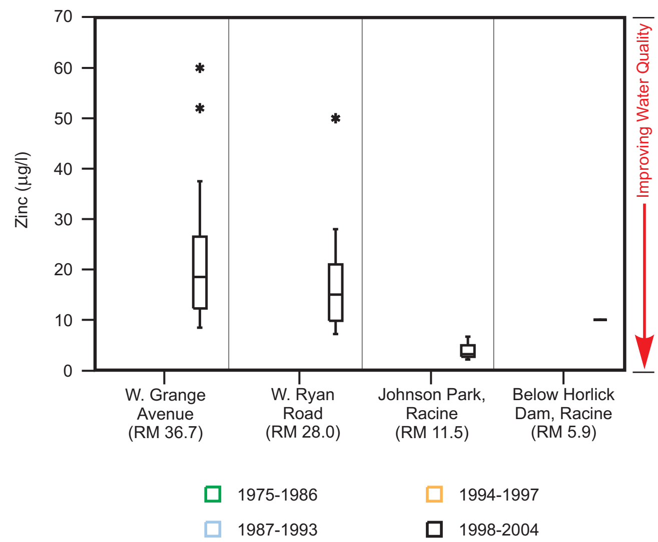
The mean concentration of nickel in the Root River over the period of record was 10.6 μg/l. While some sites had outliers, variability was generally low. No trends in nickel concentration were detected along the length of the River (see Table 159). When examined on an annual basis, significant declines over time were observed at the sampling stations for which data were available (see Table C-5 in Appendix C). There was no evidence of seasonal variation in nickel concentration in the Root River. The decrease in nickel concentrations in the Root River represents an improvement in water quality.

Zinc

The mean concentration of zinc in the Root River during the period of record was 19.1 μg/l. Zinc concentrations showed moderate variability. Concentrations in individual samples ranged from 2.1 to 70.0 μg/l. Figure 248 shows that zinc concentrations in the River tended to decrease from upstream to downstream. This represented a statistically significant trend (see Table 159). The higher concentrations of zinc at the upstream stations may reflect higher amounts of zinc washing into the River during snowmelt and spring rains caused by higher amounts of vehicle traffic in this portion of the watershed. Wear and tear on automobile brake pads and tires are major sources of zinc to the environment. In addition, zinc can be released to stormwater by corrosion of galvanized gutters and roofing materials. Stormwater can carry zinc from these sources into the River. Table C-5 in Appendix C of this report shows that there were few statistically significant trends in zinc concentrations over time at stations along the River. During spring decreasing trends were detected at the stations W. Cold Spring Road and County Line Road. There is no evidence of seasonal variation in the concentration of zinc in the Root River. The trend toward decreasing zinc concentrations at two stations during the spring represents an improvement in water quality.

Figure 248

ZINC CONCENTRATIONS AT SITES ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2004



NOTE: See Figure 227 for description of symbols.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Organic Compounds

Between February and June 2004, samples were collected by the USGS on three dates from two sites along the Root River—W. Grange Avenue and upstream from W. Ryan Road—and examined for the presence and concentrations of several organic compounds dissolved in water. Dissolved isophorone, a solvent, was detected in one sample at a concentration of 0.1 μg/l. As shown in Table 18 in Chapter IV of this report, this concentration is below Wisconsin's human threshold criterion for public health and welfare for fish and aquatic life waters. Carbazole, a component of dyes, lubricants, and pesticides, was detected in three samples at a concentration of 0.1 μg/l. The plasticizer triphenyl phosphate was found in two samples at a concentration of 0.1 μg/l. The following flame retardant chemicals were detected in samples from Oak Creek: 1) Tri(2-chloroethyl) phosphate was detected in four samples at concentrations of 0.1 μg/l, 2) Tri(dichloroisopropyl) phosphate was detected in one sample at a concentration of 0.1 μg/l, 3) Tributyl phosphate was found in three samples at concentrations ranging between 0.1 and 0.2 μg/l, and 4) Triphenyl phosphate was detected in two samples at concentrations of 0.1 μg/l. Finally, the compound *p*-nonylphenol, a metabolite of nonionic detergents, was detected in two samples at concentrations ranging between 1 μg/l and 2.0 μg/l. This compound is known to be an endocrine disruptor.

Pharmaceuticals and Personal Care Products

In February, March, and May 2004, the USGS sampled water from two sites along the Root River—W. Grange Avenue and upstream from W. Ryan Road—for the presence of several compounds found in pharmaceuticals and personal care products. Caffeine, a stimulant found in beverages and analgesics, was detected in all of the samples at concentrations ranging between 0.1 μg/l and 0.4 μg/l. N,N-diethyl-meta-toluamide (DEET), the active ingredient used in many insect repellants, was detected in all of the samples at concentrations of 0.1 μg/l. Cotinine, a metabolite of nicotine, was detected in three samples at concentrations ranging between 0.16 μg/l and 0.38 μg/l. Camphor and menthol, fragrance and flavoring agents, were detected in one and two samples respectively at concentrations of 0.1 μg/l. Acetophenone, a fragrance used in soaps and detergents was detected in one sample at a concentration of 0.2 μg/l. Benzophenone, a fixative used in soaps and perfumes, was detected in two samples at concentrations of 0.1 μg/l. The sources of these compounds to the Root River are not known.

Table 160

LAKES AND PONDS OF THE ROOT RIVER WATERSHED

Name	Area (acres)	Maximum Depth (feet)	Mean Depth (feet)	Lake Type	Public Access
Boerner Botanical Garden Pond No. 1........	2	3	- -	Drainage lake	- -[a]
Boerner Botanical Garden Pond No. 2........	1	4	- -	Drainage lake	- -[a]
Boerner Botanical Garden Pond No. 3........	8	5	- -	Drainage lake	- -[a]
Dumkes Lake	7	11	- -	Seepage lake	- -
Franklin High School Pond	2	- -	- -	- -	- -
Koepmier Lake..	8	35	- -	Seepage lake	- -
Lake Brittany	- -	- -	- -	Seepage lake	- -
Lower Kelly Lake...	3	36	- -	Seepage lake	Walk in trail
Monastery Lake	12	30	- -	Seepage lake	- -
Mud Lake	5	21	- -	Seepage lake	- -[a]
North Golf Course Pond No. 1	1	4	- -	Drainage lake	- -[a]
North Golf Course Pond No. 2	1	4	- -	Drainage lake	- -[a]
North Golf Course Pond No. 3	3	8	- -	Drainage lake	- -[a]
Quarry Lake	20	64	- -	Seepage lake	Boat ramp
Root River Parkway Pond...........................	8	17	- -	Seepage lake	- -[a]
Scout Lake	8	19	6	Seepage lake	- -[a]
Shoetz Park Pond	2	- -	- -	- -	- -
Upper Kelly Lake...	12	31	- -	Spring lake	Boat ramp
Whitnall Park Pond	15	4	6	Drainage lake	- -[a]

[a]*Private boats of any kind are not allowed on ponds in Milwaukee County Parks. Where available, commercial facilities provide boat liveries operated by the park.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Water Quality of Lakes and Ponds

While the Root River watershed contains no lakes with a surface area of 50 acres or more, it does contain several named lakes and ponds. Physical characteristics of lakes and ponds in the Root River watershed are given in Table 160.

Rating of Trophic Condition

Lakes and ponds are commonly classified according to their degree of nutrient enrichment—or trophic status. The ability of lakes and ponds to support a variety of recreational activities and healthy fish and other aquatic life communities is often correlated to the degree of nutrient enrichment which has occurred. Three terms are generally used to describe the trophic status of a lake or pond: oligotrophic, mesotrophic, and eutrophic.

Oligotrophic lakes are nutrient-poor lakes and ponds. These lakes characteristically support relatively few aquatic plants and often do not contain very productive fisheries. Oligotrophic lakes and ponds may provide excellent opportunities for swimming, boating, and waterskiing. Because of the naturally fertile soils and the intensive land use activities, there are relatively few oligotrophic lakes in southeastern Wisconsin.

Mesotrophic lakes and ponds are moderately fertile lakes and ponds which may support abundant aquatic plant growths and productive fisheries. However, nuisance growths of algae and macrophytes are usually not exhibited by mesotrophic lakes and ponds. These lakes and ponds may provide opportunities for all types of recreational activities, including boating, swimming, fishing, and waterskiing. Many lakes and ponds in southeastern Wisconsin are mesotrophic.

Eutrophic lakes and ponds are nutrient-rich lakes and ponds. These lakes and ponds often exhibit excessive aquatic macrophyte growths and/or experience frequent algae blooms. If they are shallow, fish winterkills may be common. While portions of such lakes and ponds are not ideal for swimming and boating, eutrophic lakes and ponds may support very productive fisheries.

The Trophic State Index (TSI) assigns a numerical trophic condition rating based on Secchi-disc transparency, and total phosphorus and chlorophyll-*a* concentrations. The original Trophic State Index developed by Carlson[5] has been modified for Wisconsin lakes by the Wisconsin Department of Natural Resources using data on 184 lakes throughout the State.[6] The Wisconsin Trophic State Index (WTSI) ratings for Upper Kelly Lake in the City of New Berlin and the Village of Hales Corners, Lower Kelly Lake in the City of New Berlin, and Scout Lake in the Village of Greendale are shown in Figure 249 as a function of sampling date.

Based on the Wisconsin Trophic State Index ratings shown, Lower Kelly Lake may be classified as meso-eutrophic. The data shown in Figure 249 for this lake are not sufficient to assess whether the trophic status of this lake has changed over the study period.

Based on the Wisconsin Trophic State Index ratings shown, Upper Kelly Lake may be classified as eutrophic. While the annual median WTSI rating based on Secchi depth has changed over the study period, the overlap of annual ranges suggests that any trends in WTSI ratings for this lake probably are the result of interannual variability.

Based on the Wisconsin Trophic State Index ratings shown, Scout Lake may be classified as eutrophic. While WTSI ratings for this lake have generally decreased since 1999, the overlap of annual ranges, the increases in the ratings based upon Secchi depth and chlorophyll-*a* since 2002, and the similarity of the pattern of change in the ratings based upon Secchi depth to the pattern of change of ratings for Upper Kelly Lake suggest that the changes in WTSI ratings for this lake probably are the result of interannual variability.

Bacterial Parameters

Figure 250 shows five-day geometric means of bacterial concentrations over the course of the summer swimming season in Quarry Lake in the Village of Mt. Pleasant—fecal coliform bacteria for the years 1994-1998 and *E. coli* for the years 1999-2001. While bacterial concentrations showed much interannual variation, they tended to be highest during July and August. For most dates, the concentrations of bacteria in Quarry Lake were below the threshold used for issuing advisories to swimmers; however, concentrations exceeded the threshold and advisories were issued on five dates in 1998 and 10 dates in 2001.

Chemical and Physical Parameters

Data on water chemistry were available for three lakes in the Root River watershed: Scout Lake, Lower Kelly Lake, and Upper Kelly Lake.

Figure 251 shows summer surface and hypolimnetic water temperatures from Scout Lake from the years 1993-2001. Surface water temperatures represent those samples taken within three feet of the lake's surface. Hypolimnetic temperatures represent samples taken from depths below 15 feet beneath the lake's surface. The data indicate that Scout Lake is thermally stratified during the summer months, with hypolimnetic water temperatures being about 15°C below surface water temperatures on average. During thermal stratification, a layer of relatively warm water floats on top of a layer of cooler water. Thermal stratification is a result of the differential heating of the lake water, and the resulting water temperature-density relationships at various depths within the lake water column. Water is unique among liquids because it reaches its maximum density, or mass per unit of volume, at about 4°C. During stratification, the top layer, or epilimnion, of the waterbody is cut off from nutrient inputs from the sediment. At the same time, the bottom layer, or hypolimnion, is cut off from the atmosphere and sunlight penetration. Over the course of the summer, water chemistry conditions can become

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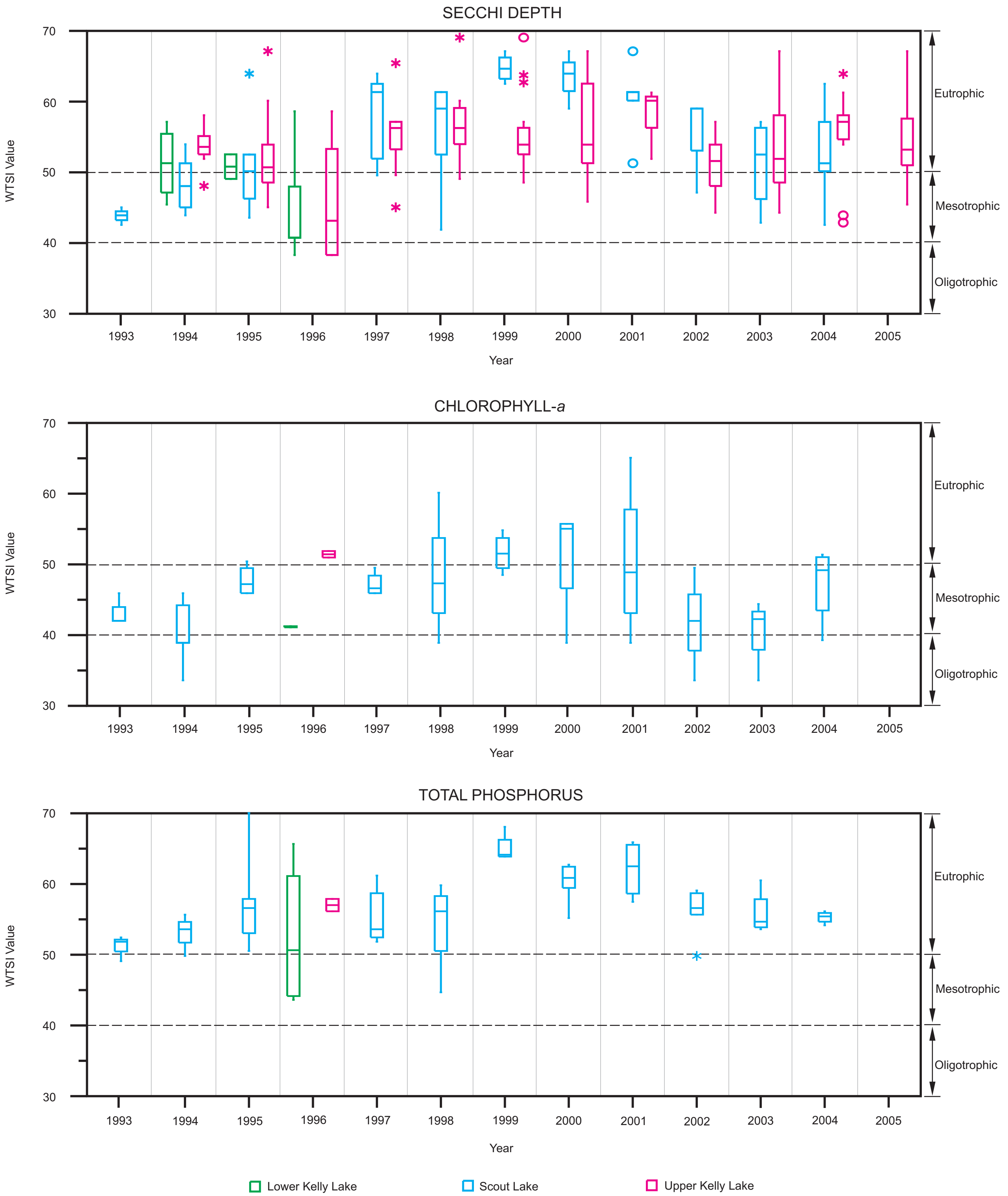
[5]*R.E. Carlson, "A Trophic State Index for Lakes,"* Limnology and Oceanography, *Vol. 22, No. 2, 1*977.

[6]*R.A. Lillie, S. Graham, and P. Rasmussen, "Trophic State Index Equations and Regional Predictive Equations for Wisconsin Lakes,"* Research and Management Findings, *Wisconsin Department of Natural Resources Publication No. PUBL-RS-735 93, May 1993.*

Figure 249

WISCONSIN TROPHIC STATE INDEX (WTSI) OF LAKES IN THE ROOT RIVER WATERSHED: 1993-2005

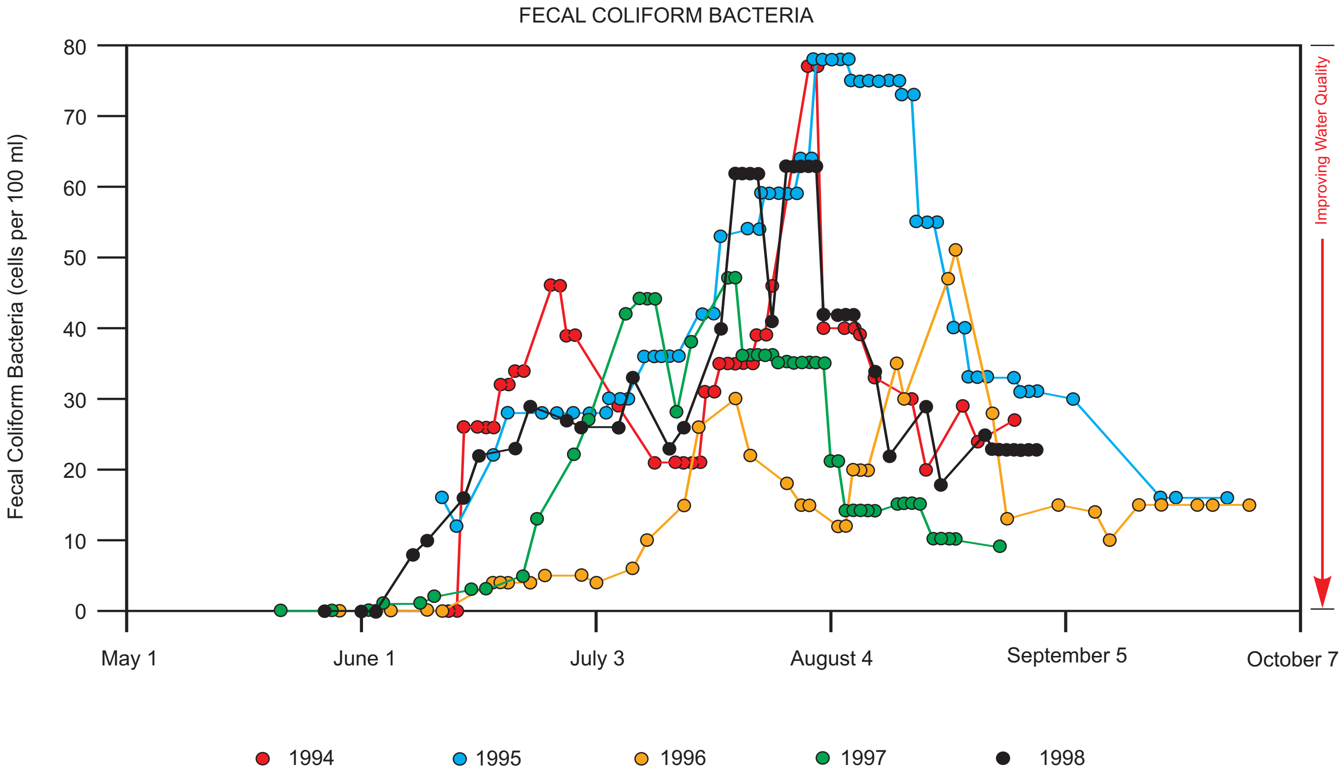


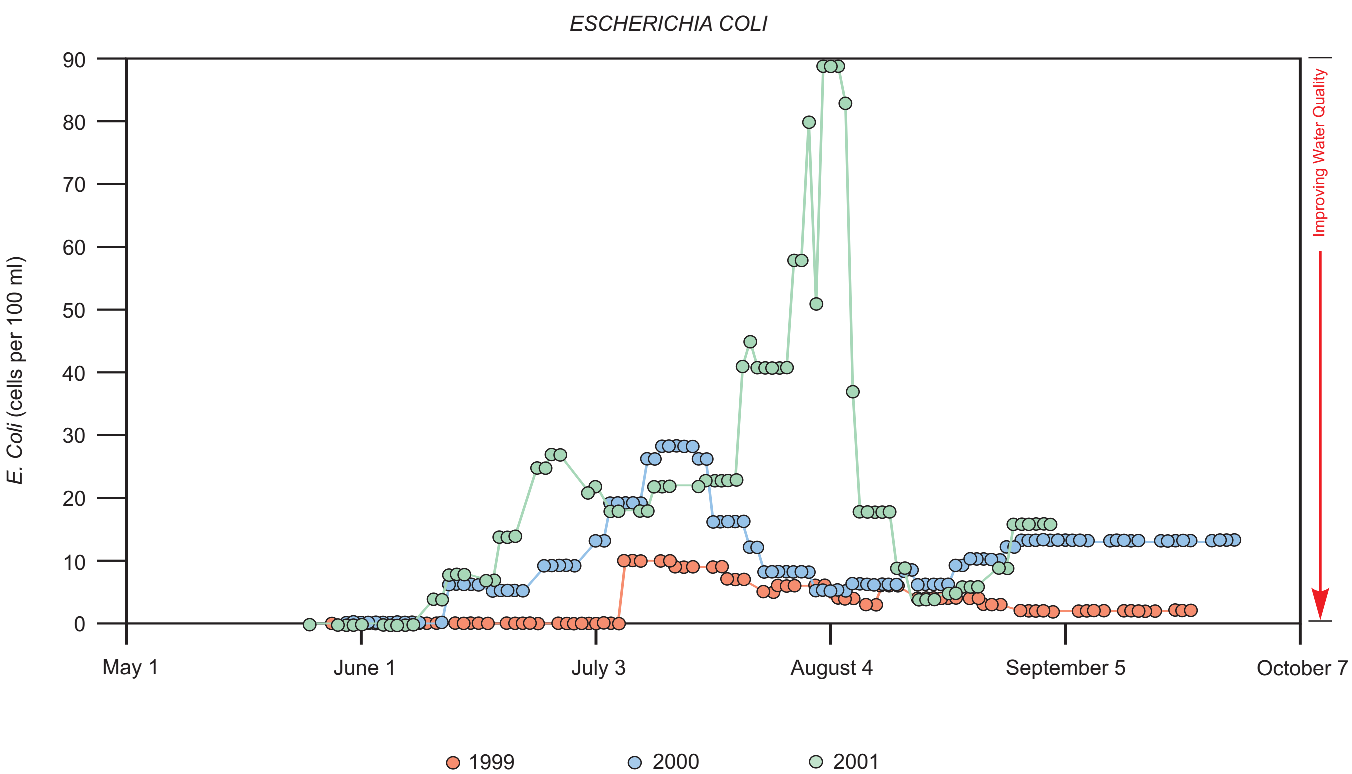
NOTE: See Figure 227 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 250

CONCENTRATIONS OF FECAL COLIFORM BACTERIA AND *ESCHERICHIA COLI* IN QUARRY LAKE: 1994-2001

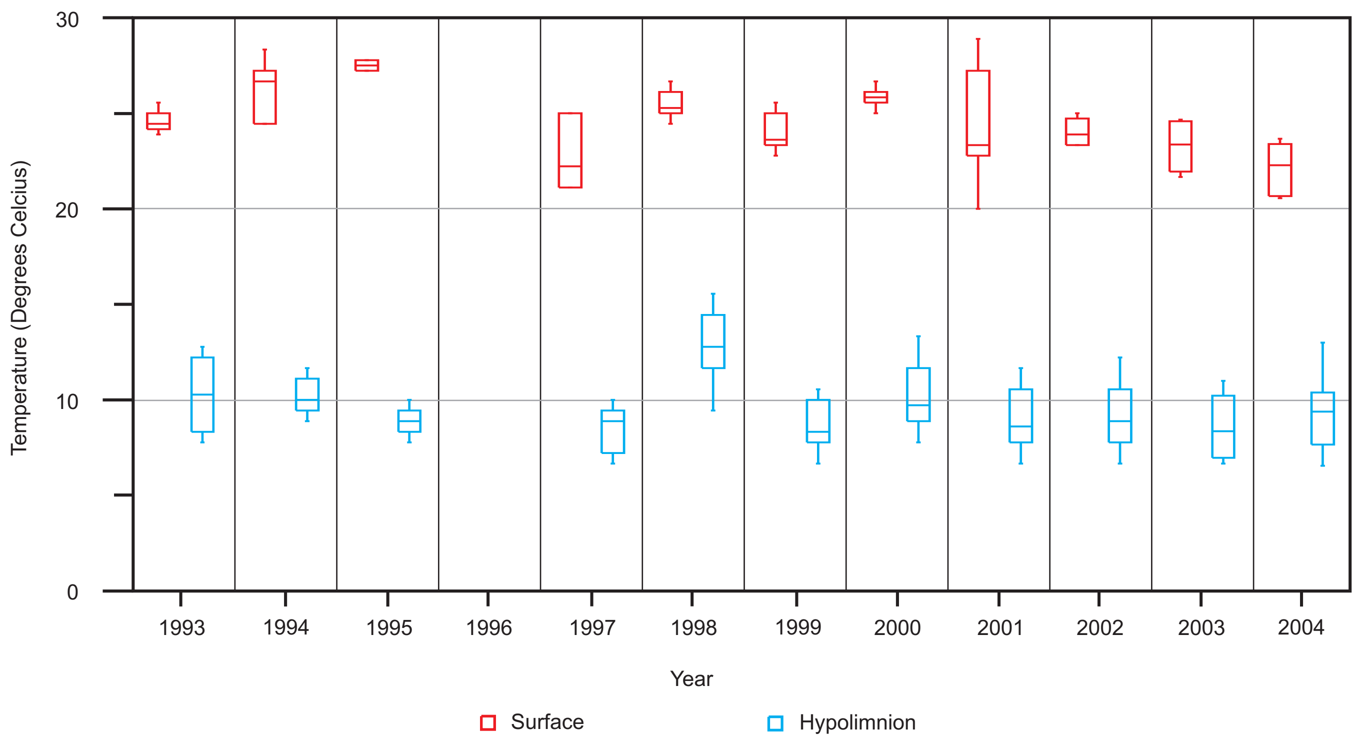




Source: City of Racine Health Department and SEWRPC.

Figure 251

SURFACE AND HYPOLIMNETIC WATER TEMPERATURES IN SCOUT LAKE DURING SUMMER: 1993-2004



Source: Wisconsin Department of Natural Resources and SEWRPC.

different between the layers of a stratified waterbody. In southeastern Wisconsin, the development of summer thermal stratification begins in late spring or early summer, reaches its maximum in late summer, and disappears in the fall.

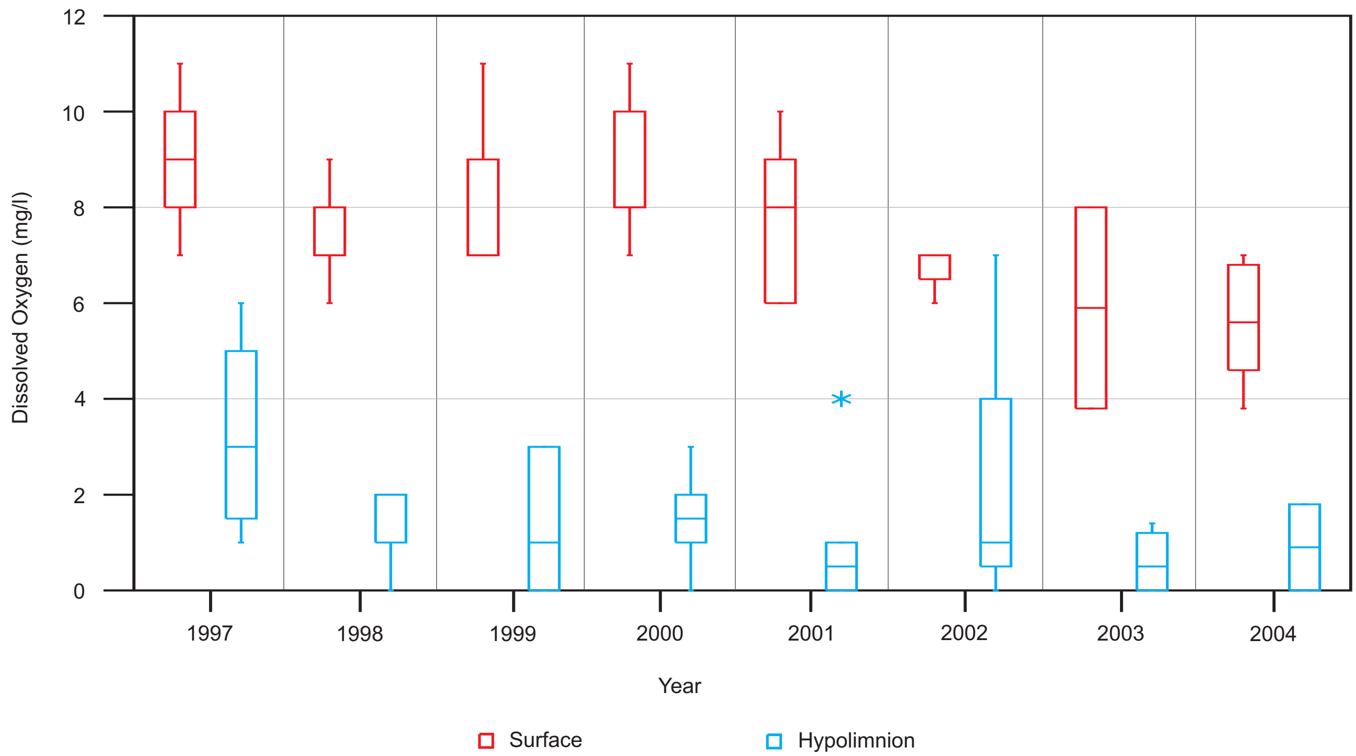
Figure 252 shows summer surface and hypolimnetic dissolved oxygen concentrations from Scout Lake from the years 1997-2001. During the summer, dissolved oxygen concentration in the hypolimnion of Scout Lake tends to be substantially lower than dissolved oxygen concentration at the surface, with the hypolimnion becoming anoxic during most summers. This is consistent with the characterization of this lake as being eutrophic. The lower oxygen concentration in the hypolimnion results from chemical oxidation and microbial degradation of organic material in water and sediment depleting available oxygen.

Hypolimnetic anoxia is common in many of the lakes in southeastern Wisconsin during summer stratification. The depleted oxygen levels in the hypolimnion cause fish to move upward, nearer to the surface of the lakes, where higher dissolved oxygen concentrations exist. This migration, when combined with temperature, can select against some fish species that prefer the cooler water temperatures that generally prevail in the lower portions of the lakes. When there is insufficient oxygen at these depths, these fish are susceptible to summer-kills, or, alternatively, are driven into the warmer water portions of the lake where their condition and competitive success may be severely impaired.

In addition to these biological consequences, the lack of dissolved oxygen at depth can enhance the development of chemoclines, or chemical gradients, with an inverse relationship to the dissolved oxygen concentration. For example, the sediment-water exchange of elements such as phosphorus, iron, and manganese is increased under anaerobic conditions, resulting in higher hypolimnetic concentrations in these elements. Under anaerobic conditions, iron and manganese change oxidation states enabling the release of phosphorus from the iron and

Figure 252

SURFACE AND HYPOLIMNETIC DISSOLVED OXYGEN CONCENTRATIONS IN SCOUT LAKE DURING SUMMER: 1997-2004



Source: Wisconsin Department of Natural Resources and SEWRPC.

manganese complexes to which they are bound under aerobic conditions. This "internal loading" can affect water quality significantly if these nutrients and salts are mixed into the epilimnion, especially during early summer when these nutrients can become available for algal and rooted aquatic plant growth.

Figure 252 also shows that surface concentrations of dissolved oxygen in Scout Lake during the summer have been decreasing over time. Linear regression analysis shows that this trend is statistically significant and accounts for about 24 percent of the variation in the data. The rate of decrease is about 0.4 mg/l per year. The temperature trends shown in Figure 251 suggest that this trend in dissolved oxygen data is not being driven by changes in temperature. Because the solubility of oxygen in water tends to increase with decreasing temperature, if temperature changes were driving these changes in surface dissolved oxygen concentration, it is likely that dissolved oxygen concentrations would increase. The decrease in surface dissolved oxygen concentrations during the summer in Scout Lake is unknown.

Limited water chemistry data were available for Upper Kelly and Lower Kelly Lakes. Both lakes were sampled for dissolved oxygen during summer 1996. Dissolved oxygen samples collected in July and September 1996 from Lower Kelly Lake indicate that thermal stratification and hypolimnetic anoxia were present in this lake. Similarly, samples collected from Upper Kelly Lake in July 1996 indicate that thermal stratification and hypolimnetic anoxia were also present in this Lake. The dissolved oxygen data from these lakes are not sufficient for evaluating how common hypolimnetic anoxia is in these lakes during summer stratification.

TOXICITY CONDITIONS OF THE ROOT RIVER

Toxic Substances in Water

Pesticides

The Root River watershed has been sampled for the presence of pesticides in water on several occasions. The site below the Horlick dam on the mainstem of the River in Racine was sampled in 1995, 1998, and 2002. Three additional sites along the mainstem, W. Layton Avenue, W. Grange Avenue, and upstream of W. Ryan Road, were sampled in 2004. It is important to note that the results from the samples taken in 2004 are not directly comparable to those from the early periods. The data from the earlier periods were derived from unfiltered samples which included both pesticides dissolved in water and pesticides contained in and adsorbed to particulates suspended in the water. The data from 2004 were derived from filtered samples and measure only the fraction of pesticides dissolved in water. Since most pesticides are poorly soluble in water, the data from 2004 may underestimate ambient pesticide concentrations relative to the earlier data. The insecticides carbaryl and diazinon were detected in some samples from each site. The herbicide atrazine was detected in most of the samples. The atrazine metabolite deethylatrazine was detected at the two upstream sites. The herbicide glyphosate was detected in samples from the station below the Horlick dam. Concentrations of the insecticides dieldrin, lindane, and malathion were below the limit of detection. The concentrations of atrazine and diazinon reported were below the USEPA draft aquatic life criteria.

Polycyclic Aromatic Hydrocarbons (PAHs)

Extensive sampling for 16 PAH compounds in unfiltered water was conducted at the MMSD long-term stations along the mainstem of the Root River in Milwaukee County between 1999 and 2001. Measurable concentrations of PAHs were detected in most of the samples. Concentrations of total PAHs in these samples ranged from below the limit of detection to 2.39 μg/l, with a mean concentration of 0.47 μg/l. It is important to note that there was considerable variation in the concentrations detected among different sites within these sections of the River and among samples taken at individual sites on different dates. In 2004, two sites along the mainstem of the River were sampled on three dates for six PAH compounds dissolved in water. The mean concentration from these samples was 0.27 μg/l. It is important to note that the results from this last sampling are not directly comparable to the results from the earlier sampling both for the reasons discussed in the previous paragraph and because fewer compounds were screened for in the 2001 sampling than in the previous samplings.

Polychlorinated Biphenyls (PCBs)

Between 1999 and 2001 six sites along the mainstem of the Root River in Milwaukee County were sampled on six dates for the presence and concentrations of 14 PCB congeners in water. Since concentrations of only 14 out of 209 congeners from this family of compounds were examined, the results from the mainstem should be considered minimum values. In all of the samples, the concentrations of these PCB congeners were below the limit of detection.

Toxic Contaminants in Aquatic Organisms

The WDNR periodically surveys tissue from fish and other aquatic organisms for the presence of toxic and hazardous contaminants. Several surveys were conducted at sites within the Root River watershed between 1976 and 2002. These surveys screened for the presence and concentrations of several contaminants including metals, PCBs, and organochloride pesticides. Because of potential risks posed to humans by consumption of fish containing high levels of contaminants, the WDNR has issued fish consumption advisories for several species of fish taken from the Root River (see Table 161).

Some of the samples collected from the Root River consisted of whole organism homogenates while other samples consisted of fillets of skin and muscle tissue. These types of samples are not directly comparable. Consumption advisory determinations are based upon fillet samples. In both types of samples, a single sample may represent tissue from several fish of the same species.

Table 161

FISH CONSUMPTION ADVISORIES FOR THE REACH OF THE ROOT RIVER FROM THE HORLICK DAM TO LAKE MICHIGAN[a]

Species	Consumption Advisory Level			
	One Meal per Week	One Meal per Month	One Meal per Two Months	Do Not Eat
Carp	- -	- -	- -	All sizes
Chubs	- -	All sizes	- -	- -
Chinook Salmon	- -	Less than 32 inches	Larger than 32 inches	- -
Coho Salmon	- -	All sizes	- -	- -
Brown Trout	- -	Less than 22 inches	Larger than 22 inches	- -
Lake Trout	- -	Less than 23 inches	23-27 inches	Larger than 27 inches
Rainbow Trout	Less than 22 inches	Larger than 22 inches	- -	- -
Smelt	All sizes	- -	- -	- -
Whitefish	- -	All sizes	- -	- -
Yellow Perch	All sizes	- -	- -	- -

[a]*The statewide general fish consumption advisory applies to other fish species not listed in this table.*

Source: Wisconsin Department of Natural Resources.

Mercury

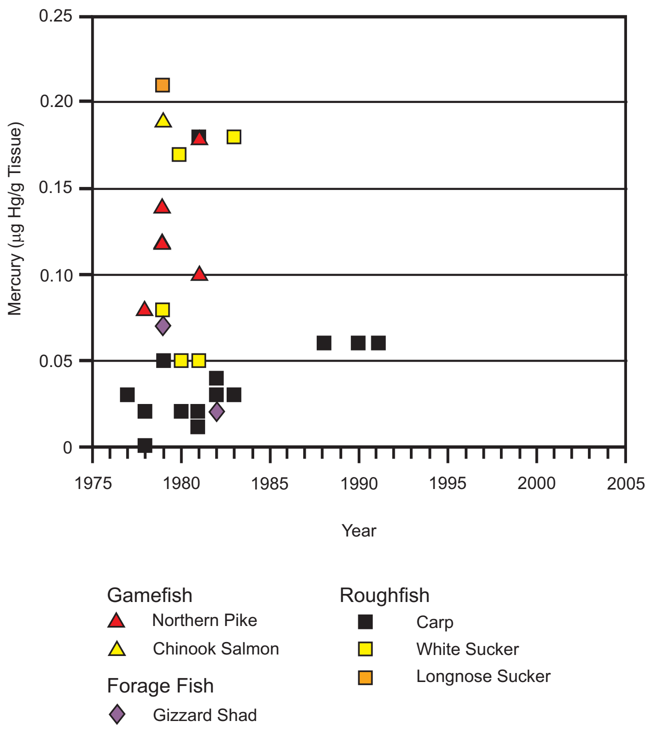
Between 1977 and 2002 the WDNR sampled tissue from individuals from several species of aquatic organisms collected from the Root River for mercury contamination. As shown in Figure 253, the concentration of mercury reported in whole fish samples ranged from below the limit of detection to 0.21 micrograms per gram tissue (μg per g tissue) with a mean concentration of 0.08 μg per g tissue. While the maximum concentrations of mercury detected appear to have declined, it is uncertain whether this represents a trend because different species were collected at different dates. In addition, a few fillet samples were also collected from the Root River. The concentrations of mercury in these samples ranged from 0.05 μg per g tissue to 0.63 μg per g tissue with a mean concentration of 0.19 μg per g tissue. It is important to note that all of the fish in these whole fish and fillet samples were collected downstream from Horlick dam. Because this reach of the River is the only section that is connected to Lake Michigan, these results may not reflect conditions upstream from the dam. In addition to sampling the Root River, in 1988 the WDNR examined a fillet sample from one largemouth bass collected in Quarry Lake. The concentration of mercury in the tissue of this fish was 0.28 μg per g tissue. The number of individual organisms and the range of species taken from this watershed that have been screened for the presence of mercury contamination are quite small. In addition, no recent data were available. Because of this, these data may not be completely representative of current body burdens of mercury carried by aquatic organisms in the River and its tributaries.

PCBs

Between 1976 and 2002 the WDNR examined tissue taken from individuals of several species of aquatic organisms collected from the Root River for contamination with PCBs. While samples were collected both at sites above and below Horlick dam, most of the samples were collected below the dam. Figure 254 shows tissue concentrations of PCBs in fish collected from the Root River. While the maximum concentrations of PCBs detected appear to have declined, it is uncertain whether this represents a trend because different species were collected at different dates. Concentrations of PCBs in whole fish samples collected from below Horlick dam ranged between 0.05 μg per g tissue and 16.00 μg per g tissue, with a mean concentration of 1.03 μg per g tissue. Concentrations of PCBs in fillet samples collected from below Horlick dam ranged below the limit of detection to 6.60 μg per g tissue, with a mean concentration of 0.58 μg per g tissue. It is important to note that the majority of the fish sampled since 1991 consisted of coho salmon and rainbow trout, two species that spend the majority of their lives in Lake Michigan. Concentrations of PCBs in whole fish samples collected from above Horlick dam ranged between 0.02 μg per g tissue and 1.30 μg per g tissue, with a mean concentration of 0.28 μg per g tissue

Figure 253

TISSUE CONCENTRATIONS OF MERCURY IN WHOLE FISH SAMPLES COLLECTED FROM BELOW HORLICK DAM IN THE ROOT RIVER: 1975-2005



Source: Wisconsin Department of Natural Resources.

(see Figure 254). Concentrations of PCBs in fillet samples collected from above Horlick dam ranged between 0.20 µg per g tissue and 4.50 µg per g tissue, with a mean concentration of 2.44 µg per g tissue. In addition to sampling the Root River, in 1988 the WDNR examined a fillet sample from one largemouth bass collected in Quarry Lake. The concentration of PCBs in the tissue of this fish was 0.20 µg per g tissue.

The tissues samples for PCBs collected from coho salmon and rainbow trout during 1992 and 1993 consisted of both whole fish samples and fillet samples taken from the same fish. This offers the opportunity to examine how the concentrations determined by these two sampling methodologies relate to one another. Figure 255 shows the relationship between whole fish tissue concentrations and fillet tissue concentrations of PCB in these fish for both species. Two conclusions are evident from the graph and subsequent analysis using linear regression. First, PCB concentrations in whole fish samples and fillet samples of the same fish appear to be strongly related to one another. Second, the strength of the relationship may be species-specific. This second conclusion is supported by the amounts of variation in the data explained by the regression equations. For rainbow trout, the relationship between whole fish PCB concentration and fillet PCB concentration accounts for about 64 percent of the variation in the data. For coho salmon, this relationship accounts for about 87 percent of the variation in the data.

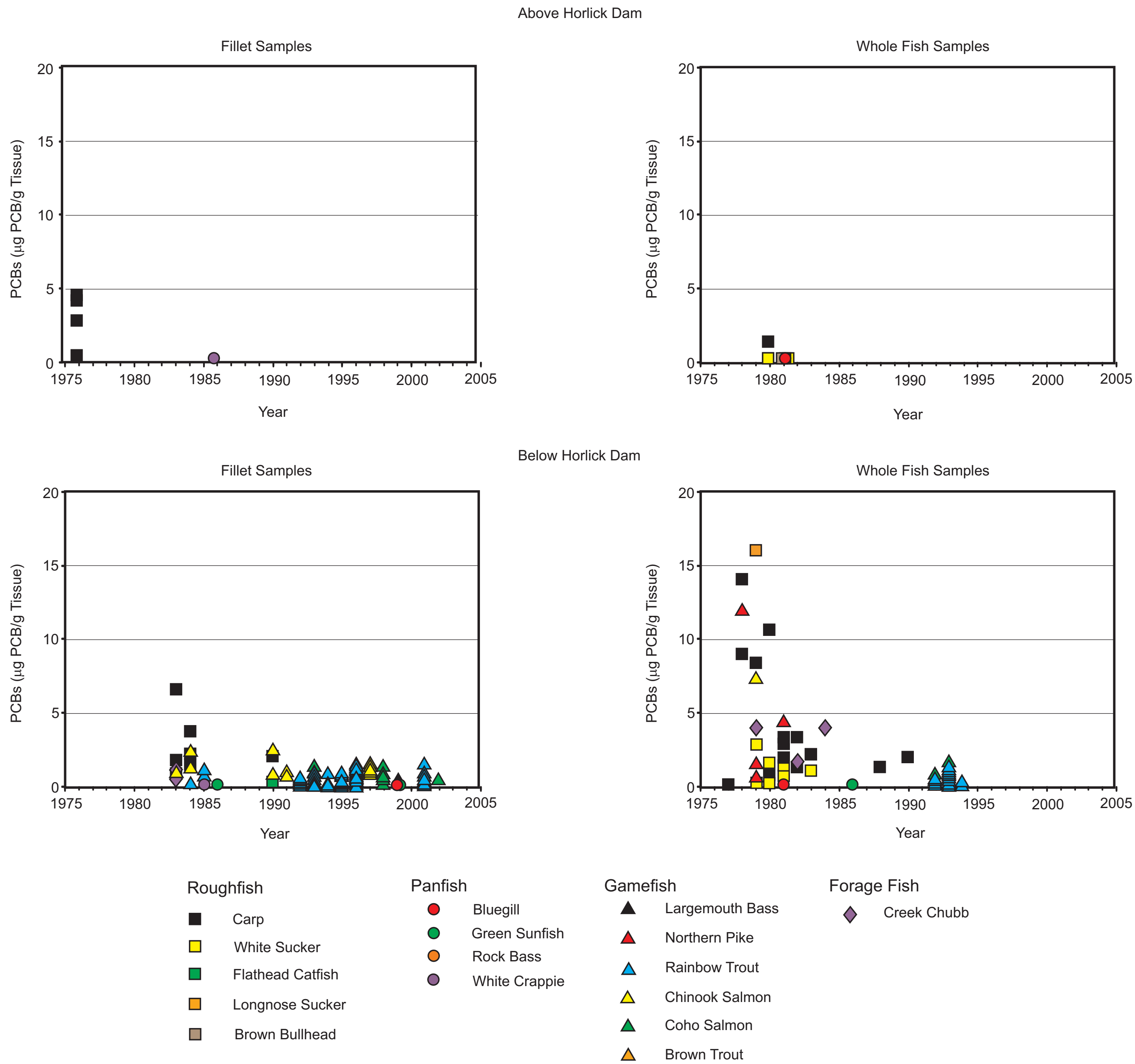
The number of individual organisms and the range of species taken from this watershed that have been screened for the presence of PCB contamination are quite small. In addition, no recent data on PCB contamination were available from sites above Horlick dam. Because of this, these data may not be completely representative of current body burdens of PCB**s** carried by aquatic organisms in the River and its tributaries.

Pesticides

Between 1977 and 2001 the WDNR sampled several species of aquatic organisms from the Root River watershed for contamination by historically used, bioaccumulative pesticides and their breakdown products. Many of these compounds are no longer in use. For example, crop uses of most of these compounds were banned in the United States between 1972 and 1983. While limited uses were allowed after this for some of these substances, by 1988 the uses of most had been phased out. During the 1970s and 1980s, measurable concentrations of *p,p'*-DDT were occasionally detected in tissue of chinook salmon and longnose sucker collected from the Root River. Neither *o,p'*-DDT nor *p,p*'-DDT were detected in the tissue of other species during this period. During the same period measurable concentrations of the DDT breakdown products of, *p,p'*-DDD and *p,p'*-DDE were detected in the tissue of fish from several species including bluegill, carp, chinook salmon, gizzard shad, northern pike, and white sucker. Since 1990, measurable concentrations of *p,p*'-DDT have been detected in tissue from chinook salmon and coho salmon. Measurable concentrations of the DDT breakdown products of, *p,p'*-DDD and *p,p'*-DDE were detected in several species, including carp, chinook salmon, coho salmon, and rainbow trout. Tissue concentrations of *p,p'*-DDE were especially high in the tissue of coho salmon, exceeding 227 µg per g tissue.

Figure 254

TISSUE CONCENTRATIONS OF PCBs IN FISH SAMPLES COLLECTED FROM THE ROOT RIVER: 1975-2005

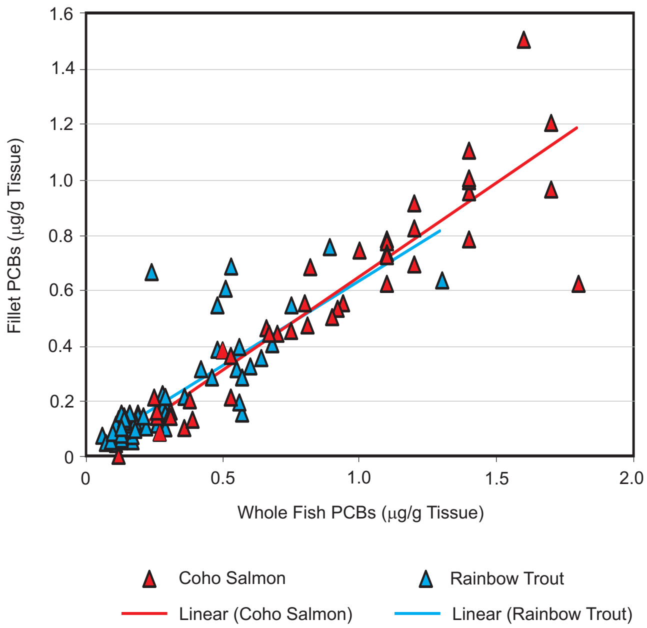


Source: Wisconsin Department of Natural Resources.

During the same period, tissue from fish collected in the Root River watershed was analyzed for the presence of several other pesticides. During the 1970s and 1980s measurable concentrations of α-chlordane, γ-chlordane, cis-nonachlor, and trans-nonachlor were detected in the tissue of carp, chinook salmon, gizzard shad, longnose sucker, northern pike, and white sucker. Since 1990, chlordane isomers have been detected in the tissue of chinook salmon, coho salmon, and rainbow trout. Similarly, measurable concentrations of dieldrin were detected in tissue from carp collected in the early 1980s and coho salmon collected in the late 1990s. Tissue from coho salmon collected in the 1990s contained measurable concentrations of the insecticide toxaphene. Concentrations of toxaphene in this species were high, in one sample exceeding 200 μg/g tissue. It is important to recognize, however, that the number of individual organisms and the range of species taken from this watershed that have

Figure 255

RELATIONSHIPS BETWEEN TISSUE CONCENTRATIONS OF PCBs IN FILLET AND WHOLE FISH SAMPLES OF COHO SALMON AND RAINBOW TROUT COLLECTED FROM THE ROOT RIVER: 1992-1993



Source: Wisconsin Department of Natural Resources and SEWRPC.

been screened for the presence of pesticide contamination are quite small. Because of this, these data may not be completely representative of pesticide body burdens of pesticides carried by aquatic organisms in the River and its tributaries.

In addition to sampling streams of the Root River watershed, in 1988 the WDNR examined tissue from one largemouth bass collected in Quarry Lake for the presence of several pesticides including DDT and its metabolites and several isomers of chlordane. The concentrations of these compounds in the tissue of this fish were below the limit of detection.

Toxic Contaminants in Sediment

Between 1989 and 2003 the WDNR sampled sediment from streams in the Root River watershed for the presence and concentrations of toxic substances on several occasions. In 1989, sediment was collected from four sites along the mainstem of the River in the City of Racine. In 1997, sediment was collected from five sites along the mainstem of the River, two in upstream reaches and three in the City of Racine, and three sites along Whitnall Park Creek. In 2001, sediment was collected from three sites in the impoundment upstream from the Horlick dam. In 2003, sediment was collected from three sites in the Crayfish Creek subwatershed, one along Crayfish Creek and two along an unnamed tributary. Toxicants that were sampled for include metals, PAHs, PCBs, and pesticides. Sediment samples collected from the Root River during the period 1989 to 2003 show detectable concentrations of arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, thallium, and zinc. Summary statistics for concentrations of selected metals are shown in Table 162. The mean concentrations of arsenic, cadmium, chromium, copper, manganese, mercury, nickel, and zinc in these samples were between the Threshold Effect Concentrations (TEC) and the Probable Effect Concentrations (PECs), indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms (see Table 13 in Chapter III of this report).

The amount of organic carbon in sediment can exert considerable influence on the toxicity of nonpolar organic compounds such as PAHs, PCBs, and certain pesticides to benthic organisms. While the biological responses of benthic organisms to nonionic organic compounds has been found to differ across sediments when the concentrations are expressed on a dry weight basis, they have been found to be similar when the concentrations have been normalized to a standard percentage of organic carbon.[7] Because of this, the concentrations of PAHs, PCBs, and pesticides were normalized to 1 percent organic carbon prior to analysis.

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[7] *U.S. Environmental Protection Agency,* Technical Basis for the Derivation of Equilibrium Partitioning Sediment Guidelines (ESGs) for the Protection of Benthic Organisms: Nonionic Organics*, USEPA Office of Science and Technology, Washington, D.C., 2000.*

Table 162

CONCENTRATIONS OF TOXIC METALS IN SEDIMENT SAMPLES FROM THE ROOT RIVER, CRAYFISH CREEK, AND WHITNALL PARK CREEK: 1989-2003[a]

Statistic	Metals							
	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Mean	19.2	3.41	73.1	68.0	102.8	0.09	30.1	292.1
Standard Deviation	17.0	10.20	108.4	69.6	112.9	0.05	13.7	286.8
Minimum	0.0	0.00	16.0	20.0	19.0	0.03	14.0	66.6
Maximum	65.0	44.00	400.0	280.0	380.0	0.21	70.0	932.0
Number of Samples	14	18	14	14	14	11	14	14
Date of Earliest Sample	1997	1989	1997	1997	1997	1997	1997	1997
Date of Latest Sample	2003	2003	2003	2003	2003	2003	2003	2003

[a]*All concentrations in mg/kg based on dry weight.*

Source: Wisconsin Department of Natural Resources.

Concentrations of PAHs in 11 sediment samples collected between 1997 and 2001 ranged between about 270 micrograms PAH per kilogram sediment (μg PAH/kg sediment) and about 127,000 μg PAH/kg sediment with a mean value of 47,000 μg PAH/kg sediment. Total organic carbon data was not available for two of the samples. For two of the nine samples that had associated total organic carbon data, the concentrations of PAHs found in the sediments of the Root River exceed the PEC for total PAHs and are high enough to pose substantial risk of toxicity to benthic organisms. Concentrations of PCBs in 10 sediment samples collected between 1989 and 2001 ranged below the limit of detection to about 2,300 micrograms PCB per kilogram sediment (μg PCB/kg sediment) with a mean value of 350 μg PCB/kg sediment. Total organic carbon data was not available for one of the samples. For all nine of the samples that had associated total organic carbon data, the concentrations of PCBs found in the sediments of the Root River were below the PEC for total PCBs. The concentrations of PCBs in four samples were between the Threshold Effect Concentration (TEC) and the PEC, indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms.

Sediment from the Root River was examined for the presence of the pesticide toxaphene and its derivatives compounds at four sites in 1989. The concentrations in these samples were below the limit of detection.

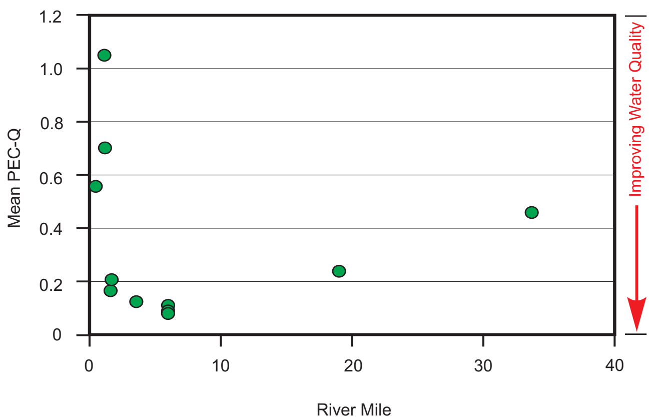
The combined effects of several toxicants in sediment of the Root River were estimated using the methodology described in Chapter III of this report. Figure 256 shows that for sediments in the Root River, overall mean PEC-Q values, a measure that integrates the effects of multiple toxicants on benthic organisms, range between 0.086 and 1.049. These PEC-Q levels suggest that benthic organisms in the Root River are experiencing moderate to substantial incidences of toxic effects, as indicated in Figure 257. In these samples, the estimated incidence of toxicity ranges between 8.5 and 66.7 percent. Sampling of Crayfish Creek, Whitnall Park Creek, and an unnamed tributary in the Crayfish Creek subwatershed suggest that benthic organisms in these streams are experiencing similar incidences of toxicity, with estimated incidences ranging between 20 and 72 percent.

BIOLOGICAL CONDITIONS OF THE ROOT RIVER AND ITS TRIBUTARIES

Aquatic and terrestrial wildlife communities have educational and aesthetic values, perform important functions in the ecological system, and are the basis for certain recreational activities. The location, extent, and quality of fishery and wildlife areas and the type of fish and wildlife characteristic of those areas are, therefore, important determinants of the overall quality of the environment in the Root River watershed.

Figure 256

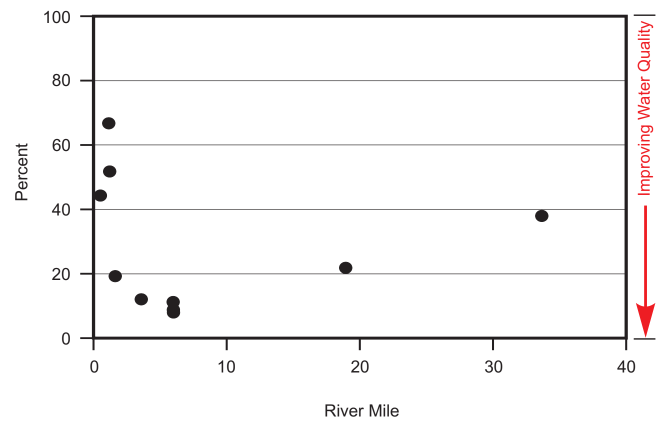
MEAN PROBABLE EFFECT CONCENTRATION QUOTIENTS (PEC-Q) FOR SEDIMENT ALONG THE MAINSTEM OF THE ROOT RIVER: 1989-2001



Source: Wisconsin Department of Natural Resources, and SEWRPC.

Figure 257

ESTIMATED INCIDENCE OF TOXICITY TO BENTHIC ORGANISMS ALONG THE MAINSTEM OF THE ROOT RIVER: 1989-2001



Source: Wisconsin Department of Natural Resources, and SEWRPC.

Fisheries

Creeks and Rivers

Review of the fishery data collected in the Root River basin between 1900 and 2004 indicates no apparent net loss in the overall total number of species throughout the watershed during this time period as shown in Table 163.[8] Table 163 does indicate a loss of more than 20 species during the period of 1987 through 1997; however, this apparent decrease seems to be due, in part, to a decreased sampling effort and sampling location. For example, in the 1987-1993 time period only two samples were taken and the majority of the sampling in the 1994-1997 time period was located in the West Branch of the Root River and upper reaches of the Hoods Creek subwatersheds, which do not contain a very high abundance and diversity of fishes compared to other areas of the watershed. Table 163 also shows that the historical and current numbers of species have been, and continue to be, relatively high with a total of 46 different species, but the overall fish species composition has changed during this time period. The most recent fishery surveys in 1998-2004 indicated an apparent loss of about 10 species that have not been observed since 1986 that include the redfin shiner and longear sunfish, which are threatened species in the State of Wisconsin; lake chubsucker, least darter, and redside dace, which are species of special concern in the State of Wisconsin; and the bullhead minnow, hornyhead chub, largescale stoneroller, southern redbelly dace, and spottail shiner. Four of these species lost were intolerant fish species sensitive to degraded water quality conditions. The 1998-2004 surveys also indicate an apparent gain of about 10 species that include the river redhorse, which is a threatened species in the State of Wisconsin; mimic shiner, slenderhead darter, and smallmouth bass, which are all intolerant species; and the channel catfish, longnose dace, orangespotted sunfish, sand shiner, shorthead redhorse, and trout perch, which are all intermediate tolerance species. It is important to

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[8]*Wisconsin Department of Natural Resources,* The State of the Root Pike River Basin*, PUBL WT-700-2002, May 2002; Don Fago, Wisconsin Department of Natural Resources, "Distribution and Relative Abundance of Fishes in Wisconsin: VIII. Summary Report,"* Technical Bulletin No. 75*, 1992; Wisconsin Department of Natural Resources, "Distribution and Relative Abundance of Fishes in Wisconsin: IV. Root, Milwaukee, Des Plaines, and Fox River Basins,"* Technical Bulletin No. 147*, 1984; George Becker,* Fishes of Wisconsin*, University of Wisconsin Press, 1983; and M. Miller, J. Ball, and R. Kroner, Wisconsin Department of Natural Resources,* An Evaluation of Water Quality in the Root River Priority Watershed*, Publication WR-298-92, January 1992.*

Table 163

FISH SPECIES COMPOSITION IN THE ROOT RIVER WATERSHED: 1900-2004

Species According to Their Relative Tolerance to Pollution	Percent Occurrence[a]				
	1900-1974	1975-1986	1987-1993	1994-1997	1998-2004
Intolerant					
Blackchin Shiner	0.0	1.0	0.0	0.0	14.0
Blacknose Shiner	21.0	0.0	0.0	0.0	18.0
Least Darter[b]	15.0	0.0	0.0	0.0	0.0
Longear Sunfish[c]	3.0	0.0	0.0	0.0	0.0
Iowa Darter	9.0	7.0	0.0	0.0	14.0
Mimic Shiner	0.0	0.0	0.0	0.0	9.0
Redside Dace[b]	- -[d]	0.0	0.0	0.0	0.0
Rock Bass	24.0	1.0	0.0	0.0	23.0
River Redhorse[c]	0.0	0.0	0.0	0.0	5.0
Slenderhead Darter	0.0	0.0	0.0	0.0	14.0
Smallmouth Bass	0.0	0.0	0.0	0.0	5.0
Spottail Shiner	- -[d]	0.0	0.0	0.0	0.0
Stonecat	3.0	2.0	0.0	0.0	5.0
Tolerant					
Black Bullhead	32.0	37.0	100.0	55.0	36.0
Blacknose Dace	12.0	4.0	0.0	3.0	5.0
Bluntnose Minnow	39.0	11.0	100.0	61.0	55.0
Brown Bullhead	12.0	4.0	0.0	0.0	23.0
Central Mudminnow	45.0	30.0	0.0	76.0	45.0
Common Carp	27.0	27.0	100.0	27.0	32.0
Creek Chub	61.0	60.0	100.0	97.0	68.0
Fathead Minnow	9.0	48.0	0.0	85.0	50.0
Golden Shiner	33.0	27.0	100.0	15.0	18.0
Goldfish	3.0	21.0	100.0	0.0	5.0
Green Sunfish	30.0	59.0	100.0	94.0	91.0
Yellow Bullhead	9.0	1.0	100.0	27.0	50.0
White Sucker	45.0	77.0	100.0	91.0	91.0
Intermediate					
Alewife	3.0	4.0	0.0	0.0	9.0
Black Crappie	15.0	5.0	0.0	3.0	18.0
Blackside Darter	12.0	6.0	0.0	15.0	32.0
Bluegill	21.0	20.0	100.0	27.0	41.0
Bigmouth Shiner	3.0	28.0	100.0	64.0	14.0
Brook Stickleback	6.0	22.0	100.0	70.0	36.0
Brown Trout[e]	3.0	4.0	- -[d]	- -[d]	14.0
Bullhead Minnow	0.0	1.0	0.0	0.0	0.0
Central Stoneroller	0.0	0.0	0.0	3.0	0.0
Channel Catfish	0.0	0.0	0.0	0.0	9.0
Chinook Salmon[e]	- -[d]	5.0	- -[d]	- -[d]	- -[d]
Coho Salmon[e]	- -[d]	- -[d]	- -[d]	- -[d]	- -[d]
Common Shiner	21.0	28.0	100.0	33.0	0.0
Emerald Shiner	3.0	1.0	0.0	0.0	5.0
Gizzard Shad	0.0	4.0	0.0	0.0	0.0
Golden Redhorse	3.0	0.0	0.0	0.0	5.0
Grass Pickerel	30.0	1.0	0.0	0.0	0.0
Hornyhead Chub	3.0	0.0	0.0	0.0	0.0
Johnny Darter	36.0	22.0	100.0	70.0	59.0
Lake Chubsucker[b]	0.0	4.0	0.0	0.0	0.0
Largemouth Bass	6.0	27.0	0.0	27.0	36.0
Largescale Stoneroller	27.0	0.0	0.0	0.0	0.0
Logperch	0.0	0.0	0.0	3.0	0.0
Longnose Dace	0.0	1.0	0.0	0.0	5.0
Northern Pike	12.0	2.0	0.0	21.0	32.0
Orangespotted Sunfish	0.0	0.0	0.0	0.0	5.0
Pumpkinseed	21.0	15.0	0.0	6.0	5.0

Table 163 (continued)

Species According to Their Relative Tolerance to Pollution	Percent Occurrence[a]				
	1900-1974	1975-1986	1987-1993	1994-1997	1998-2004
Intermediate (continued)					
Rainbow Smelt	0.0	1.0	0.0	0.0	0.0
Rainbow Trout[e]	3.0	9.0	- -[d]	- -[d]	14.0
Redfin Shiner[c]	21.0	0.0	0.0	0.0	0.0
Sand Shiner	0.0	5.0	0.0	6.0	36.0
Shorthead Redhorse	0.0	0.0	0.0	0.0	5.0
Southern Redbelly Dace	0.0	1.0	0.0	0.0	0.0
Tadpole Madtom	9.0	0.0	0.0	0.0	5.0
Trout Perch	0.0	0.0	0.0	0.0	5.0
Warmouth	9.0	5.0	0.0	6.0	5.0
White Crappie	9.0	12.0	0.0	0.0	0.0
Yellow Perch	9.0	21.0	0.0	0.0	0.0
Total Number of Samples	33	82	2	33	22
Total Number of Samples per Year	<1	7	<1	8	4
Total Number of Species	46	44	18	29	46

NOTE: Data includes samples in both streams and lakes within the Root River watershed.

[a]*Values represent percent occurrence, which equals the number of sites where each species was found divided by the total number of sites within a given time period.*

[b]*Designated species of special concern.*

[c]*Designated threatened species.*

[d]*This species was observed, but percent occurrence is unknown.*

[e]*These species are stocked by Wisconsin Department of Natural Resources managers and limited to areas downstream of Horlick dam (see Figure 264).*

Source: Wisconsin Department of Natural Resources and SEWRPC.

note that most of the new records of fish species observations were found in the six mile reach of the Root River between the confluence of Lake Michigan and the Horlick dam, which indicates the potential influence of Lake Michigan fishes has on the abundance and diversity of fishes within this lower reach of the Root River.

The Horlick dam has been and continues to have a significant influence on the diversity of fishes in the Root River Watershed. Prior to 1975, the fish assemblages above the Horlick dam versus below the dam only shared 18 of the same fish species or about 40 percent of the total fish species recorded in the Root River watershed. In this same time period the areas above the Horlick dam contained an additional 19 different species for a total of 37 species. The areas downstream of the dam were much less diverse and only contained 9 additional fish species for a total of 26 species, which are 10 less species compared to the areas upstream of Horlick dam. In contrast, the 1998-2004 fisheries surveys indicate that the areas upstream and downstream of the Horlick dam contained a total of 32 and 34 species, respectively, which indicates that there has been a loss of five fish species in the areas upstream of the dam and a gain of eight fish species below the dam when compared to the historic assemblage prior to 1975 as summarized above. This represents a shift in the diversity of fishes in the Root River and shows that fish species diversity has decreased in the areas above Horlick dam and increased in areas below the dam. In addition, the 1998-2004 surveys also show that the fish assemblages above the Horlick dam versus below the dam only shared 20 of the same fish species or about 44 percent of the total fish species recorded in the Root River watershed for that time period, which continues to demonstrate that these assemblages are fundamentally different. It is important to note that the increased diversity in the areas below the Horlick dam is due, in part, to the maintenance of the Root River Steelhead Facility managed by the Wisconsin Department of Natural Resources where coho salmon, chinook salmon, rainbow trout (steelhead), and brown trout are actively stocked (see Root River Steelhead Facility section below). Many of these stocked fishes periodically also migrate upstream of the Root River as far up as the dam,[9] which precludes any fish migration further upstream. This dam also prevents migration from upstream areas on the Root River to the lower reaches of Root River and Lake Michigan, and is potentially contributing to the maintenance of the reduced abundance and diversity of this fishery over time. This dam limits the Root River fishery by preventing both upstream and downstream immigration and emigration of fishes to and from Lake Michigan; preventing the ability of fishes to reach feeding areas, spawning areas, juvenile rearing habitat, and/or overwintering sites; and increasing the vulnerability of fishes to predation, especially in the downstream area spillway.[10]

In Wisconsin, high-quality warmwater streams are characterized by many native species, darters, suckers, sunfish, and intolerant species (species that are particularly sensitive to water pollution and habitat degradation).[11] Within such environments, tolerant fish species also occur that are capable of persisting under a wide range of degraded conditions and are also typically present within high-quality warmwater streams, but they do not dominate. Insectivores (fish that feed primarily on small invertebrates) and top carnivores (fish that feed on other fish, vertebrates, or large invertebrates) are generally common. Omnivores (fish that feed on both plant and animal material) are also generally common, but do not dominate. Simple lithophilous spawners which are species that lay their eggs directly on large substrate, such as clean gravel or cobble, without building a nest or providing parental care for the eggs are also generally common.

When applying the Index of Biotic Integrity (IBI) that is used to measure environmental quality in warmwater streams of Wisconsin, it is recommended that electrofishing gear be used as opposed to other techniques such as seining or fyke netting.[12] Table 163 summarizes all fish species found within both stream and lake systems by selected time periods throughout the entire Root River watershed from samples collected by a variety of gear types both known and unknown. Map 98 shows the location and quality of fisheries samples collected by all gear types for the Root River watershed from 1900 to 2004. Figure 258 shows the fisheries samples collected among rivers and creeks throughout the Root River watershed by selected time periods and their associated IBI scores among specific gear types that include the backpack electrofisher (generator carried on a backpack), stream electrofisher (generator towed by hand in the stream), boom electrofisher (generator located on a boat), seining, and an unknown category where gear type was not specified. Since different sampling gear types affect the type and amount of different fish species caught, the small-mesh seine, boom electrofisher, and unknown gear type categories were removed prior to computing IBI scores among each of the time periods. The backpack electrofishing and stream electrofishing gear types are both legitimate gear types when applying the fisheries IBI and these are the only gear types sampled most consistently among the selected time periods as shown in Figure 258. Therefore, only samples using backpack and stream electrofishing gear types were used to assess the fisheries community in the Root River watershed as summarized below.

Index of Biotic Integrity (IBI) results indicate that there has been an improvement in the quality of the fishery of the Root River watershed compared to the historical conditions moving from the very poor (IBI score 0-20) to a poor community IBI rating score of 20 to 30 based on mean IBI scores for each time period as shown in Figure 259. In addition, 25 percent of the current 1998-2004 time period samples were classified as fair and one

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[9]*James Thompson, Wisconsin Department of Natural Resources, Personal Communication to SEWRPC, 2004.*

[10]*Wisconsin Department of Natural Resources, PUBL WT-700-2002,* op. cit.

[11]*John Lyons, "Using the Index of Biotic Integrity (IBI) to Measure Environmental Quality in Warmwater Streams of Wisconsin," United States Department of Agriculture,* General Technical Report NC-149*, 1992.*

[12]*John Lyons, "Using the Index of Biotic Integrity (IBI) to Measure Environmental Quality in Warmwater Streams of Wisconsin," United States Department of Agriculture,* General Technical Report NC-149*, 1992.*

Map 98

FISHERIES SAMPLE LOCATIONS AND CONDITIONS WITHIN THE ROOT RIVER WATERSHED: 1900-2004

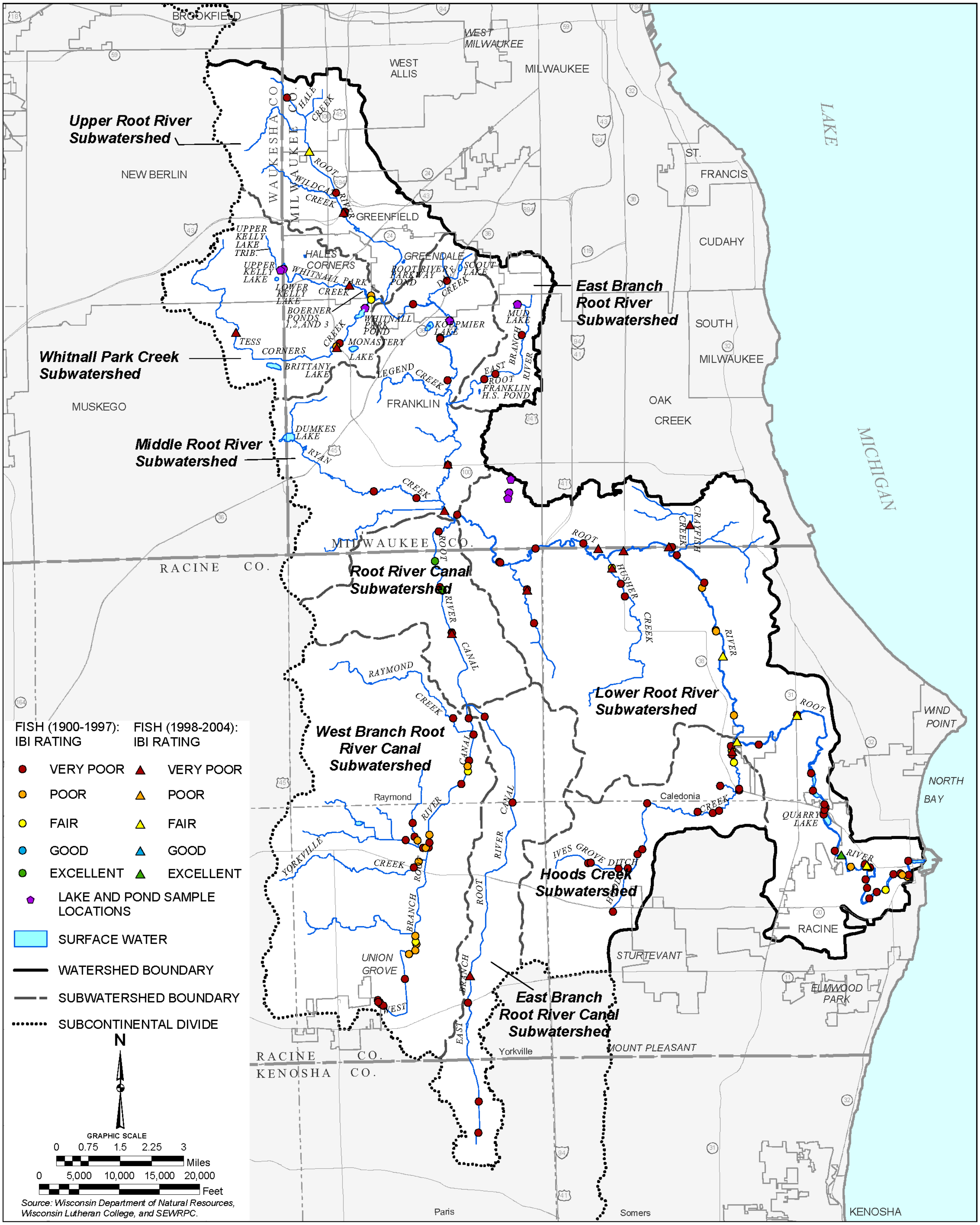
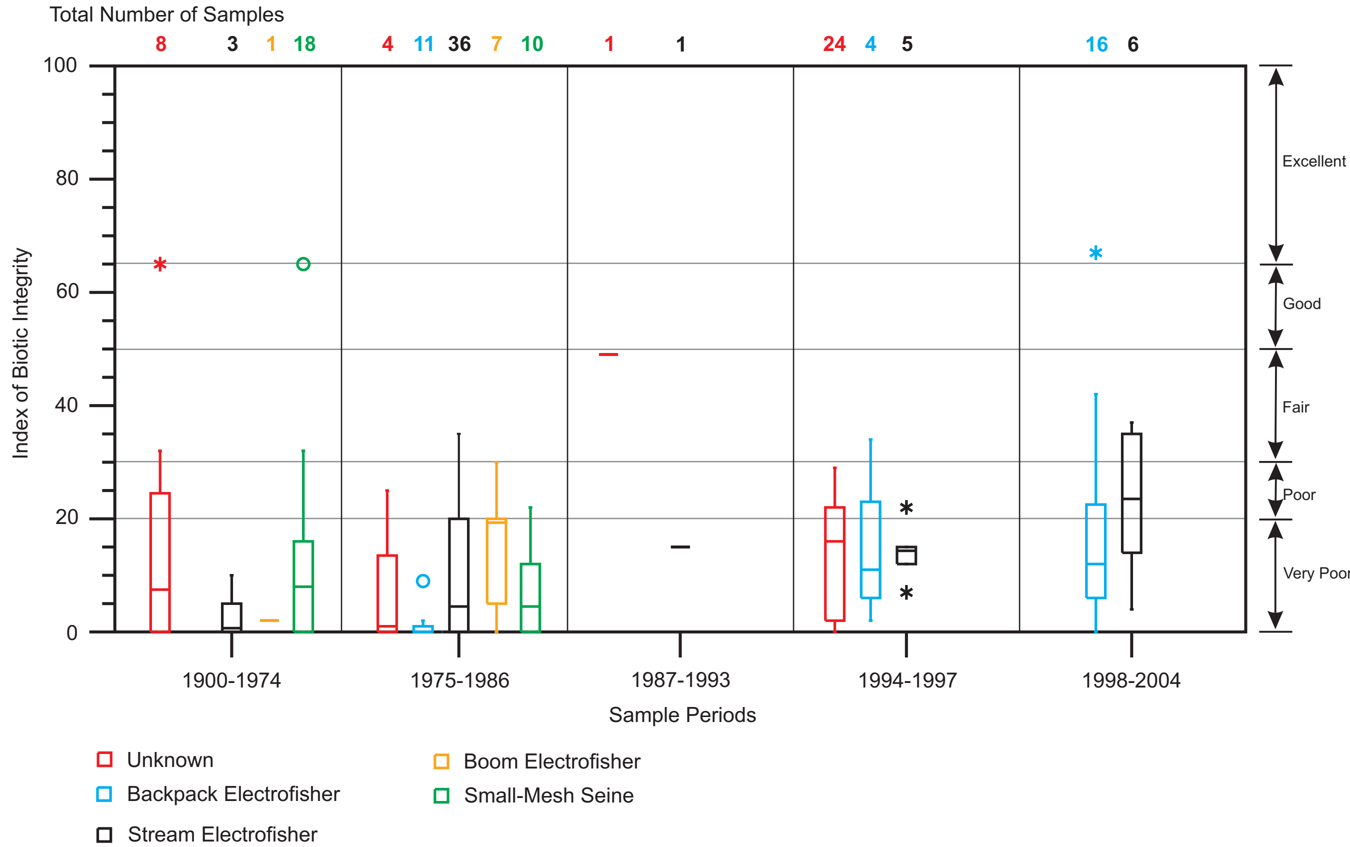


Figure 258

FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION BY GEAR TYPE IN THE ROOT RIVER WATERSHED: 1900-2004



NOTES: See Figure 227 for description of symbols.

One sample was collected using a Long Line Electrofisher; it is not shown in this gear-type comparison.

Source: Wisconsin Department of Natural Resources and SEWRPC.

sample contained an excellent IBI score. However, 75 percent of the samples in the current time period still remain classified within the very poor to poor categories, which indicate that the majority of the watershed contains a low abundance and diversity of fishes.

The Root River watershed fishery has become increasingly dominated by a high proportion of low dissolved oxygen tolerant fishes as shown in Figure 260 and Table 163, which is supported by dissolved oxygen problems identified in the water quality analysis above. Tolerant fish species tend to become dominant when water quality conditions become degraded that potentially leads to low levels of dissolved oxygen concentrations, increased levels of ammonia and other toxic substances, and/or high turbidity levels.[13] From 1975 to present, the most dominant fish species found in the Root River watershed have been the tolerant fish species white sucker, green sunfish, creek chub, black bullhead, bluntnose minnow, and common carp as shown in Table 163, which are a typical "urban" tolerant fishery assemblage.[14] Low dissolved oxygen concentrations and extreme high or low

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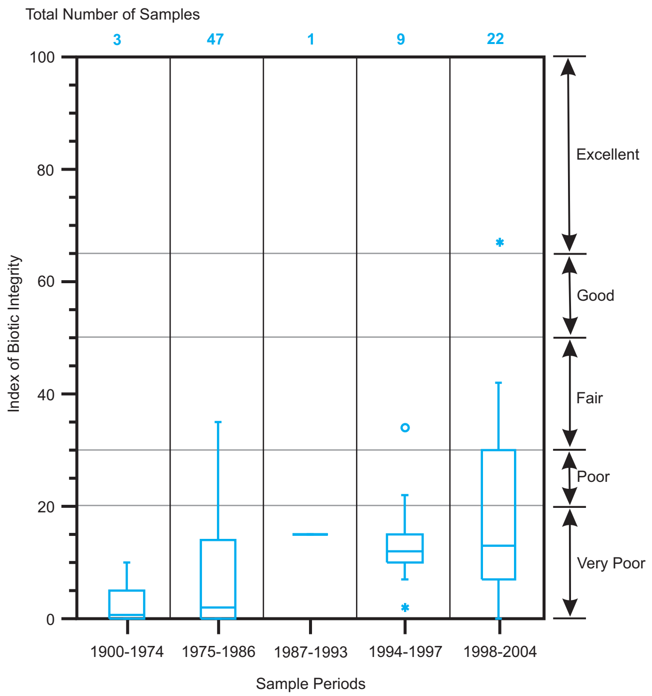
[13]*George Becker,* op. cit.

[14]*William Wawrzyn, Wisconsin Department of Natural Resources, Personal Communication to SEWRPC, 2004.*

Figure 259

FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION FROM BACKPACK AND STREAM ELECTROFISHING EFFORT IN THE ROOT RIVER WATERSHED: 1900-2004



NOTE: See Figure 227 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

temperature fluctuations have been identified to be the major factors negatively impacting the warmwater fishery on this system.[15] Carp, an exotic invasive species, are a dominant component of the fishery in this watershed and continue to have a negative effect on overall quality of this fishery by destroying habitat and competing for food and spawning areas of native fish species.

Although the proportions of tolerant species have been increasing over time, there has also been a concurrent increase in the proportion of top carnivore fish species, which is indicative of an improvement in the balance of predator fishes to forage fishes ratio in this system as shown in Figure 261. The top carnivore species also tend to be highly sought after gamefish species by anglers, which indicate that recreational fishing opportunities may be increasing. The top carnivore species responsible for this shift include the largemouth bass, northern pike, and black crappie (see Table 163).

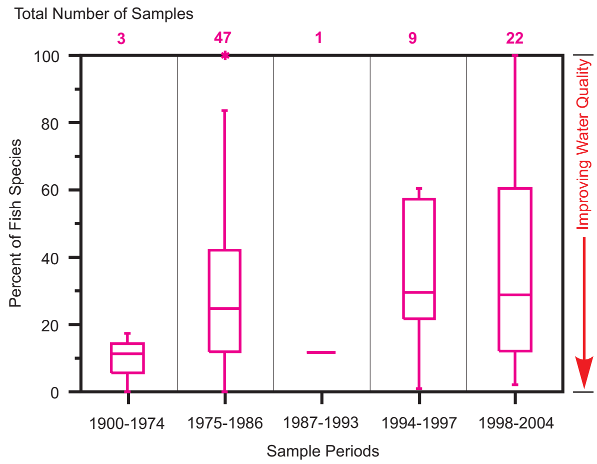
Results of the IBI scores by individual subwatersheds in the Root River indicates that the data are limited to assess the current fishery conditions within most of subwatersheds during the 1998 through 2004 period as shown in Figure 262. For example, the Upper Root River, East Branch of the Root River, East and West Branches of the Root River Canal, Root River Canal, and the Hoods Creek subwatersheds either have only one survey record or no data in the current time period (see Figure 262). The results for these subwatersheds generally indicate that their has been no improvement in the fishery community quality from the historic very poor IBI rating, with the possible exception of the Upper Root River subwatershed that shows an improvement to a fair IBI classification. However, data from the remaining subwatersheds indicates that nearly all of the improvement in the Root River fishery is located within the Lower Root River subwatershed where it achieves the highest quality community IBI scores of the entire Root River watershed. The Whitnall Park Creek and Middle Root River subwatersheds show no change from the historic very poor community IBI classification. Figure 262 demonstrates that, except for the Lower Root River subwatershed and possibly the Upper Root River subwatershed, each of these subwatersheds continues to sustain a limited fishery. It is important to note that the highest IBI scores within the Lower Root River subwatershed come from sites located downstream of the Horlick dam, which indicates that this portion of the subwatershed contains a much higher quality fishery than the areas upstream of the dam.

Further analysis of the Lower Root River subwatershed indicates that the proportions of insectivorous fishes have significantly increased from 1975 to 2004 as shown in Figure 263. This shift in the trophic structure in this subwatershed implies that there have been improvements in the diversity and abundance of the food base. This trophic shift also agrees with the macroinvertebrate community improvements in the Lower Root River

[15]*Wisconsin Department of Natural Resources, PUBL WT-700-2002,* op. cit.

Figure 260

PROPORTIONS OF DISSOLVED OXYGEN TOLERANT FISHES FROM BACKPACK AND STREAM ELECTROFISHING EFFORT IN THE ROOT RIVER WATERSHED: 1900-2004

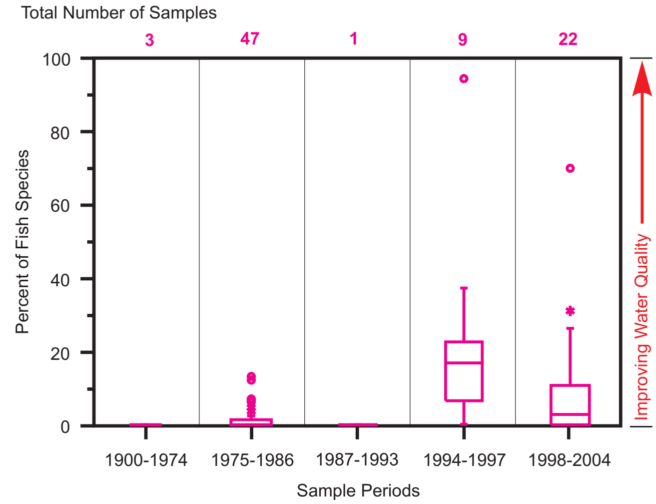


NOTE: See Figure 227 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 261

PROPORTIONS OF TOP CARNIVORES FROM BACKPACK AND STREAM ELECTROFISHING EFFORT IN THE ROOT RIVER WATERSHED: 1900-2004



NOTE: See Figure 227 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

subwatershed as summarized below. In addition, there have also been significant increases in the proportion of intolerant fish species and top carnivore species in this subwatershed, all of which are contributing to the improved fishery. However, as previously mentioned these improvements are largely influenced by the higher quality sites located below the Horlick dam.

The apparent stagnation of the majority of the fishery community within the Root River watershed can be attributed to habitat loss and degradation as a consequence of human activities primarily related to the historic and current agricultural and urban land use development that has occurred within the watershed. Agricultural and/or urban development can cause numerous changes to streams that have the potential to alter aquatic biodiversity that include but are not limited to the following factors which have been observed to varying degrees in the Root River watershed:[16]

- Increased flow volumes and channel-forming storms—These alter habitat complexity, change availability of food organisms related to timing of emergence and recovery after disturbance, reduce prey availability, increase scour related mortality, deplete large woody debris for cover in the channel, and accelerate streambank erosion;

- Decreased base flows—These lead to increased crowding and competition for food and space, increased vulnerability to predation, a decrease in habitat quality, and increased sediment deposition;

- Increased sediment load from cultivated agricultural lands and urban lands during and after construction of urban facilities, resulting in sediment transport and deposition in streams—This leads to

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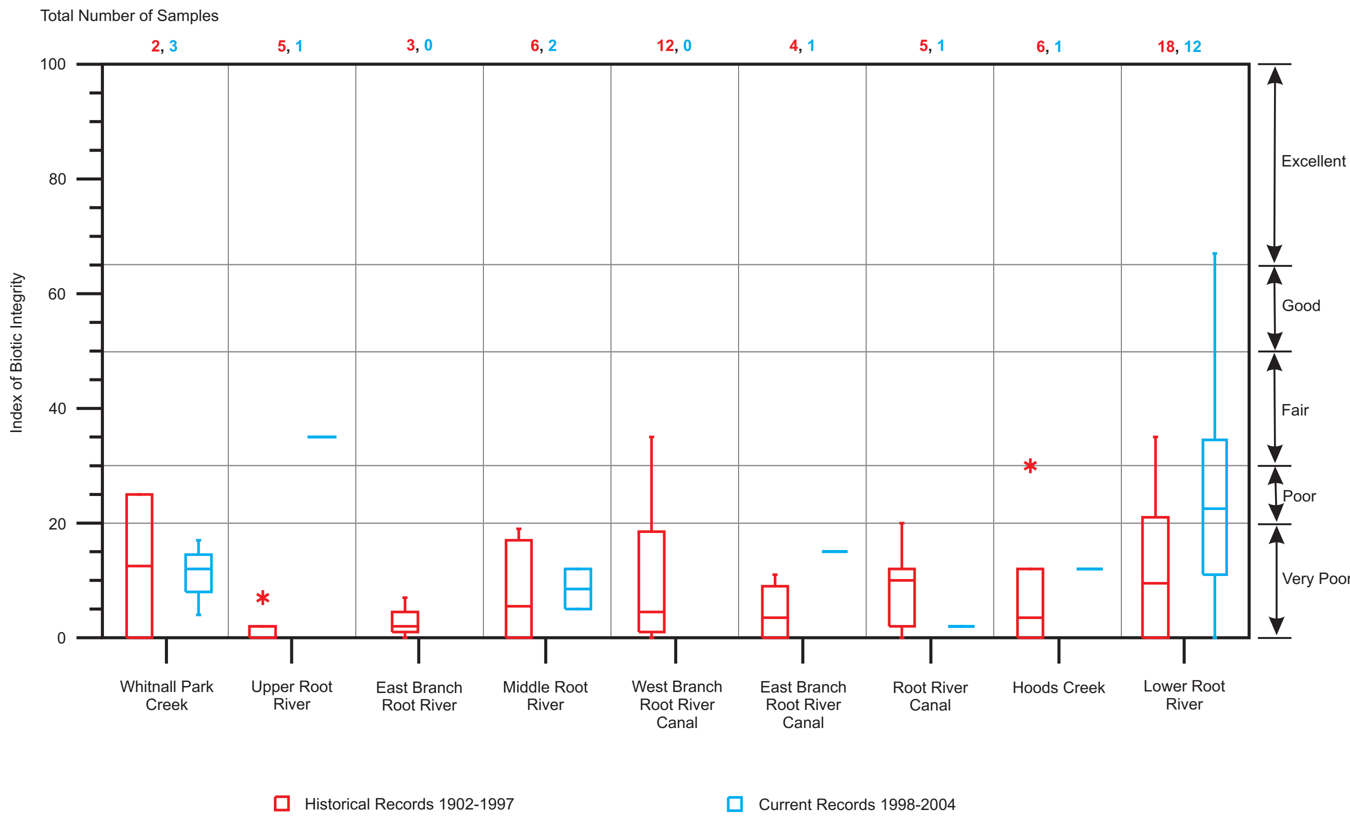
[16]*Center for Watershed Protection, "Impacts of Impervious Cover on Aquatic Systems,"* Watershed Protection Research Monograph No. 1*, March 2003.*

Figure 262

HISTORICAL AND BASE PERIOD FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION FROM BACKPACK AND STREAM ELECTROFISHING EFFORT IN STREAMS IN THE ROOT RIVER WATERSHED: 1900-2004



NOTE: See Figure 227 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

reduced survival of eggs, loss of habitat due to deposition, siltation of pool areas, and reduced macroinvertebrate reproduction;

- Loss of pools and riffles—This leads to a loss of deep water cover and feeding areas causing a shift in balance of species due to habitat changes;

- Changed substrate composition—This leads to reduced survival of eggs, loss of inter-gravel cover refuges for early life stages for fishes, and reduced macroinvertebrate production;

- Loss of large woody debris—This leads to loss of cover from large predators and high flows, reduced sediment and organic matter storage, reduced pool formation, and reduced organic substrate for macroinvertebrates;

- Increased temperatures due to loss of riparian buffers, as well as runoff from pavement versus natural landscapes—This leads to changes in migration patterns, increased metabolic activity, increased disease and parasite susceptibility, and increased mortality of sensitive fishes and macroinvertebrates;

- Creation of fish blockages by road crossings, culverts, drop structures, and dams—This leads to loss of spawning habitat, inability to reach feeding areas and/or overwintering sites, loss of summer rearing habitat, and increased vulnerability to predation;

- Loss of vegetative rooting systems—This leads to decreased channel stability, loss of undercut banks, and reduced streambank integrity;

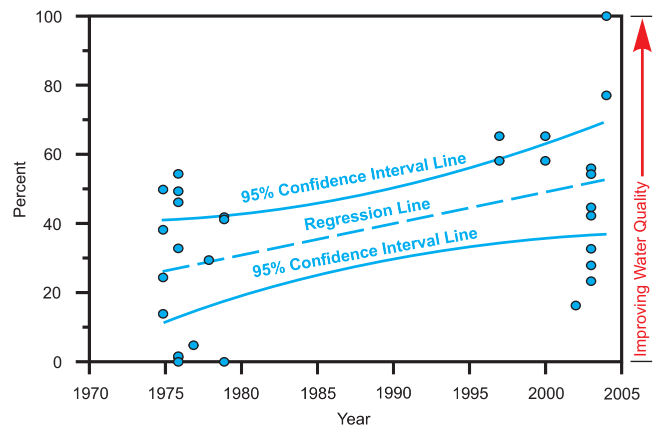
- Channel straightening or hardening—This leads to increased stream scour and loss of habitat quality and complexity i.e. width, depth, velocity, and substrate diversity) through disruption of sediment transport ability;

- Reduced water quality—This leads to reduced survival of eggs and juvenile fishes, acute and chronic toxicity to juveniles and adult fishes, and increased physiological stress;

- Increased turbidity—This leads to reduced survival of eggs, reduced plant productivity, and increased physiological stress on aquatic organisms;

Figure 263

PROPORTIONS OF INSECTIVOROUS FISHES IN THE LOWER ROOT RIVER SUBWATERSHED: 1975-2004



Source: Wisconsin Department of Natural Resources and SEWRPC.

- Increased algae blooms due to increased nutrient loading—Chronic algae blooms, resulting from increased nutrient loading, lead to oxygen depletion, causing fish kills, and to increased eutrophication of standing waters. These effects can be worsened through encroachment into the riparian buffer adjacent to the waterbody and loss of riparian canopy which increases light penetration.

Chapter II of this report includes a description of the correlation between urbanization in a watershed and the quality of the aquatic biological resources. The amount of imperviousness in a watershed that is directly connected to the stormwater drainage system can be used as a surrogate for the combined impacts of urbanization in the absence of mitigation. The Root River watershed included about 17 percent urban land use by 1970, which approximately corresponds to about 5 percent directly connected imperviousness in the watershed, and, as of 2000, it has about 27 percent urban land overall (approximately 10 percent directly connected imperviousness). That level of imperviousness is right at the threshold level of 10 percent at which previously cited studies indicate that negative biological impacts have been observed. However, given the pattern of development in the upper portions of this watershed the Whitnall Park Creek, Upper Root River, and East Branch of the Root River subwatersheds currently contain about 62 to 85 percent urban land use, which approximately corresponds to about 20 to 30 percent directly connected imperviousness. These localized areas upstream are well above the threshold level of 10 percent where negative biological impacts are expected. As also described in Chapter II of this report, studies have indicated that the amount of agricultural land in a watershed can also be correlated with negative instream biological conditions. The Root River watershed was comprised of about 62 percent agricultural land use by 1970 and it currently has about 51 percent agricultural land overall. Agricultural land use has dominated the lower portion of the Root River watershed, whereas the upper portions of the watershed have been dominated by urban development with the exception of localized urban development near the lower portion of the Lower Root River subwatershed. Based upon the amount of agricultural and urban lands in the watershed and, in the past, a lack of measures to mitigate the adverse effects of those land uses, the resultant poor to very poor IBI scores observed throughout this watershed are not surprising. Consequently, the Wisconsin Department of Natural Resources has recently concluded that quality of the fishery remains impaired throughout the Root River watershed primarily due to the impacts of heavy metal toxicity, eutrophication and flow modifications.[17] The

[17] *Wisconsin Department of Natural Resources, PUBL WT-700-2002,* op. cit.

possible exception to this general condition is the Lower Root River subwatershed, which currently contains a higher quality fishery than the upstream portions of the watershed, although there are similar levels of toxicants in sediments and fishes in this reach.

The standards and requirements of Chapter NR 151 "Runoff Management," and Chapter NR 216, "Storm Water Discharge Permits," of the *Wisconsin Administrative Code* are intended to mitigate the impacts of existing and new urban development and agricultural activities on surface water resources through control of peak flows in the channel-forming range, promotion of increased baseflow through infiltration of stormwater runoff, and reduction in sediment loads to streams and lakes. The implementation of those rules is intended to mitigate, or improve, water quality and instream/inlake habitat conditions.

As shown on Map 99, habitat data have been collected as part of the WDNR baseline monitoring program and by the WDNR Fish and Habitat Research Section in the Root River watershed. The baseline monitoring program data were analyzed using the Qualitative Habitat Evaluation Index (QHEI),[18] which integrates the physical parameters of the stream and adjacent riparian features to assess potential habitat quality. This index is designed to provide a measure of habitat that generally corresponds to those physical factors that affect fish communities and which are important to other aquatic life (i.e. macroinvertebrates). This index has been shown to correlate well with fishery IBI scores. The habitat data from the WDNR Research Section evaluated the quality of fish habitat at sites based upon the guidelines developed from several publications.[19] Based upon the limited data available, the results suggest that fisheries habitat is generally fair to good-very good throughout the Root River watershed as shown on Map 99. Comparing these results with previous reported qualitative habitat assessments suggests that habitat quality may have improved in some areas of the watershed.[20] However, since there are no data available to compare specific locations over time it is not possible to definitively assess changes in habitat conditions. It is important to note that the majority of the streams have been channelized within the Root River watershed. Such channelization impacts habitat quality by reducing instream and riparian vegetation cover, increasing sedimentation, decreasing diversity of flow, decreasing water depths, and decreasing substrate diversity, among others. Consequently, despite the habitat classification of fair to good-very good, the WDNR has recently concluded that instream habitat is impaired in nearly every reach of the Root River watershed primarily due to the impacts of hydrologic modification, stream flow fluctuations caused by unnatural conditions, stream bank erosion, urban storm water runoff, cropland erosion, and roadside erosion emanating from both agricultural and urban land use areas of this watershed.[21]

Root River Steelhead Facility

The Root River Steelhead Facility (RRSF) is one of three weirs operated by the Wisconsin Department of Natural Resources (WDNR) to collect information and broodstock from Lake Michigan trout and salmon. Each fall and spring, migrating chinook salmon, coho salmon, brown trout and rainbow trout (steelhead) enter the streams as part of their spawning ritual. Because successful natural reproduction of trout and salmon does not occur in Wisconsin waters, the fishery is entirely dependent upon hatchery-raised fish. This facility is Wisconsin's primary source of steelhead eggs and brood (parent) stock, and is the backup facility for the collection of eggs of other

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[18]*Edward T. Rankin, The Quality Habitat Evaluation Index [QHEI]: Rationale, Methods, and Application, State of Ohio Environmental Protection Agency, November 1989.*

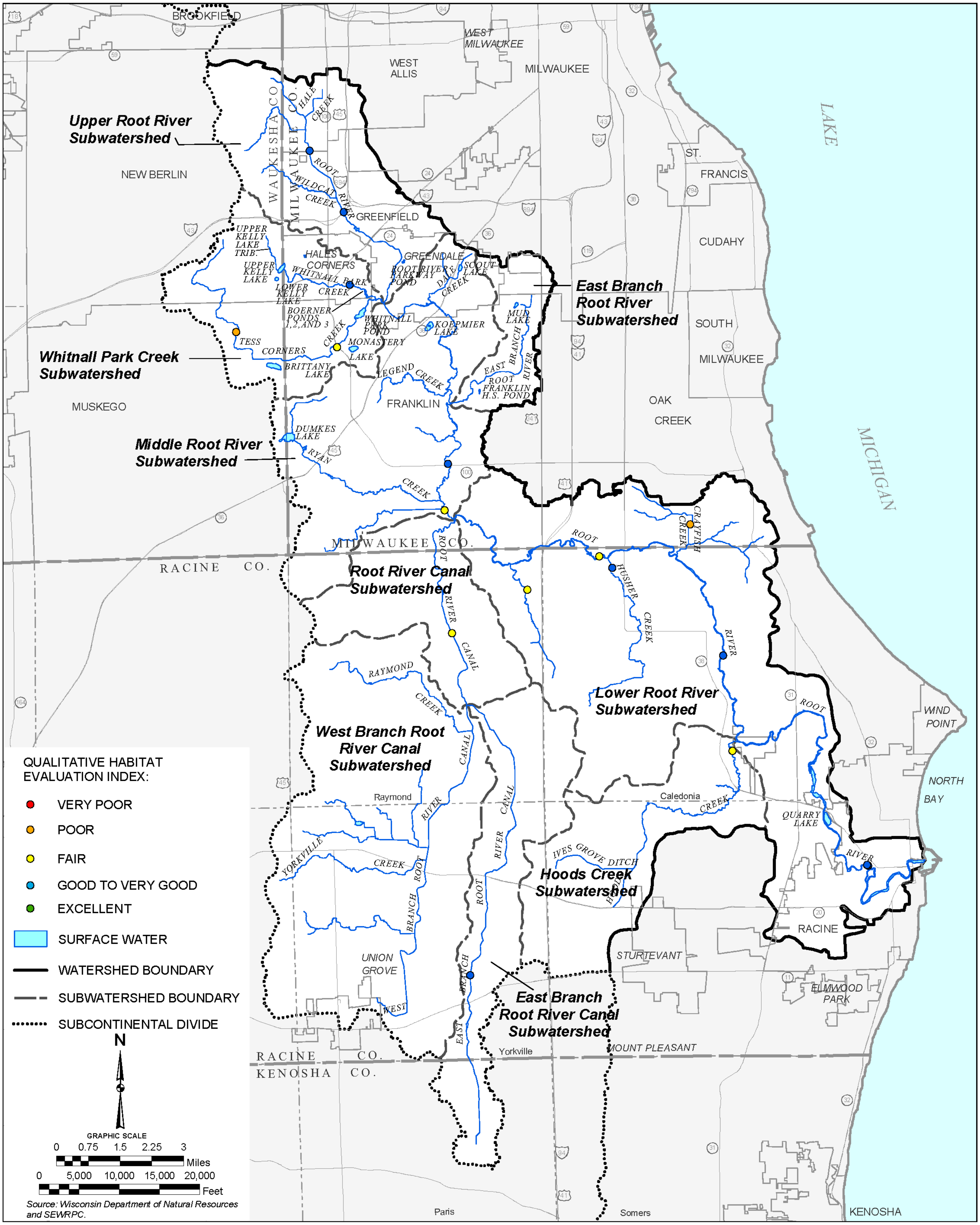
[19]*Timothy Simonson, John Lyons, and Paul Kanehl, "Guidelines for Evaluating Fish Habitat in Wisconsin Streams,"* General Technical Report NC-164*, 1995; and Lihzu Wang, "Development and Evaluation of a Habitat Rating System for Low-Gradient Wisconsin Streams,"* North American Journal of Fisheries Management*, Vol. 18, 1998.*

[20]*Wisconsin Department of Natural Resources, PUBL WR-298-92,* op. cit.

[21]*Wisconsin Department of Natural Resources, PUBL WT-700-2002,* op. cit.

Map 99

STREAM HABITAT SAMPLE LOCATIONS AND CONDITIONS WITHIN THE ROOT RIVER WATERSHED: 2000-2004



Source: Wisconsin Department of Natural Resources and SEWRPC.

trout and salmon species. The Strawberry Creek Weir in Sturgeon Bay targets chinook salmon, while the Besadny Area Fishery Facility (BAFF) on the Kewaunee River targets coho salmon and steelhead and the RRSF contributes primarily steelhead and coho. In addition, BAFF and RRSF function as backup collection sites for the other species. Management of trout and salmon in Lake Michigan brood rivers is intended to ensure adequate egg collections, conserve the genetic diversity of feral trout and salmon stocks and provide fishing opportunities. To accomplish these objectives, weir operations follow strategies outlined by WDNR guiding documents.[22] (e.g., Ives 1996, WDNR 1999).

The weirs provide a more efficient and reliable method to collect adult salmonids than the portable weirs and electrofishing efforts employed during past years. The RRSF was constructed in 1994 through a cooperative effort by WDNR, Salmon Unlimited, City of Racine and U.S. Fish & Wildlife Service. In addition to providing a collection and processing site for returning adult salmonids, the RRSF provides a unique educational tool for school groups and other interested publics.

The data collected at the RRSF contribute to a long-term index of chinook, coho and steelhead populations in the Root River to track the abundance of salmonid returns, measure growth and condition of each species and/or strain, and estimate return rate of each species. These data are collected to assess short-term and long-term overall health of the fish, growth rates, migration patterns and other important information to help learn more about the fishery.

Spring and fall in 2004 were dry seasons in southeastern Wisconsin, resulting in a weak run of salmon and brown trout into the Root River as shown in Figure 264.[23] The Root River is a flashy stream system, and the relative abundance of all the species of migrating salmonids as shown in Figure 264 is largely dependent upon river level fluctuations. Hypothetically, if discharge was constant throughout either spring or fall seasons, the difference between those population estimate numbers would most likely be statistically insignificant.[24] Alewives are the main forage fishes for salmon, and although alewife species abundances have declined in Lake Michigan, there has been no corresponding decrease in the abundance of either chinook or coho salmon to date. In fact, the population of chinook has increased in spite of recent stocking reductions, due to the influx of naturally reproduced fish on the Michigan side. The States of Wisconsin, Michigan, Illinois, and Indiana have agreed to reduce chinook stocking again by 25 percent to compensate for the naturally reproducing fish. The drop in the forage base for both chinook and coho is likely negatively impacting the condition factor and growth rates of both species.

Lakes and Ponds

There are no major lakes (i.e. lakes greater than 50 acres in size) within the Root River watershed, but there are several lakes and ponds within the watershed as listed in Table 164.

The last recorded fishery survey for the North Golf Course Ponds, Mud Lake, Root River Parkway Pond, and Whitnall Park Pond were completed in 1981. The surveys indicate that that these waterbodies contained a typical urban fish species mixture mostly dominated by tolerant species of green sunfish, black bullhead, central mudminnow, carp, and white sucker. However, largemouth bass and pumpkinseed were also recorded to occur in several of these ponds. Additional information from WDNR staff indicate that Koepmier Lake, Monastery Lake,

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[22]*D. Ives, Wisconsin Department of Natural Resources, Anadromous feral broodstock protocol, 1996; and Wisconsin Department of Natural Resources,* Lake Michigan steelhead fisheries management plan 1999*, Administrative Report 44, 1999.*

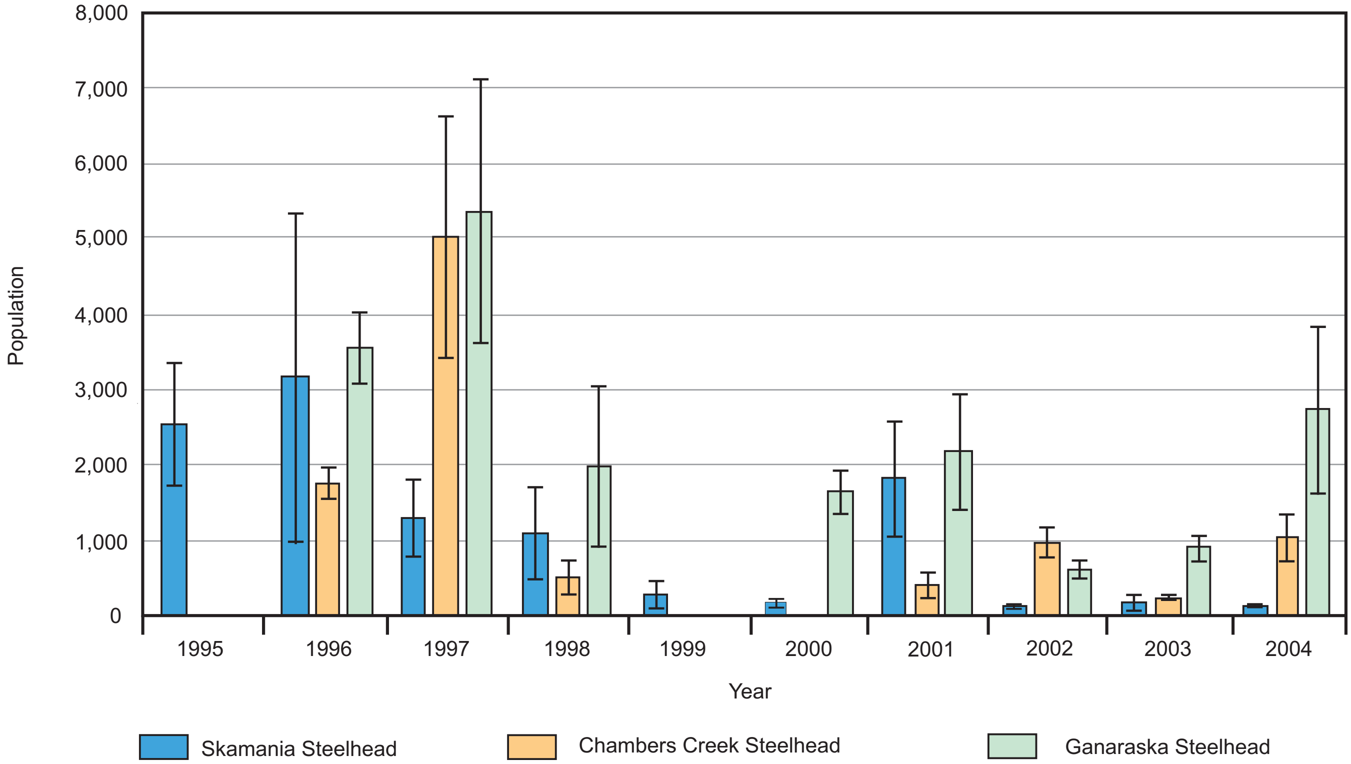
[23]*Jim Thompson and Brad Eggold, Wisconsin Department of Natural Resources,* Root River Steelhead Facility Fall 2004 and Spring 2005*, August 2005.*

[24]*James Thompson, Wisconsin Department of Natural Resources, Personal Communication to SEWRPC, 2006.*

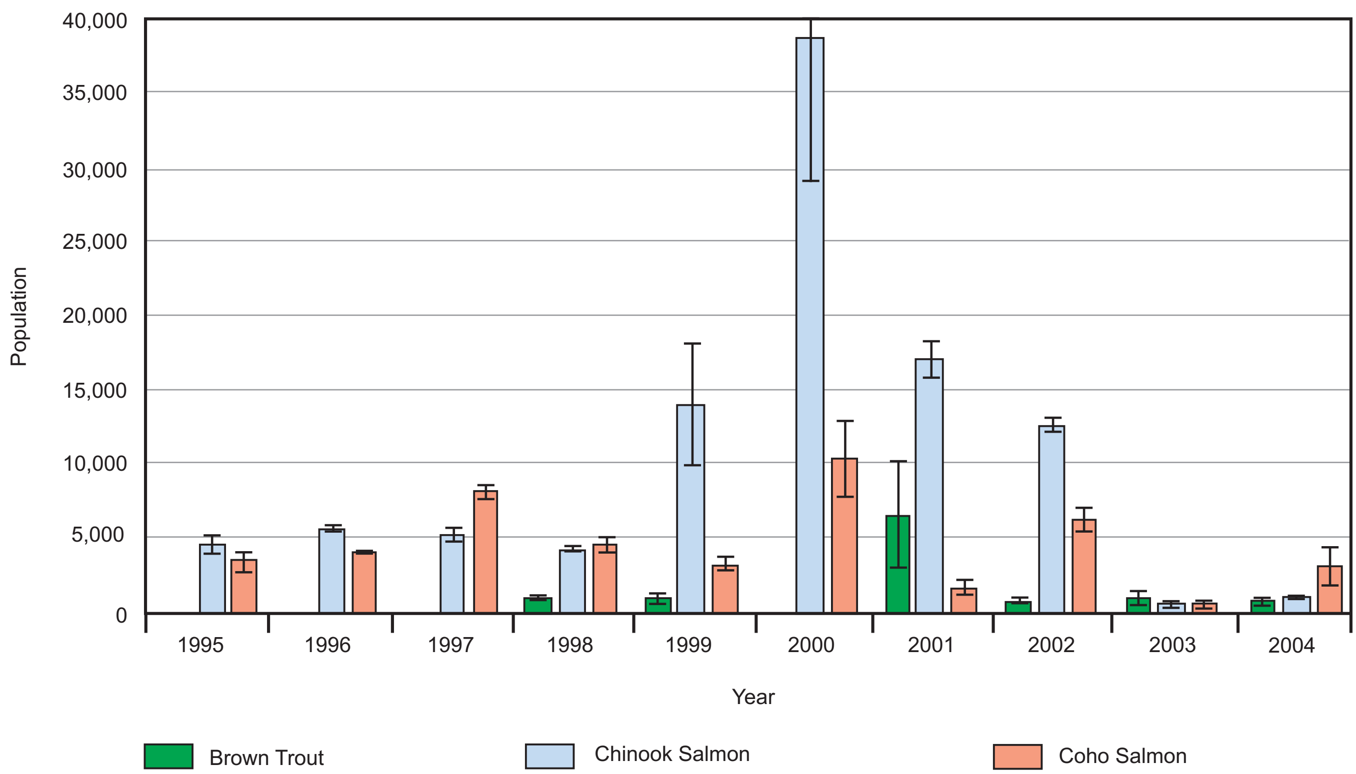
Figure 264

POPULATION ESTIMATES OF FISH STOCKED IN THE ROOT RIVER: 1995-2004

STEELHEAD POPULATION ESTIMATES PER YEAR



SALMON AND BROWN TROUT POPULATION ESTIMATES PER YEAR



Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 164

FISH AND EXOTIC SPECIES IN LAKES AND PONDS IN THE ROOT RIVER WATERSHED

Name	Northern Pike	Largemouth Bass	Panfish	Catfish	Carp	Zebra Mussel	Eurasian Water Milfoil	Curly-Leaf Pondweed
Boerner Botanical Garden Pond No. 1	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Boerner Botanical Garden Pond No. 2	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Boerner Botanical Garden Pond No. 3	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Dumkes Lake	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Franklin High School Pond	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Koepmier Lake	Present	Present	Abundant	- -	- -	- -	- -[a]	- -[a]
Lake Brittany	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Lower Kelly Lake		Present	Abundant	- -	- -	- -	Present	- -[b]
Monastery Lake	Present	Common	Abundant	- -	- -	- -	- -[a]	- -[a]
Mud Lake	- -	- -	Present	- -	- -	- -	- -[a]	- -[a]
North Golf Course Pond No. 1	- -	- -	Present	- -	- -	- -	- -[a]	- -[a]
North Golf Course Pond No. 2	- -	Present	Present	Present	- -	- -	- -[a]	- -[a]
North Golf Course Pond No. 3	- -	- -	Present	Present	- -	- -	- -[a]	- -[a]
Quarry Lake	- -	- -	- -	- -	- -	Present	- -[a]	- -[a]
Root River Parkway Pond	- -	- -	Present	Present	Common	- -	- -[a]	- -[a]
Scout Lake	Present	Common	Abundant	- -	- -	- -	Present	- -[a]
Shoetz Park Pond	- -	- -	- -	- -	- -	- -	- -[a]	- -[a]
Upper Kelly Lake	Present	Present	Abundant	Present	- -	- -	Present	Present
Whitnall Park Pond (Mallard Lake)	- -	Present	Present	Present	Present	- -	- -[a]	- -[a]

[a]*These aquatic exotic, invasive plant species are known to occur in the counties that these lakes are found, but there is no data to confirm their presence in the waterbody.*

[b]*An aquatic plant survey conducted in 2005 showed no Eurasian water milfoil was present in Lower Kelly Lake.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Lower and Upper Kelly Lakes, Mud Lake, North Golf Course Ponds, Root River Parkway Ponds, Scout Lake, and Whitnall Park Pond all provide various recreational fishing opportunities for gamefish and/or panfish species which indicates that they may support some limited natural fishery.

Quarry Lake and Scout Lake are enrolled in the Wisconsin Department of Natural Resources' Urban Fishing Program in partnership with Milwaukee County. That program was initiated in 1983 for the metropolitan Milwaukee area and is still active today. The program provides fishing in urban ponds for anglers who do not have opportunities to leave the urban environment. The program stocks rainbow trout and other species to provide seasonal and year-round fishing.

Table 164 also shows that exotic invasive species have been recorded in several lakes and ponds within the Root River watershed. Carp are present and common in the Whitnall Park Pond and Root River Parkway Pond, respectively. Zebra mussels have only been recorded in Quarry Lake. While data on aquatic plant communities are limited (see Table 165), Eurasian water milfoil is known to exist in Upper and Lower Kelly Lakes and Scout Lake, and curly-leaf pondweed is known to exist in Upper Kelly Lake.

Macroinvertebrates

The Hilsenhoff Biotic Index[25] (HBI) and percent EPT (percent of families comprised of Ephemeroptera, Plecoptera, and Trichoptera) were used to classify the historic and existing macroinvertebrate and environmental quality in this stream system using survey data from various sampling locations in the Root River watershed.

[25]*William L. Hilsenhoff,* Rapid Field Assessment of Organic Pollution with Family-Level Biotic Index*, University of Wisconsin- Madison, 1988.*

Table 165

FREQUENCY OF OCCURRENCE OF AQUATIC PLANT SPECIES IN UPPER AND LOWER KELLY LAKES: 2005

Plant Genus and Species	Plant Common Name	Relative Frequency of Occurrence (percent)[a] Upper Kelly	Relative Frequency of Occurrence (percent) Lower Kelly	Ecological Significance[b]
Ceratophyllum demersum	Coontail	97.7	100.0	Provides good shelter for young fish and supports insects valuable as food for fish and ducklings
Chara vulgaris	Muskgrass	0.0	12.5	Excellent producer of fish food, especially for young trout, bluegills, small and largemouth bass, stabilizes bottom sediments, and has softening effect on the water by removing lime and carbon dioxide
Elodea canadensis	Waterweed	5.0	0.0	Provides shelter and support for insects which are valuable as fish food
Lemna minor	Lesser duckweed[c]	Present	Present	Provides important food for waterfowl and attracts small aquatic animals
Myriophyllum spicatum	Eurasian water milfoil[d]	50.0	0.0	Exotic invasive plant species that can lead to a decrease in native aquatic plant community abundance and diversity, but it can provide cover for invertebrates and forage fish species
Myriophyllum sp.	Native milfoil	59.1	4.2	Provides valuable food and shelter for fish; fruits eaten by many wildfowl
Nuphar sp.	Yellow water lily[c]	Present	Present	Leaves, stems, and flowers are eaten by deer; roots eaten by beaver and porcupine; seeds eaten by wildfowl; leaves provide harbor to insects, in addition to shade and shelter for fish
Nymphaea tuberosa	White water lily[c]	Present	Present	Provides shade and shelter for fish; seeds eaten by wildfowl; rootstocks and stalks eaten by muskrat; roots eaten by beaver, deer, moose, and porcupine
Potamogeton amplifolius	Large-leaf pondweed	0.0	20.8	Provides cover for panfish, largemouth bass, muskellunge, and northern pike; nesting grounds for bluegill; supports insects valuable as food for fish and ducklings
Potamogeton crispus	Curly-leaf pondweed	38.6	0.0	Provides food, shelter, and shade for some fish and food for waterfowl
Potamogeton foliosus	Leafy pondweed	0.0	29.2	Provides valuable food for geese and ducks; grazed by muskrat, deer, beaver, and moose; good surface area for invertebrates and cover for young fish
Potamogeton natans	Floating-leaf pondweed	0.0	12.5	Provides valuable grazing for ducks and geese. Portions eaten by muskrat, beaver, deer, and moose; provides shade and food for fish
Potamogeton pectinatus	Sago pondweed	4.5	29.2	This plant is the most important pondweed for ducks, in addition to providing food and shelter for young fish
Potamogeton zosteriformis	Flat-stemmed pondweed	0.0	41.6	Provides some cover for bluegills, perch, northern pike, and muskellunge; food for waterfowl; supports insects valuable as food for fish and ducklings
Typha augustafolia	Cattail[c]	Present	Present	Supports insects; stalks and roots important food for muskrat and beaver; attracts marsh birds, wildfowl, and songbirds, in addition to being used as spawning grounds by sunfish and shelter for young fish
Utricularia vulgaris	Common bladderwort	0.0	16.6	Free floating plant that can provide needed fish habitat in areas not easily colonized by rooted plants; provides food and cover for fish

[a]*Maximum equals 100 percent.*

[b]*Information obtained from Norman C. Fassett, A Manual of Aquatic Plants, Wisconsin Department of Natural Resources,* Guide to Wisconsin Aquatic Plants, *and Wisconsin Lakes Partnership,* Through the Looking Glass…A Field Guide to Aquatic Plants*, 1997.*

[c]*Not measurable using the Jesson and Lound Survey Technique for Submersed Aquatic Plants.*

[d]*Section NR 109.07, "Designated Invasive and Nonnative Aquatic Plant."*

Source: SEWRPC.

When applying the HBI that is used to measure the amount of organic pollution in warmwater streams of Wisconsin, it is recommended that a similar type of gear be used as well as similar type of habitat be sampled. Analysis of the macroinvertebrate data in the Root River watershed indicates that a D-Frame kick net was the only gear type used to sample these organisms, which indicates that there is sampling consistency among all sites. In contrast, there have been a variety of habitat types sampled within the Root River watershed as shown in Figure 265. Figure 265 shows that riffle habitats contain the highest quality macroinvertebrate communities compared to pool, run, or snag habitats in the Root River. Habitat types such as pools, riffles, and runs generally contain very different compositions of substrates, water depths, and flows, which greatly affects the abundance and diversity of the associated macroinvertebrate community. Hence, the HBI procedures recommend that macroinvertebrate communities be samples from shallow fast flowing riffle habitats, and that samples from pools or under the stream banks should not be used.[26] Therefore, only samples from riffle habitats were used to assess the macroinvertebrate community in the Root River watershed as summarized below.

Macroinvertebrate surveys conducted from 1979 through 2004 by the WDNR show that HBI scores generally range from poor-fairly poor (HBI score 6.51-8.5) to good-very good (HBI score 3.51-5.5) in the Root River watershed (see Figure 266 and Map 100). Figure 266 also shows that there have been substantial improvements in the macroinvertebrate community quality over time. Results generally indicate that current macroinvertebrate diversity and abundances are indicative of fair to good-very good water quality in the Root River watershed; which was based upon 32 samples collected during the 1998 through 2004 time period that were well distributed along the Root River from upstream to downstream. From 1975 to present the average total number of genera has increased, but the number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) genera have not changed as shown in Figure 267. This indicates that the diversity of macroinvertebrates has been improved by the addition of organisms not within the EPT genera. In addition, percent dominance of the top five families has been decreasing as shown in Figure 268, which is another indication that there is a long-term improvement in the abundance and diversity of macroinvertebrates.[27]

Results of the HBI scores and percent EPT by individual subwatersheds in the Root River indicates that the data are limited to assess the current macroinvertebrate community conditions within most of subwatersheds during the 1998 through 2004 period as shown in Figures 269 and 270. For example, the Upper Root River, East Branch of the Root River, Middle Root River, West Branch of the Root River Canal, Root River Canal, and the Hoods Creek subwatersheds either have only one survey record or no data in the current time period (see Figure 269). The EPT results indicate that there have been no improvement among subwatersheds for these genera (see Figure 270. The HBI results for these subwatersheds generally indicate that there has been no improvement in the macroinvertebrate community quality from the historic poor-fairly poor to fair HBI rating. However, data from the remaining subwatersheds indicates that nearly all of the improvement in the Root River fishery is located within the Lower Root River subwatershed where it achieves some of the highest quality community HBI scores of the entire Root River watershed. The East Branch of the Root River Canal subwatershed shows no change from the historic poor-fairly poor community HBI classification. In contrast, the Whitnall Park Creek subwatershed continues to remain the highest quality subwatershed and shows no change from the historic good-very good community HBI classification. Figure 269 demonstrates that, except for the Lower Root River and Whitnall Park Creek subwatersheds that rank as good to very good, each of these subwatersheds continues to sustain a poor to fair macroinvertebrate community.

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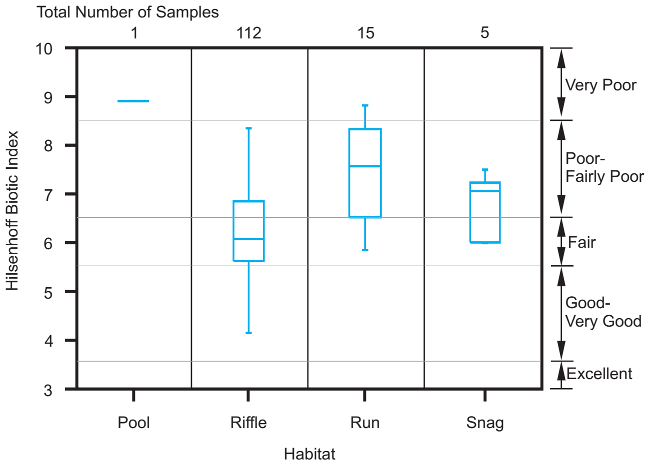
[26]*William L. Hilsenhoff, "An Improved Biotic Index of Organic Stream Pollution,"* The Great Lakes Entomologist*, Volume 20, 19887.*

[27]*M.T. Barbour, J. Gerritsen, B.D. Snyder, and J.B. Stribling, Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition, EPA 841-B-99-002, U.S. Environmental Protection Agency, Office of Water, Washington, D.C., 1999.*

Figure 265

HILSENHOFF BIOTIC INDEX (HBI) MACROINVERTEBRATE SCORES AMONG HABITAT TYPES IN THE ROOT RIVER WATERSHED: 1975-2004



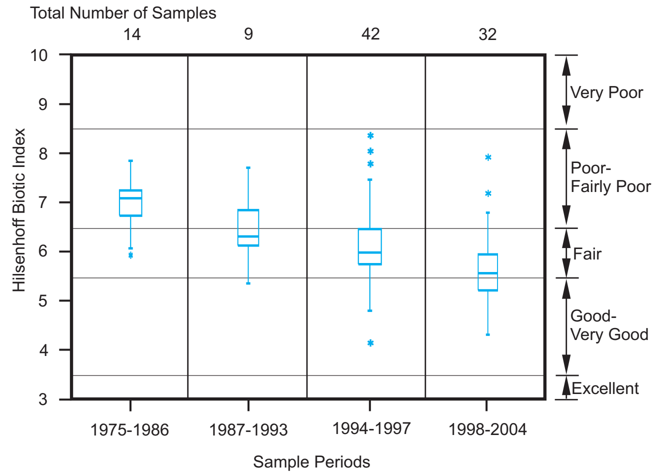
NOTES: See Figure 227 for description of symbols.

Eight cases had no habitat classification and so were not included.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 266

HILSENHOFF BIOTIC INDEX (HBI) MACROINVERTEBRATE SCORES WITHIN RIFFLE HABITATS IN THE ROOT RIVER WATERSHED: 1975-2004



NOTES: See Figure 227 for description of symbols.

Sorted by riffle habitat and gear type (D-Frame Net).

Source: Wisconsin Department of Natural Resources and SEWRPC.

Further analysis of the Lower Root River subwatershed indicates that the proportions of collectors have significantly decreased from 1979 to 2004 as shown in Figure 271. This shift in the trophic structure in this subwatershed implies that there have been improvements in water quality. Similarly, there have been significant increases in the proportions of scrapers and shredders. A description of the collectors, scrapers, and shredders can be found in Chapter II of this report. Each of these patterns are consistent with improvements in water quality and may be related to a decrease in organic or inorganic pollution, decrease in nutrients, improvements in dissolved oxygen concentrations, decreases in heavy metals or some other toxic contaminant. This trophic shift also agrees with the fishery community improvements in the Lower Root River subwatershed as summarized above.

Wisconsin researchers have generally found that as the amount of human land disturbance increases, such as in the Root River watershed, the subsequent macroinvertebrate community diversity and abundance decreases, which is generally supported by the data for this watershed.[28] The Lower Root River and Whitnall Park Creek subwatersheds again are an exception to this generalization. This may be a function of the extensive system of parklands adjacent to these reaches (see Habitat and Riparian Corridor Conditions section below) which provides significant buffering capacity and help reduce pollutant loadings and other human disturbances.

Synthesis

With the possible exception of the Lower Root River and Whitnall Park Creek subwatersheds, the watershed of the Root River in general contains a very poor fishery and poor to fair macroinvertebrate communities at present. The fish community contains a fair abundance of species of fishes, but is trophically unbalanced, contains few or

[28] *J. Masterson and R. Bannerman, "Impact of Stormwater Runoff on Urban Streams in Milwaukee County, Wisconsin," Wisconsin Department of Natural Resources, Madison, Wisconsin, 1994.*

Map 100

MACROINVERTEBRATE SAMPLE LOCATIONS AND CONDITIONS WITHIN THE ROOT RIVER WATERSHED: 1979-2003

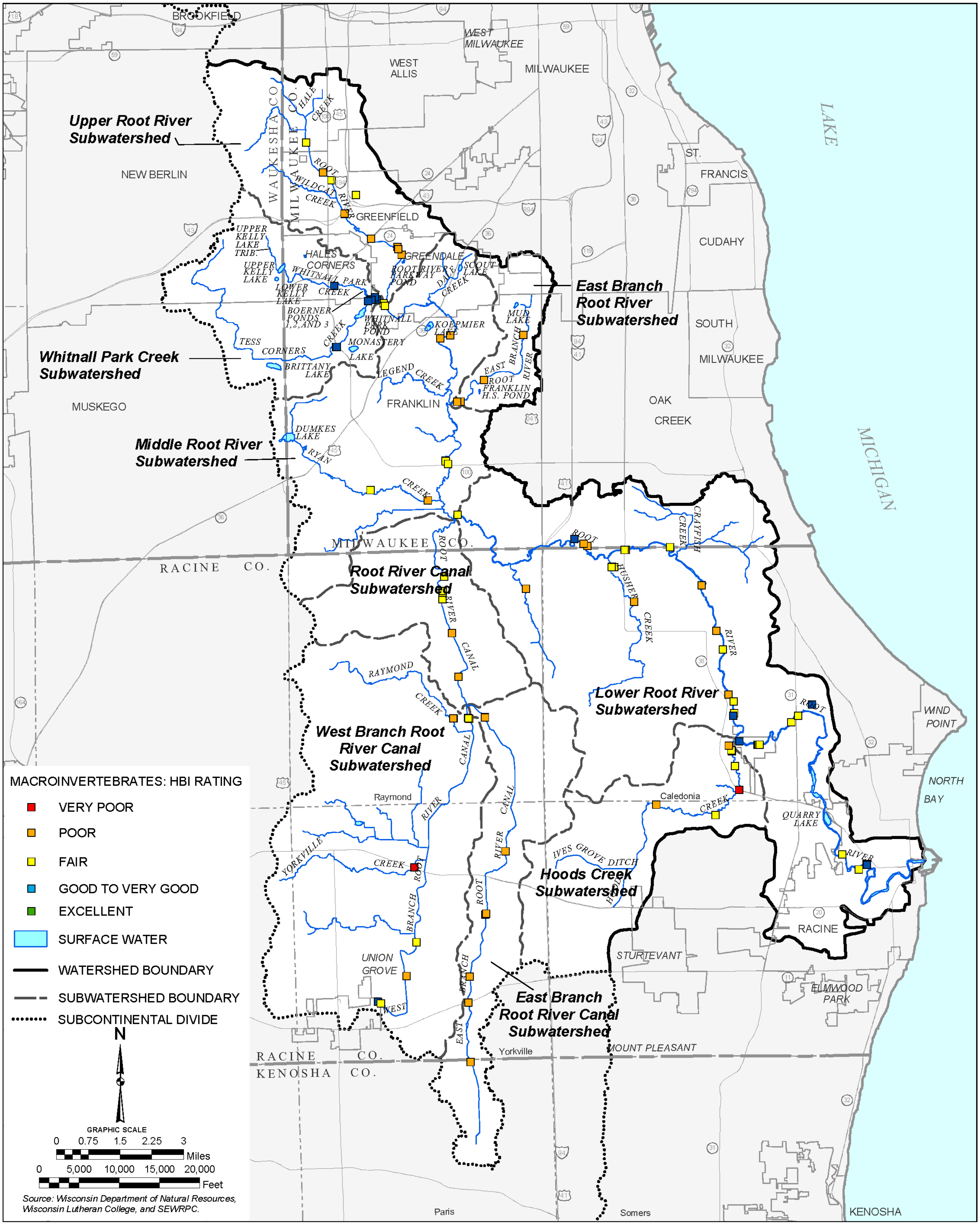
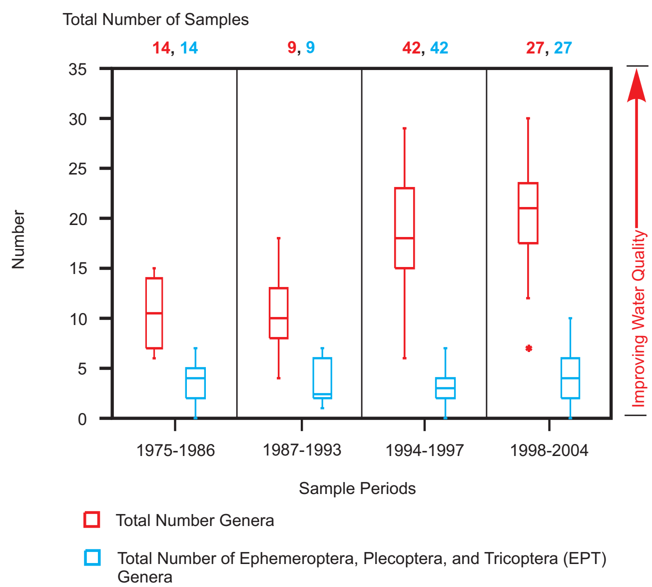


Figure 267

TOTAL NUMBER OF GENERA AND EPHEMEROPTERA, PLECOPTERA, AND TRICHOPTERA (EPT) GENERA IN RIFFLE HABITAT IN THE ROOT RIVER WATERSHED: 1975-2004

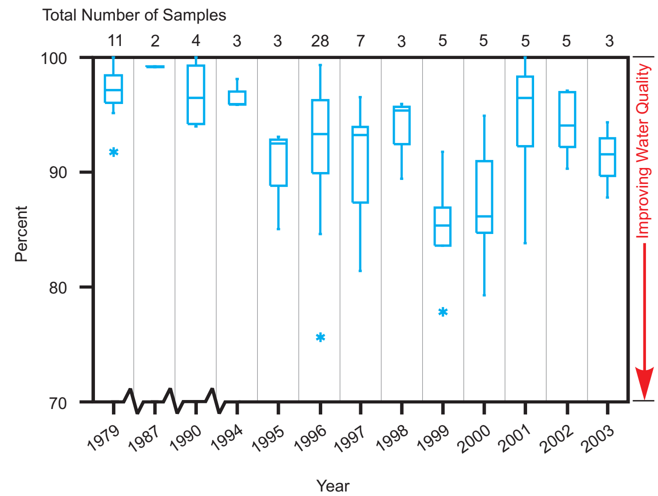


NOTE: See Figure 227 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 268

PERCENT DOMINANCE OF TOP FIVE MACROINVERTEBRATE FAMILIES IN RIFFLE HABITAT IN THE ROOT RIVER WATERSHED: 1975-2004



NOTE: Years are not plotted on a continuous scale.

Source: Wisconsin Department of Natural Resources and SEWRPC.

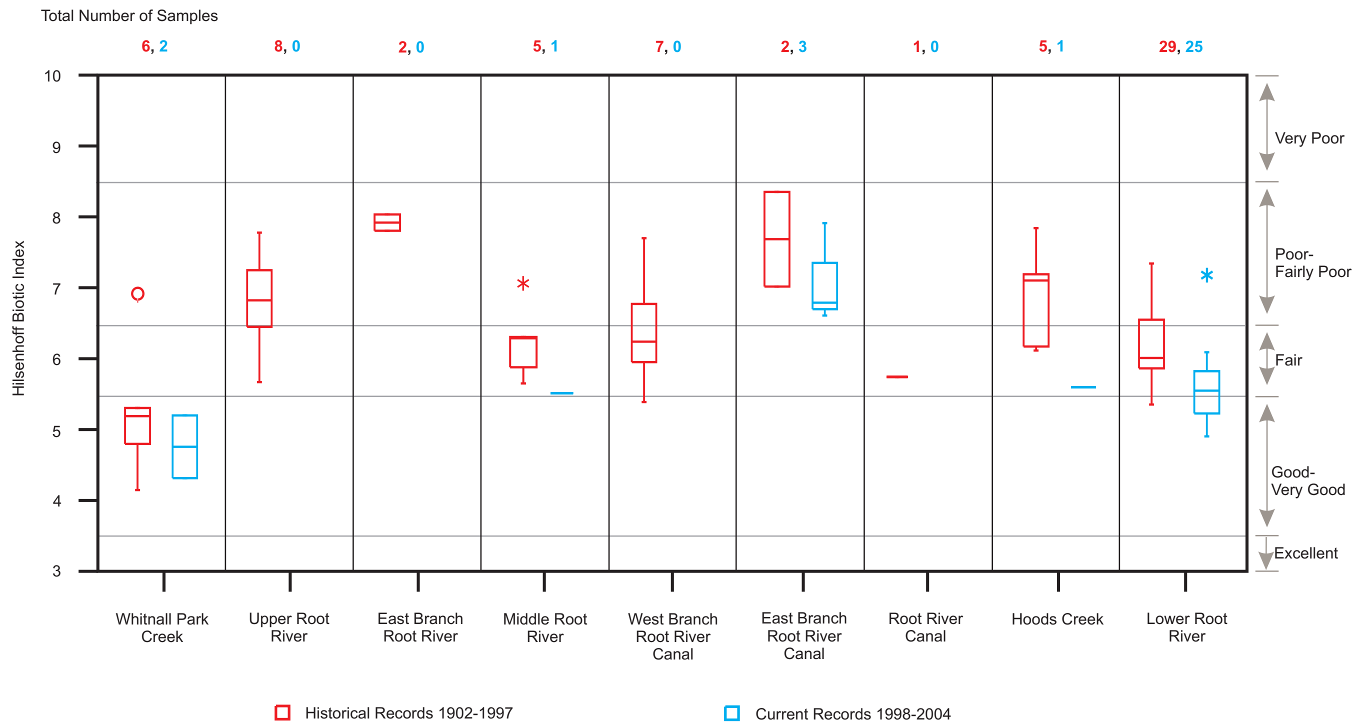
no top carnivores (except for those species stocked), and is dominated by tolerant fishes. The macroinvertebrate community is also generally dominated by tolerant taxa. Since water quality has generally either not improved or has decreased in the streams of the watershed for most constituents, water quality and habitat seem to potentially be the most important factors limiting both the fishery and macroinvertebrate community. It is also important to note there are several other factors that are likely limiting the aquatic community, including but not limited to 1) periodic stormwater loads and sediment toxicity; 2) decreased base flows; 3) continued fragmentation due to culverts, drop structures, and concrete lined channels, enclosed conduits, and dams; 4) past channelization; and/or 5) increased water temperatures due to urbanization.

Other Wildlife

Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of this study, it is possible, by polling naturalists and wildlife managers familiar with the area, to compile lists of amphibians, reptiles, birds, and mammals which may be expected to be found in the area under existing conditions. The technique used in compiling the wildlife data involved obtaining lists of those amphibians, reptiles, birds, and mammals known to exist, or known to have existed, in the Root River watershed area, associating these lists with the historic and remaining habitat areas in the area as inventoried, and projecting the appropriate amphibian, reptile, bird, and mammal species into the watershed area. The net result of the application of this technique is a listing of those species which were probably once present in the watershed area, those species which may be expected to still be present under currently prevailing conditions, and those species which may be expected to be lost or gained as a result of urbanization within the area. It is important to note that this inventory was conducted on a countywide basis for each of the aforementioned major groups of organisms. Some of the organisms listed as occurring in the Milwaukee, Racine, and Kenosha Counties may only infrequently occur within the Root River watershed.

Figure 269

HISTORICAL AND BASE PERIOD PERCENT HILSENHOFF BIOTIC INDEX (HBI) SCORES IN RIFFLE HABITAT IN STREAMS IN THE ROOT RIVER WATERSHED: 1975-2004



NOTE: See Figure 227 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

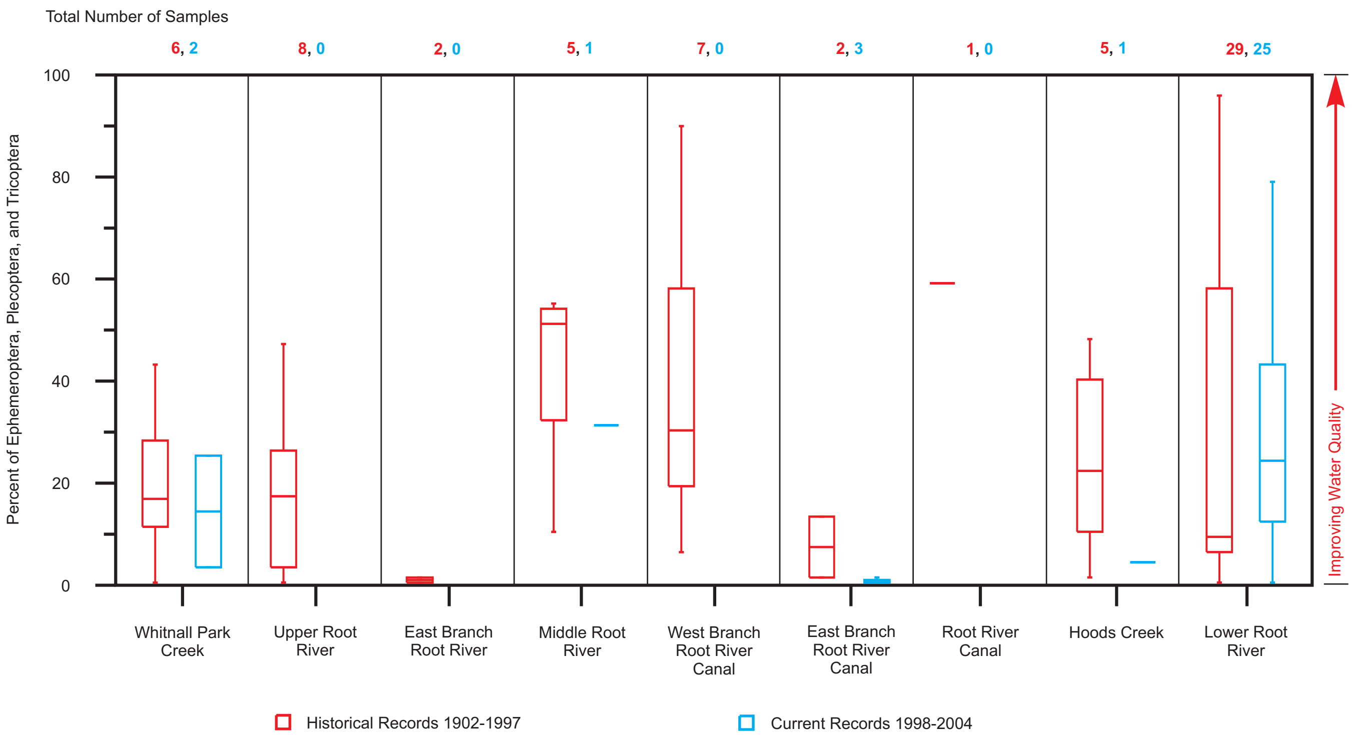
A variety of mammals, ranging in size from large animals like the white-tailed deer, to small animals like the meadow vole, are likely to be found in the watershed area of Root River watershed. Muskrat, white-tailed deer, gray squirrel, and cottontail rabbit are mammals reported to occur in the area. Appendix D lists the mammals whose ranges historically extended into the watershed area.

A large number of birds, ranging in size from large game birds to small songbirds, are found in the Root River watershed area. Appendix E lists those birds that normally occur in this watershed. Each bird is classified as to whether it breeds within the area, visits the area only during the annual migration periods, or visits the area only on rare occasions. The Root River watershed also supports a significant population of waterfowl, including mallards and Canada geese. Larger numbers of various waterfowl likely move through the watershed area during the annual migrations when most of the regional species may also be present. Many game birds, songbirds, waders, and raptors also reside or visit the watershed.

Amphibians and reptiles are vital components of the ecosystem within an environmental unit like that of the Root River watershed area. Examples of amphibians native to the area include frogs, toads, and salamanders. Turtles and snakes are examples of reptiles common to the Root River area. Appendix F lists the amphibian and reptile species normally expected to be present in the Root River area under present conditions. Most amphibians and reptiles have specific habitat requirements that are adversely affected by agricultural disturbances and advancing urban development. The major detrimental factors affecting the maintenance of amphibians in a changing environment is the destruction of breeding ponds, urban development occurring in migration routes, and changes in food sources brought about by urbanization.

Figure 270

HISTORICAL AND BASE PERIOD PERCENT EPHEMEROPTERA, PLECOPTERA, AND TRICHOPTERA (EPT) MACROINVERTEBRATE GENERA IN RIFFLE HABITAT IN STREAMS IN THE ROOT RIVER WATERSHED: 1975-2004



NOTE: See Figure 227 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Endangered and threatened species and species of special concern present within the Root River watershed area include 46 species of plants, eight species of birds, six species of fish, five species of herptiles, and two species of invertebrates from Wisconsin Department of Natural Resources records dating back to the late 1800s (see Table 166). Since 1975, there have been observed 17 species of plants, seven species of birds, two species of fish, three species of herptiles, and two species of invertebrates totaling to an apparent loss of 36 total species.

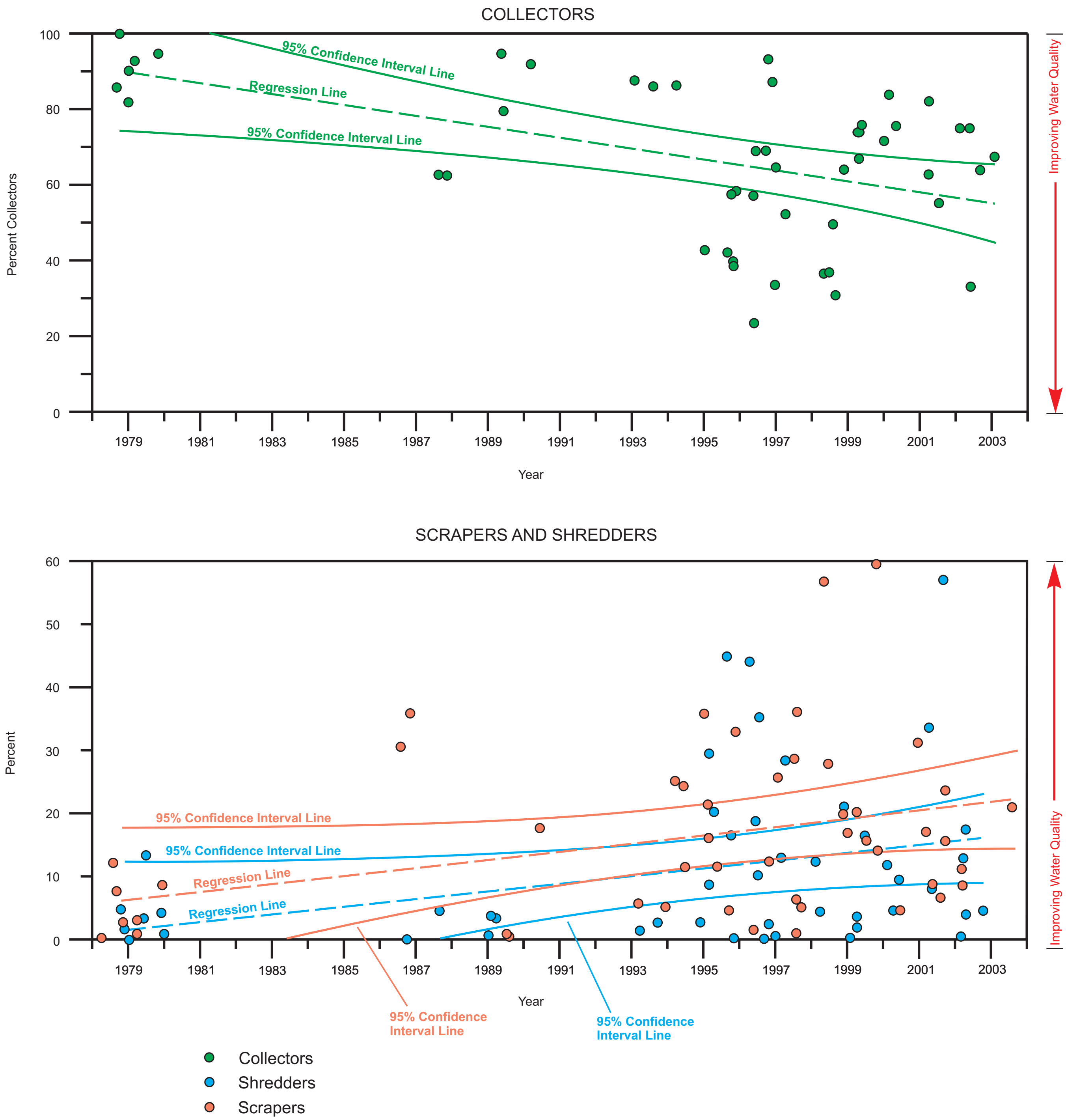
The complete spectrum of wildlife species originally native to the watershed, along with their habitat, has undergone significant change in terms of diversity and population size since the European settlement of the area. This change is a direct result of the conversion of land by the settlers from its natural state to agricultural and urban uses, beginning with the clearing of the forest and prairies, the draining of wetlands, and ending with the development of urban land in some areas. Successive cultural uses and attendant management practices, primarily urban, have been superimposed on the land use changes and have also affected the wildlife and wildlife habitat. In urban areas, cultural management practices that affect wildlife and their habitat include the use of fertilizers, herbicides, and pesticides; road salting for snow and ice control; heavy motor vehicle traffic that produces disruptive noise levels and air pollution and nonpoint source water pollution; and the introduction of domestic pets.

CHANNEL CONDITIONS AND STRUCTURES

The conditions of the bed and bank of a stream are greatly affected by the flow of water through the channel. The great amount of energy possessed by flowing water in a stream channel is dissipated along the stream length by turbulence, streambank and streambed erosion, and sediment resuspension. Sediments and associated substances

Figure 271

PERCENT SCRAPER, SHREDDER, AND COLLECTOR MACROINVERTEBRATE TROPHIC GROUPS IN THE LOWER ROOT RIVER SUBWATERSHED: 1979-2003



Source: Wisconsin Department of Natural Resources and SEWRPC.

delivered to a stream may be stored, at least temporarily, on the streambed, particularly where obstructions or irregularities in the channel decrease the flow velocity or act as particle traps or filters. On an annual basis or a long-term basis, streams may exhibit net deposition, net erosion, or no net change in internal sediment transport, depending on tributary land uses, watershed hydrology, precipitation, and geology. From 3 to 11 percent of the

Table 166

ENDANGERED AND THREATENED SPECIES AND SPECIES OF SPECIAL CONCERN IN THE ROOT RIVER WATERSHED: 2004

Common Name	Scientific Name	Status under the U.S. Endangered Species Act	Wisconsin Status
Crustacea			
Prairie Crayfish	*Procambarus gracilis*	Not listed	Special concern
Other Insects			
A Side Swimmer	*Crangonyx gracilis*	Not listed	Special concern
Fish			
Lake Chubsucker	*Erimyzon sucetta*	Not listed	Special concern
Lake Sturgeon[a]	*Acipenser fulvescens*	Not listed	Special concern
Least Darter[a]	*Etheostoma microperca*	Not listed	Special concern
Longear Sunfish	*Lepomis megalotis*	Not listed	Threatened
Redfin Shiner[a]	*Lythrurus umbratilis*	Not listed	Threatened
Redside Dace[a]	*Clinostomus elongatus*	Not listed	Special concern
Reptiles and Amphibians			
Butler's Garter Snake	*Thamnophis butleri*	Not listed	Threatened
Blanchard's Cricket Frog[a]	*Acris crepitans blanchardi*	Not listed	Endangered
Blanding's Turtle	*Emydoidea blandingii*	Not listed	Threatened
Bullfrog	*Rana catesbeiana*	Not listed	Special concern
Queen Snake[a]	*Regina septemvittata*	Not listed	Endangered
Birds			
Black Crowned Night Heron[a]	*Nycticorax nycticorax*	Not listed	Special concern
Dickcissel	*Spiza americana*	Not listed	Special concern
Grasshopper Sparrow	*Ammodramus savannarum*	Not listed	Special concern
Orchard Oriole	*Icterus spurius*	Not listed	Special concern
Red-Headed Woodpecker	*Melanerpes erythrocephalus*	Not listed	Special concern
Red-Shouldered Hawk	*Buteo lineatus*	Not listed	Threatened
Upland Sandpiper	*Bartramia longicauda*	Not listed	Special concern
Western Meadowlark	*Sturnella neglecta*	Not listed	Special concern
Plants			
American Fever-Few	*Parthenium integrifolium*	Not listed	Threatened
American Gromwell	*Lithospermum latifolium*	Not listed	Special concern
Bluestem Goldenrod	*Solidago caesia*	Not listed	Endangered
Christmas Fern[a]	*Polystichum acrostichoides*	Not listed	Special concern
Climbing Fumitory[a]	*Adlumia fungosa*	Not listed	Special concern
Cluster Fescue[a]	*Festuca paradoxa*	Not listed	Special concern
Cooper's Milkvetch[a]	*Astragalus neglectus*	Not listed	Endangered
Crawe Sedge[a]	*Carex crawei*	Not listed	Special concern
Earleaf Foxglove[a]	*Tomanthera auriculata*	Not listed	Special concern
False Hop Sedge	*Carex lupuliformis*	Not listed	Endangered
Forked Aster	*Aster furcatus*	Not listed	Threatened
Great Indian-Plantain	*Cacalia muehlenbergii*	Not listed	Special concern
Hairy Beardtongue[a]	*Penstemon hirsutus*	Not listed	Special concern
Handsome Sedge	*Carex formosa*	Not listed	Threatened
Heart-Leaved Plantain	*Plantago cordata*	Not listed	Endangered
Hill's Thistle[a]	*Cirsium hillii*	Not listed	Threatened
Hooker Orchis[a]	*Platanthera hookeri*	Not listed	Special concern
Indian Cucumber Root[a]	*Medeola virginiana*	Not listed	Special concern
Leafy-White Orchis[a]	*Platanthera dilatata*	Not listed	Special concern
Lesser Fringed Gentain[a]	*Gentianopsis procera*	Not listed	Special concern
Low Calamint[a]	*Calamintha arkansana*	Not listed	Special concern
Marsh Blazing Star[a]	*Liatris spicata*	Not listed	Special concern
Pale-Purple Coneflower	*Echinacea pallida*	Not listed	Threatened
Prairie Indian-Plantain	*Cacalia tuberosa*	Not listed	Threatened
Prairie Milkweed	*Asclepias sullivantii*	Not listed	Threatened
Prairie White-Fringed Orchid[a]	*Platanthera leucophaea*	Threatened	Endangered
Purple Milkweed	*Asclepias purpurascens*	Not listed	Endangered
Ravenfoot Sedge	*Carex crus-corvi*	Not listed	Endangered
Reflexed Trillium	*Trillium recurvatum*	Not listed	Special concern
Richardson Sedge[a]	*Carex richardsonii*	Not listed	Special concern
Seaside Crowfoot[a]	*Ranunculus cymbalaria*	Not listed	Threatened
Seaside Spurge[a]	*Euphorbia polygonifolia*	Not listed	Special concern

Table 166 (continued)

Common Name	Scientific Name	Status under the U.S. Endangered Species Act	Wisconsin Status
Plants (continued)			
Showy Lady's Slipper[a]	*Cypripedium reginae*	Not listed	Special concern
Slim-Stem Small Reedgrass[a]	*Calamagrostis stricta*	Not listed	Special concern
Small White Lady's Slipper[a]	*Cypripedium candidum*	Not listed	Threatened
Small Yellow Lady's Slipper[a]	*Cypripedium calceolus*	Not listed	Special concern
Smooth Black-Haw	*Viburnum prunifolium*	Not listed	Special concern
Smooth Phlox[a]	*Phlox glaberrima ssp. Interior*	Not listed	Endangered
Sparse-Flowered Sedge[a]	*Carex tenuiflora*	Not listed	Special concern
Sticky False Asphodel[a]	*Tofieldia glutinosa*	Not listed	Threatened
Tufted Hairgrass[a]	*Deschampsia cespitosa*	Not listed	Special concern
Waxleaf Meadowrue	*Thalicrum revolutum*	Not listed	Special concern
Whip Nutrush[a]	*Scleria triglomerata*	Not listed	Special concern
Wilcox Panic Grass[a]	*Panicum wilcoxianum*	Not listed	Special concern
Woody Milkweed[a]	*Asclepias lanuginosa*	Not listed	Threatened
Yellow Gentain	*Gentiana alba*	Not listed	Threatened

[a]*Species observed prior to year 1975.*

Source: Wisconsin Department of Natural Resources, Wisconsin State Herbarium, Wisconsin Society of Ornithology, and SEWRPC.

annual sediment yield in a watershed in southeastern Wisconsin may by contributed by streambank erosion.[29] In the absence of mitigative measures, increased urbanization in the watershed may be expected to result in increased streamflow rates and volumes, with potential increases in streambank erosion and bottom scour, and flooding problems. The impacts of development on streamflow rates and volumes can be mitigated to some degree by properly installed and maintained stormwater management practices. In many of the communities in the Root River watershed, the requirements of MMSD Chapter 13, "Surface Water and Storm Water," are applied to mitigate instream increases in peak rates of flow that could occur due to new urban development without runoff controls. In communities outside of the MMSD service area, local ordinances provide for varying degrees of control of runoff from new development. Also, where soil conditions allow, the infiltration standards of Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* are applied to limit increases in runoff volume from new development. The effectiveness of regulations to control rates and volumes of runoff is, in part, dependent upon the level of compliance with, and enforcement of, the regulations.

Milwaukee County commissioned an assessment of stability and fluvial geomorphic character of streams within four watersheds in the County including the Root River watershed.[30] This study, conducted in fall 2003, examined channel stability in about six miles of stream channel along the mainstem of the Root River and several of its tributaries. A major goal of this study was to create a prioritized list of potential project sites related to mitigation of streambank erosion and channel incision, responses to channelization, and maintenance of infrastructure integrity. In addition, the City of Racine commissioned a study to evaluate the condition of storm sewer outfalls and streambanks and associated erosion and erosion potential along the Root River within the City.[31] A goal of this study was to develop baseline data identifying, characterizing, and mapping erosion problems associated with stormwater outfalls and hydromodifications such as riprap, concrete, and retaining walls.

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[29]*SEWRPC Technical Report No. 21,* Sources of Water Pollution in Southeastern Wisconsin: 1975, *September 1978.*

[30]*Inter-Fluve, Inc.,* op. cit.

[31]*Earth Tech, Inc.,* Root River Outfall and Streambank Erosion Assessment, *January 2005.*

Map 101 shows the types of channel bed lining in streams within the Root River watershed. Reaches within Crayfish Creek, Legend Creek, Tess Corners Creek, and an unnamed tributary in the Upper Root River subwatershed are enclosed in underground conduit. Enclosed channel represents less than 1 percent of the stream length assessed. None of the streams of the Root River watershed are concrete-lined. The stream network has been substantially modified over much of the watershed, with many stretches having been channelized.

Bed and Bank Stability

Alluvial streams within urbanizing watersheds often experience rapid channel enlargement. As urbanization occurs, the fraction of the watershed covered by impervious materials increases. This can result in profound changes in the hydrology in the watershed. As a result of runoff being conveyed over impervious surfaces to storm sewers which discharge directly to streams, peak flows become higher and more frequent and streams become "flashier" with flows increasing rapidly in response to rainfall events. The amount of sediment reaching the channel often declines. Under these circumstances and in the absence of armoring, the channel may respond by incising. This leads to an increase in the height of the streambank, which continues until a critical threshold for stability is exceeded. When that condition is reached, mass failure of the bank occurs, leading to channel widening. Typically, incision in an urbanizing watershed proceeds from the mouth to the headwaters.[32] Lowering of the channel bed downstream increases the energy gradient upstream and in the tributaries. This contributes to further destabilization. Once it begins, incision typically follows a sequence of channel bed lowering, channel widening, and deposition of sediment within the widened channel. Eventually, the channel returns to a stable condition characteristic of the altered channel geometry.

It is also important to note that most of the agricultural lands in the Root River watershed contain drain tiles that are designed specifically to convey water out of the soils and into the adjacent streams that have generally been channelized. As a result of runoff being conveyed via drain tiles, relative to undrained conditions, peak flows become somewhat higher and more frequent with flows increasing more rapidly in response to rainfall events. Similar to urban development conditions, agricultural activities in a watershed can also lead to localized bank scour, channel incision, and bank failure.

Map 102 summarizes bank stability for the Root River and several of its tributaries.[33] About 55.4 miles of channel were inventoried for stability as shown on Map 102, about 48 miles of channel in Milwaukee County and about 7.4 miles of channel in the City of Racine. Most alluvial reaches that were examined appeared to be degrading and actively eroding (see Figure 272). About 34 percent of the stream length assessed was observed to be stable. The stable reaches are located on the mainstem of the Root River and Ryan Creek, Tess Corners Creek, Whitnall Park Creek, Wildcat Creek, and the Root River Canal (see Map 102). Less than 2 percent of the assessed channel was observed to be aggrading. The aggrading reaches are located along Dale Creek.

Bulkheads

The banks of the Root River, from Marquette Avenue in Racine downstream to the confluence with Lake Michigan, are largely lined with bulkheads. These serve as channel boundaries and act to inhibit lateral channel migration and associated erosion. As they degrade over time, increases in lateral bank instability and flooding are likely results. Failure of some sections of bulkhead has been observed along the south bank of the River.[34]

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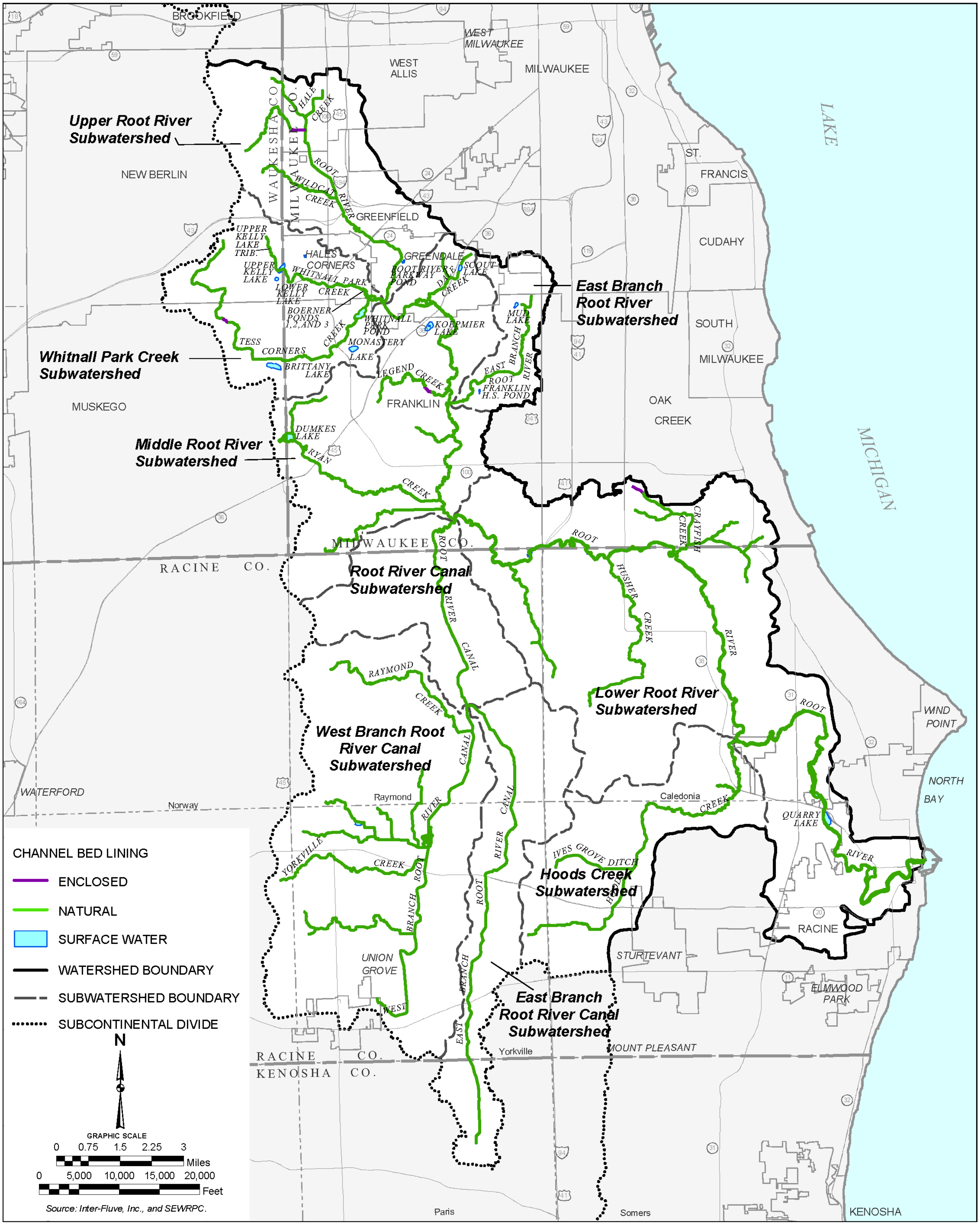
[32]*S.A. Schumm, "Causes and Controls of Channel Incision," In: S. E. Darby and A. Simon (eds.),* Incised River Channels: Processes, Forms, Engineering and Management, *John Wiley & Sons, New York, 1999.*

[33]*Earth Tech, Inc.,* op. cit.; *Inter-Fluve, Inc.,* op. cit.

[34]*Earth Tech, Inc.,* op. cit.

Map 101

CHANNEL BED CONDITIONS WITHIN THE ROOT RIVER WATERSHED: 2000



Map 102

STREAMBANK STABILITY CONDITIONS WITHIN THE ROOT RIVER WATERSHED: 2000

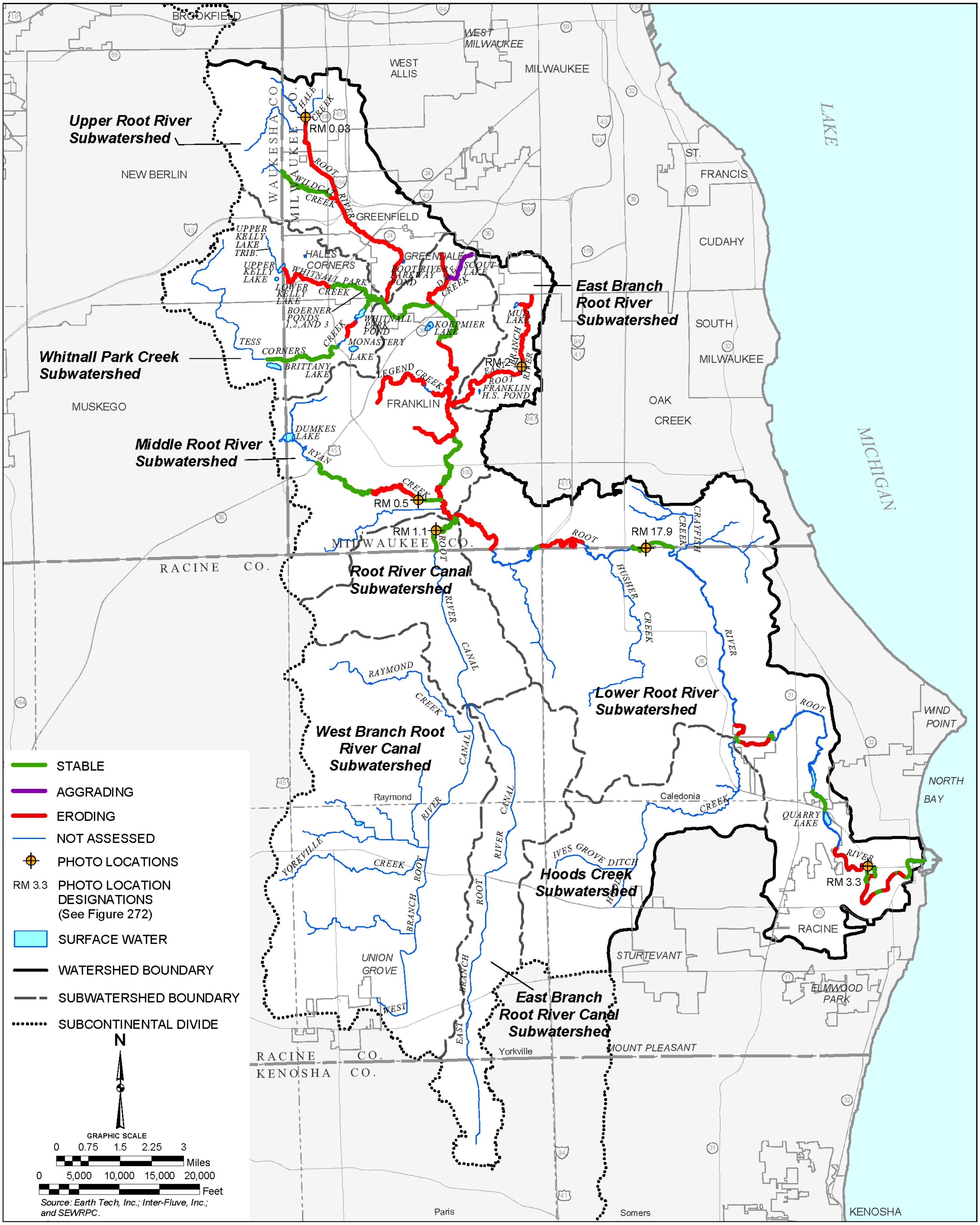


Figure 272

STREAMBANK STABILITY CONDITIONS ALONG REACHES WITHIN THE ROOT RIVER WATERSHED: 2003

HALE CREEK AT RIVER MILE 0.03

EAST BRANCH ROOT RIVER AT RIVER MILE 2.7

RYAN CREEK AT RIVER MILE 0.5

ROOT RIVER CANAL AT RIVER MILE 1.1

ROOT RIVER AT RIVER MILE 17.9

ROOT RIVER AT RIVER MILE 3.3

Source: Inter-Fluve, Inc., Wisconsin Department of Natural Resources, and SEWRPC.

Dams
There are currently eight dams within the Root River watershed. As shown on Map 103, four are located on Whitnall Park Creek, one is located on Dale Creek, one is located on Tess Corners Creek, one is located on an unnamed tributary to the West Branch of the Root River Canal, and one is located on the mainstem of the River in the City of Racine (Horlick dam). Most of these dams form impoundments. In addition, a small number of drop structures are located in Dale Creek and Whitnall Park Creek. These structures can disrupt sediment transport and limit aquatic organism passage in these systems. The latter effect acts to fragment populations, reducing overall abundance and diversity.

HABITAT AND RIPARIAN CORRIDOR CONDITIONS

One of the most important tasks undertaken by the Commission as part of its regional planning effort was the identification and delineation of those areas of the Region having high concentrations of natural, recreational, historic, aesthetic, and scenic resources and which, therefore, should be preserved and protected in order to maintain the overall quality of the environment. Such areas normally include one or more of the following seven elements of the natural resource base which are essential to the maintenance of both the ecological balance and the natural beauty of the Region: 1) lakes, rivers, and streams and the associated undeveloped shorelands and floodlands; 2) wetlands; 3) woodlands; 4) prairies; 5) wildlife habitat areas; 6) wet, poorly drained, and organic soils; and 7) rugged terrain and high-relief topography. While the foregoing seven elements constitute integral parts of the natural resource base, there are five additional elements which, although not a part of the natural resource base per se, are closely related to or centered on that base and therefore are important considerations in identifying and delineating areas with scenic, recreational, and educational value. These additional elements are: 1) existing outdoor recreation sites; 2) potential outdoor recreation and related open space sites; 3) historic, archaeological, and other cultural sites; 4) significant scenic areas and vistas; and 5) natural and scientific areas.

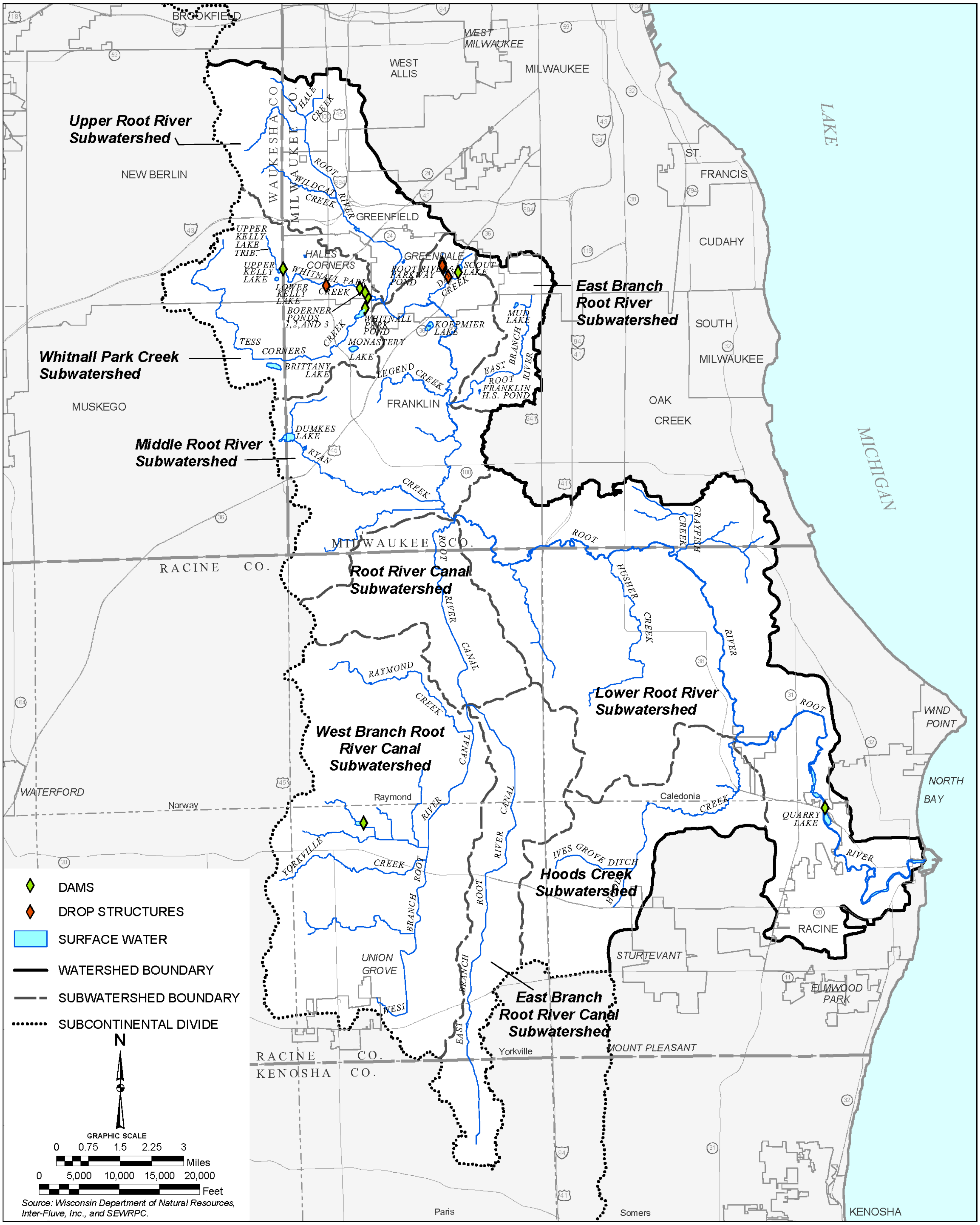
The delineation of these 12 natural resource and natural resource-related elements on a map results in an essentially linear pattern of relatively narrow, elongated areas which have been termed "environmental corridors" by the Commission. Primary environmental corridors include a wide variety of the abovementioned important resource and resource-related elements and are at least 400 acres in size, two miles in length, and 200 feet in width. Secondary environmental corridors generally connect with the primary environmental corridors and are at the least 100 acres in size and one mile long. In addition, smaller concentrations of natural resource features that have been separated physically from the environmental corridors by intensive urban or agricultural land uses have also been identified. These areas, which are at least five acres in size, are referred to as isolated natural resource areas.

It is important to point out that, because of the many interlocking and interacting relationships between living organisms and their environment, the destruction or deterioration of any one element of the total environment may lead to a chain reaction of deterioration and destruction among the others. The drainage of wetlands, for example, may have far-reaching effects, since such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas of interconnecting lake and stream systems. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater. Groundwater serves as a source of domestic, municipal, and industrial water supply and provides a basis for low flows in rivers and streams. Similarly, the destruction of woodland cover, which may have taken a century or more to develop, may result in soil erosion and stream siltation and in more rapid runoff and increased flooding, as well as destruction of wildlife habitat. Although the effects of any one of these environmental changes may not in and of itself be overwhelming, the combined effects may lead eventually to the deterioration of the underlying and supporting natural resource base, and of the overall quality of the environment for life. The need to protect and preserve the remaining environmental corridors within the watershed area directly tributary to Root River system thus becomes apparent.

Primary Environmental Corridors
The primary environmental corridors in southeastern Wisconsin generally lie along major stream valleys and around major lakes, and contain almost all of the remaining high-value woodlands, wetlands, and wildlife habitat

Map 103

DAMS AND DROP STRUCTURES WITHIN THE ROOT RIVER WATERSHED: 2005



areas, and all of the major bodies of surface water and related undeveloped floodlands and shorelands. As shown on Map 104, in the year 2000 primary environmental corridors in the Root River watershed area encompassed about 5,583 acres, or about 4 percent of the watershed area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of primary environmental corridors within the watershed. Primary environmental corridors may be subject to urban encroachment because of their desirable natural resource amenities. Unplanned or poorly planned intrusion of urban development into these corridors, however, not only tends to destroy the very resources and related amenities sought by the development, but tends to create severe environmental and development problems as well. These problems include, among others, water pollution, flooding, wet basements, failing foundations for roads and other structures, and excessive infiltration of clear water into sanitary sewerage systems.

Secondary Environmental Corridors

Secondary environmental corridors are located generally along intermittent streams or serve as links between segments of primary environmental corridors. As shown on Map 104, secondary environmental corridors in the Root River watershed area encompassed about 3,395 acres, or about 3 percent of the watershed area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of secondary environmental corridors within the watershed. Secondary environmental corridors contain a variety of resource elements, often remnant resources from primary environmental corridors which have been developed for intensive agricultural purposes or urban land uses, and facilitate surface water drainage, maintain “pockets” of natural resource features, and provide for the movement of wildlife, as well as for the movement and dispersal of seeds for a variety of plant species.

Isolated Natural Resource Areas

In addition to primary and secondary environmental corridors, other small concentrations of natural resource base elements exist within the watershed area. These concentrations are isolated from the environmental corridors by urban development or agricultural lands and, although separated from the environmental corridor network, have important natural values. These isolated natural resource areas may provide the only available wildlife habitat in a localized area, provide good locations for local parks and nature study areas, and lend a desirable aesthetic character and diversity to the area. Important isolated natural resource area features include a variety of isolated wetlands, woodlands, and wildlife habitat. These isolated natural resource area features should also be protected and preserved in a natural state whenever possible. Such isolated natural resource areas five or more acres in size within the Root River watershed area also are shown on Map 104 and total about 4,066 acres, or about 4 percent of the watershed area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of isolated natural resource areas within the watershed.

Natural Areas and Critical Species Habitat

The regional natural areas and critical species habitat protection and management plan[35] ranked natural resource features based upon a system that considered areas to be of statewide or greater significance, NA-1; countywide or regional significance, NA-2; or local significance, NA-3. In addition, certain other areas were identified as critical species habitat sites. Within the Root River watershed area, as shown on Map 105 and Table 167, 50 such sites were identified, 20 of which were identified as critical species habitat sites. Three sites totaling 156 acres were identified as being of statewide or great significance (NA-1), about 60 percent of which are already in public ownership. There were eight sites identified as natural areas of countywide or regional significance (NA-2) totaling 1,016 acres, about 545 acres or about 53 percent of which are already in public ownership and the remaining lands are proposed to be acquired. A further approximately five acres of natural area of local significance (NA-3) were identified. Of the approximately 539 acres of critical species habitat identified in the regional natural areas and critical species habitat protection and management plan, only 157 acres at eight sites are

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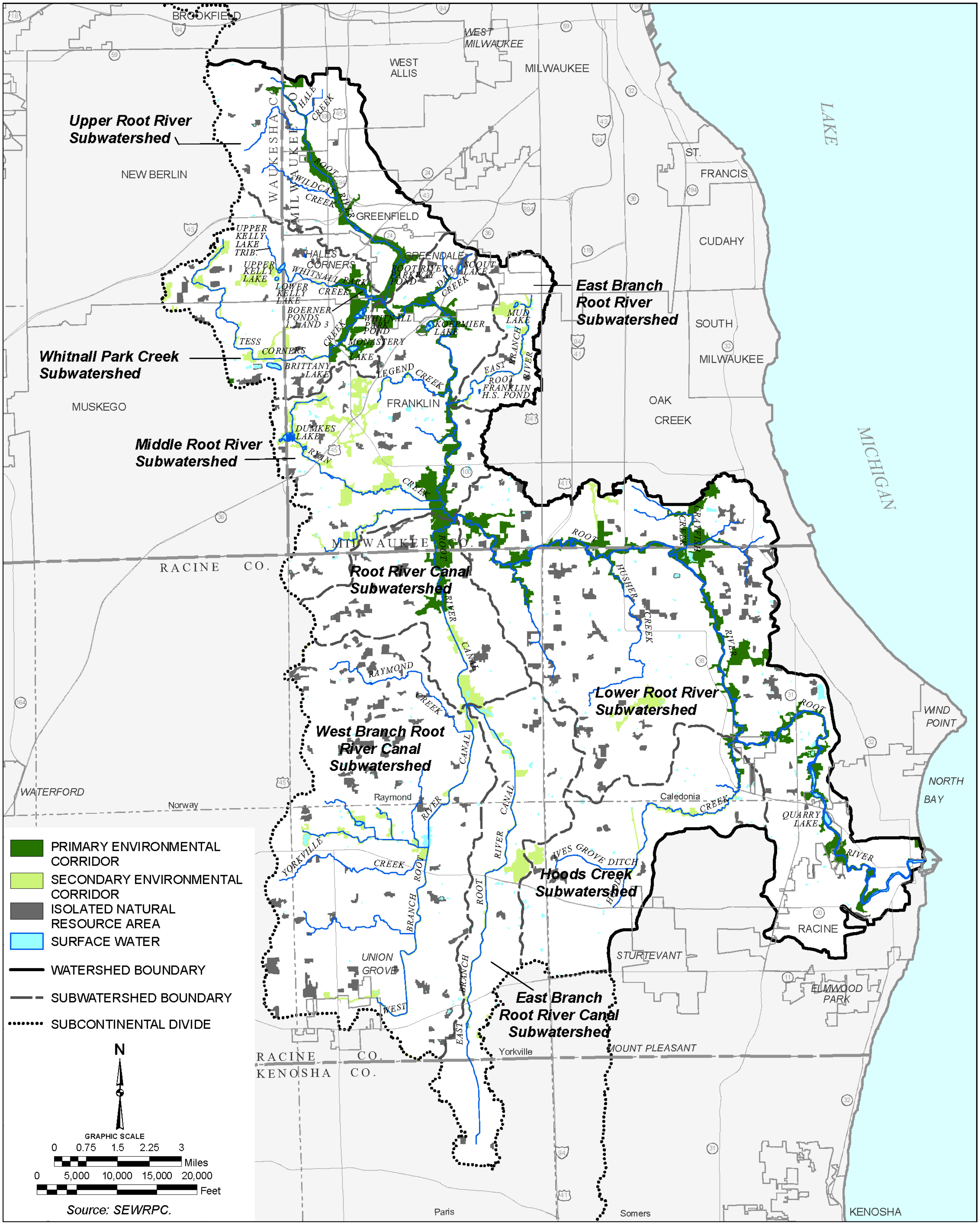
[35]*SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*, September 1997.*

Map 104

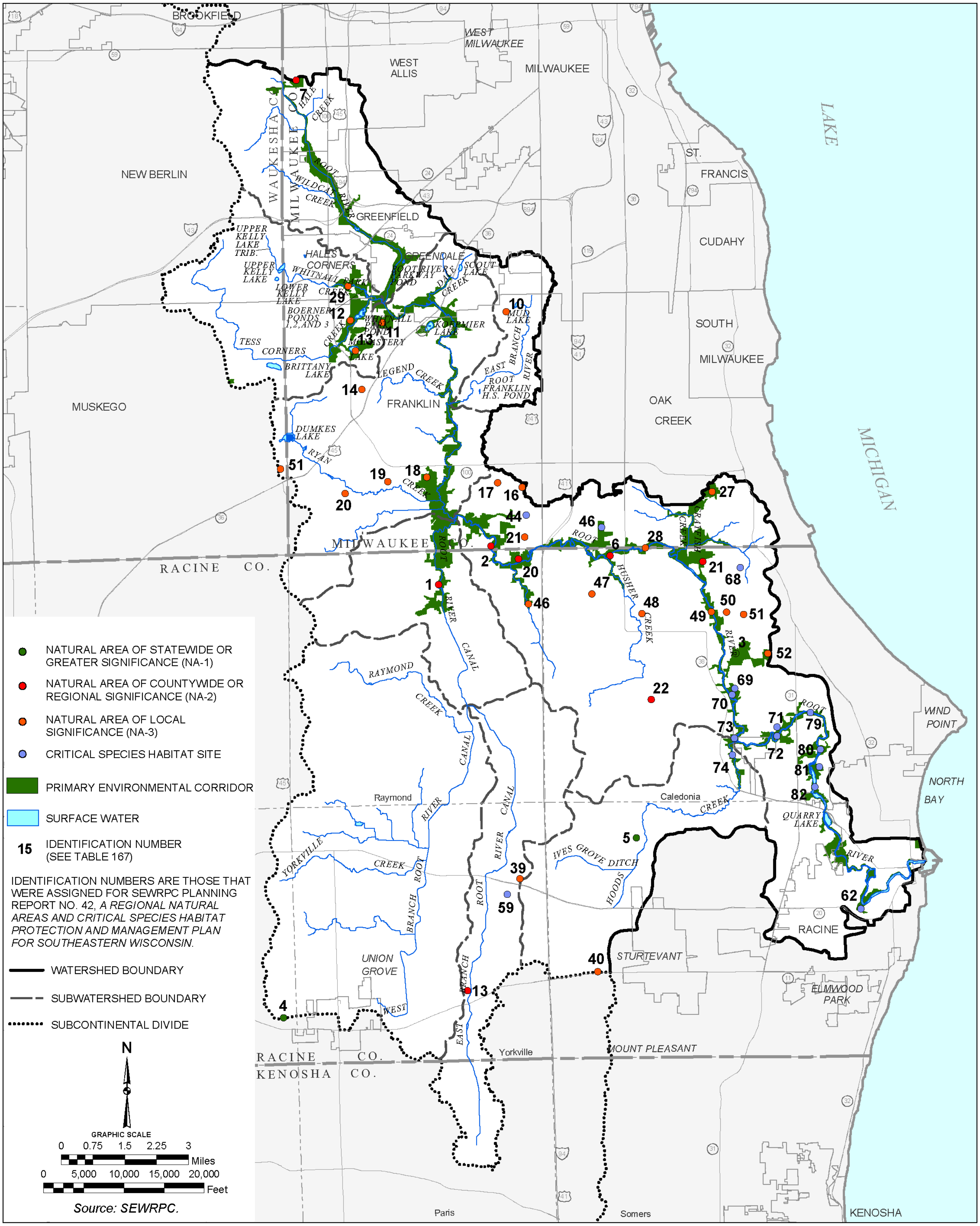
ENVIRONMENTAL CORRIDORS WITHIN THE ROOT RIVER WATERSHED: 2000



Source: SEWRPC.

Map 105

KNOWN NATURAL AREAS AND CRITICAL SPECIES HABITAT SITES WITHIN THE ROOT RIVER WATERSHED: 1994



Source: SEWRPC.

Table 167

NATURAL AREAS AND CRITICAL SPECIES HABITAT AREAS IN THE ROOT RIVER WATERSHED

Number on Map 105	Name	Type of Area	Location	Owned (acres)	Proposed to Be Acquired[a] (acres)	Total (acres)	Proposed Acquisition Agency
	Natural Areas						
1	Root River Canal Woods	NA-2, CSH	City of Franklin, Town of Raymond	111	168	279	Milwaukee and Racine Counties[b]
2	Root River Wet-Mesic Woods-West	NA-2, CSH	City of Franklin	153	107	260	Milwaukee County
3	Renak-Polak Maple-Beech Woods State Natural Area	NA-1, CSH	Village of Caledonia	96	42	138	University of Wisconsin-Parkside
4	Kansasville Railroad Prairie	NA-1	Town of Dover, Town of Yorkville	- -	14	14	Racine County
5	Franksville Railroad Prairie	NA-1	Village of Mt. Pleasant	- -	4	4	The Nature Conservancy
6	Root River Wet-Mesic Woods-East	NA-2	City of Oak Creek, Village of Caledonia	52	- -	52	Milwaukee and Racine Counties[c]
7	Greenfield Park Woods	NA-2	City of West Allis	52	- -	52	Milwaukee County
10	Grobschmidt Park Wetlands and Upland Woods	NA-3	City of Franklin	76	4	80	Milwaukee County
11	Root River Parkway Woods	NA-3	Village of Greendale	53	- -	53	Milwaukee County
12	Whitnall Park Woods-South	NA-3	City of Franklin, Village of Hales Corners	136	1	137	Milwaukee County
13	Monastery Lake Wetlands	NA-3	City of Franklin	31	14	45	Milwaukee County[d]
13	Union Grove Railroad Prairie	NA-2	Town of Yorkville	- -	32	32	Racine County[e]
14	Mission Hills Wetlands	NA-3	City of Franklin	- -	- -[f]	38	- -
16	Fitzsimmons Road Woods	NA-3	City of Franklin	14	28	42	City of Franklin
17	Oakwood Park Oak Woods	NA-3	City of Franklin	5	17	22	City of Franklin
18	Root River Parkway Prairie	NA-3	City of Franklin	27	- -	27	Milwaukee County
19	Ryan Creek Woods	NA-3	City of Franklin	- -	- -[f]	87	- -
20	Franklin Oak Woods and Oak Savanna	NA-3	City of Franklin	76	- -	76	Milwaukee County
20	County Line Riverine Woods	NA-2	Town of Raymond	41	100	141	Racine County
21	Elm Road Woods	NA-3	City of Franklin	- -	20	20	City of Franklin
21	Hunts Woods	NA-2	Village of Caledonia	3	31	34	Racine County
22	Caledonia Wildlife Area	NA-2, CSH	Village of Caledonia	133	33	166	Village of Caledonia
27	Oak Creek Low Woods	NA-3	City of Oak Creek	31	37	68	Milwaukee County
28	Root River Riverine Forest	NA-3, CSH	City of Oak Creek, Village of Caledonia	323	1	324	Milwaukee and Racine Counties[g]
29	Whitnall Park Woods-North	NA-3	Village of Hales Corners	82	- -	82	Milwaukee County
39	Ives Grove Woods	NA-3	Town of Yorkville	54	110	164	Racine County
40	Sylvania Railroad Prairie	NA-3	Village of Mt. Pleasant	- -	7	7	Racine County
46	Kimmel Woods	NA-3	Town of Raymond	- -	40	40	Private conservancy organization
47	Seven Mile Road Woods	NA-3	Village of Caledonia	- -	20	20	Private conservancy organization
48	Zirbes Woods	NA-3	Village of Caledonia	- -	13	13	Private conservancy organization
49	Caledonia Low Woods	NA-3	Village of Caledonia	61	46	107	Racine County
50	Foley Road Woods-West	NA-3	Village of Caledonia	- -	19	19	Private conservancy organization
51	Foley Road Woods-East	NA-3	Village of Caledonia	- -	24	24	Private conservancy organization
51	Luther Park Cemetery Prairie	NA-3	City of Muskego	- -	- -[f]	1	- -
52	Tabor Woods	NA-3	Village of Caledonia	- -	107	107	Village of Caledonia
	Critical Species Habitat						
44	Elm Road Woods-North	CSH	City of Franklin	- -	- -[f]	19	- -
46	PPG Woods	CSH	City of Oak Creek	- -	19	19	City of Oak Creek
59	Ives Grove Prairie Remnant	CSH	Town of Yorkville	- -	- -[f]	1	- -
62	Washington Park Woods	CSH	City of Racine	12	- -	12	City of Racine
68	Sherwood Property	CSH	Village of Caledonia	- -	- -[f]	3	- -
69	River Meadow Woods	CSH	Village of Caledonia	- -	13	13	Racine County
70	Forked Aster Site	CSH	Village of Caledonia	- -	18	18	Racine County
71	Caledonia Sanitary Sewer Right-of-Way	CSH	Village of Caledonia	13	62	75	Racine County
72	Caledonia Site South	CSH	Village of Caledonia	- -[h]	- -[h]	- -[h]	Racine County
73	Root River Bluff	CSH	Village of Caledonia	18	24	42	Racine County

Table 167 (continued)

Number on Map 105	Name	Type of Area	Location	Owned (acres)	Proposed to Be Acquired[a] (acres)	Total (acres)	Proposed Acquisition Agency
	Critical Species Habitat (continued)						
74	Hoods Creek Swamp	CSH	Village of Caledonia	- -	5	5	Village of Caledonia
79	Four Mile Road Woods	CSH	Village of Caledonia	- -	30	30	Racine County
80	Caledonia Low Woods	CSH	Village of Caledonia	20	9	29	Racine County
81	River Bend Upland Woods	CSH	Village of Caledonia	13	- -	13	Racine County
82	Root River Strip Woods	CSH	Village of Caledonia	10	- -	1	Racine County

[a]*Acquisition is recommended in SEWRPC Planning Report No. 42 (PR No. 42),* Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*, September 1997.*

[b]*Includes 121 acres in Milwaukee County and 158 acres in Racine County. Milwaukee County currently owns 111 acres of that portion of the Natural Area within its boundaries. PR No. 42 recommends that Milwaukee County acquire the remaining 10 acres within its boundaries and that Racine County acquire the 158 acres of the Natural Area located within its boundaries.*

[c]*Includes 50 acres in Milwaukee County and two acres in Racine County. The entire Natural Area is protected through existing ownership by the two Counties.*

[d]*About 31 acres of the 45-acre Monastery Lake Wetlands are currently owned by the Nature Foundation. PR No. 42 recommends that Milwaukee County acquire the remaining 14 acres.*

[e]*Acquisition of the railway right-of-way associated with this Natural Area is recommended for development of a trail under the adopted Racine County park and open space plan in the event that the right-of-way is abandoned by CP rail system.*

[f]*Not proposed for acquisition.*

[g]*Includes 140 acres in Milwaukee County—all of which are currently owned by that County—and 184 acres in Racine County—183 acres of which are owned by that County. It is recommended that the remaining one acre be acquired by Racine County.*

[h]*The Caledonia Site South Critical Species Habitat Site is located entirely within the Caledonia Sanitary Sewer Right-of-Way Critical Species Habitat Site.*

Source: SEWRPC.

proposed for acquisition by state and county government, as shown in Table 167. Endangered and threatened species and species of special concern present within the Root River watershed include 46 species of plants, eight species of birds, six species of fish, five species of herptiles, and two species of invertebrates.

Measures for Habitat Protection

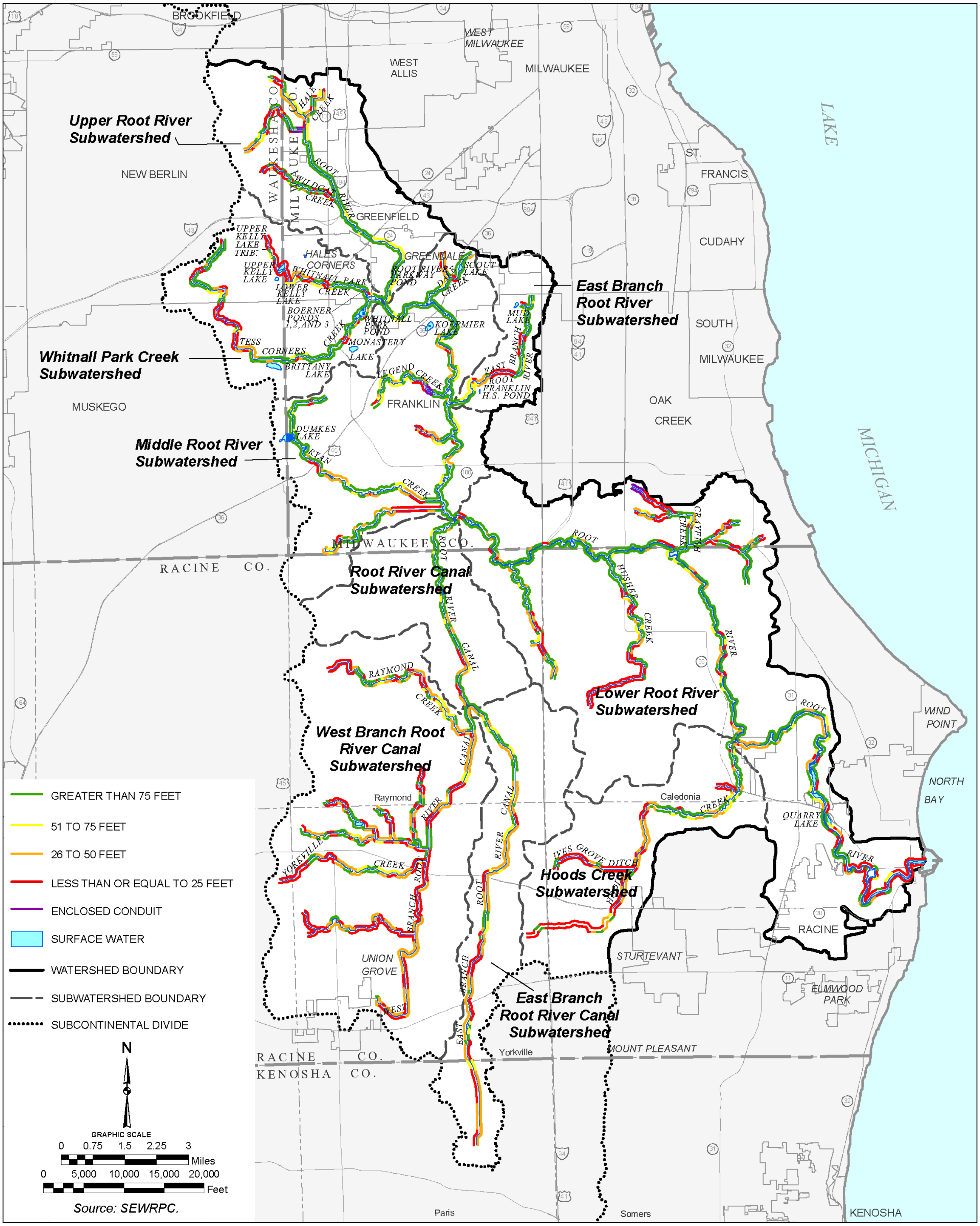
Varying approaches to the protection of stream corridor have been adopted within the Root River basin. In Milwaukee County, stream corridor protection has been focused on public acquisition of the lands adjacent to the stream banks and their preservation as river parkways. These lands are frequently incorporated into public parks and other natural areas. Racine County has also acquired some lands adjacent to the mainstem of the Root River and preserved it as river parkway. In Waukesha County, a comprehensive shoreland and floodland protection ordinance requires setbacks of principal structures and places limits upon removal of shoreland vegetative cover, excavation of shoreland, and encroachment into shorelands by structures.

The provision of buffer strips around waterways represents an important intervention that addresses anthropogenic sources of contaminants, with even the smallest buffer strip providing environmental benefit.[36] Map 106 shows the current status of riparian buffers along the Root River and its major tributary streams. Enclosed conduits, which comprise approximately 1.2 miles of the Root River watershed stream system, offer limited opportunity for installation of buffers. Enclosures are located in Crayfish, Legend, and Tess Corners Creeks and an unnamed tributary to the Root River. Buffers greater than 75 feet in width are often associated with adjacent recreational and park lands within the Root River watershed. This is especially the case in the portions of the watershed within Milwaukee County.

[36]*A. Desbonnet, P. Pogue, V. Lee, and N. Wolff, "Vegetated Buffers in the Coastal Zone - a summary review and bibliography,"* CRC Technical Report No. 2064. *Coastal Resources Center, University of Rhode Island, 1994.*

Map 106

RIPARIAN CORRIDOR WIDTHS WITHIN THE ROOT RIVER WATERSHED: 2000



Source: SEWRPC.

Figure 273 shows the current status of buffer widths ranging from less than 25 feet, 25 to 50 feet, 50 to 75 feet, and greater than 75 feet among each of the major Root River subwatersheds. Buffers greater than 75 feet in width are the most common category of buffer, accounting for about 16 to 71 percent of the buffer widths in the subwatersheds. Buffer widths less than 25 feet were the next most common category of buffer, accounting for 8 to 43 percent of the buffer widths in the subwatersheds. The subwatersheds contained an average of about 25 percent and 20 percent of the buffer categories that ranged from 25 to 50 feet in width and 50 to 75 feet in width, respectively. The subwatersheds with the greatest proportion of the buffers greater than 75 feet in width include the Root River Canal, the Middle Root River, the Lower Root River, and Upper Root River.

SUMMARY AND STATUS OF IMPLEMENTATION OF ELEMENTS OF THE REGIONAL WATER QUALITY MANAGEMENT PLAN IN THE ROOT RIVER WATERSHED

The initial regional water quality management plan for the Southeastern Wisconsin Region, which was adopted in 1979, had five elements: a land use element, a point source pollution abatement element, a nonpoint source pollution abatement element, a sludge management element, and a water quality monitoring element.[37] For the purposes of documenting current conditions and trends in water quality and pollution sources, it is deemed important to redocument the point source and nonpoint source pollution abatement elements of the regional water quality management plan as amended. This section provides that redocumentation and describes the action taken to implement that plan. Those two specific elements of the plan as they relate to the Root River watershed and actions taken to implement them are described below for those components of the plan elements most directly related to water quality conditions.

Point Source Pollution Abatement Plan Element

The point source pollution abatement element of the initial plan made several recommendations regarding sewerage service in the Root River watershed. The plan recommended the abandonment of five public sewage treatment plants, one located in the City of Franklin, one located in the City of Muskego, one located in the City of New Berlin, one located in the Town (now Village) of Caledonia, and one located in the Village of Hales Corners, that were operating in the watershed in 1975. By 1985, all of the plants had been abandoned (see Sources of Water Pollution section below). The plan recommended that the attendant service areas for these plants be connected to the Milwaukee Metropolitan Sewerage District's sewerage system for treatment purposes. To facilitate that connection, the plan recommended the construction of four intercommunity trunk sewers to connect the Cities of Franklin, Muskego, and New Berlin, the Village of Hales Corners, and the Caddy Vista Sanitary District to MMSD's system. In addition, the construction of two additional intercommunity trunk sewers was recommended to provide additional capacity to convey wastewater to MMSD's system. These trunk sewers were completed over the period 1981-1984.

The plan also recommended construction and expansion of a new sewage treatment plant for the Village of Union Grove. The expansion of this plant was complete by 1995. A subsequent upgrade of this plant was completed in 2003.

The plan also recommended that the private sewage treatment plant serving the Racine County Ives Grove Complex be expanded and upgraded to serve as a public sewage treatment plant for the former Town of Yorkville Sanitary District. This plant was converted to a public sewage treatment plant in 1981.

The plan recommended the abandonment of six private sewage treatment plants, two located in the City of Franklin, two located in the City of New Berlin, one located in the Towns (now Villages) of Caledonia and Mt. Pleasant, and one located in the Town of Dover. By 1990, these plants had all been abandoned. To facilitate

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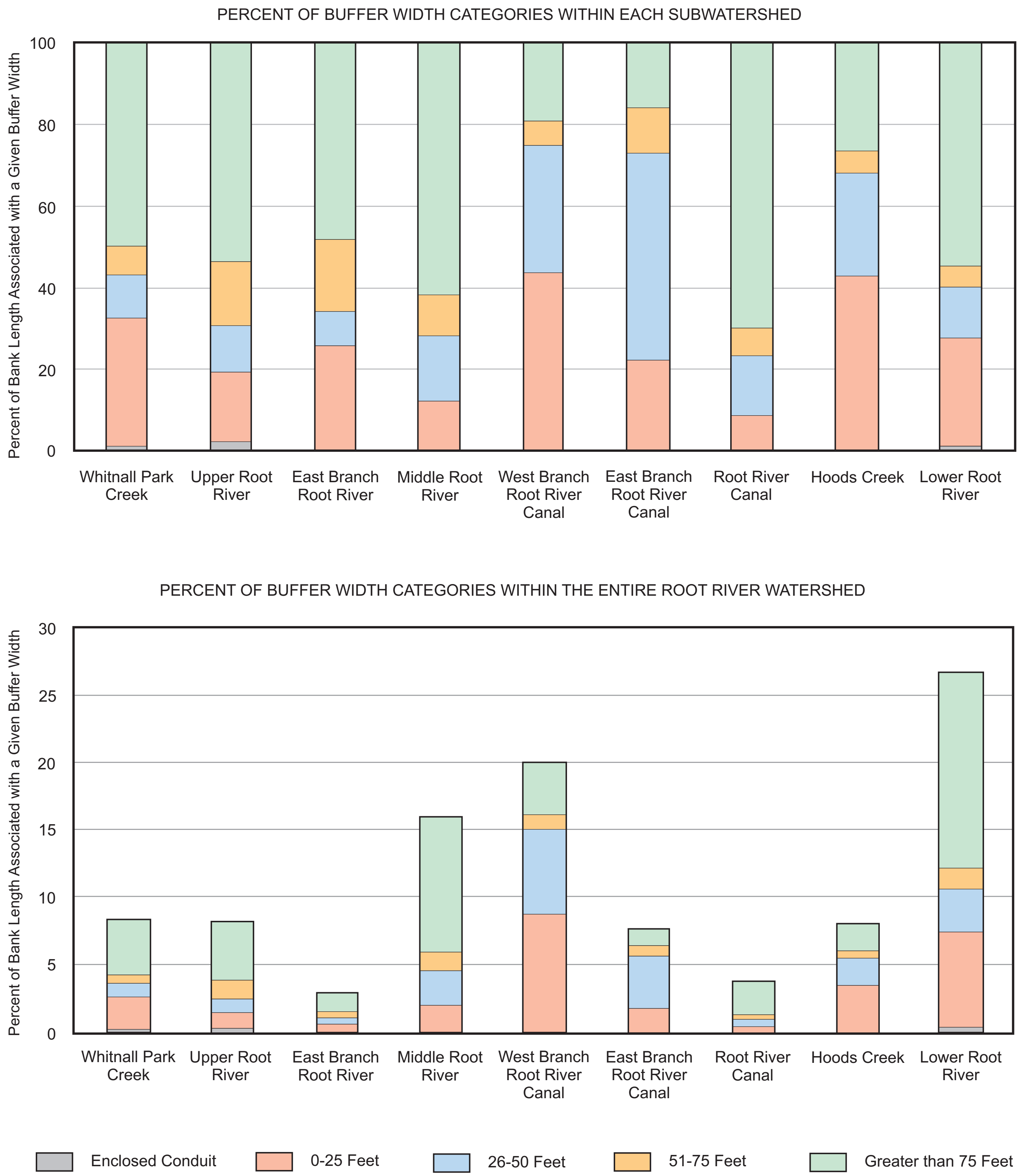
[37]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume One,* Inventory Findings, *September 1978; Volume Two,* Alternative Plans, *February 1979; Volume Three,* Recommended Plan*, June 1979.*

Figure 273

RIPARIAN CORRIDOR BUFFER WIDTHS WITHIN THE ROOT RIVER WATERSHED: 2000



Source: SEWRPC.

abandonment of the plant at the Center for the Developmentally Disabled in the Town of Dover, the plan recommended the construction of an intercommunity trunk sewer to convey wastewater from the Center to the Village of Union Grove's sewage treatment plant. This trunk sewer was completed in 1995. One additional private sewage treatment plant in the Town of Yorkville that had not been recommended for abandonment in the initial plan was abandoned in 1989. Finally, the initial plan recommended the refinement of sanitary sewer service areas for all sewer areas in the watershed. As of 2005, this had been done for all service areas in the watershed except for the MMSD area, which in the Root River watershed, is almost entirely served by sewers and the Yorkville Sanitary District which has been partially refined.

A preliminary recommendation to abate combined sewer overflows through the partial separation of the remaining combined sewer areas in the City of Racine was made in the initial regional water quality management plan. Separation of the combined sewers was completed in the early 1980s. Since then, combined sewer overflows have not been an issue in the Root River watershed.

In 1975, there were eight combined sewer outfalls and 53 known separate sanitary sewer overflow relief devices located in the Root River watershed. The combined sewer outfalls were all in the City of Racine and discharged to the Root River. These were abated with the separation of the combined sewers in the City of Racine. Similarly, during the period of 1988-1993 the majority of separate sanitary flow relief devices were eliminated as sewage treatment plants were upgraded or abandoned. During the period 1995-2002, sanitary sewer overflows were reported at 15 sites in the watershed.

In 1975, there were 13 point sources of wastewater other than public and private sewage treatment plants. These sources discharged industrial cooling, process, rinse, and wash waters through 20 outfalls directly, or indirectly, to the surface water system. The initial regional water quality management plan included a recommendation that these industrial point sources of wastewater be monitored, and discharges limited to levels determined on a case-by-case basis under the Wisconsin Pollutant Discharge Elimination System (WPDES) permit process. Currently, this recommendation has been nearly fully implemented for the point sources that currently exist in the watershed, the only exception being an unplanned discharge or spill.

Due to the dynamic nature of permitted point sources, it is recognized that the number of wastewater sources changes as industries and other facilities change locations or processes and as decisions are made with regard to the connection of such sources to public sanitary sewer systems. Many of the historical dischargers are now connected to the public sanitary sewer system.

Nonpoint Source Pollution Abatement Plan Element

The nonpoint source element of the original plan described a variety of methods and practices for abatement of nonpoint source pollution in urban and rural areas and estimated the percent reduction of released pollutants that could be achieved through implementation of these methods and practices. It identified phosphorus and fecal coliform bacteria as pollutants requiring nonpoint source control in the Root River watershed. For urban areas, it recommended construction site erosion control and implementation of urban land practices sufficient to produce a 50 percent reduction in pollutants released to the streams of the watershed. For rural areas in most of the watershed, it recommended livestock waste control and conservation practices sufficient to produce a 25 percent reduction in pollutants released to the streams of the watershed. For rural areas in the Root River Canal subwatershed, it recommended additional conservation practices sufficient to produce a 50 percent reduction in pollutants released to the streams of the subwatershed.

In 1979, the Root River Watershed was designated a priority watershed under the Wisconsin Nonpoint Source Priority Watershed Pollution Abatement Program.[38] This plan identified the need for reductions in total pollutant

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[38]*SEWRPC Community Assistance Planning Report No 37,* A Nonpoint Source Water Pollution Control Plan for the Root River Watershed, *March 1980.*

loadings, phosphorus loadings, and sediment loadings to the streams of the watershed in order to meet water quality objectives. In addition, it recommended a number of management actions and practices to be implemented over the period 1979 to 1989 for both urban and rural lands and provided funding for a variety of activities related to abatement of nonpoint source pollution. The plan recommendations for nonpoint source pollution control were partially implemented as of completion of the project.[39]

Several additional measures to abate nonpoint source pollution have been instituted since adoption of the initial plan. Facilities engaged in certain industrial activities have been required to apply for and obtain stormwater discharge permits under the WPDES and to develop and follow storm water pollution prevention plans. Many of the communities in the watershed have applied for WPDES discharge permits, and have adopted construction site erosion control ordinances. All of the communities except the Towns of Dover, Paris, Raymond, and Yorkville and the Village of Sturtevant have adopted stormwater management plans or ordinances. The communities with permits will be required to develop new stormwater management ordinances, or update existing ordinances, to be consistent with the standards of Chapter NR 151 of the *Wisconsin Administrative Code.* Stormwater management measures are described more fully in the section on nonpoint source pollution in this chapter.

SOURCES OF WATER POLLUTION

An evaluation of water quality conditions in the Root River watershed must include an identification, characterization, and where feasible, quantification of known pollution sources. This identification, characterization, and quantification are intended to aid in determining the probable causes of water pollution problems.

Point Source Pollution

Point source pollution is defined as pollutants that are discharged to surface waters at discrete locations. Examples of such discrete discharge points include sanitary sewerage system flow relief devices, sewage treatment plant discharges, and industrial discharges.

Sewage Treatment Plants

The status of implementation in regard to the abandonment of public and private sewage treatment plants in the Root River watershed, as recommended in the initial regional water quality management plan, is summarized in Table 168. In 1975, there were six public sewage treatment facilities located in or discharging to the Root River watershed. The Caddy Vista Sanitary District plant and the Village of Union Grove plant discharged effluent to the West Branch of the Root River Canal, the City of Muskego Northeast District plant discharged effluent to Tess Corners Creek, the City of New Berlin Greenridge plant and the Village of Hales Corners plant discharged effluent to tributaries of Whitnall Park Creek, and the Rawson Homes Sewer and Water Trust plant discharged effluent to the East Branch of the Root River. Five of these plants, all except for the Village of Union Grove plant, were abandoned in or after 1975 and the attendant service areas were connected to the MMSD system for treatment purposes, as recommended in the initial regional water quality management plan. As recommended in the initial regional water quality management plan, a new plant was constructed to serve the Village of Union Grove. This plant was subsequently expanded and upgraded. Since 1975, one additional public sewage treatment plant has operated in the Root River watershed. The initial water quality management plan recommended expanding and upgrading the private sewage treatment plant serving the Racine County Highway and Park Commission building to serve as a public sewage treatment plant serving the Town of Yorkville Sewer Utility District No. 1. Conversion and upgrading of this plant was completed in 1981. Over the short-term, the plan recommends maintaining this plant. In the long term, the entire Yorkville system is anticipated to be connected to the sewerage system tributary to the Racine sewage treatment plant—and the Yorkville sewage treatment plant

[39]*M. Miller, J. Ball, and R. Kroner,* An Evaluation of Water Quality in the Root River Priority Watershed*, Wisconsin Department of Natural Resources Publication WR-298-92, 1992.*

Table 168

IMPLEMENTATION STATUS OF THE INITIAL REGIONAL WATER QUALITY MANAGEMENT PLAN FOR PUBLIC SEWAGE TREATMENT PLANTS IN THE ROOT RIVER WATERSHED: 2004

Plant	Receiving Water	Plan Recommendation	Implementation Status	Year of Implementation
Public				
Caddy Vista Sanitary District	West Branch of the Root River Canal	Abandon plant	Plant abandoned	1982
City of Muskego Northeast District Plant	Tess Corners Creek	Abandon plant	Plant abandoned	1985
City of New Berlin Greenridge Plant	Tributary to Whitnall Park Creek	Abandon plant	Plant abandoned	1975
Rawson Homes Sewer and Water Trust	East Branch Root River	Abandon plant	Plant abandoned	1977
Town of Yorkville Sewer Utility District No. 1	Hoods Creek	Upgrade and expand plant[a,b]	Completed	1981
Village of Hales Corners	Tributary to Whitnall Park Creek	Abandon plant	Plant abandoned	1981
Village of Union Grove	West Branch of the Root River Canal	Construct new plant, expand plant	New plant completed, expansion completed	1978 1995
Private				
C&D Foods, Inc.	Tributary to the West Branch of the Root River Canal	Maintain and upgrade as needed	Maintained	- -
Fonk's Mobile Home Park No. 1	East Branch of the Root River Canal	Maintain and upgrade as needed	Maintained	- -
Fremont Company[c]	Hoods Creek	Abandon plant	Plant abandoned	1985
Highway 100 Drive-In Theater	Soil absorption	Abandon plant	Plant abandoned	
Highway 24 Outdoor Theater	Soil absorption	Abandon plant	Plant abandoned	1984
New Berlin Memorial Hospital	Tributary to the Root River	Abandon plant	Plant abandoned	
Pekin Duck Farm, Inc.	Soil absorption	Maintain and upgrade as needed	Plant abandoned	1989
Racine County Highway and Park Commission	Hoods Creek	Expand as a public plant to serve Town of Yorkville Sewer Utility District No. 1[a]	Plant upgraded and expanded as a public plant	1981
Southern Wisconsin Center for the Developmentally Disabled[d]	West Branch of the Root River Canal	Abandon plant	Plant abandoned	1995
Union Oil Truck Stop	Tributary to the Root River	Abandon plant	Plant abandoned	1980

[a]*The initial regional water quality management plan recommended the conversion and expansion of the Racine County Highway and Park Commission private sewage treatment facility to a public sewage treatment facility that would serve the entire Yorkville sewer service area.*

[b]*A revision to the initial regional water quality management plan, documented in Alvord, Burdick, and Howson,* A Coordinated Sanitary Sewer and Water Supply System Plan for the Greater Racine Area, *1992 recommends the abandonment of the Town of Yorkville sewage treatment plant when it has reached the end of its useful life, and for the Yorkville sewer service area to be served by the City of Racine sewage treatment plant.*

[c]*Formerly Frank's Pure Food Company.*

[d]*Formerly Southern Colony Training School and Treatment Facility.*

Source: SEWRPC.

Table 169

WASTEWATER TREATMENT FACILITIES IN THE ROOT RIVER WATERSHED: 2004

Number on Map 108	Facility Name	Address	Municipality	Ownership
1	Fonk's Mobile Home Park No. 1	5035 Schoen Road	Union Grove	Private
2	Village of Union Grove	3710 67th Drive	Union Grove	Public
3	Yorkville Sewer Utility District No. 1	720 Main Street	Union Grove	Public

Source: SEWRPC.

abandoned—when the Yorkville plant reaches the end of its useful life.[40] Currently, the existing sewered portions of the Root River watershed are served by the Milwaukee Metropolitan Sewerage District Jones Island and South Shore treatment plants, the City of Racine treatment plant, the Town of Yorkville Sewer Utility District treatment plant, and the Village of Union Grove treatment plant (see Table 169).[41]

In 1975, there were 10 private sewage treatment facilities located in or discharging to the Root River watershed. Three of these plants discharged effluent to soil for absorption. The other seven discharged effluent to various streams in the Root River watershed (see Table 168). The initial regional water quality management plan recommended that six of these plants be abandoned. By 1995, all of these plants had been abandoned. One additional private sewage treatment plant that the initial plan recommended be maintained and upgraded as needed, the Pekin Duck Farm plant, was also abandoned in 1989. A final private sewage treatment plant, Maple Leaf Farms, is currently permitted and regulated as a concentrated animal feeding operation and industrial discharger and not as a sewage treatment plant. As noted above, the private sewage treatment plant serving the Racine County Highway and Park Commission building was converted to a publicly owned sewage treatment plant to serve the Town of Yorkville Sewer Utility District and was expanded and upgraded. Currently, one privately owned sewage treatment plant, serving Fonk's Mobile Home Park No. 1, is in operation in the Root River watershed (see Table 169).

The initial regional water quality management plan recommended that all of the sanitary sewer service areas identified in the plan be refined and detailed in cooperation with the local units of government concerned. There were eight sewer service areas identified within, or partially within, the Root River watershed: the Caddy Vista Sanitary District, the Center for the Developmentally Disabled, the Milwaukee Metropolitan Sewerage District, Muskego, New Berlin, Racine, Union Grove, and Yorkville. As of 2005, all of these areas with the exception of the Milwaukee Metropolitan Sewerage District service area and a portion of the Yorkville sanitary sewer service area, had undergone refinements as recommended. In addition, the Franklin and Oak Creek sewer service areas, which were initially included as parts of the Milwaukee Metropolitan Sewerage District service areas, were identified and refined since completion of the initial plan. Table 170 lists the plan amendment prepared for each initial refinement, the date the Commission adopted the document as an amendment to the regional water quality management plan, and the date the Commission adopted the most recent refinement to the sewer service area. The table also identifies the original service area names and the relationship of these service areas to the service area names following the refinement process. The planned sewer service areas in the Root River watershed, as refined through June 2005, total about 73.4 square miles, or about 37 percent of the total watershed area. Planned sewer service areas in the Root River watershed are shown on Map 107.

[40]*SEWRPC Community Assistance Planning Report No. 147, 2nd Edition,* Sanitary Sewer Service Area for the City of Racine and Environs, *June 2003.*

[41]*The Jones Island, South Shore, and City of Racine plants discharge directly to Lake Michigan.*

Table 170

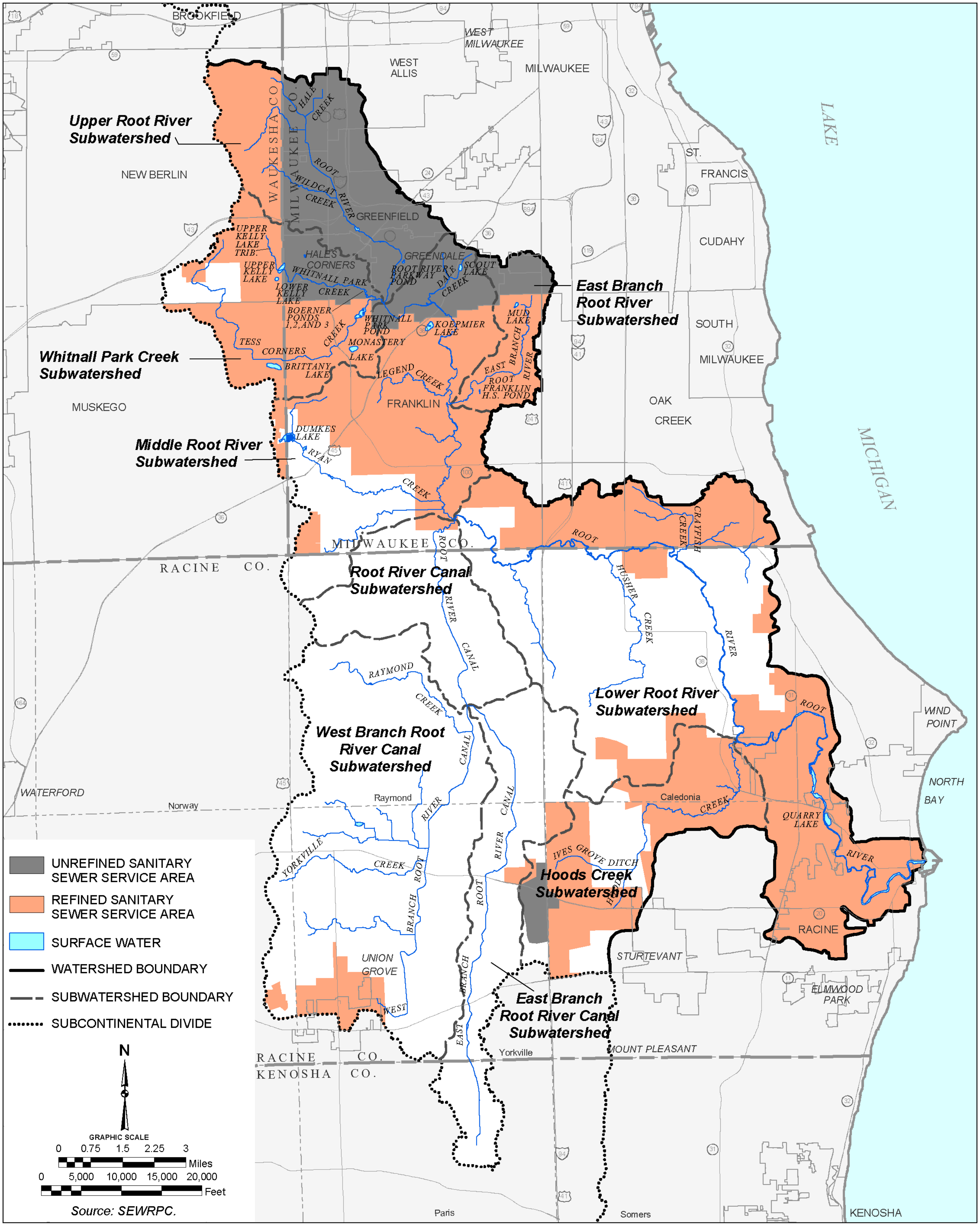
PLANNED SANITARY SEWER SERVICE AREAS IN THE ROOT RIVER WATERSHED: 2005

Name of Initially Defined Sanitary Sewer Service Area	Planned Sewer Service Area (square miles)	Name of Refined and Detailed Sanitary Sewer Service Area(s)	Initial Plan Amendment Document	Date of SEWRPC Adoption of Initial Plan Amendment	Date of SEWRPC Adoption of Most Recent Plan Amendment
Refined Sanitary Sewer Area					
Caddy Vista	0.71	Caddy Vista	SEWRPC CAPR No. 147, *Sanitary Sewer Service Area for the City of Racine and Environs, Racine County, Wisconsin*	December 1, 1986	June 15, 2005
Center for the Developmentally Disabled	0.22	Southern Wisconsin Center	SEWRPC CAPR No. 180, *Sanitary Sewer Service Area for the Village of Union Grove and Environs, Racine County, Wisconsin*	September 12, 1990	- -
Milwaukee Metropolitan Sewerage District (portion)	23.73	Franklin	SEWRPC CAPR No. 176, *Sanitary Sewer Service Area for the City of Franklin, Milwaukee County,*	December 5,1990	- -
Muskego	3.83	Muskego	SEWRPC CAPR No. 64, 2nd Edition, *Sanitary Sewer Service Area for the City of Muskego, Waukesha County, Wisconsin*	March 3, 1986	June 15, 2005
New Berlin	7.81	New Berlin	SEWRPC CAPR No. 157, *Sanitary Sewer Service Area for the City of New Berlin, Waukesha County, Wisconsin*	December 7, 1987	June 15, 2005
Milwaukee Metropolitan Sewerage District (portion)	7.14	Oak Creek	SEWRPC CAPR No. 213, *Sanitary Sewer Service Area for the City of Oak Creek, Wisconsin*	September 7, 1994	- -
Racine	27.52	Racine	SEWRPC CAPR No. 147, *Sanitary Sewer Service Area for the City of Racine and Environs, Racine County, Wisconsin*	December 7, 1987	June 18, 2003
Union Grove	2.09	Union Grove	SEWRPC CAPR No. 180, *Sanitary Sewer Service Area for the Village of Union Grove and Environs, Racine County, Wisconsin*	September 12, 1990	- -
Yorkville (portion)	0.31	Yorkville	*Amendment to the Regional Water Quality Management Plan—2000, Towns of Yorkville and Mt. Pleasant*	December 5, 1990	- -
Subtotal	73.36	- -	- -	- -	- -
Unrefined Sanitary Sewer Service Areas					
Milwaukee Metropolitan Sewerage District (portion)	18.89	- -	- -	- -	- -
Yorkville (portion)	1.07	- -	- -	- -	- -
Subtotal	19.96	- -	- -	- -	- -
Total	93.32	- -	- -	- -	- -

Source: SEWRPC.

Map 107

PLANNED SEWER SERVICE AREAS WITHIN THE ROOT RIVER WATERSHED: 2005



Source: SEWRPC.

Table 171

SEPARATE SANITARY SEWER OVERFLOW LOCATIONS IN THE ROOT RIVER WATERSHED

Identification Number	Location	Community	Number of Days with Overflow: August 1995 to August 2002
HC01	S. 111 Street and W. Copeland Avenue	Hales Corners	2
HC02	10735 S. Grange Avenue	Hales Corners	4
HC04	Garen Court Lift Station	Hales Corners	1
HC05	S. Lory Lane and W. Bunny Court	Hales Corners	1
HC06	S. 92nd Street and W. Garden Court	Hales Corners	1
MI43	S. 92nd Street and W. Howard Avenue	Milwaukee	1
MI44	S. 99th Street and W. Oklahoma Avenue	Milwaukee	4
MS02	McShane Lift Station-S76 W13950 McShane Road	Muskego	2
MS02	McShane Road and Tess Corners Creek	Muskego	2
WA15	2700-3400 S. Root River Parkway	West Allis	1
WA16	Cleveland Avenue (between 112th and 117th Streets)	West Allis	1
WA17	S. 110th and W. Becher Street	West Allis	1
17	6724 Four Mile Road	Caledonia	1[a]
LS02	Lift Station at 2000 Spring Street	Racine	9[a]
LS08	Lift Station at 3640 Northwestern Avenue	Racine	10[a]
LS10	Lift Station at 800 S. Memorial Drive	Racine	8[a]
SO05	21st Street and Grove Avenue	Racine	8[a]
SO06	Washington Avenue and Grove Avenue	Racine	9[a]
SO09	Ontario Street Siphon	Racine	10[a]
SO12	Golf Avenue and Conrad Drive	Racine	10[a]
16	E. 6th Street Siphon	Racine	8[a]
- -	Wastewater Treatment Plant	Union Grove	4

[a]*Racine SSO counts include overflows reported as occurring at multiple locations. This may result in overestimates of days with overflows for some overflow sites.*

Source: Triad Engineering, Wisconsin Department of Natural Resources, and SEWRPC.

Sanitary Sewer Overflow (SSO) Sites in the Watershed

During the period from August 1995 to August 2002, sanitary sewer overflows were reported at 15 locations in the Root River watershed. Table 171 gives the locations of sanitary sewer overflow locations in the Root River. Table 171 indicates the number of days during which overflows were reported as occurring at each location during the period from August 1995 to August 2002. The SSO sites which are being incorporated into the water quality model are indicated on Map 108.

Combined Sewer Overflows (CSOs)

Because the combined sewers in the City of Racine were separated in the early 1980s and the area served by combined sewers in the City of Milwaukee does not extend into Root River watershed, combined sewer overflows are not a potential source of pollution in the Root River watershed.

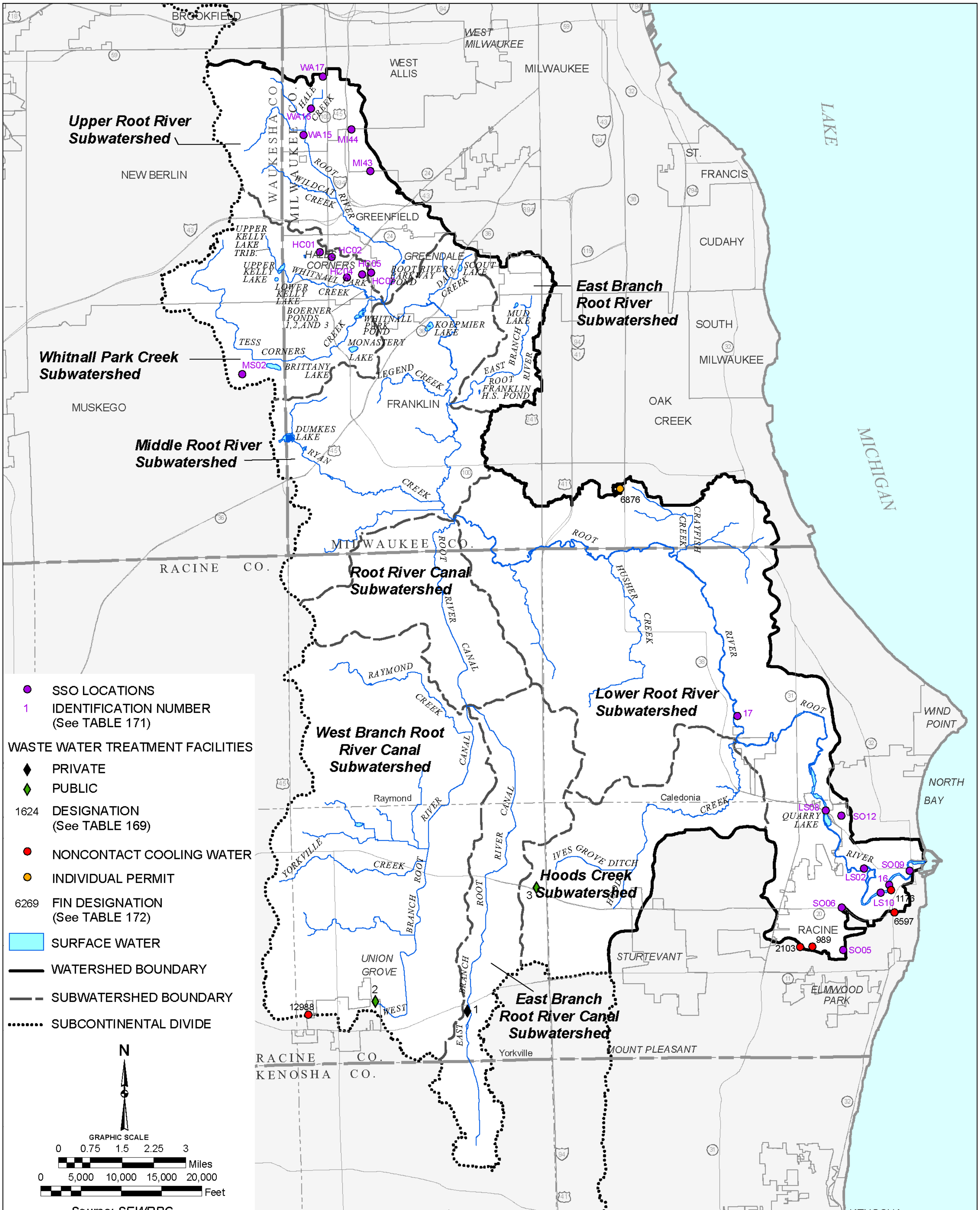
Other Known Point Sources

Industrial Discharges

The number of known industrial wastewater permitted dischargers in the Root River watershed has increased over time. In 1975, there were a total of 13 known industrial wastewater permitted dischargers identified in the watershed. These permitted facilities discharged industrial cooling, process, rinse, and wash waters to surface

Map 108

POINT SOURCES OF POLLUTION WITHIN THE ROOT RIVER WATERSHED: 2003



Source: SEWRPC.

waters.[42] In 1990, 25 permitted facilities discharged wastewater to the Root River, its tributaries, or the groundwater system.[43]

Table 172 lists the industrial discharge permits in effect through the WPDES during February 2003 in the Root River watershed. At that time, 39 WPDES industrial permits were in effect in the watershed. Individual permits represent five of these permits, the rest are spread among seven categories of general permits. The most common category of general permit issued in this watershed was for the discharge of hydrostatic test water which regulates the discharge of water used to pressure test pipelines and tanks. There were eight facilities in the watershed covered by permits in this category. Six facilities had been issued general permits for noncontact cooling water which regulates the discharge of noncontact cooling water, boiler blowdown, and air conditioning condensate. The other general permit categories were each represented by six or fewer facilities. Data from discharge monitoring reports for several facilities covered by individual permits or general permits for noncontact cooling water are being included in water quality modeling for the regional water quality management plan update and the MMSD 2020 Facility Plan. These sites are shown on Map 108.

Due to the dynamic nature of permitted point sources, it is recognized that the number of wastewater sources in the watershed will change as industries and other facilities change locations or processes and as decisions are made with regard to the connection of such sources to public sanitary sewer systems.

Nonpoint Source Pollution

Urban Stormwater Runoff

As shown in Table 156, as of the year 2000, about 32.8 percent of land in the Root River watershed was in urban uses. Urban land uses within the watershed were primarily residential (17.5 percent); followed by transportation, communication, and utilities (8.6 percent) and industrial and extractive, and governmental and institutional, commercial, and recreational each of which fell into the range of about 1 to 3 percent of watershed area. Chapter II of this report includes descriptions of the types of pollutants associated with specific urban nonpoint sources.

Regulation of Urban Nonpoint Source Pollution through the Wisconsin Pollutant Discharge Elimination System Permit Program

Facilities engaged in industrial activities listed in Section NR 216.21(2)(b) of Chapter NR 216 of the *Wisconsin Administrative Code* must apply for and obtain a stormwater discharge permit. The WDNR originally developed a three-tier system of industrial storm water permits. Tier 1 permits apply to facilities involved in heavy industry and manufacturing, including facilities involved in lumber and wood product manufacturing, leather tanning, and primary metal industries. Tier 2 permits apply to facilities involved in light industry and manufacturing and transportation facilities, including facilities involved in printing, warehousing, and food processing. Tier 3 permits used to be issued to facilities which have certified, with WDNR concurrence, that they have no discharges of contaminated stormwater. WDNR authority for Tier 3 permits no longer exists and the Tier 3 permits have been terminated. Facilities now submit a certificate of no exposure. In addition, the WDNR also issues separate permits for automobile parts recycling facilities and scrap recycling facilities. Associated with each category of permit are specific requirements for monitoring and inspection. For all categories of permits except Tier 3 industrial permits, the permit requires the facility to develop and follow a storm water pollution prevention plan (SWPPP). Specific requirements for the SWPPP are listed in Chapter NR 216.27 of the *Wisconsin Administrative Code*. They include provisions related to site mapping, implementation scheduling, conducting annual plan assessments, and monitoring of discharge.

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[42]*SEWRPC Planning Report No. 30,* op. cit.

[43]*SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report*, March 1995.*

Table 172

PERMITTED WASTEWATER DISCHARGERS UNDER THE WPDES GENERAL PERMIT AND INDIVIDUAL PERMIT PROGRAMS IN THE ROOT RIVER WATERSHED: FEBRUARY 2003

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Carriage/Interstitial Water from Dredging[a]	- -	- -	- -	- -	- -	- -
Concrete Products Operations	Carri-Crete Corporation	13360 W. College Avenue	New Berlin	- -	- -	12834
	Central Ready Mix LP–Caledonia	911 Highway 41	Caledonia	0046507	252028920	12818
	Gleason Ready Mix	5255 Phillips Avenue	Racine	0046507	252147280	12819
	Hales Corners Block Company–Raynor	8222 Raynor Avenue	Racine	0046507	252147390	12820
	Meyer Material Oak Creek–Yard 46	841 Rawson Avenue	Oak Creek	0046507	241323500	19254
Contaminated Groundwater Remedial Actions	Bob's Mobil, Inc.	740 S. Main Street	Union Grove	0046566	252060490	14634
	Former Speedy Lube	3101 S. 108th Street	West Allis	0046566	241423600	14602
	Jerry's Midtown Service	11123 W. Forest Home Avenue	Hales Corners	0046566	241299410	14611
Discharge to Subsurface Absorption System	Harry Hansen Meat Service	10407 Highway K	Raymond	0055611	252008570	7009
Hydrostatic Test Water and Water Supply System	Caddy Vista Sanitary District	10201 Caddy Lane	Caledonia	0057681	252002740	6329
	Caledonia Sewer Utility District No. 1	6922 Nicholson Road	Caledonia	0057681	252018470	18615
	City of Franklin Water Utility	9229 W. Loomis Road	Franklin	0057681	241490810	18601
	Milwaukee County HOC–Water Pit	8885 S. 68th Street	Franklin	0057681	241346050	17676
	Oak Creek Water and Sewer Utility	170 W. Drexel Avenue	Oak Creek	0057681	251017260	6581
	Racine Water Utility	100 Hubbard Street	Racine	0057681	252006260	6199
	Southern Wisconsin Center for the Developmentally Disabled	21425 Spring Street	Union Grove	0057681	252019900	19016
	Village of Union Grove	1015 State Street	Union Grove	0057681	252020010	19015
Land Applying Liquid Industrial Wastes	Harry Hansen Meat Service	10407 Highway K	Raymond	0055867	252008570	7009
Land Applying Food Process By-Products Solids	Harry Hansen Meat Service	10407 Highway K	Raymond	0057655	252008570	7009
Land Applying Sludge	Harry Hansen Meat Service	10407 Highway K	Raymond	0057657	252008570	7009
Noncontact Cooling Water	In Sink Erator Division–Emerson	4700 21st Street	Racine	0044938	252004940	2103
	Pen and Inc. of Milwaukee	9860 S. Franklin Drive	Franklin	0044938	241912990	22504
	Plastic Parts, Inc.	1300 Industrial Park Drive	Union Grove	0044938	252007360	12988
	Printing Developments, Inc.	2010 Indiana Street	Racine	0044938	252007580	989
	Racine Heat Treating Company, Inc.	1215 8th Street	Racine	0044938	252014540	1176
	Twin Disc, Inc.–Plant 1	1328 Racine Street	Racine	0044938	252007030	6597
Nonmetallic Mining Operations	Payne & Dolan–Franklin Aggregates	6211 W. Rawson Avenue	Franklin	0046515	241095910	2802
	Vulcan Materials Company–Franklin Quarry	5713 W. Rawson Avenue	Franklin	0046515	241009350	3444
Petroleum Contaminated Water	Air Products & Chemicals, Inc.	701 W. Oakwood Road	Oak Creek	0046531	241168290	3453
Pit/Trench Dredging[b]	- -	- -	- -	- -	- -	- -
Potable Water Treatment and Conditioning	Chrometech of Wisconsin, Inc.	10020 S. 54th Street	Franklin	0046540	241321960	3499

Table 172 (continued)

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number
Swimming Pool Facilities	Hales Corners Park/Pool	5765 S. New Berlin Road	Hales Corners	0046523	241087550	12850
	Tuckaway Country Club	6901 W. Drexel Avenue	Franklin	0046523	241069510	12852
	Village Club, Inc.	6263 Sherwood Road	Greendale	0046523	- -	14250
Individual Permits	Fonks Home Center, Inc.	15941 Durand Avenue	Yorkville	0026689	252002960	6151
	Henkel Surface Technologies, Inc.	420 W. Marquette Avenue	Oak Creek	47643	241165210	6917
	Maple Leaf Farms–Main Farm	T3N R21E Section 4 NE	Yorkville	0001694	252004500	5038
	PPG Industries, Inc.	10800 S. 13th Street	Oak Creek	29149	241014620	6269
	Viasystems Milwaukee, Inc.	S. Howell Avenue	Oak Creek	46493	241116700	6876

[a] *There were no active WPDES general permits for Carriage/Interstitial Water from Dredging in the Root River watershed during February 2003.*

[b] *There were no active WPDES general permits for Pit/Trench Dredging in the Root River watershed during February 2003.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

As shown in Appendix G, "WPDES Permitted Stormwater Facilities," 61 industrial stormwater permits were in effect in the Root River watershed in February 2003. Most of these were Tier 2 permits. With 39 of these permits in effect, this category represented slightly over half of the permitted facilities in the watershed. Tier 3 permits were the next most common in the watershed. In February 2003, 11 of these were in effect. There was seven or fewer each of Tier 1, Automobile Parts Recycling, and Scrap Recycling permits in effect in the watershed at this time.

The WDNR also issues and administers construction site stormwater permits through the WPDES General Permits program. All construction sites that disturb one acre of land or more are required to obtain coverage under the General Permit. Permitted construction sites are required to implement a construction erosion control plan, and a post-construction stormwater management plan as required in Chapter NR 216.46 and Chapter NR 216.47 of the *Wisconsin Administrative Code*. Owners of permitted construction sites are also required to conduct inspections of their construction erosion control measures on a weekly basis and within 24 hours of a precipitation event of 0.5 inches or more. Due to the dynamic nature of construction activities, it is recognized that the number of sites requiring Construction Site Storm Water permits in the watershed will change as construction projects are completed and new projects are initiated.

The WPDES stormwater permits for municipalities within the watershed are described below.

Chapter NR 151 of the Wisconsin Administrative Code

Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* establishes performance standards for the control of nonpoint source pollution from agricultural lands, nonagricultural (urban) lands, and transportation facilities. The standards for urban lands apply to areas of existing development, redevelopment, infill, and construction sites. In general, the construction erosion control, post-construction nonpoint source pollution control, and stormwater infiltration requirements of NR 151 apply to projects associated with construction activities that disturb at least one acre of land.

The urban standards are applied to activities covered under the WPDES program for stormwater discharges. As noted below, communities with WPDES discharge permits must adopt stormwater management ordinances that have requirements at least as stringent as the standards of Chapter NR 151. Those communities must also achieve levels of control of nonpoint source pollution from areas of existing development (as of October 1, 2004), that are specified under Chapter NR 151.

Stormwater Management Systems

Stormwater management facilities are defined, for purposes of this report, as conveyance, infiltration, or storage facilities, including, but not limited to, subsurface pipes and appurtenant inlets and outlets, ditches, streams and engineered open channels, detention and retention basins, pumping facilities, infiltration facilities, constructed wetlands for treatment of runoff, and proprietary treatment devices based on settling processes and control of oil and grease. Such facilities are generally located in urbanized areas and constructed or improved and operated for purposes of collecting stormwater runoff from tributary drainage areas and conveying, storing, and treating such runoff prior to discharge to natural watercourses. In the larger and more intensively developed urban communities, these facilities consist either of complete, largely piped, stormwater drainage systems which have been planned, designed, and constructed as systems in a manner similar to sanitary sewer and water utility systems, or of fragmented or partially piped systems incorporating open surface channels to as great a degree as possible. In the Root River watershed, the stormwater drainage systems provide the means by which a significant portion of the nonpoint sources pollutants reach the surface water system.

With the relatively recent application of the WPDES permitting program to stormwater discharges and the adoption of local stormwater management ordinances, controls on the quality of stormwater runoff prior to discharge to receiving streams have become more common. Table 173 indicates the status of stormwater management activities in each of the communities in the watershed.

Table 173

STORMWATER MANAGEMENT INFORMATION FOR CITIES, VILLAGES, AND TOWNS WITHIN THE ROOT RIVER WATERSHED

Civil Division	Stormwater Management Ordinance and/or Plan	Construction Erosion Control Ordinance	Stormwater Utility, General Fund, and/or Established Stormwater Fee Program
Kenosha County			
Town of Paris	- -	- -	- -
Milwaukee County			
City of Franklin	X	X	- -
City of Greenfield	X	X	- -
City of Milwaukee	X	X	X
City of Oak Creek	X	X	X
City of West Allis	X	X	X
Village of Greendale	X	X	X
Village of Hales Corners	X	X	- -
Racine County			
City of Racine	X	X	X
Village of Caledonia	X	X	X
Village of Mt. Pleasant	X	X	- -
Village of Sturtevant	- -[a]	X	X
Village of Union Grove	X	X	- -
Town of Dover	- -	X	- -
Town of Norway	X	X	- -
Town of Raymond	- -	- -	- -
Town of Yorkville	- -	- -	- -
Waukesha County			
City of Muskego	X	X	- -
City of New Berlin	X	X	X

[a]*Will develop an ordinance as required under WPDES stormwater discharge permit.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

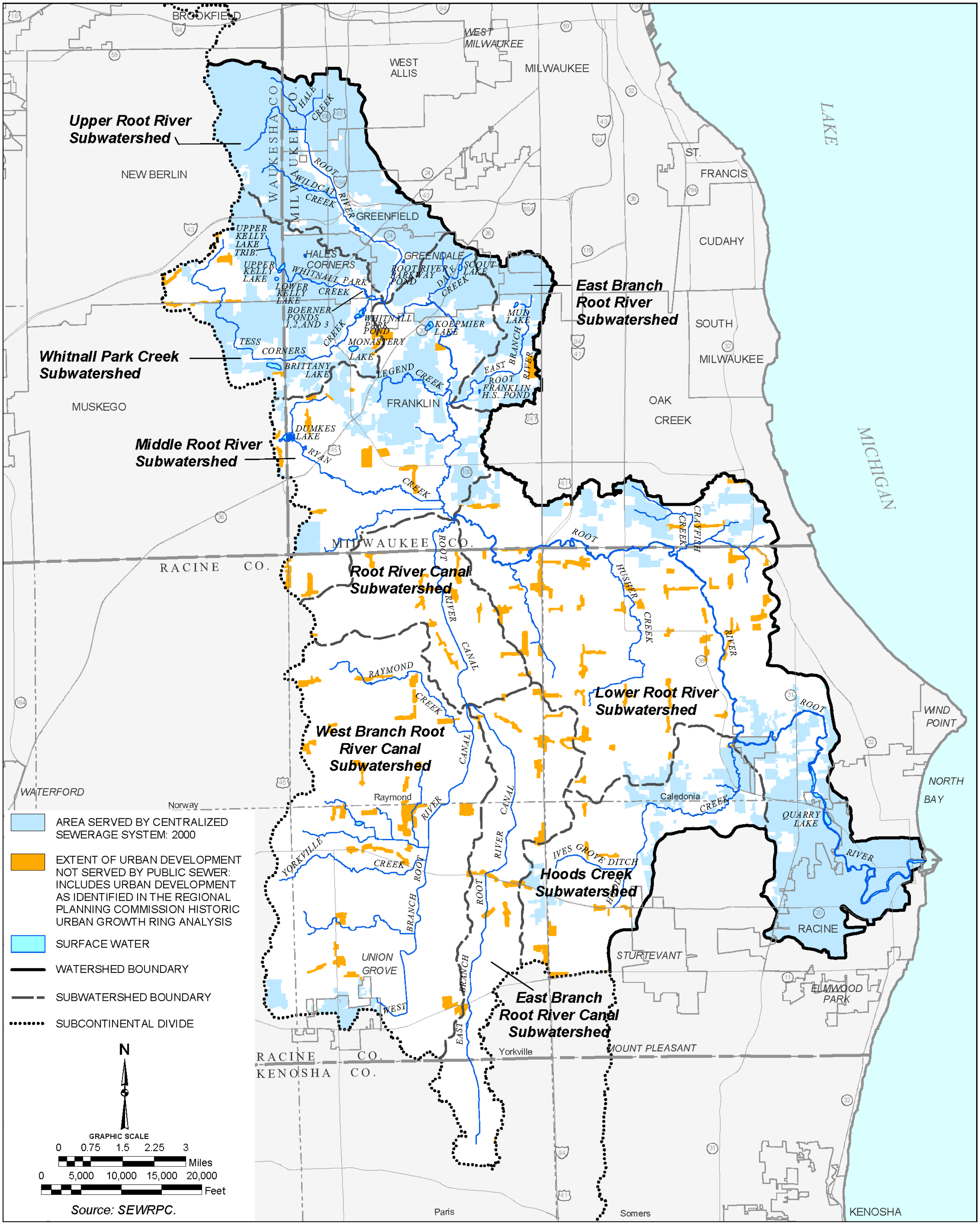
Table G-5 in Appendix G indicates that Milwaukee and Waukesha Counties; the Cities of Franklin, Greenfield, Milwaukee, Muskego, New Berlin, Oak Creek, Racine, and West Allis; and the Villages of Caledonia, Greendale, Hales Corners, Mt. Pleasant, and Sturtevant have WPDES stormwater discharge permits. The Towns of Dover, Norway, Paris, Raymond, and Yorkville, and the Village of Union Grove do not currently have stormwater discharge permits. Thus, communities comprising 64 percent of the watershed area have been issued WPDES stormwater discharge permits. In addition to specific nonpoint source pollution control activities recommended under their WPDES permits, the permitted communities will also all be required to develop new, or update existing, stormwater management ordinances to be consistent with the standards of Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*. As part of their permit application, each community prepared maps of the stormwater outfalls that are part of the municipal separate stormwater system.

Urban Enclaves Outside Planned Sewer Service Areas

Map 109 shows areas served by centralized sanitary sewer systems in the Root River watershed in 2000. In that year, 33,155 acres of the watershed were served by sanitary sewer systems. In addition, there were about 3,852 acres of urban-density enclaves that were not served by public sanitary sewer systems. As shown on Map 110, about 3,014 acres of these enclaves are in areas served by onsite sewage disposal systems that were developed prior to 1980. These older systems may be at particular risk for malfunctioning. As described in Chapter II of this report, failure of onsite disposal systems can contribute nonpoint source pollutants to streams and groundwater.

Map 109

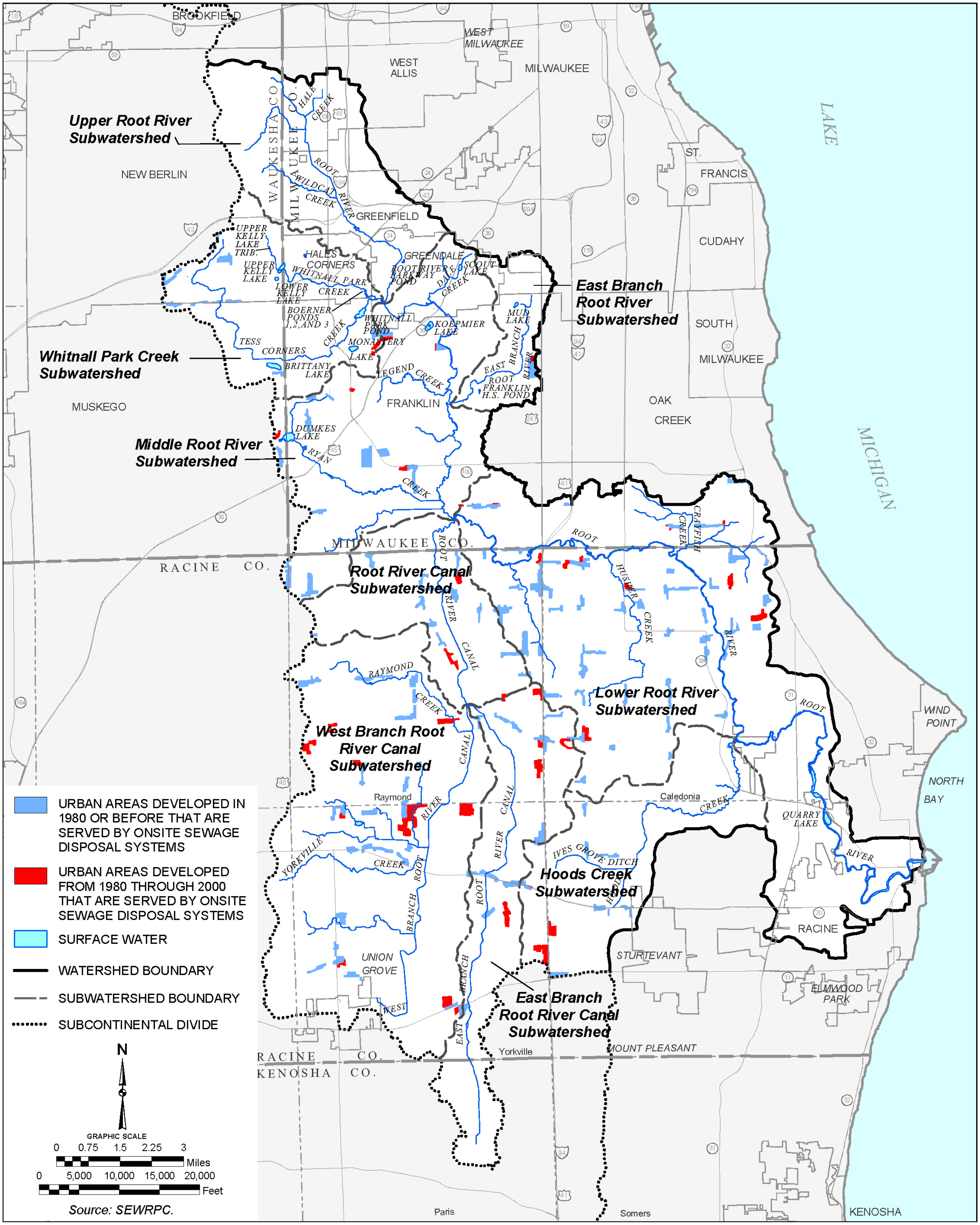
AREAS SERVED BY CENTRALIZED SANITARY SEWERAGE SYSTEMS WITHIN THE ROOT RIVER WATERSHED: 2000



Source: SEWRPC.

Map 110

URBAN AREAS WITHIN THE ROOT RIVER WATERSHED THAT ARE SERVED BY ONSITE SEWAGE DISPOSAL SYSTEMS: 1980 AND PRIOR AND 1981 THROUGH 2000



Source: SEWRPC.

In 1978, the State of Wisconsin established the Private Onsite Wastewater Treatment System Replacement or Rehabilitation Financial Assistance Program under the Wisconsin Fund Program. That voluntary program annually awards grants to counties, Indian tribes, and municipalities to assist homeowners and small businesses in replacing or rehabilitating failing private, onsite systems. The program is administered by the Wisconsin Department of Commerce in cooperation with the counties and communities. Grant eligibility is subject to specific income, revenue, occupancy, and operation requirements. Onsite systems that are installed, replaced, or rehabilitated after the date on which the county or community elects to participate are required to have a maintenance program. Thus, given the 1978 date of establishment of the grant program, the determination of areas developed with onsite systems before 1980 and those developed in 1980 or later,[44] provides an indication of which systems are subject to the requirement of having formal maintenance programs and which are not. The counties, or communities in the case of Milwaukee County, are responsible for administering the maintenance program with the goal of assuring the onsite systems function properly. In the Root River watershed, Kenosha, Racine, and Waukesha Counties and the City of Franklin currently participate in the program.

Solid Waste Disposal Sites

Solid waste disposal sites are a potential source of surface water, as well as groundwater, pollution. It is important to recognize, however, the distinction between a properly designed and constructed solid waste landfill and the variety of operations that are referred to as refuse dumps, especially with respect to potential effects on water quality. A solid waste disposal site may be defined as any land area used for the deposit of solid wastes regardless of the method of operation, or whether a subsurface excavation is involved. A solid waste landfill may be defined as a solid waste disposal site which is carefully located, designed, and operated to avoid hazards to public health or safety, or contamination of groundwaters or surface waters. The proper design of solid waste landfills requires careful engineering to confine the refuse to the smallest practicable area, to reduce the refuse mass to the smallest practicable volume, to avoid surface water runoff, to minimize leachate production and percolation into the groundwater and surface waters, and to seal the surface with a layer of earth at the conclusion of each day's operation or at more frequent intervals as necessary.

In order for a landfill to produce leachate, there must be some source of water moving through the fill material. Possible sources included precipitation, the moisture content of the refuse itself, surface water infiltration, groundwater migrating into the fill from adjacent land areas, or groundwater rising from below to come in contact with the fill. In any event, leachate is not released from a landfill until a significant portion of the fill material exceeds its saturation capacity. If external sources of water are excluded from the solid waste landfill, the production of leachates in a well-designed and managed landfill can be effectively minimized if not entirely avoided. The quantity of leachate produced will depend upon the quantity of water that enters the solid waste fill site minus the quantity that is removed by evapotranspiration. Studies have estimated that for a typical landfill, from 20 to 50 percent of the rainfall infiltrated into the solid waste may be expected to become leachate. Accordingly, a total annual rainfall of about 35 inches, which is typical of the Root River watershed, could produce from 190,000 to 480,000 gallons of leachates per year per acre of landfill if the facility is not properly located, designed, and operated.

As of 2005, there was one active solid waste landfill within the watershed, located in the Middle Root River subwatershed. As set forth in Table 174 and shown on Map 111, there are 13 inactive landfills in the watershed: four in the Upper Root River subwatershed, five in the Lower Root River subwatershed, one each in the Middle Root River and East Branch Root River Canal subwatersheds, and two in the West Branch Root River Canal subwatershed.

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[44]*Since 1970, the SEWRPC land use inventory has been conducted at five-year intervals. Thus the 1980 inventory was the best available information for establishing which systems have maintenance requirements.*

Table 174

ACTIVE AND INACTIVE SOLID WASTE DISPOSAL SITES IN THE ROOT RIVER WATERSHED: 2004

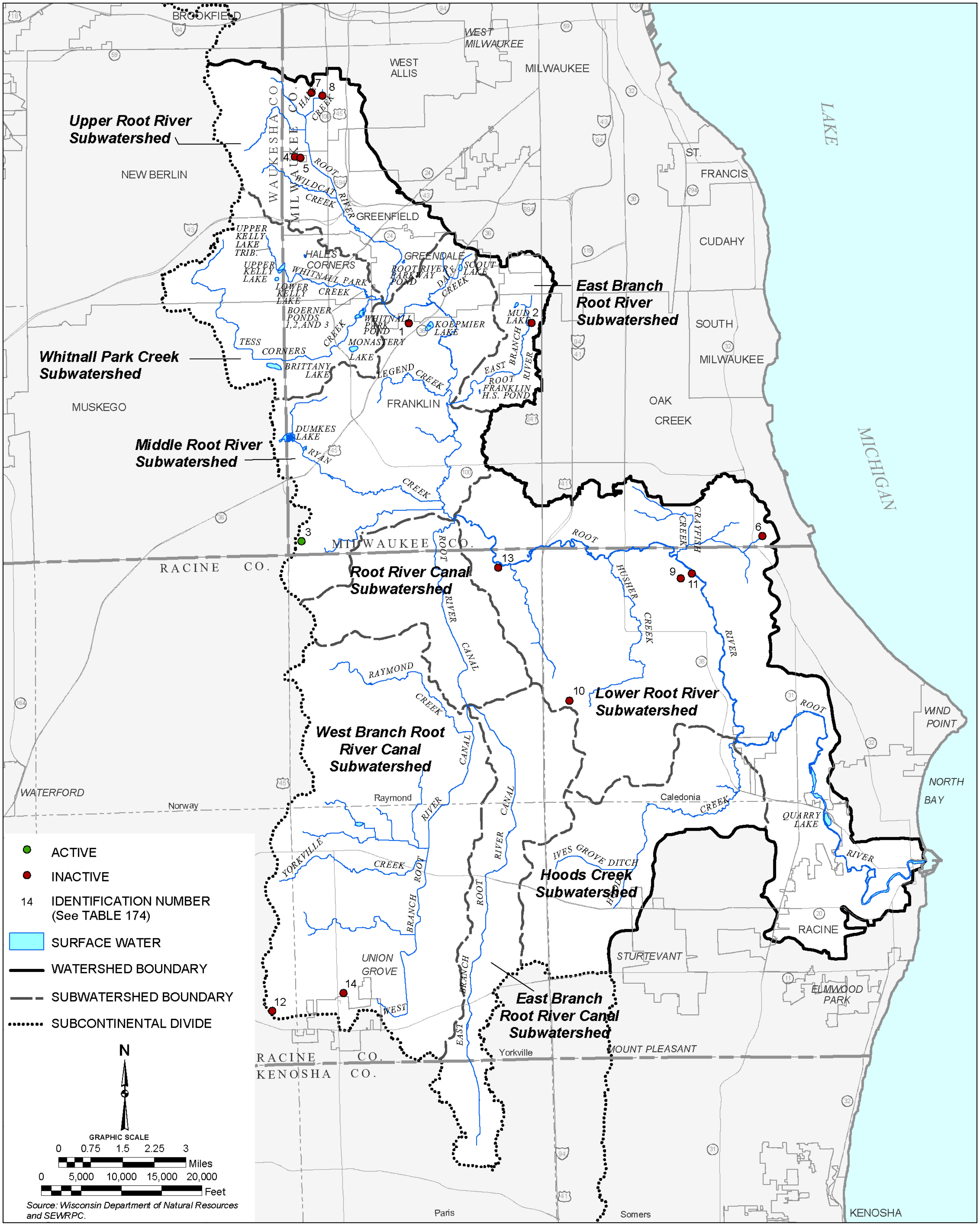
Number on Map 111	Facility Name	Address	Municipality	Classification	Subwatershed	Facility ID	Status
1	Milwaukee County Highway Department Landfill	- -	City of Franklin	Landfill> 500,000 cubic yards	Middle Root River	241206130	Inactive
2	Fadrowski Drum Disposal	- -	City of Franklin	- -	East Branch Root River	241376520	Inactive, Superfund site (mitigated)
3	Waste Management of Wisconsin Metro Landfill	10712 S. 124th Street	City of Franklin	Landfill> 500,000 cubic yards	Middle Root River[a]	241168620	Active
4	City of Greenfield Landfill	- -	City of Greenfield	- -	Upper Root River	- -	Inactive
5	Allis-Chalmers Corporation Landfill	11815 W. Morgan Avenue	City of Greenfield	Landfill> 500,000 cubic yards-monofill	Upper Root River	241182480	Inactive
6	Wisconsin Electric Power Company, Oak Creek	- -	City of Oak Creek	Landfill> 500,000 cubic yards	Lower Root River	241219770	Inactive
7	City of West Allis Landfill	S. 113th Street and Lincoln Avenue	City of West Allis	Landfill 50,000 to 500,000 cubic yards	Upper Root River	241209540	Inactive
8	- -	- -	City of West Allis	- -	Upper Root River	- -	Inactive
9	Caledonia Corporation	- -	Village of Caledonia	- -	Lower Root River	- -	Inactive
10	Hillside Sand and Gravel	- -	Village of Caledonia	- -	Lower Root River	- -	Inactive
11	Hunt's Disposal Landfill	- -	Village of Caledonia	- -	Lower Root River	252076330	Inactive, Superfund site (mitigated)
12	Center for the Developmentally Disabled	- -	Town of Dover	- -	West Branch Root River Canal	252076660	Inactive
13	Waste Management Wisconsin Reclamation	Reclamation, Inc.	Town of Raymond	Landfill, unclassified	Lower Root River	252076440	Inactive
14	Village of Union Grove Landfill	- -	Town of Yorkville	Landfill 50,000 to 500,000 cubic yards	West Branch Root River Canal	252076110	Inactive

[a]*A portion of the Metro Landfill drains to the Fox River watershed.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 111

ACTIVE AND INACTIVE SOLID WASTE DISPOSAL SITES WITHIN THE ROOT RIVER WATERSHED: 2004



Rural Stormwater Runoff

Rural land uses within the Root River watershed include agricultural—mostly crop production—and woodlands, wetlands, water, and other open lands as set forth in the beginning of this chapter. As noted above, Chapter NR 151 of the *Wisconsin Administrative Code* establishes performance standards for the control of nonpoint source pollution from agricultural lands, nonagricultural (urban) lands, and transportation facilities. Agricultural performance standards are established for soil erosion, manure storage facilities, clean water diversions, nutrient management, and manure management. Those standards must only be met to the degree that grant funds are available to implement projects designed to meet the standards.

Livestock Operations

The presence of livestock and poultry manure in the environment is an inevitable result of animal husbandry and is a major potential source of water pollutants. Animal manure composed of feces, urine, and sometimes bedding material, contributes suspended solids, nutrients, oxygen-demanding substances, bacteria, and viruses to surface waters. Animal waste constituents of pastureland and barnyard runoff, and animal wastes deposited on pastureland and cropland and in barnyards, feedlots, and manure piles, can potentially contaminate water by surface runoff, infiltration to groundwater, and volatilization to the atmosphere. During the warmer seasons of the year the manure is often scattered on cropland and pastureland where the waste material is likely to be taken up by vegetative growth composing the land cover. However, when the animal manure is applied to the land surface during the winter, the animal wastes are subject to excessive runoff and transport, especially during the spring snowmelt period.

Based on data from 2002, animal operations in the Root River watershed include 199 operations rearing a total of about 11,700 cattle and calves, 32 operations rearing a total of about 2,500 pigs, 35 operations rearing a total of about 900 sheep, and 62 operations rearing a total of about 55,600 chickens, mostly broilers. Most of these operations are in the portions of the watershed in Racine County.

One concentrated animal feeding operation (CAFO), Maple Leaf Farms in the Town of Yorkville, is situated in the watershed. This operation rears about 500,000 ducks. Concentrated animal feeding operations are defined as livestock and poultry operations with more than 1,000 animal units. Animal units are calculated for each different type and size class of livestock and poultry. For example, facilities with 1,000 beef cattle, 700 milking cows, or 200,000 chickens each would be considered to have the equivalent of 1,000 animal units. Concentrated animal feeding operations are regulated by the State of Wisconsin under the WPDES permit program.

Crop Production

In the absence of mitigating measures, runoff from cropland can have an adverse effect upon water quality within the Root River watershed by contributing excess sediments, nutrients, and organic matter, including pesticides to streams. Negative effects associated with soil erosion and transport to waterbodies includes reduced water clarity, sedimentation on streambeds, and contamination of the water from various agricultural chemicals and nutrients that are attached to the individual soil particles. Some of these nutrients, in particular phosphorus, and to some extent nitrogen, are directly associated with eutrophication of water resources. The extent of the water pollution from cropping practices varies considerably as a result of the soils, slopes, and crops, as well as in the numerous methods of tillage, planting, fertilization, chemical treatment, and conservation practices. Conventional tillage practices, or moldboard plowing, involve turning over the soil completely, leaving the soil surface bare of most cover or residue from the previous year's crop, and making it highly susceptible to erosion due to wind and rain. The use of conservation tillage practices has become common in the watershed in recent years within areas most susceptible to erosion and surface water impacts.

Crops grown in the Root River watershed include row crops, such as corn and soybeans; small grains, such as winter wheat; hay, such as alfalfa; and vegetables, such as cabbages, snap beans, and sweet corn. Row crops and vegetable crops, which have a relatively higher level of exposed soil surface, tend to contribute higher pollutant loads than do hay and pastureland, which support greater levels of vegetative cover. Crop rotations typically follow a two- or three-year sequence of corn and soybeans and occasionally winter wheat in the third year. However, hay is periodically included as part of a long-term rotation of corn, oats, and alfalfa.

Since the early 1930s, it has been a national objective to preserve and protect agricultural soil from wind and water erosion. Federal programs have been developed to achieve this objective, with the primary emphasis being on sound land management and cropping practices for soil conservation. An incidental benefit of these programs has been a reduction in the amount of eroded organic and inorganic material entering surface waters as sediment or attached to sediment. Some practices are effective in both regards, while others may enhance the soil conditions with little benefit to surface water quality. Despite the implementation of certain practices aimed at controlling soil erosion from agricultural land, and development of soil erosion plans for the portions of the Root River basin in Kenosha,[45] Racine,[46] Milwaukee,[47] and Waukesha[48] counties, such erosion and the resultant deposition of sediment in the streams of the Root River watershed remains a significant water resource problem. Soil erosion from agricultural lands is one of the major sources of sediment and nutrients in the Root River and its tributaries.

Nutrients such as phosphorus and agri-chemicals, including herbicides and pesticides, are electrostatically attracted to silt sized particles and are transported to surface waters through soil erosion. As previously mentioned, phosphorus is one of the primary nutrients associated with eutrophication of water resources, and agri-chemicals can negatively impact the life cycles of aquatic organisms. In the eutrophication process, phosphorus enhances growth of aquatic vegetation and algae, which has the effect of accelerating the aging process of a water resource. Phosphorus is usually not susceptible to downward movement through the soil profile; instead, the majority of phosphorus reaches water resources by overland flow, or erosion. Nitrogen also is a nutrient that contributes to eutrophication; however, it is most often associated with subsurface water quality contamination. Nitrogen in the form of nitrate can be associated with respiration problems in newborn infants. Nitrogen is susceptible to downward movement through the soil profile; however, due to the nature of soils in the watershed, nitrogen is not as significant a threat due to various chemical reactions that occur within the soil.[49]

Woodlands

A well-managed woodland contributes few pollutants to surface waters. Under poor management, however, woodlands may have detrimental water quality effects through the release of sediments, nutrients, organic matter, and pesticides into nearby surface waters. If trees along streams are cut, thermal pollution may occur as the direct rays of the sun strike the water. Disturbances caused by tree harvesting, livestock grazing, tree growth promotion, tree disease prevention, fire prevention, and road and trail construction are a major source of pollution from silvicultural activities. Most of these activities are seldom practiced in the Root River watershed.

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[45]*SEWRPC Community Assistance Planning Report No. 164,* Kenosha County Agricultural Soil Erosion Control Plan, *April 1989.*

[46]*SEWRPC Community Assistance Planning Report No. 160,* Racine County Agricultural Soil Erosion Control Plan, *July 1988.*

[47]*Milwaukee County Land Conservation Committee,* Milwaukee County Land and Water Resource Management Plan, *April 2001.*

[48]*SEWRPC Community Assistance Planning Report No. 159,* Waukesha County Agricultural Soil Erosion Control Plan, *June 1988.*

[49]*Soils that have a high clay content and stay wet for long periods of time, or even well-drained soils after a rainfall event are susceptible to nitrogen losses to the atmosphere through a chemical reaction known as denitrification. This reaction converts nitrate, NO_3^-, to gaseous nitrogen, N_2, which is lost to the atmosphere.*

Pollution Loadings

Annual Loadings

Annual average pollutant loads to the Root River watershed are set forth in Tables 175 through 181. Average annual per acre loads are set forth in Table 182. These estimates represent point and nonpoint source loads delivered to the modeled stream reaches, after accounting for any trapping factors that would retain pollutants on the surface of the land. They include loads from groundwater. It is important to note that the stream channel pollutant loads may be expected to be different from the actual transport from the watershed, because physical, chemical, and biological processes may retain or remove pollutants or change their form during transport over the land surface or within the stream system. These processes include particle deposition or entrapment on the land surface or in floodplains, stream channel deposition or aggradation, biological uptake, and chemical transformation and precipitation. The total pollutant loads set forth in Table 175 are representative of potential pollutants moved from the Root River watershed into stream channels, but are not intended to reflect the total amount of pollutants moving from those sources through the entire hydrologic-hydraulic system.

Point Source Loadings

Annual average total point source pollutant loads of six pollutants in the Root River watershed are set forth in Tables 176 through 181. Contributions of these pollutants by point sources represent a minor portion of the total average loads, generally about 4 percent or less.

Average annual point source loads of total phosphorus in the Root River watershed are shown in Table 176. The total average annual point source load of total phosphorus is about 3,290 pounds. Most of this is contributed by the West Branch Root River Canal and Hoods Creek subwatersheds. Sewage treatment plants account for 96 percent of the total phosphorus load from point sources.

Average annual point source loads of TSS in the Root River watershed are shown in Table 177. The total average annual point source load of total suspended solids is about 11,910 pounds. Most of this is contributed by the West Branch Root River Canal subwatershed. Sewage treatment plants represent the major source of TSS, contributing about 87 percent of the total load from point sources.

Average annual point source loads of fecal coliform bacteria in the Root River watershed are shown in Table 178. The total average annual point source load of fecal coliform bacteria is about 22.94 trillion cells per year. Most of this is contributed by the Lower Root River subwatershed. Separate sanitary sewer overflows account for 86 percent of the fecal coliform bacteria load from point sources.

Average annual point source loads of total nitrogen in the Root River watershed are shown in Table 179. The total average annual point source load of total nitrogen is about 27,100 pounds. Most of this is contributed by the West Branch Root River Canal subwatershed. Sewage treatment plants account for 98 percent of the total nitrogen load from point sources.

Average annual point source loads of BOD in the Root River watershed are shown in Table 180. The total average annual point source load of BOD is about 14,110 pounds. Most of this is contributed by the West Branch Root River Canal subwatershed. Sewage treatment plants represent 92 percent of the BOD load from point sources.

Average annual point source loads of copper in the Root River watershed are shown in Table 181. The total average annual point source load of copper is about 43 pounds per year. Most of this is contributed by the West Branch Root River Canal subwatershed. Sewage treatment plants represent 93 percent of the copper load from point sources.

Nonpoint Source Loads

Because nonpoint source pollution is delivered to streams in the watershed through many diffuse sources, including direct overland flow, numerous storm sewer and culvert outfalls, and swales and engineered channels, it

Table 175

AVERAGE ANNUAL TOTAL NONPOINT SOURCE POLLUTANT LOADS IN THE ROOT RIVER WATERSHED[a]

Subwatershed	Total Phosphorus (pounds)	Total Suspended Solids (pounds)	Fecal Coliform Bacteria (trillions of cells)	Total Nitrogen (pounds)	Biochemical Oxygen Demand (pounds)	Copper (pounds)
Lower Root River	23,420	20,951,670	3,494.25	281,100	793,570	575
Middle Root River	8,910	6,730,640	1,640.24	100,830	292,300	264
Upper Root River	6,170	1,937,170	2,203.71	39,830	176,230	307
Hoods Creek	6,630	7,945,110	695.42	103,380	252,700	133
Root River Canal	4,900	7,162,240	277.27	91,120	239,010	57
East Branch Root River Canal	7,310	10,889,460	466.35	134,680	403,190	91
West Branch Root River Canal	16,930	25,671,040	1,012.74	312,440	906,830	189
East Branch Root River	1,840	723,490	557.12	14,600	50,320	79
Whitnall Park Creek	4,660	1,748,700	1,410.11	38,090	130,360	201
Total	80,770	83,759,520	11,757.21	1,116,070	3,244,510	1,896

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

Table 176

AVERAGE ANNUAL LOADS OF TOTAL PHOSPHORUS IN THE ROOT RIVER WATERSHED[a]

Subwatershed	Point Sources				Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Lower Root River	130	10	0	140	8,750	14,670	23,420	23,560
Middle Root River	0	0	0	0	3,780	5,130	8,910	8,910
Upper Root River	0	<10	0	<10	6,000	170	6,170	6,170
Hoods Creek	0	0	940	940	1,020	5,610	6,630	7,570
Root River Canal	0	0	0	0	180	4,720	4,900	4,900
East Branch Root River Canal	0	0	220	220	430	6,880	7,310	7,530
West Branch Root River Canal	<10	0	1,990	1,990	1,040	15,890	16,930	18,920
East Branch Root River	0	0	0	0	1,660	180	1,840	1,840
Whitnall Park Creek	0	<10	0	<10	3,650	1,010	4,660	4,660
Total	130	10	3,150	3,290	26,510	54,260	80,770	84,060
Percent of Total Load	0.2	<0.1	3.7	3.9	31.5	64.6	96.1	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

Source: Tetra Tech, Inc.

would be prohibitively expensive and time-consuming to directly measure nonpoint source pollution loads to streams. Thus, the calibrated water quality model was applied to estimate average annual nonpoint source pollutant loads delivered to the streams in the watershed. The results of that analysis are set forth in Tables 175 through 181 and depicted graphically on Maps H-49 through H-60 in Appendix H of this report. General water quality modeling procedures are described in Chapter V of SEWRPC Planning Report No. 50, *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds.*

Table 175 shows the average annual total nonpoint source pollutant loads for subwatersheds of the Root River watershed. Average annual per acre nonpoint source pollution loads for subwatersheds of the Root River watershed are shown in Table 182.

Table 177

AVERAGE ANNUAL LOADS OF TOTAL SUSPENDED SOLIDS IN THE ROOT RIVER WATERSHED[a]

	Point Sources				Nonpoint Sources			
Subwatershed	Industrial Point Sources (pounds)	SSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	Total (pounds)
Lower Root River	480	710	0	1,190	2,781,990	18,169,680	20,951,670	20,952,860
Middle Root River	0	0	0	0	1,290,740	5,439,900	6,730,640	6,730,640
Upper Root River	0	80	0	80	1,918,200	18,970	1,937,170	1,937,250
Hoods Creek	0	0	1,060	1,060	536,060	7,409,050	7,945,110	7,946,170
Root River Canal	0	0	0	0	114,030	7,048,210	7,162,240	7,162,240
East Branch Root River Canal	0	0	450	450	271,250	10,618,210	10,889,460	10,889,910
West Branch Root River Canal	0	0	8,890	8,890	468,430	25,202,610	25,671,040	25,679,930
East Branch Root River	0	0	0	0	494,130	229,360	723,490	723,490
Whitnall Park Creek	0	240	0	240	1,112,640	636,060	1,748,700	1,748,940
Total	480	1,030	10,400	11,910	8,987,470	74,772,050	83,759,520	83,771,430
Percent of Total Load	<0.1	<0.1	<0.1	<0.1	10.7	89.3	100	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Table 178

AVERAGE ANNUAL LOADS OF FECAL COLIFORM BACTERIA IN THE ROOT RIVER WATERSHED[a]

	Point Sources				Nonpoint Sources			
Subwatershed	Industrial Point Sources (trillions of cells)	SSOs (trillions of cells)	Sewage Treatment Plants (trillions of cells)	Subtotal (trillions of cells)	Urban (trillions of cells)	Rural (trillions of cells)	Subtotal (trillions of cells)	Total (trillions of cells)
Lower Root River	0.00	13.58	0.00	13.58	2,641.12	853.13	3,494.25	3,507.83
Middle Root River	0.00	0.00	0.00	0.00	1,323.10	317.14	1,640.24	1,640.24
Upper Root River	0.00	1.55	0.00	1.55	2,202.96	0.75	2,203.71	2,205.26
Hoods Creek	0.00	0.00	0.30	0.30	418.83	276.59	695.42	695.72
Root River Canal	0.00	0.00	0.00	0.00	96.48	180.79	277.27	277.27
East Branch Root River Canal	0.00	0.00	0.14	0.14	215.12	251.23	466.35	466.49
West Branch Root River Canal	0.00	0.00	2.85	2.85	451.94	560.80	1,012.74	1,015.59
East Branch Root River	0.00	0.00	0.00	0.00	554.63	2.49	557.12	557.12
Whitnall Park Creek	0.00	4.52	0.00	4.52	1,309.52	100.59	1,410.11	1,414.63
Total	0.00	19.65	3.29	22.94	9,213.70	2,543.51	11,757.21	11,780.15
Percent of Total Load	0	0.2	<0.1	0.2	78.2	21.6	99.8	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

The average annual nonpoint load of total phosphorus is estimated to be 80,770 pounds per year. About 31.5 percent of the total point and nonpoint source load is from urban nonpoint sources and about 64.6 percent is from rural nonpoint sources (see Table 176). The distribution of total load among the subwatersheds is shown on Map H-49 in Appendix H. Map H-50 in Appendix H shows the annual per acre loads of total phosphorus from the subwatersheds. Contributions of total phosphorus vary among the subwatersheds (see Table 175) from a low of about 1,840 pounds per year from the East Branch Root River subwatershed to about 23,420 pounds per year from the Lower Root River subwatershed. The highest loads of total phosphorus are contributed by the Lower

Table 179

AVERAGE ANNUAL LOADS OF TOTAL NITROGEN IN THE ROOT RIVER WATERSHED[a]

Subwatershed	Point Sources				Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Lower Root River	540	30	0	570	48,810	232,290	281,100	281,670
Middle Root River	0	0	0	0	24,170	76,660	100,830	100,830
Upper Root River	0	<10	0	<10	38,610	1,220	39,830	39,830
Hoods Creek	0	0	3,980	3,980	6,060	97,320	103,380	107,360
Root River Canal	0	0	0	0	1,180	89,940	91,120	91,120
East Branch Root River Canal	0	0	1,820	1,820	2,600	132,080	134,680	136,500
West Branch Root River Canal	<10	0	20,720	20,720	6,720	305,720	312,440	333,160
East Branch Root River	0	0	0	0	10,570	4,030	14,600	14,600
Whitnall Park Creek	0	10	0	10	23,440	14,650	38,090	38,100
Total	540	40	26,520	27,100	162,160	953,910	1,116,070	1,143,170
Percent of Total Load	0.1	<0.1	2.3	2.4	14.2	83.4	97.6	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Table 180

AVERAGE ANNUAL LOADS OF BIOCHEMICAL OXYGEN DEMAND IN THE ROOT RIVER WATERSHED[a]

Subwatershed	Point Sources				Nonpoint Sources			Total (pounds)
	Industrial Point Sources (pounds)	SSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Lower Root River	820	180	0	1,000	215,660	577,910	793,570	794,570
Middle Root River	0	0	0	0	105,600	186,700	292,300	292,300
Upper Root River	0	20	0	20	169,850	6,380	176,230	176,250
Hoods Creek	0	0	990	990	37,740	214,960	252,700	253,690
Root River Canal	0	0	0	0	8,330	230,680	239,010	239,010
East Branch Root River Canal	0	0	750	750	19,720	383,470	403,190	403,940
West Branch Root River Canal	10	0	11,280	11,290	36,630	870,200	906,830	918,120
East Branch Root River	0	0	0	0	42,060	8,260	50,320	50,320
Whitnall Park Creek	0	60	0	60	99,220	31,140	130,360	130,420
Total	830	260	13,020	14,110	734,810	2,509,700	3,244,510	3,258,620
Percent of Total Load	<0.1	<0.1	0.4	0.4	22.6	77.0	99.6	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Root River and West Branch Root River Canal subwatersheds. This reflects both the relatively high unit area load (pounds per acre) (see Table 182) and the large areas of these subwatersheds. The highest unit area loads occur in the East Branch Root River Canal and Lower Root River subwatersheds.

The average annual nonpoint load of total suspended solids is estimated to be 83,759,520 pounds per year. About 10.7 percent of the total point and nonpoint source load is from urban nonpoint sources and about 89.3 percent is from rural nonpoint sources (see Table 177). The distribution of this load among the subwatersheds is shown on Map H-51 in Appendix H. Map H-52 in Appendix H shows the annual per acre loads of total suspended solids for

Table 181

AVERAGE ANNUAL LOADS OF COPPER IN THE ROOT RIVER WATERSHED[a]

	Point Sources				Nonpoint Sources			
Subwatershed	Industrial Point Sources (pounds)	SSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	Total (pounds)
Lower Root River	3	<1	0	3	404	171	575	578
Middle Root River	0	0	0	0	194	70	264	264
Upper Root River	0	<1	0	<1	305	2	307	307
Hoods Creek	0	0	4	4	69	64	133	137
Root River Canal	0	0	0	0	15	42	57	57
East Branch Root River Canal	0	0	1	1	36	55	91	92
West Branch Root River Canal	0	0	35	35	67	122	189	224
East Branch Root River	0	0	0	0	77	2	79	79
Whitnall Park Creek	0	<1	0	<1	181	20	201	201
Total	3	<1	40	43	1,348	548	1,896	1,939
Percent of Total Load	0.1	<0.1	2.1	2.2	69.5	28.3	97.8	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

Table 182

AVERAGE ANNUAL PER ACRE NONPOINT SOURCE POLLUTANT LOADS IN THE ROOT RIVER WATERSHED[a]

Subwatershed	Total Phosphorus (pounds per acre)	Total Suspended Solids (pounds per acre)	Fecal Coliform Bacteria (trillions of cells per acre)	Total Nitrogen (pounds per acre)	Biochemical Oxygen Demand (pounds per acre)	Copper (pounds per acre)
Lower Root River	0.68	611	0.10	8.20	23.15	0.017
Middle Root River	0.58	435	0.11	6.52	18.89	0.017
Upper Root River	0.60	189	0.22	3.89	17.22	0.030
Hoods Creek	0.66	789	0.07	10.27	25.10	0.013
Root River Canal	0.64	932	0.04	11.86	31.12	0.007
East Branch Root River Canal	0.74	1,098	0.05	13.58	40.66	0.009
West Branch Root River Canal	0.67	1,017	0.04	12.37	35.92	0.007
East Branch Root River	0.60	237	0.19	4.79	16.50	0.026
Whitnall Park Creek	0.49	183	0.15	3.99	13.66	0.021

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Tetra Tech, Inc.

the subwatersheds. Contributions of total suspended solids vary among the subwatersheds (see Table 175) from a low of about 723,490 pounds per year from the East Branch Root River subwatershed to about 25,671,040 pounds per year from the West Branch Root River Canal subwatershed. The highest loads of total suspended solids are contributed by the West Branch Root River Canal and the Lower Root River subwatersheds. For both of these subwatersheds, this reflects the relatively large subwatershed areas, and, in the case of the West Branch Root River Canal subwatershed, it reflects a relatively high unit area load. The highest unit area loads occur in the East Branch Root River Canal and West Branch Root River Canal subwatersheds.

The average annual nonpoint source load of fecal coliform bacteria is estimated to be 11,757.21 trillion cells per year. About 78.2 percent of the total point and nonpoint source load is from urban nonpoint sources and about 21.6 percent is from rural nonpoint sources (see Table 178). The distribution of this load among the subwatersheds is shown on Map H-53 in Appendix H. Map H-54 in Appendix H shows the annual per acre loads of fecal coliform bacteria for the subwatersheds. Contributions of fecal coliform bacteria vary among the subwatersheds (see Table 175) from a low of about 277.27 trillion cells per year from the Root River Canal subwatershed to about 3,494.25 trillion cells per year from the Lower Root River subwatershed. The highest loads of fecal coliform bacteria are contributed by the Lower Root River and the Upper Root River subwatersheds. In the case of the Lower Root River subwatershed, this reflects the relatively large subwatershed area, and in the case of the Upper Root River subwatershed, this reflects a relatively high unit area load. The highest unit area loads occur in the Upper Root River and East Branch Root River subwatersheds.

The average annual nonpoint load of total nitrogen is estimated to be 1,116,070 pounds per year. About 14.2 percent of the total point and nonpoint source load is from urban nonpoint sources and about 83.4 percent is from rural nonpoint sources (see Table 179). The distribution of this load among the subwatersheds is shown on Map H-55 in Appendix H. Map H-56 in Appendix H shows the annual per acre loads of total nitrogen for the subwatersheds. Contributions of total nitrogen vary among the subwatersheds (see Table 175) from a low of about 14,600 pounds per year from the East Branch Root River subwatershed to about 312,440 pounds per year from the West Branch Root River Canal subwatershed. The highest loads of total nitrogen are contributed by the West Branch Root River Canal and the Lower Root River subwatersheds. In the case of the West Branch Root River Canal subwatershed, this is due to both the relatively large area of this subwatershed and a large unit area load. In the case of the Lower Root River subwatershed, this reflects a relatively large area, since its unit area load is near the average. The highest unit area loads occur in the East Branch Root River Canal and West Branch Root River Canal subwatersheds.

The average annual nonpoint load of BOD is estimated to be 3,244,510 pounds per year. About 22.6 percent of the total point and nonpoint source load is from urban nonpoint sources and about 77.0 percent is from rural nonpoint sources (see Table 180). The distribution of this load among the subwatersheds is shown on Map H-57 in Appendix H. Map H-58 in Appendix H shows the annual per acre loads of BOD for the subwatersheds. Contributions of BOD vary among the subwatersheds (see Table 175) from a low of about 50,320 pounds per year from the East Branch Root River subwatershed to about 906,830 pounds per year from the West Branch Root River Canal subwatershed. The highest loads of BOD are contributed by the West Branch Root River Canal and the Lower Root River subwatersheds. In both subwatersheds, this reflects relatively large subwatershed areas, and in the case of the West Branch Root River Canal subwatershed this reflects a relatively high unit area load. The highest unit area loads occur in the East Branch Root River Canal and West Branch Root River Canal subwatersheds.

The average annual nonpoint load of copper is estimated to be 1,896 pounds per year. About 69.5 percent of the total point and nonpoint source load is from urban nonpoint sources and about 28.3 percent is from rural nonpoint sources (see Table 181). The distribution of this load among the subwatersheds is shown on Map H-59 in Appendix H. Map H-60 in Appendix H shows the annual per acre loads of copper for the subwatersheds. Contributions of copper vary among the subwatersheds (see Table 175) from a low of 57 pounds per year from the Root River Canal subwatershed to 575 pounds per year from the Lower Root River subwatershed. The highest loads of copper are contributed by the Lower Root River and the Upper Root River subwatersheds. In the case of the Upper Root, this reflects a relatively large unit area load, and in the case of the Lower Root this reflects the relatively large subwatershed area, since the unit area load is near the average. The highest unit area loads occur in the Upper Root River and East Branch Root River subwatersheds.

Wet-Weather and Dry-Weather Loads

It is important to distinguish between instream water quality during dry weather conditions and during wet weather conditions. Differences between wet-weather and dry-weather instream water quality reflect differences between the dominant sources and loadings of pollutants associated with each condition. Dry-weather instream water quality reflects the quality of ground water discharge to the stream plus the continuous or intermittent discharge of various point sources, for example, industrial cooling or process waters, and leakage or other unplanned dry-weather discharges from sanitary sewers or private process water systems. While instream water quality during wet weather conditions includes the above discharges, and in extreme instances discharges from separate and/or combined sanitary sewer overflows, the dominant influence, particularly during major rainfall or snowmelt runoff events, is likely to be the soluble or insoluble substances carried into streams by direct land surface runoff. That direct runoff moves from the land surface to the surface waters by overland routes, such as drainage swales, street and highway ditches, and gutters, or by underground storm sewer systems.

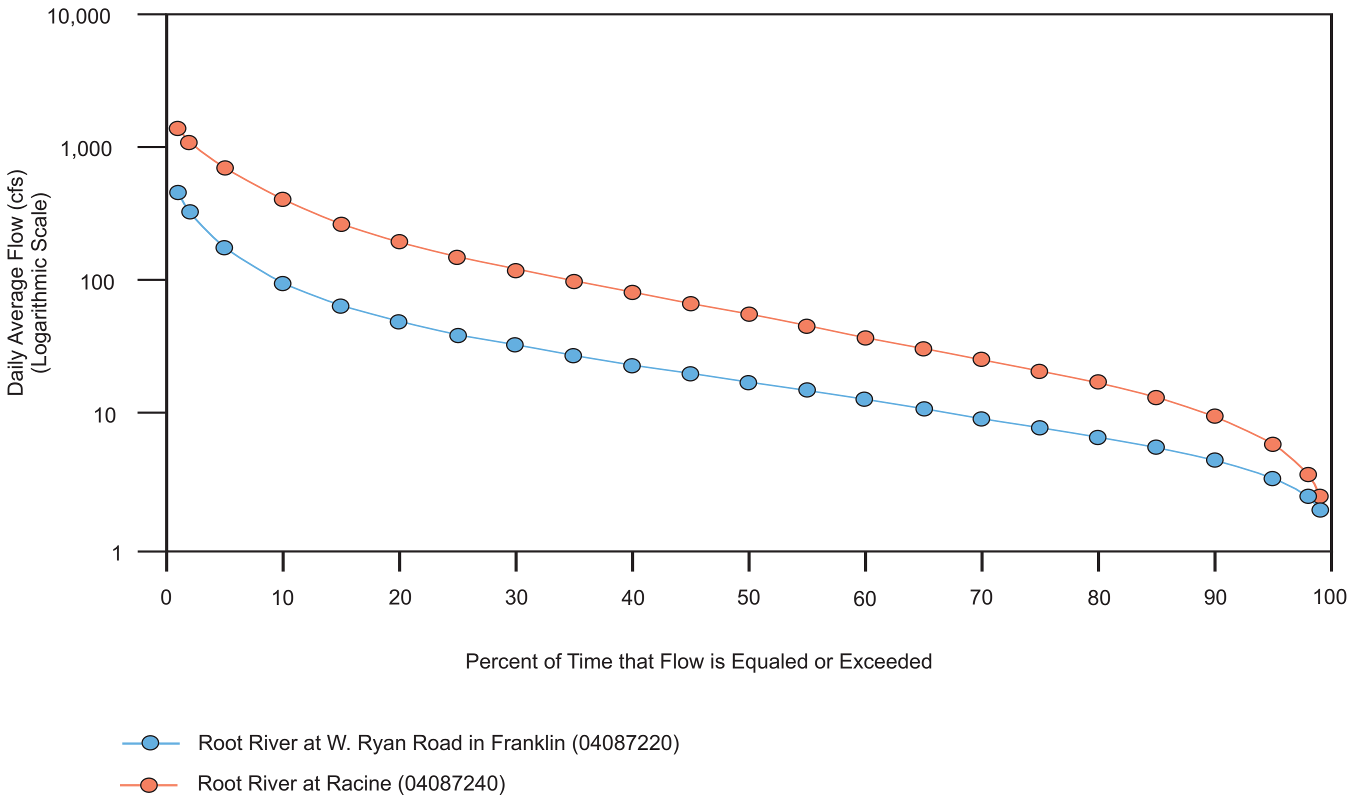
Daily average loads of six pollutants—total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, biochemical oxygen demand, and copper, were estimated for both wet-weather and dry-weather conditions for two sites along the Root River—the W. Ryan Road station (River Mile 28.0) and the Johnson Park station (River Mile 11.5)—based upon flow and water quality data. A water quality sample was assumed to represent wet-weather conditions when daily mean flow was in the upper 20th percentile of the flow duration curve for the relevant flow gauge. This includes flows that are high due to rainfall events, runoff from snowmelt, or a combination of rainfall and snowmelt. The flow duration curves for the Root River at W. Ryan Road in Franklin and the Root River below the Horlick dam at Racine are shown in Figure 274. For the W. Ryan Road station, water quality samples were considered to reflect wet-weather conditions when daily mean flow for the corresponding date equaled or exceeded 49 cubic feet per second (cfs). For the Johnson Park station, water quality samples were considered to reflect wet-weather conditions when daily mean flow at the gauge below the Horlick dam equaled or exceeded 192 cfs. On dates when daily mean flow was less than these thresholds, the corresponding water quality samples were considered to reflect dry-weather conditions. Daily average pollutant loads were estimated by appropriately combining daily average flow and pollutant ambient concentration. To adjust for the fact that the water quality station at Johnson Park is about 5.6 miles upstream from the stream flow gauge below the Horlick dam, the loads were multiplied by the ratio of the drainage area above the Johnson Park station and the drainage area above the Horlick dam station.

Figure 275 shows the daily average pollutant loads for total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, and biochemical oxygen demand from the Root River at the Johnson Park sampling station. In all cases, the estimated loads occurring during wet-weather periods were considerably higher than the estimated loads occurring during dry-weather periods. For the 1998 through 2004 baseline period, the mean estimated daily average wet-weather load of total phosphorus was about 258 pounds, which is about 11 times the mean estimated daily average dry-weather load of about 23 pounds. For the baseline period, the mean estimated daily average wet-weather load of total suspended solids was about 53,060 pounds, about 14 times the mean estimated daily average dry-weather load of about 3,730 pounds. For the baseline period, the mean estimated daily average wet-weather load of fecal coliform bacteria was about 2.6 trillion cells, about 26 times the mean estimated daily average dry-weather load of 0.1 trillion cells. For the baseline period, the mean estimated daily average wet-weather load of total nitrogen was 8,370 pounds, about eight times the mean estimated daily average dry-weather load of 1,050 pounds. There were not sufficient wet-weather samples of BOD to compare wet-weather and dry-weather loads during the baseline period. A sufficient number of wet-weather samples were available only for the period 1975-1986. During this period, the mean estimated daily average wet-weather load of BOD was about 22,000 pounds, about 16 times the mean estimated daily average dry-weather load of about 1,400 pounds.

Figure 276 shows the daily average pollutant loads for total phosphorus, total suspended solids, fecal coliform bacteria, total nitrogen, and biochemical oxygen demand from the Root River at the W. Ryan Road sampling station. Sufficient data were only available to make comparisons during the period 1998-2004. In all cases, the estimated loads occurring during wet-weather periods were considerably higher than the estimated loads occurring during dry-weather periods. The mean estimated daily average wet-weather load of total phosphorus was about 155.8 pounds, which is about 26 times the mean estimated daily average dry-weather load of about 5.91 pounds. The mean estimated daily average wet-weather load of total suspended solids was about 122,000 pounds, about 86 times the mean estimated daily average dry-weather load of about 1,418 pounds. The mean estimated daily average wet-weather load of fecal coliform bacteria was about 36 trillion cells, about 29 times the mean estimated daily average dry-weather load of 1.2 trillion cells. The mean estimated daily average wet-weather load of total nitrogen was 2,800 pounds, about 25 times the mean estimated daily average dry-weather

Figure 274

FLOW DURATION CURVES FOR USGS STREAM GAUGES IN THE ROOT RIVER WATERSHED: 1963-2004



Source: U.S. Geological Survey and SEWRPC.

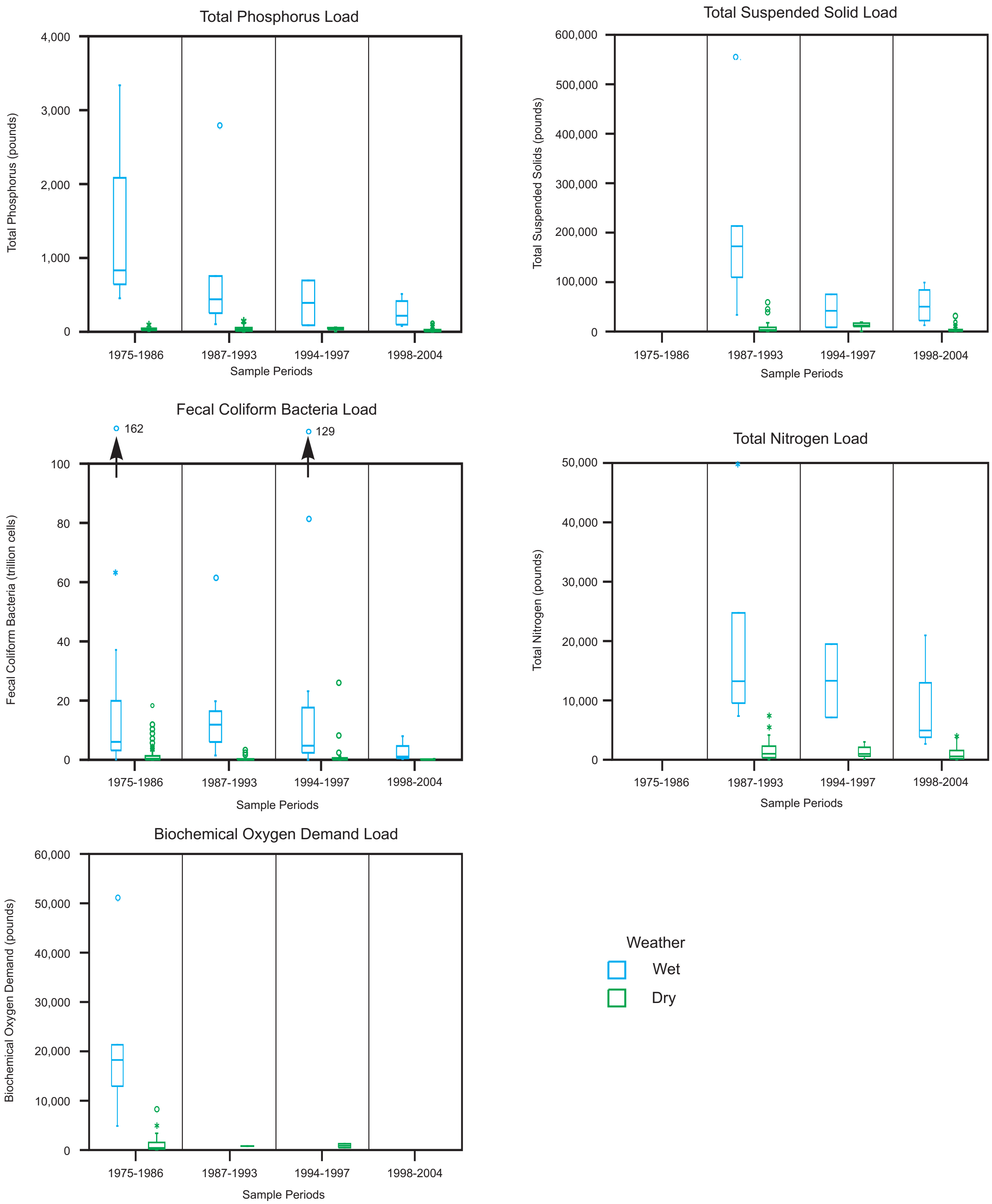
load of 114 pounds. The mean estimated daily average wet-weather load of BOD was 4,400 pounds, about 53 times the mean estimated daily average dry-weather load of about 83 pounds. The mean estimated daily wet-weather load of copper was 13.3 pounds, about 25 times the mean estimated daily dry-weather load of 0.5 pound.

ACHIEVEMENT OF WATER USE OBJECTIVES IN THE ROOT RIVER AND ITS TRIBUTARIES

The water use objectives and the supporting water quality standards and criteria for the Root River watershed are discussed in Chapter IV of this report. Most of the stream reaches in the Root River watershed are recommended for fish and aquatic life and full recreational uses. The exceptions to this are all subject to variances under Chapter NR 104 of the *Wisconsin Administrative Code*. The East Branch of the Root River Canal from STH 20 to the confluence with the West Branch of the Root River Canal, Hoods Creek, Tess Corners Creek, the West Branch of the Root River Canal between STH 20 and CTH C, and Whitnall Park Creek downstream from the site of the former Hales Corners sewage treatment plant to Whitnall Park Pond are recommended for limited forage fish and subject to variances under which dissolved oxygen concentrations are not to be less than 3.0 mg/l. The East Branch of the Root River, the East Branch of the Root River Canal upstream from STH 20, Ives Grove Ditch, the West Branch of the Root River Canal upstream from CTH C, Whitnall Park Creek upstream from the site of the former Hales Corners sewage treatment plant, and an unnamed tributary of the Root River from downstream from the site of the former New Berlin Memorial Hospital sewage treatment plant are recommended for limited aquatic life and are subject to variances under which dissolved oxygen concentrations are not to be less than 1.0 mg/l.

Figure 275

DAILY AVERAGE POLLUTION LOADS IN THE ROOT RIVER AT JOHNSON PARK (RIVER MILE 11.5): 1975-2004

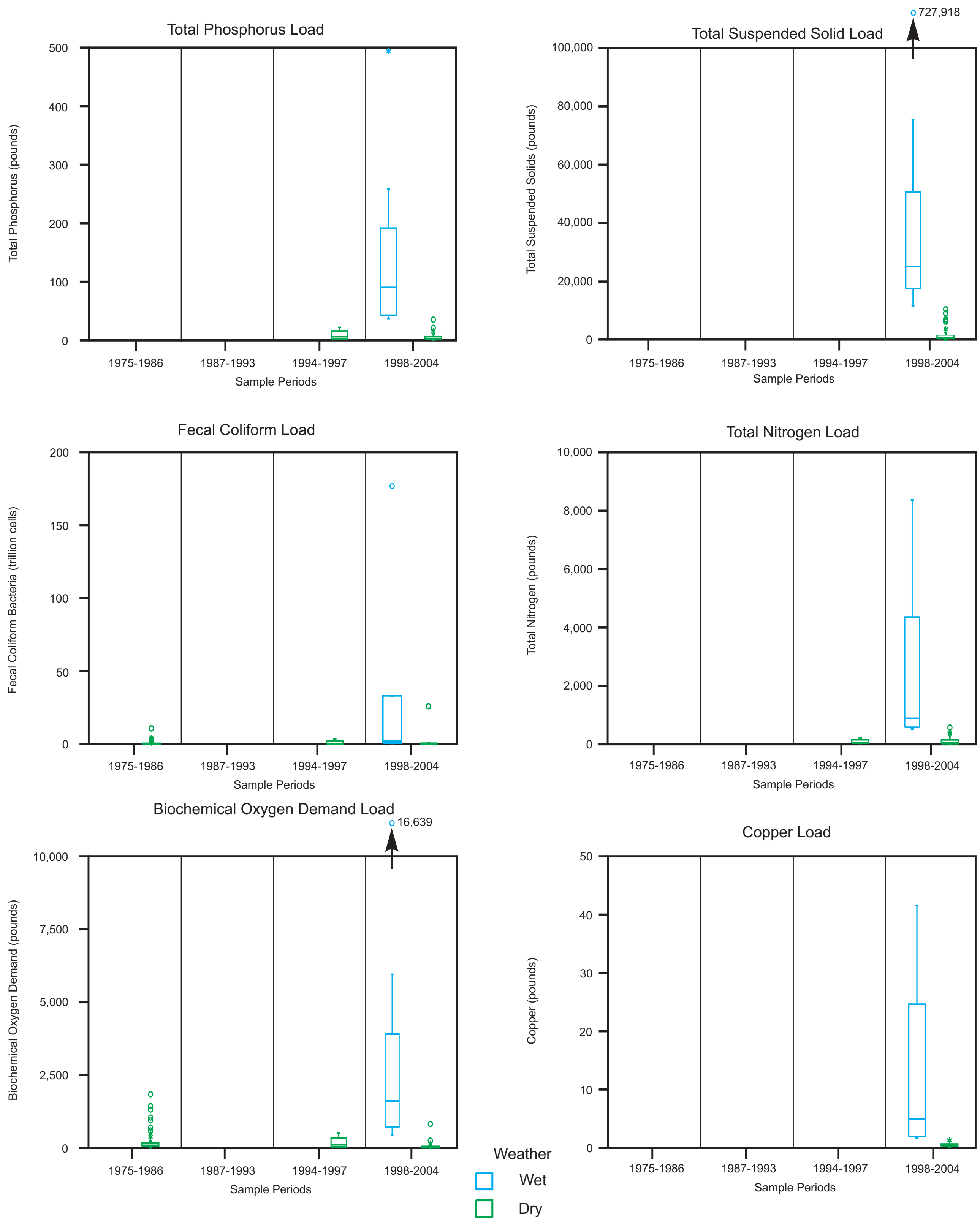


NOTE: See Figure 227 for description of symbols.

Source: U.S. Environmental Protection Agency, U.S. Geological Survey, Wisconsin Department of Natural Resources, City of Racine Health Department, and SEWRPC.

Figure 276

DAILY AVERAGE POLLUTION LOADS IN THE ROOT RIVER AT W. RYAN ROAD (RIVER MILE 28.0): 1975-2004



NOTE: See Figure 227 for description of symbols.

Source: U.S. Environmental Protection Agency, U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

Based upon the available data for sampling stations in the watershed, the mainstem of the Root River and its major tributaries did not fully meet the water quality standards associated with the recommended water use objectives during and prior to 1975, the base year of the initial plan. Review of subsequent data indicated that as of 1995, the recommended water use objectives were only being partially achieved in the majority of the streams in the watershed.[50]

During the 1998-2004 extended baseline period, the recommended water use objectives were only being partially achieved in much of the Root River Watershed. Table 183 shows the results of comparisons of water quality data from the baseline period to supporting water quality standards. Review of data from 1998 to 2004 shows the following:

- Ammonia concentrations in all samples taken along the mainstem and Husher Creek were under the acute toxicity criterion for fish and aquatic life for ammonia, indicating compliance with the standard.
- Dissolved oxygen concentrations from stations along the mainstem of the Root River upstream of Grange Avenue, from the station near the mouth of the River, and from the station along the Root River Canal were commonly below the relevant standard, indicating frequent violation of the standard. Dissolved oxygen concentrations from all of the samples from Husher Creek were above the relevant standard, indicating compliance with the standard.
- Water temperatures in all samples taken from the mainstem and from Husher Creek and the Root River Canal were at or below the relevant standard, indicating compliance with the standard.
- Fecal coliform bacteria standards are commonly exceeded at stations along the mainstem of the Root River and at the station along the Root River Canal, indicating frequent violation of the standard.
- Concentrations of total phosphorus in the mainstem of the Root River, Husher Creek, and the Root River Canal commonly exceeded the recommended levels in the regional water quality management plan.

Thus, during the baseline period the stream reaches for which data are available only partially achieved the recommended water use objectives.

An additional issue to consider when examining whether stream reaches are achieving water use objectives is whether toxic substances are present in water, sediment, or tissue of aquatic organisms in concentrations sufficient to impair beneficial uses. Table 184 summarizes the data from 1998 to 2004 regarding toxic substances in water, sediment, and tissue from aquatic organisms for the Root River watershed. For toxicants, the baseline period was extended to 2004 in order to take advantage of results from sampling conducted by the USGS specifically for the regional water quality management plan update.

Pesticides were detected in water from three stations along the mainstem of the River. The concentrations detected did not exceed water quality standards. Pesticides were detected in tissue from aquatic organisms at one station during the baseline period.

At six long-term stations on the mainstem of the River, concentrations of 12 (out of 209) PCB congeners were below the limit of detection. The concentrations of PCBs in tissue from aquatic organisms collected during the baseline period at the mouth of the River were above the threshold used by the WDNR for issuing fish consumption advisories. No data were available from the period 1998 to 2004 on the concentration of PCBs in sediment.

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[50]*SEWRPC Memorandum Report No. 93,* op. cit.

Table 183

CHARACTERISTICS OF STREAMS IN THE ROOT RIVER WATERSHED: 1998-2004

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a]					Fish Biotic Index Rating[a,b]	Macroinvertebrate Biotic Index Rating (HBI)[a,b]	303(d) Impairments[e]
		Dissolved Oxygen	Temperature	NH_3[c]	Total Phosphorus[d]	Fecal Coliform Bacteria			
Mainstem									
Root River above Cleveland Avenue	1.1	46.4 (28)	100.0 (28)	100.0 (27)	64.3 (28)	21.4 (28)	- -	- -	Dissolved oxygen
Root River between the intersection of W. National Avenue and W. Oklahoma Avenue and Cleveland Avenue	0.5	44.4 (27)	100.0 (27)	100.0 (23)	42.3 (26)	7.4 (27)	- -	- -	Dissolved oxygen
Root River between W. Cold Spring Road and the intersection of W. National Avenue and W. Oklahoma Avenue	0.8	53.6 (28)	100.0 (28)	100.0 (26)	67.9 (28)	25.0 (28)	Fair (1)	- -	Dissolved oxygen
Root River between W. Grange Avenue and W. Cold Spring Road	2.5	79.5 (39)	100.0 (39)	100.0 (33)	78.9 (38)	16.1 (31)	Very poor (1)	- -	Dissolved oxygen
Root River between W. Ryan Road and W. Grange Avenue	8.7	90.6 (32)	100.0 (32)	100.0 (26)	75.8 (33)	36.7 (30)	Very poor (1)	- -	Dissolved oxygen
Root River between County Line Road and W. Ryan Road	4.2	100.0 (25)	100.0 (26)	100.0 (24)	26.9 (26)	34.6 (26)	Very poor(1)	- -	Dissolved oxygen
Root River between Johnson Park and County Line Road	12.3	97.6 (42)	100.0 (62)	100.0 (31)	47.4 (38)	79.5 (39)	Very poor to fair (4)	Fair to very good (6)	Dissolved oxygen[f]
Root River between below the Horlick Dam and Johnson Park	5.6	94.4 (107)	100.0 (172)	100.0 (2)	2.7 (31)	20.0 (10)	Fair (1)	Fair to very good (3)	- -
Root River between near the mouth of the River and below the Horlick Dam	5.5	32.5 (120)	100.0 (181)	- -	8.3 (48)	20.0 (5)	Fair to excellent (2)	Fair to very good (2)	Fish consumption advisory
Tributaries									
Hale Creek	1.0	- -	- -	- -	- -	- -	- -	- -	- -
Wildcat Creek	1.6	- -	- -	- -	- -	- -	- -	- -	- -
Whitnall Park Creek	2.0	- -	- -	- -	- -	- -	Very poor (2)	- -	- -
Tess Corners Creek	4.0	- -	- -	- -	- -	- -	Very poor (1)	Good to very good (2)	- -
Dale Creek	1.4	- -	- -	- -	- -	- -	- -	- -	- -
East Branch of the Root River	4.0	- -	- -	- -	- -	- -	- -	- -	- -

Table 183 (continued)

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a]					Fish Biotic Index Rating[a,d]	Macroinvertebrate Biotic Index Rating (HBI)[a,d]	303(d) Impairments[e]
		Dissolved Oxygen	Temperature	NH_3[b]	Total Phosphorus[c]	Fecal Coliform Bacteria			
Tributaries (continued)									
Ryan Creek	6.0	- -	- -	- -	- -	- -	- -	Fair (1)	- -
Yorkville Creek	2.0	- -	- -	- -	- -	- -	- -	- -	- -
Raymond Creek	2.0	- -	- -	- -	- -	- -	- -	- -	- -
West Branch of the Root River Canal	10.7	- -	- -	- -	- -	- -	- -	- -	Dissolved oxygen
Legend Creek	3.0	- -	- -	- -	- -	- -	- -	- -	- -
East Branch of the Root River Canal	10.9	- -	- -	- -	- -	- -	Very poor (1)	Poor to fairly poor (3)	- -
Root River Canal	5.5	77.6 (98)	100.0 (104)	- -	3.9 (51)	60.0 (10)	Very poor (1)	- -	Dissolved oxygen
Husher Creek	5.2	100.0 (4)	100.0 (6)	100.0 (4)	33.3 (6)	- -	Very poor (1)	Poor to fair (2)	- -
Crayfish Creek	2.7	- -	- -	- -	- -	- -	Very poor (1)	- -	- -
Ives Grove Ditch	1.2	- -	- -	- -	- -	- -	- -	- -	- -
Hoods Creek	9.3	- -	- -	- -	- -	- -	Very poor (1)	Fair (1)	- -

[a]*Number in parentheses shows number of samples.*

[b]*Based upon the acute toxicity criterion for ammonia.*

[c]*Total phosphorus is compared to the concentration recommended in the regional water quality management plan.*

[d]*The State of Wisconsin has not promulgated water quality standards or criteria for biotic indices.*

[e]*As listed in the Approved Wisconsin 303(d) Impaired Waters List.*

[f]*The upstream 1.9 miles of this reach are listed as impaired due to low dissolved oxygen concentrations. The downstream portion of this reach is not listed as impaired.*

Source: SEWRPC.

Table 184

TOXICITY CHARACTERISTICS OF STREAMS IN THE ROOT RIVER WATERSHED: 1998-2001[a]

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
Mainstem															
Root River above Cleveland Avenue	- -	- -	- -	N (6)	- -	- -	D (6)	- -	- -	- -	- -	- -	E-44 (25)	- -	- -
Root River between the intersection of W. National Avenue and W. Oklahoma Avenue and Cleveland Avenue	- -	- -	- -	N (6)	- -	- -	D (6)	- -	- -	- -	- -	- -	E-46 (24)	- -	- -
Root River between W. Cold Spring Road and the intersection of W. National Avenue and W. Oklahoma Avenue	- -	- -	- -	N (6)	- -	- -	D (6)	- -	- -	- -	- -	- -	E-44 (25)	- -	- -
Root River between W. Grange Avenue and W. Cold Spring Road	D (5)	- -	- -	N (6)	- -	- -	D (9)	- -	- -	D (3)	- -	- -	E-45 (24)	- -	- -
Root River between W. Ryan Road and W. Grange Avenue	D (3)	- -	- -	N (6)	- -	- -	D (6)	- -	- -	D (3)	- -	- -	E-41 (25)	- -	- -
Root River between County Line Road and W. Ryan Road	- -	- -	- -	N (6)	- -	- -	D (6)	- -	- -	- -	- -	- -	E-50 (20)	- -	- -
Root River between Johnson Park and County Line Road	- -	- -	- -	N (6)	- -	- -	- -	- -	- -	- -	- -	- -	E-100 (10)	- -	- -
Root River between below the Horlick Dam and Johnson Park	D (5)	- -	- -	- -	- -	- -	- -	D (3)	- -	- -	- -	- -	D (12)	D (3)	- -
Root River between near the mouth of the River and below the Horlick Dam	- -	- -	D (7)	- -	- -	E-100 (31)[c]	- -	- -	- -	- -	- -	- -	D (6)	- -	E-100 (13)[c]
Tributaries															
Hale Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Wildcat Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Whitnall Park Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Tess Corners Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Dale Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
East Branch of the Root River	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Ryan Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Yorkville Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Raymond Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
West Branch of the Root River Canal	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Legend Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Table 184 (continued)

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
Tributaries (continued)															
East Branch of the Root River Canal	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Root River Canal	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	D (10)	- -	- -
Husher Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Crayfish Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	D (1)	- -
Ives Grove Ditch	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Hoods Creek	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

NOTE: E-X denotes exceedence of a water quality standard in X percent of the samples; D denotes detection of a substance in this class in at least one sample; N denotes that no substances in this class were detected in any sample.

[a]*Number in parentheses indicates sample size.*

[b]*Metals sampled were arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. Sample sizes are shown for most metals. Mercury was sampled less frequently.*

[c]*Tissue concentration exceeds threshold used by Wisconsin Department of Natural Resources for issuing fish consumption advisories.*

Source: SEWRPC.

Water samples from six stations along the mainstem of the Root River showed detectable concentrations of several PAH compounds. PAHs were also detected in sediment at one station.

Limited sampling for other organic compounds showed detectable concentrations of several compounds in water from the mainstem of the Root River. Compounds detected included pharmaceutical and personal care products such as the stimulant caffeine, industrial solvents such as isophorone, dye components such as carbazole, aroma and flavoring agents such as camphor and menthol, flame retardants, and metabolites of nonionic detergents. Where water quality criteria have been promulgated, the concentrations of these substances were below the relevant criteria.

Water samples from the long-term stations along the mainstem of the River were examined for concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. While the sample sizes given in Table 184 are representative of sampling for most of these metals, it is important to note that mercury was sampled less intensively. The number of samples analyzed for mercury was about two-thirds the number analyzed for other metals. Detectable concentrations of each of these metals were present in samples from most of the stations tested. Two of these metals were present at times in concentrations that exceeded water quality standards. Concentrations of mercury in water commonly exceeded both the human threshold concentration for public health and welfare and the wildlife criterion for surface water quality. The percent of samples exceeding the lower of these two concentrations is given in Table 184. In addition, concentrations of copper in water samples occasionally exceeded the EPA's criterion maximum concentration (CMC) for copper. About 0 to 8 percent of samples, depending on the station, had copper concentrations exceeding this standard. Water samples from the Root River Canal were examined for concentrations of copper, mercury and zinc. While mercury was not detected in water from this site, detectable concentrations of copper and zinc were found. Arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc were detected in sediment collected in the impoundment upstream from the Horlick dam and from a site along Crayfish Creek. Detectable concentrations of barium, beryllium, manganese, and thallium were also present in the sediment from the latter site. Finally, the concentrations of mercury in tissue from aquatic organisms collected during the baseline period at the mouth of the River were above the threshold used by the WDNR for issuing fish consumption advisories.

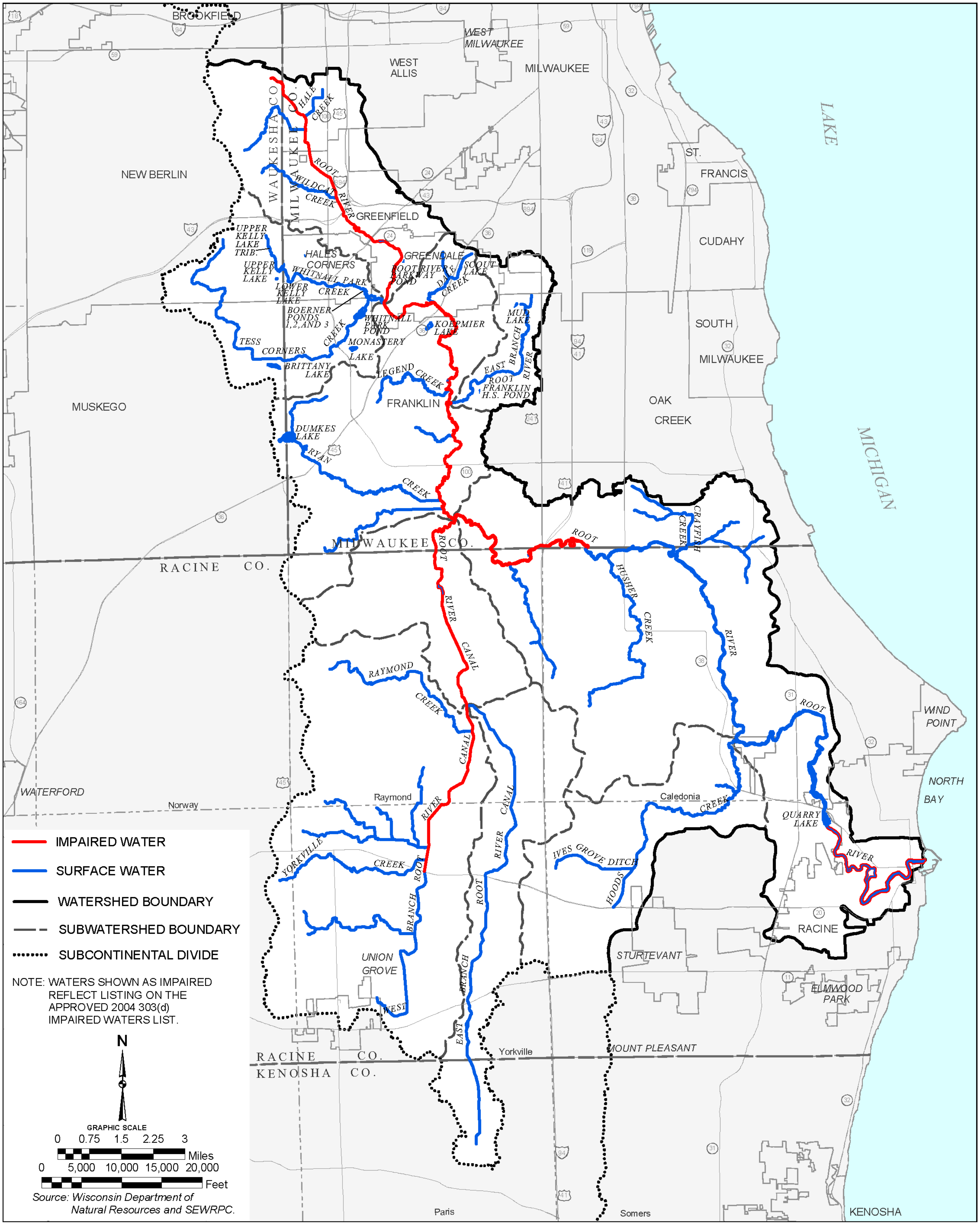
The summary above suggests that some beneficial uses are being impaired by the presence of contaminants, especially PCBs and mercury. The fish consumption advisories in effect for the Root River shown in Table 161 reflect this.

Section 303(d) of the Clean Water Act requires that the states periodically submit a list of impaired waters to the EPA for approval. Wisconsin most recently submitted this list in 2004.[51] This list was subsequently approved by the EPA. Table 183 and Map 112 indicate stream reaches in the Root River watershed that are listed as being impaired waters. Two sections of the mainstem of the Root River are listed as impaired. Approximately 12 stream-miles in the reach of the River between 21 and 43 miles upstream from the confluence with Lake Michigan is considered impaired due to lack of compliance with standards for dissolved oxygen concentration. Phosphorus and sedimentation from a combination of point and nonpoint sources are cited as factors contributing to the impairment of this section of the River. Samples collected during the extended baseline period suggest that low dissolved oxygen concentrations may no longer be impairing the downstream portion of this reach (see Table 183). A six-mile section of the Root River between the Horlick dam and the confluence with Lake Michigan is considered impaired due to fish consumption advisories necessitated by high concentrations of PCBs in the tissue of fish collected from this reach. Two tributary streams are also listed as impaired. The Root River Canal is considered impaired due to lack of compliance with standards for dissolved oxygen concentration. Phosphorus and sedimentation mostly from nonpoint sources are cited as factors contributing to the impairment of

[51] *Wisconsin Department of Natural Resources,* Approved 2004 Wisconsin 303(d) Impaired Waters List, *August 2004.*

Map 112

IMPAIRED WATERS WITHIN THE ROOT RIVER WATERSHED: 2004



this stream. The West Branch of the Root River Canal is considered impaired due to lack of compliance with standards for dissolved oxygen concentration. Phosphorus and sedimentation mostly from nonpoint sources are cited as factors contributing to the impairment of this stream.

SUMMARY

The summary of water quality and pollution sources inventory for the Root River system have been summarized by answering five basic questions. The chapter provided detailed information needed to answer the questions. The information is summarized below.

How Have Water Quality Conditions Changed Since 1975?

Water quality conditions in the Root River watershed have both improved in some respects and declined in other respects since 1975.

Improvements in Water Quality

Concentrations in the Root River of some pollutants such as BOD and ammonia have decreased along much of the length of the Root River. In addition, concentrations of other pollutants, such as fecal coliform bacteria, chlorophyll-*a,* and total phosphorus have decreased in some reaches of the River while, in some cases, increasing in others. At two stations, specific conductance has decreased, suggesting a decrease in the concentrations of dissolved material. Improvements have also occurred in the concentrations of some toxic metals detected in the Root River. These improvements likely reflect both changes in the types of industries present in the watershed, the connection of most process wastewaters to the sanitary sewerage systems, and the implementation of treatment requirements for all industrial discharges.

No Change or Reductions in Water Quality

Concentrations of some pollutants, such as chloride, have remained unchanged or increased. For some of these pollutants, such as dissolved phosphorus and fecal coliform bacteria, concentrations have increased in some reaches while remaining unchanged or decreasing in others. In addition, specific conductance has increased in at least one reach of the River, suggesting that the total concentration of dissolved material in the water has increased. In other reaches, the concentration of dissolved material, as indicated by specific conductance, has decreased or remained unchanged. Concentrations of mercury at one station have increased.

How Have Toxicity Conditions Changed Since 1975?

In some respects, toxicity conditions in the Root River have improved since 1975; in other respects, they have declined or not changed.

Improvements in Toxicity Conditions

As noted above, the concentrations of some toxic metals in the water in the Root River have declined.

Worsened Toxicity Conditions

Other toxicity conditions in the Root River have gotten worse. The concentration of mercury in water has increased at one sampling site. While the quantity of data is not sufficient to determine if this indicates a worsened condition, the concentrations of PCBs and mercury in the tissue of fish are such that consumption advisories remain in effect for portions of the watershed.

Inconclusive Toxicity Data

In some cases the available data are not adequate to assess changes. For example, the maximum concentrations of PCBs and mercury detected in the tissue of aquatic organisms have declined since 1975; however, it is not clear whether this represents an actual reduction because different species were examined in different years. Similarly, the mean concentration of PAHs detected in water during 2004 was lower than the mean concentration during the period 1999-2001; however, the most recent samplings may underestimate PAH concentrations both because of methodological differences in sample collection and because they only screened for a subset of PAH compounds.

Various pesticides have been detected in water in the Root River, but different compounds were screened for in recent samplings than were examined in historical samplings.

Sediment Conditions
In the available data on sediment toxicity, the expected incidence of toxicity to benthic organisms ranges from 8 to 67 percent at sites along the mainstem of the Root River and from 20 to 72 percent at sites along two tributaries, Crayfish Creek and Whitnall Park Creek. The overall quality of sediment, as measured by mean PEC-Q, remains poor. Sediment in the Root River contains concentrations of PAHs high enough to pose substantial risks of toxicity to benthic organisms and contains concentrations of arsenic, cadmium, chromium, copper, manganese, mercury, nickel, zinc, and PCBs high enough to likely produce some toxic effects in benthic organisms.

What Are the Sources of Water Pollution?
The Root River watershed contains several potential sources of water pollution. These fall into two broad categories: point sources and nonpoint sources.

Point Sources
Two public sewage treatment plants and one private plant currently discharge into streams of the Root River watershed. Since 1995, separate sanitary sewer overflows have been reported at 15 locations: all within local communities. As of February 2003, 39 industrial dischargers and other point sources were permitted through the WPDES program to discharge wastewater to streams in the Root River watershed. About one fifth of the permitted facilities discharged noncontact cooling water. The remaining discharges are of a nature which typically meets or exceeds the WPDES permit levels which are designed to meet water quality standards.

Nonpoint Sources
The Root River watershed is comprised of combinations of urban land uses and rural land uses. As of 2000, about 67 percent of the watershed was in rural and other open land uses. About 47 percent of the watershed is contained within planned sewer service areas: 9 percent within MMSD's planned service area, 22 percent within the sanitary sewer service areas of local communities that are connected to MMSD's conveyance and treatment systems, 14 percent within the City of Racine's planned sewer service area, 1 percent within the Village of Union Grove's planned sewer service area, and less than 1 percent within the Town of Yorkville Sanitary District's planned sewer service area. With the exception of the Towns of Paris, Raymond, and Yorkville, the communities in the watershed have adopted construction erosion control ordinances. All communities in the watershed except for the Towns of Dover, Paris, Raymond, and Yorkville and the Village of Sturtevant have adopted stormwater management ordinances or plans. As of 2005, there was one active solid waste landfill within the watershed, located in the Middle Root River subwatershed. In addition, there are six inactive landfills in the watershed: two each in the Upper Root River and Lower Root River subwatersheds and one each in the Middle Root River and West Branch of the Root River Canal subwatersheds.

Quantification of Pollutant Loads
The current annual average load of BOD to streams of the Root River watershed is estimated to be 3,258,620 pounds per year. Sewage treatment plants contribute about 0.4 percent of this load, and industrial discharges and separate sanitary sewer overflows each contribute less than 0.1 percent. The rest of BOD loadings to streams in the Root River watershed, about 99.6 percent, are contributed by nonpoint sources, with 77.0 percent from rural sources and 22.6 percent from urban sources.

The current annual average load of TSS to streams of the Root River watershed is estimated to be 83,771,430 pounds per year. Sewage treatment plants, separate sanitary sewer overflows, and industrial dischargers each contribute less than 0.1 percent of this load. The rest of TSS loadings to streams in the Root River watershed, almost 100 percent, are contributed by nonpoint sources, with 89.3 percent from rural sources and 10.7 percent from urban sources.

The current annual average load of fecal coliform bacteria to streams of the Root River watershed is estimated to be 11,780.15 trillion cells per year. Sewage treatment plants and separate sanitary sewer overflows contribute less than 0.1 percent and about 0.2 percent, respectively, of this load. The rest of fecal coliform bacteria loadings to streams in the Root River watershed, about 99.8 percent, are contributed by nonpoint sources, with 78.2 percent from urban sources and 21.6 percent from rural sources.

The current annual average load of total phosphorus to streams of the Root River watershed is estimated to be 84,060 pounds per year. Sewage treatment plants and separate sanitary sewer overflows contribute about 3.7 percent and less than 0.1 percent, respectively, of this load. Industrial discharges contribute about 0.2 percent of this load. The rest of total phosphorus loadings to streams in the Root River watershed, about 96.1 percent, are contributed by nonpoint sources, with 64.6 percent from rural sources and 31.5 from urban sources.

What is the Current Condition of the Fishery?

The Root River watershed seems to have very poor fishery and macroinvertebrate communities at present. The fish community contains relatively few species of fishes, is trophically unbalanced, contains few or no top carnivores, and is dominated by tolerant fishes. The macroinvertebrate community is equally depauperate and dominated by tolerant taxa. Since water quality has generally been improving in the watershed for some constituents, habitat seems to potentially be the most important factor limiting both the fishery and macroinvertebrate community.

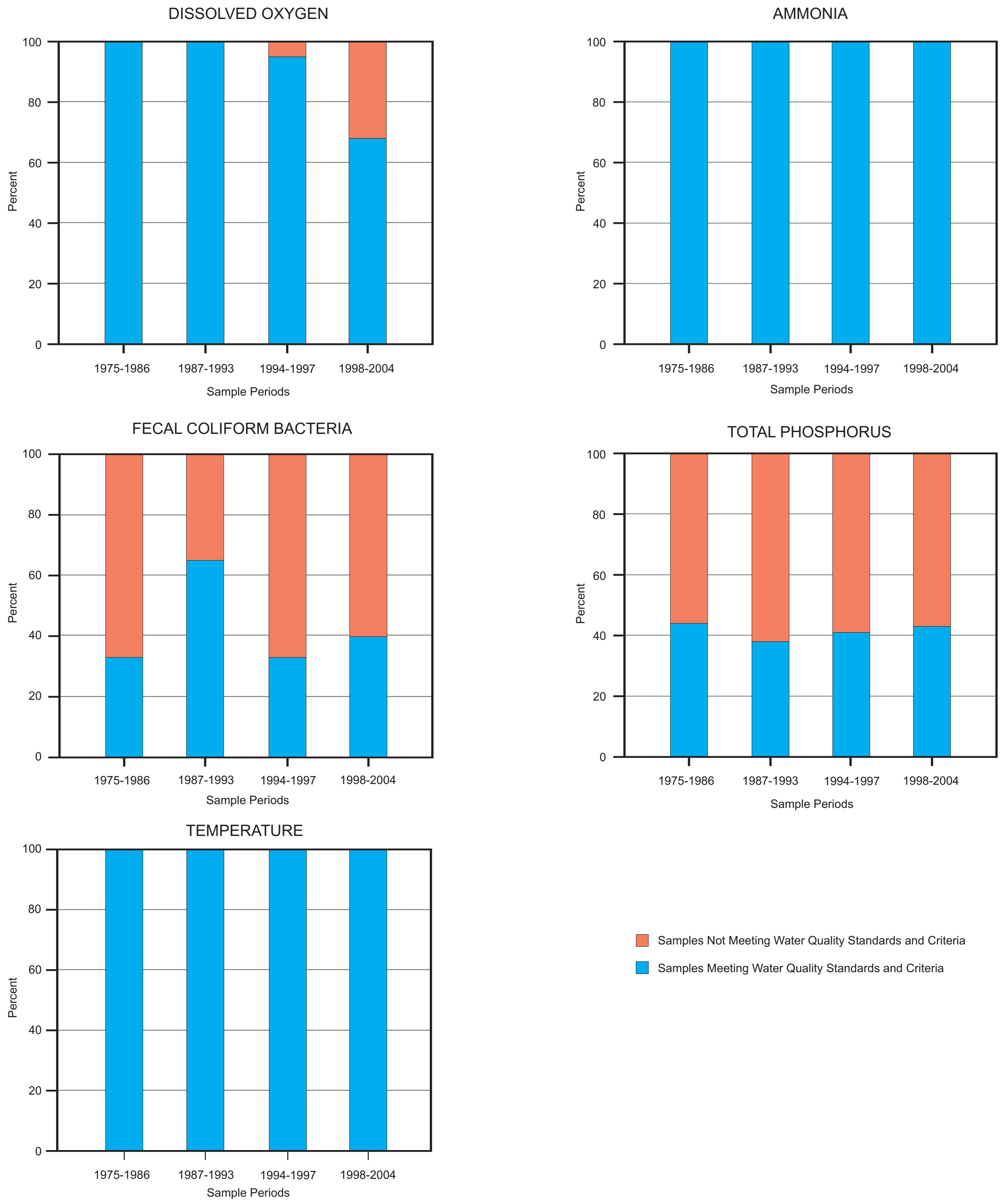
To What Extent Are Water Use Objectives and Water Quality Standards Being Met?

During the 1998 to 2004 extended study baseline period, the Root River only partially met the water quality criteria supporting its recommended water use classification. In all of the samples taken from the mainstem of the River temperatures and concentrations of ammonia were in compliance with the relevant water quality standards. The proportion of samples in which dissolved oxygen concentrations equaled or exceeded the 5.0 mg/l standard for fish and aquatic life varied considerably among stations, with compliance being lowest at the upstream stations and at the station near the mouth of the River. For example, in the upstream reaches above W. Grange Avenue, dissolved oxygen concentrations were below the standard in about 21 to 56 percent of the samples, depending upon the station. Concentrations of fecal coliform bacteria in the Root River usually exceed the recreational use standard of 200 cells per 100 ml which applies to the River. While the rate of compliance varied among stations, it was generally low. In the upper reaches of the mainstem of the River, upstream of River Mile 23.8, concentrations of fecal coliform bacteria exceeded 200 cells per ml in the majority of samples. Depending upon the station, the percentage of samples in this section of the River that complied with the standard ranged between about 7 and 37 percent. Downstream, fecal coliform bacteria concentrations were below the standard in the majority of samples at the stations at Johnson Park and below the Horlick dam. About 80 percent and 54 percent of samples respectively at these two stations were below the standard. Finally, in the majority of samples collected near the mouth of the River, the concentration of fecal coliform bacteria exceeded 200 cells per ml. Compliance with the standard for total phosphorus recommended in the regional water quality management plan was also low with the number of samples showing total phosphorus below the 0.1 mg/l standard ranging from 8 to 79 percent at stations along the mainstem. In most stations in the upper reaches of the River, concentrations of total phosphorus were below the standard in about 42 percent to 79 percent of the samples. There was one exception to this generalization, at the station at County Line Road (River Mile 23.8) dissolved phosphorus concentration were below 0.1 mg/l in only 27 percent of the samples. About 48 percent of samples at the next station downstream, Johnson Park, were in compliance with this standard. At two stations downstream from here, less than 11 percent of the samples were in compliance with this standard.

Figure 277 shows changes over time in the proportions of samples showing compliance with applicable water quality standards for the Root River. Over the entire study period of 1975-2004, water temperatures and concentrations of ammonia were in compliance with the applicable water quality standards in all of the samples. By contrast, a significant percentage of samples collected in each period had concentrations of fecal coliform bacteria or total phosphorus that were not in compliance with the applicable water quality standard and significant percentages of samples during the period 1998-2004 had concentrations of dissolved oxygen that were

Figure 277

PROPORTION OF SAMPLES FOR SEVERAL CONSTITUENTS MEETING WATER QUALITY STANDARDS AND CRITERIA ALONG THE MAINSTEM OF THE ROOT RIVER: 1975-2004



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and City of Racine Health Department.

not in compliance with the applicable water quality standard. In about 93 percent of the samples collected during the period 1994-1997, dissolved oxygen concentrations were in compliance with the standard. This rate of compliance decreased to about 68 percent of the samples collected during the period 1998-2004. The rate of compliance with the standard recommended for total phosphorus in the regional water quality management plan shows a different pattern. Over the study period, it varied only slightly between 38 and 44 percent of samples collected being in compliance with the standard. During the entire study period, concentrations of fecal coliform bacteria exceeded the recreational use standard of 200 cells per 100 ml in the majority of samples collected. In each period, about 33 to 66 percent of samples collected were in compliance with the standard.

Relatively few data are available for assessing whether streams tributary to the Root River are meeting water use objectives and water quality standards. Based on available data, Husher Creek and the Root River Canal are only partially meeting their water use objectives. While ammonia concentrations in Husher Creek were below the acute toxicity standard for fish and aquatic life all samples and dissolved oxygen concentrations and temperatures were in compliance with the applicable standards in all samples, total phosphorus concentrations exceeded the recommended concentration in about 67 percent of the samples. While temperatures in the Root River Canal were in compliance in all samples, dissolved oxygen concentrations were below the standard for fish and aquatic life in about 23 percent of the samples and concentrations of fecal coliform bacteria exceeded the recreational use standard of 200 cells per 100 ml in about 40 percent of samples. In the vast majority of samples collected from the Root River Canal, total phosphorus concentrations exceeded the standard recommended for total phosphorus in the regional water quality management plan.

Four sections of stream in the Root River Watershed are listed as impaired pursuant to Section 303(d) of the Clean Water Act. Three of these, the Root River Canal, the West Branch of the Root River Canal, and the uppermost 12 miles of the upper reaches of the mainstem of the Root River, are considered impaired due to concentrations of dissolved oxygen which do not meet the applicable water quality standard. The fourth, the mainstem of the Root River between the Horlick dam and the confluence with Lake Michigan, is considered impaired due to fish consumption advisories necessitated by the concentrations of PCBs in the tissue of fish collected in this reach.

Some toxic substances have been detected in the Root River watershed at concentrations that may impair beneficial uses. Concentrations of mercury in water samples taken from the Root River often exceeded both the human threshold concentration for public health and welfare and the wildlife criterion for surface water quality. Also, concentrations of copper in water samples occasionally exceeded the USEPA’s criterion maximum concentration. Concentrations of mercury and PCBs in tissue of fish collected in the Root River below the Horlick dam were above the threshold used by the WDNR for issuing fish consumption advisories in all samples.

Chapter X

SURFACE WATER QUALITY CONDITIONS AND SOURCES OF POLLUTION IN THE MILWAUKEE HARBOR ESTUARY AND ADJACENT NEARSHORE LAKE MICHIGAN AREAS

INTRODUCTION AND SETTING WITHIN THE STUDY AREA

A basic premise of the Commission watershed studies is that the human activities within a watershed affect, and are affected by, surface and groundwater quality conditions. This is true in the urban and urbanizing areas of the Milwaukee Harbor estuary and adjacent nearshore Lake Michigan areas, where the effects of human activities on water quality tend to overshadow natural influences. The hydrologic cycle provides the principal linkage between human activities and the quality of surface and ground waters in that the cycle transports potential pollutants from human activities to the environment and from the environment into the sphere of human activities.

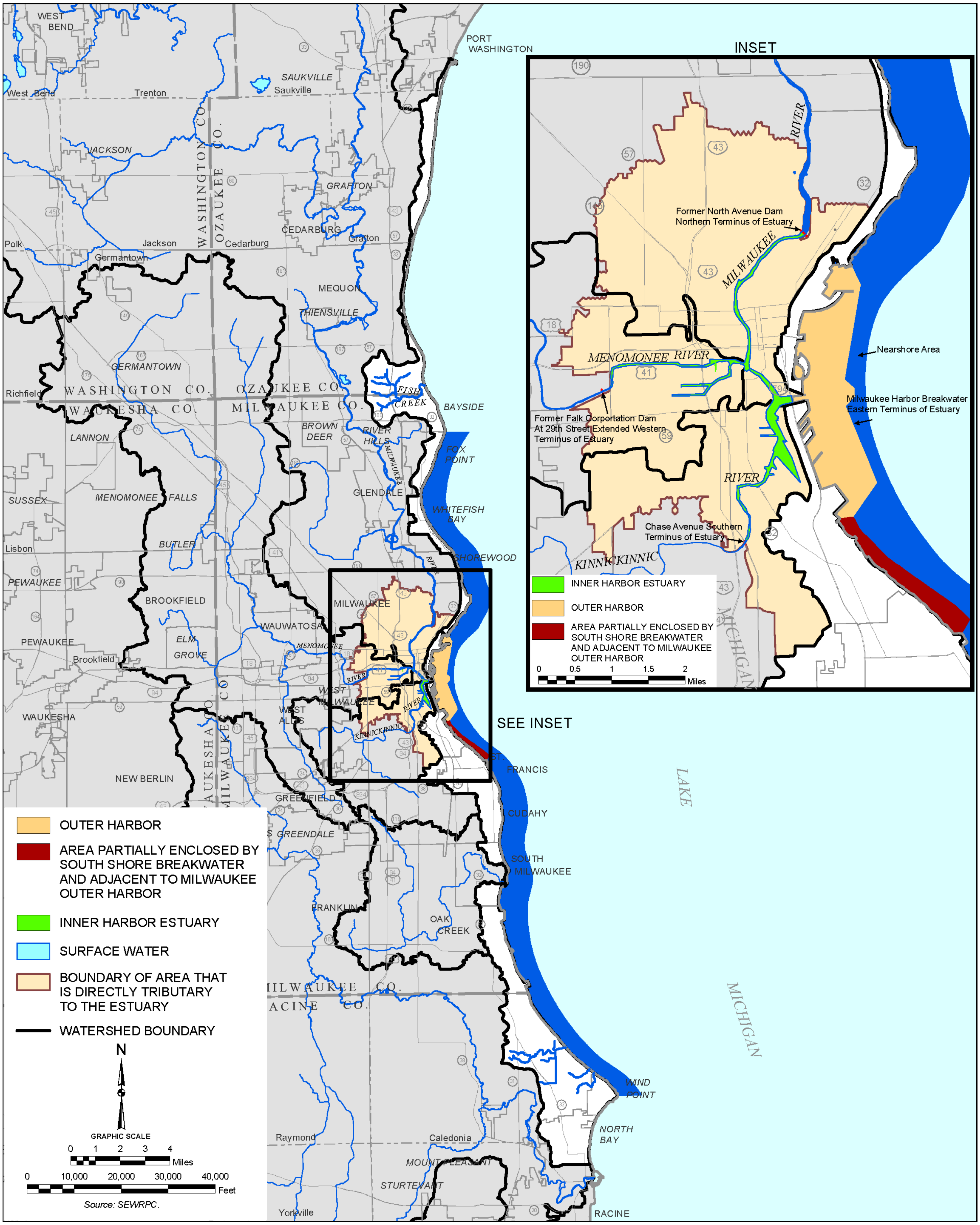
Comprehensive water quality planning efforts such as the regional water quality management plan update should include an evaluation of historical, present, and anticipated water quality conditions and the relationship of those conditions to existing and probable future land and water uses. The purpose of this chapter is to determine the extent to which surface waters in the Milwaukee Harbor estuary, the adjacent nearshore Lake Michigan areas, and the Lake Michigan direct drainage area have been and are polluted, and to identify the probable causes for, or sources of, that pollution. More specifically, this chapter documents current surface water pollution problems in these waters utilizing field data from a variety of water quality studies, most of which were conducted during the past 30 years; indicates the location and type of the numerous and varied sources of wastewater, industrial discharges, stormwater runoff, and other potential pollutants discharged to the surface water system of the watershed; describes the characteristics of the discharges from those sources; and, to the extent feasible, quantifies the pollutant contribution of each source. The information presented herein provides an important basis for the development and testing of the alternative water quality control plan elements under the regional water quality management plan update.

DESCRIPTION OF THE WATERSHED

As shown on Map 113, the Milwaukee Harbor includes the outer harbor area—from the breakwater to the shoreline, excluding the anchorage area protected by the offshore breakwater south of E. Lincoln Avenue extended—and the inner harbor area—which includes those lower reaches of the Kinnickinnic, Menomonee, and Milwaukee Rivers that are maintained to depths which will accommodate navigation by deep draft commercial vessels. The inner harbor is approximately bounded by the Becher Street bridge on the Kinnickinnic River, S. 25th Street on the Menomonee River, and Buffalo Street extended on the Milwaukee River. The Milwaukee Harbor estuary itself includes the 3.1-mile-long reach of the Milwaukee River below the site of the former North

Map 113

SURFACE WATER WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 2000



Source: SEWRPC.

Avenue dam, the 2.2-mile-long reach of the Menomonee River below the former Falk Corporation dam, and the 2.4-mile-long reach of the Kinnickinnic River below the Chase Avenue bridge along with the outer harbor to the breakwater structure. In addition, about 1.4 miles of canal reaches consisting of Burnham Canal and the South Menomonee Canal are within the estuary. Thus defined, the Milwaukee Harbor estuary has a total length of stream of about 9.1 miles, and a total surface water area of approximately 1,630 acres, or about 2.5 square miles. A break wall shelters the Milwaukee Harbor area and is aligned from approximately one mile north to about 1.7 miles south of the mouth of the Milwaukee River. Lake Michigan water level conditions affect stages in each river in the Milwaukee Harbor estuary. The nearshore Lake Michigan area protected by the South Shore breakwater immediately south of the Milwaukee Outer Harbor is an important part of the study area. This area is protected by a breakwater structure extending from the Milwaukee Harbor about 12,500 feet south along the Lake Michigan shoreline and partially protecting the South Shore Yacht Club, South Shore Park, and Bay View Park.

Map 113 also shows that the adjacent nearshore area of Lake Michigan extends from the Village of Fox Point to a point approximated by Three Mile Road extended in the Village of Wind Point in Racine County.

The Lake Michigan direct drainage area is a limited area drained by a number of small streams, drainage swales, and storm sewers discharging directly to Lake Michigan. This collection of small watersheds covers an area of approximately 40.7 square miles. The largest subwatershed tributary to a stream is the Fish Creek subwatershed, which covers an approximately five-square mile land area in both Milwaukee and Ozaukee Counties. While the Lake Michigan direct drainage area contains no lakes with a surface area of 50 acres or more, it does contain some named ponds.

Civil Divisions

Superimposed on the watershed boundary is a pattern of local political boundaries. As shown on Map 114, the Lake Michigan direct drainage area as defined for this study lies in Milwaukee, Ozaukee, and Racine Counties. Twenty civil divisions lie partially, or entirely, within the direct drainage area, as also shown on Map 114 and in Table 185. Geographic boundaries of the civil divisions are an important factor which must be considered in the regional management plan update since the civil divisions form the basic foundation of the public decision making framework within which intergovernmental, environmental, and developmental problems must be addressed.

LAND USE

This section describes the changes in land use which have occurred within the Lake Michigan direct drainage area since 1970, the approximate base year of the initial regional water quality management plan, and indicates the changes in such land uses since 1990, the base year of the initial plan update, as shown in Table 186. Although most of the Lake Michigan direct drainage area is urbanized, about 34 percent of the direct drainage area was still in rural and other open space land uses in 2000. These rural and open space uses included about 15 percent of the total area of the watershed in unused and other open lands and about 2 percent in surface water and wetlands. Most of the rural and open spaces remaining in the watershed are located in central Ozaukee County, southeastern Milwaukee County, and northeastern Racine County. The remaining approximately 66 percent of the direct drainage area was devoted to urban uses, as shown on Map 115.

As shown in Table 186, residential land represents over one-half of the urban land in the direct drainage area. The historic urban growth within the Lake Michigan direct drainage area is summarized on Map 116 and in Table 187. Urban land use in the area increased from about 25.5 square miles in 1990 to about 26.9 square miles in 2000, an increase of about 5 percent. Since 1990, much, though not all, of the urban growth in the area has occurred near existing urban centers such as the Cities of Mequon and St. Francis. Additional urban growth has occurred in the Village of Caledonia.

The changes in land use reflect changes in population and population distribution within the watershed. Several trends are apparent in the data. Over the long term the number of persons living in the direct drainage area has

Map 114

CIVIL DIVISIONS WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 2000

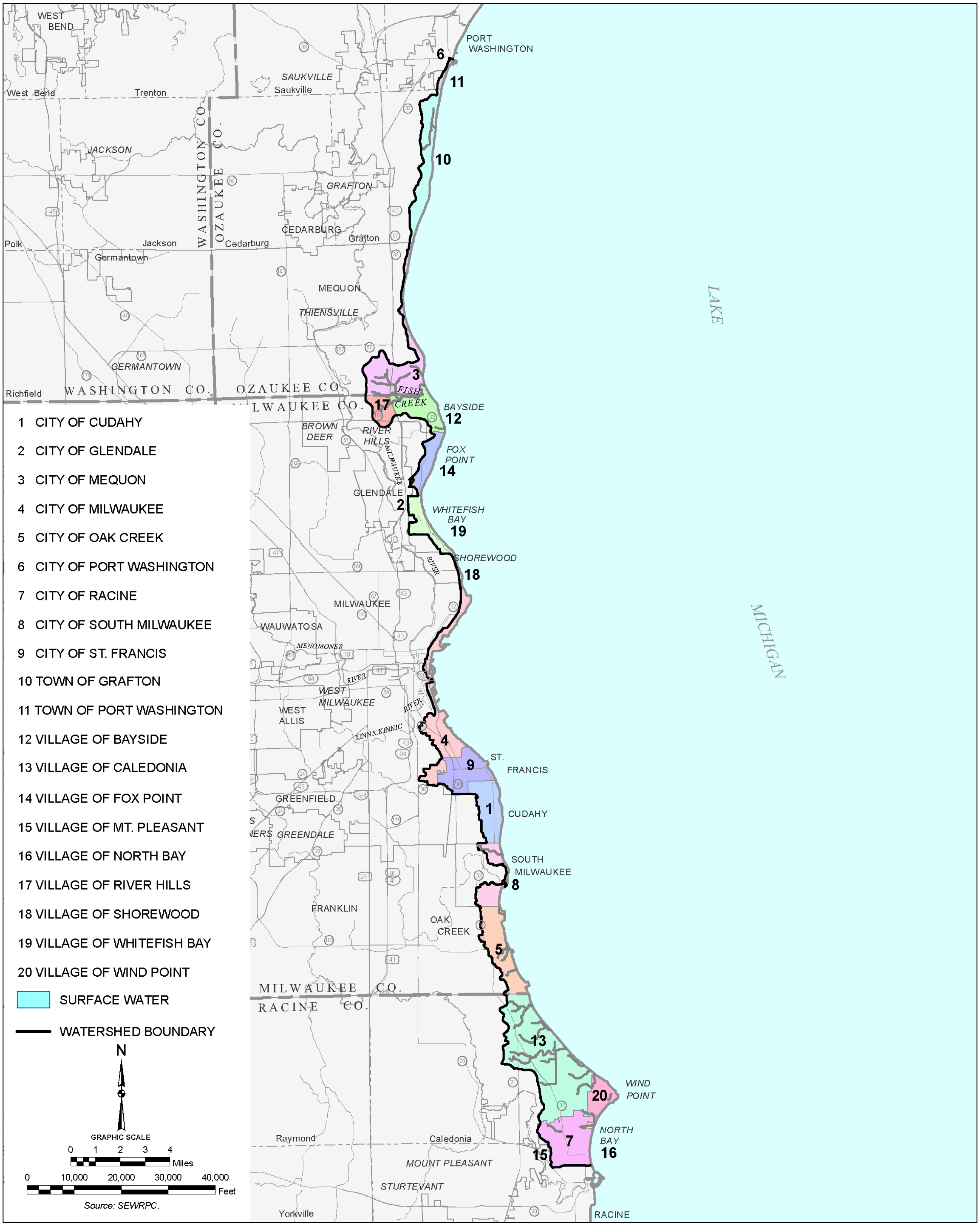


Table 185

AREAL EXTENT OF COUNTIES, CITIES, VILLAGES, AND TOWNS WITHIN THE AREA TRIBUTARY TO LAKE MICHIGAN: 2000

Civil Division	Area (square miles)	Percent of Total
Ozaukee County		
City of Mequon	3.90	9.57
City of Port Washington	0.08	0.20
Village of Bayside	0.10	0.25
Town of Grafton	2.94	7.22
Town of Port Washington	0.14	0.35
Subtotal	7.16	17.59
Milwaukee County		
City of Cudahy	2.30	5.66
City of Glendale	0.04	0.09
City of Milwaukee	3.73	9.16
City of Oak Creek	3.03	7.43
City of South Milwaukee	1.57	3.85
City of St. Francis	2.45	6.03
Village of Bayside	1.92	4.71
Village of Fox Point	1.28	3.14
Village of River Hills	1.05	2.59
Village of Shorewood	0.12	0.30
Village of Whitefish Bay	1.38	3.38
Subtotal	18.87	46.34
Racine County		
City of Racine	3.57	8.77
Village of Caledonia	9.74	23.91
Village of Mt. Pleasant	0.01	0.03
Village of North Bay	0.11	0.27
Village of Wind Point	1.26	3.09
Subtotal	14.69	36.07
Total	40.72	100.00

Source: SEWRPC.

decreased. From 1970 through 1990, the population decreased by about 9,350, from 112,829 to 103,479; however, during that time period the number of households increased by 6,560, from 34,046 to 40,606. Between 1990 and 2000 the population in the direct drainage area continued to decline, decreasing to 101,740 persons, or a decrease of 1,739 persons. During this decade of decreasing population, the number of households in the watershed increased by 1,496 units to 42,102.

QUANTITY OF SURFACE WATER

Since 1994, measurements of discharge have been taken at one location within the estuary, Jones Island at the mouth of the Milwaukee River. The period of record for this station is 42 months, with data collection occurring during two periods—April 1994 to October 1995 and November 2001 to September 2003.[1] Historical and baseline period discharge for this station is shown in Figure 106 in Chapter VII of this report. In order to estimate the relative contributions of discharge from the Kinnickinnic, Menomonee, and Milwaukee Rivers to the harbor, flow fractions were calculated for the S. 11th Street station along the Kinnickinnic River, the 70th Street station

[1]*The gauge was reactivated in May 2006.*

Table 186

LAND USE IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA: 1970-2000[a,b]

Category	1970		1990		2000		Change 1970-2000	
	Square Miles	Percent of Total	Square Miles	Percent of Total	Square Miles	Percent of Total	Square Miles	Percent
Urban								
Residential	11.7	29.1	13.8	34.3	14.6	36.1	2.9	24.8
Commercial	0.6	1.5	0.9	2.2	0.9	2.2	0.3	50.0
Industrial and Extractive	1.0	2.5	1.2	3.0	1.2	3.0	0.2	20.0
Transportation, Communication, and Utilities[c]	5.8	14.4	6.3	15.6	6.9	17.0	1.1	19.0
Governmental and Institutional	1.5	3.7	1.6	4.0	1.5	3.7	0.0	0.0
Recreational	1.3	3.2	1.7	4.2	1.8	4.4	0.5	28.5
Subtotal	21.9	54.4	25.5	63.3	26.9	66.4	5.0	22.8
Rural								
Agricultural and Related	9.5	23.6	6.5	16.1	4.3	10.6	-5.2	-54.7
Water	0.1	0.3	0.2	0.5	0.2	0.5	0.1	100.0
Wetlands	0.5	1.3	0.5	1.2	0.7	1.7	0.2	40.0
Woodlands	2.2	5.5	2.2	5.5	2.2	5.5	0.0	0.0
Unused and Other Open Lands	6.0	14.9	5.4	13.4	6.2	15.3	0.2	3.3
Subtotal	18.3	45.6	14.8	36.7	13.6	33.6	-4.7	-25.7
Total	40.2	100.0	40.3	100.0	40.5	100.0	0.3[d]	0.7

[a] *As approximated by whole U.S. Public Land Survey one-quarter sections.*

[b] *As part of the regional land use inventory for the year 2000, the delineation of existing land use was referenced to real property boundary information not available for prior inventories. This change increases the precision of the land use inventory and makes it more usable to public agencies and private interests throughout the Region. As a result of the change, however, year 2000 land use inventory data are not strictly comparable with data from the 1990 and prior inventories. At the county and regional level, the most significant effect of the change is to increase the transportation, communication, and utilities category, the result of the use of narrower estimated right-of-ways in prior inventories. The treatment of streets and highways generally diminishes the area of adjacent land uses traversed by those streets and highways in the 2000 land use inventory relative to prior inventories.*

[c] *Off-street parking of more than 10 spaces are included with the associated land use.*

[d] *The change in the total direct drainage area over time is attributable to changes in the configuration of the Lake Michigan shoreline.*

Source: SEWRPC.

along the Menomonee River, and the Estabrook Park station along the Milwaukee River relative to the discharge at the Jones Island station using the procedure described in Chapter III of this report. Several generalizations emerge from this analysis:

- The Milwaukee River is the dominant source of discharge to the harbor. Median discharge at the gauge at Estabrook Park represents about 75 percent of the median discharge at Jones Island.

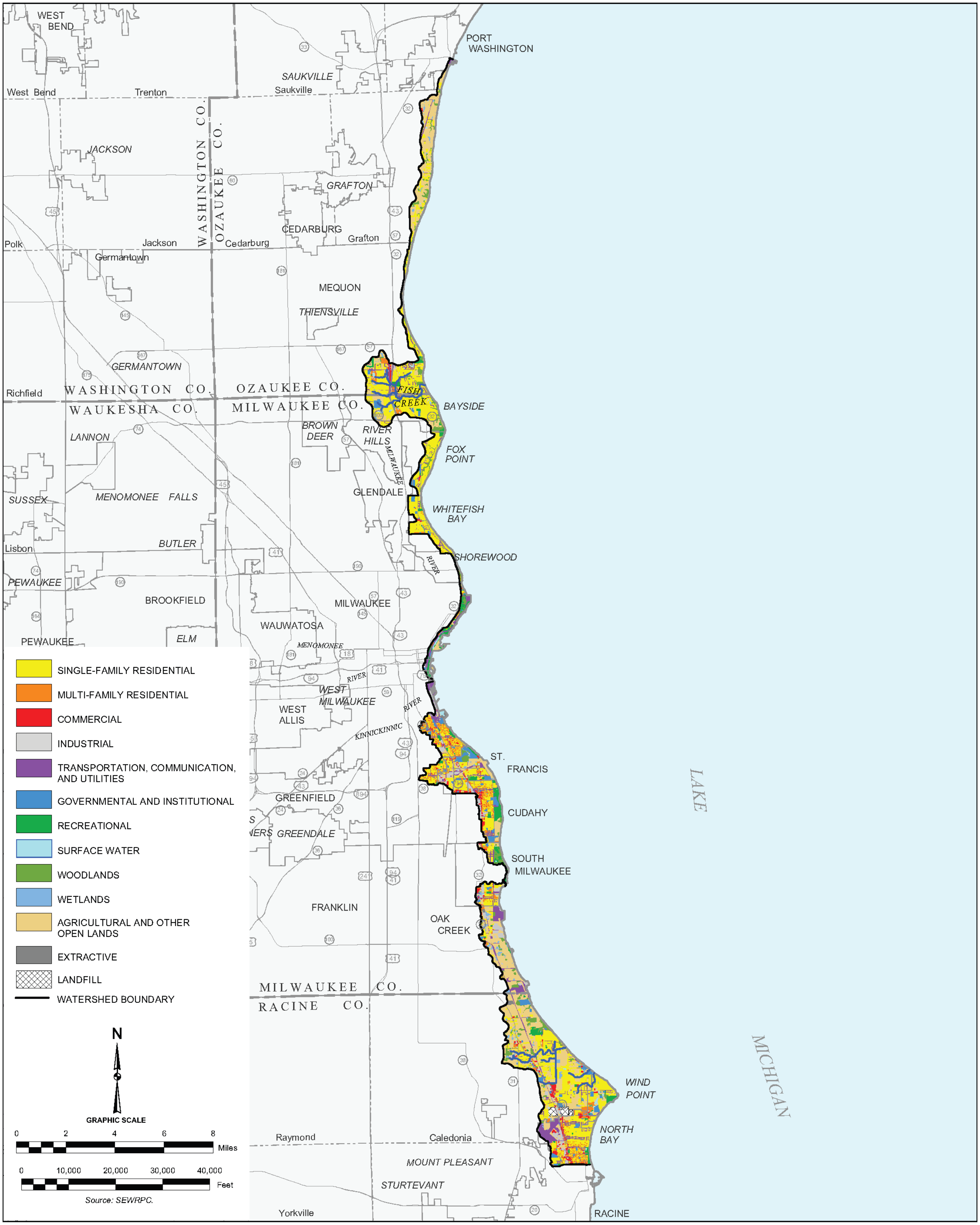
- The Menomonee River accounts for much of the remaining discharge into the harbor. Median discharge at the gauge at 70th Street represents slightly more than 13 percent of the median discharge at Jones Island.

- The Kinnickinnic River contributes only a small portion of the discharge entering the harbor. Median discharge at S. 11th Street represents less than 3 percent of the median discharge at Jones Island.

- About 9 percent of the discharge at the gauge at Jones Island is not accounted for by discharge at the gauges on the three Rivers. This represents contributions entering the Rivers between their respective gauges and Jones Island gauge from at least one tributary, Woods Creek, as well as direct runoff.

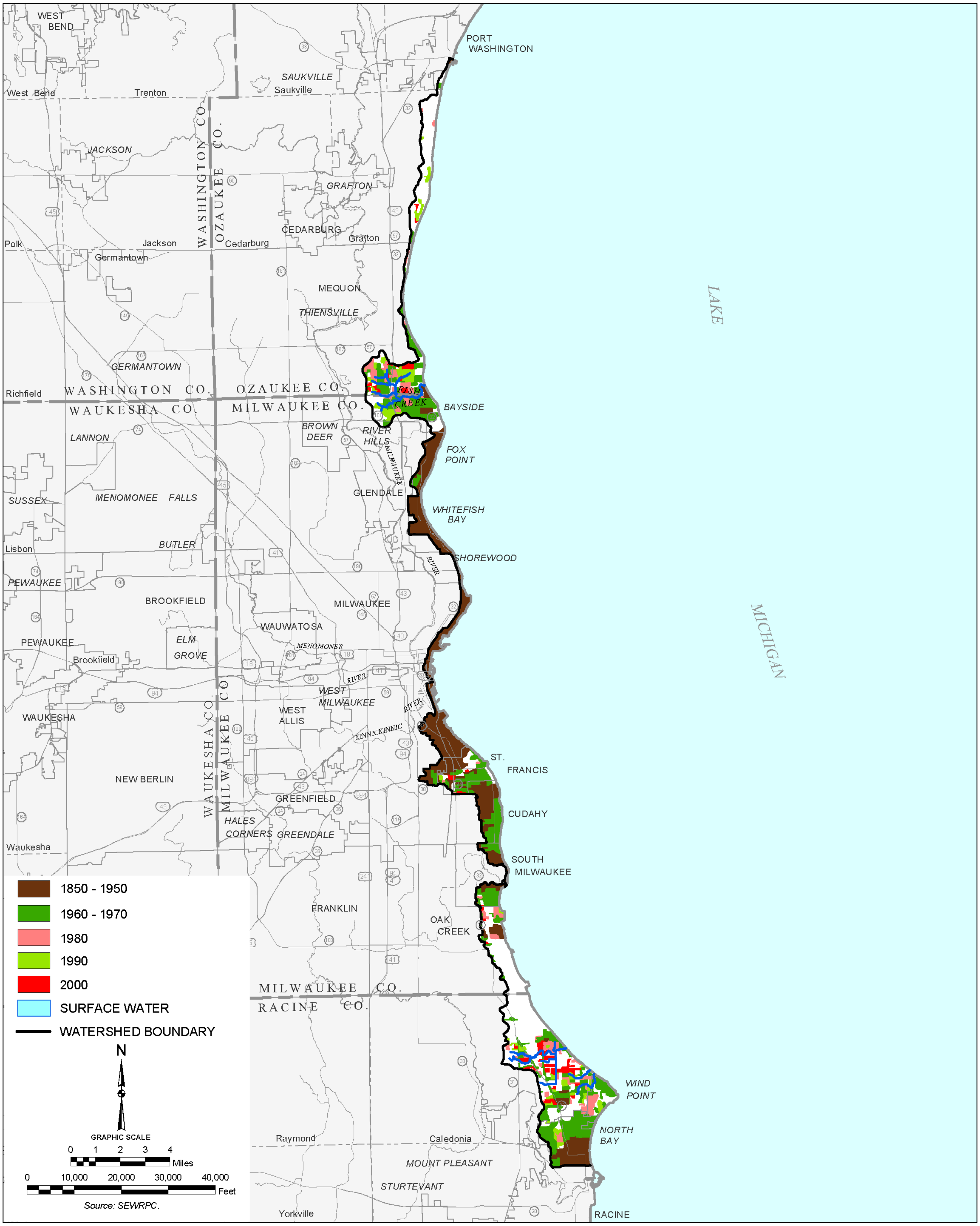
Map 115

EXISTING LAND USE WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 2000



Map 116

HISTORICAL URBAN GROWTH WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 1850-2000



A second aspect of water quantity is the level of water in Lake Michigan. Figure 278 shows both the daily mean level of water in the Lake above the International Great Lakes Datum 1985 (IGLD 1985) and a 45-day running mean as measured at Milwaukee for the period 1973-2005. The running mean was computed to elucidate annual and longer-term trends in the data.[2] Several trends are apparent in the data. First, there is a seasonal cycle of changes in the level of water in the Lake. Generally, water levels in the Lake rise from February to July and fall during the rest of the year. The seasonal rise from February to July reflects the pattern of higher runoff and lower evaporation during that period in comparison to the remainder of the year. In a typical one-year period, the range in average monthly Lake Michigan levels may be expected to be about 0.3 meters. Second, the seasonal cycles appear to be superimposed over fluctuations of approximately decadal length. The maximum water levels of the last two fluctuations were achieved in 1986 and 1997. Third, these fluctuations appear to be superimposed over a general lowering in lake level since the early 1970s. Large declines in lake level were observed following the maximum levels achieved in 1986 and 1997. In fact, the decline since 1997 is the largest drop observed since records have consistently been kept, beginning in 1860. It is not clear whether the current decline represents a long-term trend or reflects an additional fluctuation.[3] The long-term average Lake Michigan level, based on data collected from 1918 into 2006 is about 176.5 meters above International Great Lakes Datum 1985. Based on the data presented in Figure 278, daily average Lake levels have been below that long-term average since early in 1999.

Table 187

EXTENT OF URBAN GROWTH WITHIN THE LAKE MICHIGAN DIRECT TRIBUTARY DRAINAGE AREA: 1850-2000

Year	Extent of New Urban Development Occurring Since Previous Year (acres)[a]	Cumulative Extent of Urban Development (acres)[a]	Cumulative Extent of Urban Development (percent)[a]
1850	464	464	1.8
1880	622	1,086	4.2
1900	391	1,477	5.7
1920	1,302	2,779	10.7
1940	2,212	4,991	19.2
1950	1,903	6,894	26.5
1963	5,407	12,301	47.2
1970	1,411	13,442	51.6
1975	891	14,333	55.0
1980	681	15,013	57.6
1985	502	15,515	59.6
1990	649	16,164	62.1
1995	386	16,550	63.8
2000	503	17,053	65.5

[a]*Urban development, as defined for the purposes of this discussion, includes those areas within which houses or other buildings have been constructed in relatively compact groups, thereby indicating a concentration of urban land uses. Scattered residential developments were not considered in this analysis.*

Source: U.S. Bureau of the Census and SEWRPC.

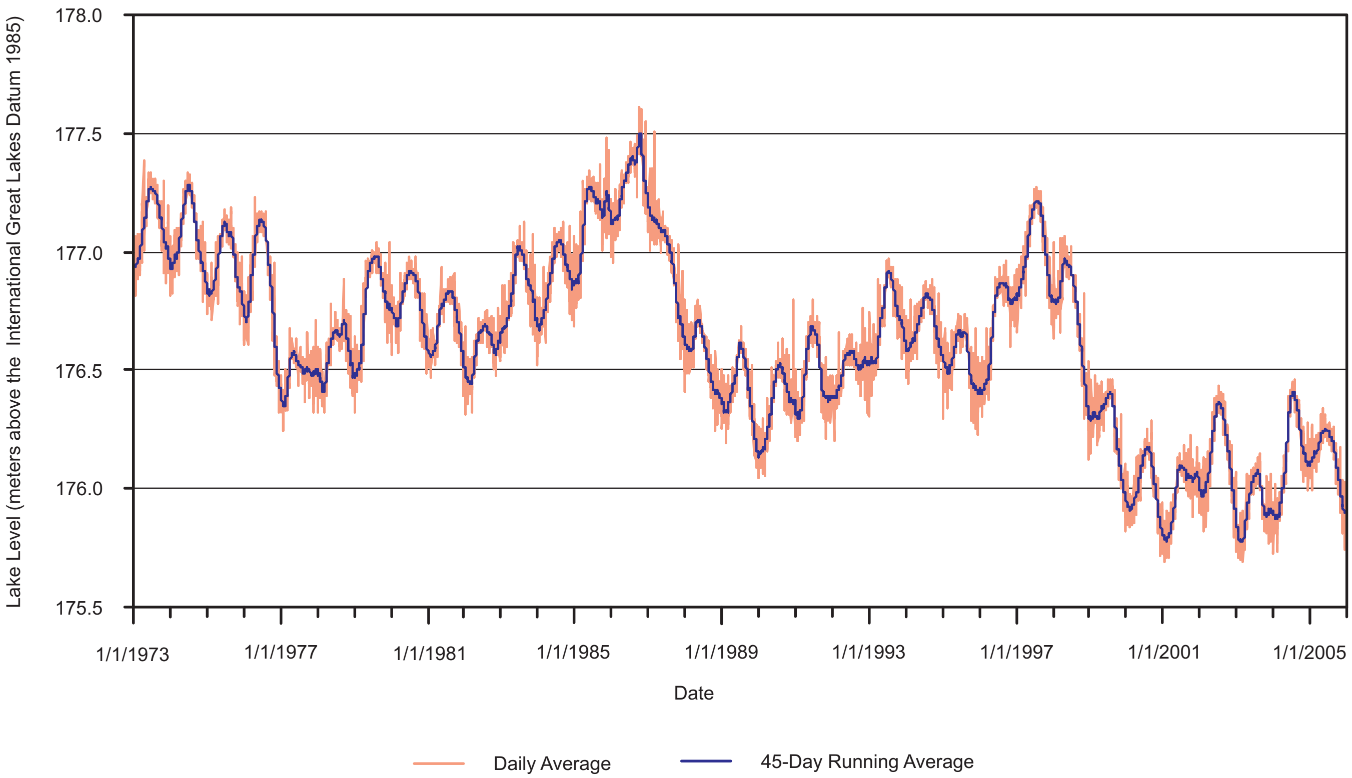
Fluctuations in water levels in Lake Michigan can have several effects. Water level fluctuations require shippers to adjust payloads and can result in increased shipping costs when water levels are low. Low lake levels can dewater coastal habitat used as spawning and nursery areas by species of fish in the Lake, especially those which spawn in water less than one meter deep. Lower water levels can create an increased potential for resuspension of and transport of contaminated sediment into the Lake from “prop wash” caused by ships and recreational boats, natural river currents, and waves in coastal areas.

[2]*The running mean was computed by averaging the day of interest with the 22 days before and the 22 days after the day of interest.*

[3]*Additional, detailed information on historical Lake Michigan levels is set forth in SEWRPC Technical Record, Volume 4, No. 5, December 1989.*

Figure 278

TRENDS IN LAKE MICHIGAN WATER LEVELS: 1973-2006



Source: National Oceanic and Atmospheric Administration and SEWRPC.

SURFACE WATER QUALITY OF THE MILWAUKEE HARBOR ESTUARY, LAKE MICHIGAN DIRECT TRIBUTARY DRAINAGE AREA, AND THE ADJACENT NEARSHORE LAKE MICHIGAN AREAS: 1975-2004

Water Quality of the Milwaukee Harbor Estuary

The earliest systematic collection of water quality data in the Milwaukee Harbor estuary occurred in the mid-1960s.[4] Data collection after that was sporadic until the 1970s. Since then, considerable data have been collected, both from stations along the mainstems of the Rivers making up the estuary and from stations within and adjacent to the outer harbor. The major sources of data include the Milwaukee Metropolitan Sewerage District (MMSD), the Wisconsin Department of Natural Resources (WDNR), the U.S. Geological Survey (USGS), the University of Wisconsin-Milwaukee, and the U.S. Environmental Protection Agency's (USEPA) STORET legacy and modern databases. Much of these data were obtained from sampling stations along the mainstems of the Kinnickinnic, Menomonee, and Milwaukee Rivers (see Maps 18, 33, and 52 in Chapters V, VI, and VII, respectively, of this report). In addition, considerable data were obtained from survey stations in and adjacent to the outer harbor (see Map 117).

Data and analyses documenting historical and baseline period water quality conditions and trends for the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers comprising the estuary and inner harbor were presented in Chapters V, VI, and VII, respectively of this report. This section will summarize the results presented in those

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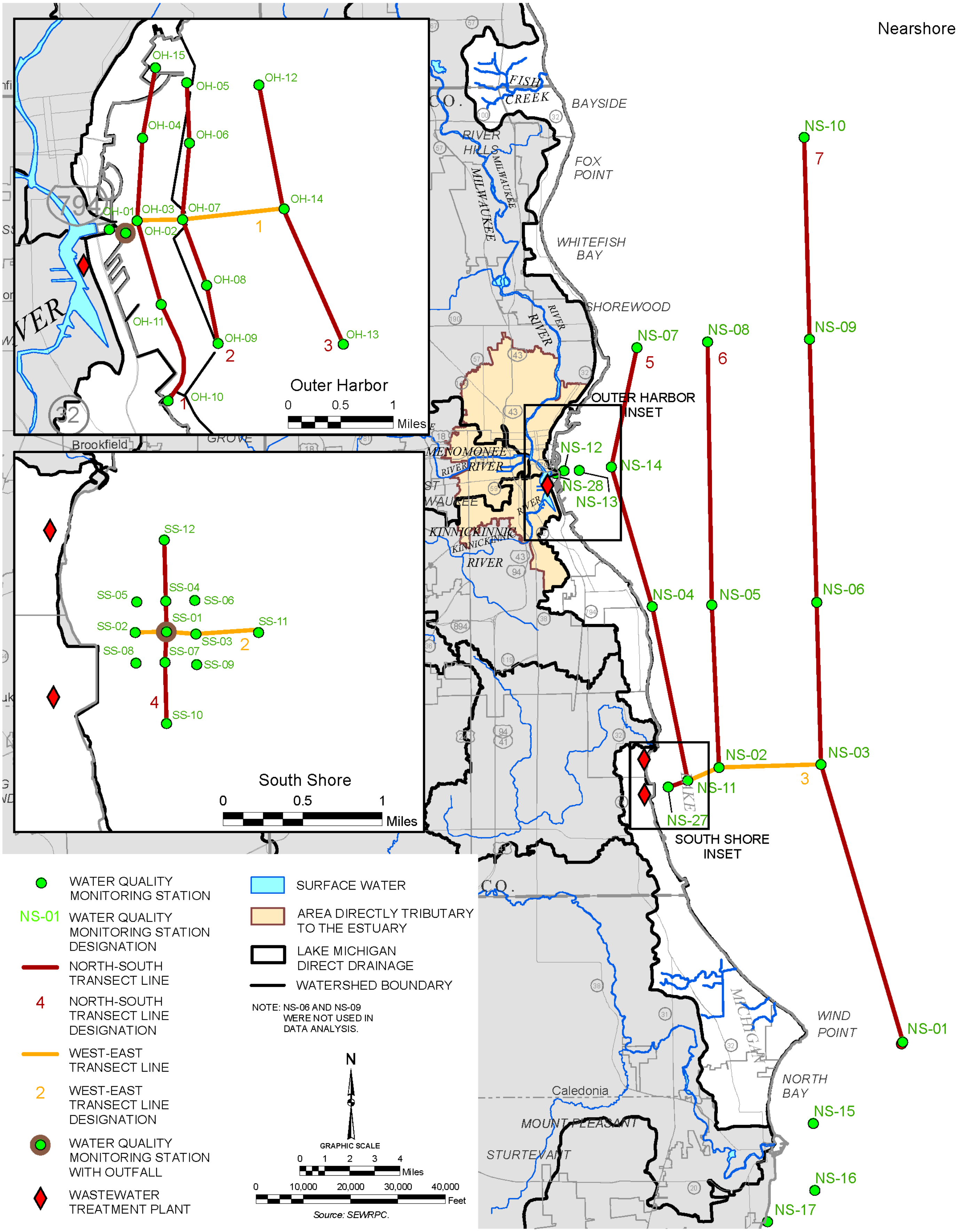
[4]*SEWRPC Technical Report No. 4,* Water Quality and Flow of Streams in Southeastern Wisconsin*, April 1964.*

Map 117

WATER AND SEDIMENT QUALITY MONITORING STATIONS WITHIN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN NEARSHORE AREA: 1975-2004



chapters and presents comparisons of conditions among the three Rivers in order to characterize historical and baseline period conditions and water quality trends within the estuary. In addition, these summaries will be supplemented by data and analyses, also presented in this chapter, documenting historical and baseline period water quality conditions and trends within the outer harbor.

For analytical purposes, data from four time periods were examined: 1975-1986, 1987-1993, 1994-1997, and 1998-2004. Bimonthly data records exist from several of MMSD's long-term monitoring stations, beginning in 1975. After 1986, MMSD no longer conducted sampling during the winter months. In 1994, the Inline Storage System (ISS), or Deep Tunnel, came online. The remaining period from 1998-2004 defines the baseline water quality conditions of the river system, since the Inline Storage System came online.

Baseline water quality conditions were graphically compared to historical conditions on a monthly basis. As shown in the sample graph presented in Figure 23 of Chapter III of this report, for each water quality parameter examined, the background of the graph summarizes the historical conditions. The white area in the graphs shows the range of values observed during the period 1975-1997. The dashed upper and lower boundaries between the white and gray areas show historical maxima and minima, respectively. A blue background indicates months for which no historical data were available. The heavy black dashed line plots the monthly mean value of the parameter for the historical period. Overlaid on this background is a summary of baseline conditions from the period 1998-2004. Relative to the Kinnickinnic River, Menomonee River, and Milwaukee River watersheds, the baseline period examined for the outer harbor was extended to 2004 in order to take advantage of data collected in 2004 by the MMSD. The black dots show the monthly mean value of the parameter for the 1998-2004 period. The black bars show the monthly ranges of parameter for the same period.

Differences among the mean values of water quality parameters from the sections of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were assessed using analysis of variance (ANOVA). In some cases, parameters were log-transformed before being entered into the analysis in order to meet the normal distribution assumption of ANOVA. Significant differences among means were considered present at a probability level less than or equal to 0.05. When significant differences were found among means, the Bonferroni pairwise mean comparison procedure was used to determine which means differed from one another.

In addition to this summarization, water quality parameters from the outer harbor were examined for the presence of two different types of trends: changes at individual sampling stations over time and seasonal changes throughout the year. Locations of sampling stations in the estuary are indicated on Maps 18, 33, and 52 and described in Tables 29, 53, and 86 in Chapters V, VI, and VII, respectively, of this report. Map 117 and Table 188 show the sampling stations in and adjacent to the outer harbor which had sufficiently long periods of sampling to be used for these analyses. These sampling stations were aligned along four transects running through and adjacent to the outer harbor. West-east transect number 1 passes eastward through the outer harbor from the mouth of Milwaukee River, through the main gap in the breakwall, to a sampling station outside the breakwall. North-south transect number 1 runs from north to south through the center of the outer harbor. North-south transect number 2 runs along the outside of the breakwall. Three sampling stations, OH-05, OH-07, and OH-09 are located at gaps in the breakwall. The other two, OH-06 and OH-08 are located along the breakwall itself. North-south transect number 3 consists of three stations that are located roughly one mile east of the breakwall. Changes over time were assessed both on an annual and on a seasonal basis as set forth in Table C-6 in Appendix C.

Bacterial and Biological Parameters

Bacteria

Over the period of record, the median concentration of fecal coliform bacteria in the Milwaukee Harbor estuary was about 930 cells per 100 milliliters (ml). The median concentrations of fecal coliform bacteria during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 430 cells per 100 ml, 930 cells per 100 ml, and 930 cells per 100 ml, respectively. Fecal coliform counts in the estuary varied over seven orders of magnitude, ranging from as low as one cell per 100 ml to over 2,400,000 cells

Table 188

SAMPLE SITES USED FOR ANALYSIS OF WATER QUALITY TRENDS IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN NEARSHORE AREA

Location	Synonym	Period of Record	Mean Depth (m)			Data Sources
			Surface	Middle	Bottom	
Outer Harbor						
OH-01	NS-28	1979-2004	1.0	4.8	8.8	MMSD
OH-02	- -	1979-2004	1.0	4.6	8.4	MMSD
OH-03	NS-12	1979-2004	1.0	4.6	8.4	MMSD
OH-04	- -	1979-2004	1.0	2.8	5.0	MMSD
OH-05	- -	1979-2004	1.0	4.8	8.8	MMSD
OH-06	- -	1979-2004	1.0	5.3	10.1	MMSD
OH-07	NS-13	1979-2004	1.0	5.2	9.8	MMSD
OH-08	- -	1979-2004	1.0	5.3	10.1	MMSD
OH-09	- -	1979-2004	1.0	5.6	10.5	MMSD
OH-10	- -	1979-2004	1.0	3.0	5.4	MMSD
OH-11	- -	1979-2004	1.0	4.6	8.4	MMSD
OH-12	- -	1980-2004	1.0	6.1	11.4	MMSD
OH-13	- -	1980-2004	1.0	7.3	13.9	MMSD
OH-14	NS-14	1980-2004	1.0	8.0	15.5	MMSD
OH-15	- -	1980-2004	1.0	2.0	2.6	MMSD
Nearshore						
NS-01	- -	1980-2004	1.2	11.7	22.5	MMSD
NS-02	- -	1980-2004	1.2	5.5	10.2	MMSD
NS-03	- -	1980-2004	1.1	10.9	21.1	MMSD
NS-04	- -	1980-2004	1.2	2.8	4.8	MMSD
NS-05	- -	1980-2004	1.1	10.0	19.1	MMSD
NS-06	- -	1980-1992	1.3	15.5	26.1	MMSD
NS-07	- -	1980-2004	1.0	8.6	16.6	MMSD
NS-08	- -	1980-2004	1.0	17.8	33.2	MMSD
NS-09	- -	1980-1992	1.3	25.4	50.0	MMSD
NS-10	- -	1980-2004	1.2	37.8	71.8	MMSD
NS-11	SS-11	1980-2004	1.0	4.1	7.3	MMSD
NS-12	OH-03	1980-2004	1.0	4.2	7.4	MMSD
NS-13	OH-07	1980-2004	1.0	5.1	9.3	MMSD
NS-14	OH-14	1980-2004	1.0	8.0	14.8	MMSD
NS-15	- -	1987-1988	1.0	5.1	9.6	MMSD
NS-16	- -	1987-1988	1.0	4.8	8.7	MMSD
NS-17	- -	1987-1988	1.0	2.5	4.9	MMSD
NS-18	- -	1987-1988	1.0	4.1	8.0	MMSD
NS-19	- -	1987-1988	1.0	6.5	12.4	MMSD
NS-20	- -	1987-1988	1.0	9.3	19.4	MMSD
NS-21	- -	1987-1988	1.0	5.1	7.8	MMSD
NS-22	- -	1987-1988	1.0	4.8	9.6	MMSD
NS-23	- -	1987-1988	1.0	2.4	4.7	MMSD
NS-24	- -	1987-1988	1.0	4.8	9.3	MMSD
NS-25	- -	1987-1988	1.0	7.8	15.2	MMSD
NS-26	- -	1987-1988	1.0	20.1	41.3	MMSD
NS-27	SS-07	1998-2004	1.0	3.3	5.7	MMSD
NS-28	OH-01	1998-2004	1.0	4.4	8.0	MMSD
South Shore						
SS-01	- -	1979-2004	1.0	3.8	6.8	MMSD
SS-02	- -	1979-2004	1.0	2.9	5.3	MMSD
SS-03	- -	1979-2004	1.0	4.2	7.6	MMSD
SS-04	- -	1979-2004	1.0	3.7	6.8	MMSD
SS-05	- -	1979-2004	1.0	2.8	4.9	MMSD
SS-06	- -	1979-2004	1.0	4.1	7.6	MMSD
SS-07	NS-27	1979-2004	1.0	3.5	6.3	MMSD
SS-08	- -	1979-2004	1.0	2.8	5.0	MMSD
SS-09	- -	1979-2004	1.0	4.1	7.5	MMSD
SS-10	- -	1980-2004	1.0	3.3	6.0	MMSD
SS-11	NS-11	1980-2004	1.1	4.7	8.5	MMSD
SS-12	- -	1980-2004	1.0	3.7	6.8	MMSD

Source: SEWRPC.

per 100 ml. Counts in many samples exceeded the standard of 1,000 cells per 100 ml applied by the variance covering the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers that are in the estuary. In addition, the fecal coliform bacteria concentrations in the estuary in most samples exceeded the standard for full recreational use of 200 cells per 100 ml.

Statistically significant trends toward concentrations of fecal coliform bacteria decreasing over time were detected at all sampling stations in the estuary (see Tables C-1 through C-3 in Appendix C of this report). In part, these trends reflect sharp decreases in fecal coliform bacteria count between the periods 1987-1993 and 1994-1997. The occurrence of these reductions coincides with the period during which the Inline Storage System came on line. This suggests that, since 1994, reductions in inputs from combined sewer overflows related to operation of the Inline Storage System have contributed to reduced loadings of fecal coliform bacteria into the estuary.

At most sampling stations in the estuary, concentrations of fecal coliform bacteria increased between the periods 1994-1997 and 1998-2002. However, at most stations, the concentrations of fecal coliform bacteria observed during the period 1998-2002 were still below the levels observed in the periods before 1994. At some stations, these increases in concentration during the period 1998-2002 were accompanied by increases in variability.

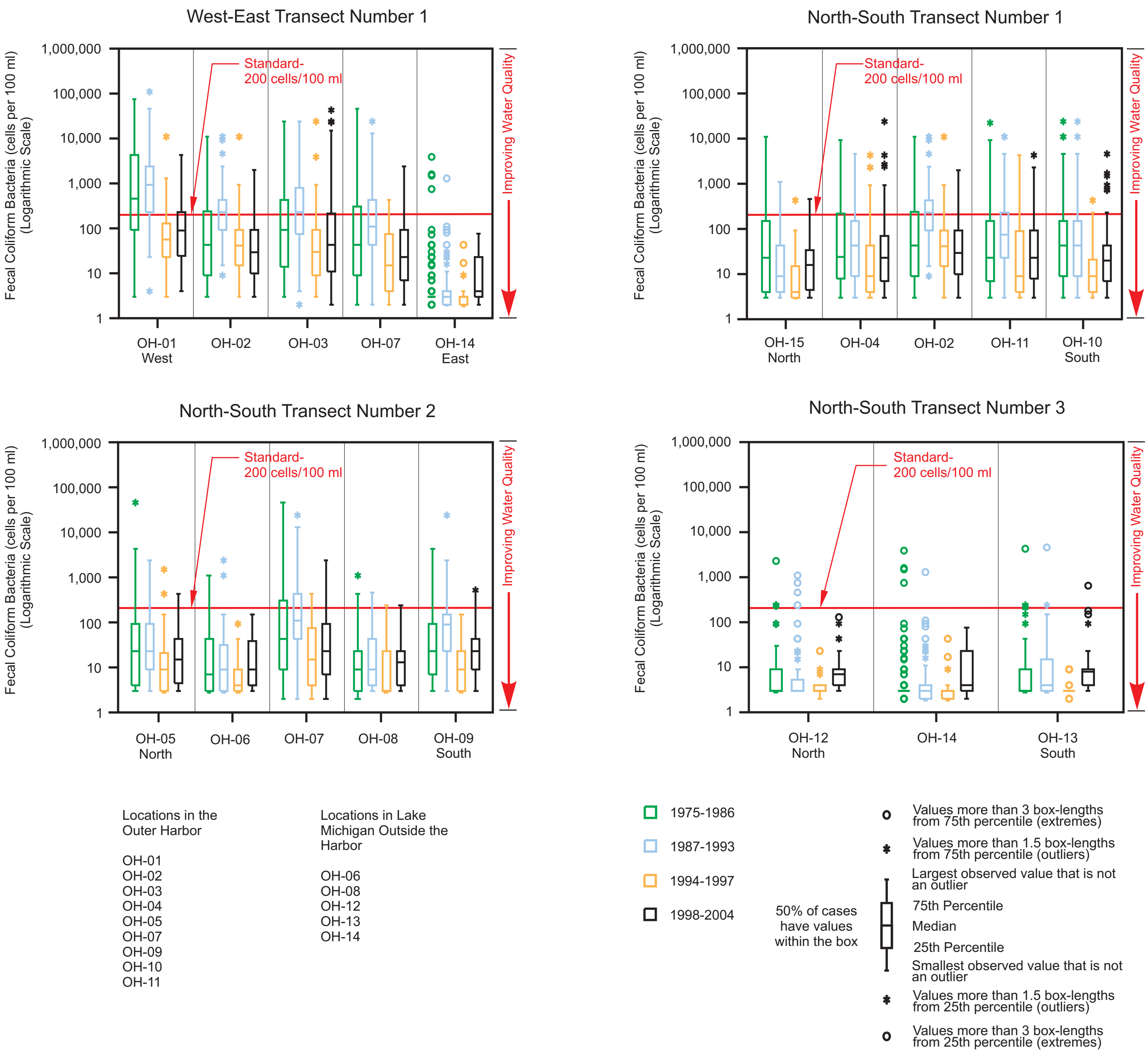
Fecal coliform bacteria concentrations in the estuary tend to be positively correlated with concentrations of biochemical oxygen demand and with concentrations of several nutrients including ammonia, dissolved phosphorus, total phosphorus, and total nitrogen. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the estuary. Fecal coliform bacteria concentrations are also strongly positively correlated with concentrations of *E. coli*, reflecting the fact that *E. coli* constitute a major component of fecal coliform bacteria. In addition, fecal coliform bacteria concentrations at some stations in the estuary are negatively correlated with several measures of dissolved material, such as alkalinity, chloride, hardness, and pH. The long-term trends toward declining fecal coliform bacteria concentrations at all sampling stations represent a long-term improvement in water quality in the estuary. The recent increases in fecal coliform bacteria concentrations at many of these same stations suggest that water quality may have declined somewhat over that period, although the long-term trend still indicates an improvement.

Figure 279 shows concentrations of fecal coliform bacteria at sampling stations along transects through and adjacent to the outer harbor. The median concentration of fecal coliform bacteria in the outer harbor during the period of record was 761 cells per 100 milliliters (ml). Fecal coliform bacteria counts in the outer harbor ranged from below the limit of detection to 110,000 cells per 100 ml. Concentrations of fecal coliform bacteria in the outer harbor tend to be about an order of magnitude lower than concentrations in the estuary. Concentrations of fecal coliform bacteria in the outer harbor tend to be one to two orders of magnitude higher than concentrations at stations in Lake Michigan outside of the harbor. The highest concentrations of fecal coliform bacteria in the outer harbor were observed at station OH-01 near the mouth of the Milwaukee River. Concentrations of fecal coliform bacteria were lower at other stations in the outer harbor. This suggests that transport of bacteria with water flowing in from the estuary constitutes a major source of fecal coliform bacteria to the outer harbor. Concentrations of fecal coliform bacteria at all stations in the outer harbor and along the breakwall decreased sharply after 1993. At several of these stations, these decreases reflect statistically significant trends toward decreasing concentrations of fecal coliform bacteria (see Table C-6 in Appendix C). The occurrence of these reductions coincides with the period during which the Inline Storage System came on line. It suggests that, since 1994, reductions in inputs from combined sewer overflows related to operation of the Inline Storage System have contributed to reduced loadings of fecal coliform bacteria into the estuary and, consequently, loadings from the estuary into the outer harbor. At most sampling stations in the outer harbor, concentrations of fecal coliform bacteria increased between the periods 1994-1997 and 1998-2002. However, at most stations, the concentrations of fecal coliform bacteria observed during the period 1998-2002 were below the levels observed in the periods before 1994. At some stations, these increases in concentration during the period 1998-2002 were accompanied by increases in variability.

Figure 280 shows a comparison of monthly mean concentrations of fecal coliform bacteria from the baseline period to historical monthly means for four sampling stations along a west-to-east transect through the outer

Figure 279

FECAL COLIFORM BACTERIA IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004

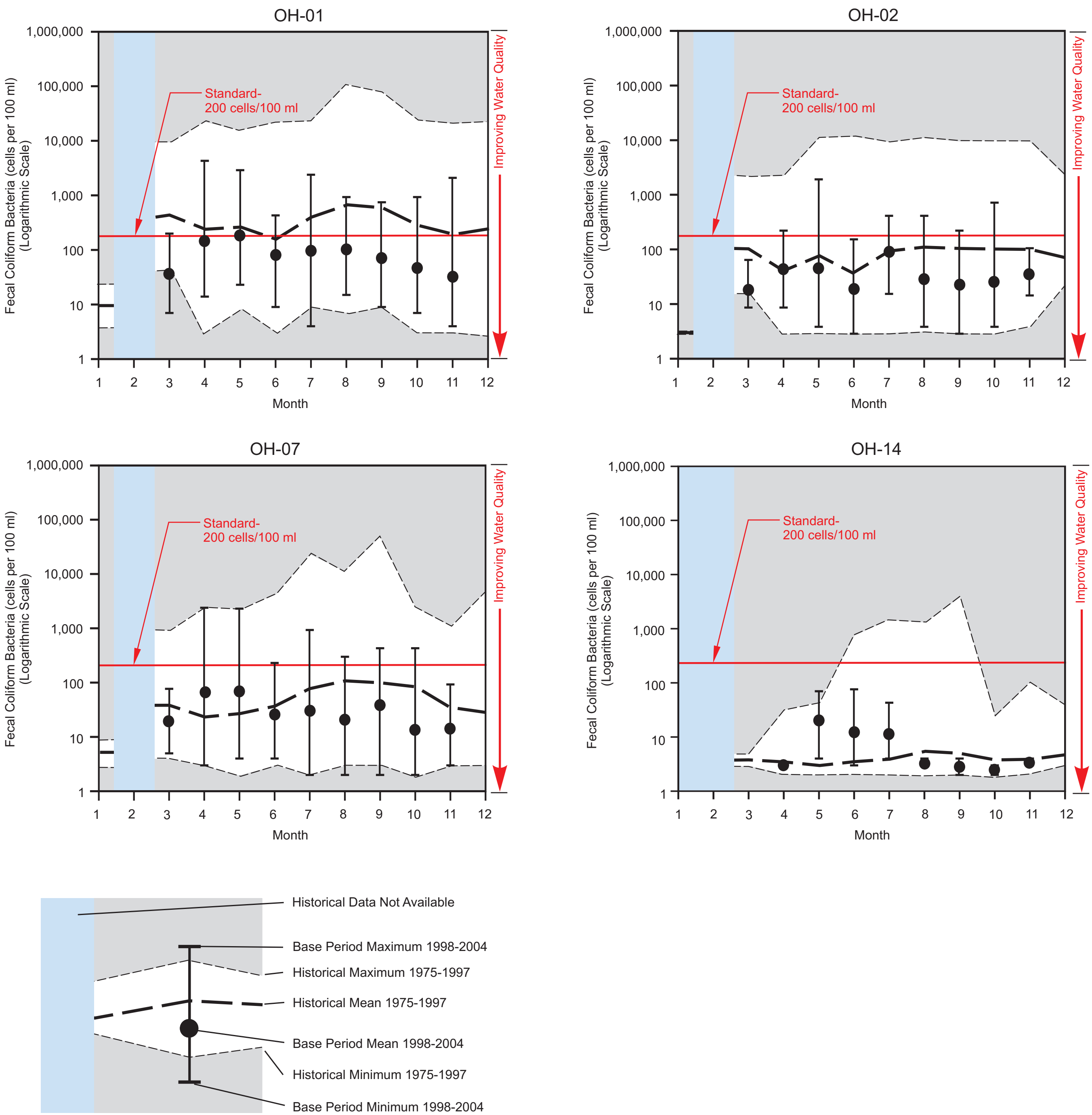


Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

harbor. Baseline period concentrations of fecal coliform bacteria at these stations were generally within historical ranges. At the stations within the outer harbor, OH-01 and OH-02, baseline period monthly mean concentrations of fecal coliform bacteria tended to be near historical means during the spring. By contrast, baseline period monthly mean concentrations during the summer and fall at these stations were lower than historical means. Outside the outer harbor, at station OH-14, baseline period monthly mean concentrations of fecal coliform bacteria were higher than historical means during the late spring and early summer and slightly below historical means during the fall. The pattern observed at station OH-07, at the gap in the breakwall, contains aspects of the patterns observed at stations located inside and outside of the outer harbor. Fecal coliform bacteria concentrations

Figure 280

HISTORICAL AND BASE PERIOD FECAL COLIFORM BACTERIA AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004



NOTE: See Map 117 for locations of monitoring stations relative to the outer harbor and the adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

in the outer harbor are positively correlated with concentrations of total phosphorus. This correlation may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the outer harbor.

MMSD began regular sampling for *E. coli* at sampling stations in the estuary and outer harbor in 2000. Median concentrations of *E. coli* in the Milwaukee Harbor estuary during the period 2000-2002 were 410 per 100 ml. The median concentrations of *E. coli* during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 290 cells per 100 ml, 520 cells per 100 ml, and 410 cells per 100 ml, respectively. Counts of *E. coli* in the estuary varied over six orders of magnitude, ranging from as low as 0.5 cells per 100 ml to 240,000 cells per 100 ml. No statistically significant differences in mean concentrations of *E. coli* were detected through ANOVA among the Kinnickinnic River, Menomonee River, and Milwaukee River portions of the estuary.

Figure 281 shows the concentrations of *E. coli* at sites along transects through and adjacent to the outer harbor. The median concentration of *E. coli* in the outer harbor during the period 2000-2002 was 22 cells per 100 ml. Counts of *E. coli* in the outer harbor varied over four orders of magnitude, ranging from below the limit of detection to 3,300 cells per 100 ml. Median concentrations of *E. coli* at sites in the outer harbor ranged between seven and 96 cells per 100 ml. Median concentrations of *E. coli* at sites outside the outer harbor were below the limit of detection.

During 2003 and 2004, the University of Wisconsin-Milwaukee Great Lakes WATER Institute conducted studies on the transport and fate of bacteria through the estuary, outer harbor, and adjacent areas of Lake Michigan.[5] These studies included extensive surveys of *E. coli* concentrations to characterize transport of bacteria through the estuary and harbor and antibiotic resistance testing to determine whether fecal coliform bacteria including *E. coli* were derived from human sources. Bacterial surveys conducted for that study demonstrated that after a rainfall, bacterial pollution travels in a distinct plume with river water as it moves through the outer harbor and past the breakwall. Concentrations of *E. coli* in samples collected from this plume were 30 to 100 times higher than in samples collected less than 50 meters outside of the plume. Based on comparisons of specific conductance, this decrease is larger than can be accounted for by the effects of dilution. For example, samples from the plume containing 60-80 percent river water contained concentrations of *E. coli* that were only 12-17 percent of the mean concentration of *E. coli* in the channel just upstream from the mouth of the Milwaukee River. Surveys conducted during combined sewer overflow (CSO) events during 2004 demonstrated that *E. coli* concentrations decreased drastically outside the breakwall during overflows as the pollution plume mixed with lake water. In addition, *E. coli* during overflow events could not be detected at concentrations above 10 cells per 100 ml at distances greater than 3.1 miles from the harbor breakwall.

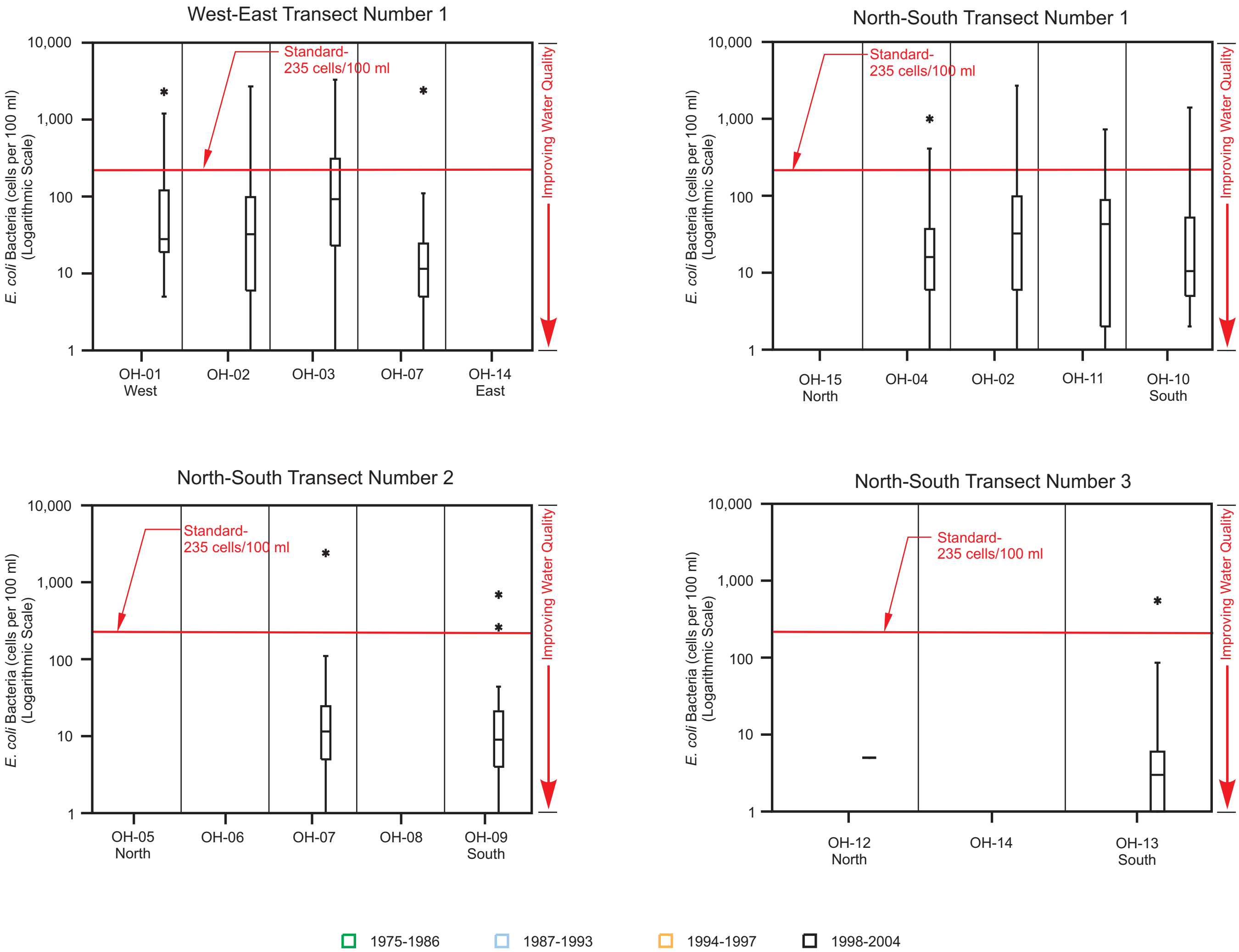
Map 118 shows concentrations of *E. coli* in the estuary, outer harbor and adjacent areas of Lake Michigan during a survey taken following a precipitation event without the occurrence of combined sewer overflows.[6] Total precipitation during the 24 hours preceding this survey was 0.29 inches. While high concentrations of *E. coli* were observed in the Rivers, especially the Milwaukee River, concentrations of *E. coli* at most locations surveyed in the outer harbor and outside the breakwall were under 235 cells per 100 ml. Higher concentrations of *E. coli* were detected at the southern end of the outer harbor near the Milwaukee Confined Disposal Facility. The low concentrations of *E. coli* at the mouth of the Milwaukee River and in most of the southern half of the outer harbor make it unlikely that the high concentrations at the southern end were due to loadings from the estuary and the tributary rivers. Instead these high concentrations were probably the result of local inputs from adjacent land. In the absence of sewer overflows and rain events greater than one inch of precipitation, concentrations of *E. coli* above 235 cells per 100 ml were rarely observed in open waters of Lake Michigan. Map 119 shows concentra-

[5]*Sandra L. McLellan and Erika Jensen Hollis, Bacteria Source, Transport and Fate Study—Phase I, Volume 3, University of Wisconsin Great Lakes WATER Institute Contribution No. 470, August 2005.*

[6]Ibid.

Figure 281

***E. COLI* BACTERIA CONCENTRATIONS IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004**



NOTES: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Data are only available for the period from 2000 through 2004.

No data were available for Stations OH-05, OH-06, OH-08, and OH-15. Concentrations of *E. coli* at Station OH-14 were below the limit of detection in all samples.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

tions of *E. coli* in the estuary, outer harbor and adjacent areas of Lake Michigan during a survey taken following heavy precipitation accompanied by combined sewer overflows.[7] Total precipitation during the 24 hours preceding that survey was 1.99 inches, and 2.33 inches of precipitation fell in the 72 hours preceding that survey. In addition, combined sewer overflows at 52 outfalls totaling approximately 449 million gallons occurred on the day before and day of that survey. Concentrations of *E. coli* were above 235 cells per 100 ml throughout the outer

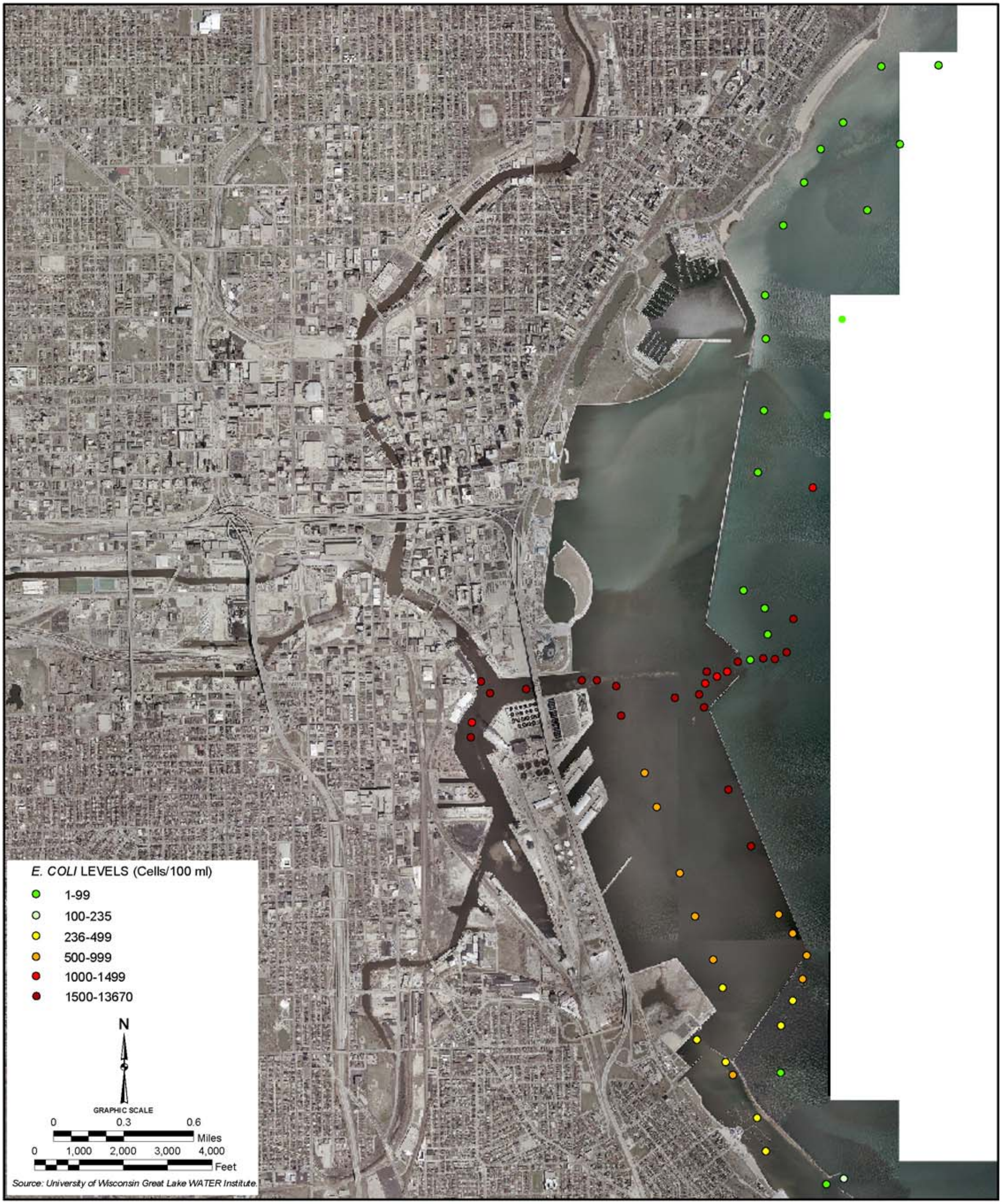
[7]Ibid.

Map 118

CONCENTRATION OF *E. COLI* AT SITES IN THE MILWAUKEE HARBOR ESTUARY, OUTER HARBOR AND ADJACENT LAKE MICHIGAN NEARSHORE AREAS: JULY 5, 2003

Map 119

CONCENTRATION OF *E. COLI* AT SITES IN THE MILWAUKEE HARBOR ESTUARY, OUTER HARBOR AND ADJACENT LAKE MICHIGAN NEARSHORE AREAS: MAY 14, 2004



harbor. Highest concentrations occurred in a pollution plume that ran from the mouth of the Milwaukee River through the main gap in the breakwall. Despite this, concentrations of *E. coli* in the open waters of Lake Michigan were generally below 235 cells per 100 ml except in the pollution plume.

The Great Lakes WATER Institute study also compared patterns of antibiotic resistance in *E. coli* isolates collected both during precipitation events without CSO events in 2003 and during CSO events in 2004. Bacterial isolates originating from human sources should show a greater amount of resistance to commonly used antibiotics than bacterial isolates originating from nonhuman sources such as other mammals or waterfowl. While concentrations of *E. coli* during CSO events were higher than during precipitation events without overflows, no differences were observed in the patterns of antibiotic resistance in bacteria isolated during these two conditions. This suggests that the proportion of *E. coli* from human sources entering the harbor during CSO events is similar to the proportion from human sources entering the harbor during precipitation events without overflows. The study's authors suggest that this lack of difference may be caused by unrecognized sanitary sewage inputs such as cross connections between the sanitary and stormwater sewer systems or leaking sanitary sewer lines, both of which would tend to increase *E. coli* concentrations during smaller rain storms that would not result in overflows.[8] However, since the study did not directly investigate the possible *E. coli* sources through field sampling or monitoring, these suggestions, while plausible, are somewhat speculative. The MMSD has instituted a systematic program to collect data in an effort to better define the origin of human-sourced *E. coli* found in the harbor and upstream locations.

Chlorophyll-a

Over the period of record, the mean concentration of chlorophyll-*a* in the Milwaukee Harbor estuary was 16.6 micrograms per liter (μg/l). Individual samples of this parameter ranged from 0.1 μg/l to 382.0 μg/l. The mean concentrations of chlorophyll-*a* during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 7.9 μg/l, 9.7 μg/l, and 25.2 μg/l, respectively. These differences in mean chlorophyll-*a* concentration among the Rivers were generally statistically significant. For example, analysis of variance showed that the mean concentration of chlorophyll-*a* in the portion of the Milwaukee River in the estuary was significantly higher than the mean concentrations of chlorophyll-*a* in the Kinnickinnic and Menomonee Rivers during all periods. During the baseline period, the mean concentration of chlorophyll-*a* in the portion of the Menomonee River in the estuary was higher than the mean concentration of chlorophyll-*a* in the portion of the Kinnickinnic River in the estuary. Concentrations of chlorophyll-*a* have decreased in much of the estuary. Chlorophyll-*a* concentrations decreased in the Kinnickinnic River portion of the estuary and some stations in the Menomonee River portion of the estuary after 1994 (see Figure 30 in Chapter V and Figure 67 in Chapter VI of this report). Statistically significant trends toward decreasing chlorophyll-*a* concentrations were detected at sampling stations in the estuary portions of both these rivers. These changes occurred at roughly the time when the Inline Storage System came online and may reflect reductions of nutrient inputs related to the reduction in the number of combined sewer overflows. Decreases in chlorophyll-*a* concentrations have also been observed at sampling stations in the estuary portion of the Milwaukee River; however, these decreases generally took place after 1998 (see Figure 115 in Chapter VII of this report).

Figure 282 presents concentrations of chlorophyll-*a* at stations along transects through and near the outer harbor. In all periods, chlorophyll-*a* concentrations were higher at sampling stations in, and immediately adjacent to, the outer harbor than at sampling stations farther outside the harbor. Concentrations of chlorophyll-*a* in samples collected at stations along the breakwall tend to be higher at those stations located at the gaps in the breakwall than in samples at stations not located in gaps at the breakwall. This is especially the case in samples collected from near the surface of the Lake. At most stations in the outer harbor, concentrations of chlorophyll-*a* increased between the periods 1975-1986 and 1987-1993. This increase was followed by a decrease after 1994. At some stations within the outer harbor, chlorophyll-*a* concentrations increased slightly after 1997. Figure 283 shows historical and baseline period chlorophyll-*a* concentrations from four stations along a west-to-east transect

[8]Ibid.

Figure 282

CHLOROPHYLL-*a* CONCENTRATIONS AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004

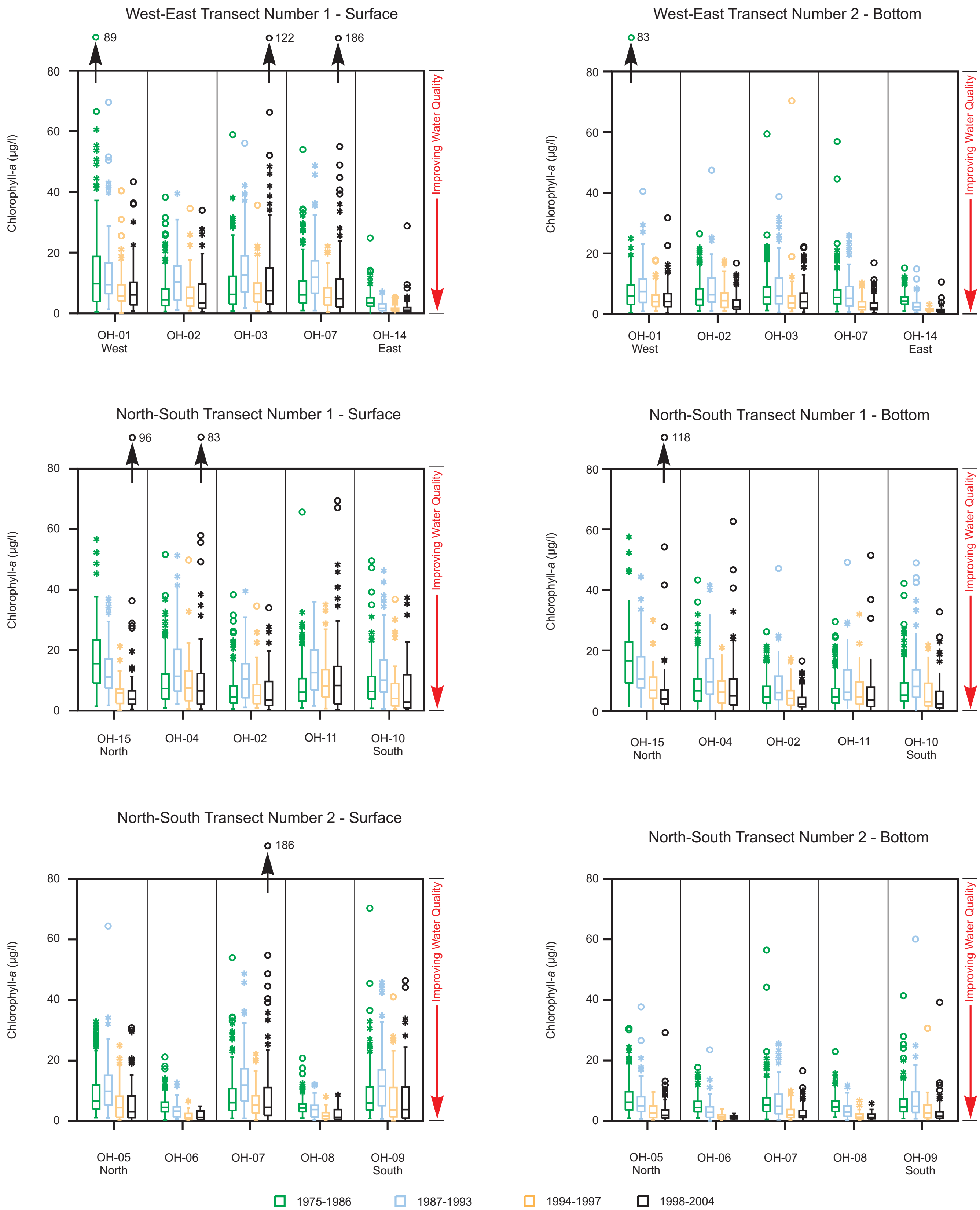
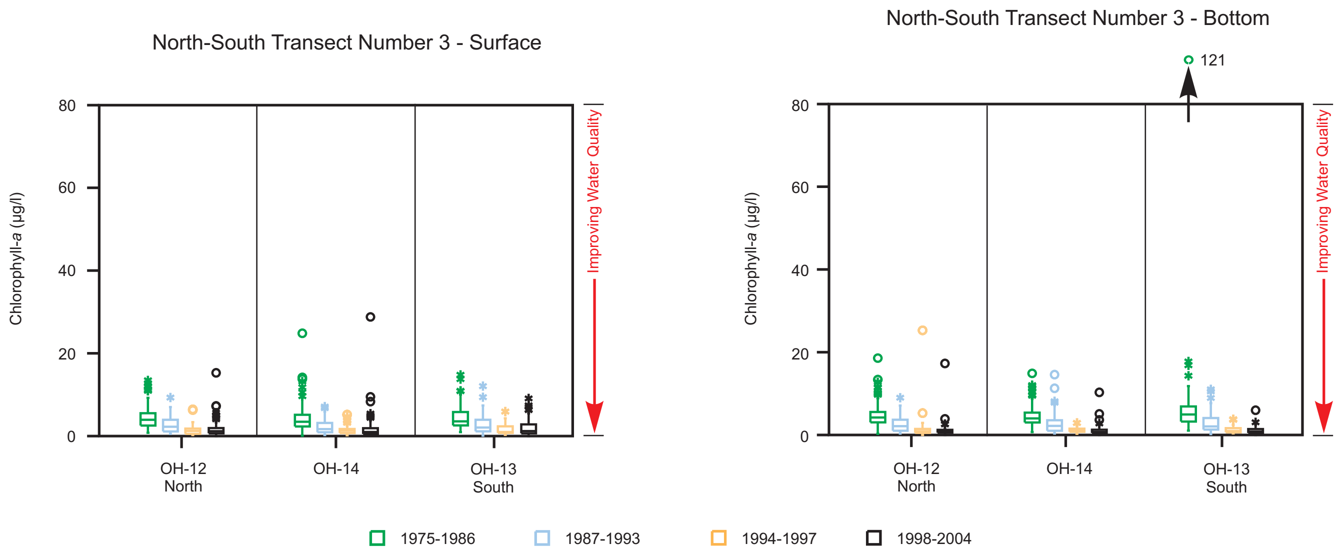


Figure 282 (continued)



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

through the outer harbor. At station OH-01, near the mouth of the Milwaukee River, baseline period monthly mean concentrations of chlorophyll-*a* were lower than historical monthly mean concentrations, especially during late spring and summer months. At station OH-02 baseline period monthly mean concentrations of chlorophyll-*a* were below historical means during spring months and near historical means during most summer and fall months. It is important to note that this sampling station is near the outfall from the Jones Island wastewater treatment plant, and that chlorophyll-*a* concentrations in samples collected at this station may show the influence of effluent from this outfall. At station OH-07, near the main gap in the breakwall, baseline period monthly mean chlorophyll-*a* concentrations were below historical means during the spring and late fall and above historical means during the summer and early fall. At station OH-14, outside the outer harbor, baseline period monthly mean chlorophyll-*a* concentrations were below or near historical means. When examined on an annual basis, statistically significant trends toward decreasing chlorophyll-*a* concentrations were detected at most sampling stations in and around the outer harbor (see Table C-6 in Appendix C). When examined on a seasonal basis, statistically significant trends toward decreasing chlorophyll-*a* concentrations were detected at all sampling stations in and around the outer harbor during the spring. In both cases, these trends tend to account for a greater amount of variation at stations outside the outer harbor than at stations inside the outer harbor. Several factors may account for the decrease in chlorophyll-*a* concentrations in the outer harbor. Chlorophyll-*a* concentrations have generally decreased in the nearshore regions of Lake Michigan (see Figure 282 and the section on Water Quality of the Nearshore Lake Michigan Areas in this chapter). Much of this decrease appears to be the result of filtering activities of zebra mussels and quagga mussels. Beds of zebra mussels containing 100,000 or more mussels per square meter have been reported in Lake Erie[9] and Lake Michigan.[10] Large adult zebra mussels have

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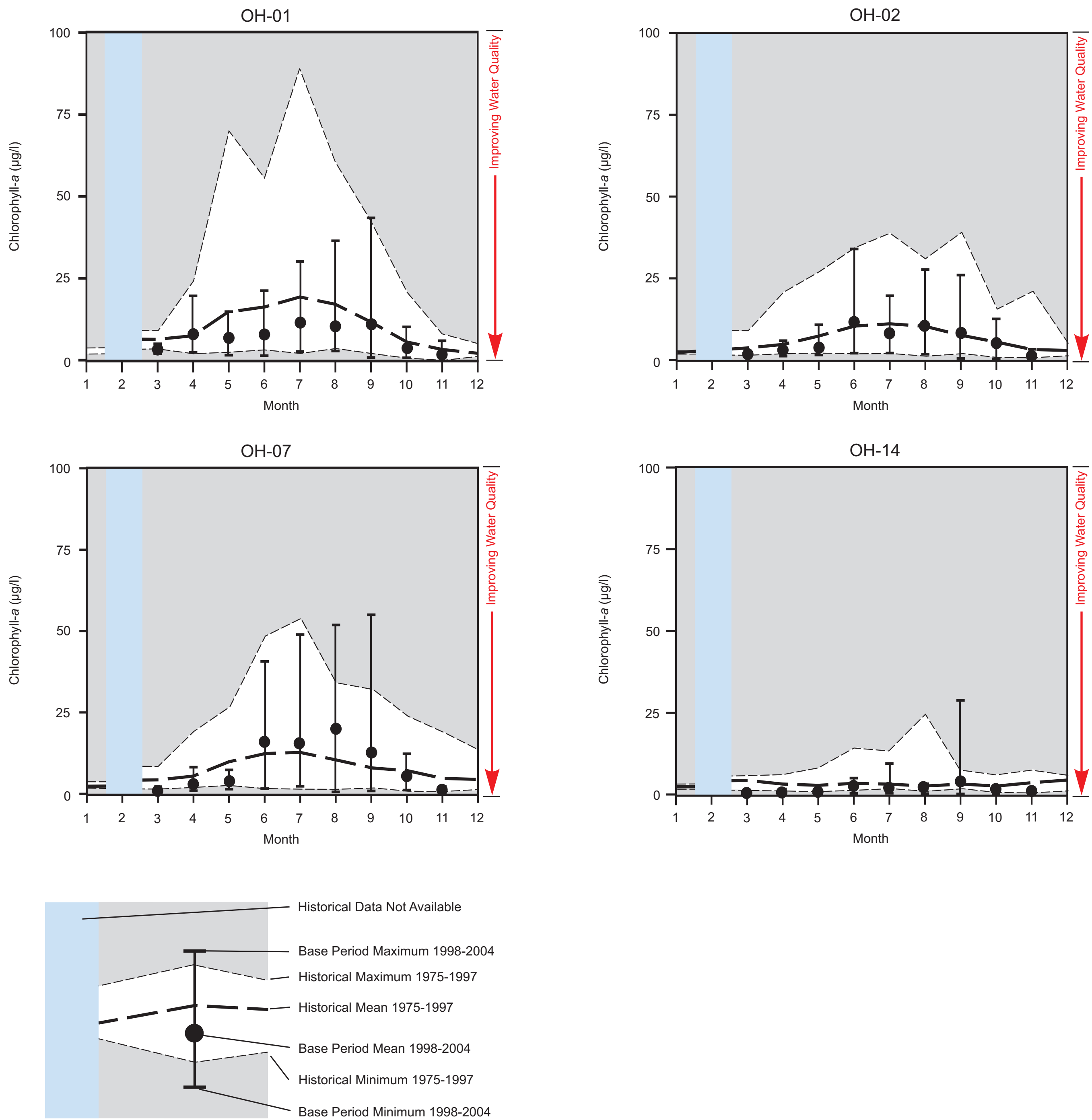
[9]*F.L. Snyder, M.B. Hilgendorf, and D.W. Garton, "Zebra Mussels in North America: The Invasion and its Implications," Ohio Sea Grant, Ohio State University, Columbus, Ohio, http://www.sg.ohio-state.edu/f-searchhtml. 1997.*

[10]*J.E. Marsden, N. Trudeau, and T. Keniry, Illinois Natural History Survey, "Zebra Mussel Study on Lake Michigan: Final Report to the Illinois Department of Conservation,"* Technical Report No. 93/4*, 1993.*

Figure 283

HISTORICAL AND BASE PERIOD CHLOROPHYLL-*a* CONCENTRATIONS AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004



NOTE: See Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

been observed to remove particles from water at rates over 1.5 liters per day through filter feeding.[11] This removal of phytoplankton from the water column coupled with reduced nutrient loads to the inner harbor, resulting from both reductions of combined sewer overflows since the Inline Storage System came online and nonpoint source pollution control efforts, may account for the decrease in chlorophyll-*a* concentrations in the inner harbor.

Several factors can affect chlorophyll-*a* concentration in the outer harbor. Phytoplankton populations, which are estimated from chlorophyll-*a* concentration, are strongly influenced by the availability of nutrients, especially phosphorus and, during the spring diatom bloom, silica. Changes in levels of nutrient input from the rivers flowing into the outer harbor or from the sediment can be reflected as changes in chlorophyll-*a* concentration. Grazing by zooplankton and other suspension feeding animals, such as zebra mussels, can remove phytoplankton from the water column, resulting in a decrease in the concentration of chlorophyll-*a*. At most stations in the estuary and outer harbor chlorophyll-*a* concentrations are negatively correlated with concentrations of nitrate and dissolved phosphorus. This reflects the role of these compounds as nutrients for algal growth. As algae grow, they remove these compounds from the water and incorporate them into cellular material. Chlorophyll-*a* concentrations are also positively correlated with temperature, reflecting higher algal growth rates and standing crops during warmer weather. Chlorophyll-*a* concentrations are also negatively correlated with alkalinity. Since chlorophyll-*a* concentrations in water strongly reflect algal productivity, this correlation probably reflects lowering of alkalinity during photosynthesis through removal of inorganic carbon, mostly carbon dioxide, bicarbonate, and carbonate, from the water. The trends toward decreasing chlorophyll-*a* concentrations in the estuary and outer harbor represent improvements in water quality.

Chemical and Physical Parameters

Temperature

The mean water temperature in the Milwaukee Harbor estuary during the period of record was 14.8 degrees Celsius (ºC). Water temperatures in individual samples ranged from 0ºC to 34.1ºC. The mean water temperatures during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 12.2ºC, 14.8ºC, and 13.0ºC, respectively. Analysis of variance showed that during all periods, the mean water temperature in the Menomonee River portion of the estuary was significantly higher than the mean water temperatures in the Kinnickinnic River and Milwaukee River portions of the estuary. During most periods, no statistically significant differences were found between mean water temperatures in the Kinnickinnic River and Milwaukee River portions of the estuary. Statistically significant trends toward increasing water temperature were detected at most sampling stations in the estuary, though at several stations these trends accounted for only a small portion of the variation in the data.

The median water temperature in the outer harbor over the period of record was 12.5ºC. Water temperatures in individual samples ranged from 0.4ºC to 27.6ºC. Figure 284 shows water temperatures collected at sampling stations along transects through and adjacent to the outer harbor. Water temperatures at sampling station OH-01 tended to be warmer than water at other stations in the outer harbor. This was especially true for water near the surface. This indicates that water flowing into the outer harbor from the estuary tended to be warmer than ambient water temperatures in the outer harbor. Similarly, water temperatures in the outer harbor tended to be warmer than water temperatures at stations outside the breakwall. Figure 284 shows evidence of overall changes in the temperature regime over time for most stations in the outer harbor. Temperatures at most of the stations in or adjacent to the outer harbor appear to have remained stable or decreased over the three sample periods from 1987 through 2004. It is important to note that the increase in temperatures between the sample periods 1975-1986 and 1987-1993, as shown in Figure 284, was due to the inclusion of data collected during the winter during the earlier period.[12]

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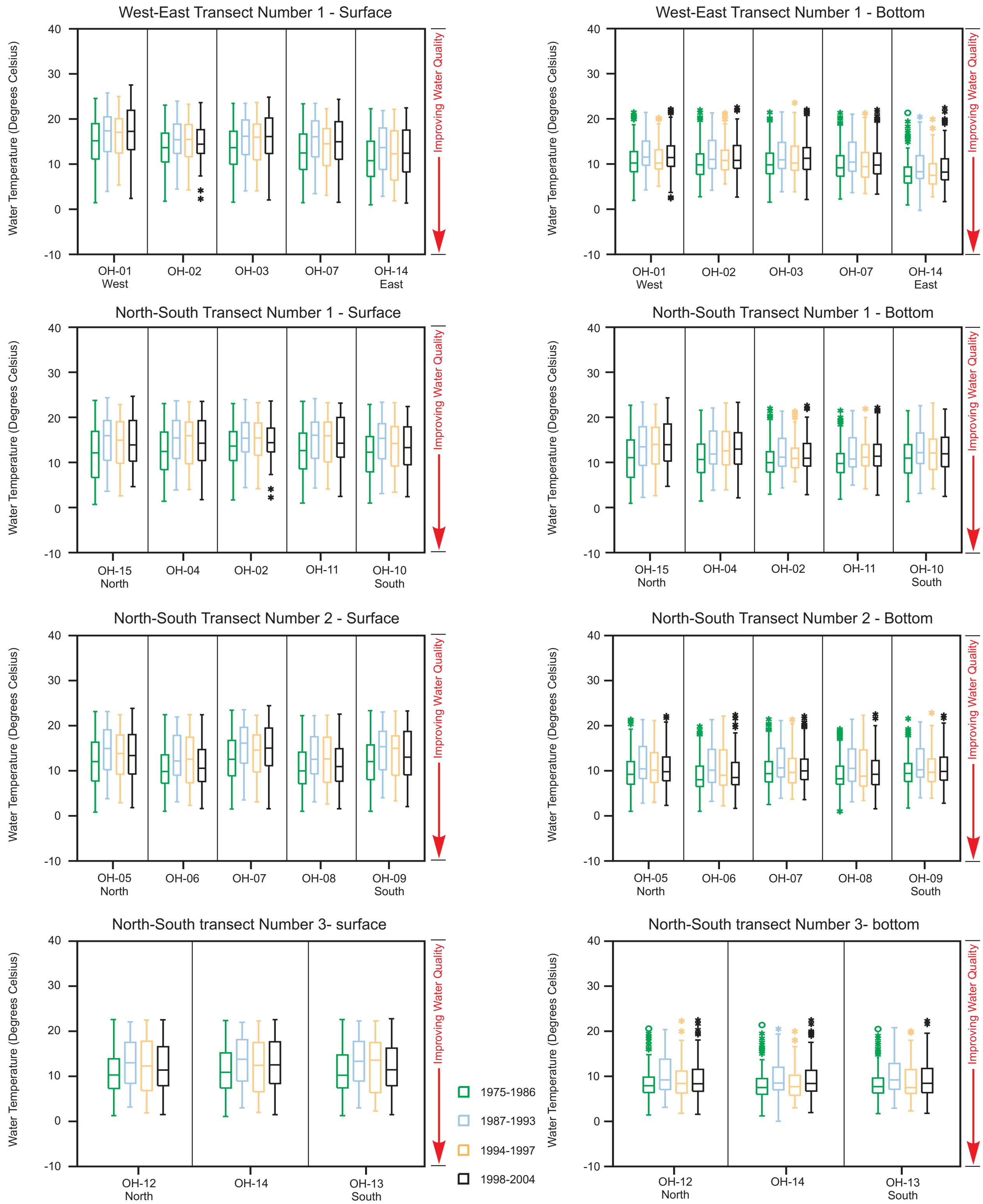
[11] *Jin Lei, Barry S. Payne, and Shiao Y. Wang, "Filtration Dynamics of the Zebra Mussel,* Dreissena polymorpha,*"* Canadian Journal of Fisheries and Aquatic Sciences, *Volume 48, 1996.*

[12] *MMSD stopped sampling during the winter in 1987.*

Figure 284

WATER TEMPERATURE AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

This apparent stability obscures the presence of some trends in the data. When examined on an annual basis, regression analysis revealed that there were statistically significant trends toward increasing water temperatures at most sampling stations in the outer harbor (see Table C-6 in Appendix C).[13] In addition, when the data were analyzed on a seasonal basis, statistically significant trends toward increasing water temperatures during the summer were found at almost all stations in and adjacent to the outer harbor. The presence of these trends during the summer is illustrated in the comparison of historical and baseline period monthly mean surface water temperatures shown in Figure 285. Several features of the dynamics of water temperature in the outer harbor emerge from this graph. First, there is a strong seasonal cycle to water temperatures. Second, during most months, baseline period monthly mean water temperatures were warmer than historical monthly mean temperatures. Third, during the spring, the ranges of temperatures observed during the baseline period were within historical ranges. During some spring months, baseline period maximum temperatures exceeded the historical maxima, but were usually less than the historical maximum for the following month. This suggests that the higher monthly mean water temperatures observed during baseline period spring months resulted from warming that occurred earlier in the year during the baseline period than it did during the historical period. Fourth, while the pattern does not seem as pronounced, a similar change appears to have occurred during the fall. The data suggest that cooling of water in the outer harbor and adjacent areas of Lake Michigan occurred later during the baseline period. Finally, during both the historical and baseline period, the highest monthly mean water temperatures were observed during August. At several sampling stations baseline period maximum water temperatures during this month exceeded the historical maxima.

Water temperatures in the outer harbor are the result of a complex process driven by several factors. Ultimately, water temperatures in the outer harbor are the result of solar heating and the seasonal cycle. More immediately, influx of relatively warm water from the estuary and solar heating tends to increase temperatures in the outer harbor while influx of relatively cool water from Lake Michigan through the gaps in the breakwall tends to decrease temperatures in the outer harbor. The relative strengths of these influences will be affected by factors such as water levels in the Lake, the amount of discharge from the Rivers flowing into the estuary, and water clarity in the outer harbor.

The trends toward increasing water temperature in estuary stations at some outer harbor stations represent a reduction in water quality.

Water temperatures in the estuary, outer harbor, and nearshore Lake Michigan areas were further examined to test for the presence of time-based trends related to sources other than the effect of air temperature on water temperatures. This was done through a two-step process. First, the relationships between monthly mean water temperatures at sampling sites and monthly mean air temperatures at General Mitchell International Airport were determined by performing linear regressions using air temperature as the independent variable and water temperature as the dependent variable. Second, in instances where statistically significant relationships between air temperature and water temperature were detected, the residuals from the air temperature-water temperature regressions were examined for the presence of time-based trends through linear regression of the residuals against time. In linear regression analysis, residuals consist of the deviations from the line fitted by the regression to the observed value (see Figure 286). For any data point in a regression, the residual is the difference between the value of the dependent variable in the observed data and the value of the dependent variable predicted by the regression equation for the corresponding value of the independent variable. The residuals in a linear regression represent the variation in the data that is not accounted for by the relationship between the independent and dependent variables, including both variation due to other factors and random variation. The effect of this procedure is to remove the influence of air temperature from the data and allow for examination of the water temperature data for the presence of time-based trends that are not related to changes in air temperature. The

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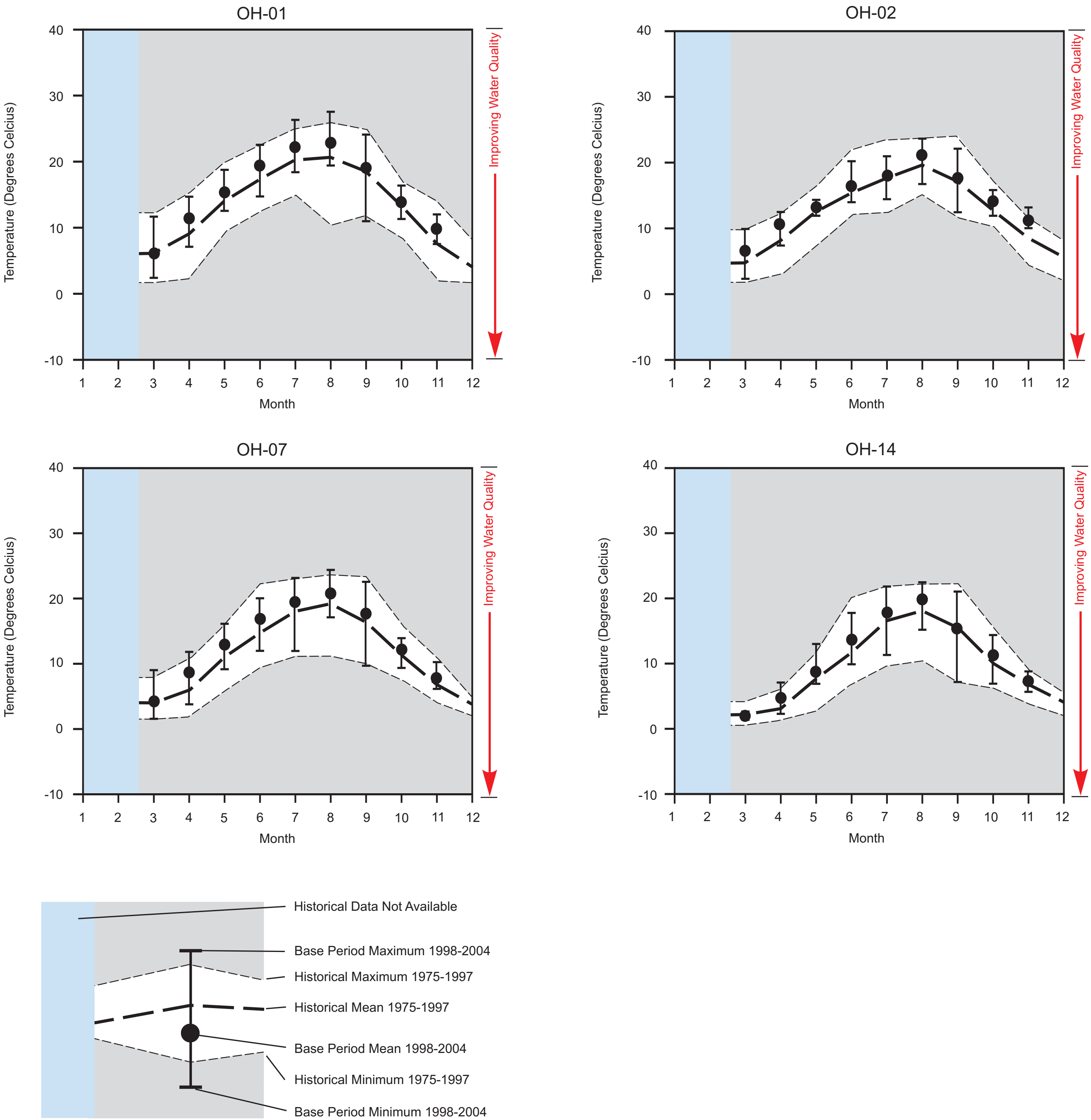
[13]*The trend analysis of water temperatures excluded the winter data, which were only collected from 1975 through 1986.*

Figure 285

HISTORICAL AND BASE PERIOD WATER TEMPERATURE AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004



NOTE: See Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

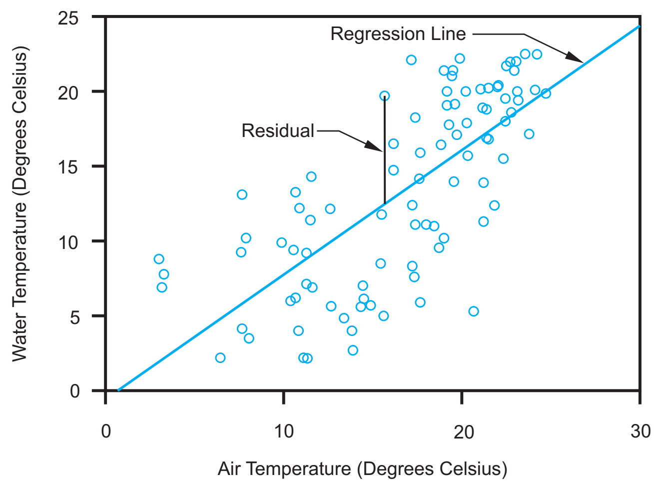
Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

detection of a statistically significant regression in the second step indicates the presence of a trend toward water temperatures changing over time that is due to some factor other than changes in air temperature. The use of this procedure allows for the detection of trends whose presence would otherwise be obscured by the variability related to changes in air temperature.

Table 189 shows results of regression analysis for selected sampling stations in the estuary, outer harbor, and nearshore Lake Michigan areas. At all stations, there were strong relationships between monthly mean air temperature and monthly mean water temperature. At stations in the estuary and outer harbor, these relationships accounted for about 69 percent to 91 percent of the variation in the water temperature data. While the relationships between air and water temperature at stations in the nearshore Lake Michigan area are weaker, they still account for a substantial portion of the variation in the water temperature data. Statistically significant regressions were found between the residuals and time at several stations in the estuary and outer harbor. There was a distinct geographic pattern to where significant regressions were found. No significant time-based trends were found in the residuals at Kinnickinnic River station at S. 1st Street, the Menomonee River station at N. 25th Street, and the Milwaukee River station at Wells Street, all stations in upstream reaches of the estuary (see Table 189). At one station in the upstream reaches of the estuary, the Milwaukee River station at Walnut Street, a statistically significant trend was detected toward the residuals decreasing over time. This indicates that, when the effects of air temperature are removed from the data, there is a trend toward water temperatures decreasing over time at this site. It is important to note that the magnitude of the decrease is small, less than 0.1 degree Celsius per year, and that this trend accounts for a small portion of the variation in the data. A different pattern was seen at stations in downstream reaches of the estuary. At these sites, statistically significant trends were detected toward the residuals increasing over time, indicating that when the effects of air temperature are removed from the data, there are trends toward water temperatures increasing over time. The strongest relationship, both in terms of the amount of variation accounted for and in terms of the magnitude of the increase, was detected at the Menomonee River station at Burnham Canal (see Table 189). When the effects of air temperature are removed from the analysis, water temperatures at this site appear to be increasing at a rate of about 0.61ºC per year. This station is within the influence of thermal discharges from several industrial dischargers, most notably the We Energies power plant. Increasing trends were detected at the other stations in the downstream reaches of the estuary. The rates of temperature increase at these sites, after accounting for the effects of air temperature, were less than the rate at the Burnham Canal stations, ranging from about 0.06 to 0.10ºC per year. It is important to note that these stations are all downstream of the Burnham Canal station. Similar trends were detected at stations in the outer harbor. The rate of temperature increase at these sites, after accounting for the effects of air temperature, was about 0.04ºC per year. These rates of increase are lower than the rates of increase observed at stations in the downstream portions of the estuary. No significant time-based trends were found in the residuals at stations in Lake Michigan outside of the outer harbor.

Figure 286

RESIDUALS IN LINEAR REGRESSION



Source: SEWRPC.

Alkalinity

The mean value of alkalinity in the Milwaukee Harbor estuary over the period of record was 199.2 milligrams per liter (mg/l) expressed as the equivalent concentration of calcium carbonate (mg/l as $CaCO_3$). The data show moderate variability, ranging from 5.0 to 999.0 mg/l as $CaCO_3$. The mean values of alkalinity during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 164.4 mg/l as $CaCO_3$, 200.2 mg/l as $CaCO_3$, and 218.6 mg/l as $CaCO_3$, respectively. During all periods except the period 1987-1993, significant differences were detected among the mean values of alkalinity from the estuary portions of all three rivers. During these periods, mean alkalinity in the Milwaukee River portion of the estuary was significantly higher than mean alkalinity in both the Menomonee River and Kinnickinnic River portions of the estuary and mean alkalinity in the Menomonee River portion of the estuary was significantly higher than mean

Table 189

TRENDS IN WATER TEMPERATURE ADJUSTED FOR THE EFFECT OF AIR TEMPERATURE IN THE MILWAUKEE HARBOR ESTUARY, OUTER HARBOR, AND NEARSHORE LAKE MICHIGAN AREAS: 1975-2004

		Regression				
		Air Temperature versus Water Temperature		Residuals versus Time		
Sampling Station	Samples	Trend	R^2	Trend	R^2	Slope (ºC per year)
Estuary						
Kinnickinnic River at S. 1st Street	194	⬆	0.89	0	- -	- -
Kinnickinnic River at Greenfield Avenue (extended)	170	⬆	0.80	⬆	0.27	0.065
Menomonee River at N. 25th Street	151	⬆	0.86	0	- -	- -
Menomonee River at Burnham Canal	83	⬆	0.69	⬆	0.34	0.610
Menomonee River at S. 2nd Street	182	⬆	0.85	⬆	0.06	0.096
Milwaukee River at Walnut Street	216	⬆	0.90	⬇	0.04	-0.066
Milwaukee River at Wells Street	208	⬆	0.91	0	- -	- -
Milwaukee River at Water Street	205	⬆	0.81	⬆	0.02	0.063
Milwaukee River at Union Pacific Railroad	179	⬆	0.79	⬆	0.05	0.087
Outer Harbor						
OH-01	210	⬆	0.85	⬆	0.02	0.044
OH-03	213	⬆	0.84	⬆	0.02	0.038
OH-07	212	⬆	0.82	⬆	0.02	0.043
Nearshore Lake Michigan Area						
NS-01	97	⬆	0.38	0	- -	- -
NS-04	98	⬆	0.60	0	- -	- -
NS-14	186	⬆	0.68	0	- -	- -
SS-01	167	⬆	0.59	0	- -	- -

NOTE: The following symbols were used:
⬆ indicates a statistically significant increase from upstream to downstream.
⬇ indicates a statistically significant decrease from upstream to downstream.
0 indicates that no trend was detected.
R^2 indicates the fraction of variance accounted for by the regression.

Source: SEWRPC.

alkalinity in the Kinnickinnic River portion of the estuary. During the period 1987-1993, no differences were detected between the mean value of alkalinity in the Milwaukee River portion of the estuary and the mean value of alkalinity in the Menomonee River portion of the estuary. Both of these means were found to be significantly higher than mean alkalinity in the Kinnickinnic River portion of the estuary. These differences may reflect differences in the relative importance of groundwater and surface runoff on the chemistry of water in different portions of the estuary with surface runoff having a greater influence on the water chemistry of the Kinnickinnic River portion of the estuary. Mean alkalinity in the outer harbor during the period of record was 136.9 mg/l as $CaCO_3$. Alkalinity in the Lake Michigan waters adjacent to the outer harbor was even lower. Mean alkalinity at those MMSD survey stations which are located just outside the breakwall was 116.9 mg/l as $CaCO_3$ over the period of record. Few statistically significant time-based trends were found in alkalinity in the estuary and outer harbor. When examined on an annual basis, the trends toward increasing alkalinity were found at one station within the outer harbor (see Table C-6 in Appendix C) and two stations in the Milwaukee River portion of the estuary (see Table C-3 in Appendix C). These trends accounted for a small portion of the variation in the data. Alkalinity concentrations in the estuary and outer harbor are strongly positively correlated with hardness, pH, specific conductance, and concentrations of chloride, all parameters which, like alkalinity, measure amounts of dissolved material in water. At several stations, alkalinity is negatively correlated with temperature, reflecting the fact that it indirectly measures concentrations of carbon dioxide in water and that solubility of gases in water decreases with increasing temperature.

Biochemical Oxygen Demand (BOD)

The mean concentration of BOD in the Milwaukee Harbor estuary during the period of record was 2.88 mg/l. Individual samples varied from below the limit of detection to 52.43 mg/l. The mean values of BOD during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 2.76 mg/l, 2.88 mg/l, and 2.96 mg/l, respectively. Statistically significant differences were found among mean BOD concentrations in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary; however, the relationships among BOD concentrations in these sections of the estuary appear to be dynamic and changing over time. During the period 1998-2002, the mean concentrations of BOD in the Menomonee River and Milwaukee River portions of the estuary were significantly higher than the mean concentration of BOD in the Kinnickinnic River portion of the estuary. When examined on an annual basis, statistically significant decreasing trends in BOD concentration over time were detected at all stations in the estuary (see Tables C-1 through C-3 in Appendix C of this report). At several stations, these trends accounted for a substantial portion of the variation in the data. The fact that the sampling stations in the estuary are all within the area served by combined sewers suggests that the decrease over time in BOD concentrations in the estuary is being caused, at least in part, by reductions of inputs from combined sewer overflows resulting from operation of the Inline Storage System. The mean concentration of BOD over the period of record at sampling stations in the outer harbor was 1.75 mg/l. Figure 287 shows BOD concentrations from sample sites along transects within and adjacent to the outer harbor. At those stations for which sufficient data exist, the concentration of BOD has decreased over time. These decreases represent statistically significant trends (see Table C-6 in Appendix C).

Several factors may influence BOD concentrations in the Milwaukee Harbor estuary and the outer harbor. Parts of the estuary and outer harbor act as settling basins for suspended material. Decomposition of organic material in sediment may act as a source of BOD to overlying water. BOD concentrations in the estuary are positively correlated at most stations with concentrations of fecal coliform bacteria and some nutrients such as ammonia, organic nitrogen, and total phosphorus. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the estuary. In addition, at some stations BOD concentrations are negatively correlated with dissolved oxygen concentrations. Aerobic metabolism of many organic nitrogen compounds requires oxygen and thus these compounds contribute to BOD. The declining trends in BOD concentrations over time in the estuary and outer harbor represent an improvement in water quality.

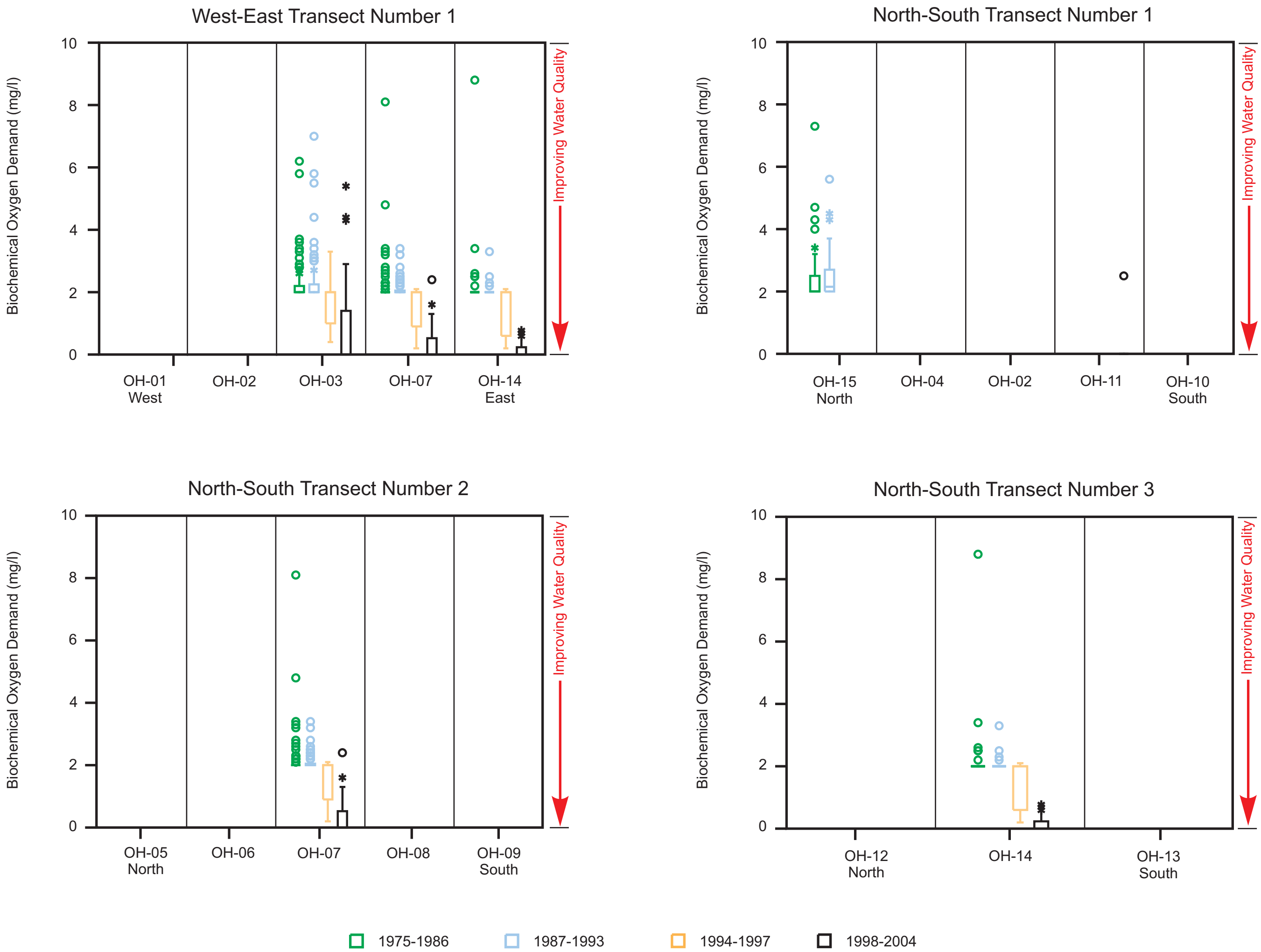
Chloride

The mean chloride concentration in the Milwaukee Harbor estuary for the period of record was 61.7 mg/l. All sites show wide variations between minimum and maximum values. Individual samples of this parameter ranged from 5.6 mg/l to 650.5 mg/l. The mean concentrations of chloride during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 59.3 mg/l, 84.7 mg/l, and 49.6 mg/l, respectively. These differences in mean chloride concentration among the portions of the estuary were generally statistically significant. For example, ANOVA showed that the mean concentration of chloride in the portion of the Menomonee River in the estuary was significantly higher than the mean concentrations of chloride in the Kinnickinnic and Milwaukee River during all periods. During the periods 1975-1986 and 1987-1993, the mean concentration of chloride in the portion of the Kinnickinnic River in the estuary was greater than the mean concentration of chloride in the portion of the Milwaukee River in the estuary. This changed after 1994. During the period 1994-1997, no statistically significant difference was detected between the mean chloride concentrations in the Kinnickinnic River and Milwaukee River portions of the estuary. During the 1998-2001 baseline period, the mean concentration of chloride in the portion of the Milwaukee River in the estuary was higher than the mean concentration of chloride in the portion of the Kinnickinnic River in the estuary. Statistically significant trends toward increasing chloride concentration were detected at all stations in the estuary (see Tables C-1 through C-3 in Appendix C). The fact that the mean concentration of chloride in the Milwaukee River portion of the estuary has gone from being lower than the mean concentration in the Kinnickinnic River portion of the estuary to being higher suggests that the chloride concentrations in the Milwaukee River portion of the estuary are increasing at a faster rate than in the Kinnickinnic River portion of the estuary.

The mean concentration of chloride in the outer harbor during the period of record was 32.5 mg/l. Concentrations of individual samples ranged between 0.3 mg/l to 250.0 mg/l. Figure 288 shows chloride concentrations at sampling stations in and around the outer harbor. Concentrations of chloride were higher at stations in the inner harbor than at stations outside the breakwall. The highest concentrations of chloride were detected at stations OH-

Figure 287

BIOCHEMICAL OXYGEN DEMAND AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004



NOTES: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

No data were available for Stations OH-01, OH-02, OH-04, OH-05, OH-06, OH-08, OH-09, OH-10, OH-12, and OH-13.

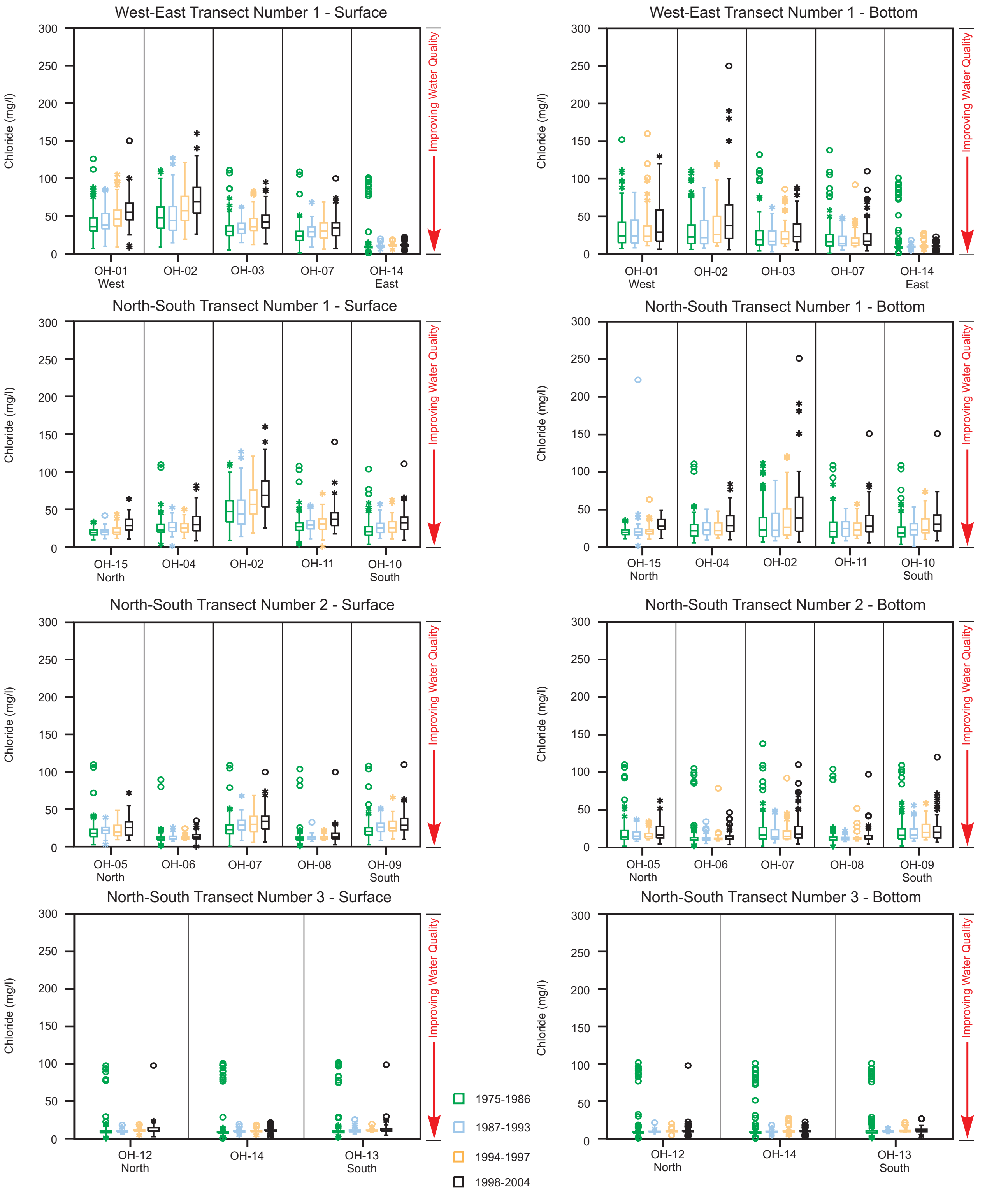
Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

02, near the outfall from the Jones Island Wastewater Treatment Plant (WWTP), and OH-01, near the mouth of the Milwaukee River.[14] Chloride concentrations were lower at other stations in the outer harbor. This suggests that inputs from the River and effluent from the Jones Island WWTP are major sources of chloride to the outer harbor. The higher concentrations of chloride at stations located at gaps in the breakwall (OH-05, OH-07, and OH-09) than at the other two stations along the breakwall indicate that chloride is being exported from the harbor into the nearshore areas of the Lake. The relatively low chloride concentrations at the three stations outside the

[14]*The mouth of the Milwaukee River is located at Lake Michigan, downstream of the confluence of the Milwaukee River with the Kinnickinnic and Menomonee Rivers. Thus, the combined effects of all three rivers are reflected at the mouth of the Milwaukee.*

Figure 288

CHLORIDE CONCENTRATIONS AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004



NOTES: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

The acute toxicity criterion for fish and aquatic life is 757 mg/l, and the chronic toxicity criterion for fish and aquatic life is 395 mg/l.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

harbor suggest that the exported chloride is dispersing into the Lake. At all stations, chloride concentrations have increased over time (see Figure 288). This is especially apparent in surface samples. Table C-6 in Appendix C shows that statistically significant trends toward increasing chloride concentration were detected at all sampling stations within, and adjacent to, the outer harbor.

Observed chloride concentrations in the Milwaukee Harbor estuary did not approach the planning standard of 1,000 milligrams per liter (mg/l) that was adopted under the original regional water quality management plan. Observed concentrations sometimes exceeded the 250 mg/l secondary drinking water standard in the Kinnickinnic and Menomonee River portions of the estuary, but only one measurement in the Milwaukee River portion exceeded that standard.[15] Observed concentrations in the Kinnickinnic and Menomonee River portions of the estuary rarely exceeded the chronic toxicity criterion of 395 mg/l and never exceeded the acute toxicity criterion of 757 mg/l as set forth in Chapter NR 105, "Surface Water Quality Criteria and Secondary Values for Toxic Substances," of the *Wisconsin Administrative Code*. Observed concentrations in the Milwaukee River portion of the estuary only exceeded the chronic toxicity criterion on one occasion and never exceeded the acute toxicity criterion.

Observed chloride concentrations in the outer harbor and nearshore Lake Michigan areas did not approach the planning standard adopted under the original regional water quality management plan or the State chronic and acute toxicity criteria. Observed concentrations in those areas very rarely approached the secondary drinking water standard.

Chloride concentrations in the estuary and outer harbor show strong positive correlations with alkalinity, hardness, and specific conductance, all parameters which, like chloride, measure amounts of dissolved material in water. In addition, chloride concentrations in the estuary are negatively correlated with temperature, reflecting the use of deicing salts on streets and highways during the winter. The increase in chloride concentrations in the estuary and outer harbor represents a decline in water quality.

Dissolved Oxygen

Over the period of record, the mean concentration of dissolved oxygen in the Milwaukee Harbor estuary was 7.2 mg/l. The data ranged from concentrations that were undetectable to concentrations in excess of saturation. The mean concentrations of dissolved oxygen during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 6.2 mg/l, 5.8 mg/l, and 8.6 mg/l, respectively. During most periods, mean concentrations of dissolved oxygen in the Milwaukee River portion of the estuary were significantly higher than mean concentrations in the Kinnickinnic River and Menomonee River portions of the estuary. No statistically significant differences were found between mean concentrations of dissolved oxygen in the Kinnickinnic River and Menomonee River portions of the estuary. Few statistically significant time-based trends were found in dissolved oxygen concentration in the estuary (see Tables C-1 through C-3 in Appendix C). When examined on an annual basis, trends toward increasing concentration for dissolved oxygen were detected at four stations in the estuary. In addition, when the data were examined on a seasonal basis, statistically significant increasing trends in dissolved oxygen concentration during the summer were detected at several stations in the estuary. Comparison of these trends toward increasing dissolved oxygen concentrations at some stations in the estuary to trends toward decreasing BOD and decreasing ammonia suggests that a decrease in loadings of organic pollutants may be responsible for the increase in dissolved oxygen concentration at these sites during the summer. This is a likely consequence of a reduction in loadings from combined sewer overflows since the MMSD Inline Storage System went on line.

The mean concentration of dissolved oxygen during the period of record in the outer harbor was 9.3 mg/l. The data ranged from concentrations that were undetectable to concentrations in excess of saturation. Figure 289

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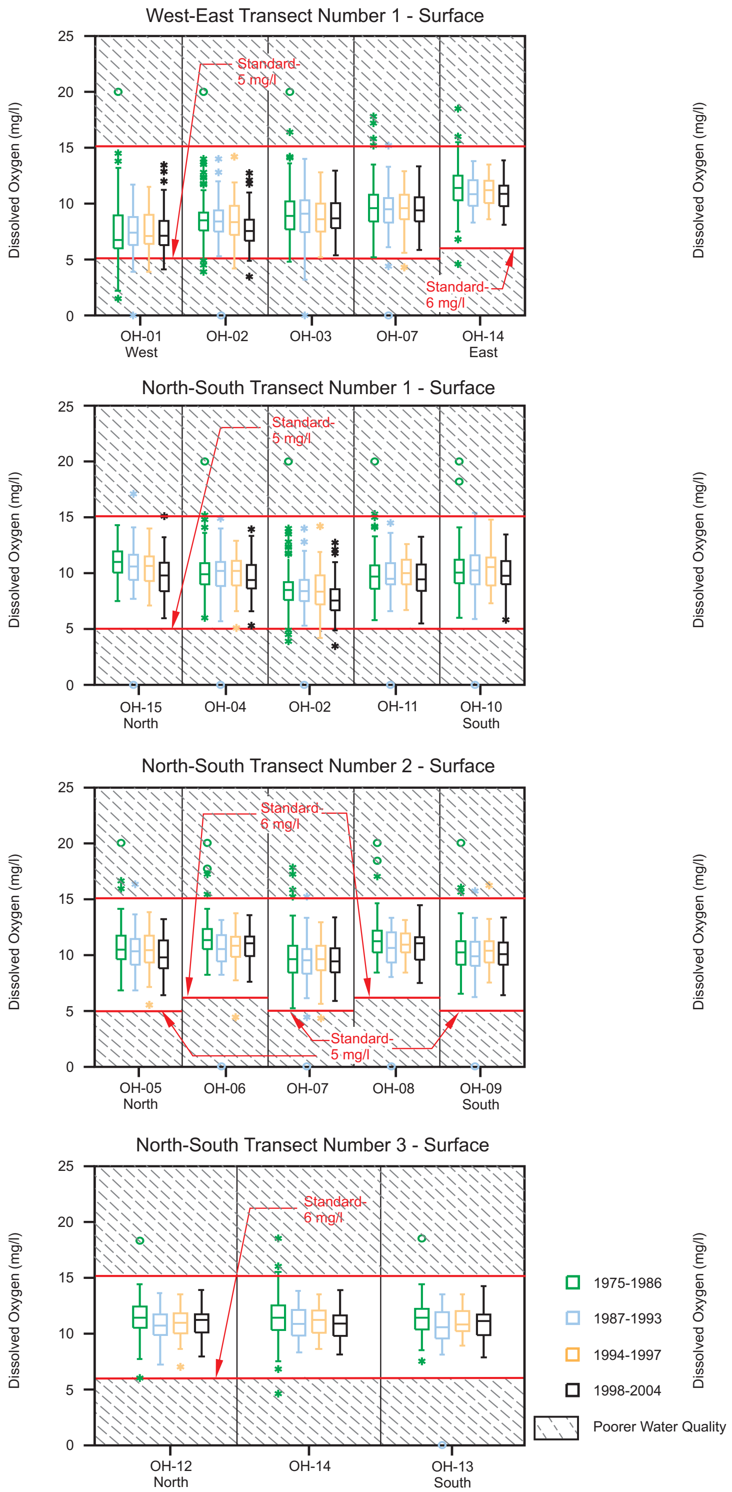
[15]*Section 809.60 of Chapter NR 809, "Safe Drinking Water," of the* Wisconsin Administrative Code, *establishes a secondary standard for chloride of 250 mg/l and notes that, while that concentration is not considered hazardous to health, it may be objectionable to an appreciable number of persons.*

Figure 289

DISSOLVED OXYGEN CONCENTRATIONS AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004



NOTES: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

shows dissolved oxygen concentrations at sampling stations along transects through, and adjacent to, the outer harbor. The lowest concentrations of dissolved oxygen in the outer harbor occurred at station OH-01, near the mouth of the Milwaukee River, and station OH-02, near the outfall from the Jones Island WWTP. Concentrations of dissolved oxygen at other locations in the outer harbor tended to be higher than at these two sampling stations. Concentrations of dissolved oxygen tend to be lower at stations in the outer harbor than at stations outside the breakwall. Figure 289 also shows changes over time in dissolved oxygen concentrations. The range of dissolved oxygen concentrations decreased at most stations after 1986, reflecting the fact that after 1986 MMSD discontinued sampling during the winter when increased dissolved oxygen concentrations would occur due to the higher solubility of oxygen in colder water. Thus, this decrease reflects changes in the sampling protocol, not changes in the range of dissolved oxygen concentrations in the River. Dissolved oxygen concentrations decreased at several stations in the outer harbor between the periods 1994-1997 and 1998-2004. Statistically significant trends toward decreasing dissolved oxygen concentration were detected at some sampling stations in and adjacent to the outer harbor (see Table C-6 in Appendix C). These generally accounted for a small portion of the variation in the data. For the sampling stations in the outer harbor, Figure 289 also compares dissolved oxygen concentrations to the warm water criterion for fish and aquatic life of 5 mg/l. Because Wisconsin has not established a numerical dissolved oxygen criterion for Lake Michigan, the figure compares concentrations at stations in the nearshore area of the Lake to the inland coldwater criterion of 6.0 mg/l.

Figure 290 compares monthly baseline period concentrations of dissolved oxygen to historical concentrations at four stations along a west-to-east transect through the outer harbor. For the most part, baseline monthly mean concentrations of dissolved oxygen are within historical ranges. At stations OH-02 within the outer harbor and station OH-14 outside the breakwall, base period monthly means are generally lower than historical means. The data show strong seasonal patterns to the mean concentrations of dissolved oxygen. The mean concentration of dissolved oxygen is highest during the winter. It declines through spring to reach a minimum during the summer. It then rises through the fall to reach maximum values in winter. This seasonal pattern is driven by changes in water temperature. In addition, the metabolic demands and oxygen requirements of most aquatic organisms, including bacteria, tend to increase with increasing temperature.

Several factors can affect dissolved oxygen concentrations in the estuary and outer harbor.

- First, decomposition of organic matter contained in sediment, through chemical and especially biological processes, removes oxygen from the overlying water, lowering the dissolved oxygen concentration. Portions of the estuary and outer harbor act as settling basins in which material suspended in water sink and fall out into the sediment. This supplies organic material to the sediment in these sections of the estuary and outer harbor. Table 190 shows estimates of sediment oxygen demand at six sites in the estuary and outer harbor from a recent study.[16] In the estuary, sediment oxygen demand ranged from 740 milligrams oxygen per square meter per day (mg per m^2 per day) in the Milwaukee River at Wells Street to 1,410 mg per m^2 per day in the Kinnickinnic River at the Jones Island Ferry. In the outer harbor, sediment oxygen demand ranged from 940 mg per m^2 per day at station OH-04 to 1,010 mg per m^2 per day at station OH-11.

- Second, influxes of water from Lake Michigan and from the Rivers that flow into the estuary may influence dissolved oxygen concentrations in the estuary and outer harbor. When dissolved oxygen concentrations in these waterbodies are higher than in the estuary, mixing may act to increase dissolved oxygen concentrations in the lower estuary. Similarly, when dissolved oxygen concentrations in these waterbodies are lower than in the estuary, mixing may act to decrease dissolved oxygen concentrations in the lower estuary.

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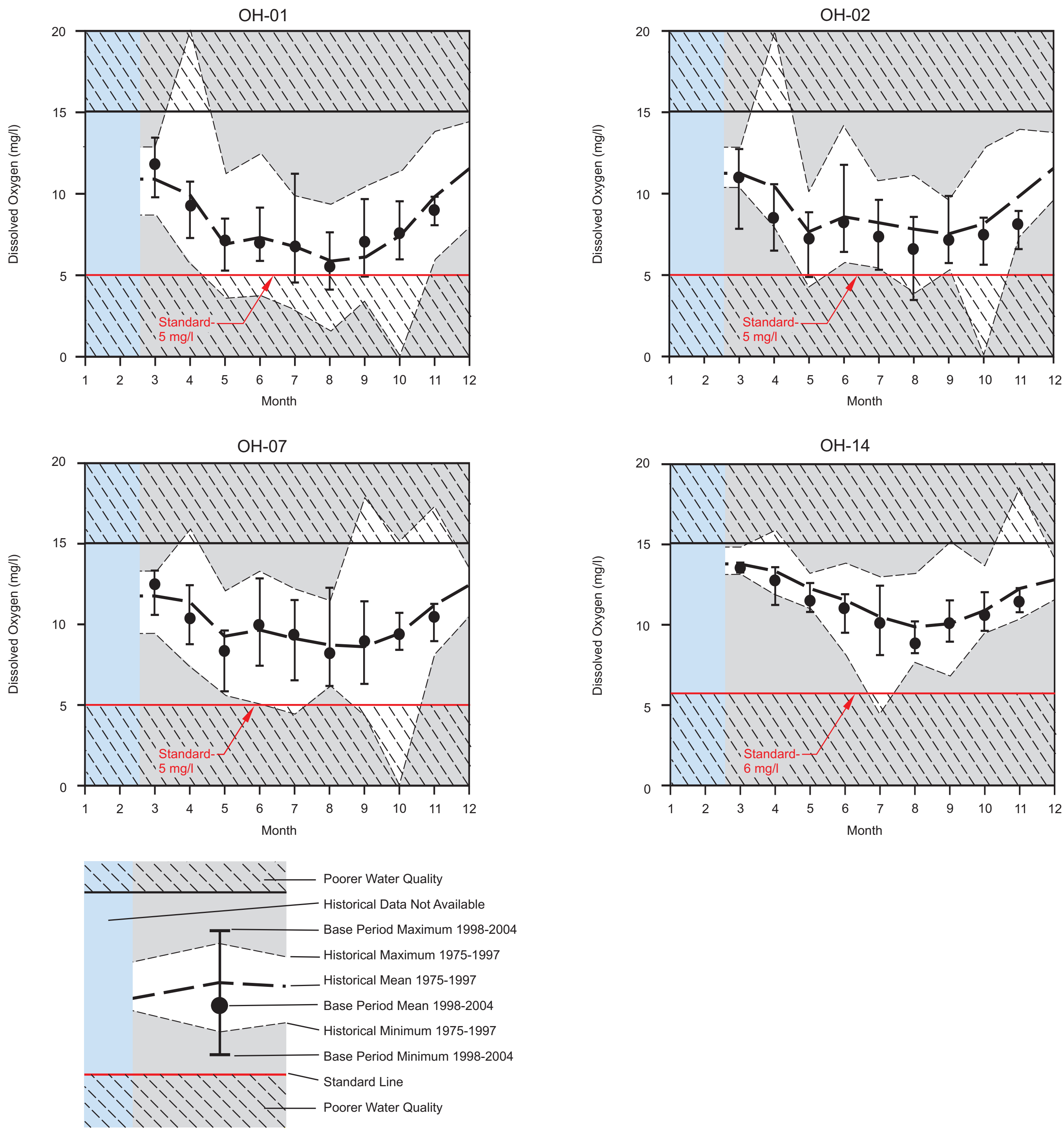
[16]*J. Val Klump, Patrick D. Anderson, Donald C. Szmania, and Kim Weckerly, Milwaukee Harbor Sediment Oxygen Demand Study Final Report,* Great Lakes WATER Institute Technical Report No. 2004-B1*, December 2004.*

Figure 290

HISTORICAL AND BASE PERIOD DISSOLVED OXYGEN CONCENTRATIONS AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004



NOTES: See Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Table 190

ESTIMATED SEDIMENT OXYGEN DEMAND AT SITES IN THE MILWAUKEE HARBOR ESTUARY AND OUTER HARBOR: 2004

Site	Mean Sediment Oxygen Demand (mg oxygen per square meter per day)	Number of Samples
Kinnickinnic River at Jones Island Ferry	1,310	9
Kinnickinnic River at S. 1st Street	1,410	4
Menomonee River at Muskego Avenue	1,000	6
Milwaukee River at Wells Street	740	6
Outer Harbor at Station OH-04	940	9
Outer Harbor at Station OH-11	1,010	9

Source: University of Wisconsin-Milwaukee Great Lakes WATER Institute and SEWRPC.

- Third, dissolved oxygen concentrations at some stations in the estuary and outer harbor are positively correlated with pH. This reflects the effect of photosynthesis on both of these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the pH of the water. At the same time, oxygen is released as a byproduct of the photosynthetic reactions.

- Fourth, dissolved oxygen concentrations in water can be affected by numerous other factors including the presence of aquatic plants, sunlight, and the amount of and type of sediment as summarized in the Water Quality Indicators section in Chapter II of this report.

The increases in dissolved oxygen concentrations at some stations in the estuary represent an improvement in water quality. The decreases in dissolved oxygen at some stations in the outer harbor represent a decline in water quality.

Hardness

Over the period of record, the mean hardness in the Milwaukee Harbor estuary was 254.7 mg/l as $CaCO_3$. The data show moderate variability, ranging from 18.6 to 750.1 mg/l as $CaCO_3$. The mean values of hardness during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 214.3 mg/l as $CaCO_3$, 269.4 mg/l as $CaCO_3$, and 269.7 mg/l as $CaCO_3$, respectively. On a commonly used scale, these means are considered to represent very hard water.[17] The range of the data runs from 18.6 to 750.1 mg/l as $CaCO_3$, showing considerable variability. Some of this variability probably results from inputs of relatively soft water during storm events. During most periods, mean hardness in the Kinnickinnic River portion of the estuary was significantly lower than mean hardness in the Menomonee River and Milwaukee River portions of the estuary. In most periods, no statistically significant difference was found between mean hardness in the Menomonee River portion of the estuary and the Milwaukee River portion of the estuary. Few time-based trends were detected in hardness in the estuary. Statistically significant trends toward increasing hardness were detected at some stations in the Milwaukee River portion of the estuary. These accounted for only a small portion of the variation in the data.

Mean hardness in the outer harbor during the period of record ranged from 176.7 mg/l as $CaCO_3$ to 354 mg/l as $CaCO_3$. The data show moderate variability, ranging from 1.7 to 617.3 mg/l as $CaCO_3$. Few statistically significant time-based trends were detected at sampling stations in or adjacent to the outer harbor (see Table C-6 in Appendix C). When examined on a seasonal basis, trends toward decreasing hardness were detected at two stations in the outer harbor and five stations adjacent to the outer harbor; however, these do not appear to represent a strong pattern of decreasing concentration.

Hardness concentrations in the Milwaukee Harbor estuary show strong positive correlations with alkalinity, chloride, pH, and specific conductance, all parameters which, like hardness, measure amounts of dissolved material in water.

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[17] *E. Brown, M.W. Skougstad, and M.J. Fishman,* Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, *U.S. Department of Interior, U.S. Geological Survey, 1970.*

pH

The mean pH in the Milwaukee Harbor estuary over the period of record was 7.9 standard units. The mean values of pH during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 7.6 standard units, 7.8 standard units, and 8.1 standard units, respectively. These differences in pH may reflect differences among the three rivers in the relative contributions of groundwater and surface runoff to flow. During all periods, mean pH in the Milwaukee River portions of the estuary was significantly higher than mean pH in the Kinnickinnic River and Menomonee River portions of the estuary. Similarly, during all periods mean pH in the Menomonee River portion of the estuary was higher than mean pH in the Kinnickinnic River portion of the estuary. Significant trends toward decreasing pH were detected at several stations in the estuary, mostly, but not entirely, in upstream sections (see Tables C-1 through C-3 in Appendix C). Mean pH at stations in the outer harbor during the period of record was 7.8. Significant trends toward increasing pH were detected at several stations in the outer harbor (see Table C-6 in Appendix C). At most of these stations these trends accounted for a small portion of the variation in the data. Positive correlations are seen between pH and alkalinity, hardness, and specific conductance at some stations in the estuary, but they are neither as common nor as strong as the correlations detected among alkalinity, hardness, and specific conductance. At some stations, dissolved oxygen concentrations and chlorophyll-*a* concentrations are positively correlated with pH. These correlations reflect the effect of photosynthesis on these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the pH of the water. At the same time, oxygen is released as a byproduct of the photosynthetic reactions. This often results in increased algal growth, which is reflected in higher chlorophyll-*a* concentrations.

Secchi Depth

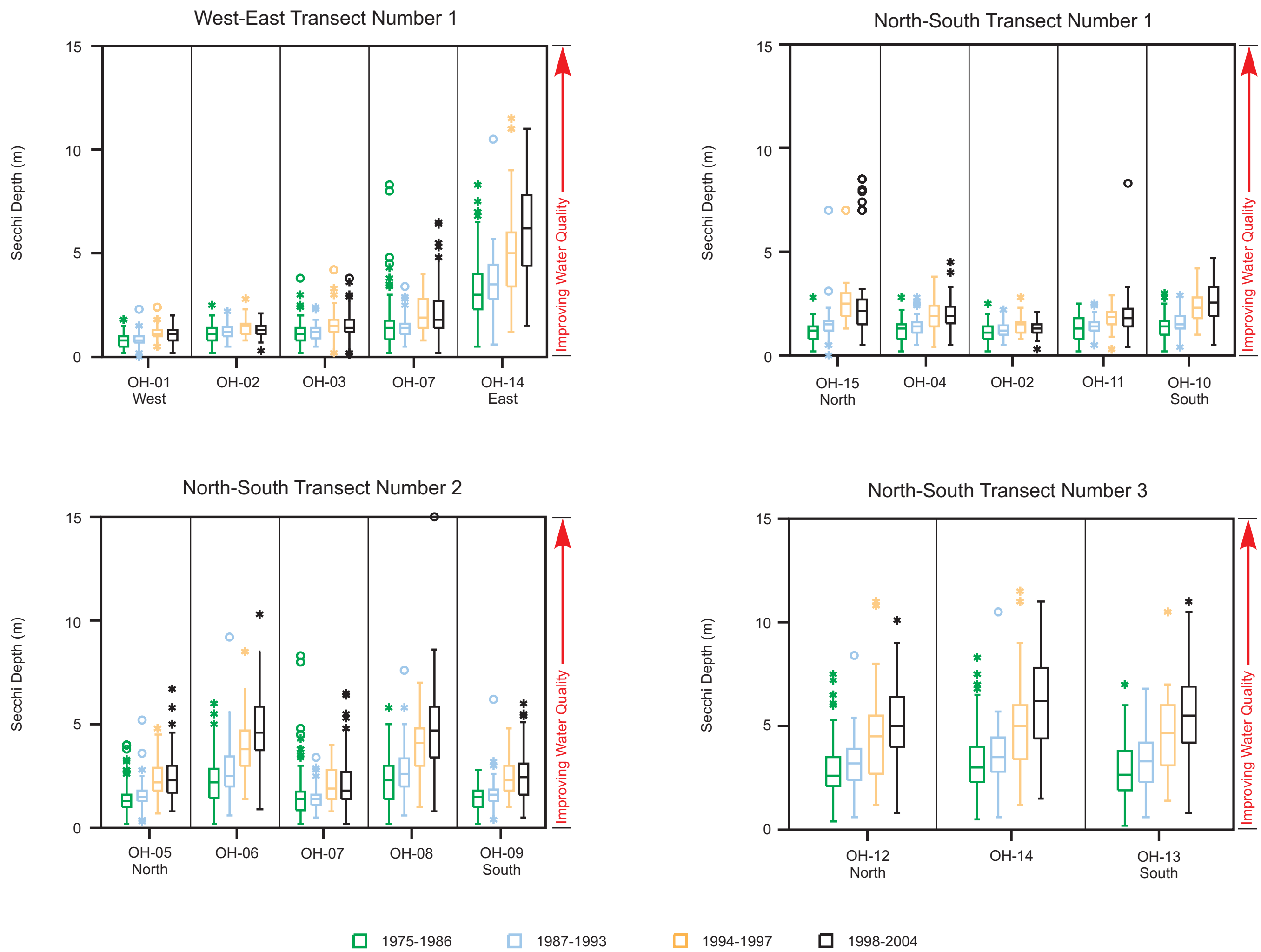
No secchi depth data were available for the estuary. The mean secchi depth in the outer harbor over the period of record was 1.46 meters (m). Secchi depth in the outer harbor ranged from just below the water surface to 8.50 m. Figure 291 shows secchi depths at stations along transects through and adjacent to the outer harbor. Two patterns are apparent in these data. First, in the outer harbor, secchi depth was lowest at station OH-01 near the mouth of the Milwaukee River and station OH-02 near the outfall from the Jones Island WWTP and tended to be higher at other stations. In part, this reflects the effects of water motions and the settling of suspended material. Second, secchi depths, both within the harbor and at sampling stations along transects adjacent to the outer harbor, have increased since 1975. There is one exception to this generalization. At stations within the harbor, secchi depths during the period 1998-2004 were slightly lower than during the period 1994-1997. Despite this exception, statistically significant trends toward increasing secchi depth over time were detected at all sampling stations in and adjacent to the outer harbor (see Table C-6 in Appendix C). Figure 292 shows a monthly comparison of the historical and baseline secchi depths at four sampling stations along a west-to-east transect through the outer harbor. At stations OH-01 and OH-02, monthly mean secchi depths during the baseline period were near historical means. At station OH-07, near the main gap in the breakwall, monthly mean secchi depths during the baseline period were near historical means during the spring and early summer. During the late summer and fall, monthly mean secchi depths during the baseline period were above historical means. At station OH-14, outside of the outer harbor, monthly mean secchi depths during the baseline period were above historical means in all months; however, the greatest increase in monthly mean secchi depths occurred during the late summer and fall. Several factors may be responsible for the increase in secchi depth. Chlorophyll-*a* concentrations have generally decreased in the outer harbor and adjacent areas of Lake Michigan. Much of this decrease appears to be the result of filtering activities of zebra mussels and quagga mussels which removes phytoplankton from the water column. In addition, reduced nutrient loads to the outer harbor, resulting from both reductions of combined sewer overflows since the Inline Storage System came online and nonpoint source pollution control efforts, may account for the decrease in chlorophyll-*a* concentrations in the outer harbor. Secchi depths in the outer harbor were negatively correlated with concentrations of chlorophyll-*a*, total nitrogen, and total phosphorus, suggesting that the increases in secchi depth are being driven, at least in part, by smaller standing crops of phytoplankton. In addition, secchi depths in the outer harbor were negatively correlated with ammonia and fecal coliform bacteria.

Specific Conductance

The mean value for specific conductance in the Milwaukee Harbor estuary over the period of record was 625 microSiemens per centimeter (μS/cm). Considerable variability was associated with this mean. Specific

Figure 291

SECCHI DEPTH IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004



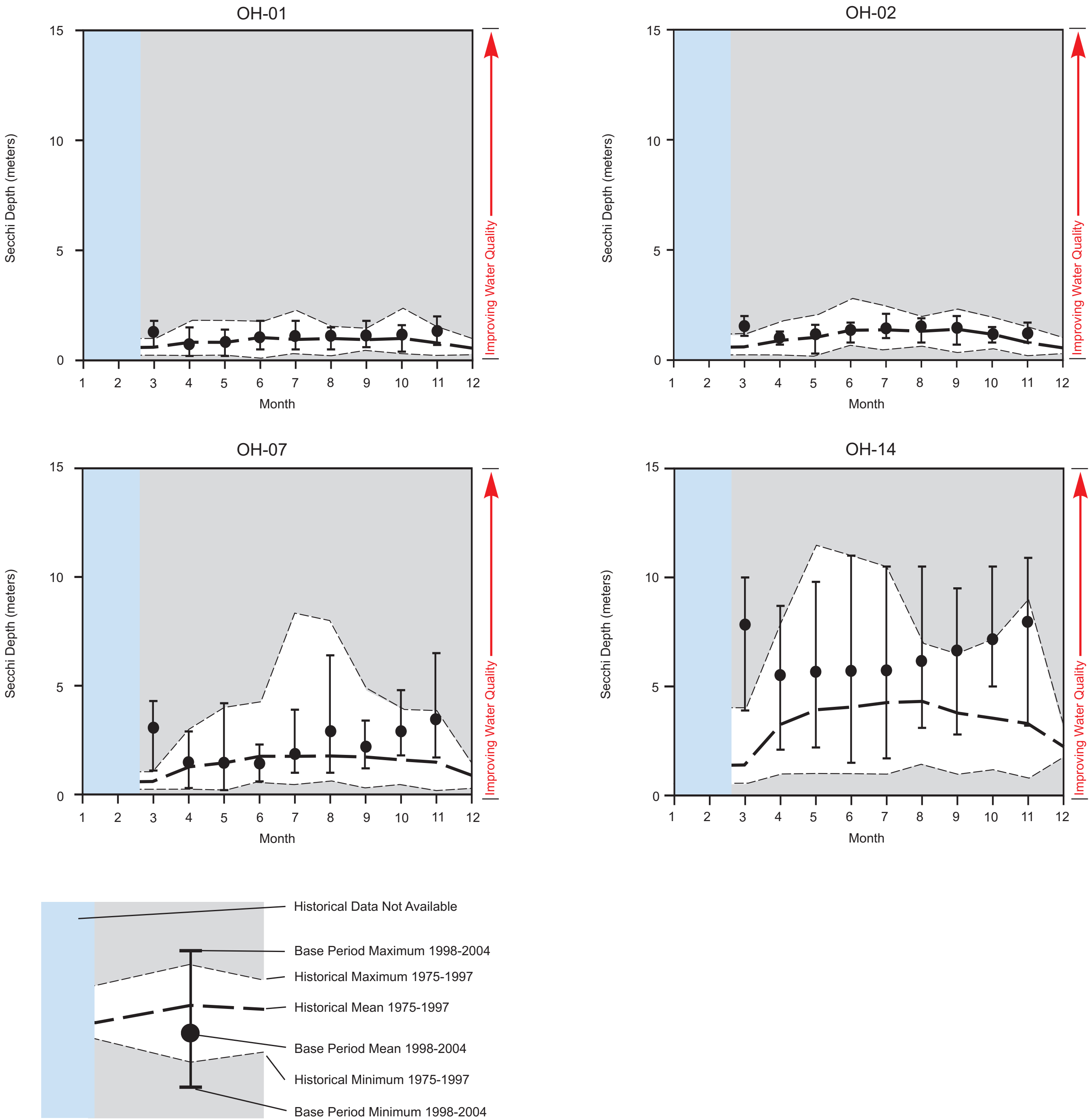
NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

conductance in the estuary ranged from below the limit of detection to 2,350 μS/cm. Some of this variability may reflect the discontinuous nature of inputs of dissolved material into the rivers that flow into the estuary. Runoff associated with storm events can have a major influence on the concentration of dissolved material in a river. The first runoff from a storm event transports a large pulse of salts and other dissolved material from the watershed into the rivers. This will tend to raise specific conductance in the rivers. Later runoff associated with the event will be relatively dilute. This will tend to lower specific conductance. The mean values of specific conductance during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 559 μS/cm, 725 μS/cm, and 603 μS/cm, respectively. Analysis of variance shows that during all periods mean specific conductance in the Menomonee River portion of the estuary was significantly higher than mean conductance in the Kinnickinnic River and Milwaukee River portions of the estuary. The relationship between the values of mean specific conductance in the Kinnickinnic River and Milwaukee River portions of the estuary is more complex. During the period 1975-1986, mean specific conductance in the Milwaukee River portion of the estuary was significantly higher than mean specific conductance in the Kinnickinnic River portion of the estuary. This relationship changed following 1986. During the periods 1987-1993 and 1994-1997 no

Figure 292

HISTORICAL AND BASE PERIOD SECCHI DEPTH AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004



NOTE: See Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

statistically significant differences were detected between the mean values of specific conductance in these two sections of the estuary. The relationship changed again following 1997. During the period 1998-2002, mean specific conductance in the Milwaukee River portion of the estuary was significantly higher than mean specific conductance in the Kinnickinnic River portion of the estuary. There were also differences in the amount of variability in specific conductance among sections of the estuary. Specific conductance tended to be most variable in the Kinnickinnic River portion of the estuary. The coefficient of variation (CV), a measure of variability, for this section of the estuary was 0.41. By contrast, specific conductance in the Menomonee River and Milwaukee River portions of the estuary was less variable; the CVs for these sections of the estuary were 0.34 and 0.25, respectively. These differences in variability are most likely related to the differences in the areas of the watersheds drained by the rivers flowing into the estuary, differences among the watersheds in relative amounts of urban land uses, and the differences in discharge among these rivers. Statistically significant trends toward specific conductance increasing over time were detected at most sampling stations within the estuary (see Tables C-1 through C-3 in Appendix C). At several of these stations, however, these trends account for only a small portion of the variation in the data.

The mean value for specific conductance in the outer harbor over the period of record was 413 μS/cm. Considerable variability was associated with this mean. Specific conductance in the estuary ranged between 170 μS/cm and 2,350 μS/cm. This variability is most likely influenced by the same factors influencing the variability in specific conductance in the estuary. An additional source of variability in specific conductance in the outer harbor is the influx of water into the outer harbor from Lake Michigan. The mean value of specific conductance at sampling stations adjacent to the harbor over the period of record was 316 μS/cm. Statistically significant trends toward specific conductance decreasing over time were detected at most sampling stations in the outer harbor. These trends correspond to similar decreasing trends in specific conductance at stations adjacent to the outer harbor and at stations in the nearshore Lake Michigan area (see the section on Water Quality of the Nearshore Lake Michigan Areas below) and indicate that water quality in the outer harbor is influenced by water quality in Lake Michigan.

The data show a seasonal pattern of variation in specific conductance both in the estuary and in the outer harbor. For those years in which data were available, specific conductance was highest during the winter. It then declined during the spring to reach lower levels in the summer and early fall. The pattern also appears to be present at sampling stations adjacent to the outer harbor, though the magnitude of the seasonal differences observed at these sites is much smaller.

Specific conductance in the Milwaukee Harbor estuary show strong positive correlations with alkalinity, chloride, hardness, and pH, all parameters which, like specific conductance, measure amounts of dissolved material in water. At most stations, specific conductance also shows negative correlations with water temperature, reflecting the fact that specific conductance in the estuary tends to be lower during the summer. Specific conductance in the outer harbor shows positive correlations with alkalinity and chloride. Specific conductance in the outer harbor shows negative correlations with water temperature and secchi depth. The latter correlation indicates that high values of specific conductance occur during periods of high turbidity and suggests that dissolved material enters the harbor at the same times and by similar mechanisms as suspended materials. These increases in specific conductance in the estuary indicate that the concentrations of dissolved materials in water in the estuary are increasing and represent a decline in water quality. The decreases in specific conductance in the outer harbor indicate that concentrations of dissolved materials in water in the outer harbor are decreasing and represent an improvement in water quality.

Suspended Material

The mean value for total suspended solids (TSS) concentration in the Milwaukee Harbor estuary over the period of record was 22.1 mg/l. Considerable variability was associated with this mean, with values ranging from 1.0 to 892 mg/l. The mean concentrations of TSS during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 18.6 mg/l, 19.8 mg/l, and 25.7 mg/l, respectively. During all periods, the mean concentrations of TSS in the Milwaukee River portion of the estuary were significantly higher than the mean concentrations in the Kinnickinnic River and Menomonee River portions of the estuary. When analyzed on an annual basis, most sampling stations in the Menomonee River and Milwaukee River portions of the estuary showed trends toward increasing TSS concentration over time. By contrast, most sampling stations in the Kinnickinnic River portion of the estuary showed trends toward decreasing TSS concentration (see Tables C-1 through C-3 in Appendix C). In all three portions of the estuary, these trends accounted for a small portion of the variation in the data. Mean concentrations of TSS tended to be lower at estuary stations than at stations upstream from the estuary. This reflects the fact that portions of the estuary act as a settling basing in which material suspended in water sink and fall out into the sediment. TSS concentrations in the estuary showed strong positive correlations with total phosphorus concentrations, reflecting the fact that total phosphorus concentrations include a large particulate fraction. TSS concentrations were also positively correlated with concentrations of fecal coliform bacteria and nutrients. The trends toward increasing TSS concentrations in the Menomonee River and Milwaukee River portions of the estuary represent declines in water quality.

The mean concentration of TSS in the outer harbor over the period of record was 8.0 mg/l. Considerable variability was associated with this mean, with values ranging from below the limit of detection to 280 mg/l. Concentrations of TSS in the outer harbor were generally lower than concentrations of TSS in the estuary. Figure 293 shows concentrations of TSS at sampling stations along transects through and adjacent to the outer harbor (see Map 117). Concentrations of TSS were highest at stations OH-01, near the mouth of the Milwaukee River, and OH-02, near the outfall from the Jones Island WWTP. Along west-east transect number 1, concentrations of TSS decreased from west to east through the outer harbor and into the Lake. Similarly, during most periods, TSS concentrations along north-south transect number 1 decreased with distance away from stations OH-02. These decreases probably reflect both the effects of dilution as TSS carried by water flowing in from the estuary mixes with water in the outer harbor and the effects of settling of suspended material. Concentrations of TSS in the outer harbor were higher than concentrations of TSS outside the breakwall. The relatively high concentrations of TSS observed along north-south transect number 2 at sampling stations located at gaps in the breakwall, stations OH-05, OH-07, and OH-09, suggest that some TSS is exported from the outer harbor into Lake Michigan (see Figure 293). Concentrations of TSS appear to have decreased since the period 1975-1986 at most sampling stations in the outer harbor. When examined on an annual basis, statistically significant trends toward TSS decreasing over time were detected at several stations in the outer harbor (see Table C-6 in Appendix C). Concentrations of TSS in the outer harbor showed strong positive correlations with total phosphorus concentrations, reflecting the fact that total phosphorus concentrations include a large particulate fraction. TSS concentrations were also positively correlated with concentrations of nutrients. The trends toward decreasing TSS concentrations in the outer harbor represent an improvement in water quality.

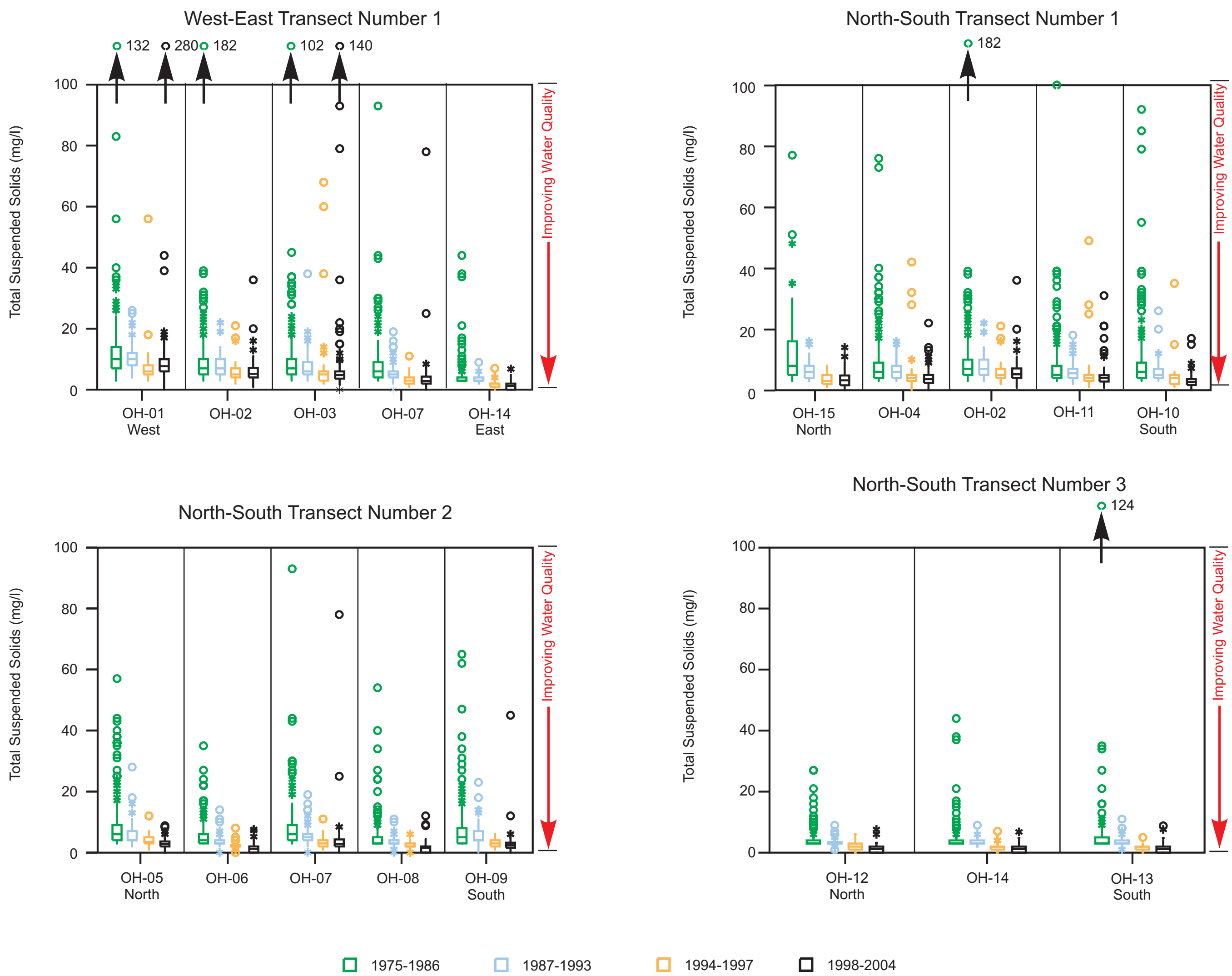
Nutrients

Nitrogen Compounds

The mean concentration of total nitrogen in the Milwaukee Harbor estuary over the period of record was 1.72 milligrams per liter measured as nitrogen (mg/l as N). Concentrations ranged from below the limit of detection to 17.26 mg/l as N. The mean concentrations of total nitrogen during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 1.61 mg/l as N, 1.71 mg/l as N, and 1.78 mg/l as N, respectively. At all stations, concentrations of total nitrogen during the period 1987-1993 were lower than during the period 1975-1986. In subsequent periods, concentrations of total nitrogen increased. By the period 1994-1997, mean concentrations of total nitrogen at several stations had returned to levels similar to the mean concentrations from 1975-1986. During all periods except 1987-1993, statistically significant differences were found among mean total nitrogen concentrations in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary; however, the relationships among total nitrogen concentrations in these sections of the estuary appear to be dynamic and changing over time. During the period 1998-2002, the mean concentration of total nitrogen in the Milwaukee River portion of the estuary was significantly higher than the mean concentration of total nitrogen in the Menomonee River portion of the estuary. During this period, the mean concentrations of total nitrogen in both the Milwaukee River and Menomonee River portions of the estuary were higher than the mean concentration of total nitrogen in the Kinnickinnic River portion of the estuary. When examined on an annual basis, statistically significant trends toward increasing total nitrogen concentrations were

Figure 293

CONCENTRATIONS OF TOTAL SUSPENDED SOLIDS AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

detected at four sampling stations in the estuary (see Tables C-1 through C-3 in Appendix C). These stations were in upstream sections of the estuary. A statistically significant trend toward decreasing total concentration was detected at one station. No statistically significant trends in total nitrogen concentration were detected at the other seven sampling stations. The concentration of total nitrogen in the estuary is positively correlated with the concentrations of nitrate and organic nitrogen, reflecting the fact that these tend to be the major forms of nitrogen compounds in the estuary. In addition, concentrations of total nitrogen were positively correlated with concentrations of total phosphorus at most stations. This probably reflects the nitrogen and phosphorus contained in particulate organic matter in the water, including live material such as plankton and detritus. Finally, total nitrogen concentrations in the estuary are negatively correlated with temperature, reflecting the fact that total nitrogen concentrations tend to be highest during the winter.

The mean concentration of total nitrogen in the outer harbor during the period of record was 1.51 mg/l as N. Concentrations ranged from 0.09 mg/l as N to 13.29 mg/l as N. Figure 294 shows changes in total nitrogen concentrations at sampling stations along transects through and adjacent to the outer harbor. Concentrations of total nitrogen were higher at sampling stations in the outer harbor than at stations outside the breakwall. Within the harbor, the highest concentration of total nitrogen was detected at station OH-02. This sampling station is located near the outfall from the Jones Island WWTP. The high concentrations observed at this station probably reflect the effects of inputs of effluent from the treatment plant. The lower concentrations of total nitrogen detected at other stations in the outer harbor indicate that this effluent is rapidly mixed throughout the outer harbor. With some differences in timing, a similar pattern of change in total nitrogen concentration over time was observed at most sampling stations along transects through and adjacent to the outer harbor. After the period 1975-1986, total nitrogen concentrations decreased through 1993 or 1997, depending on the location. After that, total nitrogen concentrations increased. At most stations, total nitrogen concentrations were lower during the period 1998-2002 than during the period 1975-1986. Statistically significant trends toward decreasing total nitrogen concentrations were detected at two stations in the outer harbor and at a few stations outside the breakwall (see Table C-6 in Appendix C). These trends accounted for a small fraction of the variation in the data. Total nitrogen concentrations in the outer harbor were positively correlated with concentrations of ammonia, nitrate, and organic nitrogen, reflecting the fact that these tend to be the major forms of nitrogen compounds in the outer harbor. In addition, concentrations of total nitrogen were positively correlated with concentrations of total phosphorus at most stations. This probably reflects the nitrogen and phosphorus contained in particulate organic matter in the water, including live material such as plankton and detritus. Finally, total nitrogen concentrations in the estuary are negatively correlated with secchi depth.

Total nitrogen is a composite measure of several different compounds which vary in their availability to algae and aquatic plants and vary in their toxicity to aquatic organisms. Common constituents of total nitrogen include ammonia, nitrate, and nitrite. In addition a large number of nitrogen-containing organic compounds, such as amino acids, nucleic acids, and proteins commonly occur in natural waters. These compounds are usually reported as organic nitrogen.

The mean concentration of ammonia in the Milwaukee Harbor estuary during the period of record was 0.32 mg/l as N. Over the period of record, ammonia concentrations varied from below the limit of detection to 5.01 mg/l as N. The mean concentrations of ammonia during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 0.44 mg/l as N, 0.34 mg/l as N, and 0.24 mg/l as N, respectively. Analysis of variance shows that during all periods mean ammonia concentrations in the Kinnickinnic River and Menomonee River portions of the estuary were significantly higher than mean ammonia concentration in the Milwaukee River portion of the estuary. In addition, mean ammonia concentration in the Kinnickinnic River portion of the estuary was higher than mean ammonia concentration in the Menomonee River portion of the estuary in all periods except the period 1998-2002. During this final period, no statistically significant differences in mean ammonia concentrations were detected between these two sections of the estuary. Statistically significant trends toward decreasing ammonia concentration over time were detected at all stations in the estuary (see Tables C-1 through C-3 in Appendix C). Ammonia concentrations in the estuary were positively correlated with concentrations of fecal coliform bacteria and BOD. This may reflect common sources and modes of transport into the estuary for these pollutants. At some stations, ammonia concentrations were negatively correlated with concentrations of dissolved oxygen and nitrate. These correlations may reflect a tendency toward oxidation of ammonia in aerobic environments.

The mean concentration of ammonia in the outer harbor during the period of record was 0.42 mg/l as N. Individual samples of this parameter ranged from below the limit of detection to 8.90 mg/l as N. Figure 295 shows ammonia concentrations at sampling stations along transects through, and adjacent to, the outer harbor. Concentrations of ammonia were higher at sampling stations in the outer harbor than at stations outside the breakwall. Within the harbor, the highest concentration of ammonia was detected at station OH-02. This sampling station is located near the outfall from the Jones Island WWTP. The high concentrations observed at this station probably reflect the effects of inputs of effluent from the treatment plant. The lower concentrations of ammonia

Figure 294

TOTAL NITROGEN CONCENTRATIONS AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004

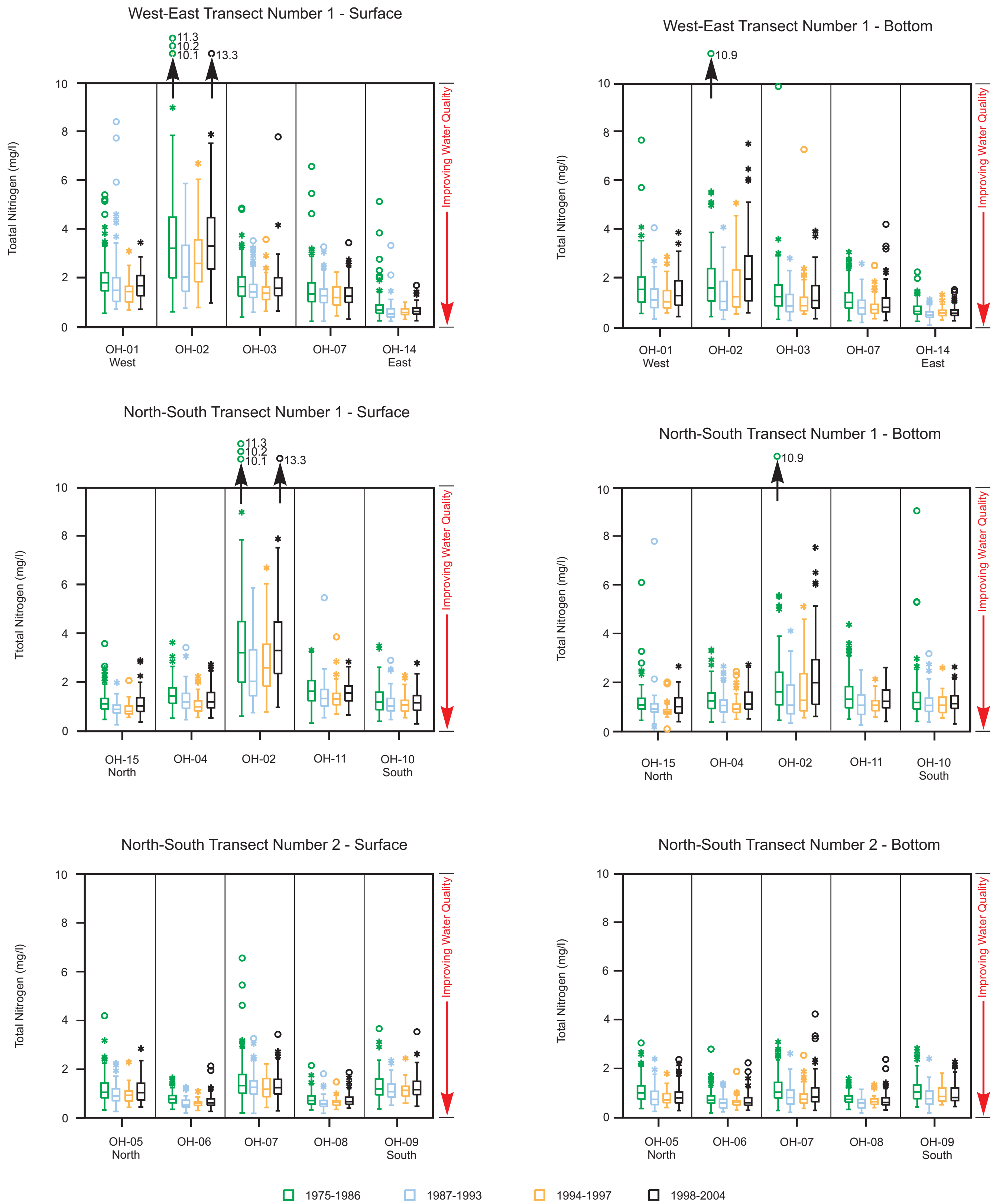
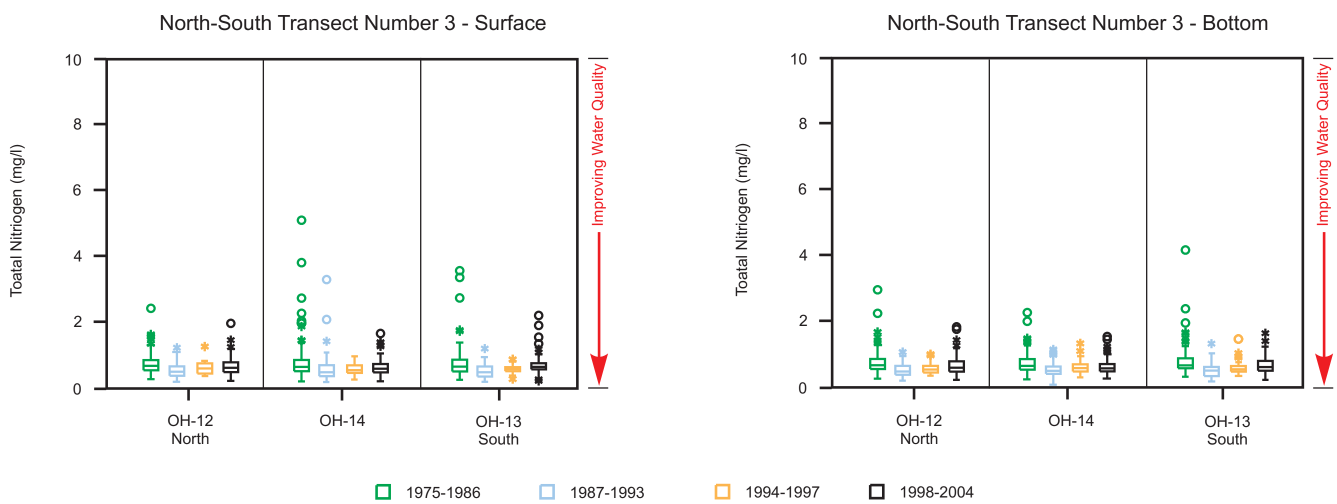


Figure 294 (continued)



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

detected at other stations in the outer harbor indicate that this effluent is rapidly mixed throughout the outer harbor. Ammonia concentrations from samples collected from sampling stations along the breakwall were higher at the sampling stations at the gaps in the wall. This suggests that ammonia was exported from the outer harbor to the Lake. Figure 295 also shows that ammonia concentrations have decreased at all stations in and adjacent to the outer harbor. These decreases represent statistically significant trends (see Table C-6 in Appendix C). Ammonia concentrations in the outer harbor were positively correlated with total nitrogen and negatively correlated with secchi depth.

The mean concentration of nitrate in the Milwaukee Harbor estuary for the period of record was 0.63 mg/l as N. During this time, concentrations in the estuary varied from below the limit of detection to 3.07 mg/l as N. The mean concentrations of nitrate during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 0.57 mg/l as N, 0.62 mg/l as N, and 0.68 mg/l as N, respectively. Analysis of variance showed that the relationships among nitrate concentrations in the three sections of the estuary appear to be dynamic and changing over time. During the period 1975-1986, no statistically significant differences were detected among mean nitrate concentrations in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary. During the periods 1994-1997 and 1998-2002, the mean nitrate concentrations in the Milwaukee River portion of the estuary were higher than the mean nitrate concentrations in the Kinnickinnic River and Menomonee River portions of the estuary. No significant differences were detected between the mean concentrations of nitrate in the Kinnickinnic River and Menomonee River portions of the estuary during these periods. With the exception of one sampling station in the Menomonee River portion of the estuary, statistically significant trends toward increasing nitrate concentrations were detected at all sampling stations (see Tables C-1 through C-3 in Appendix C). Nitrate concentrations in the estuary were negatively correlated with concentrations of chlorophyll-*a*. This correlation reflects the role of nitrate as a nutrient for algal growth. During periods of high algal productivity, algae remove nitrate from water and incorporate it into cellular material.

The mean concentration of nitrate in the outer harbor during the period of record was 0.57 mg/l as N. Concentrations in individual samples ranged from below the limit of detection to 8.57 mg/l as N. It is important to note that, with the exception of some outliers, the ranges of nitrate concentrations at sampling stations in the outer harbor are similar to the ranges of nitrate concentrations at sampling stations in the estuary. Statistically

Figure 295

AMMONIA CONCENTRATIONS AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004

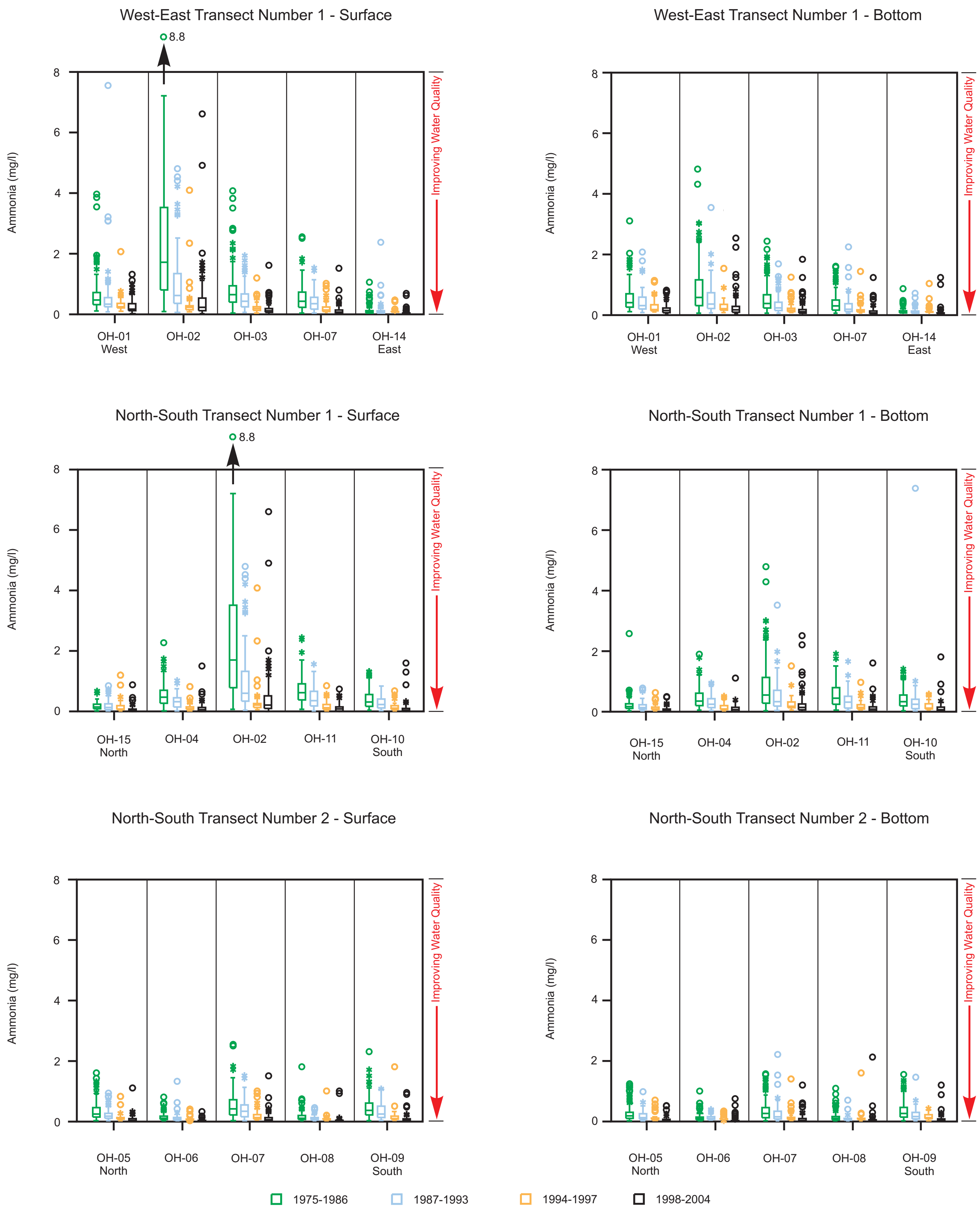
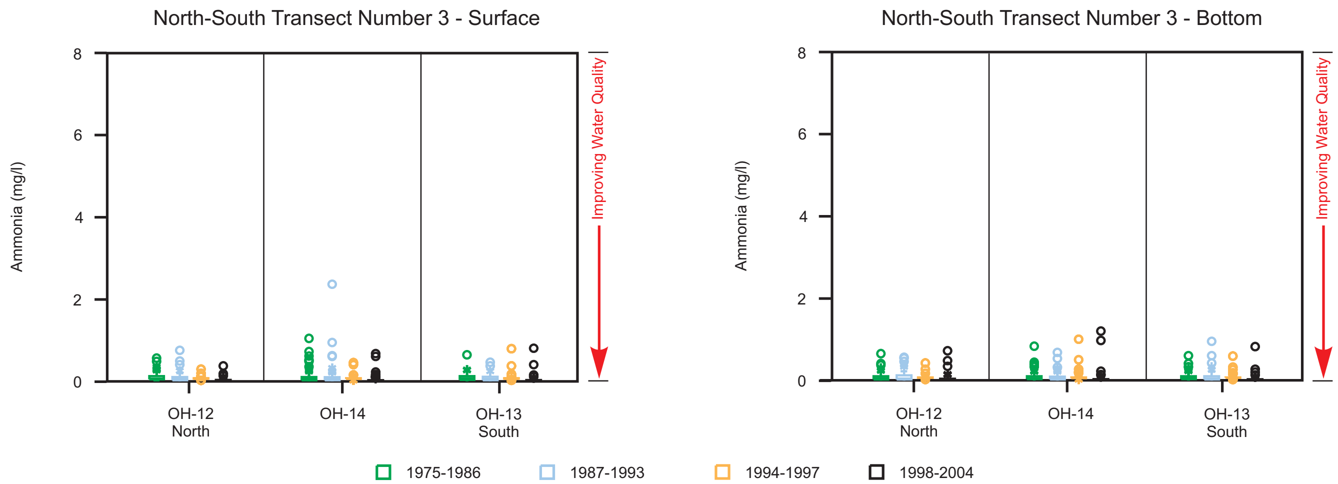


Figure 295 (continued)



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

significant trends toward increasing nitrate concentrations were detected at several stations in the outer harbor, though at some stations the trends accounted for a small portion of the variation in the data. Concentrations of nitrate in the outer harbor were positively correlated with concentrations of total nitrogen and total phosphorus. Concentrations of nitrate were negatively correlated with temperature and chlorophyll-*a*.

The mean concentration of nitrite in the Milwaukee Harbor estuary for the period of record was 0.032 mg/l as N. During this time, concentrations in the estuary varied from below the limit of detection to 4.000 mg/l as N. The mean concentrations of nitrite during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 0.039 mg/l as N, 0.038 mg/l as N, and 0.024 mg/l as N, respectively. Analysis of variance detected no statistically significant differences between mean nitrite concentrations in the Kinnickinnic River and Menomonee River portions of the estuary during any period. During all periods, however, mean nitrite concentration in the Kinnickinnic River and Menomonee River portions of the estuary were significantly higher than mean nitrite concentration in the Milwaukee River portion of the estuary. Few time-based trends were detected in nitrite concentration in the estuary (see Tables C-1 through C-3 in Appendix C). Some significant trends were detected when the data were analyzed on a seasonal basis, but the directions of the trends varied by station and season. None of these trends accounted for more than a small portion of the variation in the data. Nitrite concentrations at some sampling stations in the estuary were negatively correlated with dissolved oxygen concentration. This reflects the tendency for nitrite to be oxidized in aerobic waters.

The mean concentration of nitrite in the outer harbor during the period of record was 0.034 mg/l as N. Concentrations in individual samples ranged from below the limit of detection to 1.100 mg/l as N. At most stations in the outer harbor, statistically significant trends were detected toward nitrite concentrations decreasing over time (see Table C-6 in Appendix C). These trends account for a small portion of the variation in the data. By contrast, statistically significant trends were detected toward nitrite concentrations increasing over time were detected at some stations outside the outer harbor. These trends also account for a small portion of the variation in the data. Nitrite concentrations at most sampling stations in the outer harbor were negatively correlated with dissolved oxygen concentration.

During the period of record the mean concentration of organic nitrogen in the Milwaukee Harbor estuary was 0.75 mg/l as N. This parameter showed considerable variability with concentrations ranging from undetectable to 16.04 mg/l as N. The mean concentrations of organic nitrogen during the period of record in the portions of the

Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 0.58 mg/l as N, 0.74 mg/l as N, and 0.86 mg/l as N, respectively. During most periods, the mean concentration of organic nitrogen in the Milwaukee River portion of the estuary was greater than the mean concentrations of organic nitrogen in the Kinnickinnic River and Menomonee River portions of the estuary. In addition, the mean concentration of organic nitrogen in the Menomonee River portion of the estuary was greater than the mean concentration of organic nitrogen in the Kinnickinnic River portion of the estuary. Few time-based trends were detected in organic nitrogen concentrations in the estuary (see Tables C-1 through C-3 in Appendix C). Organic nitrogen concentrations in the estuary were positively correlated with total nitrogen.

During the period of record the mean concentration of organic nitrogen in the outer harbor was 0.54 mg/l as N. This parameter showed considerable variability with concentrations ranging from undetectable to 10.09 mg/l as N. Statistically significant trends toward increasing organic nitrogen concentrations over time were detected at several sampling stations in the outer harbor (see Table C-6 in Appendix C). For the most part, no time-based trends in organic nitrogen concentrations were detected at stations outside the breakwall. Organic nitrogen concentrations in the outer harbor were positively correlated with concentrations of total nitrogen and total phosphorus.

Several processes can influence the concentrations of nitrogen compounds in a waterbody. Primary production by plants and algae will result in ammonia and nitrate being removed from the water and incorporated into cellular material. This effectively converts the nitrogen to forms which are detected only as total nitrogen. Decomposition of organic material in sediment can release nitrogen compounds to the overlying water. For example, a recent study estimated release of ammonia from sediment in the estuary as ranging between 130 and 180 milligrams measured as nitrogen per square meter per day (mg as N per m^2 per day) and release of ammonia from sediment in the outer harbor as ranging between 30 and 64 mg as N per m^2 per day.[18] Finally, bacterial action may convert some nitrogen compounds into others.

Several things emerge from this analysis of nitrogen chemistry in the Milwaukee Harbor estuary and outer harbor:

- Concentrations of total nitrogen have been increasing at several stations in the estuary and outer harbor. This represents a decrease in water quality.
- The relative proportions of different nitrogen compounds in the estuary and outer harbor seem to be changing with time.
- Ammonia concentrations at all sampling stations in the estuary and outer harbor have been decreasing over time. This represents an improvement in water quality.
- Concentrations of nitrate have been increasing at most stations in the estuary and outer harbor. This appears to account for at least some of the increase in total nitrogen concentrations. This represents a decrease in water quality.
- Concentrations of organic nitrogen have increased at a few stations in the estuary and several stations in the outer harbor.

Total and Dissolved Phosphorus

Two forms of phosphorus are commonly sampled in surface waters: dissolved phosphorus and total phosphorus. Dissolved phosphorus represents the form that can be taken up and used for growth by algae and aquatic plants. Total phosphorus represents all the phosphorus contained in material dissolved or suspended within the water, including phosphorus contained in detritus and organisms and attached to soil and sediment.

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[18]*Klump,* et al., *2004,* op. cit.

The mean concentration of total phosphorus in the Milwaukee Harbor estuary during the period of record was 0.115 mg/l, and the mean concentration of dissolved phosphorus in the estuary over the period of record was 0.041 mg/l. Total phosphorus concentrations varied over four orders of magnitude, ranging from 0.002 to 3.000 mg/l. Dissolved phosphorus concentrations varied over three orders of magnitude from 0.004 to 0.647 mg/l. The mean concentrations of total phosphorus during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 0.092 mg/l, 0.117 mg/l, and 0.126 mg/l, respectively. The mean concentrations of dissolved phosphorus during the period of record in the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers within the estuary were 0.033 mg/l, 0.042 mg/l, and 0.044 mg/l, respectively. While some of the differences among the portions of the estuary in mean total phosphorus concentration and mean dissolved phosphorus concentration were statistically significant, the relationships among mean total and dissolved phosphorus concentrations in the sections of the estuary appear to be dynamic and changing over time. For example, ANOVA showed that the mean concentration of total phosphorus in the portions of the Menomonee and Milwaukee Rivers in the estuary was significantly higher than the mean concentration of total phosphorus in the Kinnickinnic River during all periods. During the periods 1975-1986 and 1994-1997, the mean concentration of total phosphorus in the Milwaukee River was significantly higher than the mean concentration of total phosphorus in the Menomonee River. During the other two periods, no statistically significant differences were detected between mean total phosphorus concentrations in those two sections of the estuary.

Similar patterns of changes were seen in the relationships among the sections of the estuary in mean concentrations of dissolved phosphorus. During the period 1998-2002, the mean concentration of dissolved phosphorus in the Menomonee River portion of the estuary were significantly higher than mean concentrations of dissolved phosphorus in the Milwaukee River and Kinnickinnic River sections of the estuary. In addition, during this period the mean concentration of dissolved phosphorus in the Milwaukee River section of the estuary was significantly higher than the mean concentration of dissolved phosphorus in the Kinnickinnic River section of the estuary. It is important to note that at all stations during all periods, total phosphorus concentrations in a substantial fraction of samples exceeded the planning standard of 0.1 mg/l recommended in the regional water quality management plan.

On an annual basis, trends toward decreasing total phosphorus concentrations over time were detected at several sampling stations in the estuary (see Tables C-1 through C-3 in Appendix C). While these trends represent an improvement in water quality, they mask increases in total phosphorus concentrations at most sampling stations during the period 1998-2002.

Dissolved phosphorus concentrations show a different pattern of time-based trends. When examined on an annual basis, trends toward dissolved phosphorus concentrations increasing over time were detected at five stations in the estuary. A trend toward dissolved phosphorus concentrations decreasing over time was detected at one estuary station. These trends represent a decline in water quality. It is important to note that many of these trends account for small portions of the variation in the data. Dissolved phosphorus concentrations in the estuary were negatively correlated with concentrations of chlorophyll-*a*. Concentrations of total phosphorus were positively correlated with concentrations of total nitrogen and negatively correlated with concentrations of dissolved oxygen. These correlations reflect the roles of phosphorus and nitrogen as nutrients for algal growth. During periods of high algal productivity, algae remove dissolved phosphorus and nitrogen compounds from the water and incorporate them into cellular material. At the same time, respiratory demands of bacteria degrading the organic matter produced will tend to lower concentrations of dissolved oxygen. Concentrations of total phosphorus at stations in the estuary are positively correlated with concentrations of fecal coliform bacteria. This may reflect common sources and modes of transport into the estuary for these pollutants. Concentrations of dissolved and total phosphorus can also be affected by sedimentation of particulate material and release of dissolved phosphorus from the sediment. A recent study estimated that release of soluble reactive phosphorus, a dissolved form consisting mostly of orthophosphate, in the estuary ranged from 2.9 milligrams per square meter per day (mg per m^2 per day) to 19.3 mg per m^2 per day.[19]

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[19]Ibid.

The mean concentration of total phosphorus in the outer harbor during the period of record was 0.056 mg/l, and the mean concentration of dissolved phosphorus in the outer harbor over the period of record was 0.022 mg/l. Total phosphorus concentrations varied over four orders of magnitude, ranging from below the limit of detection to 3.880 mg/l. Dissolved phosphorus concentrations varied over four orders of magnitude from below the limit of detection to 1.330 mg/l. Figure 296 shows concentrations of total phosphorus at sampling stations along transects through and adjacent to the outer harbor. Concentrations of total phosphorus were higher at sampling stations in the outer harbor than at sampling stations outside the breakwall. Within the outer harbor, the highest concentrations of total phosphorus were observed at station OH-01, near the mouth of the Milwaukee River, and station OH-02, near the outfall from the Jones Island WWTP. At all sampling stations in and adjacent to the outer harbor, concentrations of total phosphorus decreased from the 1975-1986 period through the 1994-1997 period. During the period 1998-2004, concentrations of total phosphorus at stations in the outer harbor and at stations located at gaps in the breakwall increased. Despite these recent increases, statistically significant trends toward decreasing total phosphorus concentration were detected at several sampling stations (see Table C-6 in Appendix C). These trends account for only a small portion of the variation in the data. While the long-term decrease in total phosphorus indicates that water quality has improved since 1975, the recent increases indicate that water quality may currently be declining. Concentrations of total phosphorus in the outer harbor were positively correlated with dissolved phosphorus and total nitrogen and negatively correlated with secchi depth. Concentrations of dissolved and total phosphorus can also be affected by sedimentation of particulate material and release of dissolved phosphorus from the sediment. A recent study estimated that release of soluble reactive phosphorus, a dissolved form consisting mostly of orthophosphate, in the outer harbor ranged from a transfer of 0.2 milligrams per square meter per day (mg per m^2 per day) from the water column to the sediment to a release of 10.1 mg per m^2 per day from the sediment.[20]

Figure 297 shows the annual mean total phosphorus concentrations in the Milwaukee Harbor estuary for the years 1986 to 2002 and the outer harbor and adjacent areas of Lake Michigan for the years 1985-2004. While mean annual total phosphorus concentrations in the estuary and outer harbor from the years after 1996 were within the range of variation from previous years, they increased after 1996 and remained elevated. While mean annual total phosphorus in the adjacent Lake Michigan area did increase after 1996, it has fluctuated considerably since and probably largely represents natural variation rather than a sustained increase. One possible cause of the increase in the estuary and outer harbor was phosphorus loads from facilities discharging noncontact cooling water drawn from municipal water utilities. The City of Milwaukee, for example, began treating its municipal water with orthophosphate to inhibit release of copper and lead from pipes in the water system and private residences in 1996. In 2004, for instance, concentrations of orthophosphate in plant finished water from the Milwaukee Water Works ranged between 1.46 mg/l and 2.24 mg/l,[21] considerably above average concentrations of total phosphate in the Milwaukee Harbor estuary and outer harbor. In addition, between 1992 and 2003, a number of other municipalities in the Milwaukee River Watershed began treating their municipal water with orthophosphate or polyphosphate for corrosion control (see Table 91 in Chapter VII of this report).

Metals

Arsenic

The mean concentration of arsenic in the water of the Milwaukee Harbor estuary over the period of record was 1.69 μg/l. The data ranged from below the limit of detection to 51.00 μg/l. The mean concentrations of arsenic over the period of record in the Kinnickinnic River, Menomonee River, and Milwaukee River portions of the estuary were 1.44 μg/l, 1.96 μg/l, and 1.59 μg/l, respectively. No statistically significant differences were found among the mean concentrations of arsenic in these three sections of the estuary. When examined on an annual basis, statistically significant trends toward arsenic concentrations decreasing over time were detected at most

[20]Ibid.

[21]*Milwaukee Water Works,* Annual Water Quality Report, 2004, *February 2005.*

Figure 296

TOTAL PHOSPHORUS CONCENTRATIONS AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004

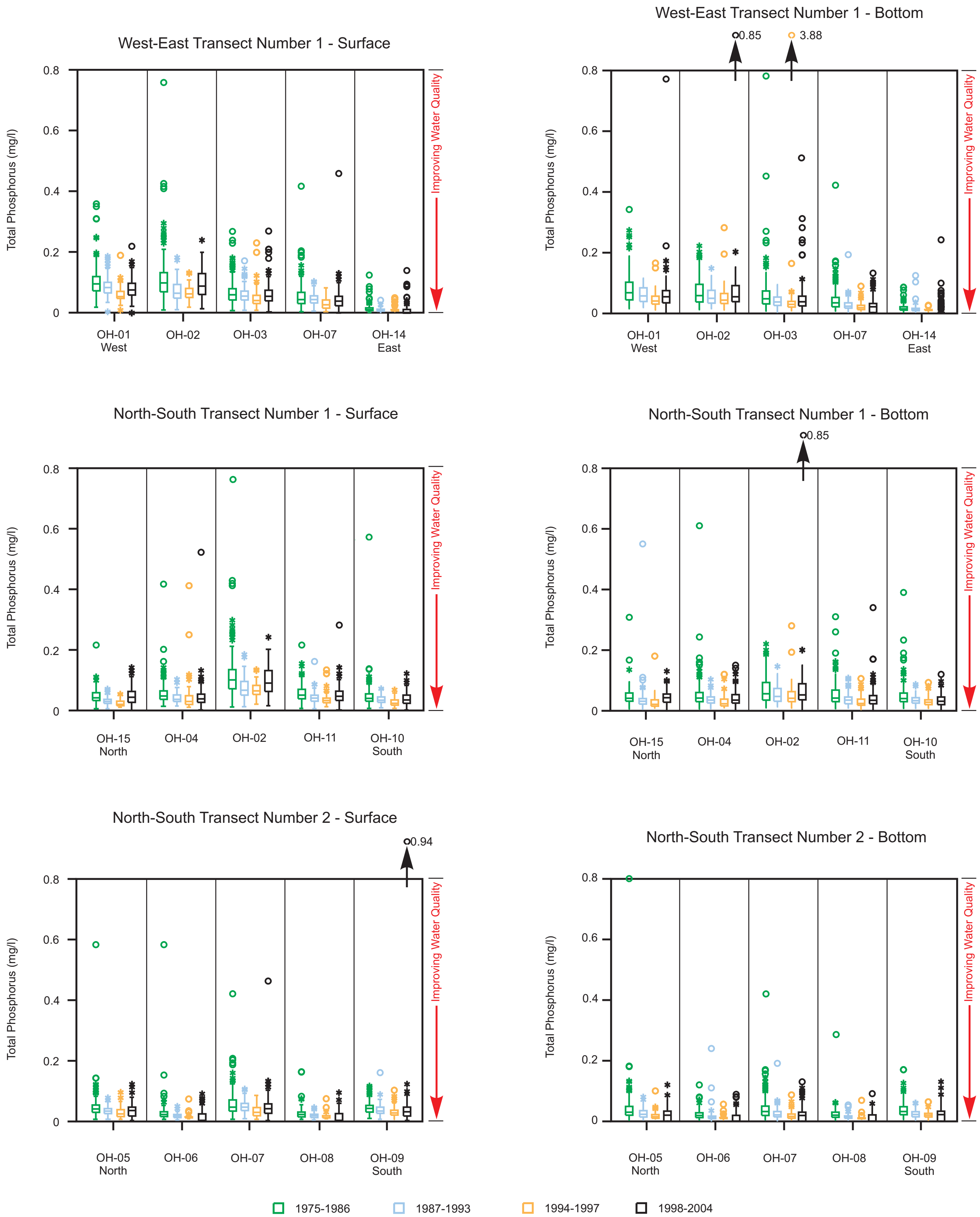
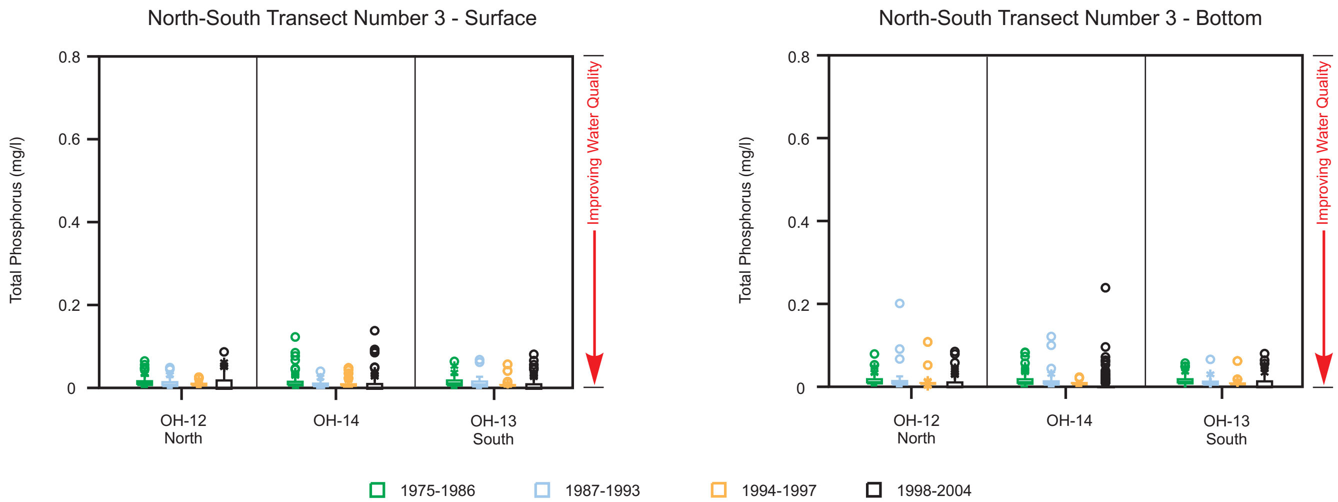


Figure 296 (continued)



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

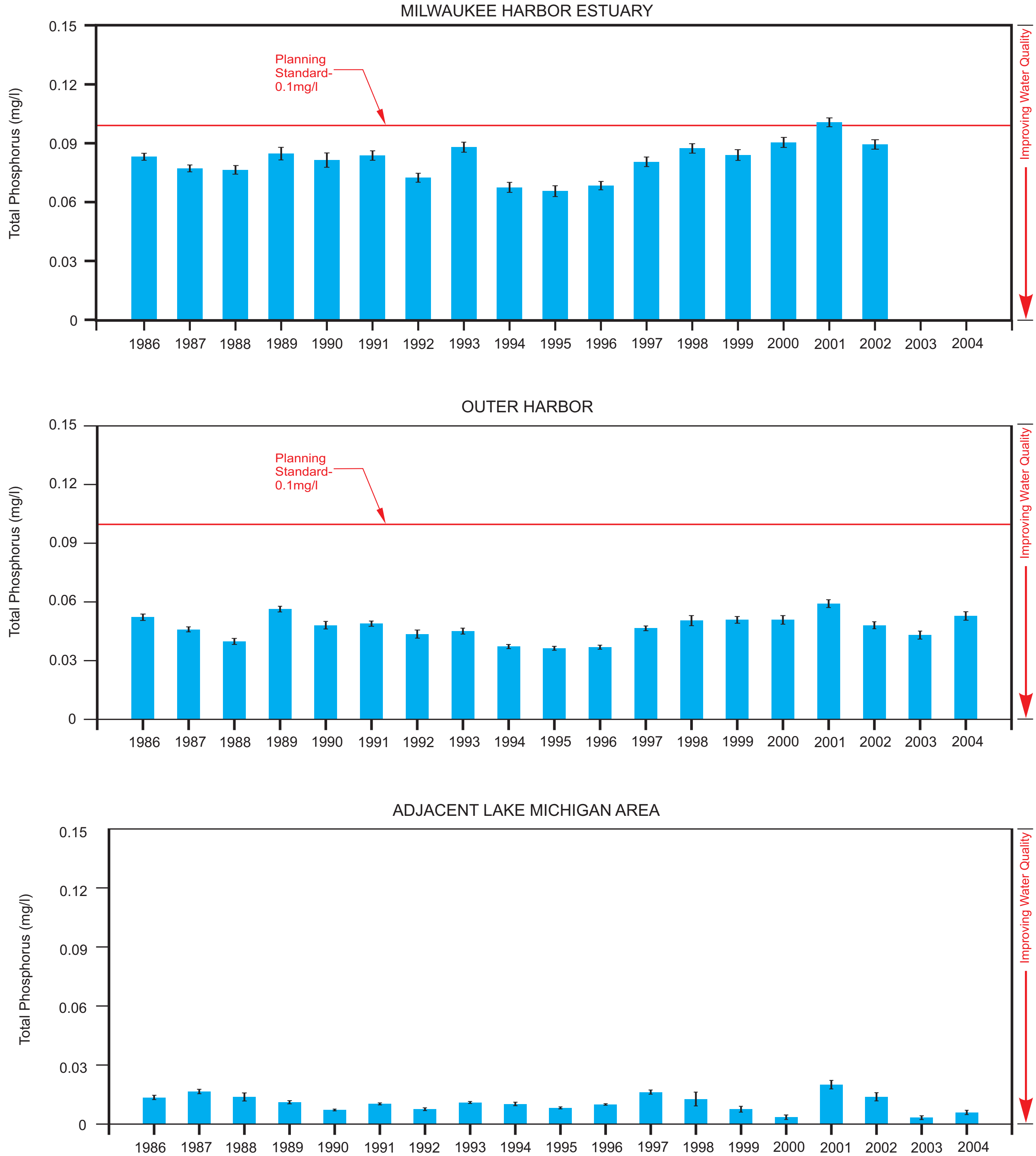
stations in the estuary (see Tables C-1 through C-3 in Appendix C). This may reflect changes in the amount and types of industry within the Milwaukee River watershed such as the loss of tanneries which utilized arsenic in the processing of hides. In addition, sodium arsenite has not been used in herbicide in Wisconsin since 1969. The mean concentration of arsenic over the period of record in the outer harbor was 1.93 μg/l. Concentrations in individual samples ranged from below the limit of detection to 57.00 μg/l. Significant trends toward arsenic concentrations increasing over time were detected at several stations in the outer harbor and outside the breakwall (see Table C-6 in Appendix C). Given that significant trends toward arsenic concentrations increasing over time were also detected at several stations in the MMSD nearshore surveys (see Table C-6 in Appendix C), trends in the outer harbor may be more significantly influenced by events in the nearshore areas of Lake Michigan than by events in the estuary. The reductions in arsenic concentration in the Milwaukee Harbor estuary represent an improvement in water quality. The trends toward increasing concentrations of arsenic in the outer harbor represent a reduction in water quality.

Cadmium

The mean concentration of cadmium in the Milwaukee Harbor estuary over the period of record was 1.62 μg/l. Concentrations in individual samples ranged from below the limit of detection to 27.00 μg/l. The mean concentrations of cadmium over the period of record in the Kinnickinnic River, Menomonee River, and Milwaukee River portions of the estuary were 1.70 μg/l, 1.38 μg/l, and 1.74 μg/l, respectively. Statistical analysis revealed the presence of strong decreasing trends in cadmium concentration over time at all stations in the estuary (see Tables C-1 through C-3 in Appendix C). The mean concentration of cadmium in the outer harbor over the period of record was 1.79 μg/l. Concentrations in individual samples ranged from below the limit of detection to 82.00 μg/l. Table C-6 in Appendix C shows that strong decreasing trends in cadmium concentration over time were present at all stations in the outer harbor and outside the breakwall. During the baseline period the mean concentrations of cadmium in Kinnickinnic River, Menomonee River, and Milwaukee River portions of the estuary and the outer harbor were 0.31 μg/l, 0.14 μg/l, 0.13 μg/l, and 0.08 μg/l, respectively. The declines in cadmium concentration may reflect changes in the number and types of industry present in the watershed, reductions due to treatment of industrial discharges, and reductions in airborne deposition of cadmium to the Great Lakes region. The reduction in cadmium concentrations in the estuary and outer harbor represents an improvement in water quality.

Figure 297

MEAN ANNUAL CONCENTRATIONS OF TOTAL PHOSPHORUS CONCENTRATIONS IN THE MILWAUKEE HARBOR ESTUARY, OUTER HARBOR, AND ADJACENT LAKE MICHIGAN AREA: 1986-2004



NOTE: Error bars (I) represent one standard error of the mean.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

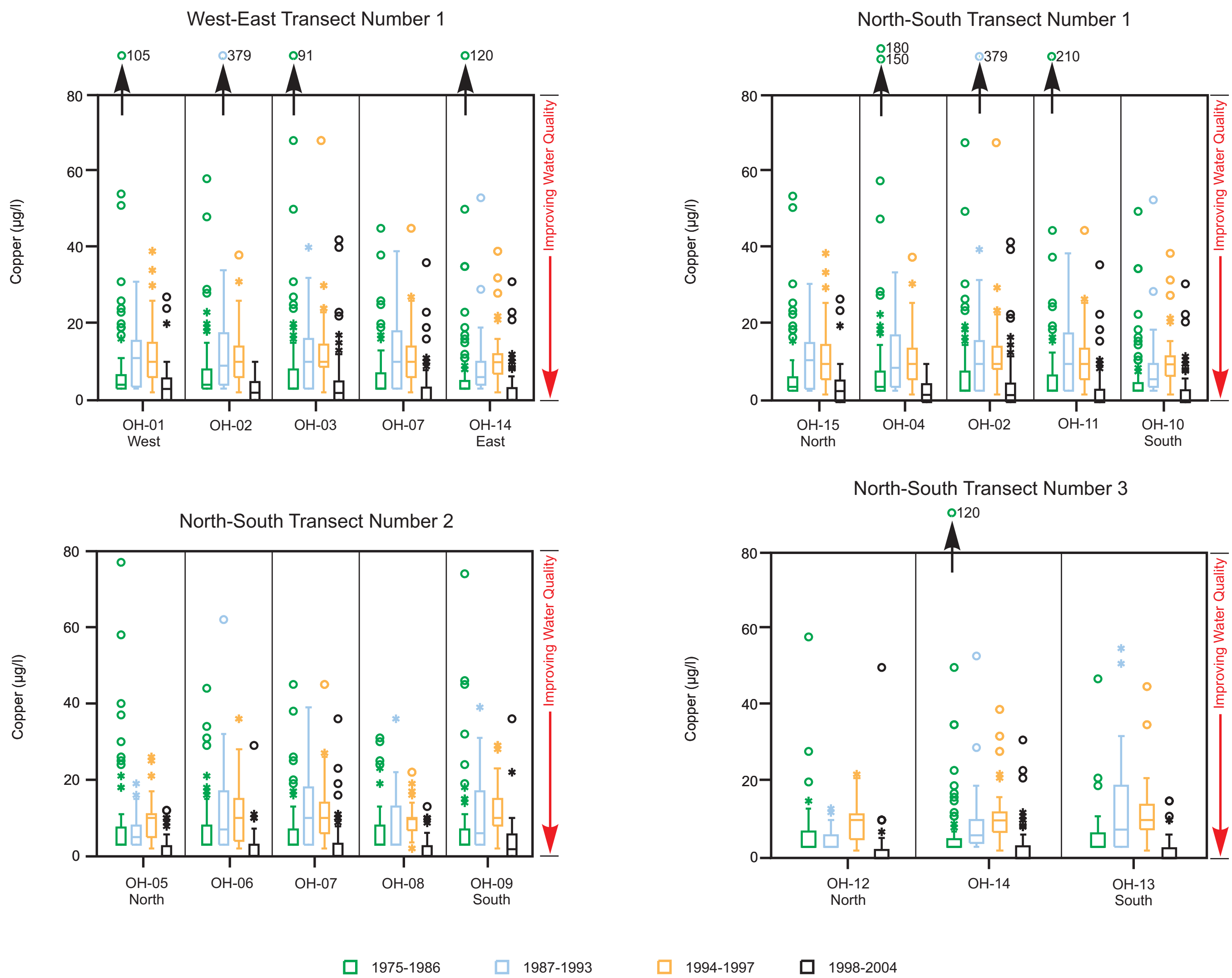
Chromium
The mean concentration of chromium in the Milwaukee Harbor estuary over the period of record was 15.0 μg/l. Chromium concentration showed moderate variability, with individual sample concentrations ranging from below the limit of detection to 8,866.4 μg/l. The mean concentrations of chromium over the period of record in the Kinnickinnic River, Menomonee River, and Milwaukee River portions of the estuary were 9.9 μg/l, 10.4 μg/l, and 21.2 μg/l, respectively. No statistically significant differences were detected among the mean concentrations of chromium in these three sections of the estuary. Statistically significant trends toward chromium concentrations decreasing over time were detected at most sampling stations in the estuary (see Tables C-1 through C-3 in Appendix C). The mean concentration of chromium in the outer harbor over the period of record was 12.0 μg/l. Concentrations in individual samples ranged from below the limit of detection to 520.0 μg/l. Significant trends toward decreasing chromium concentrations were detected at all sampling stations in the outer harbor (see Table C-6 in Appendix C). The declines in chromium concentrations in the estuary and outer harbor may reflect the loss of industry in some parts of the Kinnickinnic River, Menomonee River, and Milwaukee River watersheds and the decreasing importance of the metal plating industry in particular, as well as the treatment of discharges for the remaining and new industries since the late 1970s. There is no evidence of seasonal variation in chromium concentrations in the estuary or outer harbor. The decline in chromium concentrations represents an improvement in water quality.

Copper
The mean concentration of copper in the Milwaukee Harbor estuary during the period of record was 10.66 μg/l. Concentrations varied from below the limit of detection to 413.00 μg/l. The mean concentrations of copper over the period of record in the Kinnickinnic River, Menomonee River, and Milwaukee River portions of the estuary were 9.98 μg/l, 11.78 μg/l, and 10.25 μg/l, respectively. During the periods 1975-1986 and 1987-1993, no statistically significant differences were detected among the mean concentrations of copper in these three sections of the estuary. During the periods 1994-1997 and 1998-2002, the mean concentration of copper in the Menomonee River portion of the estuary was significantly higher than the mean concentrations of copper in the Kinnickinnic River and Milwaukee River portions of the estuary. At all sampling stations in the estuary, copper concentrations increased over time, reaching their highest levels during the period 1994-1997. Copper concentrations were lower during the period 1998-2004 than during the period 1994-1997. Statistically significant trends toward copper concentrations increasing over time were detected at most sampling stations in the estuary (see Tables C-1 through C-3 in Appendix C). The mean concentration of copper during the period of record in the outer harbor was 8.21 μg/l. Concentrations in individual samples ranged from below the limit of detection to 379.00 μg/l. Figure 298 shows copper concentrations at sampling stations along transects through and adjacent to the outer harbor. Copper concentrations at these stations followed the same pattern as copper concentrations at stations in the estuary, increasing over time and reaching their highest levels during the period 1994-1997 and then declining during the period 1998-2004. Few statistically significant time-based trends were detected in copper concentrations in the outer harbor (see Table C-6 in Appendix C). Where trends were detected, they tended to be trends toward increasing concentrations. Despite the overall increasing trend, the decreases in copper concentrations in the estuary and outer harbor since 1997 represent improvements in water quality.

Lead
The mean concentration of lead in the Milwaukee Harbor estuary over the period of record was 31.25 μg/l. This mean is not representative of current conditions because lead concentrations in the water of the estuary have been decreasing since the late 1980s. At all sampling stations for which sufficient data exist to assess trends in lead concentrations, baseline period monthly mean lead concentrations are quite low when compared to historical means and ranges. These decreases represent statistically significant decreasing trends (see Appendix C). The mean concentration of lead in the estuary during the period 1998-2002 was 5.35 μg/l. The mean concentrations in the Kinnickinnic River, Menomonee River, and Milwaukee River portions of the estuary during this period were 6.53 μg/l, 5.33 μg/l, and 4.65 μg/l, respectively. The mean concentration of lead in the outer harbor during the period 1998-2004 was 1.88 μg/l. Figure 299 shows lead concentrations at sampling stations along transects through and adjacent to the outer harbor. At all stations, dramatic decreases were observed in lead concentrations over time. These decreases represent statistically significant trends (see Table C-6 in Appendix C). A major factor

Figure 298

CONCENTRATION OF COPPER AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

causing the decline in lead concentrations has been the phasing out of lead as a gasoline additive. From 1983 to 1986, the amount of lead in gasoline in the United States was reduced from 1.26 grams per gallon (g/gal) to 0.1 g/gal. In addition, lead was completely banned for use in fuel for on-road vehicles in 1995. The major drop in lead in water in the estuary and outer harbor followed this reduction in use. In freshwater, lead has a strong tendency to adsorb to particulates suspended in water.[22] As these particles are deposited, they carry the adsorbed lead into residence in the sediment. Because of this, the lower concentrations of lead in the water probably reflect the

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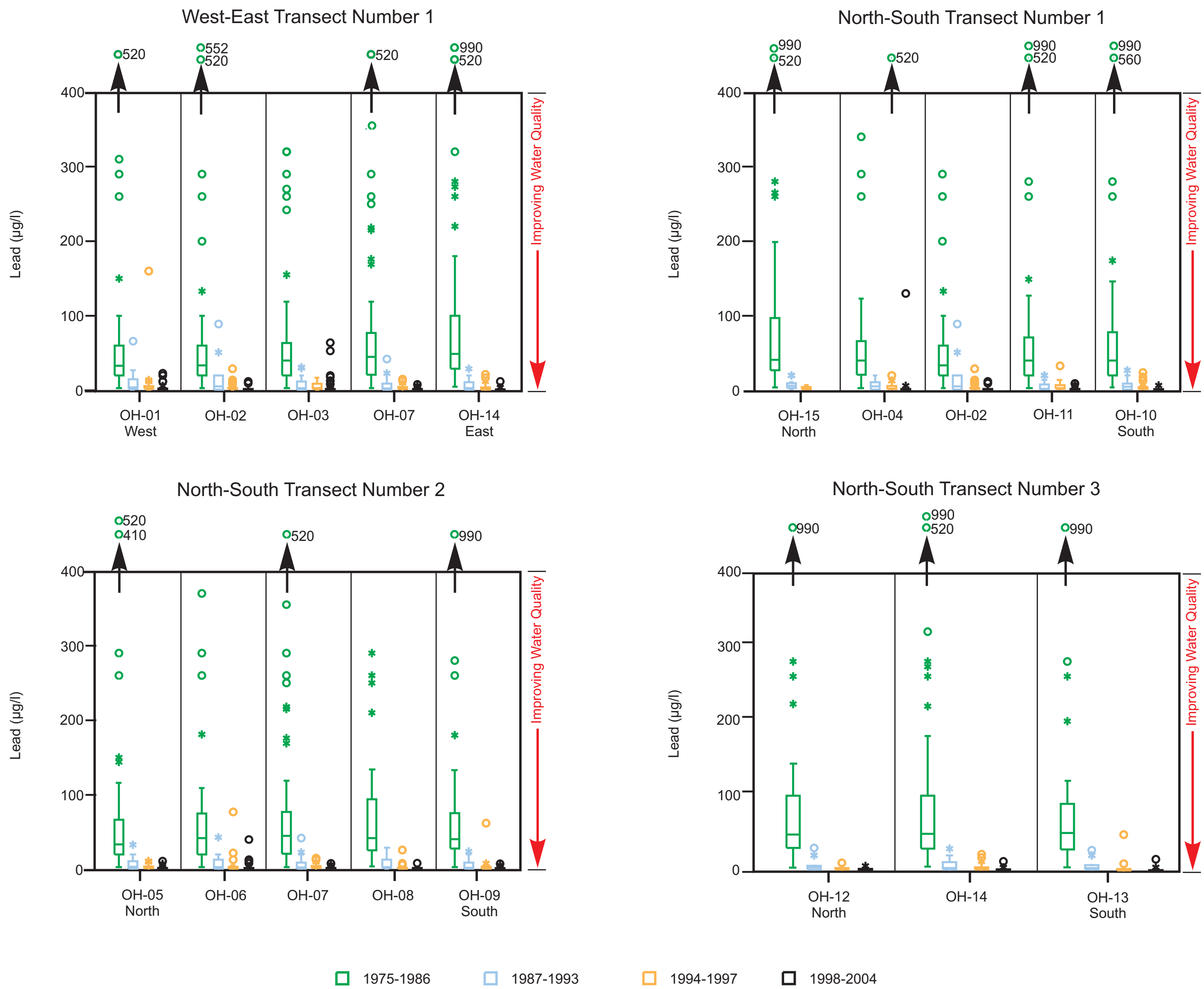
[22]*H.L. Windom, T. Byrd, R.G. Smith, and F. Huan, "Inadequacy of NASQUAN Data for Assessing Metal Trends in the Nation's Rivers,"* Environmental Science and Technology *Volume 25, 1991.*

Figure 299

CONCENTRATION OF LEAD AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

actions of three processes: reduction of lead entering the environment, washing out of lead into Lake Michigan, and deposition of adsorbed lead in the sediment. The decrease in lead concentrations over time in the estuary and outer harbor represents an improvement in water quality.

Mercury

Few historical data on the concentration of mercury in the water of the Milwaukee Harbor estuary exist. Most sampling for mercury in water in the estuary was conducted during or after 1995. The mean concentration of mercury in the estuary over the period of record was 0.0.0535 μg/l. Mercury concentrations showed moderate variability, with a range from below the limit of detection to 2.1000 μg/l. The mean concentrations of mercury over the period of record in the Kinnickinnic River, Menomonee River, and Milwaukee River portions of the estuary were 0.0422 μg/l, 0.0676 μg/l, and 0.0483 μg/l, respectively. Few statistically significant differences were detected among the mean concentrations of mercury in these sections of the estuary. During the period 1998-2002, the mean concentration of mercury in the water of the Menomonee River portion of the estuary was significantly higher than the mean concentrations of mercury in the water of the Kinnickinnic River and Milwaukee River portions of the estuary. When examined on an annual basis, significant trends toward decreasing mercury concentrations were detected at all stations in the estuary (see Tables C-1 through C-3 in Appendix C). Few historical data on the concentration of mercury in the water of the outer harbor exist. Most sampling for mercury in water in the outer harbor was conducted at three sampling stations during or after 1997. The mean concentration of mercury in the outer harbor over the period of record was 0.0.0156 μg/l. Concentrations of mercury in individual samples ranged from below the limit of detection to 0.2200 μg/l. When examined on an annual basis, a significant trend toward decreasing mercury concentration over time was detected at one station in the outer harbor (see Table C-6 in Appendix C). In addition, a significant trend toward decreasing mercury concentration over time was detected at a second station when the data were analyzed on a seasonal basis. The concentrations of mercury in several samples in the estuary and outer harbor exceed both the State of Wisconsin's wildlife criteria for surface water of 0.0013 μg/l and Wisconsin's human threshold criteria for public health and welfare of 0.0015 μg/l (see Chapter IV in this report). The trends toward decreasing mercury concentrations at stations in the estuary and outer harbor represent improvements in water quality.

Nickel

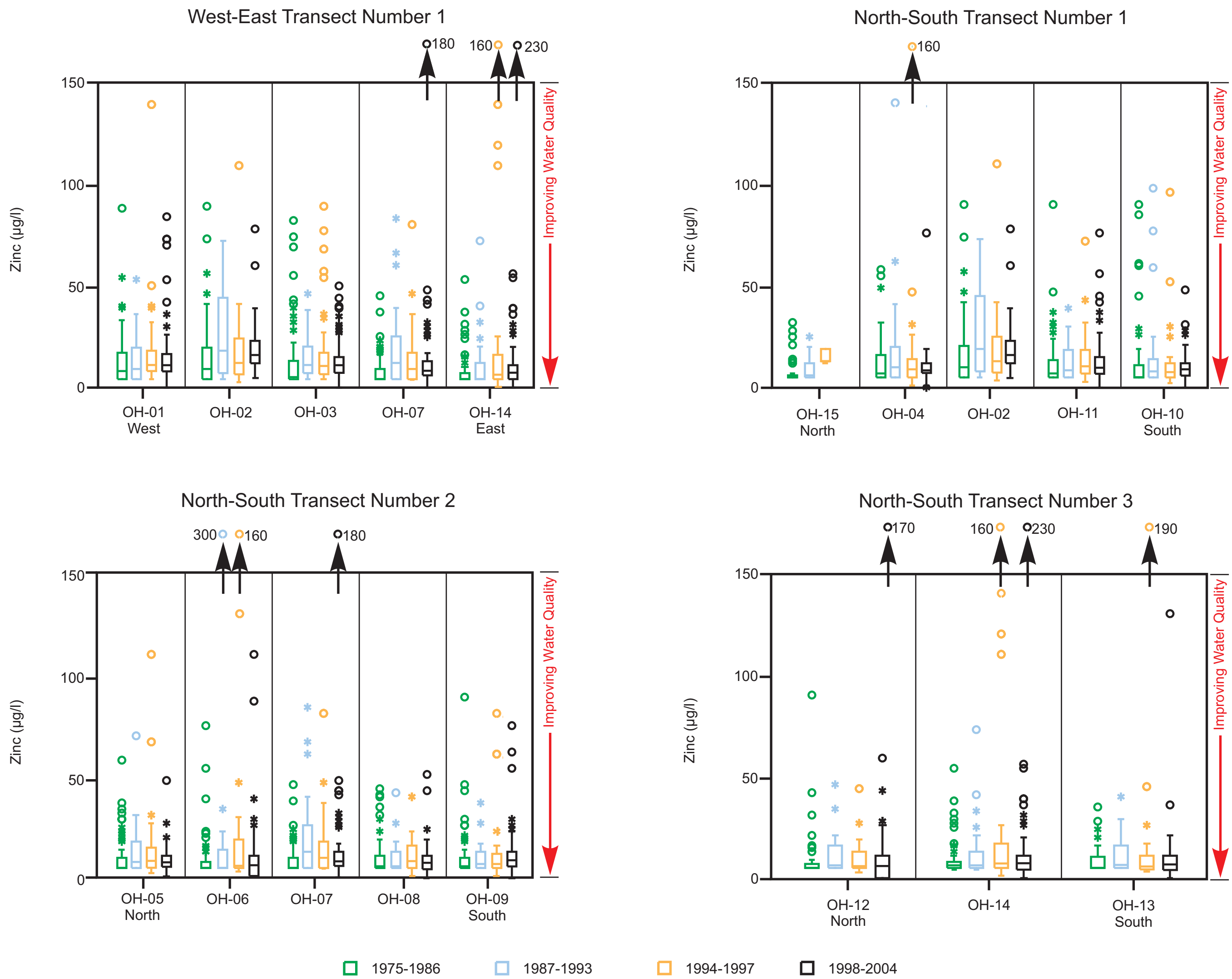
The mean concentration of nickel in the Milwaukee Harbor estuary over the period of record was 13.3 μg/l. Concentrations in individual samples ranged from below the limit of detection to 3,810.8 μg/l. The mean concentrations of nickel over the period of record in the Kinnickinnic River, Menomonee River, and Milwaukee River portions of the estuary were 11.5 μg/l, 10.3 μg/l, and 16.9 μg/l, respectively. No statistically significant differences were found among mean concentrations in these three sections of the estuary. When examined on an annual basis, significant decreases over time were observed at several sampling stations in the estuary (see Tables C-1 through C-3 in Appendix C). The mean concentration of nickel over the period of record in the outer harbor was 6.6 μg/l. Concentrations in individual samples ranged from below the limit of detection to 97.0 μg/l. Statistically significant trends toward nickel concentrations decreasing over time were detected at all stations in the outer harbor (see Table C-6 in Appendix C). The trends toward decreasing nickel concentration in the estuary and outer harbor may reflect changes in the amount and types of industry within the Kinnickinnic River, Menomonee River, and Milwaukee River watersheds. The decreases in nickel concentrations in the estuary and outer harbor represent an improvement in water quality.

Zinc

The mean concentration of zinc in the Milwaukee harbor estuary during the period of record was 23.7 μg/l. Concentrations in individual samples ranged from 4.3 μg/l to 376.5 μg/l. The mean concentrations of zinc over the period of record in the Kinnickinnic River, Menomonee River, and Milwaukee River portions of the estuary were 27.2 μg/l, 25.0 μg/l, and 20.8 μg/l, respectively. Analysis of variance showed that mean concentrations of zinc were higher in the Kinnickinnic River and Menomonee River portions of the estuary than in the Milwaukee River portion of the estuary during most periods. Statistically significant trends toward zinc concentrations increasing over time were detected at most stations in the estuary (see Tables C-1 through C-3 in Appendix C). At several stations, these trends account for a small portion of the variation in the data. The mean concentration of zinc over the period of record in the outer harbor was 14.4 μg/l. Concentrations in individual samples ranged from below the limit of detection to 160.0 μg/l. Figure 300 shows zinc concentrations at sampling stations along transects through and adjacent to the outer harbor. Zinc concentrations tended to be higher at stations in the outer harbor than at stations outside the breakwall. The highest concentrations of zinc in the outer harbor were detected at station OH-02, near the outfall from the Jones Island WWTP. The high concentrations observed at this station probably reflect the effects of inputs of effluent from the Jones Island treatment plant. The lower concentrations of zinc detected at other stations in the outer harbor indicate that this effluent is rapidly mixed throughout the outer harbor. At most stations in the outer harbor, zinc concentrations have increased over time. At some sampling stations these increases represent statistically significant trends. These trends account for a small portion of the variation in the data. The higher concentrations of zinc in the estuary and outer harbor may reflect higher amounts

Figure 300

CONCENTRATION OF ZINC AT SITES IN THE MILWAUKEE OUTER HARBOR AND ADJACENT LAKE MICHIGAN AREA: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

of zinc washing into the Kinnickinnic, Menomonee, and Milwaukee Rivers during snowmelt and spring rains caused by higher amounts of vehicle traffic. Wear and tear on automobile brake pads and tires are major sources of zinc in the environment. In addition, zinc can be released to stormwater by corrosion of galvanized gutters and roofing materials. Stormwater can carry zinc from these sources into streams. The trends toward increasing zinc concentrations in the estuary and outer harbor represent a reduction in water quality

Organic Compounds

On three dates between February and June 2004, samples were collected by the USGS from the Milwaukee Harbor estuary at Jones Island. Those samples were examined for the presence and concentrations of several organic compounds dissolved in water. Dissolved isophorone, a solvent, was detected in 2004 in one sample at a concentration of 0.1 μg/l. As shown in Table 18 in Chapter IV of this report, this concentration is below

Wisconsin's human threshold criterion for public heath and welfare for fish and aquatic life waters. Carbazole, a component of dyes, lubricants, and pesticides, was detected in one sample at a concentration of 0.1 μg/l. The plasticizer triphenyl phosphate was found in two samples at a concentration of 0.1 μg/l. Three flame retardant chemicals were detected in samples from the estuary. Tri(2-chloroethyl) phosphate was detected at a concentration of 0.1 μg/l. In 2004, Tri(dichloroisopropyl) phosphate was detected at a concentration of 0.1 μg/l. Tributyl phosphate was detected in one sample at a concentration of 0.1 μg/l. Finally, the compound p-nonylphenol, a metabolite of nonionic detergents, was detected in one sample at a concentration of 1.0 μg/l. This compound is known to be an endocrine disruptor.

On 11 dates between February 2004 and August 2005, the USGS collected water samples at six sites in the outer harbor and adjacent areas of Lake Michigan. Those samples were examined for the presence and concentrations of several organic compounds dissolved in water. Dissolved isophorone was detected in one sample at a concentration of 0.1 μg/l. As shown in Table 18 in Chapter IV of this report, this concentration is below Wisconsin's human threshold criterion for public heath and welfare for fish and aquatic life waters. Carbazole was detected in one sample at a concentration of 0.1 μg/l. Triphenyl phosphate was found in four samples at a concentration of 0.1 μg/l. Four flame retardant chemicals were detected in samples from the outer harbor. Tri(2-butoxyethyl) phosphate was detected in 24 samples at concentrations ranging between 0.1 μg/l and 2.5 μg/l. Tri(2-chloroethyl) phosphate was detected in seven samples at a concentration of 0.1 μg/l. In 2004, Tri(dichloroisopropyl) phosphate was detected in four samples at a concentration of 0.1 μg/l. Tributyl phosphate was detected in four samples at a concentration of 0.1 μg/l. Finally, two metabolites of nonionic detergents were detected in samples collected in the outer harbor. The first, p-nonylphenol was detected in two samples at concentrations ranging between 1.0 μg/l and 2.0 μg/l. The second, diethoxynonylphenol was detected in nine samples at concentrations ranging between 1.0 μg/l and 2.0 μg/l. These two compounds are known to be endocrine disruptors.

Pharmaceuticals and Personal Care Products

On three dates between February and May 2004, the USGS sampled water from the Milwaukee Harbor estuary at Jones Island for the presence of several compounds found in pharmaceuticals and personal care products. Caffeine, a stimulant found in beverages and analgesics, was detected in two samples at concentrations ranging between 0.1 μg/l and 0.2 μg/l. N,N-diethyl-meta-toluamide (DEET), the active ingredient used in many insect repellants, was detected in two samples at a concentration of 0.1 μg/l. Camphor, a fragrance and flavoring agent, was detected in one sample at a concentration of 0.1 μg/l. Acetophenone, a fragrance used in soaps and detergents was detected in one sample at a concentration of 0.1 μg/l. Benzophenone, a fixative used in soaps and perfumes, was detected in two samples at a concentration of 0.1 μg/l. Acetyl-hexamethyl-tetrahydro-naphthalene (AHTN), a synthetic musk fragrance, was detected in one sample at a concentration of 0.1 μg/l. Hexahydrohexamethyl-cyclopentabenzopyran (HHCB), another musk fragrance, was detected in one sample at a concentration of 0.1 μg/l. Finally, triethyl citrate, a component of cosmetics, was detected in one sample at a concentration of 0.1 μg/l. The sources of these compounds to the estuary are not known.

On 11 dates between February 2004 and August 2005, the USGS collected water samples at six sites in the outer harbor and adjacent areas of Lake Michigan. Those samples were examined for the presence of several compounds found in pharmaceuticals and personal care products. The deodorizer 1,4-dichlorobenzene was detected in six samples at concentrations ranging between 0.1 μg/l and 0.2 μg/l. Caffeine was detected in 21 samples at concentrations ranging between 0.1 μg/l and 0.2 μg/l. Cotinine, a metabolite of nicotine, was detected in 11 samples at concentrations ranging between 0.022 μg/l 0.340 μg/l. Cholesterol, a sterol related to steroid hormones, was detected in one sample at a concentration of 1.0 μg/l. DEET was detected in 20 samples at a concentration of 0.1 μg/l. Camphor was detected in one sample at a concentration of 0.1 μg/l. Menthol, another flavoring agent, was detected in three samples at concentrations ranging between 0.1 μg/l and 0.2 μg/l. Acetophenone was detected in nine samples at a concentration of 0.1 μg/l. Benzophenone was detected in 12 samples at concentrations ranging between 0.1 μg/l and 0.2 μg/l. AHTN was detected in 19 samples at concentrations ranging between 0.1 μg/l and 0.2 μg/l. HHCB was detected in three samples at a concentration of 0.1 μg/l. Finally, triethyl citrate, a component of cosmetics, was detected in three samples at a concentration of

0.1 μg/l. The sources of these compounds to the estuary are not known. Additional information on pharmaceuticals and personal care products, including general descriptions of possible sources of these pollutants, is set forth in Chapter II of this report.

Water Quality of Streams of the Lake Michigan Direct Drainage Area

Until recently, there was little systematic collection of water quality data in the Lake Michigan direct drainage area. In 2002, MMSD began monthly sampling at two sites along Fish Creek. These stations are shown on Map 120 and described in Table 191. Data from these stations constitute the majority of data available for streams in the Lake Michigan direct drainage area. The data record for the other tributary streams in the watershed is fragmentary. It is important to note that because of differences in location, geography, and land use and the fact that many of the other streams in this area are intermittent, the data from the Fish Creek sampling stations may not be representative of water quality conditions in other streams of the Lake direct drainage area.

The time periods examined for analytical purposes and the graphical comparisons of baseline water quality conditions to historical water quality conditions used for the Lake Michigan direct drainage area were similar to those described above for the Milwaukee Harbor estuary. Based on the availability of data, the period from 2002-2005 defines the baseline water quality conditions of Fish Creek. Because of the short period of record and the small number of sampling stations in the Lake Michigan direct drainage area, formal statistical analyses of longitudinal and time-based trends were not conducted.

Bacterial and Biological Parameters

Bacteria

Fecal coliform bacteria data for two locations along Fish Creek are shown in Figure 301. The median concentration of fecal coliform bacteria in Fish Creek during the period 2002-2005 was 435 cells per 100 milliliters (ml). Fecal coliform counts in the Creek varied over four orders of magnitude, ranging from as low as 16 cells per 100 ml to 93,000 cells per 100 ml. Median concentrations of fecal coliform bacteria were higher at the sampling station at W. Port Washington Road and Katherine Lane than at the downstream station at Broadmoor Drive and the Union Pacific Railroad. The range of variability in fecal coliform bacterial concentration appears to be higher during late spring, summer, and early fall as shown in Figure 302. Counts in many samples exceed the standard for full recreational use of 200 cells per 100 ml. Fecal coliform bacteria concentrations in Fish Creek tend to be positively correlated with concentrations of biochemical oxygen demand and with concentrations of total phosphorus. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the Creek. Fecal coliform bacteria concentrations are also strongly positively correlated with concentrations of *E. coli*, reflecting the fact that *E. coli* constitute a major component of fecal coliform bacteria. In addition, fecal coliform bacteria concentrations in the Creek are negatively correlated with alkalinity.

Figure 303 shows the concentrations of *E. coli* at the two sites along Fish Creek. Concentrations of *E. coli* in the Creek ranged from 15 cells per 100 ml to 19,000 cells per 100 ml. Median concentrations of *E. coli* at the sampling station at W. Port Washington Road and Katherine Lane were higher than median concentrations at the station at Broadmoor Drive and the Union Pacific Railroad. Figure 304 shows that the pattern of monthly mean concentrations of *E. coli* in Fish Creek was similar to the pattern of monthly mean concentrations of fecal coliform bacteria.

*Chlorophyll-*a

Figure 305 shows concentrations of chlorophyll-*a* at the two stations along Fish Creek. During the period 2002-2005, the mean concentration of chlorophyll-*a* in the Creek was 8.8 micrograms per liter (μg/l). Individual samples of this parameter ranged from 0.2 μg/l to 133.0 μg/l. While median chlorophyll-*a* concentrations were similar at the two sampling stations, mean concentrations were higher at the upstream sampling station at W. Port Washington Road and Katherine Lane. This difference was not statistically significant.

Map 120

WATER QUALITY MONITORING STATIONS WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 2002-2005

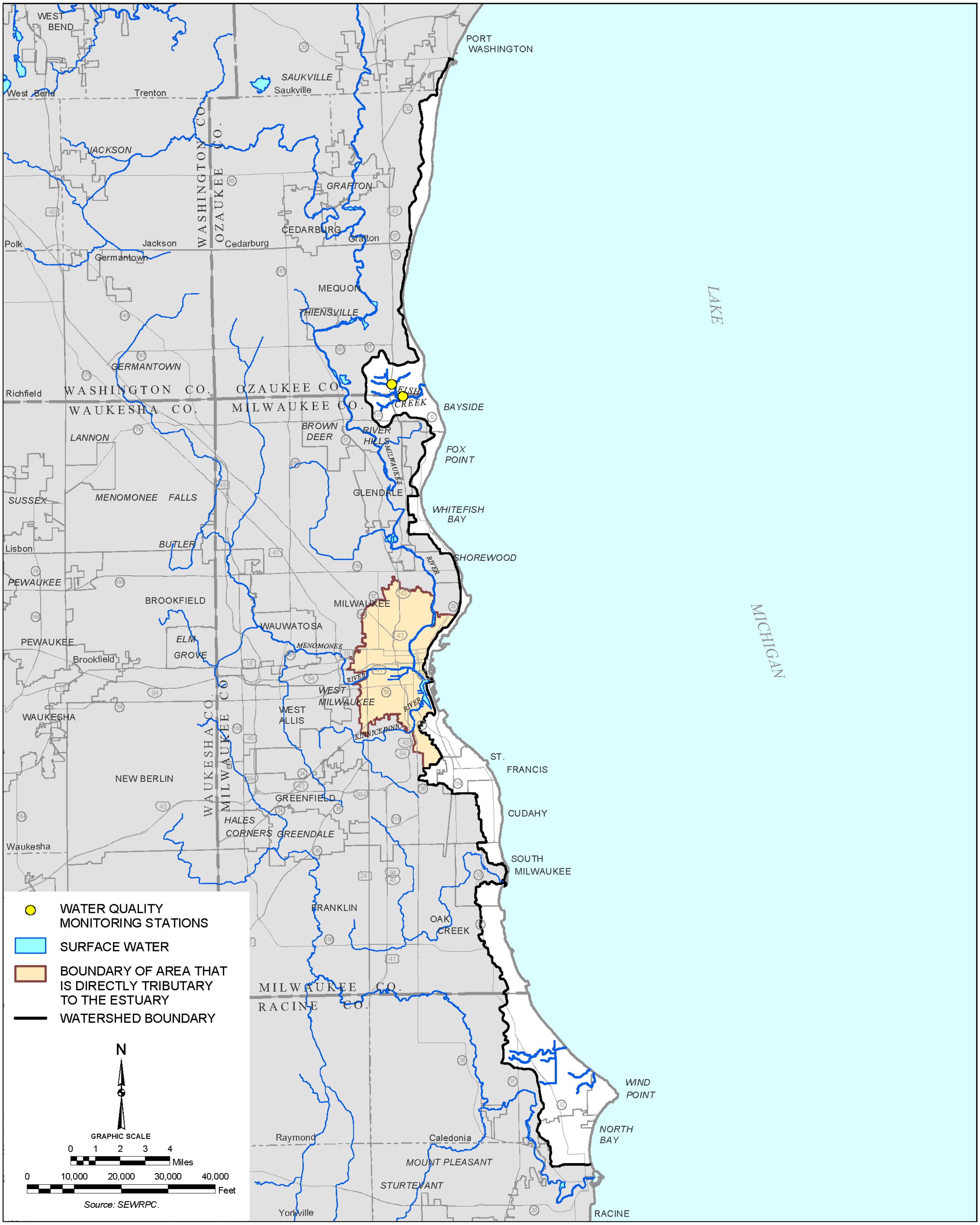


Table 191

SAMPLE SITES USED FOR ANALYSIS OF WATER QUALITY TRENDS IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA

Location	River Mile	Period of Record	Data Sources
Fish Creek at W. Port Washington Road and Katherine Lane	1.25[a]	2002-2005	MMSD
Fish Creek at Broadmoor Drive and Union Pacific Railroad	0.70[a]	2002-2005	MMSD

[a]River Mile is measured as distance upstream from the confluence with Lake Michigan.

Source: SEWRPC.

Chemical and Physical Parameters

Temperature

Figure 306 shows water temperature at the two sites along Fish Creek. The median water temperature in the Creek during the period 2002-2005 was 15.1ºC (ºC). Medians at the two sampling stations were within about 0.5ºC of this value. Water temperatures in the Creek ranged between 4.1ºC and 21.7ºC. Figure 307 shows baseline period monthly mean temperatures for one sampling station along the Creek. Highest monthly mean water temperatures were detected in Fish Creek during July. Water temperatures observed in Fish Creek were below the standard for fish and aquatic life of 31.7ºC.

Alkalinity

The mean value of alkalinity in Fish Creek during the period 2002-2005 was 229.5 milligrams per liter (mg/l) expressed as the equivalent concentration of calcium carbonate (mg/l as $CaCO_3$). The data show moderate variability, ranging from 43.0 to 330.0 mg/l as $CaCO_3$. Alkalinity concentrations in Fish Creek are positively correlated with pH and concentrations of chloride, parameters which, like alkalinity, measure amounts of dissolved material in water.

Biochemical Oxygen Demand (BOD)

The mean concentration of BOD in Fish Creek during the period 2002-2005 was 1.94 mg/l. Individual samples varied from below the limit of detection to 8.00 mg/l. As shown in Figure 308, the concentrations of BOD were similar at the two sampling stations along the Creek. Figure 309 shows monthly mean baseline period concentrations of BOD at one site along the Creek. Baseline period monthly mean concentrations tend to be higher during the summer than during most other months. Several factors may influence BOD concentrations in Fish Creek. BOD concentrations in the Creek are positively correlated with concentrations of fecal coliform bacteria, *E. coli*, and some nutrients such as nitrate, and total phosphorus. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the Creek.

Chloride

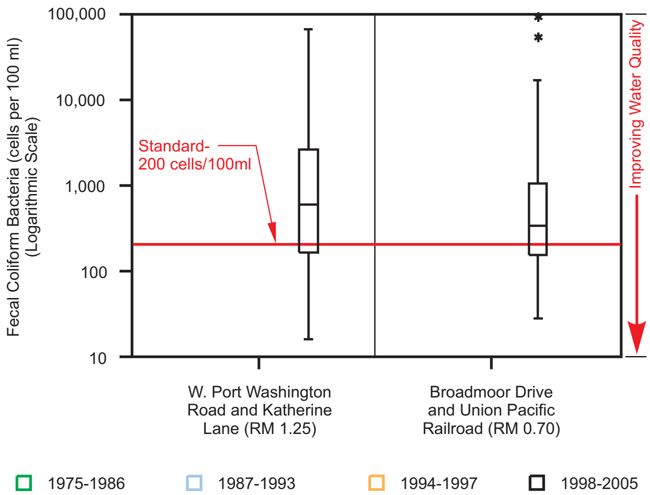
The mean chloride concentration in Fish Creek for the period of record was 250.0 mg/l. Both sampling sites show wide variations between minimum and maximum values. Figure 310 shows that concentrations of chloride tend to be more variable at the upstream sampling station at W. Port Washington Road and Katherine Lane. Chloride concentrations in Fish Creek show strong positive correlations with alkalinity and specific conductance, parameters which, like chloride, measure amounts of dissolved material in water.

Dissolved Oxygen

During the period 2002-2005, the mean concentration of dissolved oxygen in Fish Creek was 8.2 mg/l. Concentrations of dissolved oxygen in the Creek ranged from 4.0 mg/l to 12.4 mg/l. Figure 311 shows the distributions of dissolved oxygen concentrations at the two sampling stations along the Creek. Dissolved oxygen concentrations tended to be higher at the station at Broadmoor Drive and the Union Pacific Railroad than at the station farther upstream. At both stations, dissolved oxygen concentrations occasionally dropped below the standard for fish and aquatic life of 5.0 mg/l. Figure 312 shows that dissolved oxygen concentrations in Fish Creek decline through spring to reach a minimum during the summer. They then rise though the fall. This seasonal pattern is driven by changes in water temperature. The solubility of oxygen in water decreases with increasing temperature. In addition, the metabolic demands and oxygen requirements of most aquatic organisms, including bacteria, tend to increase with increasing temperature. Higher rates of bacterial decomposition when the

Figure 301

FECAL COLIFORM BACTERIA AT SITES ALONG FISH CREEK: 2002-2005

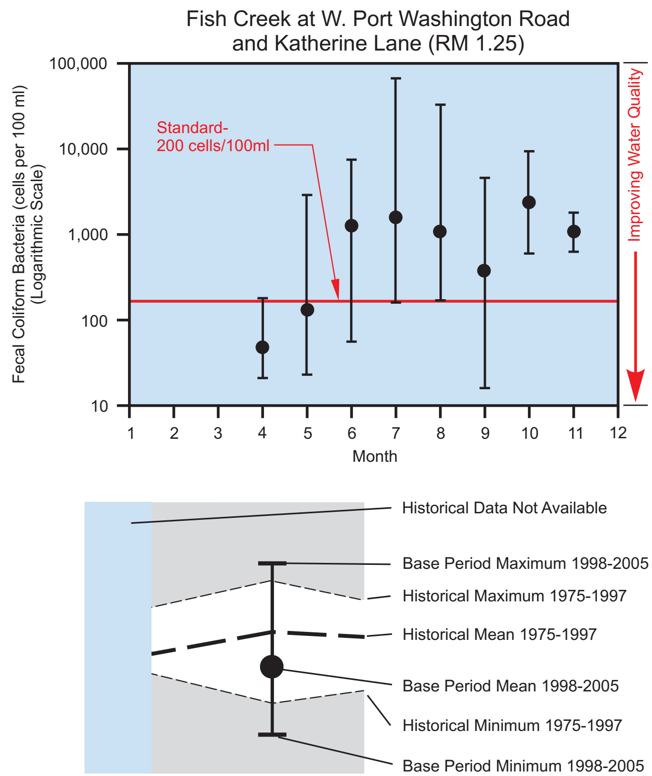


NOTE: See Figure 279 for description of symbols.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 302

HISTORICAL AND BASE PERIOD FECAL COLIFORM BACTERIA IN FISH CREEK: 1975-2005



NOTE: Consistent with the convention adopted for the data analyses presented in this report, the base period is defined as the time period from 1998-2005; however, for Fish Creek, no data are available prior to 2002.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

water is warm may contribute to the declines in the concentration of dissolved oxygen observed during the summer. Dissolved oxygen concentrations in water can be affected by numerous other factors including the presence of aquatic plants, sunlight, and the amount of and type of sediment as summarized in the Water Quality Indicators section in Chapter II of this report.

Hardness

Over the period of record, the mean hardness in Fish Creek was 287.6 mg/l as $CaCO_3$. On a commonly used scale, this is considered to be very hard water.[23] The range of the data runs from 72.0 to 480.0 mg/l as $CaCO_3$, showing considerable variability. Some of this variability probably results from inputs of relatively soft water during storm events.

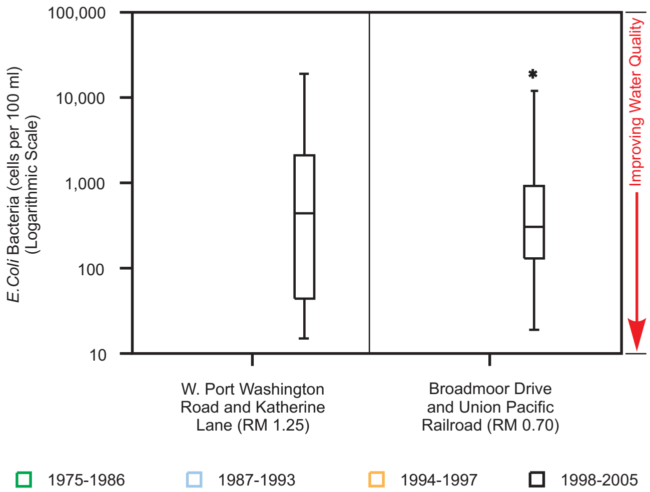
pH

The mean pH in Fish Creek over the period 2002-2005 was 7.7 standard units. The mean values at the upstream and downstream sampling stations were 7.6 and 7.7 standard units respectively. At these stations, pH varied only

[23]*E. Brown, M.W. Skougstad, and M.J. Fishman,* Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, *U.S. Department of Interior, U.S. Geological Survey, 1970.*

Figure 303

***E. COLI* BACTERIA CONCENTRATIONS AT SITES ALONG FISH CREEK: 2002-2005**

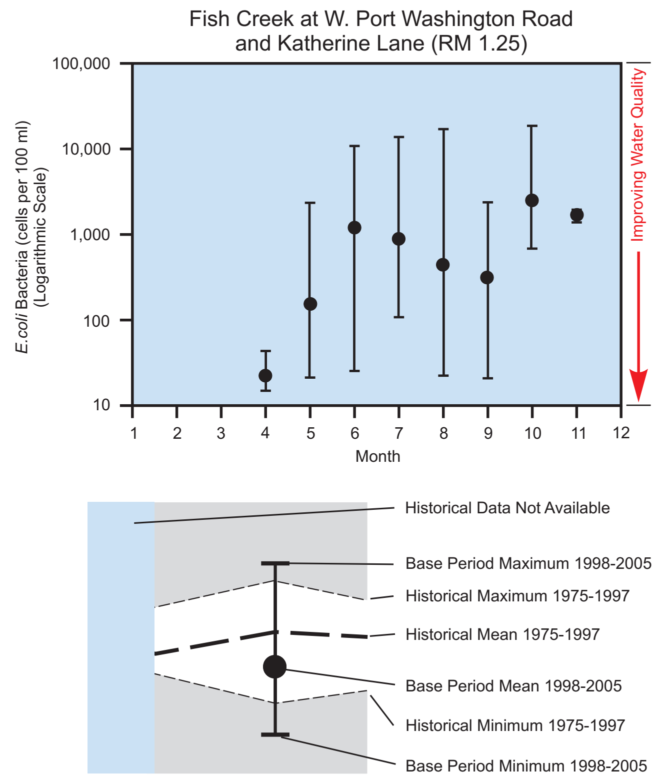


NOTE: See Figure 279 for description of symbols.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 304

HISTORICAL AND BASE PERIOD *E. COLI* BACTERIA IN FISH CREEK: 1975-2005



NOTE: Consistent with the convention adopted for the data analyses presented in this report, the base period is defined as the time period from 1998-2005; however, for Fish Creek, no data are available prior to 2002.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

by about ±0.5 standard unit from the stations' mean values. Positive correlations are seen between pH and alkalinity, both measures of material dissolved in water.

Specific Conductance

The mean value for specific conductance in Fish Creek over the period 2002-2005 was 1,295 microSiemens per centimeter (μS/cm). Considerable variability was associated with this mean. Specific conductance ranged from 252 μS/cm to 2,100 μS/cm. Some of this variability may reflect the discontinuous nature of inputs of dissolved material into the Creek. Runoff associated with storm events can have a major influence on the concentration of dissolved material in the Creek. The first runoff from a storm event transports a large pulse of salts and other dissolved material from the watershed into the Creek. This will tend to raise specific conductance in the Creek. Later runoff associated with the event will be relatively dilute. This will tend to lower specific conductance. Specific conductance in Fish Creek shows strong positive correlations with chloride, a parameter which, like specific conductance, measures amounts of dissolved material in water.

Suspended Material

The mean value for total suspended solids (TSS) concentration in Fish Creek over the period 2002-2005 was 25.5 mg/l. Considerable variability was associated with this mean, with values ranging from 1.6 to 660 mg/l. Figure 313 shows that TSS concentrations tend to be higher at the sampling station at Broadmoor Drive and the Union Pacific Railroad than at the station at W. Port Washington Road and Katherine Lane.

Nutrients

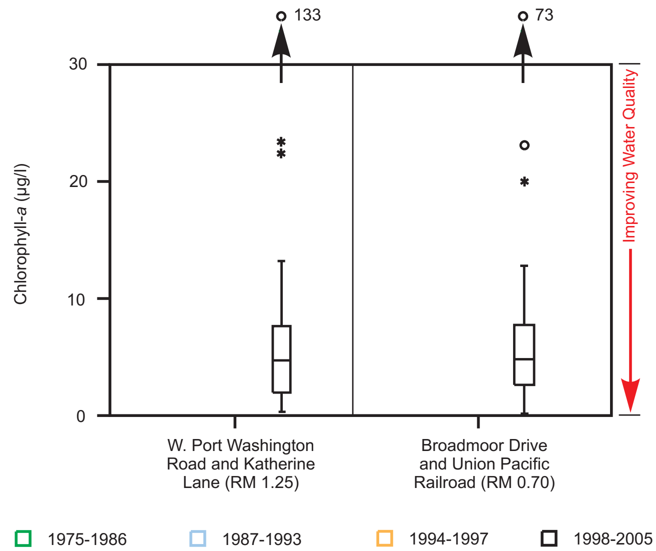
Nitrogen Compounds

The mean concentration of total nitrogen in Fish Creek over the period 2002-2005 was 1.53 milligrams per liter measured as nitrogen (mg/l as N). Concentrations ranged from 0.37 to 3.92 mg/l as N. Figure 314 shows that total nitrogen concentrations tended to be higher at the station at W. Port Washington Road and Katherine Lane, which is farther upstream, than at the station at Broadmoor Drive and the Union Pacific Railroad. The concentration of total nitrogen in Fish Creek is positively correlated with the concentrations of nitrate, nitrite, and organic nitrogen, reflecting the fact that these tend to be the major forms of nitrogen compounds in the Creek.

Total nitrogen is a composite measure of several different compounds which vary in their availability to algae and aquatic plants and vary in their toxicity to aquatic organisms. Common constituents of total nitrogen include ammonia, nitrate, and nitrite. In addition a large number of nitrogen-containing organic compounds, such as amino acids, nucleic acids, and proteins commonly occur in natural waters. These compounds are usually reported as organic nitrogen.

Figure 305

CHLOROPHYLL-*a* CONCENTRATIONS AT SITES ALONG FISH CREEK: 2002-2005



NOTE: See Figure 279 for description of symbols.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

The mean concentration of ammonia in Fish Creek was 0.08 mg/l as N. Over the period 2002-2005, ammonia concentrations varied from below the limit of detection to 1.10 mg/l as N. Figure 315 shows ammonia concentrations at the two sampling stations along Fish Creek. The median concentration of ammonia was slightly lower at the station farther downstream. Ammonia concentrations in Fish Creek tend to be highest and most variable during November. Ammonia concentrations in the Creek are positively correlated with concentrations of nitrate, nitrite, and total phosphorus. This may reflect common sources and modes of transport into the Creek for these pollutants.

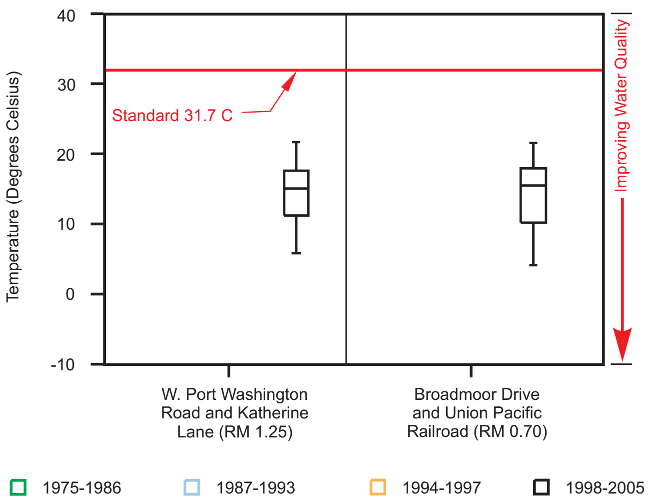
The mean concentration of nitrate in Fish Creek for the period 2002-2005 was 0.43 mg/l as N. During this time, concentrations in the Creek varied from 0.01 mg/l as N to 5.76 mg/l as N. Concentrations of nitrate tended to be higher at the sampling station at W. Port Washington Road and Katherine Lane which is farther upstream than the other station. Nitrate concentrations in Fish Creek were positively correlated with concentrations of ammonia and total nitrogen. The correlation with ammonia may reflect common sources and modes of transport into the Creek for these pollutants. The correlation with total nitrogen reflects the fact that nitrate is one of the major forms of nitrogen compounds in the Creek.

The mean concentration of nitrite in Fish Creek was 0.020 mg/l as N over the period of record. Nitrite concentrations showed more variability than nitrate. This probably reflects the fact that nitrite in oxygenated water tends to oxidize to nitrate fairly quickly. Nitrite concentrations in the Creek ranged from below the limit of detection to 0.110 mg/l as N. Nitrite concentrations in Fish Creek tend to be highest during the summer. Nitrite concentrations in the Creek are positively correlated with concentrations of ammonia, BOD, and total phosphorus. This may reflect common sources and modes of transport into the Creek for these pollutants. Nitrite concentrations were also positively correlated with concentrations of total nitrogen.

During the period 2002-2005 the mean concentration of organic nitrogen in Fish Creek was 0.98 mg/l as N. This parameter showed moderate variability with concentrations ranging from undetectable to 3.21 mg/l as N.

Figure 306

WATER TEMPERATURE AT SITES ALONG FISH CREEK: 2002-2005

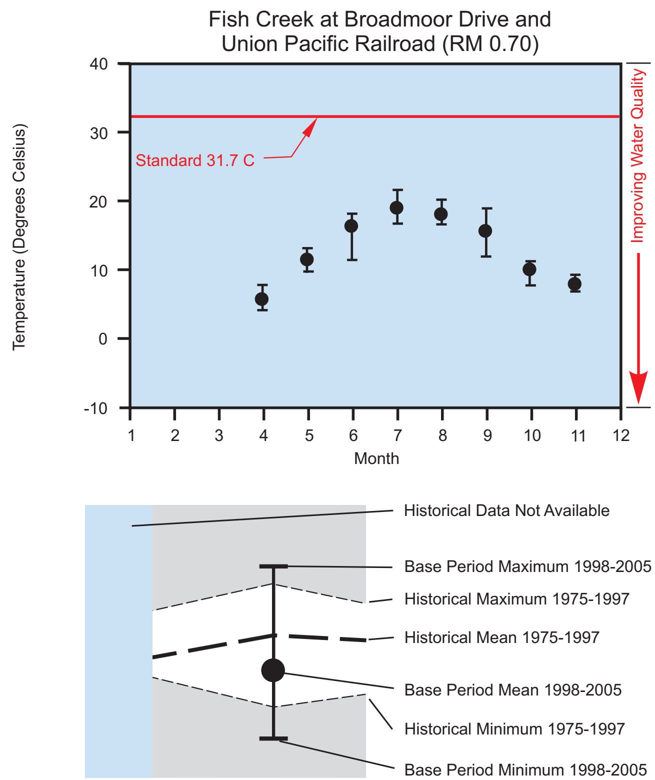


NOTE: See Figure 279 for description of symbols.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 307

HISTORICAL AND BASE PERIOD WATER TEMPERATURE IN FISH CREEK: 1975-2005



NOTE: Consistent with the convention adopted for the data analyses presented in this report, the base period is defined as the time period from 1998-2005; however, for Fish Creek, no data are available prior to 2002.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Concentrations of organic nitrogen tended to be similar at both sampling stations along the Creek. Organic nitrogen concentrations in the Creek were positively correlated with total nitrogen reflecting the fact that organic nitrogen is a major component of total nitrogen.

Several processes can influence the concentrations of nitrogen compounds in a waterbody. Primary production by plants and algae will result in ammonia, nitrite, and nitrate being removed from the water and incorporated into cellular material. This effectively converts the nitrogen to forms which are detected only as total nitrogen. Decomposition of organic material in sediment can release nitrogen compounds to the overlying water. Bacterial action may convert some nitrogen compounds into others.

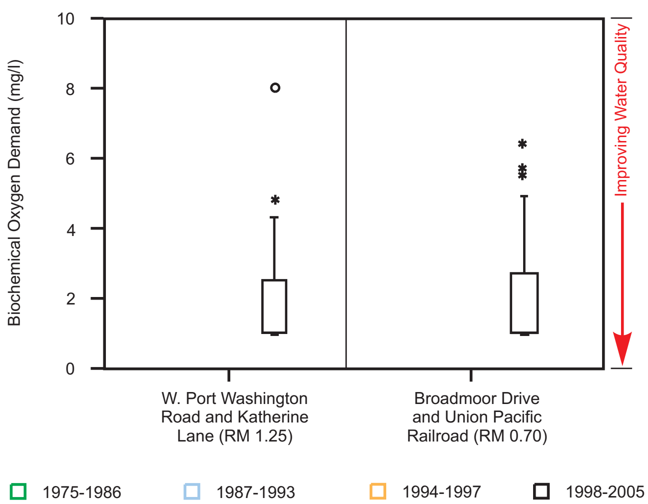
Total and Dissolved Phosphorus

Two forms of phosphorus are commonly sampled in surface waters: dissolved phosphorus and total phosphorus. Dissolved phosphorus represents the form that can be taken up and used for growth by algae and aquatic plants. Total phosphorus represents all the phosphorus contained in material dissolved or suspended within the water, including phosphorus contained in detritus and organisms and attached to soil and sediment.

The mean concentration of total phosphorus in Fish Creek during the period 2002-2005 was 0.120 mg/l, and the mean concentration of dissolved phosphorus in Fish Creek over the same period was 0.063 mg/l. Total

Figure 308

BIOCHEMICAL OXYGEN DEMAND AT SITES ALONG FISH CREEK: 2002-2005

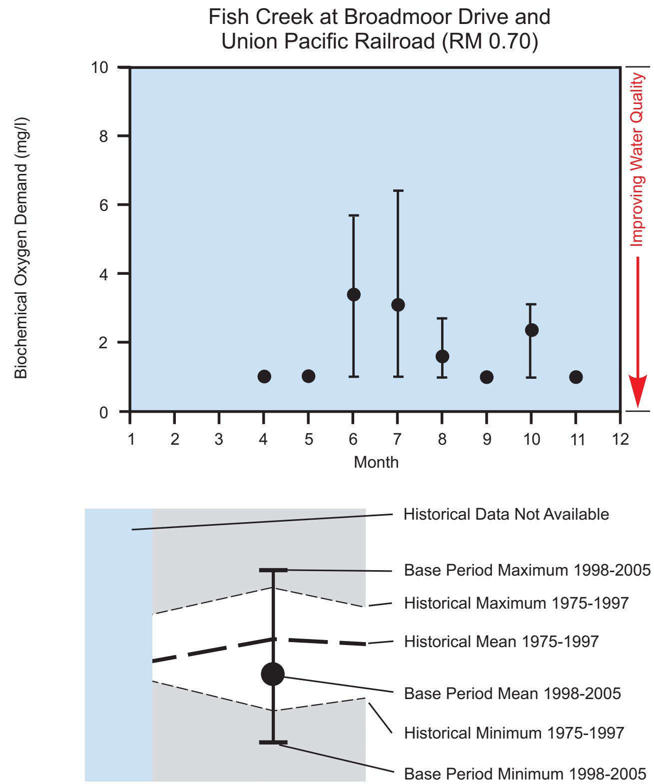


NOTE: See Figure 279 for description of symbols.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 309

HISTORICAL AND BASE PERIOD BIOCHEMICAL OXYGEN DEMAND IN FISH CREEK: 1975-2005



NOTE: Consistent with the convention adopted for the data analyses presented in this report, the base period is defined as the time period from 1998-2005; however, for Fish Creek, no data are available prior to 2002.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

phosphorus concentrations varied over two orders of magnitude, ranging from 0.018 to 0.710 mg/l. Dissolved phosphorus concentrations varied over three orders of magnitude from 0.006 to 0.150 mg/l. At most sampling sites, the data showed moderate variability. Figure 316 shows that concentrations of total phosphorus tended to be similar at the two sampling stations along the Creek. Figure 317 shows base period monthly mean total phosphorus concentrations at one station along the Creek. Concentrations of total phosphorus tend to be lowest during the spring, rise rapidly to peak levels during the summer, and decline more slowly during the fall. A similar seasonal pattern was observed for concentrations of dissolved phosphorus. Total phosphorus concentrations were positively correlated with temperature. This correlation may reflect the role of phosphorus as a nutrient for algal growth. During periods of high algal productivity, algae remove dissolved phosphorus and nitrogen compounds from the water and incorporate them into cellular material. Because the rates of biological reactions are temperature dependent, these periods tend to occur when water temperatures are warmer. Concentrations of total phosphorus were also positively correlated with concentrations of BOD, fecal coliform bacteria, and *E. coli.* These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into the Creek.

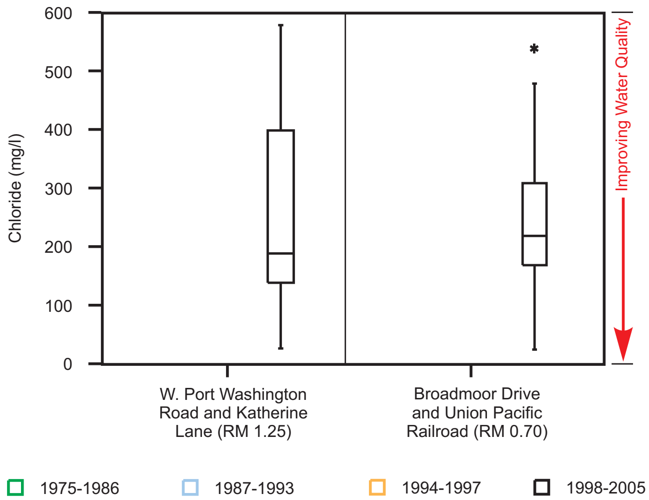
Metals

Arsenic

The mean value for the concentration of arsenic in the water of Fish Creek over the period 2002-2005 was 3.98 μg/l. The data ranged from below the limit of detection to 11.00 μg/l.

Figure 310

CHLORIDE CONCENTRATIONS AT SITES ALONG FISH CREEK: 2002-2005



NOTES: See Figure 279 for description of symbols.

The chloride planning standard of 1,000 mg/l is beyond the limits of the graph.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Cadmium
The mean concentration of cadmium in Fish Creek over the period 2002-2005 was 0.97 μg/l. Individual samples ranged from below the limit of detection to 1.70 μg/l.

Chromium
The mean concentration of chromium in Fish Creek over the period 2002-2005 was 4.3 μg/l. Individual sample concentrations ranged from below the limit of detection to 15.0 μg/l.

Copper
The mean concentration of copper in Fish Creek during the period 2002-2005 was 9.62 μg/l. Concentrations varied from 5.20 μg/l to 21.00 μg/l. Figure 318 shows that copper concentrations tended to be more variable at the downstream sampling station at Broadmoor Drive and the Union Pacific Railroad.

Lead
The mean concentration of lead in Fish Creek over the period 2002-2005 was 2.29 μg/l. Individual sample concentrations ranged from below the limit of detection to 14.0 μg/l.

Mercury
The mean concentration of mercury in Fish Creek over the period 2002-2005 was 0.027 μg/l. Mercury concentrations ranged from below the limit of detection to 0.039 μg/l.

Nickel
The mean concentration of nickel in Fish Creek over the period 2002-2005 was 5.9 μg/l. Concentrations in individual samples ranged from below the limit of detection to 22.0 μg/l. The mean concentration of nickel at the sampling station at Broadmoor Road and the Union Pacific Railroad, the station farther downstream, was more than twice the mean concentration detected at the sampling station at W. Port Washington Road and Katherine Lane. Because of the small number of samples, it is not clear whether this represents a longitudinal trend along the Creek or is the result of random statistical variation.

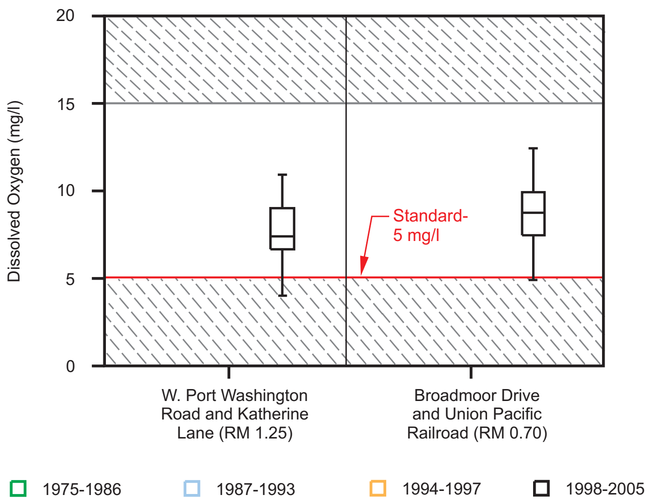
Zinc
The mean concentration of zinc in Fish Creek during the period of record was 22.8 μg/l. Concentrations in individual samples ranged from 7.8 μg/l to 75.0 μg/l. Figure 319 shows that zinc concentrations tended to be more variable at the downstream sampling station at Broadmoor Drive and the Union Pacific Railroad.

Organic Compounds
No data were available on concentrations of organic compounds in streams of the Lake Michigan direct drainage area.

Pharmaceuticals and Personal Care Products
No data were available on concentrations of pharmaceuticals and personal care products in streams of the Lake Michigan direct drainage area.

Figure 311

DISSOLVED OXYGEN CONCENTRATIONS AT SITES ALONG FISH CREEK: 2002-2005



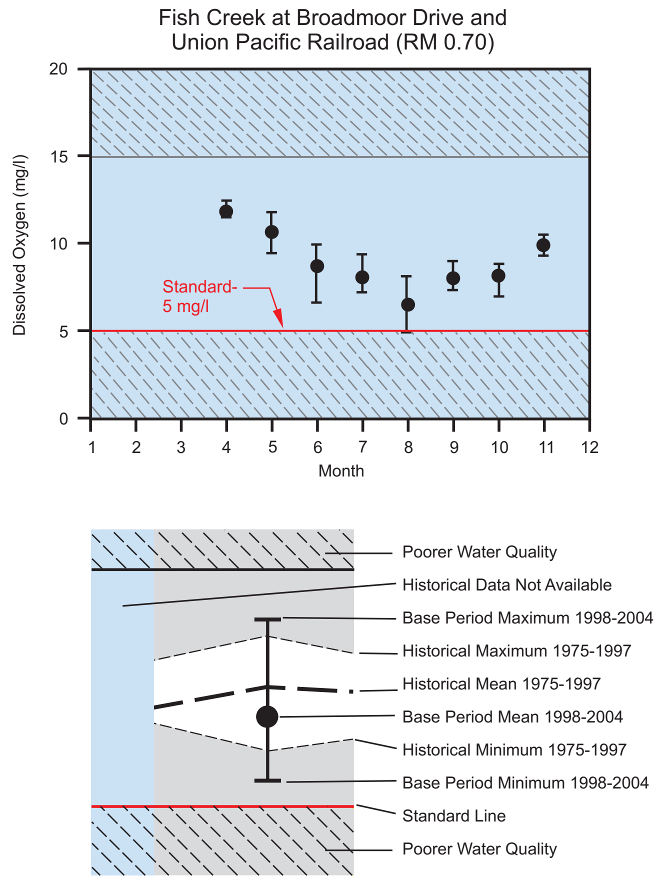
NOTES: See Figure 279 for description of symbols.

140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 312

HISTORICAL AND BASE PERIOD DISSOLVED OXYGEN IN FISH CREEK: 1975-2005



NOTES: 140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Consistent with the convention adopted for the data analyses presented in this report, the base period is defined as the time period from 1998-2005; however, for Fish Creek, no data are available prior to 2002.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

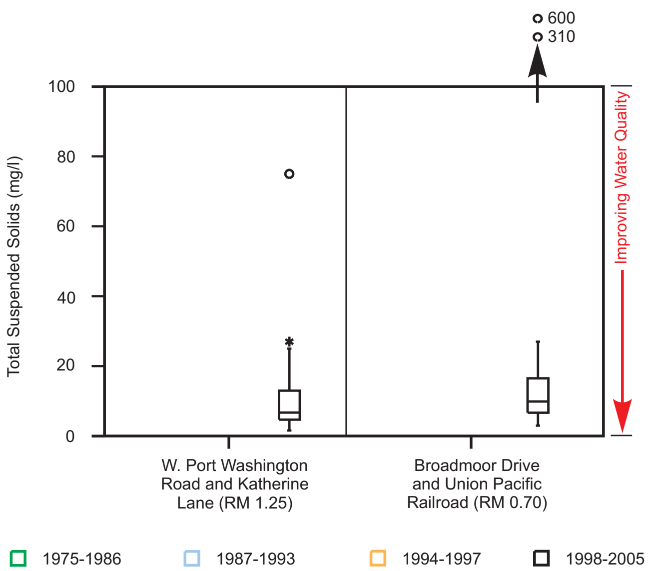
Water Quality at Lake Michigan Beaches

Beach Monitoring Programs

While Wisconsin does not have a statewide mandatory monitoring program for Great Lakes public beaches, a number of Lake Michigan communities, including the Cities of Milwaukee and Racine, have monitored the water quality at their beaches for decades. In 1999, the City of Milwaukee Health Department received a grant from the USEPA Environmental Monitoring for Public Access for Community Tracking program to expand beach monitoring in the Milwaukee-Racine area and to improve public notification and outreach. In 2003, with annual grants available through the Federal Beach Act of 2000, the WDNR began the implementation of the Wisconsin Beach Monitoring Program. This program is a collaborative effort between State and local environmental and health agencies to monitor recreational waters for health risks to help people make informed choices when they go to beaches. The WDNR coordinates the programs, but the local health departments have authority over public beaches within their jurisdictions. This program also set forth standard performance criteria for sampling and monitoring, notifying the public of exceedances of the water quality standard for *E. coli*, and reporting. Adherence

Figure 313

CONCENTRATIONS OF TOTAL SUSPENDED SOLIDS (TSS) AT SITES ALONG FISH CREEK: 2002-2005



NOTE: See Figure 279 for description of symbols.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

to the program performance criteria is required for all participants in the program. In 2005, the City of Milwaukee Health Department, the City of Racine Health Department, the Shorewood/Whitefish Bay Health Department, the South Milwaukee Health Department, and the North Shore Health Department participated in the program. The latter agency serves the City of Glendale and the Villages of Brown Deer, Fox Point, and River Hills. In addition, the Ozaukee County Health Department also participated, though they did not monitor any public beaches within the Lake Michigan direct drainage area.

The USEPA recommends using either *E. coli* or enterococci as indicators of fecal pollution in recreational waters for freshwater systems. Agencies participating in the Wisconsin Beach Monitoring Program use *E. coli.* All warm-blooded animals have *E. coli* in their feces. Because of this, the presence of high concentrations of *E. coli* in beach water indicates a high probability of the presence of fecal contamination. While some strains of this bacterium are associated with food poisoning, most strains have a low probability of causing illness in swimmers. Instead, *E. coli* acts as an indicator of the possible presence of other pathogenic agents in water. Examples of these disease causing agents are given in Table 192. While the presence of high concentrations of *E. coli* does not necessarily indicate the presence of pathogenic agents, *E. coli* is generally found when the pathogenic agents are found.

For beaches monitored under the Wisconsin Beach Monitoring Program, advisories are issued and beaches are closed when standards developed by the USEPA in the late 1970s are exceeded.[24] Water quality advisories are issued for beaches whenever the concentration of *E. coli* in a single sample exceeds 235 cells per 100 ml or when the geometric mean of at least five samples taken over a 30-day period exceeds 126 cells per 100 ml. Beaches are closed whenever the concentration of *E. coli* in water exceeds 1,000 cells per 100 ml. The epidemiological studies used in the development of the standards indicated that these concentrations represented levels of approximately eight cases of gastrointestinal illness per 1,000 recreational water users and 14 cases of gastrointestinal illness per 1,000 recreational water users, respectively. Beaches are also closed after a significant rainfall event that is determined to impact the beach area, after a major pollution event where there is the potential for *E. coli* to exceed the standard, or whenever a human health hazard exists as determined by the local health department.

The Wisconsin Beach Monitoring Program has implemented a tiered monitoring approach to sampling requirements for monitored beaches. Monitoring requirements vary depending on whether a beach is considered high, medium, or low priority. For all monitored beaches, sampling is required to begin at least one week prior to the swimming season. In 2005, high-priority beaches were required to be sampled at least four times per week during the swimming season. This requirement was increased to five times per week in 2006. In both of these years, medium-priority beaches were required to be sampled at least two times per week. The sampling frequency at

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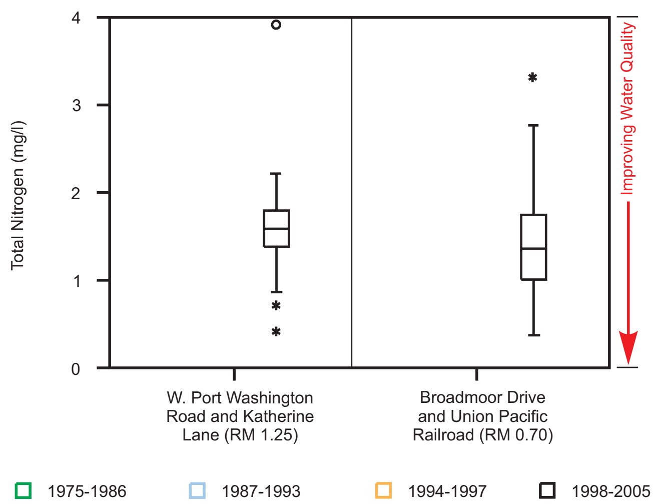
[24] *V.J. Cabelli,* Health Effects Criteria for Marine Recreational Waters, *USEPA EPA-600/1-80-031, 1983; USEPA,* Health Effects Criteria for Fresh Recreational Waters, *EPA-600/1-84-002, 1984; USEPA,* Ambient Water Quality Criteria for Bacteria-1986, *EPA-440/5-84-002, 1986.*

Figure 314

TOTAL NITROGEN CONCENTRATIONS AT SITES ALONG FISH CREEK: 2002-2005

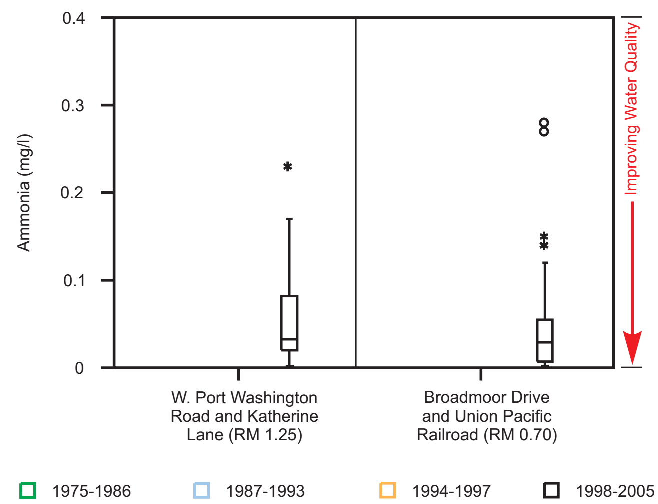


NOTE: See Figure 279 for description of symbols.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 315

AMMONIA CONCENTRATIONS AT SITES ALONG FISH CREEK: 2002-2005



NOTE: See Figure 279 for description of symbols.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

low-priority beaches is determined on a case-by-case basis by State and local authorities, taking into account resource constraints and risk factors at each low-priority beach. Additional sampling is required at all monitored beaches after the occurrence of any major pollution event where potential exists for indicator levels to exceed the standard and immediately following any exceedance of the water quality standards. Additional sampling is also required at high- and medium-priority beaches after heavy rainfall. Samples are required to be collected in the middle of the typical bathing area of the beach. For longer high- and medium-priority beaches, one sample is required for every 500 meters of beach. Three beaches in the study area, Bradford Beach in Milwaukee County and North Beach and Zoo Beach in Racine County, fall into this category. In addition, the rocky area at South Shore Beach in Milwaukee County has been monitored since 2004.

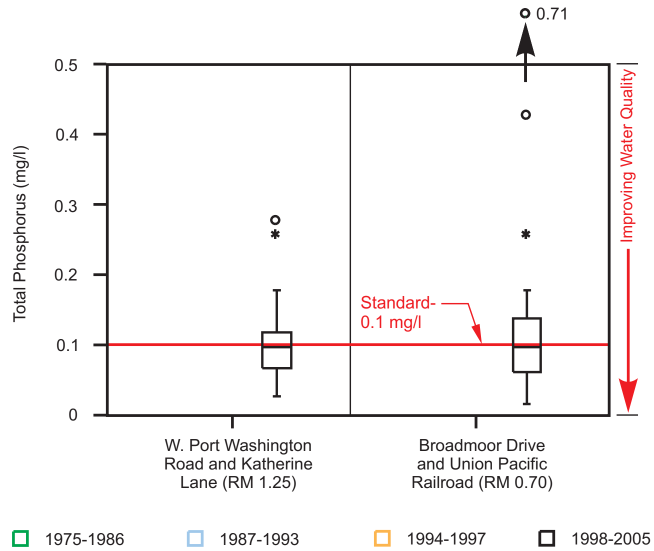
Map 121 shows the public beaches along Lake Michigan in the Lake Michigan direct drainage area. In 2000, concentrations of *E. coli* were monitored at seven out of 20 beaches in this area. By 2005 the number of monitored beaches in the area increased to 12. Six of the beaches monitored in 2005, Bradford Beach, McKinley Beach, South Shore Beach, and Watercraft Beach in Milwaukee County and North Beach and Zoo Beach in Racine County were considered high-priority beaches. The other monitored beaches in the area were considered medium priority.

Beach Closures and Water Quality Advisories

Figure 320 shows the number of days that Lake Michigan beaches were closed or under water quality advisories during the years 1999-2005. Combining closings and advisories into one number gives a more representative measure of beach water quality because, prior to the standardization that accompanied implementation of the Wisconsin Beach Monitoring Program in 2003, different jurisdictions used different standards and criteria for closing beaches. The mean number of days per beach season that individual beaches were closed or under a water quality advisory was 21.7. There was considerable variation among beaches as to how often they were closed or under a water quality advisory. For example, Bay View Park Beach had a mean number of days per beach season of closure or advisory of 4.0 over the years 2004-2005. Similarly, Bender Park Beach had a mean number of days per beach season of closure or advisory of 7.7 over the years 2003-2005. By contrast, South Shore Beach had a mean number of days per beach season of closure or advisory of 54.2 over the years 2000-2005. Three beaches,

Figure 316

TOTAL PHOSPHORUS CONCENTRATIONS AT SITES ALONG FISH CREEK: 2002-2005

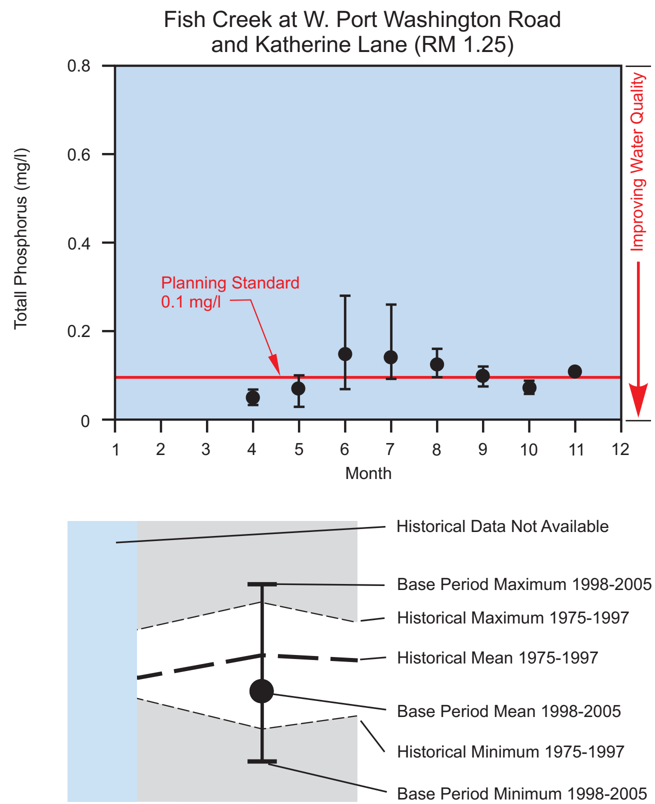


NOTE: See Figure 279 for description of symbols.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 317

HISTORICAL AND BASE PERIOD CONCENTRATIONS OF TOTAL PHOSPHORUS AT SITES ALONG FISH CREEK: 2002-2005



NOTE: Consistent with the convention adopted for the data analyses presented in this report, the base period is defined as the time period from 1998-2005; however, for Fish Creek, no data are available prior to 2002.

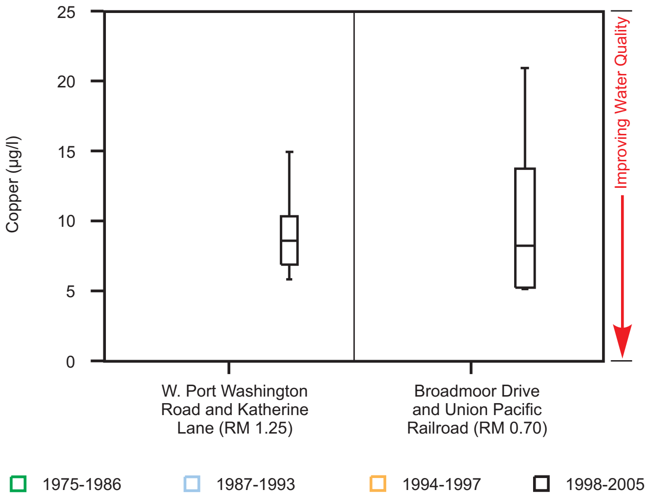
Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Bradford Beach, McKinley Beach, and South Shore Beach, showed marked increases in the number of days of closure or advisory after 2003. By contrast, Atwater Beach and Klode Park Beach showed decreases in the number of days of closure or advisory after 2002. After 2002, decreases were also seen at Watercraft and Grant Park Beaches, although the numbers of closings in 2005 at these beaches were similar to the numbers in 2001.

Figure 321 shows *E. coli* concentrations at 12 Lake Michigan beaches and the rocky site at South Shore Beach. At every monitored beach, the single sample standard for issuing advisories of 235 cells per 100 ml was exceeded in each year for which data exist. At some beaches, the proportion of samples exceeding this standard was quite high. For example, in every year except 2003, *E. coli* concentrations at South Shore Beach exceeded this standard in 50 percent or more of the samples collected. The single sample standard for beach closure of 1,000 cells per 100 ml was also often exceeded. At most beaches, it was exceeded at least once in most years for which data are available. Figure 322 shows five-day geometric means of *E. coli* concentrations at 12 Lake Michigan beaches and the rocky site at South Shore Beach. At Doctors Park, Klode, Bradford, McKinley, and South Shore Beaches, the five-day geometric mean standard for issuing advisories of 126 cells per 100 ml was commonly exceeded. At the other beaches the standard was occasionally exceeded. A few trends were apparent in the data. At most beaches, median *E. coli* concentrations were lower in 2005 than in 2004 (see Figure 321). There were three exceptions to

Figure 318

COPPER CONCENTRATIONS AT SITES ALONG FISH CREEK: 2002-2005

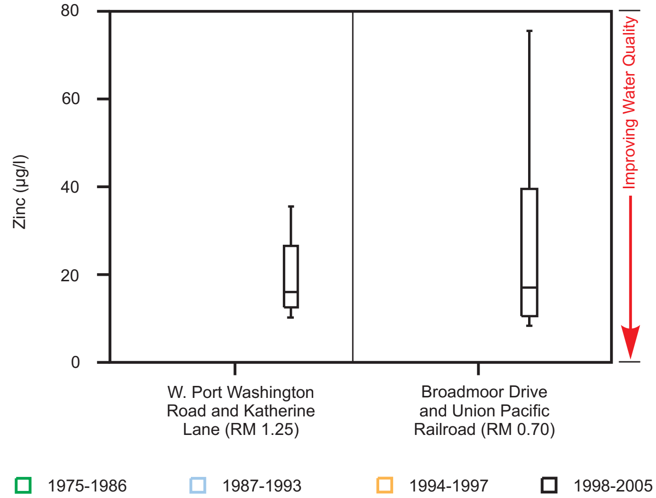


NOTE: See Figure 279 for description of symbols.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 319

ZINC CONCENTRATIONS AT SITES ALONG FISH CREEK: 2002-2005



NOTE: See Figure 279 for description of symbols.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

this generalization. Median *E. coli* concentrations at Doctors Park Beach, the rocky site at South Shore beach, and Bender Park Beach in 2005 were similar to, or higher than, median concentrations in 2004. At four beaches, Atwater Beach, Bradford Beach, McKinley Beach, and Bender Beach, concentrations of *E. coli* have increased over time. By contrast concentrations of *E. coli* at Klode Park Beach appear to have decreased. No trends over time were apparent at Doctors Park Beach, South Shore Beach, Grant Park Beach, Zoo Beach, or North Beach. At South Shore Beach, concentrations of *E. coli* at the shoreline were compared to concentrations 10 meters and 150 meters offshore. On both dry and rainy days, concentrations at the shoreline were higher than concentrations offshore.[25]

Sources of Bacterial Contamination to Lake Michigan Beaches

Several potential sources of contamination have been suggested as contributing to the high concentrations of *E. coli* detected at Lake Michigan beaches. The potential sources of contamination cited include overflows from combined and sanitary sewers, discharges of stormwater from outfalls near beaches, runoff from parking lots and other impervious areas adjacent to beaches, mobilization of *E. coli* from reservoirs in sand and sediment, contributions of *E. coli* from wildlife visiting or residing at beaches or in adjacent areas, and mobilization from reservoirs in algal mats on beaches or in nearshore waters. It is important to note that beach closings and advisories are not always related to elevated bacteria concentrations. When they are, the source of the bacteria causing the closing or advisory is not always obvious.

Combined Sewer Overflows and Sanitary Sewer Overflows (SSO)

High concentrations of *E. coli* and the resulting water quality advisories and beach closures have popularly been attributed to overflows from combined and sanitary sewers. Several lines of evidence suggest that while sewer overflows can affect water quality at some of the Lake Michigan Beaches, they may not currently be the major factor driving trends in beach water quality. First, there was not a strong correspondence between timing of

[25]*S.L. McLellan and A.K. Salmore, "Evidence for Localized Bacterial Loading as the Cause of Chronic Beach Closings in a Freshwater Marina,"* Water Research*, Volume 37, 2003.*

Table 192

PATHOGENS AND ILLNESSES ASSOCIATED WITH SWIMMING

Pathogenic Agent	Diseases
Bacteria	
Aeromonas hydrophilla	Dysenteric illnesses, gastroenteritis, septicemia, wound infections
Campylobacter jejuni	Gastroenteritis
Escherichia coli	Gastroenteritis
Helicobacter pylori	Chronic and severe inflammation of the stomach
Salmonella typhi	Typhoid fever
Salmonella spp.	Enteric fevers, gastroenteritis, septicemia
Shigella dysenteriae	Bacterial dysentery
Vibrio cholera	Cholera
Yersinia spp.	Gastroenteritis
Protozoa	
Balantidium coli	Dysentery, intestinal ulcers
Cryptosporidium parvum	Gastroenteritis
Cyclospora spp.	Gastroenteritis
Entamoeba histolytica	Amoebic dysentery, infections of other organs
Giardia lambia	Diarrhea, intestinal parasite
Isospora belli	Intestinal parasite
Isospora hominis	Intestinal parasite
Toxoplasma gondii	Toxoplasmosis
Viruses	
Adenovirus	Conjunctivitis, gastrointestinal and respiratory infections
Calicivirus	Gastroenteritis
Coxsackievirus	Aseptic meningitis, fever, rash, myocarditis, severe respiratory disease
Echovirus[a]	Aseptic meningitis, fever, rash, myocarditis, severe respiratory disease
Hepatitis	Infectious hepatitis
Norwalkvirus	Gastroenteritis
Poliovirus	Poliomyelitis
Reovirus	Gastroenteritis
Rotavirus	Gastroenteritis

[a]*Evidence linking these viruses to these diseases is not definitive except in experimental animals.*

Source: Gunther F. Craun, Waterborne Diseases in the United States, *CRC Press, 1986; Natural Resources Defense Council,* Testing the Waters 2006: A Guide to Water Quality at Vacation Beaches, *2006; Kathy Pond,* Water Recreation and Disease*, World Health Organization, 2005; and SEWRPC.*

overflows and timing of beach closings and advisories. Figure 323 compares the timing of beach advisories at three Milwaukee beaches during 2000 to rainfall and combined sewer overflow events. In the figure, overflow events are indicated by gray shading, rainfall is indicated by blue bars, and the number of beaches closed or under water quality advisory is indicated by green dots. The timing of most beach water quality advisories in 2000 did not correspond to the timing of overflow events. Beach advisories occurred consistently throughout the season. In addition, some periods with high numbers of advisories occurred several weeks after the most recent overflow event. Given that *E. coli* die off fairly rapidly in Lake Michigan water, it is unlikely that the bacteria triggering these closures were contributed by overflows. Second, while surveys of *E. coli* taken in the inner and outer harbors and adjacent areas of Lake Michigan during CSO events did indicate some impact of those events on South Shore Beach, they showed little impact of CSO on *E. coli* concentrations at Bradford, McKinley, and Watercraft Beaches (see Map 119 and the discussion in the previous section on water quality of the Milwaukee Harbor estuary).[26] These surveys also found that *E. coli* during overflow events could not be detected at

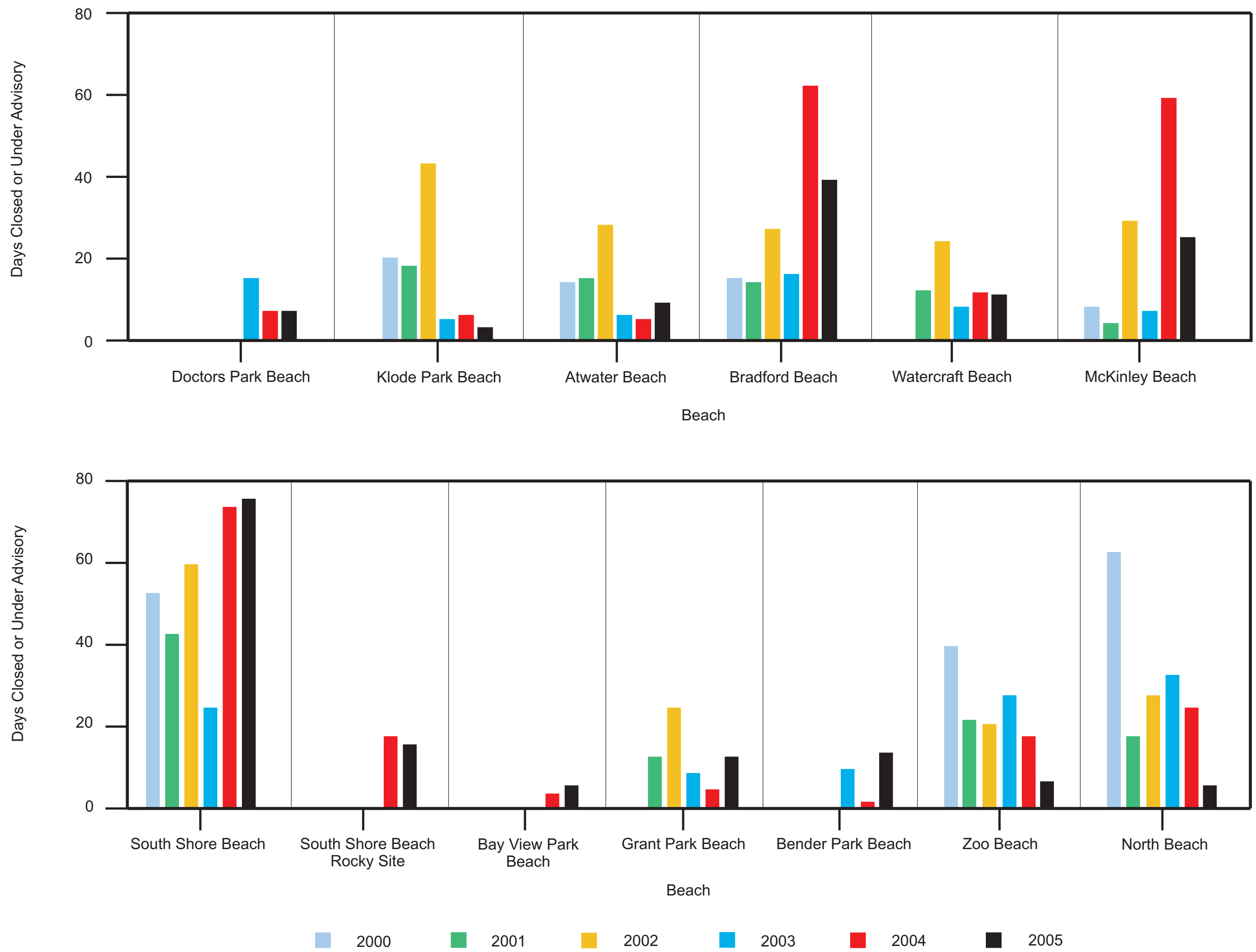
[26]*McLellan and Hollis, 2005,* op. cit.

Map 121

MONITORING OF BEACHES WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 2000-2005

Figure 320

CLOSINGS AND ADVISORIES AT LAKE MICHIGAN BEACHES: 2000-2005



Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, City of Milwaukee Health Department, City of Racine Health Department, and SEWRPC.

concentrations above 10 cells per 100 ml at distances greater than 3.1 miles from the harbor breakwall, suggesting that the impact of inputs from the harbor, including the impacts of CSOs and SSOs may be limited to those beaches that are relatively close to the harbor. Third, the results of a modeling study suggest that many of closures and advisories at Bradford, McKinley, and South Shore Beaches derived from other causes than inputs from the Rivers and overflow events.[27] That study modeled concentrations of fecal coliform bacteria as a surrogate for *E. coli*. The concentrations of fecal coliform bacteria at Bradford and McKinley Beaches calculated by the calibrated hydrologic and bacteria model for the May 2000 overflow events were consistent with the observed concentrations. For much of June and July of the same year, the concentrations of fecal coliform bacteria predicted by the model were less than the observed concentrations. Since the model only accounts for input of bacteria from the Kinnickinnic, Menomonee, and Milwaukee Rivers, CSOs, SSOs, and wastewater treatment plants, this

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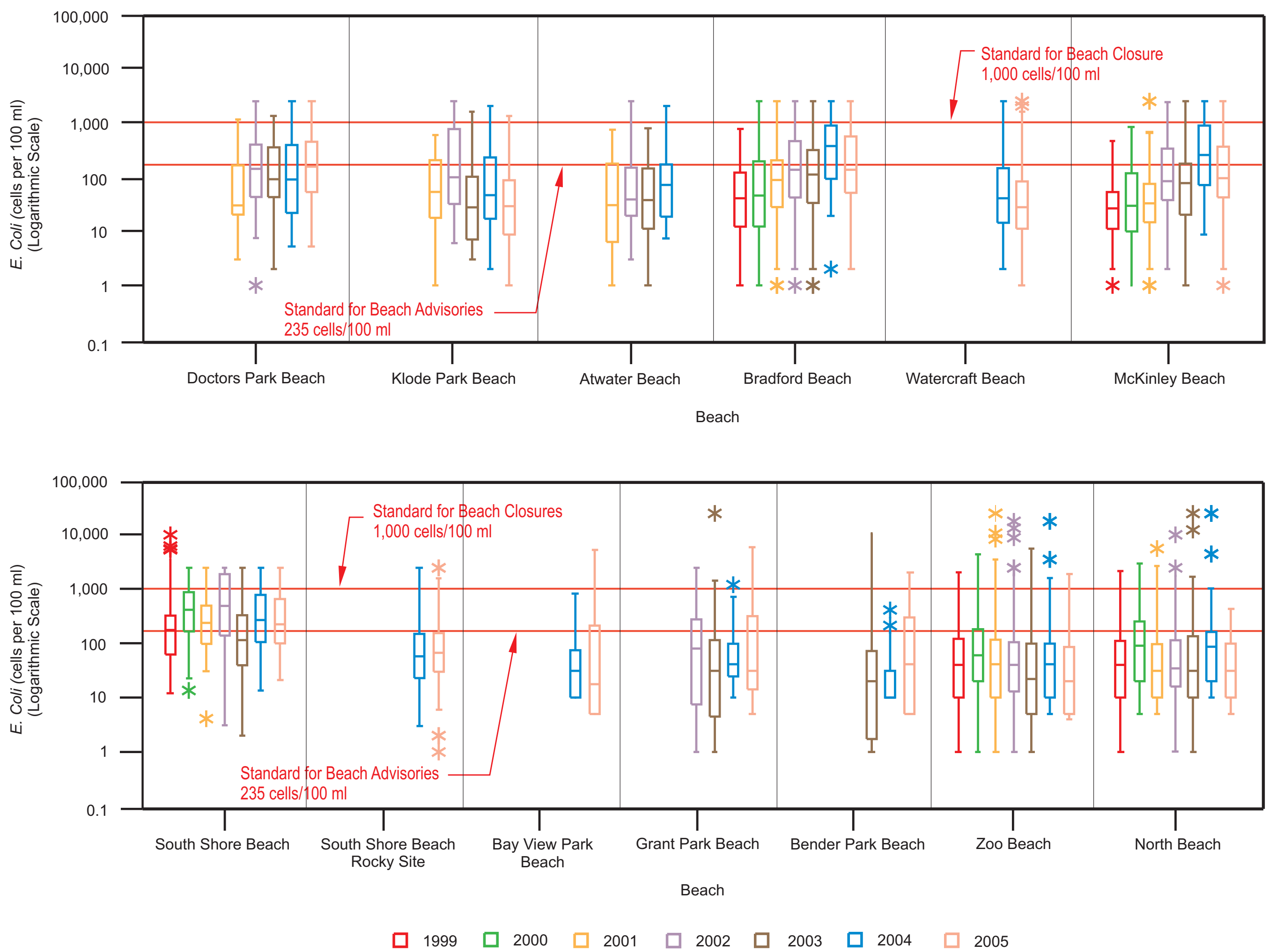
[27]*HydroQual, Inc. and Camp Dresser McKee,* Milwaukee Harbor Estuary Hydrodynamic & Bacteria Modeling Report, *Bacteria Source, Transport and Fate Study—Phase 1, August 2005.*

Figure 321

CONCENTRATIONS OF *E. COLI* AT LAKE MICHIGAN BEACHES: 1999-2005



NOTE: See Figure 279 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, City of Milwaukee Health Department, City of Racine Health Department, and SEWRPC.

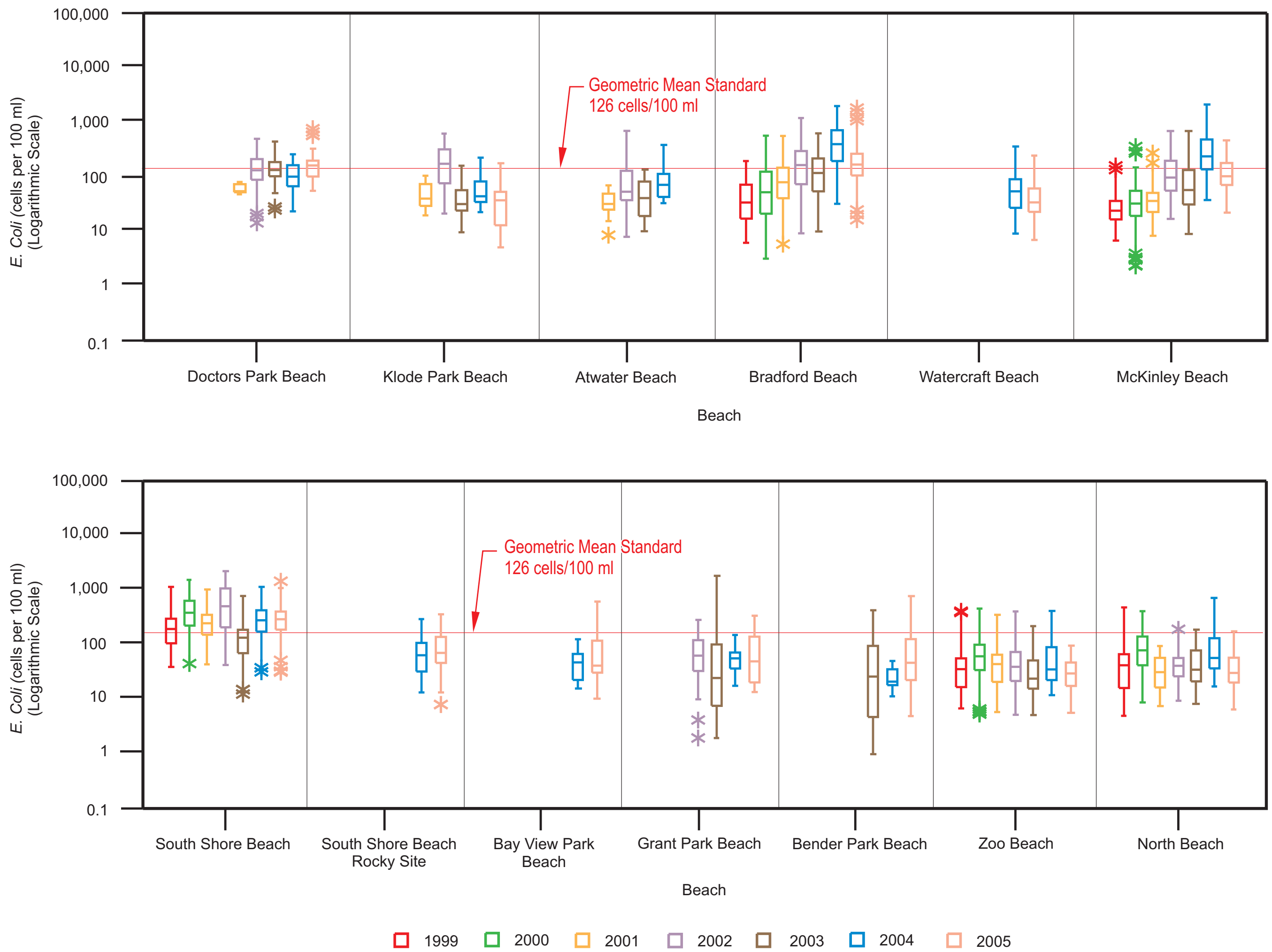
suggests that many of the advisories seen during June and July 2000 resulted from locally derived sources not accounted for in the model. The model also indicated that fecal coliform bacteria concentrations in the northern and southern portions of the model domain were typically less than 100 cells per 100 ml, suggesting that bacteria impacts north of Fox Point and south of Wind Point are not due to Milwaukee-derived sources. The study concluded that bacterial loads from the Rivers and from overflows can have an impact at Bradford, McKinley, and South Shore Beaches, but that these impacts are related to short-duration storm and overflow events and that they have a time period on the order of five days.

Stormwater Runoff

Inputs of stormwater from outfalls discharging over or near beaches can affect water quality at beaches. High concentrations of bacteria have been detected in discharges from stormwater outfalls. In one study, concentrations of *E. coli* in samples collected during 2003 through 2005 from 70 inline sampling stations and stormwater outfalls

Figure 322

FIVE-DAY GEOMETRIC MEAN CONCENTRATIONS OF *E. COLI* AT LAKE MICHIGAN BEACHES: 1999-2005



NOTE: See Figure 279 for description of symbols.

Source: U.S. Geological Survey, U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, City of Milwaukee Health Department, City of Racine Health Department, and SEWRPC.

in the Milwaukee area ranged from below the limit of detection to over 2,500,000 cells per 100 ml.[28] The same study reported that over 13 percent of 56 stormwater outfalls tested in the Milwaukee area demonstrated concentrations of *E. coli* over 100,000 cells per 100 ml. Concentrations of *E. coli* in samples from seven stormwater outfalls discharging to Bradford Beach ranged from 110 cells per 100 ml to 55,000 cells per 100 ml.[29] Concentrations of *E. coli* in 67 percent of the samples from these outfalls were over the 235 cells per 100 ml standard for issuing water quality advisories. Studies by the City of Racine Health Department found that a storm sewer outfall discharging directly onto North Beach and Zoo Beach was providing a significant bacterial burden

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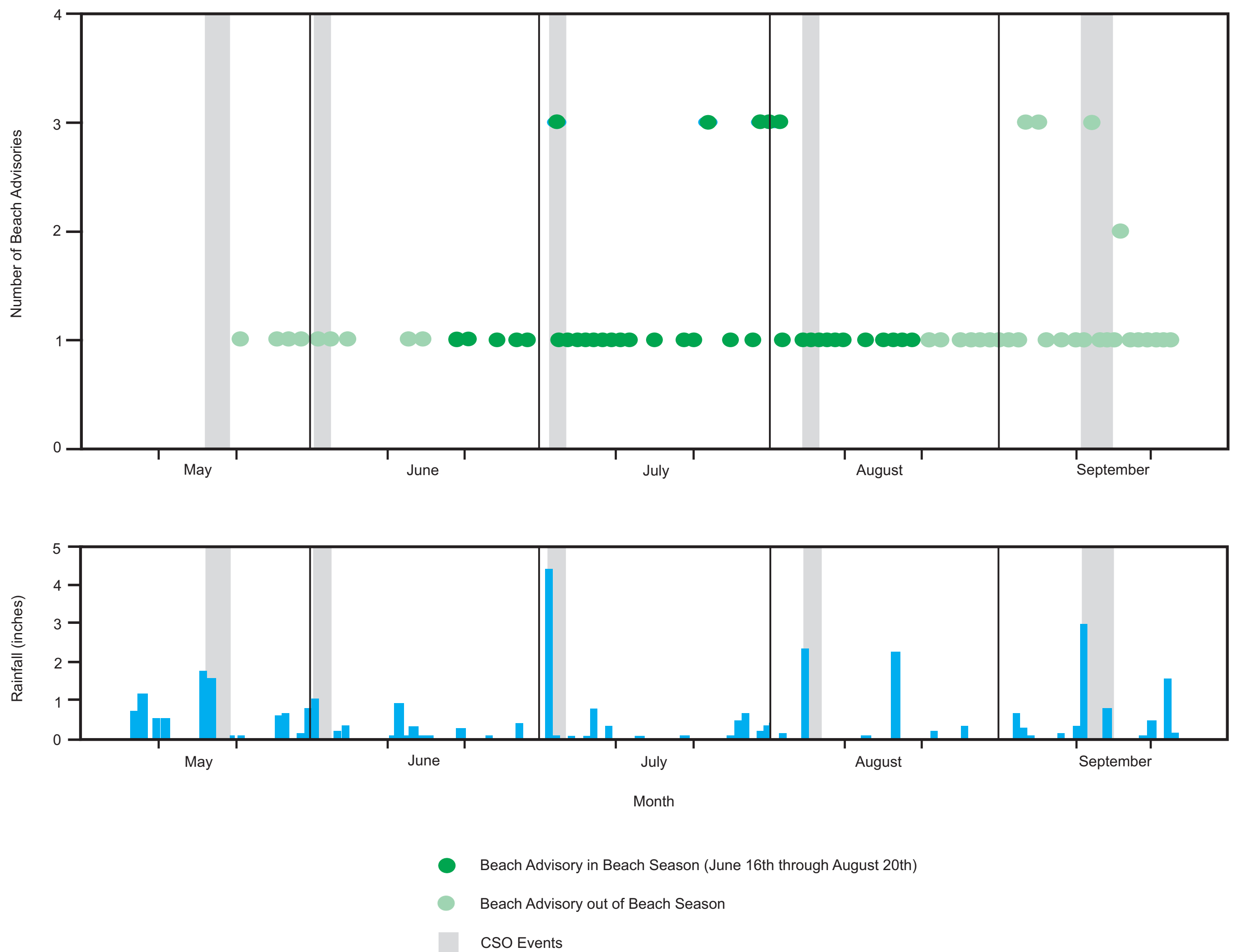
[28]*McLellan and Hollis, 2005,* op. cit.

[29]*Sandra L. McLellan and Erika T. Jensen,* Identification and Quantification of Bacterial Pollution at Milwaukee County Beaches, *Great Lakes WATER Institute Technical Report, September 2005.*

Figure 323

MILWAUKEE AREA BEACH ADVISORIES: 2000



NOTES: Milwaukee area beaches include South Shore, Bradford, and McKinley Beaches.

There were a total of 55 in-season beach advisories and 50 out-of-season beach advisories.

Rainfall amounts are recorded at General Mitchell International Airport.

Source: Milwaukee Metropolitan Sewerage District and CDM/HydroQual, Inc.

to the adjacent surface waters.[30] In 2000, this outfall was successfully reengineered to decrease the influx of bacteria to Lake Michigan.

Runoff from parking lots and other paved surfaces near beaches can contribute bacteria and other pollutants that affect water quality at beaches. Materials that accumulate on paved surfaces can be washed off into nearby

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[30] *Julie Kinzelman, Sandra L. McLellan, Annette D. Daniels, Susan Cashin, Ajaib Singh, Stephen Gradus, and Robert Bagley,* "Non-point Source Pollution: Determination of Replication Versus Persistence of Escherichia coli in Surface Water and Sediment with Correlation of Levels to Readily Measurable Environmental Parameters," *Journal of Water and Health, Volume 2, 2004.*

waterways during precipitation events. In 2001, preliminary samples of runoff collected from the parking lot at South Shore Beach following a 0.5 inch rainfall were found to have concentrations of *E. coli* in excess of 100,000 cells per 100 ml.[31] Subsequent sampling of runoff from the parking lots at Bradford and South Shore Beaches found average concentrations ranging between 100 and 39,300 cells per 100 ml. The concentrations reported are consistent with loads reported from impervious surfaces.[32] The parking lots at both of these beaches represent potential sources of contamination to the water at their respective beaches. The parking lot at Bradford Beach serves as a roosting area for gulls and is often covered with gull feces. The parking lot at South Shore Beach is directly adjacent to the beach. During precipitation events, stormwater washes over this lot and drains directly into the swimming area. In May 2005, a stormwater treatment device was installed at South Shore Beach to reduce the amount of pollutants washing into the beach area. Researchers at the University of Wisconsin-Milwaukee Great Lakes WATER Institute are currently evaluating its effectiveness.[33]

Beach Sand

Reservoirs of bacteria in beach sand and sediment may also act as sources of bacteria to water at swimming beaches. Concentrations of *E. coli* detected in foreshore sands at beaches have been reported to be 10 to 1,000 times higher than concentrations in beach waters.[34] For example, mean concentrations of *E. coli* in foreshore sand, submerged sand, and water along four transects through North Beach during summer 2001 were 1,540 cells per gram dry weight sand (cells per g dry wt), 237 cells per g dry wt, and 138 cells per 100 ml, respectively. Figure 324 shows mean concentrations of *E. coli* in sand at Bradford Beach during the beach seasons of 2004 and 2005. Concentrations of these bacteria in sand appear to be related to the moisture content of the sand. In most instances, higher concentrations were found in wet or moist sand than in dry sand. In addition, concentrations were higher at the berm near the waterline and the middle of the beach than concentrations at the top of the beach. The higher concentrations of *E. coli* in the middle of the beach in 2004 is accounted for by the fact that the moisture content of sand in the middle of the beach in that year was on average higher than the moisture content of sand in the berm.[35] Samples collected in 2005 showed that discharge of runoff over the beach from stormwater outfalls could affect concentrations of bacteria in sand. Sand samples from the top of the beach were collected from two types of locations. Samples collected from sites between outfalls received no discharges of stormwater from the outfalls. By contrast, sites immediately below outfalls would be expected to receive the greatest impact from stormwater discharges. Figure 324 shows that *E. coli* concentrations were higher at sites below stormwater outfalls than at sites between the outfalls, especially under wet conditions.

Beach grooming techniques can also affect concentrations of bacteria in beach sands. *E. coli* counts in foreshore sand at North Beach that was mechanically groomed were shown to be higher than counts in ungroomed or hand raked foreshore sand.[36] Subsequent data indicated that the finishing process used in mechanical grooming, which levels and compacts sand, can provide a more favorable environment for the bacteria. Altering mechanical

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[31]*McLellan and Salmore, 2003,* op. cit.

[32]*R.T. Bannerman, D.W. Owens, R.B. Doods, and N.J. Hornewer, "Sources of Pollutants in Wisconsin Stormwater,"* Water Science and Technology, *Volume 28, 1993.*

[33]*McLellan and Jensen, 2005,* op. cit.

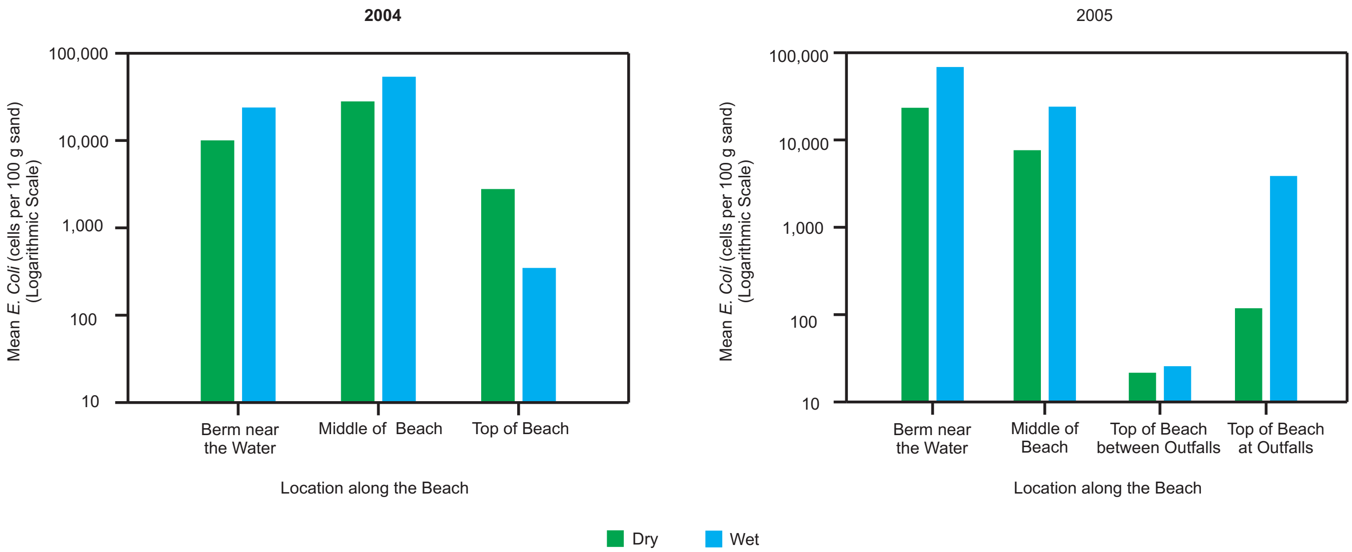
[34]*Richard L. Whitman and Meredith B. Nevers, "Foreshore Sand as a Source of* Escherichia coli *in Nearshore Water of a Lake Michigan Beach,"* Applied and Environmental Microbiology, *Volume 69, 2003*.

[35]*McLellan and Jensen, 2005,* op. cit.

[36]*Julie L. Kinzelman, Richard L. Whitman, Muruleedhara Byappanalalli, Emma Jackson, and Robert C. Bagley, "Evaluation of Beach Grooming Techniques on* Escherichia coli *Density in Foreshore Sand at North Beach, Racine, WI,"* Lake and Reservoir Management, *Volume 19, 2003.*

Figure 324

MEAN CONCENTRATIONS OF *E. COLI* IN SAND AT BRADFORD BEACH: 2004-2005



Source: University of Wisconsin-Milwaukee Great Lakes WATER Institute.

grooming techniques to provide deeper grooming and to omit the finishing process was shown to reduce concentrations in foreshore sand.[37] This effect was probably the result of more rapid desiccation and deeper ultraviolet light penetration in the unfinished sand. Beach grooming practices at beaches in the Cities of Milwaukee and Racine have been altered based upon these results.

In addition to *E. coli,* harmful pathogens associated with fecal contamination have been identified in beach sand and linked to bather illness.[38] Both *Campylobacter* and *Salmonella* species have been identified in beach sands, and strains known to be associated with human infections have been typed.[39] These bacteria have also been found in sand at times they were not found in water.[40]

Several lines of evidence suggest that beach sand can act as a source of bacteria to adjacent recreational waters. Reported concentrations of *E. coli* can be higher than concentrations in adjacent waters. Bacteria have also been shown to rapidly colonize uncontaminated sand. For example, in the foreshore at one Lake Michigan beach in Illinois, *E. coli* concentrations in newly placed sand increased to near ambient levels in surrounding sand within

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[37] *J.L. Kinzelman, K.R. Pond, K.D. Longmaid, and R C. Bagley, "The Effect of Two Mechanical Beach Grooming Strategies on* Escherichia coli *Density in Beach Sand at a Southwestern Lake Michigan Beach,"* Aquatic Ecosystem Health & Management, *Volume 7, 2004.*

[38] *K. Obrisi-Danso and K. Jones, "Intertidal Sediments as Reservoirs for Hippurate Negative Campylobacters, Salmonellae and Fecal Indicators in Three EU Recognized Bathing Waters in Northwest England,"* Water Research, *Volume 34, 2000.*

[39] *F.J. Bolton, S.B. Surman, K. Martin, D.R.A. Wareing, and T.J. Humphrey, "Presence of* Camplyobacter *and* Salmonella *in Sand from Bathing Beaches,"* Epidemiology and Infection, *Volume 122, 1999.*

[40] *J.A. Papadakis, A. Mavridou, S.C. Richardson, M. Lampiri, and U. Marcelou, "Bather-related Microbial and Yeast Populations in Sand and Seawater,"* Water Research, *Volume 31, 1997.*

about two weeks.[41] Correlation of *E. coli* concentrations in water with several environmental variables in one study found that the best predictor of *E. coli* concentration in water was wave height.[42] This suggests that waves are able to draw microorganisms out of foreshore sand and into the water. Finally, strong positive correlations were found between concentrations of *E. coli* in foreshore sands and adjacent waters.[43] Interestingly, correlations were found both when concentrations in water samples were compared to concentrations in sand samples collected on the same day and when concentrations in water samples were compared to concentrations in sand samples collected either the previous or following day. This suggests a complex relationship between bacterial levels in beach sand and beach water in which each location may, at times, serve as a source of bacteria to the other. It is important to note that bathers at beaches spend considerable time directly exposed to beach sand. Even if beach sands contribute relatively small amounts of bacteria to beach waters, concentrations of bacteria in the sand may pose a risk of infection to bathers.

Waterfowl

Fecal material from waterfowl may be a source of bacterial contamination to beach sand and water. Several species have been suggested as potentially contributing to decreases in beach water quality, including ducks, geese, and gulls. For example, elevated concentrations of fecal coliform bacteria in water at a public swimming beach on Lake Wingra in Madison were linked to the presence of mallard ducks.[44] Ring-billed gulls are a particular species of concern. Several beaches in the study area serve as roosting areas for ring-billed gulls including Bradford Beach,[45] McKinley Beach,[46] North Beach,[47] and South Shore Beach.[48] For example, during July 2002, numbers of gulls in daily counts at North Beach during the morning ranged from 336 to 1,050, with a mean of about 654. Daily counts during the afternoon were more variable, ranging between 14 and 1,150 gulls with a mean of 446 gulls. The number of ring-billed gulls in the Great Lakes area has increased markedly over the last 40 years. In 1967, it was estimated that there were 119,000 breeding pairs in the Great Lakes area.[49] By the mid-1980s this had increased to about 647,000 breeding pairs, though growth of the population may have leveled off since then.[50] A recent estimate suggests that the population around Lake Michigan may consist of about 100,000 breeding pairs.[51] These population estimates do not include juvenile gulls.

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[41]*Whitman and Nevers, 2003,* op. cit.

[42]*Kinzelman,* et al., Journal of Water and Health, *2004,* op. cit.

[43]*Whitman and Nevers, 2003,* op. cit.

[44]*Jon H. Standridge, Joseph J. Delfino, Lyle B. Kleppe, and Robert Butler, "Effect of Waterfowl (*Anas platyrhynchos*) on Indicator Bacteria Populations in a Recreational Lake in Madison, Wisconsin,"* Applied and Environmental Microbiology, *Volume 38, 1979.*

[45]*McLellan and Jensen, 2005,* op. cit.

[46]Ibid.

[47]*Kinzelman, et al., 2004,* Aquatic Ecosystem Health and Management, op. cit.

[48]*McLellan and Salmore, 2003,* op. cit.

[49]*J.P. Ludwig, "Recent Changes in the Ring-billed Gull Population and Biology in the Laurentian Great Lakes,"* The Auk, *Volume 91, 1974.*

[50]*H. Blokpoel and W.C. Scharf, "Status and Conservation of Seabirds Nesting in the Great Lakes of North America," In: J.P. Croxall (editor),* Seabird Status and Conservation, *International Council for Bird Preservation, 1991.*

[51]*Francesca Cuthbert, "Why Do We Have So Many Gulls? How Have Things Changed?" Presentation at Planning for Gulls in Your Community Conference, Milwaukee, Wisconsin, March 11, 2004.*

Several lines of evidence suggest that droppings from gulls may be contributing to water quality problems at some beaches. In one study conducted at a Lake Michigan beach, concentrations of *E. coli* in beach water and foreshore sand were found to be significantly correlated to gull counts from the previous day.[52] In a seven-day experimental study in which gulls were attracted to a beach on a small lake by providing food, the mean number of gulls frequenting the beach during hourly counts increased from 3.7 to 103.0.[53] This increase in gulls was accompanied by an increase in the geometric mean concentration of fecal coliform bacteria in beach water at 0.3 meters depth from 8.0 cells per 100 ml to 5,077.3 cells per 100 ml. Ring-billed gull feces have been shown to contain high concentrations of bacteria species used as water quality indicators. One study found a mean concentration of fecal coliform bacteria of 370 million cells per gram feces in gull feces with seasonal averages ranging between 58 million and 1,500 million cells per gram feces.[54] By contrast, the same study found that the average concentration of fecal coliform bacteria in feces from Canada geese was about 15,000 cells per gram feces. Mean concentrations of *E. coli* in feces from ring-billed gulls at two Lake Michigan beaches in Chicago and Traverse City, Michigan were 14 million and 490 million cells per gram feces, respectively.[55] Finally, ring-billed gull feces have been found to contain species and strains of bacteria known to be pathogenic to humans, including bacteria in the genera *Aeromonas, Campylobacter, Listeria,* and *Salmonella*.[56]

Algae

High concentrations of bacterial indicators of fecal contamination in swimming waters and beach sand have been associated with the presence of algal mats, particularly *Cladophora*. The mean concentration of *E. coli* from *Cladophora* mats at 10 Lake Michigan beaches was about 200,000 cells per gram (dry weight) algae.[57] The highest concentration in this study, about 1,600,000 cells per gram (dry weight) algae, was found at North Beach in Racine. No statistically significant differences were found in *E. coli* concentrations among algae attached to the substrate, algae floating in the water, and algae stranded along the beach. A second study of 11 Lake Michigan beaches found that mean concentrations of *E. coli* in *Cladophora* at most beaches ranged between 2,700 cells per 100 grams (wet weight) algae and 7,500 cells per 100 grams (wet weight) algae; however, mean concentrations at three beaches, Atwater Beach, Bradford Beach, and McKinley Beach, were considerably higher.[58] Mean concentrations of *E. coli* in *Cladophora* mats at these beaches were 12,800 cells per 100 grams (wet weight)

[52] *Whitman and Nevers, 2003,* op. cit.

[53] *Benoît Lévesque, Pierre Brousseau, Pierre Simard, Eric Dewailly, Monica Meisel, Danièl Ramsay, and Jean Joly, "Impact of the Ring-Billed Gull (*Larus delawarensis) *on the Microbiological Quality of Recreational Water,"* Applied and Environmental Microbiology, *Volume 59, 1993.*

[54] *K. A. Alderisio and N. DeLuca, " Seasonal Enumeration of Fecal Coliform Bacteria from the Feces of Ring-Billed Gulls (*Larus delawarensis) *and Canada Geese (*Branta canadensis*),"* Applied and Environmental Microbiology, *Volume 65, 1999.*

[55] *L.R. Fogarty, S.K. Haack, M.J. Wolcott, and R.L. Whitman, "Abundance and Characteristics of the Recreational Water Quality Indicator Bacteria* Escherichia coli *and Enterococci in Gull Faeces,"* Journal of Applied Microbiology, *Volume 94, 2003.*

[56] *Sylvain Quessy and Serge Messier, "Prevalence of* Salmonella *spp.,* Campylobacter *spp. and* Listeria *spp. in Ring-billed Gulls (*Larus delawarensis*),"* Journal of Wildlife Diseases, *Volume 28, 1992; Lévesque* et al., *1993,* op. cit.

[57] *Richard L. Whitman, Dawn A. Shively, Heather Pawlik, Meredith B. Nevers, and Muruleedhara N. Myappanahalli, "Occurrence of* Escherichia coli *and Enterococci in* Cladophora *(Chlorophyta) in Nearshore Water and Beach Sand of Lake Michigan,"* Applied and Environmental Microbiology, *Volume 69, 2003.*

[58] *Ola A. Olapade, Morgan M. Depas, Erika T. Jensen, and Sandra L. McLellan, "Microbial Communities and Fecal Indicator Bacteria Associated with* Cladophora *Mats on Beach Sites along Lake Michigan Shores,"* Applied and Environmental Microbiology, *Volume 72, 2006.*

algae, 21,130 cells per 100 grams (wet weight) algae, and 27,950 cells per 100 grams (wet weight) algae, respectively. Data from these studies indicate that *E. coli* is able to survive in algal mats for longer periods than in lake water. Laboratory mesocosm experiments showed that while concentrations of *E. coli* in lake water decreased to below the limit of detection within four days, concentrations in algal mats persisted for more than seven days, and in some experiments, as long as 28 days.[59] In addition, concentrations of *E. coli* in *Cladophora* mats that had been sun dried for 24 hours and refrigerated for six months increased by a factor of about 10,000 in the 24 hours following rehydration.[60] Concentrations remained stable or declined only slightly over the next 72 hours. Similar results were reported in this study for enterococci. This suggests that water quality indicator bacteria are able to persist for long periods and perhaps multiply in algal mats. While no data are available which show whether pathogenic bacteria are able to persist in *Cladophora* mats, some pathogenic bacteria, such as *Vibrio cholerae*, are known to be associated with other filamentous algae.[61]

Synthesis

There is continuing public concern about water quality at public beaches along Lake Michigan. Conditions as measured by the number of closings and advisories improved at some beaches, such as North Beach and Zoo Beach (see Figure 320). By contrast, at some other beaches, such as Bradford Beach, McKinley Beach, and South Shore Beach, water quality is declining or remains poor. Local sources of contamination appear to be important determining factors of water quality at Lake Michigan beaches. Factors such as the placement of stormwater outfalls relative to beaches and swimming areas, locations of impervious surfaces such as parking lots, and the presence of wildlife can exert a strong influence on beach water quality and appear to be contributing to the number of water quality advisories and beach closings at some beaches in the Lake Michigan direct drainage area. It is important to note that water quality indicator organisms, such as *E. coli*, contributed by these and other sources can persist in beach sand and mats of *Cladophora* present on or adjacent to beaches. The presence, concentration, and persistence of indicator bacteria in beach sand can be affected by the particular methods of beach grooming used. In any case, precipitation and wave action may mobilize indicator bacteria present in sand or algal mats to beach water. The persistence of pathogens in beach sand and *Cladophora* mats is poorly understood. To the extent that persistence of indicator bacteria in sand and *Cladophora* mats does not reflect persistence of pathogens, the persistence of indicator bacteria in these places may reduce the strength of the relationship between indicator organisms, such as *E. coli*, and actual pollution, potentially complicating beach-monitoring efforts through releases of *E. coli* that elevate concentrations in water at times when fecal contamination is not present. It is important to note, however, that issuance of beach advisories and closings under these circumstances errs on the side of being protective of human health.

Water Quality of the Nearshore Lake Michigan Areas

Prior to the late 1970s, water quality data was sporadically collected in the nearshore area of Lake Michigan. Since then, considerable data have been collected. The major sources of data include the MMSD, the WDNR, the University of Wisconsin-Milwaukee, and City of Milwaukee Water Works.

The time periods examined for analytical purposes and the graphical comparisons of baseline water quality conditions to historical water quality conditions used for the nearshore Lake Michigan areas were similar to those described previously in this report for the Milwaukee Harbor estuary. Based on the availability of data, the period from 1998-2004 defines the baseline water quality conditions of nearshore Lake Michigan areas. Map 117 and Table 188 show the sampling stations in the nearshore Lake Michigan areas used for these analyses. These

[59]Ibid.

[60]*Whitman,* et al.*, 2003,* op. cit.

[61]*M.S. Islam, B.S. Drasar, and D.J. Bradley, "Attachment of Toxigenic* Vibrio cholerae *O1 to Various Freshwater Plants and Survival with Filamentous Green Alga* Rhizoclonium fontanum,*"* Journal of Tropical Medicine and Hygiene, *Volume 92, 1989.*

sampling stations are divided into two groups, representing different surveys by MMSD. The first group of stations, the South Shore survey, is a relatively compact collection of stations located near the outfall from the MMSD South Shore WWTP. Data from sampling stations in this survey were analyzed along two transects (see Map 117). West-east transect number 2 passes eastward through four stations as it runs outward from the lakeshore into Lake Michigan. North-south transect number 4 passes southward through five stations as it runs southward, roughly parallel to the shoreline. It is important to note that one sampling station in this survey, SS-01, is located at the site of the outfall from the South Shore WWTP. Most of the stations in the second group, the nearshore survey, are located in the nearshore area roughly between Fox Point and Wind Point. A few stations in this group are located south of Wind Point; however, they have rather short periods of record (see Table 188). The nearshore stations were aligned along four transects. West-east transect number 3 begins offshore from the City of Oak Creek and passes eastward through three stations. North-south transect number 5 includes five stations and is the closest to the shore. North-south transect number 6 and north-south transect number 7 each pass through three stations. North-south transect number 7 is farthest from the shore. Stations NS-06 and NS-09 were not included in this transect because no data were available from these stations after 1992. It is important to note that one sampling station in this survey, NS-07, is located in the vicinity of the site of the water intake from the City of Milwaukee's Linnwood Avenue water treatment plant.

Bacterial and Biological Parameters

Bacteria

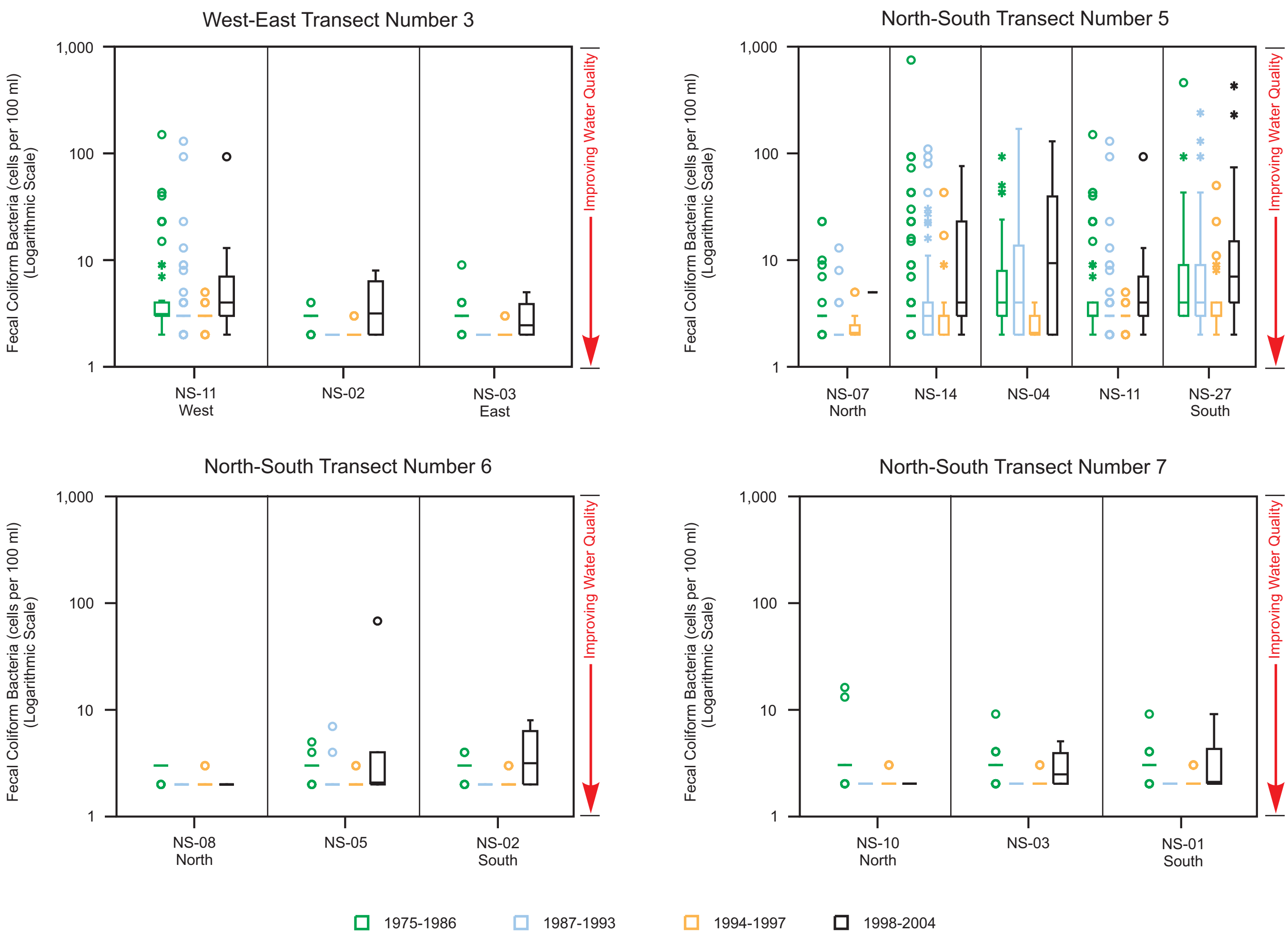
During the period of record, concentrations of fecal coliform bacteria in the nearshore Lake Michigan area ranged from below the limit of detection to 110,000 cells per 100 ml. The mean concentration was 526 cells per 100 ml. Given that the median concentration was four cells per ml, this mean is probably high due to the effects of a relatively small number of samples with unusually high concentrations. Concentrations of fecal coliform bacteria at stations in MMSD's South Shore survey ranged from below the limit of detection to 230,000 cells per 100 ml with a mean concentration of 90 cells per 100 ml and a median concentration of three cells per 100 ml. Figure 325 shows concentrations of fecal coliform bacteria at sampling stations along four transects through the nearshore areas. In general, median concentrations of fecal coliform bacteria were quite low at these stations, generally less than 10 cells per 100 ml. Differences in medians shown in Figure 325 tend to be small. For example, at station NS-08, the median concentration of fecal coliform bacteria during the period 1975-1986 was three cells per 100 ml. During subsequent periods it was two cells per 100 ml. Mean concentrations at these stations were also low, generally less than 50 cells per 100 ml. Along west-east transect number 3, concentrations of fecal coliform bacteria tended to decrease from west to east. Along north-south transects numbers 6 and 7, concentrations tended to increase slightly from north to south. A more complicated pattern was observed closer to shore, along north-south transect number 5. Higher concentrations were seen at stations NS-14 which is about one mile outside the main gap from the outer harbor, NS-27 which is near the outfall from the South Shore WWTP, and NS-04 which is very close to shore. At several nearshore stations, concentrations of fecal coliform bacteria have decreased, in part due to the presence of fewer samples with unusually high concentrations.

Figure 326 shows concentrations of fecal coliform bacteria at sampling stations along two transects through MMSD's South Shore survey. As with stations in the nearshore survey, median concentrations of fecal coliform bacteria at these stations were low, generally less than 10 cells per 100 ml. Similarly, mean concentrations were also low, generally less than 50 cells per 100 ml. Concentrations of fecal coliform bacteria were higher at station SS-01, near the outfall from the South Shore WWTP, and tended to be lower at stations away from the outfall, especially those to the south and east. At several stations, concentrations of fecal coliform bacteria have decreased, in part due to the presence of fewer samples with unusually high concentrations.

As shown in Table C-6 in Appendix C of this report, several time-based trends in fecal coliform bacteria concentrations were detected at stations in the nearshore Lake Michigan areas. When analyzed on an annual basis, several sampling sites in the nearshore survey showed statistically significant trends toward decreasing fecal coliform concentrations. At some stations, these trends accounted for small fractions of the variation observed. When examined on a seasonal basis, decreasing trends in the concentrations of fecal coliform bacteria were detected at several stations especially during the fall. By contrast, few time-based trends in the concentration of fecal coliform bacteria were detected at stations in the South Shore survey (see Table C-6 in Appendix C). Fecal

Figure 325

FECAL COLIFORM BACTERIA AT SITES IN THE NEARSHORE LAKE MICHIGAN AREA: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

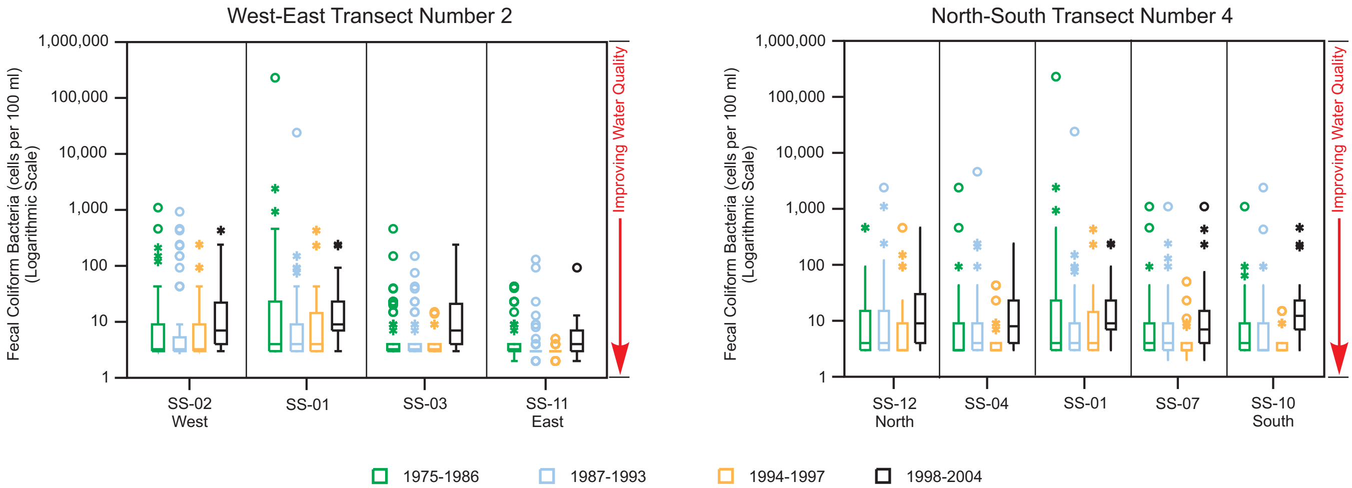
Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

coliform bacteria concentrations at stations in the nearshore survey were not significantly correlated with any other water quality parameter. Fecal coliform bacteria concentrations at several stations in the South Shore survey were positively correlated with concentrations of total phosphorus. This correlation may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into Lake Michigan. The long-term trends toward declining fecal coliform bacteria concentrations at several stations represent a long-term improvement in water quality in the nearshore Lake Michigan areas.

MMSD began regular sampling for *E. coli* at four long-term sampling stations in the nearshore survey in 2003. These stations were in or near the outer harbor. Concentrations of *E. coli* at these stations ranged from below the limit of detection to 3,300 cells per 100 ml. The mean concentration at these stations was 215 cells per 100 ml. Given that the median concentration was 20 cells per ml, this mean is probably high due to the effects of a relatively small number of samples with unusually high concentrations.

Figure 326

FECAL COLIFORM BACTERIA IN LAKE MICHIGAN OFF THE SOUTH SHORE SEWAGE TREATMENT PLANT: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

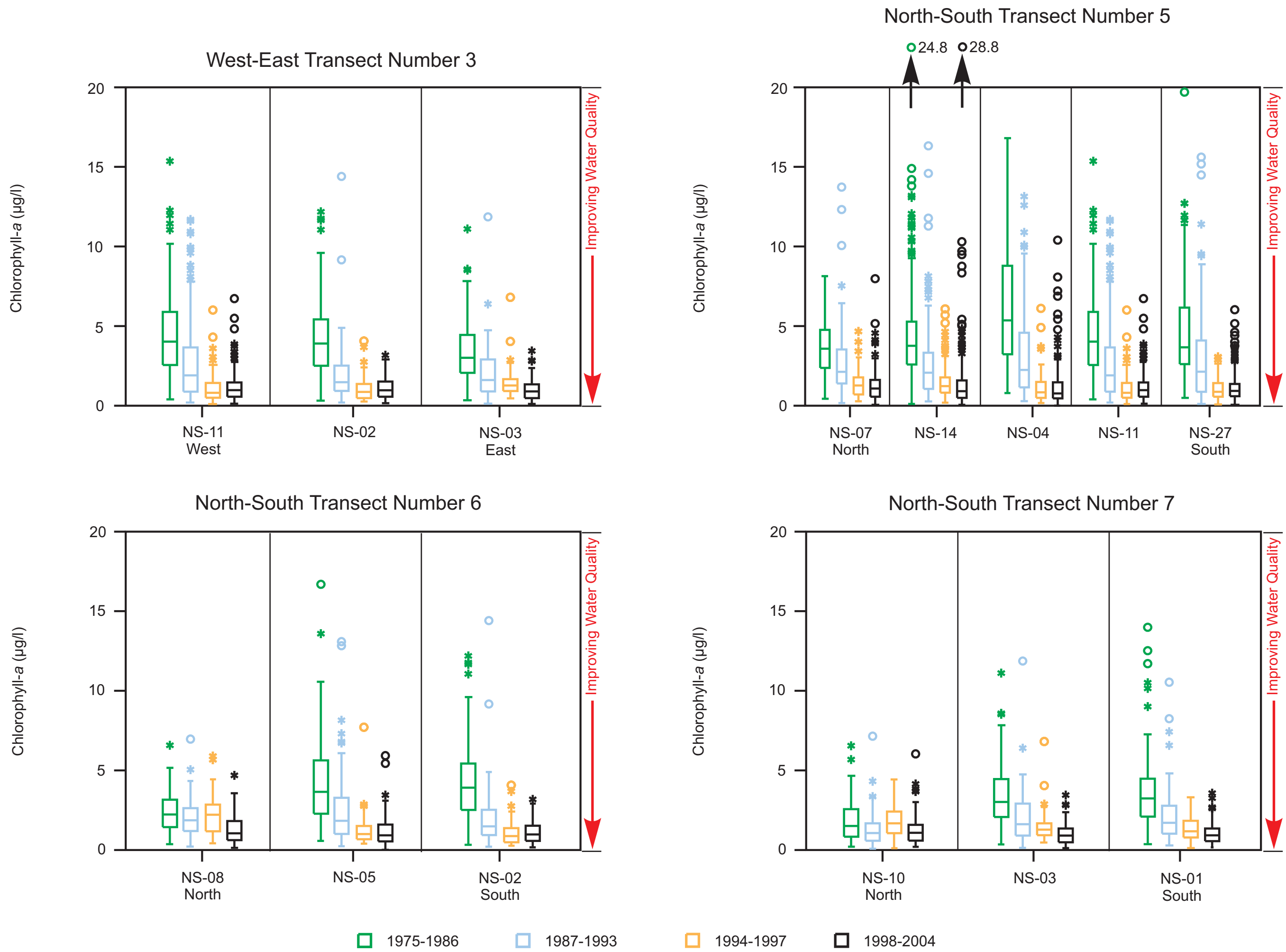
*Chlorophyll-*a

Over the period of record, the mean concentration of chlorophyll-*a* in the nearshore Lake Michigan Area was 4.91 μg/l. Individual samples of this parameter ranged from below the limit of detection to 186.00 μg/l. The mean concentrations of chlorophyll-*a* during the period of record at sampling stations in MMSD's South Shore survey was 2.53 μg/l. Concentrations in individual samples ranged from below the limit of detection to 22.24 μg/l. Figure 327 presents concentrations of chlorophyll-*a* at stations along four transects through the nearshore area. Chlorophyll-*a* concentrations were higher at sampling stations that were nearer to the shore and lower at stations that were farther out in Lake Michigan. This effect was especially apparent during periods before 1994. Chlorophyll-*a* concentrations in the nearshore area have decreased over time. The magnitude of the decreases varies among stations. Smaller decreases were observed at stations NS-08 and NS-10. Several factors may account for this. Chlorophyll-*a* concentrations at these stations were historically low compared to other sampling stations in the nearshore survey. In part, this reflects the fact that these stations are both relatively far from shore: NS-08 and NS-10 are about four miles and seven miles from shore, respectively. In addition, both of these stations are to the north and east of the Milwaukee Harbor. Given that the nearshore current runs, on average, from north to south, it would be expected that water quality at these stations would not be strongly influenced by inputs from the rivers that empty into the harbor or from effluent from the Jones Island WWTP. The decreases in chlorophyll-*a* concentrations in the nearshore area have been accompanied by improvements in the trophic status of the nearshore areas as measured by the Carlson Trophic State Indices and the Lake Trophic Status Index.[62] Figure 328 shows chlorophyll-*a* concentrations at sampling stations along two transects through the South Shore survey. Chlorophyll-*a* concentrations at these stations show decreases similar to those observed at stations in the nearshore survey.

[62]*Milwaukee Metropolitan Sewerage District, "Trophic State and Chlorophyll in the Milwaukee, Wisconsin Harbor and Surrounding Nearshore Waters," October 2001.*

Figure 327

CHLOROPHYLL-*a* CONCENTRATIONS AT SITES IN THE NEARSHORE LAKE MICHIGAN AREA: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Statistically significant trends toward decreasing chlorophyll-a concentrations were found at almost all sampling stations in the nearshore and South Shore surveys (see Table C-6 in Appendix C). When analyzed on an annual basis, trends were found at all stations except NS-12, which is located in the outer harbor. At most stations, these trends accounted for a substantial portion of the variation in the data. When analyzed on a seasonal basis, significant decreasing trends were found during spring, summer, and fall at most stations. In the case of one sampling station, NS-10, this result differs from previous findings. A study of chlorophyll-*a* concentrations in the nearshore area concluded that the concentrations at NS-10 had increased since 1994;[63] however, that study only included data through 1997. At NS-10, chlorophyll-*a* concentrations during the period 1998-2004 were lower than those during the period 1994-1997. This accounts for the difference between the results of the two studies.

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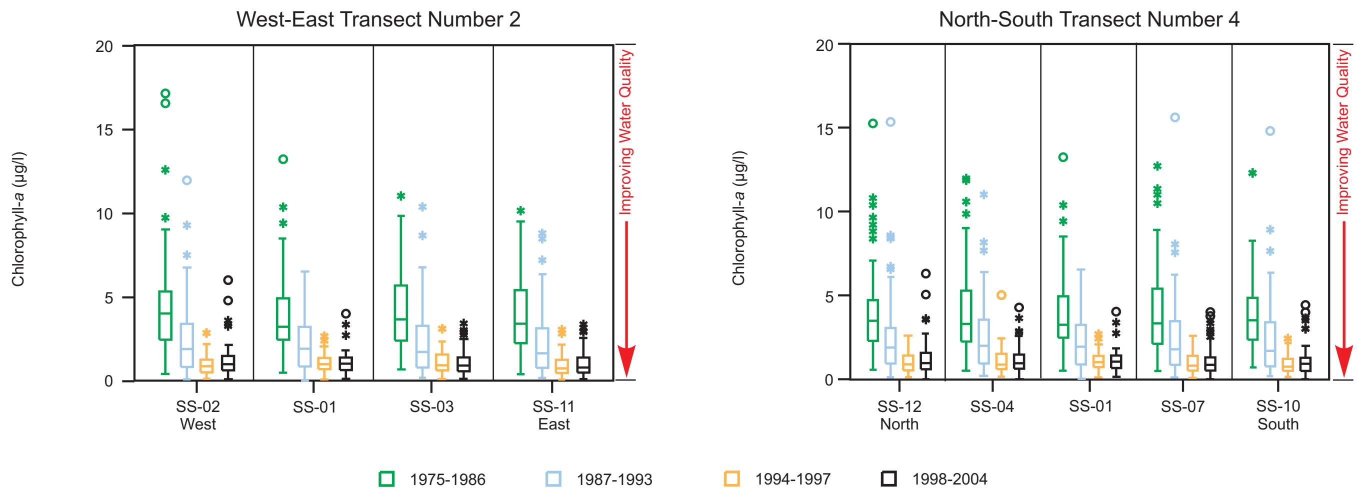
[63]Ibid.

Figure 328

CHLOROPHYLL-*a* CONCENTRATIONS IN LAKE MICHIGAN OFF THE SOUTH SHORE SEWAGE TREATMENT PLANT: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Several factors can affect chlorophyll-*a* concentrations and could potentially account for the decrease observed in the nearshore area. Phytoplankton populations, which chlorophyll-*a* concentration estimates, are strongly influenced by the availability of nutrients, especially phosphorus and, during the spring diatom bloom, silica. Changes in levels of nutrient input can be reflected as changes in chlorophyll-*a* concentration. While, substantial decreases in chlorophyll-*a* concentrations were observed at many sampling stations in the nearshore survey after 1994, increases were observed at NS-08 and NS-10, two stations that would not be greatly affected by nutrient inputs into Lake Michigan from the Milwaukee Harbor. These differences suggest that some of the decrease in chlorophyll-*a* concentrations in the nearshore area may be due to nutrient reductions related to the reduction in combined sewer overflows that occurred after the Inline Storage System came online. Chlorophyll-*a* concentrations in the nearshore area can also be influenced by biological processes in the Lake. Grazing by zooplankton and other suspension feeding animals, such as zebra mussels and quagga mussels, can remove phytoplankton from the water column, resulting in a decrease in the concentration of chlorophyll-*a*. Much of the observed decrease in chlorophyll-*a* concentrations appears to be the result of filtering activities of zebra mussels and quagga mussels. Beds of zebra mussels containing 100,000 or more mussels per square meter have been reported in Lake Erie[64] and Lake Michigan.[65] Large adult zebra mussels have been observed to remove particles from water at rates over 1.5 liters per day through filter feeding.[66] This removal of phytoplankton from the water column coupled with reduced nutrient loads to the inner harbor, resulting from both reductions of combined sewer overflows since the Inline Storage System came online and nonpoint source pollution control efforts, may account for the decrease in chlorophyll-*a* concentrations in the inner harbor.

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[64] *F.L. Snyder,* et al.*, 1997,* op. cit.

[65] *J.E. Marsden,* et al.*, 1993,* op. cit.

[66] *Jin Lei,* et al.*, 1996,* op. cit.

At most stations in the nearshore area chlorophyll-*a* concentrations are negatively correlated with concentrations of nitrate. This reflects the role of this compound as a nutrient for algal growth. As algae grow, they remove nitrate from the water and incorporate it into cellular material. The trends toward decreasing chlorophyll-*a* concentrations in the nearshore Lake Michigan area represent improvements in water quality.

Chemical and Physical Parameters

Temperature

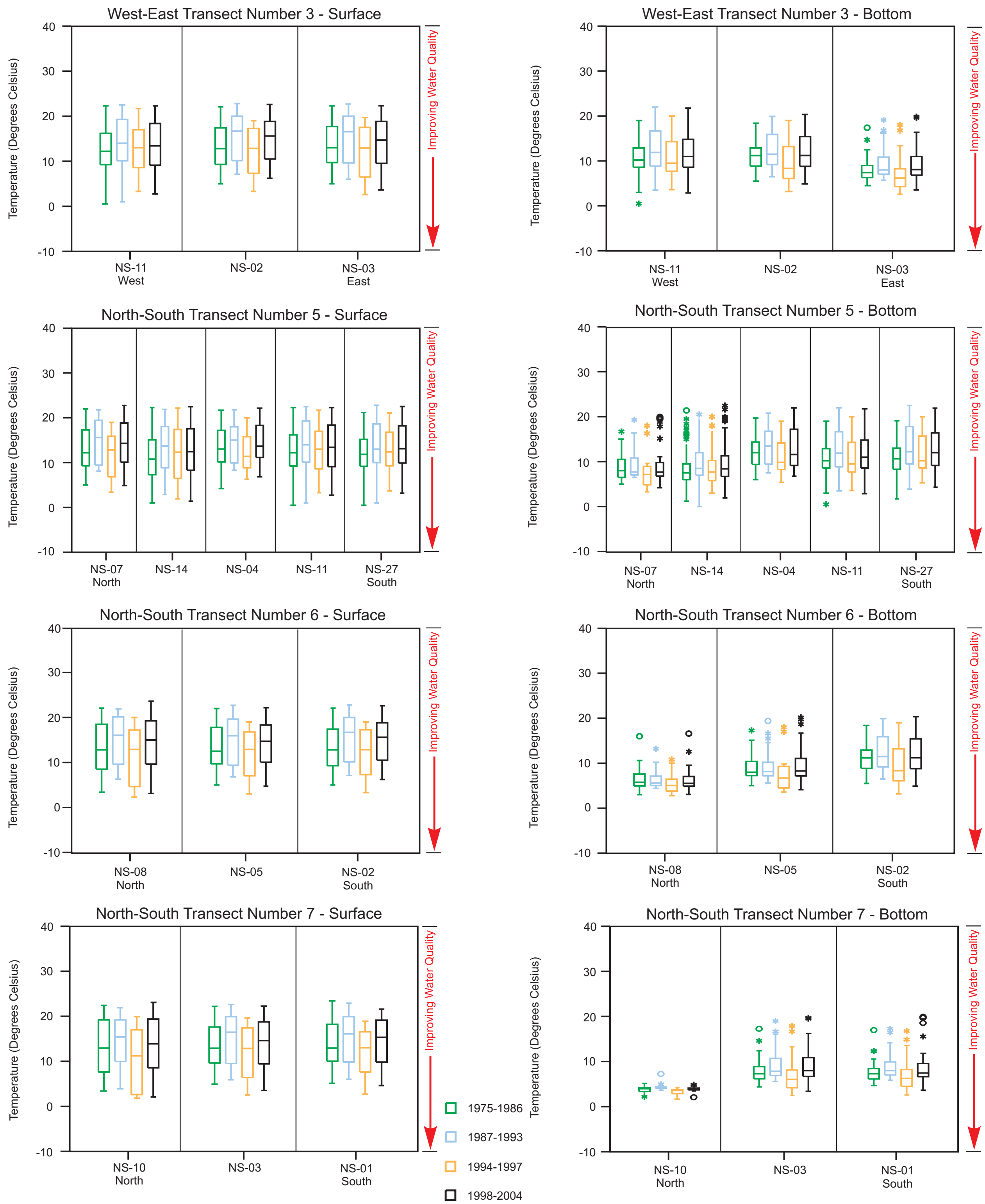
The median water temperature at stations in the nearshore area during the period 1998-2004 ranged from 4.6ºC at station NS-10 to 13.0ºC at station NS-28. The low median at station NS-10 probably reflects the fact that this is the deepest site in the survey (see Table 188). Water temperatures would be expected to be low in bottom samples at deep sites. Median water temperatures in surface water in the nearshore area during the period 1998-2004 ranged from 12.5ºC at station NS-14 to 16.1ºC at station NS-12. The median temperature in surface water at station NS-10 was 14ºC. Median water temperatures in bottom water in the nearshore area during the period 1998-2004 ranged from 4.0ºC at station NS-10 to 12.0ºC at station NS-27. Figure 329 shows water temperature at sampling stations along the four transects through the nearshore Lake Michigan Area. There are several patterns in these data. First, water temperatures tended to be higher in surface water samples than in samples collected from the bottom. This reflects thermal stratification of Lake Michigan during summer months. During thermal stratification, a layer of relatively warm water floats on top of a layer of cooler water. Thermal stratification is a result of differential heating of the lake water, and the resulting water temperature-density relationships at various depths within the lake water column. Water is unique among liquids because it reaches its maximum density, or mass per unit volume, at about 4ºC, well above its freezing point. During stratification, the top layer, or epilimnion, of the waterbody is cut off from nutrient inputs from the sediment. This layer is, however, still exposed to thermal influences from the sun and atmosphere. At the same time, the bottom layer, or hypolimnion, is cut off from the atmosphere and sunlight penetration. Over the course of the summer, water chemistry conditions can become different between the layers of a stratified waterbody. In the open waters of Lake Michigan, the epilimnion may contain the upper 20 meters or more of the water column at the height of stratification. Nearer to shore, it may be thinner due to sediment resuspension from wind-driven turbulent mixing, upwelling, higher turbidity from sediment inputs from adjacent land, and algal growth. Second, temperatures in surface water tended to be lower at stations that were farther offshore; however, statistical analysis did not detect any significant differences or trends among stations based on distance from shore. Third, water temperatures in samples collected near the bottom showed considerable variation among sites. This variation tended to correspond to water depth with temperatures being cooler and showing less variability at deeper sites. For example, mean depths of bottom samples at the stations in west-east transect number 3, NS-11, NS-02, and NS-03, were 7.3 meters, 10.2 meters, and 21.1 meters, respectively (see Table 188). Similarly, mean depths of bottom samples at the stations in north-south transect number 6, NS-08, NS-05, and NS-02, were 33.2 meters, 19.1 meters, and 10.2 meters, respectively. Fourth, water temperatures at sampling stations in the nearshore area show a complicated pattern of change over time. At most stations, they increased between the periods 1975-1986 and 1987-1993, decreased after 1993, and increased after 1998. It is important to note that the increase between the periods 1975-1986 and 1987-1993 was due to the inclusion of data collected during the winter in the earlier period.[67]

Figure 330 shows a comparison of historical and baseline period mean monthly water temperatures from surface samples collected at four sampling stations in the nearshore area. With the exception of means from April, baseline period monthly mean water temperatures were within historical ranges. At stations NS-02 and NS-10, baseline period means from April were above historical maxima. At all four of these stations, baseline period monthly means during spring months were higher than historical means. While baseline period monthly maximum temperatures during the spring occasionally exceeded historical maxima, they were usually less than the historical maxima from the following month. This suggests that the higher monthly mean water temperatures observed during baseline period spring months resulted from warming that occurred earlier in the year during the baseline period than it did during the historical period. It is important to note that the data from these stations do

[67]*MMSD stopped sampling during the winter in 1987. Winter data were excluded from trend analyses.*

Figure 329

WATER TEMPERATURE AT SITES IN THE NEARSHORE LAKE MICHIGAN AREA: 1975-2004

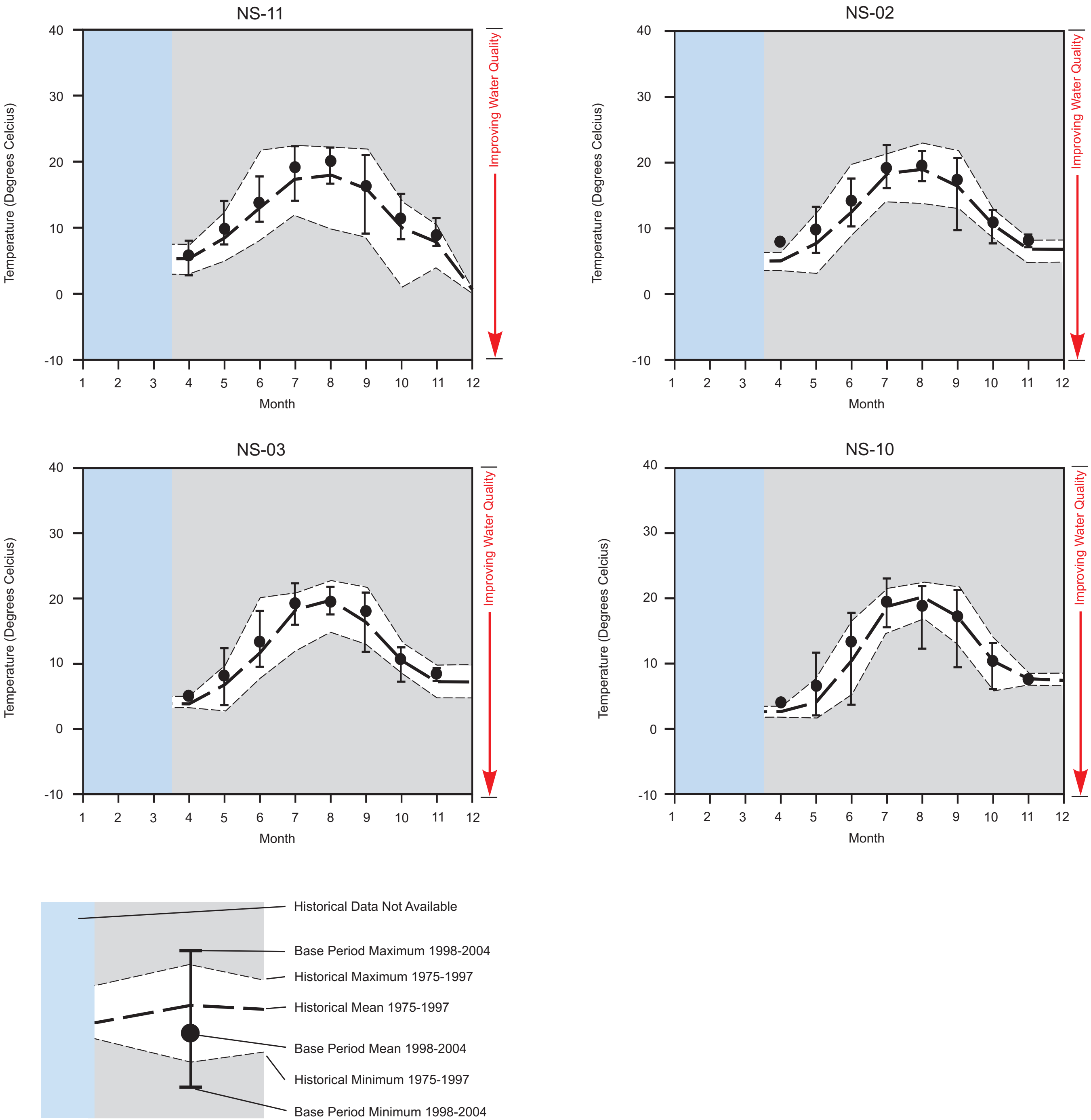


NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 330

HISTORICAL AND BASE PERIOD WATER TEMPERATURE AT SITES IN THE NEARSHORE LAKE MICHIGAN AREA: 1975-2004



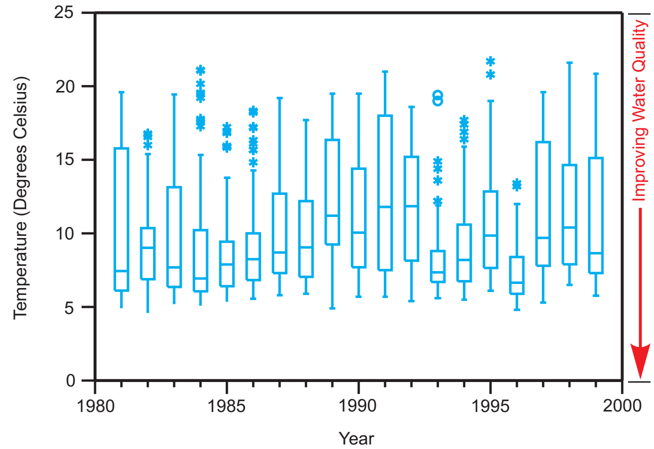
NOTE: See Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

not show strong evidence of later fall cooling during the baseline period. Figure 330 also shows that baseline period mean water temperatures at station NS-11 exceeded historical means during July and August. These higher mean water temperatures during summer months may reflect changes in summer wind patterns over the Great Lakes. Prevailing winds during summer months over southern Lake Michigan shifted from coming from the southwest during the 1980s to coming from the east during the 1990s.[68] This change in wind direction was accompanied by an increase in wind speed, especially during the month of August. It is important to note that this change in wind direction and speed represents the average condition during the summer. During any summer, there was variation in wind direction and speed. What this change in average condition means is that during summer months in the 1990s, winds coming from the east were much more common than they were during summer months in the 1980s. Any effects associated with easterly winds, should also be expected to be more common during the 1990s. A change in wind direction toward easterly winds would tend to push warmer, epilimnetic water toward the western shore of the Lake and might result in piling up of warmer water in the nearshore area. Given this, it would be expected that a greater frequency of higher temperatures in bottom water at some nearshore sampling sites would result from this change. Figure 331 shows water temperatures at the intake of the Milwaukee Water Works Linnwood Avenue treatment plant from daily sampling during summer months between 1981 and 1999. This intake is located in the vicinity of the site of sampling station NS-07 and is approximately 20 meters beneath the surface of the Lake. Prior to 1989, median water temperatures during the summer at this intake were at or below 9ºC. In 1989, the median water temperature increased markedly. In seven out of 11 years after 1988, median summer water temperatures at this intake were above the range of medians observed during the period 1981-1988. This suggests that warm water was accumulating at this site in the nearshore area more often during the 1990s than during the 1980s and it is consistent with what would be expected from the reported shift in prevailing wind direction. This change in the temperature regime of the nearshore area may have changed the suitability of the area as habitat for some organisms. The area may have become more suitable for species whose thermal tolerances and preferences are more similar to the relatively warmer summer water temperatures seen during the 1990s. By contrast, the area may have become less suitable for species whose thermal tolerances and preferences are more similar to the relatively cooler summer water temperatures seen during the 1980s. This may be a factor in the recent resurgence of *Cladophora* as a nuisance alga.

Figure 331

SUMMER WATER TEMPERATURES AT THE LINNWOOD AVENUE WATER TREATMENT PLANT INTAKE: 1981-1999



NOTE: See Figure 279 for description of symbols.

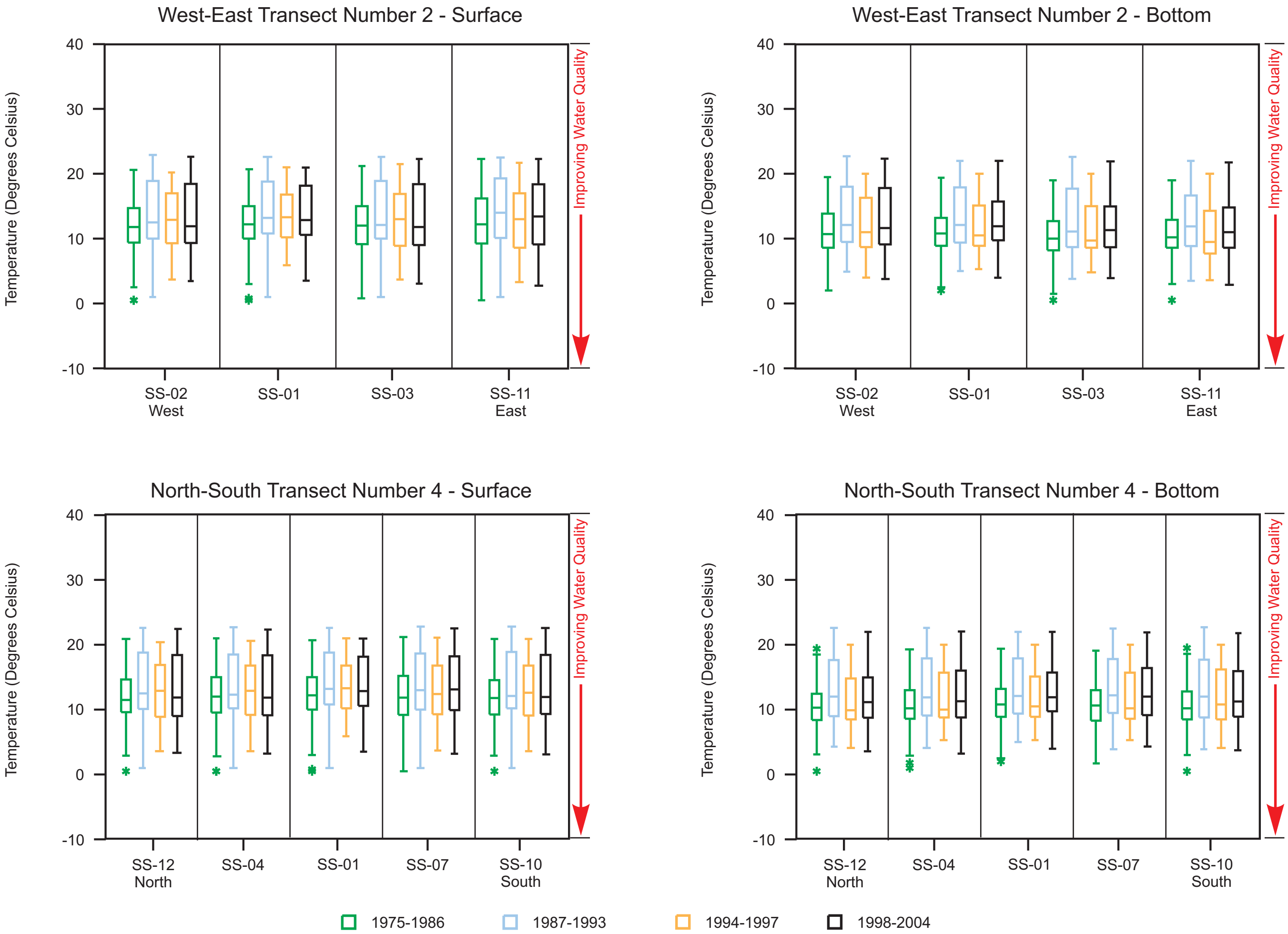
Source: Milwaukee Water Works, University of Wisconsin-Milwaukee Great Lakes WATER Institute, and SEWRPC.

The median water temperature at stations in the South Shore survey during the period 1998-2004 ranged from 11.1ºC at station SS-03 to 12.0ºC at station SS-01. Median water temperatures in surface water in the South Shore survey during the period 1998-2004 ranged from 11.7ºC at stations SS-06 and SS-08 to 13.4ºC at station SS-11. Median water temperatures in bottom water in the South Shore survey during the period 1998-2004 ranged from 11.0ºC at station SS-11 to 12.0ºC at station SS-07. The relatively small difference between median water temperatures at the surface and bottom indicates that for much of the year the water column in this portion of the nearshore area is near isothermal. Thermal stratification probably occurs rarely and is likely to be weak when

[68] *James T. Waples and J. Val Klump, "Biophysical Effects of a Decadal Shift in Summer Wind Direction Over the Laurentian Great Lakes,"* Geophysical Research Letters, *Volume 29, 2002.*

Figure 332

WATER TEMPERATURE IN LAKE MICHIGAN OFF THE SOUTH SHORE SEWAGE TREATMENT PLANT: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

present. Figure 332 shows water temperature at sampling stations along the two transects through the South Shore survey. Median water temperatures at sampling station SS-01, the site of the outfall from the South Shore WWTP, tend to be slightly higher than at most of the other stations in this survey. Water temperatures at sampling stations in the South Shore survey show a pattern of change over time that is similar to the pattern seen at stations in the nearshore survey. At most stations, they increased between the periods 1975-1986 and 1987-1993, decreased after 1993, and increased after 1998. It is important to note that the increase between the periods 1975-1986 and 1987-1993 was due to the inclusion of data collected during the winter in the earlier period.

Few time-based trends in water temperature were detected in the nearshore Lake Michigan Area (see Table C-6 in Appendix C). When examined on an annual basis, trends toward increasing water temperatures were detected at three stations in the nearshore survey. Given that these stations are associated with the outer harbor, these trends may reflect conditions in the Milwaukee Harbor estuary more than conditions in Lake Michigan. In any case, these trends account for a small portion of the variation in the data. Regression analysis was also performed on water temperature data from the Linnwood Avenue water intake for the period 1975-1999. A statistically significant trend toward water temperature increasing over time was detected at this site. It accounted for a small portion of the variation in the data.

Alkalinity

The mean value of alkalinity in the nearshore areas of Lake Michigan over the period of record was 128.9 mg/l as $CaCO_3$. The data show moderate variability, ranging from 5.0 to 1,531.0 mg/l as $CaCO_3$. The mean value of alkalinity for stations in MMSD's South Shore survey during the period of record was 114.2 mg/l as $CaCO_3$. The data at stations in this survey ranged between 11.0 mg/l as $CaCO_3$ and 310.0 mg/l as $CaCO_3$. Few stations showed any evidence of significant time-based trends when analyzed on an annual basis (see Table C-6 in Appendix C). Significant increasing trends were detected at three stations in the South Shore survey, but they accounted for a small portion of the variation in the data. When examined on a seasonal basis, trends toward increasing alkalinity during the summer were detected at five stations in the nearshore survey. At three of these stations, the trends accounted for substantial portions of the variation in the data. This probably reflects the small number of samples available during the summer at these sites and not strong increasing trends. Trends toward decreasing concentrations during the summer were detected at four stations in the South Shore survey. These accounted for a small portion of the variation in the data. Few correlations were found between alkalinity and other water quality parameters at sampling stations in the nearshore survey. Alkalinity concentrations at sampling stations in the South Shore survey are positively correlated with specific conductance and concentrations of chloride, both parameters which, like alkalinity, measure amounts of dissolved material in water. Alkalinity is negatively correlated with pH. This reflects the decline in pH that occurs as carbon dioxide is removed from the water during photosynthesis. At some stations, alkalinity is negatively correlated with temperature, reflecting the fact that it indirectly measures concentrations of carbon dioxide in water and that solubility of gases in water decreases with increasing temperature.

Biochemical Oxygen Demand (BOD)

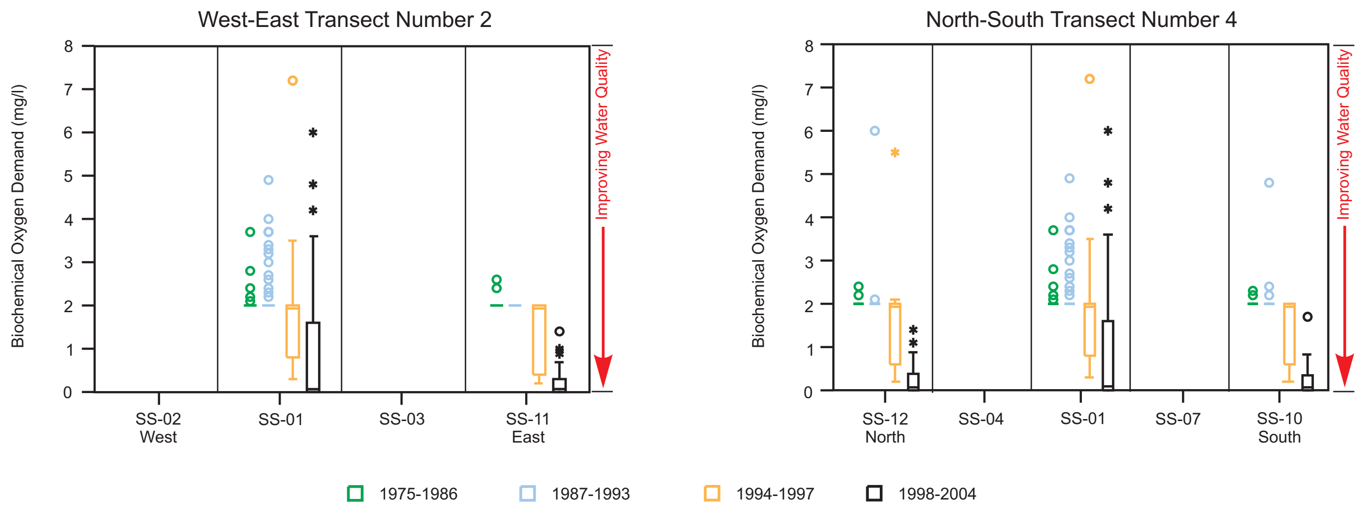
The mean concentration of BOD in the nearshore Lake Michigan area during the period of record was 1.53 mg/l. Individual samples varied from below the limit of detection to 8.80 mg/l. It is important to note that since data were available from only four sampling stations in the nearshore survey that are relatively close to either the outer harbor or the outfall from the South Shore WWTP, this average may not be representative of concentrations in other sections of the nearshore area. The mean concentration of BOD at sampling stations in MMSD's South Shore survey during the period of record was 1.41 mg/l. Individual samples varied from below the limit of detection to 7.20 mg/l. Figure 333 shows concentrations of BOD at stations along transects through the South Shore survey. No data were available from four of the stations along these two transects. BOD concentrations were highest at station SS-01, which is at the outfall from the South Shore WWTP. Concentrations were lower at other stations. Figure 333 also shows that BOD concentration decreased over time. Table C-6 in Appendix C shows that statistically significant trends toward decreasing BOD concentrations were detected at all sampling stations for which data are available. At most stations, these trends accounted for a moderate to substantial amount of the variation in the data.

Several factors may influence BOD concentrations in the nearshore Lake Michigan area. BOD concentrations in the nearshore area are positively correlated at a few stations with concentrations of some nutrients such as total nitrogen and total phosphorus. These correlations may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into Lake Michigan, especially since these stations are located at sites that would be expected to be influenced by BOD inputs from WWTP outfalls and, for some stations, inputs from the Milwaukee Harbor estuary and outer harbor. In addition, aerobic metabolism of many organic nitrogen compounds requires oxygen and thus these compounds contribute to BOD.

The declining trends in BOD concentrations over time detected at stations in the nearshore Lake Michigan areas represent an improvement in water quality.

Figure 333

BIOCHEMICAL OXYGEN DEMAND IN LAKE MICHIGAN OFF THE SOUTH SHORE SEWAGE TREATMENT PLANT: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

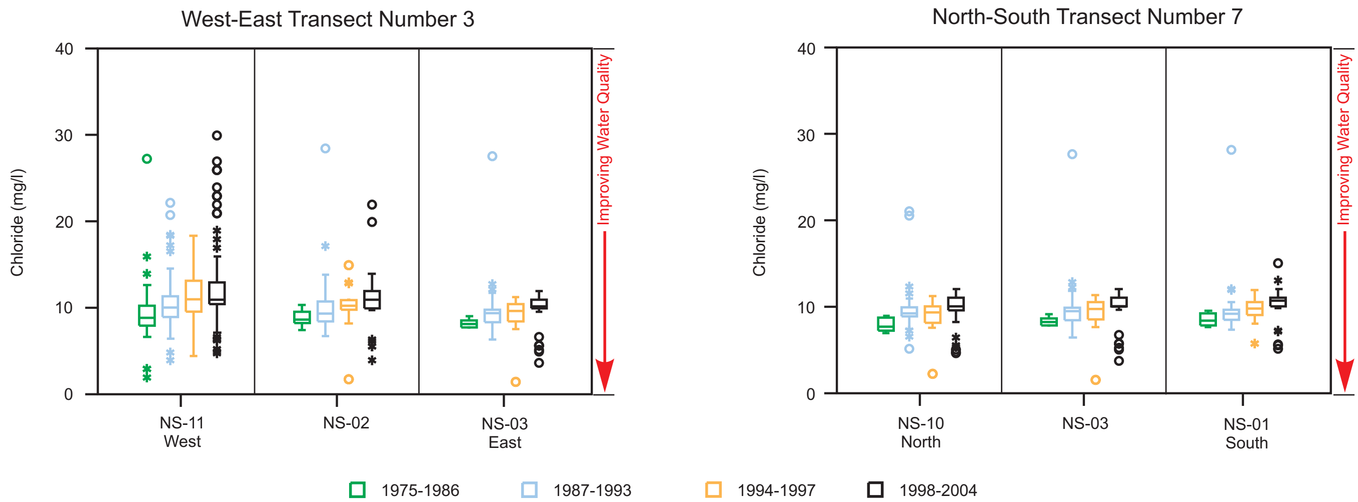
Chloride

The mean concentration of chloride in the nearshore Lake Michigan waters over the period of record was 21.1 mg/l. Concentrations in individual samples ranged between 0.9 mg/l and 160.0 mg/l. The mean concentration of chloride at sampling stations in MMSD's South Shore survey was 16.6 mg/l. Concentrations in individual samples ranged between 1.0 mg/l and 236.0 mg/l. Figure 334 shows concentrations of chloride at stations along two transects through the nearshore area. Two geographical trends are apparent in the data. Concentrations of chloride tend to decrease from west to east away from the shoreline into the lake. Concentrations of chloride also tend to increase from north to south. Figure 334 also shows that chloride concentrations in the nearshore area have also increased over time. Table C-6 in Appendix C of this report shows that these increases represent statistically significant trends at most sampling stations in the nearshore area. Figure 335 shows chloride concentrations at stations along two transects near the outfall from the South Shore WWTP. The highest concentrations of chloride were observed at the sampling station at the outfall, SS-01. Concentrations of chloride at other sampling stations in this survey appear to decrease with distance from the outfall. Mean concentrations of chloride at the sampling stations to the west of north-south transect number 4 tend to be higher than mean concentrations of chloride at sampling stations to the east of this transect. Figure 335 also shows that chloride concentrations have increased over time. At all sampling stations in the South Shore survey, these increases represent statistically significant trends (see Table C-6 in Appendix C). Chloride concentrations in the nearshore area and near the outfall from the South Shore WWTP show positive correlations with alkalinity and specific conductance, both parameters which, like chloride, measure amounts of dissolved material in water. In addition, chloride concentrations at stations in the South Shore survey are inversely correlated with temperature. This is likely to be related to the use of deicing salts on streets and highways.

Chloride concentrations in the nearshore areas of Lake Michigan have increased. These increases have occurred during a period when the ambient concentrations of chloride in offshore areas of the Lake have also increased. Between 1983 and 1999, the mean concentration of chloride at sampling stations in offshore areas of Lake

Figure 334

CHLORIDE CONCENTRATIONS AT SITES IN THE NEARSHORE LAKE MICHIGAN AREA: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Michigan increased from 8.68 mg/l to 10.86 mg/l.[69] Given that Lake Michigan contains approximately 1,180 cubic miles of water, it would require over 10.8 million tons of chloride, for instance in the form of over 17.8 million tons of salt, to produce an increase in chloride concentrations of this magnitude throughout the Lake. While this is a very rough estimate of the amount of chloride required to account for the observed increase in concentration, it does give a sense of the amount of material that the increase represents.

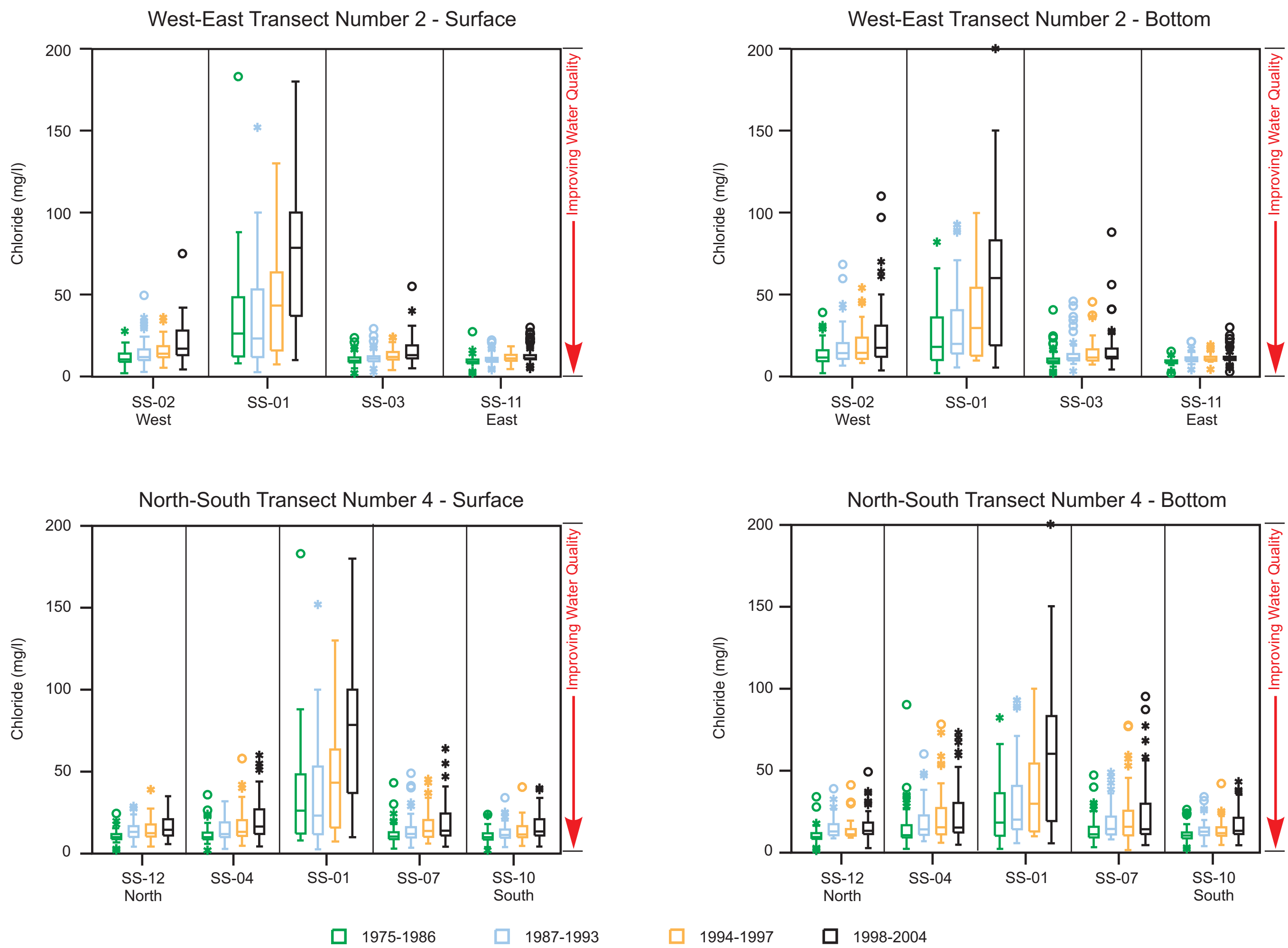
The distribution of chloride concentrations in tributaries to Lake Michigan, the Milwaukee Harbor estuary, outer harbor, and nearshore Lake Michigan areas indicate several sources of chloride to Lake Michigan. Chloride in water flowing into the lake from tributaries is one source. Mean concentrations of chloride measured in streams and rivers flowing into the Lake are many times higher than the ambient concentration offshore. For example, mean concentrations of chloride in Fish Creek, Oak Creek, and the Root River were about 250 mg/l, 158 mg/l, and 143 mg/l, respectively (see the section in this chapter on water quality of streams of the Lake Michigan direct drainage area and Chapters VIII and IX of this report). The mean concentrations of chloride in the Milwaukee Harbor estuary and the outer harbor were about 62 mg/l and 32 mg/l, respectively. While these concentrations are somewhat lower than those observed in Fish Creek, Oak Creek, and the Root River, in part due to mixing with water from the Lake, they are still higher than mean ambient concentrations in offshore areas of the Lake. The mean chloride concentration of 62 mg/l in the estuary and the mean discharge at Jones Island of 448 cfs suggest that the Kinnickinnic, Menomonee, and Milwaukee Rivers contributed approximately 490,000 tons of chloride, or the equivalent of 806,000 tons of salt, to Lake Michigan over the period 1983 to 1999. This represents about 4.5 percent of the chloride required to account for the increase in chloride concentrations in the Lake. While this is a very rough estimate, the fact that discharge from the Milwaukee Harbor estuary represents about 1.5 percent of the discharge into Lake Michigan from major tributaries[70] suggests that it is not an unreasonable estimate.

[69] *Mark E. Holey and Thomas N. Trudeau, "The State of Lake Michigan in 2000,"* Great Lakes Fisheries Commission Special Publication No. 05-01*, 2005.*

[70] *Clifford H. Moritmer,* Lake Michigan in Motion: Responses of an Inland Sea to Weather, Earth-spin, and Human Activities, *The University of Wisconsin Press, 2004.*

Figure 335

CHLORIDE CONCENTRATIONS IN LAKE MICHIGAN OFF THE SOUTH SHORE SEWAGE TREATMENT PLANT: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Effluent from sewage treatment plants constitutes a second source of chloride to the Lake. The high concentrations detected at sampling sites located near the outfalls from the South Shore WWTP (see Figure 335) and the Jones Island WWTP (see Figure 288) indicate that WWTP effluent is contributing chloride to the Lake. Direct runoff from the Lake Michigan direct drainage area is a third source. The higher mean concentrations of chloride detected at the sampling stations to the west of north-south transect number 4 in the South Shore survey suggest that runoff from the Lake Michigan Direct Drainage area is contributing chloride to the Lake.

The increase in chloride concentrations detected at stations in the nearshore Lake Michigan areas represents a decrease in water quality.

Dissolved Oxygen

Over the period of record, the mean concentration of dissolved oxygen in the nearshore Lake Michigan area was 10.2 mg/l. The mean concentration of dissolved oxygen at sampling stations in MMSD's South Shore survey was

10.6 mg/l. In both surveys, the data ranged from concentrations that were undetectable to concentrations in excess of saturation. Figure 336 shows the distributions of dissolved oxygen concentrations at sampling stations along four transects through the nearshore area. Dissolved oxygen concentrations were slightly lower at sampling stations on the southern end of the north-south transects. At most sampling stations, dissolved oxygen concentrations during the period 1987-1993 were lower than concentrations during the period 1975-1986. This was followed by an increase in concentrations during the period 1994-1997 and another decrease during the period 1998-2004. Figure 336 also shows that the range of dissolved oxygen concentrations decreased at most stations after 1986 in the 1987-1993 time period. Because the solubility of oxygen in water is dependent on water temperature (i.e. as water temperatures decrease, dissolved oxygen concentrations increase), this does not reflect any change in the range of dissolved oxygen concentrations in the Lake. Rather, it reflects the fact that MMSD discontinued sampling during the winter after 1986. While this at least partially accounts for the decrease in dissolved oxygen concentrations after 1986, it does not explain subsequent changes. Figure 337 shows a comparison of baseline period monthly mean dissolved oxygen concentrations to historical monthly mean concentrations. While baseline period monthly mean concentrations were generally in historical ranges, in most months they were less than the historical monthly means. The data show strong seasonal patterns to the mean concentrations of dissolved oxygen. The mean concentration of dissolved oxygen is highest during the winter. It declines through spring to reach a minimum during the summer. It then rises though the fall to reach maximum values in winter. This seasonal pattern is driven by changes in water temperature. In addition, the metabolic demands and oxygen requirements of most aquatic organisms, including bacteria, tend to increase with increasing temperature. Higher rates of bacterial decomposition when the water is warm may contribute to the declines in the concentration of dissolved oxygen observed during the summer.

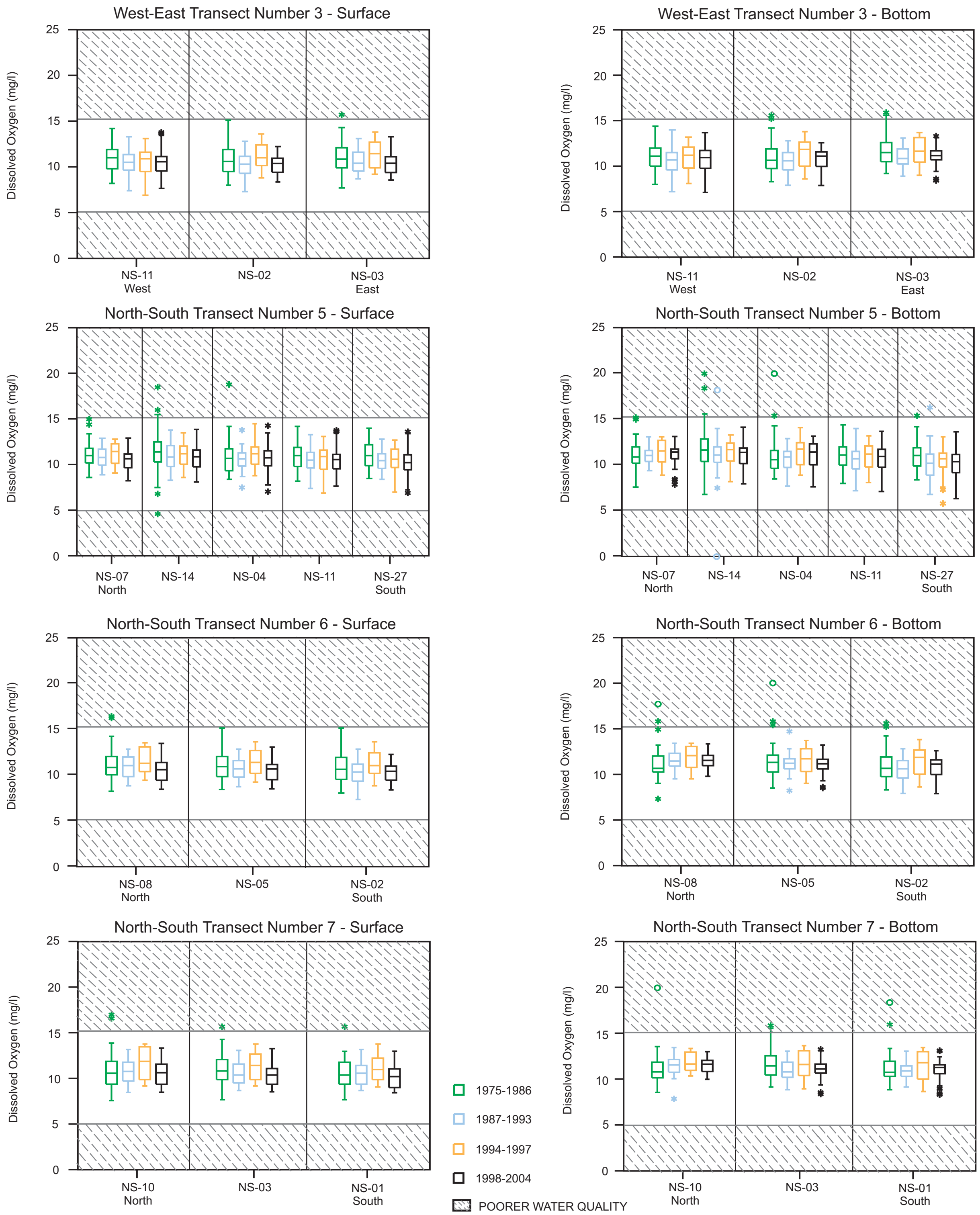
The data given in Figures 336 and 337 suggest that the changes in dissolved oxygen observed over time were driven largely by differences in water temperature and the effect of water temperature on the solubility of oxygen in water. Comparing Figure 336 to Figure 329 shows that during periods when average water temperatures were higher, average dissolved oxygen concentrations were lower. During periods when average water temperatures were lower, average dissolved oxygen concentrations were higher. These relationships were observed both in samples collected at the surface and in samples collected near the bottom. Several generalizations emerge from comparing Figure 337 to Figure 330. While baseline period monthly mean temperatures during the spring were generally within historical ranges, spring warming appears to have occurred earlier in the year during the baseline period. This was accompanied by an earlier decrease in dissolved oxygen concentrations. In addition, baseline period monthly mean temperatures during July and August were higher than historical means. In fact, baseline period monthly maximum temperatures during the month of July were higher than historical maxima at several stations. This was accompanied by monthly mean baseline period dissolved oxygen concentrations that were lower than historical means. Finally, it is important to note that in those instances where baseline period monthly mean temperatures were near or at historical means, dissolved oxygen concentrations were near or at historical means. An example of this was observed during fall months at station NS-10.

Figure 338 shows the distributions of dissolved oxygen concentrations at sampling stations along four transects through MMSD's South Shore survey. Concentrations of dissolved oxygen tended to be consistently lower at station SS-01, the site of the outfall from the South Shore WWTP, than at other stations in the survey. Concentrations of dissolved oxygen at these sites showed the same pattern of changes among periods as was observed at stations along transects in the nearshore survey (see Figure 336). Comparison of Figure 338 to Figure 332 suggests that these changes are also being driven by changes in average water temperature during these periods. The decrease in dissolved oxygen concentration at station SS-01 after 1997 appears to be stronger than decreases observed at other stations.

Several time-based trends in dissolved oxygen concentration were detected in the nearshore Lake Michigan Area. When examined on an annual basis, statistically significant trends toward decreasing dissolved oxygen concentration were detected at all sampling stations in the South Shore survey and at a few stations in the nearshore survey (see Table C-6 in Appendix C). With the exception of station SS-01, these trends accounted for only a small portion of the variation in the data. It is important to note that data from samples collected during the winter were excluded from this analysis, so the 1987 change in MMSD's sampling schedule does not account for these

Figure 336

DISSOLVED OXYGEN CONCENTRATIONS AT SITES IN THE NEARSHORE LAKE MICHIGAN AREA: 1975-2004



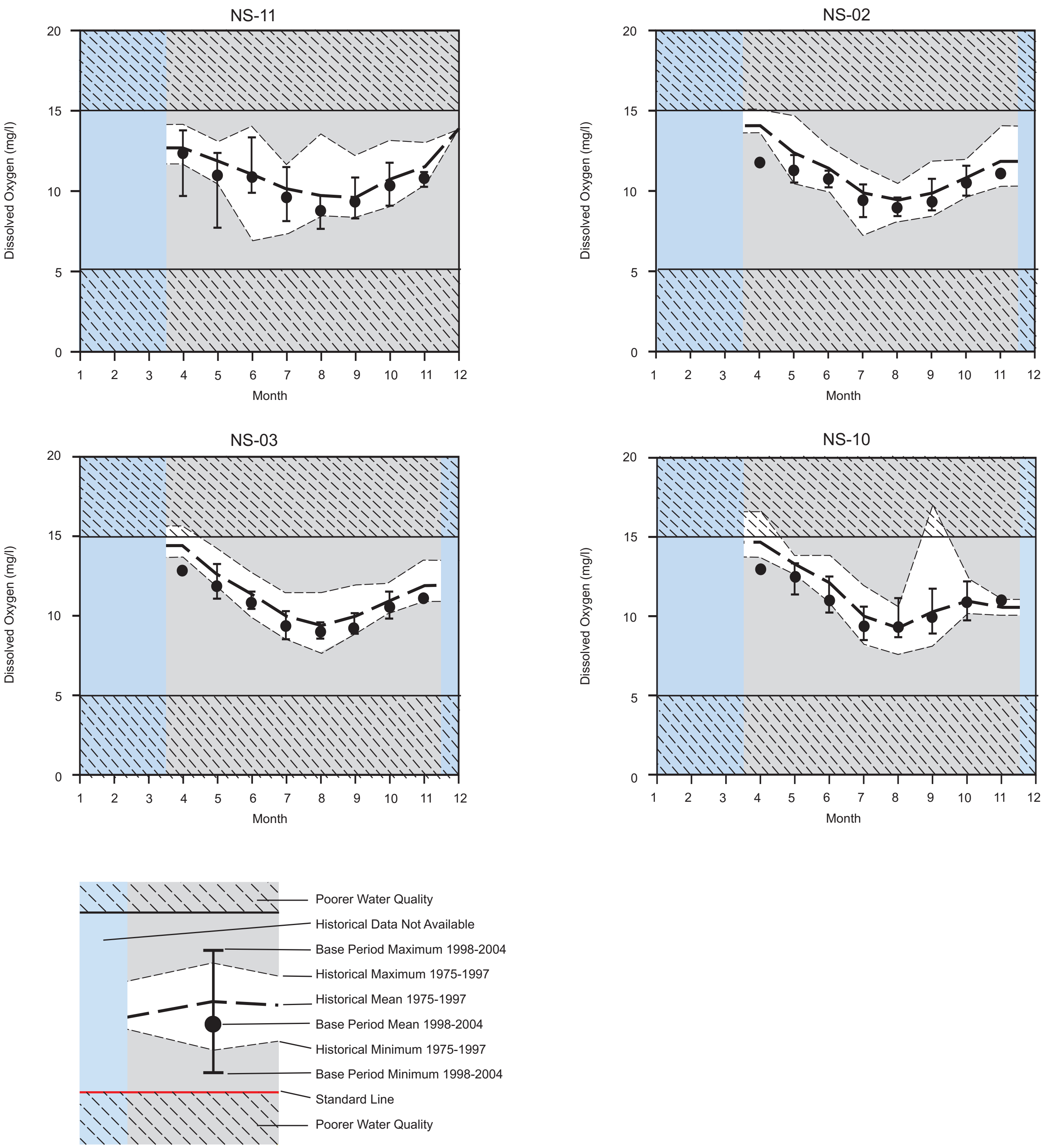
NOTES: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 337

HISTORICAL AND BASE PERIOD DISSOLVED OXYGEN CONCENTRATIONS AT SITES IN THE NEARSHORE LAKE MICHIGAN AREA: 1975-2004



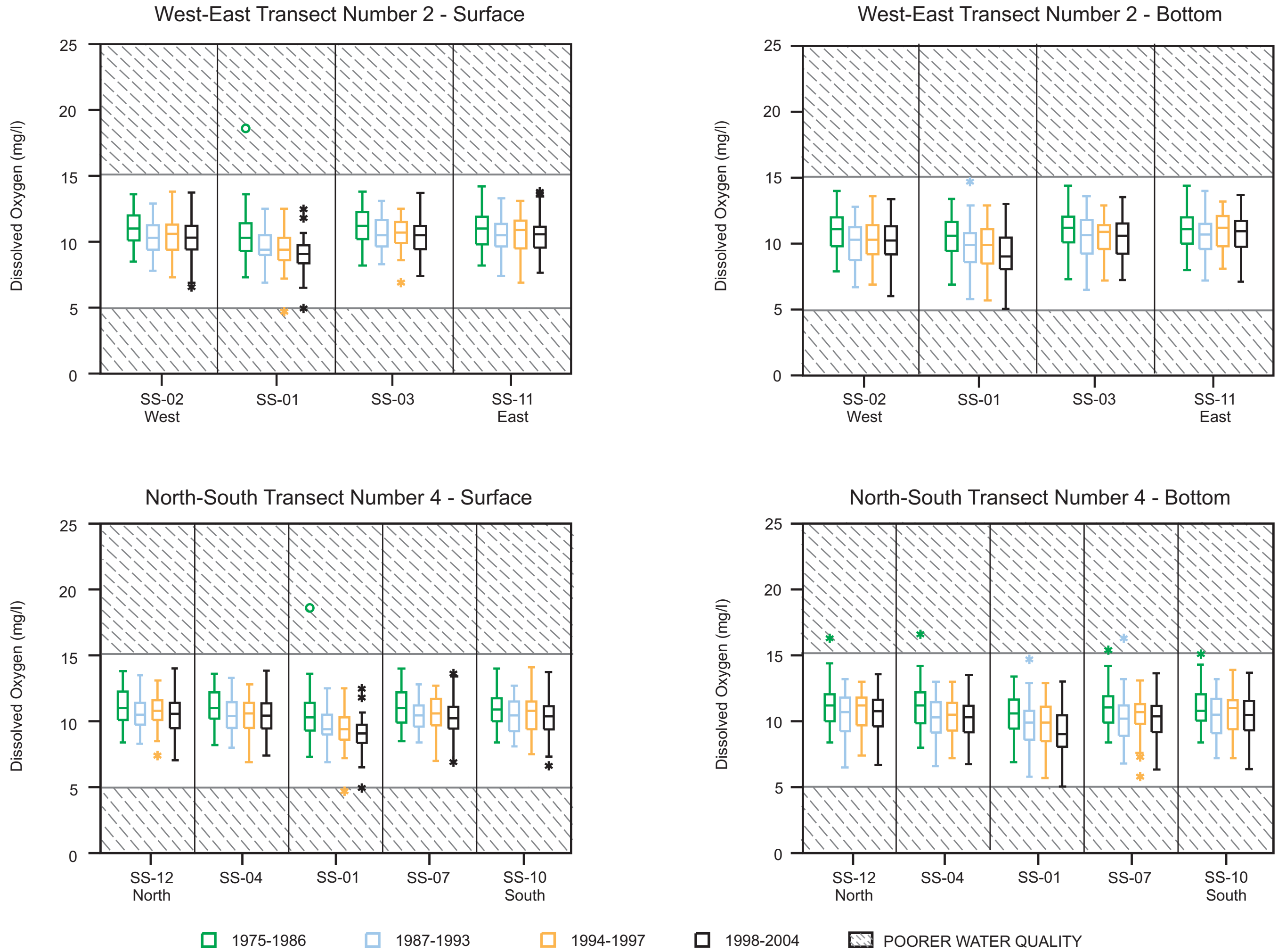
NOTES: See Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 338

DISSOLVED OXYGEN CONCENTRATIONS IN LAKE MICHIGAN OFF THE SOUTH SHORE SEWAGE TREATMENT PLANT: 1975-2004



NOTES: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

140 percent saturation and higher can cause fish kills. A 15 mg/l dissolved oxygen concentration roughly translates to a saturation of approximately 150 percent at an average water temperature of 14 degrees Celsius.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

trends. At stations in the nearshore survey, the trends appear to reflect trends toward decreasing oxygen concentration during the spring. By contrast, the decreasing trends at stations in the South Shore survey appear to reflect decreases throughout much of the year.

Several other factors in addition to temperature can affect dissolved oxygen concentrations in the nearshore Lake Michigan area. First, thermal stratification, which separates the upper portion of the water column from the water underneath, will prevent oxygen from the atmosphere from replenishing dissolved oxygen in deeper waters. Because of this, dissolved oxygen concentrations in the nearshore area will tend to vary with depth during periods of stratification. In the upper layer, dissolved oxygen concentrations, in the absence of other process, will tend to be in equilibrium with the atmosphere. This often results in dissolved oxygen concentrations being at or near the saturation concentrations determined by water temperature. Because water temperatures in the lower layer are much cooler than water temperatures in the upper layer during stratification, in the absence of any other processes, dissolved oxygen concentrations in the lower layer may be higher than dissolved oxygen concentrations in the upper layer. In Lake Michigan, thermal stratification sets up in the spring, generally beginning in the nearshore areas and moving out into the Lake. Stratification breaks down in the fall and winter with the extension of the boundary between the two layers being pushed progressively lower by loss of heat from the upper layer and wind-driven mixing. Second, decomposition of organic material in the water and underlying sediments, through chemical and especially biological processes, removes oxygen from the water, lowering the dissolved oxygen concentration. The organic material causing this can originate in the Lake through biological production, or enter from runoff or discharges from the adjacent land. Third, dissolved oxygen concentrations at most sampling stations in the nearshore area are positively correlated with chlorophyll-*a* concentrations. This reflects the effect of photosynthesis on dissolved oxygen concentrations. During photosynthesis, algae release oxygen as a byproduct of the photosynthetic reactions. Fourth, dissolved oxygen concentrations in water can be affected by numerous other factors including the presence of aquatic plants, sunlight, and the amount and type of sediment as summarized in the water quality indicators section in Chapter II of this report.

The trends toward decreasing dissolved oxygen concentration at some sampling stations in the nearshore area represent a decline in water quality. It is important to note that this decline appears to be driven by changes in water temperature in Lake Michigan which, in turn, are being driven by climatic variations.

Hardness

Over the period of record, the mean hardness in the nearshore Lake Michigan waters was 161.9 mg/l as $CaCO_3$. On a commonly used scale, this is considered to be hard water.[71] The range of the data runs from 1.7 to 617.3 mg/l as $CaCO_3$, showing considerable variability. The mean concentration of hardness at sampling stations in the South Shore survey was 147.6 mg/l as $CaCO_3$, with a corresponding range of 4.1 to 480.8 mg/l as $CaCO_3$. Some of this variability probably results from inputs of relatively soft water during storm events. When examined on an annual basis, no statistically significant time-based trends in hardness concentration were detected at stations in either the nearshore or South Shore surveys (see Table C-6 in Appendix C). Significant trends toward decreasing hardness were detected at some stations during the summer or fall, but the regression relationships at most of these stations suggest decreases on the order of less than 0.70 mg/l as $CaCO_3$ per year. This suggests that while trends in hardness concentration may be present in the nearshore area, they are not having a substantial effect on water chemistry in the Lake.

pH

The mean pH in nearshore Lake Michigan areas over the period of record was 8.0 standard units. The mean value at stations in the South Shore survey was also 8.0 standard units. Values in individual samples ranged from 6.1 to 9.2 standard units. Table C-6 in Appendix C shows that statistically significant trends toward pH increasing over time were detected at most stations in the South Shore survey and at four stations in the nearshore survey. At most of these sites, the trends account for only a small portion of the variation in the data. At some stations, dissolved oxygen concentrations are positively correlated with pH. This correlation may reflect the effect of photosynthesis on these parameters. During photosynthesis, algae and plants remove carbon dioxide from the water. This tends to raise the water's pH. At the same time, oxygen is released as a byproduct of the photosynthetic reactions.

Secchi Depth

The mean Secchi depth in the nearshore Lake Michigan areas over the period of record was 3.57 m. Secchi depth in the nearshore areas ranged from just below the surface to 16.00 m. The mean Secchi depth at sampling stations in MMSD's South Shore survey over the period of record was 3.70 m. Secchi depth at stations in this survey ranged from just below the surface to 13.70 m. Figure 339 shows Secchi depths at stations along four transects through the nearshore area. Three patterns are apparent in these data. First, Secchi depths tend to increase from west to east from the shoreline. This may reflect inputs of suspended material and nutrients from the shore and dispersal of these as water motions mix them into the Lake. Second, Secchi depths tend to decrease from north to

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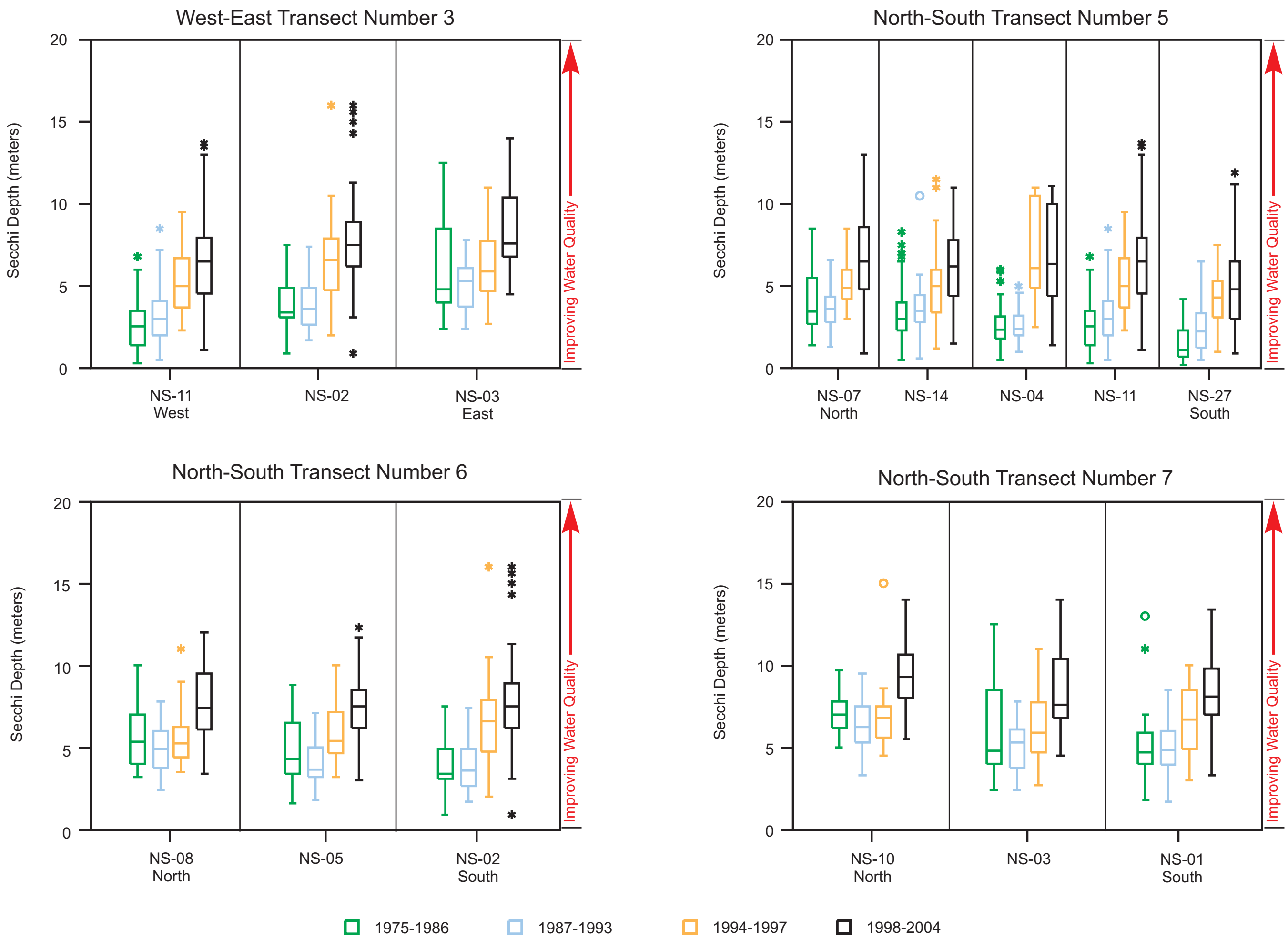
[71]*E. Brown, M.W. Skougstad, and M.J. Fishman,* Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, *U.S. Department of Interior, U.S. Geological Survey, 1970.*

Figure 339

SECCHI DEPTH AT SITES IN THE NEARSHORE LAKE MICHIGAN AREA: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

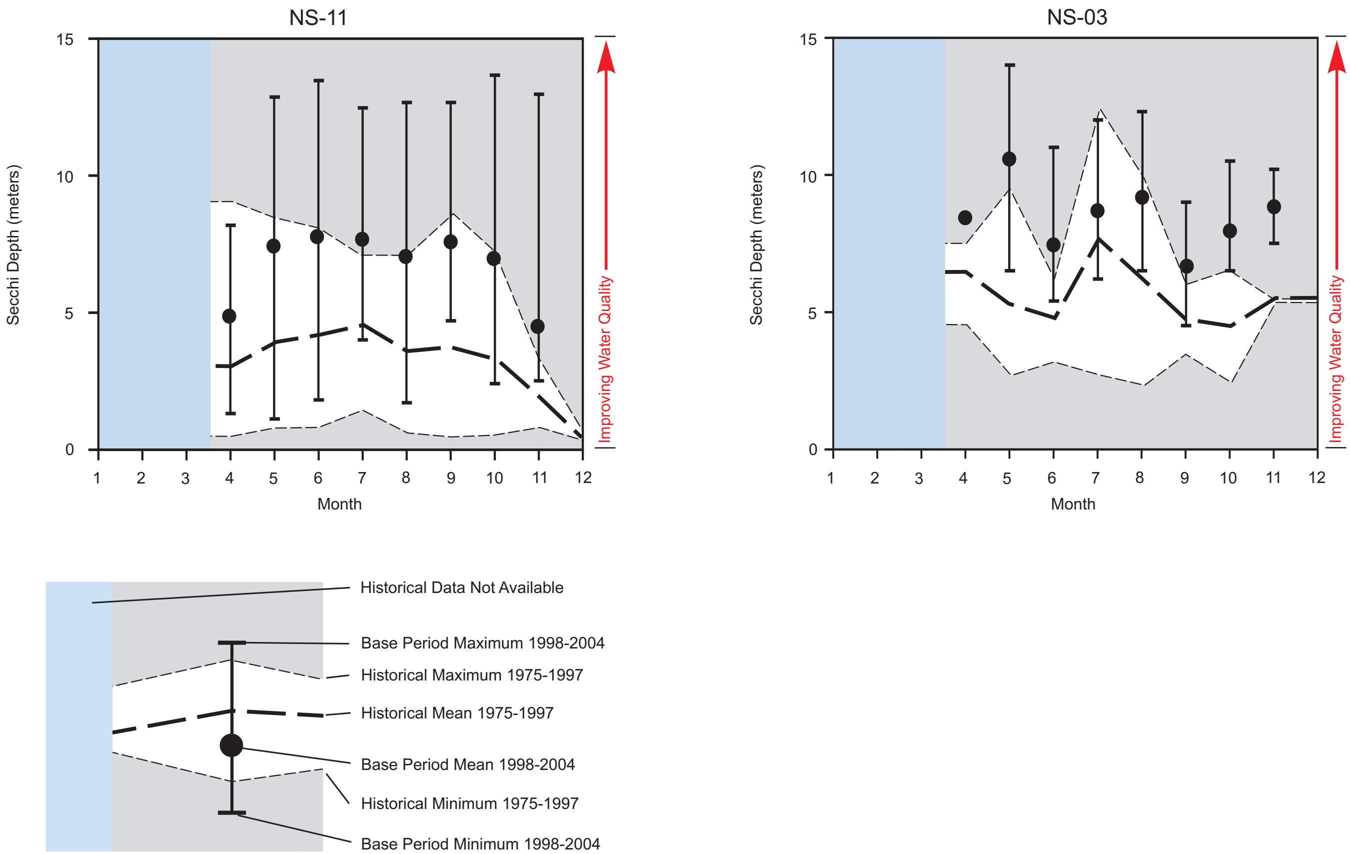
Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

south. Third, Secchi depths at all stations have increased since 1975. At some stations this increase occurred over the entire period of record; at others, it occurred after 1994. These increases represent statistically significant trends toward increasing Secchi depth over time (see Table C-6 in Appendix C).

Figure 340 shows a monthly comparison of the historical and baseline Secchi depths at two sampling stations in the nearshore area. At both stations, baseline period monthly mean Secchi depths were higher than historical means. In some months, they were near, or exceeded, historical maxima. Figure 341 shows Secchi depth at sampling stations along two transects through MMSD's South Shore survey. A different geographic pattern was observed in Secchi depths from these stations. The lowest Secchi depths were observed at station SS-01, the station at the site of the outfall from the South Shore WWTP. Secchi depth increased in all directions away from this station. Secchi depth has increased over time at all stations in this survey. At most stations, this increase occurred over the entire period of record, but at SS-01 Secchi depth decreased after 1998. The increases in Secchi depth at stations in the South Shore survey represent statistically significant trends (see Table C-6 in Appendix C). Figure 342 shows a monthly comparison of the historical and baseline Secchi depths at four

Figure 340

HISTORICAL AND BASE PERIOD SECCHI DEPTH AT SITES IN THE NEARSHORE LAKE MICHIGAN AREA: 1975-2004



NOTE: See Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

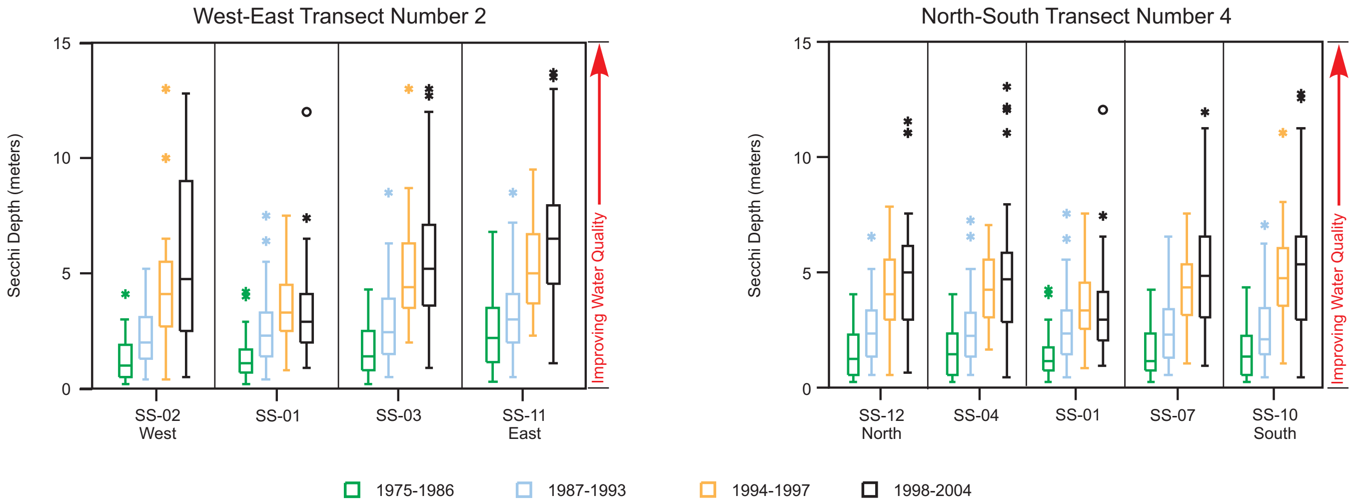
Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

sampling stations in the South Shore survey. At most of these stations, baseline period mean monthly Secchi depth was higher than historical means. The exception to this generalization occurred at station SS-01. At this station, baseline period mean monthly Secchi depth during the early and mid summer and during late fall were at or near historical means. The lower Secchi depths at station SS-01 suggest that discharges from the outfall of the South Shore WWTP may be acting to reduce water clarity. This effect is probably not caused by algal growth spurred by nutrients in effluent from the outfall, because concentrations of chlorophyll-*a* detected in samples collected at this station decreased over time (see Figure 328). Instead, this decrease in water clarity may be related either to turbidity from effluent discharged from the outfall or mixing related to temperature differences between effluent from the outfall and water in Lake Michigan. The higher Secchi depths at sampling stations adjacent to station SS-01 indicate that this decrease in water clarity is a local phenomenon.

Several factors may be responsible for the increase in Secchi depth. Chlorophyll-*a* concentrations have generally decreased in the nearshore Lake Michigan areas. Much of this decrease appears to be the result of filtering activities of zebra mussels and quagga mussels which removes phytoplankton from the water column. In addition, reduced nutrient loads to the nearshore areas, resulting from reductions of combined sewer overflows since the Inline Storage System came online, nonpoint source pollution control efforts, and basinwide reductions in phosphorus concentrations in open water areas of Lake Michigan beyond the nearshore area may also account for the decrease in chlorophyll-*a* concentrations in the nearshore areas and consequent increases in Secchi depth.

Figure 341

SECCHI DEPTH IN LAKE MICHIGAN OFF THE SOUTH SHORE SEWAGE TREATMENT PLANT: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

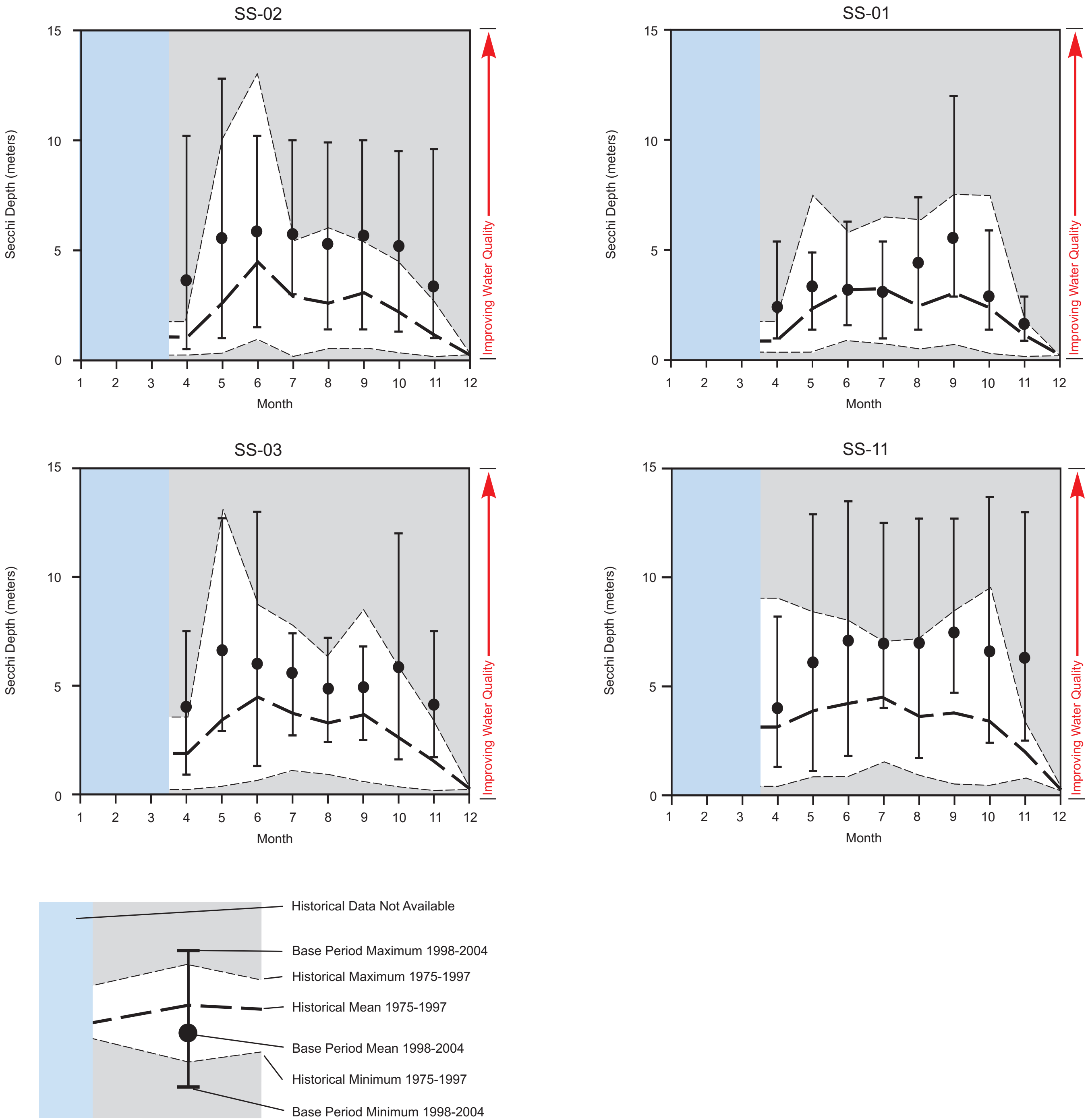
Secchi depths at all stations in the nearshore and South Shore surveys were strongly negatively correlated with concentrations of chlorophyll-*a*, suggesting that the increases in Secchi depth are being driven, at least in part, by smaller standing crops of phytoplankton. In addition, Secchi depths at several stations in the South Shore survey were negatively correlated with ammonia and fecal coliform bacteria. The increases in Secchi depths in the nearshore Lake Michigan areas represent an improvement in water quality.

Specific Conductance

The mean value for specific conductance in the nearshore Lake Michigan area over the period of record was 341 μS/cm. Specific conductance in this survey ranged from 160 μS/cm to 2,921 μS/cm. The mean value of specific conductance at sampling stations in MMSD's South Shore survey over the period of record was 318 μS/cm. Values in individual samples ranged between 130 μS/cm and 2,944 μS/cm. Some of this variability observed in specific conductance may reflect the discontinuous nature of inputs of dissolved material into Lake Michigan. Runoff associated with storm events can have a major influence on the concentration of dissolved material in tributaries discharging into the Lake. The first runoff from a storm event transports a large pulse of salts and other dissolved material into tributaries and ultimately into the Lake. This will tend to raise specific conductance. Later runoff associated with the event will be relatively dilute. This will tend to lower specific conductance. Because contributions to the Lake mix into a large volume of water, these effects will tend to be strongest at sampling stations near the shore and near the mouths of tributaries. Figure 343 shows specific conductance at sampling stations along two transects through the South Shore survey. The highest values of specific conductance occurred at sampling station SS-01, at the site of the outfall from the South Shore WWTP. The lower values of specific conductance at other stations in the survey, especially the ones farthest from SS-01, indicate that the dissolved material from the outfall mixes rapidly into the Lake and causes only a localized increase in specific conductance. Values of specific conductance at stations in the South Shore survey have fluctuated over time. Specific conductance increased after 1986. This was followed by a decrease after 1993 and another increase after 1997. Table C-6 in Appendix C shows that statistically significant trends toward specific conductance decreasing over time were detected at most stations in the nearshore and South Shore surveys for which sufficient data exist to assess trends. Specific conductance in both surveys show strong positive correlations with chloride concentrations. At stations in the South Shore survey, specific conductance also shows

Figure 342

HISTORICAL AND BASE PERIOD SECCHI DEPTH IN LAKE MICHIGAN OFF THE SOUTH SHORE SEWAGE TREATMENT PLANT: 1975-2004

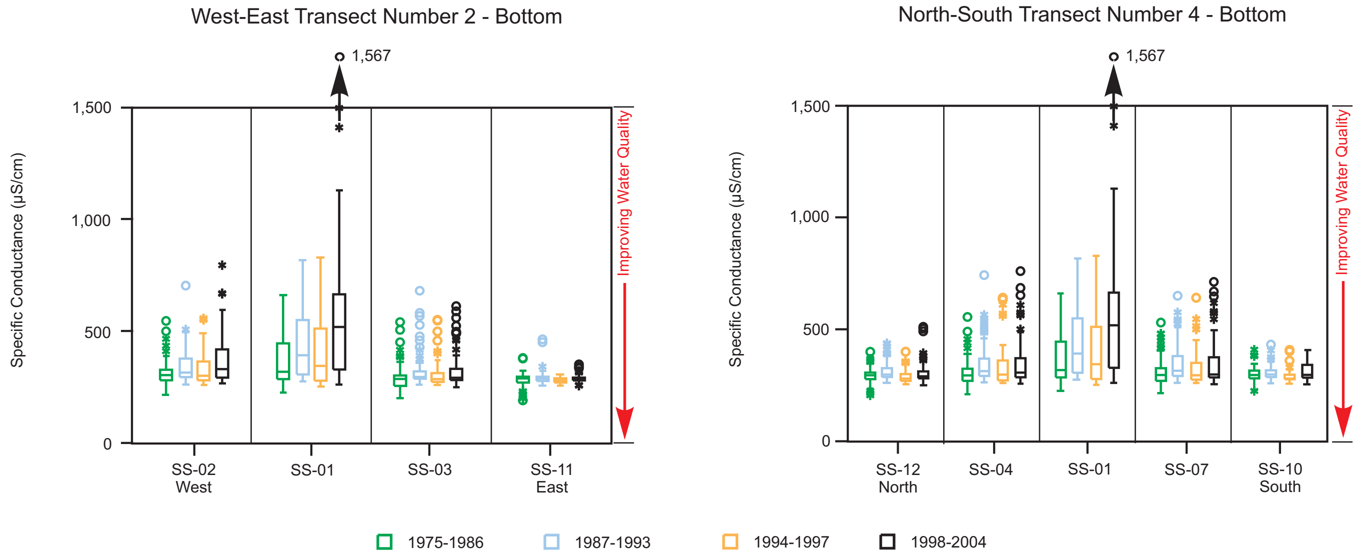


NOTE: See Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Figure 343

SPECIFIC CONDUCTANCE IN LAKE MICHIGAN OFF THE SOUTH SHORE SEWAGE TREATMENT PLANT: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

positive correlations with alkalinity and some nutrients such as nitrate and dissolved phosphorus. These are parameters which, like specific conductance, measure amounts of dissolved material in water. These decreases detected in specific conductance indicate that the concentrations of dissolved materials in water in the nearshore area are decreasing and represent an improvement in water quality.

Suspended Material

The mean value for total suspended solids (TSS) concentration in the nearshore Lake Michigan areas over the period of record was 6.8 mg/l. Considerable variability was associated with this mean, with values ranging from below the limit of detection to 280 mg/l. Data were only available for nearshore survey sampling stations in either the outer harbor survey or the South Shore survey. No data were available for stations farther out in the Lake. The mean value for TSS concentration at sampling stations in MMSD's South Shore survey over the period of record was 5.3 mg/l. Concentrations in individual samples ranged from below the limit of detection to 94 mg/l. When analyzed on an annual basis, statistically significant trends toward decreasing TSS concentrations were detected at four stations in the nearshore survey and at all stations in the South Shore survey. TSS concentrations in the nearshore areas showed positive correlations with concentrations of chlorophyll-*a* and total phosphorus. The trends toward decreasing TSS concentrations in the nearshore area represent an improvement in water quality.

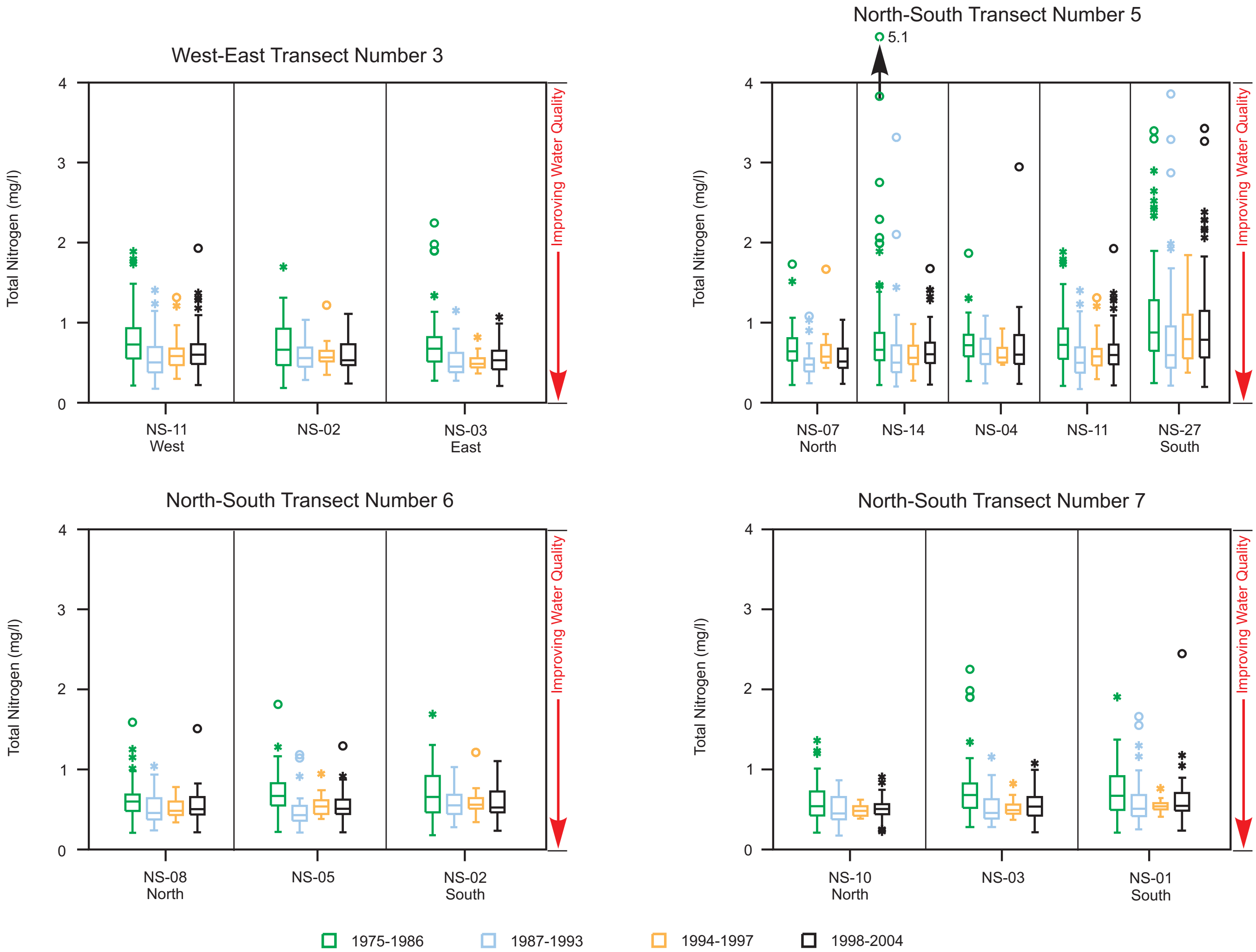
Nutrients

Nitrogen Compounds

The mean concentration of total nitrogen in the nearshore Lake Michigan area over the period of record was 0.99 milligrams per liter measured as nitrogen (mg/l as N). Concentrations ranged from 0.04 mg/l as N to 9.88 mg/l as N. The mean concentration of total nitrogen at sampling stations in MMSD's South Shore survey over the period of record was 1.00 mg/l as N. Concentrations ranged from 0.04 mg/l as N to 12.70 mg/l as N. Figure 344 shows changes in total nitrogen concentrations over time since 1975 at sampling stations along four transects through the nearshore Lake Michigan area. In general, higher concentrations of total nitrogen were detected at stations that are closer to shore. At all stations, concentrations of total nitrogen during the period 1987-1993 were lower than

Figure 344

TOTAL NITROGEN CONCENTRATIONS AT SITES IN THE NEARSHORE LAKE MICHIGAN AREA: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

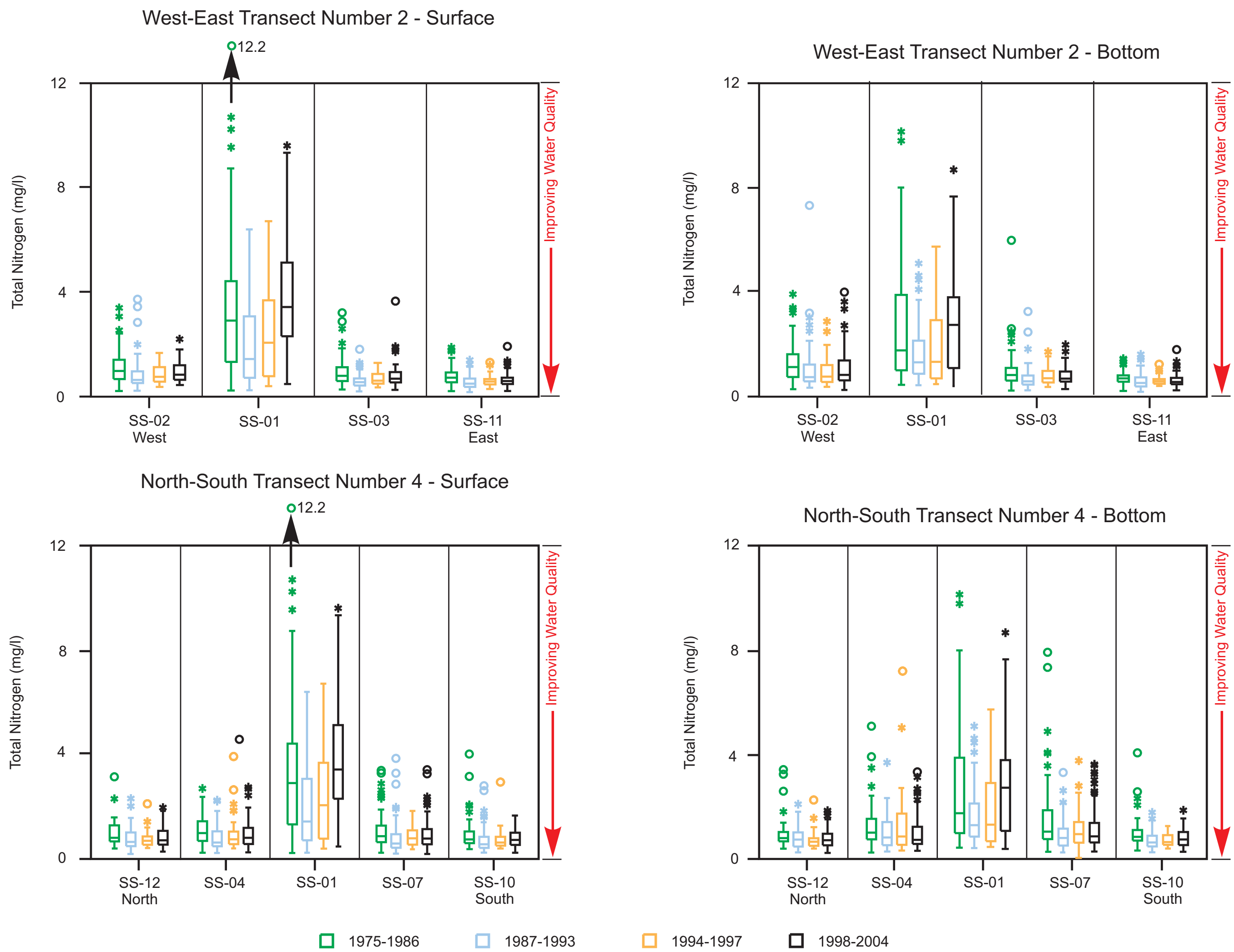
Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

during the period 1975-1986. At most stations, concentrations of total nitrogen increased in subsequent periods. At a few stations, concentrations increased after 1986 and decreased after 1997. Figure 345 shows total nitrogen concentrations at sampling stations along two transects through MMSD's South Shore survey. For the most part, concentrations of total nitrogen were higher in samples collected from the surface of the Lake than in samples collected from the bottom. Concentrations of total nitrogen were highest at station SS-01, the site of the outfall from the South Shore WWTP. Total nitrogen concentrations at this station appear to be strongly influenced by nitrogen compounds in effluent discharged from the outfall. Concentrations of total nitrogen were markedly lower at the other stations near SS-01, indicating that effluent from the outfall mixes fairly rapidly into water in the Lake.

Map 122 shows concentrations of total nitrogen from surface water in the nearshore area at the two meter depth contour along a portion of the western shore of Lake Michigan from sampling conducted by the WDNR during spring and fall of 2004. Note that the circles representing the spring samples indicate the sampling locations; the

Figure 345

TOTAL NITROGEN CONCENTRATIONS IN LAKE MICHIGAN OFF THE SOUTH SHORE SEWAGE TREATMENT PLANT: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

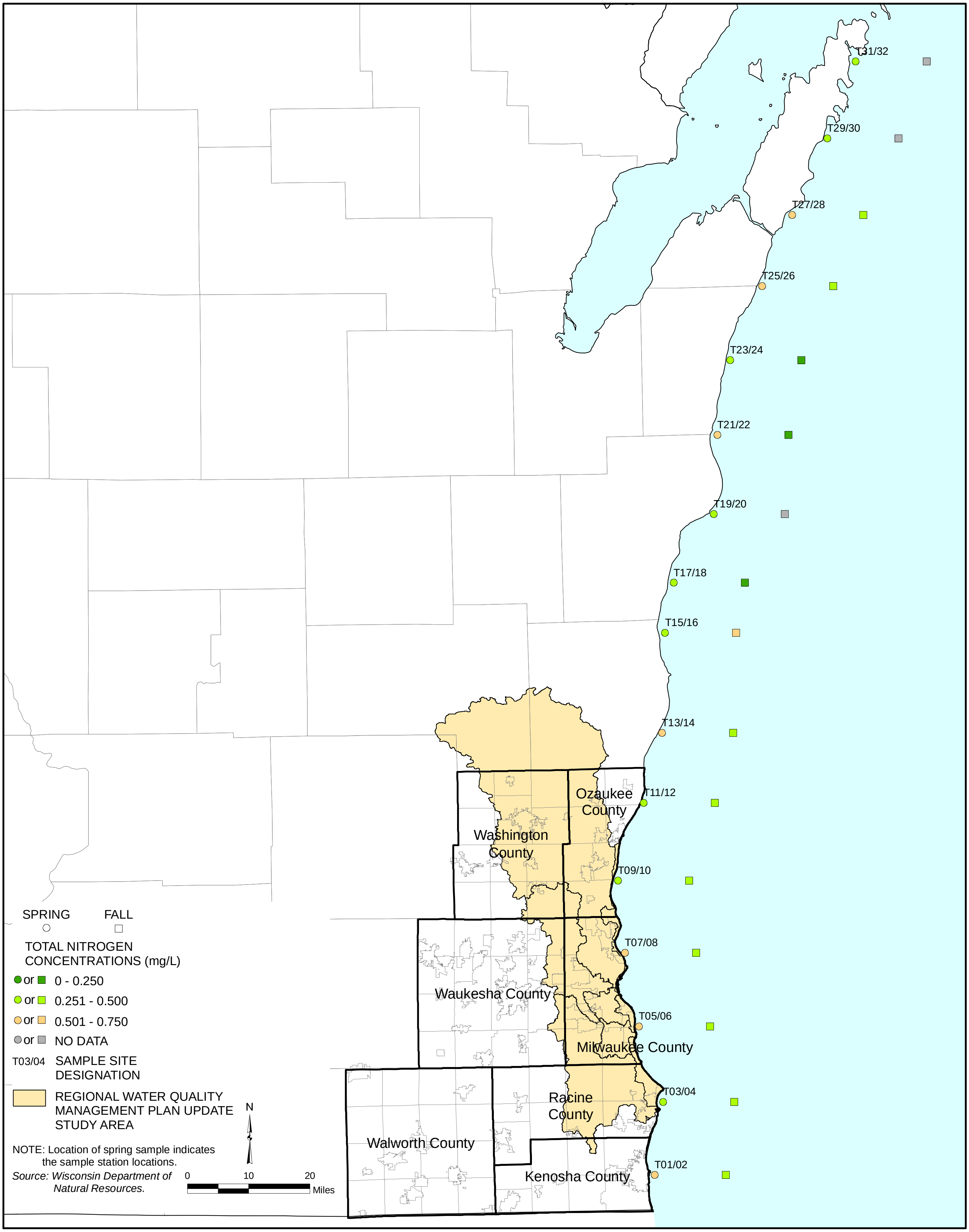
Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

squares representing fall samples are offset for clarity. There was no strong north to south trend in concentrations of total nitrogen in the nearshore area along this portion of the western shore of the Lake. Concentrations of total nitrogen tended to be higher during spring than during fall. Concentrations of total nitrogen at the two sampling stations off Milwaukee County were below 0.75 mg/l as N during the spring and 0.50 mg/l as N during the fall. The mean concentrations of total nitrogen detected in the nearshore and South Shore surveys during spring and fall 2004 were higher than those reported for the Lake by the WDNR. Concentrations at all stations decreased between the periods 1975-1986 and 1987-1993. After 1993, concentrations at most stations increased.

Few statistically significant time-based trends were detected in total nitrogen concentration in the nearshore Lake Michigan area. When examined on an annual basis, decreasing concentrations were detected at four stations (see Table C-6 in Appendix C). These trends are mostly attributable to decreases during the fall. They account for a

Map 122

TOTAL NITROGEN CONCENTRATIONS IN LAKE MICHIGAN: 2004



small portion of the variation in the data. It is important to note that, given that concentrations decreased between the periods 1975-1986 and 1987-1994, and that concentrations have increased since 1987, the results set forth in Table C-6 in Appendix C may understate current trends. The concentrations of total nitrogen in the nearshore Lake Michigan area and at the stations in the South Shore survey are positively correlated with the concentrations of nitrate and organic nitrogen, reflecting the fact that these tend to be the major forms of nitrogen compounds in the Lake.

Total nitrogen is a composite measure of several different compounds which vary in their availability to algae and aquatic plants and vary in their toxicity to aquatic organisms. Common constituents of total nitrogen include ammonia, nitrate, and nitrite. In addition a large number of nitrogen-containing organic compounds, such as amino acids, nucleic acids, and proteins commonly occur in natural waters. These compounds are usually reported as organic nitrogen.

The mean concentration of ammonia in the nearshore Lake Michigan area over the period of record was 0.21 mg/l as N. Ammonia concentrations in individual samples varied between 0.34 mg/l as N and 7.54 mg/l as N. The mean concentration of ammonia at stations in MMSD's South Shore survey over the period of record was 0.29 mg/l as N. Ammonia concentrations in individual samples varied from below the limit of detection to 22.40 mg/l as N. Figure 346 shows ammonia concentrations along four transects through the nearshore area. At most sampling stations, median ammonia concentrations increased after 1993 and then decreased after 1998.

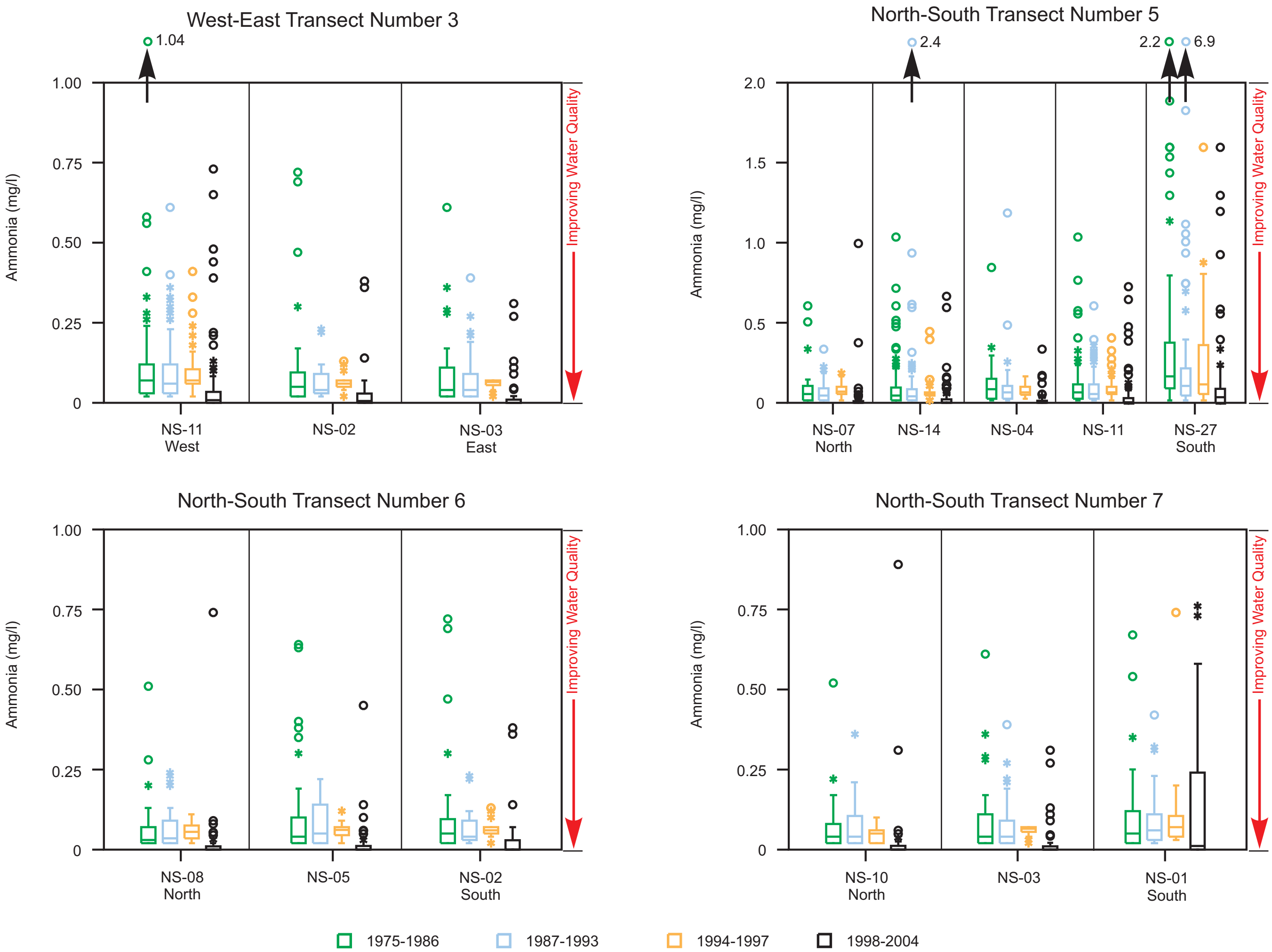
Figure 347 shows ammonia concentrations at sampling stations along two transects through MMSD's South Shore survey. The highest concentrations of ammonia were detected at station SS-01, near the outfall from the South Shore WWTP. Concentrations were dramatically lower at other nearby stations, suggesting that ammonia from effluent discharged from the outfall mixes rapidly into the Lake. Median ammonia concentrations at these stations decreased after 1986. Statistically significant decreasing trends in ammonia concentrations were detected at all sampling stations in the South Shore survey and at several stations in the nearshore survey (see Table C-6 in Appendix C). Two qualifications must be made to this generalization. First, at most, though not all, of these stations the trends detected accounted for a small portion of the variation in the data. Second, the sampling stations in the nearshore survey that had significant trends tended to be either close to shore or associated with the harbor or South Shore survey. No strong correlations were detected between ammonia concentrations and values of other water quality parameters in the nearshore Lake Michigan area.

The mean concentration of nitrate in the nearshore Lake Michigan Area for the period of record was 0.41 mg/l as N. Concentrations in individual samples ranged from below the limit of detection to 8.57 mg/l as N. The mean concentration of nitrate at sampling stations in MMSD's South Shore survey was 0.43 mg/l as N. Concentrations in individual samples ranged between 0.01 mg/l as N and 8.80 mg/l as N. Table C-6 in Appendix C shows that statistically significant trends toward nitrate concentrations increasing over time were detected at several stations in the nearshore survey and all stations in the South Shore survey. The trends at some stations in the nearshore survey account for only a small portion of the variation in the data, the trends at some stations in the South Shore survey account for a substantial portion of the variation in the data. Nitrate concentrations in the nearshore Lake Michigan area and South Shore survey were strongly positively correlated with concentrations of total nitrogen, reflecting the fact that nitrate is a major component of total nitrogen.

The mean concentration of nitrite in the nearshore Lake Michigan Area for the period of record was 0.020 mg/l as N. Concentrations in individual samples ranged from below the limit of detection to 1.00 mg/l as N. The mean concentration of nitrite at sampling stations in MMSD's South Shore survey was 0.036 mg/l as N. Concentrations in individual samples ranged from below the limit of detection to 5.00 mg/l as N. When examined on an annual basis, there were few trends in nitrite concentration over time at stations in the nearshore survey (see Table C-6 in Appendix C). Trends toward decreasing concentrations were detected at three stations and trends toward increasing concentrations were detected at two stations. At all five of these stations, the trends accounted for a small portion of the variation in the data. Significant decreasing trends were detected at most stations in the South Shore survey, though the trends at most accounted for a small portion of the variation in the data.

Figure 346

AMMONIA AS NITROGEN CONCENTRATIONS AT SITES IN THE NEARSHORE LAKE MICHIGAN AREA: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

A comparison of the nitrate and nitrite concentration data from the nearshore area to concentrations in the open waters reveals several things. The mean concentration of nitrate plus nitrite in the open waters of Lake Michigan increased from 0.262 mg/l as N in 1983 to 0.311 mg/l as N in 1999.[72] These concentrations were lower than the mean concentration of nitrate plus nitrite in the nearshore Lake Michigan area for the same period. Over the years from 1983 to 1999, the mean concentration of nitrate plus nitrite in the nearshore area was 0.45 mg/l as N. This suggests that there is a gradient in nitrate plus nitrite concentration from the nearshore area to the open waters of the Lake. The increase in nitrate plus nitrite concentration in the open waters of the Lake suggest continued loading of these nutrients.

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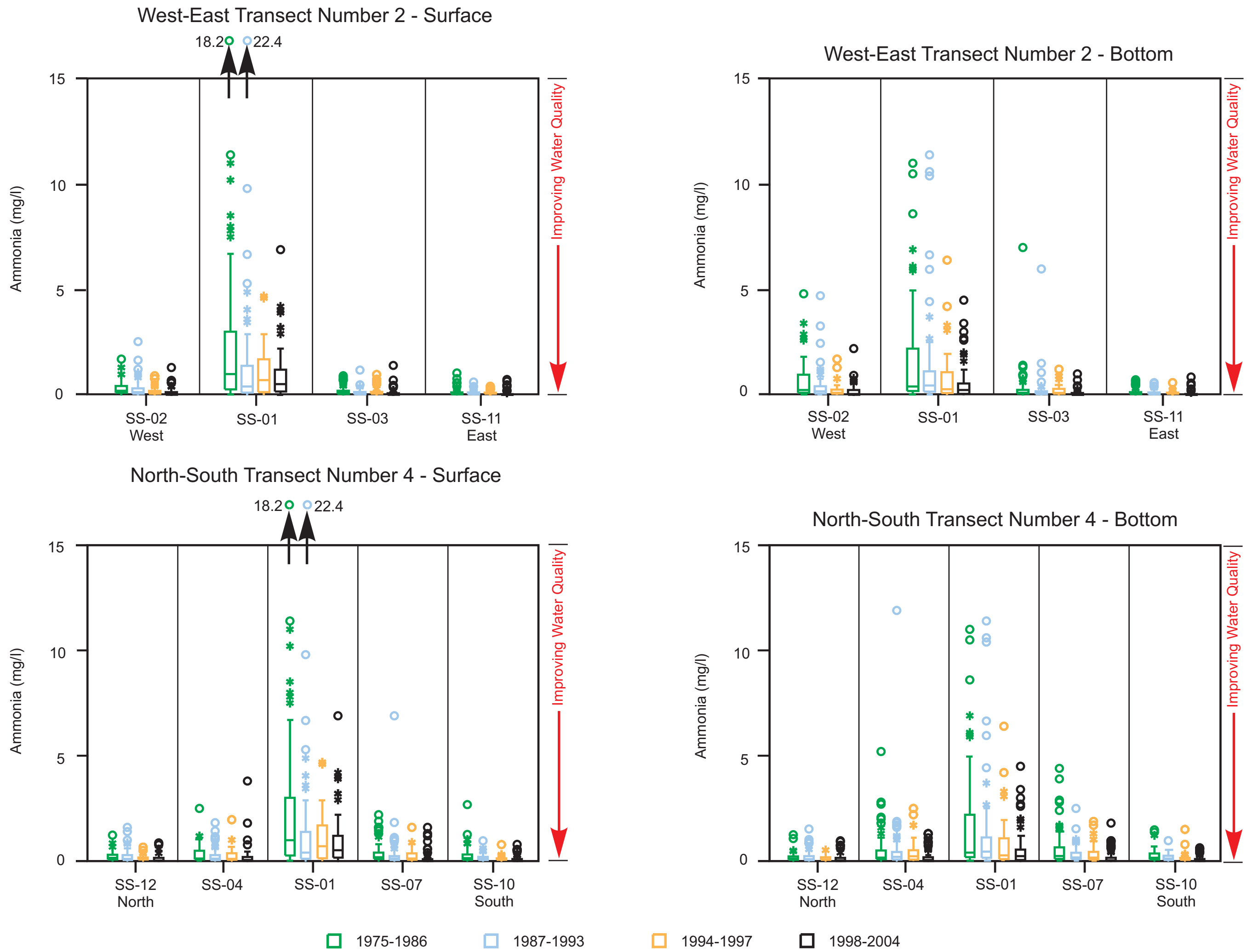
[72]*Holey and Trudeau, 2005,* op. cit.

Figure 347

AMMONIA AS NITROGEN CONCENTRATIONS IN LAKE MICHIGAN OFF THE SOUTH SHORE SEWAGE TREATMENT PLANT: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

During the period of record, the mean concentration of organic nitrogen in the nearshore Lake Michigan area was 0.38 mg/l as N. Concentrations in individual samples varied between the limit of detection and 7.4 mg/l as N. The mean concentration of organic nitrogen at the sampling stations in MMSD's South Shore survey was 0.31 mg/l as N. Concentrations in individual samples varied between the limit of detection and 12.2 mg/l as N. Few time-based trends were detected in organic nitrogen concentrations (see Table C-6 in Appendix C). Statistically significant trends toward increasing organic nitrogen concentration were detected at a few stations in the nearshore and South Shore surveys, but they accounted for a small portion of the variation in the data. Organic nitrogen concentrations in both surveys show strong positive correlations with total nitrogen, reflecting the fact that organic nitrogen compounds constitute a major portion of total nitrogen. Concentrations of organic nitrogen in the nearshore Lake Michigan area do not appear to have changed much over time.

Several processes can influence the concentrations of nitrogen compounds in a waterbody. Primary production by plants and algae will result in ammonia and nitrate being removed from the water and incorporated into cellular material. This effectively converts the nitrogen to forms which are detected only as total nitrogen. Sinking of algal cells and detritus out of the epilimnion effectively makes the nitrogen in these particles unavailable for supporting algal growth. Decomposition of organic material in sediment can release nitrogen compounds to the overlying water. Bacterial action may convert some nitrogen compounds into others.

Several things emerge from this analysis of nitrogen chemistry in the nearshore Lake Michigan area:

- Concentrations of total nitrogen have recently increased at several stations in the nearshore area. This represents a decrease in water quality.
- The relative proportions of different nitrogen compounds in the Lake seem to be changing with time.
- Ammonia concentrations at several stations have been declining over time. This represents an improvement in water quality.
- Concentrations of nitrate have been increasing at several stations in the nearshore survey and all stations in the South Shore survey. This appears to account for at least some of the recent increase in total nitrogen concentrations. This represents a decrease in water quality.
- Concentrations of nitrite have been decreasing at sampling stations in the South Shore survey.
- Concentrations of nitrate plus nitrite were higher in the nearshore area than in the open waters of Lake Michigan.
- Concentrations of organic nitrogen in the nearshore area do not appear to be changing with time.

Total and Dissolved Phosphorus
Two forms of phosphorus are commonly sampled in surface waters: dissolved phosphorus and total phosphorus. Dissolved phosphorus represents the form that can be taken up and used for growth by algae and aquatic plants. Total phosphorus represents all the phosphorus contained in material dissolved or suspended within the water, including phosphorus contained in detritus and organisms and attached to soil and sediment.

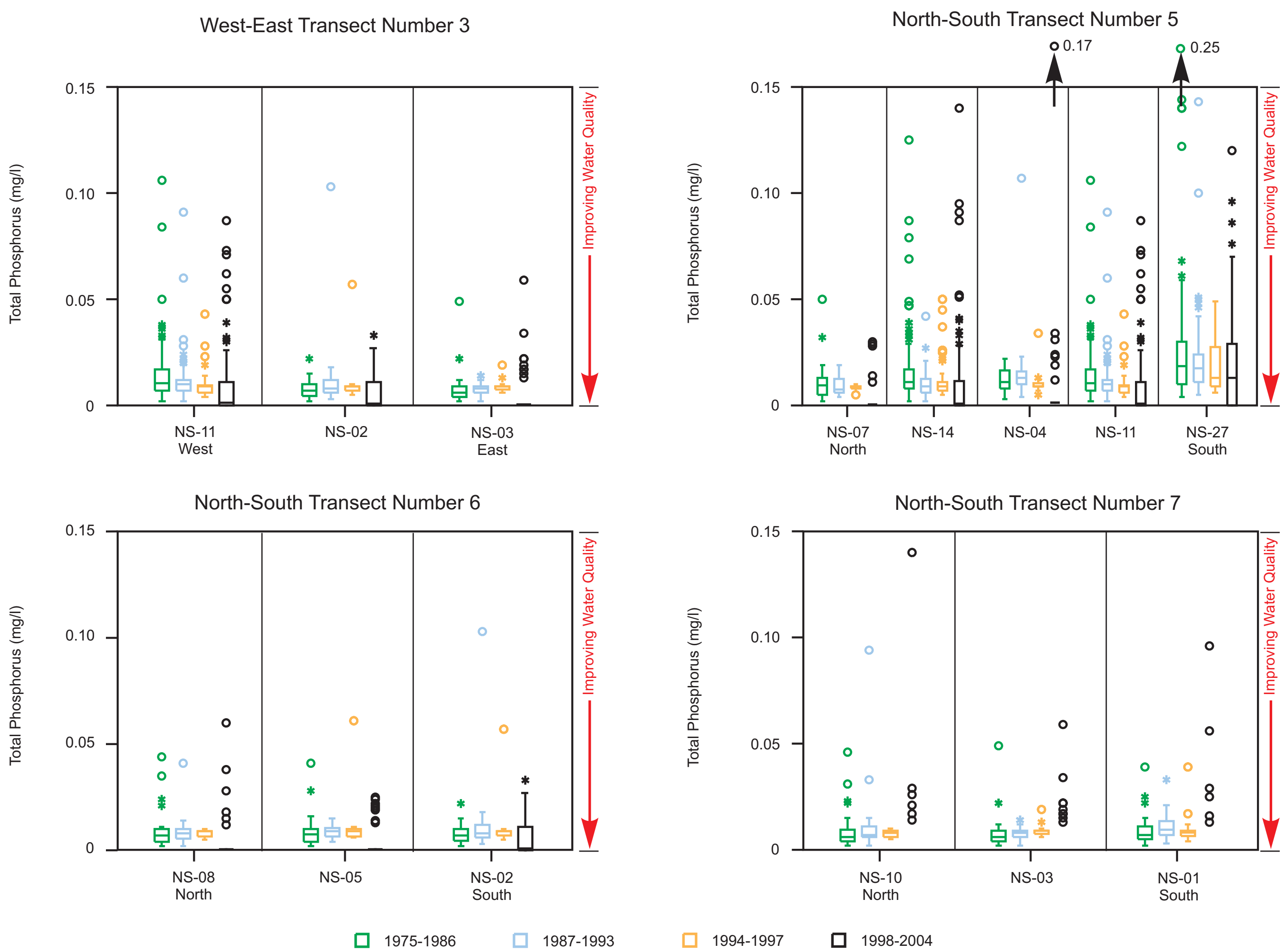
The mean concentration of total phosphorus in the nearshore Lake Michigan areas during the period of record was 0.0317 mg/l, and the mean concentration of dissolved phosphorus in the nearshore Lake Michigan areas over the period of record was 0.0147 mg/l. Total phosphorus concentrations ranged from below the limit of detection to 3.8800 mg/l. Dissolved phosphorus concentrations ranged from below the limit of detection to 10.00 mg/l. The mean concentration of total phosphorus at stations in MMSD's South Shore survey during the period of record was 0.0261 mg/l, and the mean concentration of dissolved phosphorus at stations in MMSD's South Shore survey over the period of record was 0.0141 mg/l. Total phosphorus concentrations ranged from below the limit of detection to 2.480 mg/l. Dissolved phosphorus concentrations ranged from below the limit of detection to 10.00 mg/l.[73]

Figure 348 shows total phosphorus concentrations at sampling stations along four transects through the nearshore area. At nearshore survey stations located in or near the outer harbor (*i.e.,* NS-12, NS-14, NS-28), in the South Shore survey (*i.e.,* NS-11 and NS-27), and close to shore (*i.e.,* NS-04), concentrations of total phosphorus

[73]*Although most samples analyzed included analyses for both dissolved and total phosphorus, in a small fraction of the data, only one of these constituents was analyzed. As a result, the range of dissolved phosphorus concentrations is greater than the range of total phosphorus concentrations.*

Figure 348

TOTAL PHOSPHORUS CONCENTRATIONS AT SITES IN THE NEARSHORE LAKE MICHIGAN AREA: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

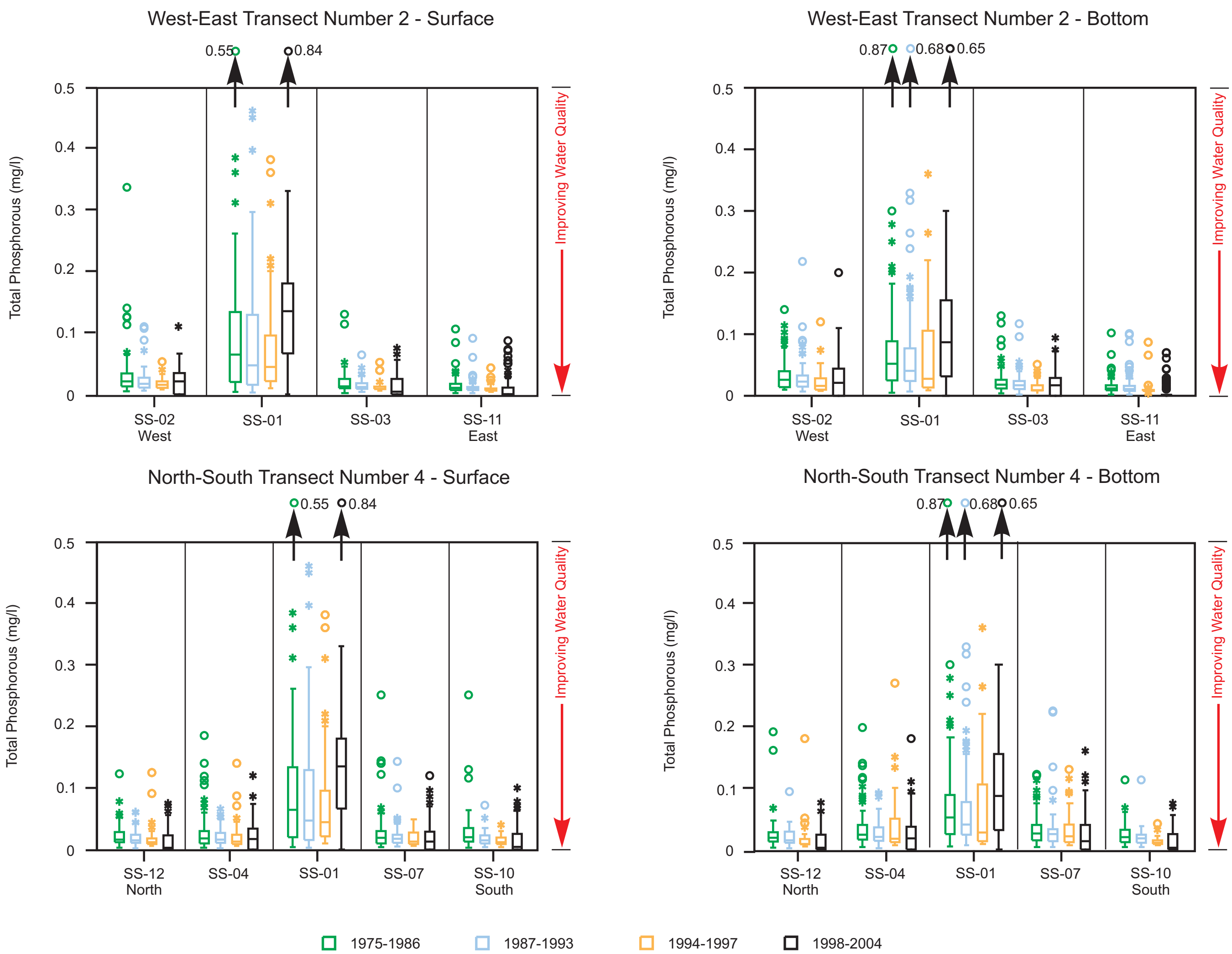
Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

decreased over time. At stations farther out into Lake Michigan, total phosphorus concentrations increased over time. Figure 349 shows concentrations of total phosphorus at sampling stations along two transects through MMSD's South Shore survey. Concentrations of total phosphorus were highest at station SS-01, the site of the outfall from the South Shore WWTP. Total phosphorus concentrations at this station appear to be strongly influenced by phosphorus in effluent discharged from the outfall. Concentrations of total phosphorus were markedly lower at the other stations near SS-01, indicating that effluent from the outfall mixes fairly rapidly into water in the Lake. At most sampling stations in the South Shore survey, concentrations of total phosphorus decreased over time. The major exception to this generalization was at station SS-01. At this station, concentrations of total phosphorus decreased between the periods 1975-1986 and 1994-1997 and then increased after 1997.

Map 123 shows concentrations of total phosphorus from surface water in the nearshore area at the two meter depth contour along a portion of the western shore of Lake Michigan from sampling conducted by the WDNR during spring and fall of 2004. Note that the circles representing the spring samples indicate the sampling

Figure 349

TOTAL PHOSPHORUS CONCENTRATIONS IN LAKE MICHIGAN OFF THE SOUTH SHORE SEWAGE TREATMENT PLANT: 1975-2004



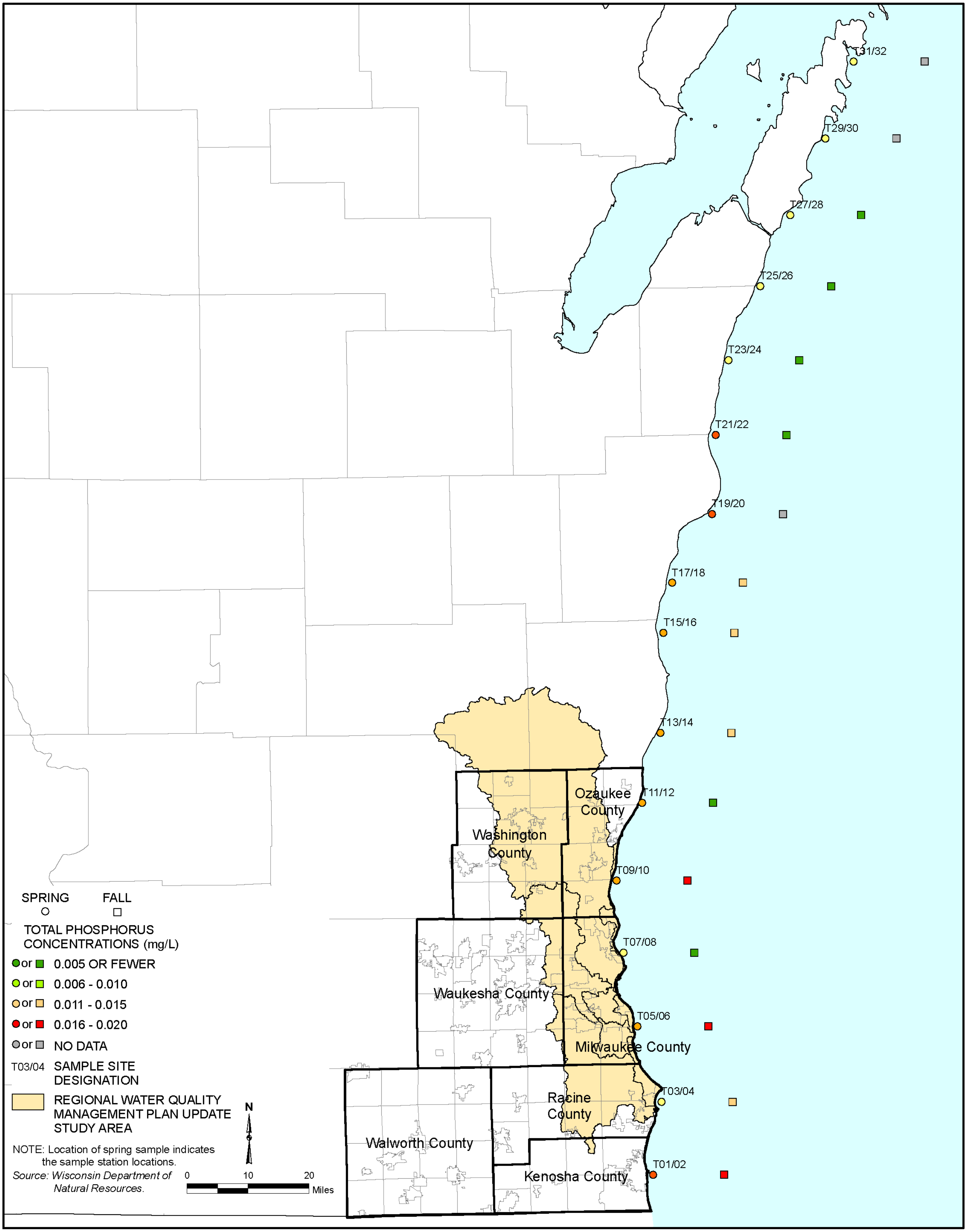
NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

locations; the squares representing fall samples are offset for clarity. Concentrations of total phosphorus in the nearshore area along this portion of the western shore of the Lake tended to increase from north to south. A similar pattern was observed in data from 2005. During spring, concentrations of total phosphorus detected at the two sampling sites in waters adjacent to Milwaukee County were below 0.010 mg/l. In comparison, total phosphorus concentrations in surface water samples collected at the stations in the MMSD nearshore survey that were not in the harbor or near the outfall from the South Shore WWTP ranged from below the limit of detection to 0.019 mg/l. Concentrations in samples in the harbor or near the South Shore WWTP outfall were higher. During fall, concentrations of total phosphorus detected at the two sampling sites in waters adjacent to Milwaukee County were below 0.015 mg/l. In comparison, total phosphorus concentrations in surface water samples collected at the stations in the MMSD nearshore survey that were not in the harbor or near the outfall from the South Shore WWTP ranged from below the limit of detection to 0.004 mg/l. Concentrations in samples in the harbor or near the South Shore WWTP outfall were higher.

Map 123

TOTAL PHOSPHORUS CONCENTRATIONS IN LAKE MICHIGAN: 2004



NOTE: Location of spring sample indicates the sample station locations.

Source: Wisconsin Department of Natural Resources.

On an annual basis, regression analysis detected statistically significant trends toward increasing total phosphorus concentrations over time at several stations in the nearshore Lake Michigan area (see Table C-6 in Appendix C). Given that the apparent decreasing trends at these stations are indicated in Figure 348, it is likely that some of the regression results are spurious, probably due to the presence of outliers in some samples. Alternatively, these may reflect actual trends toward increasing total phosphorus concentrations in Lake Michigan. Phosphorus concentrations in the open waters of Lake Michigan have shown a complex pattern of changes over time. During the period 1983-1992 the average concentration of total phosphorus in open waters decreased from 0.0064 mg/l to 0.0038 mg/l. After 1992, they increased. Between 1994 and 1999, average total phosphorus concentrations in the open waters of Lake Michigan ranged between 0.0055 mg/l and 0.0063 mg/l, concentrations that are similar to pre-1990 levels.[74] Few time-based trends were detected in total phosphorus concentrations at stations in the South Shore survey (see Table C-6 in Appendix C). Statistically significant trends toward increasing dissolved phosphorus concentrations were detected at most stations in South Shore survey and at several stations in the nearshore survey. At most of these stations, the trends detected account for a small portion of the variation in the data. These trends represent a decline in water quality.

Few statistically significant correlations were detected between total phosphorus concentrations and values of other water quality parameters at sampling stations in the nearshore Lake Michigan area. Total phosphorus concentrations at these stations were strongly positively correlated with concentrations of dissolved phosphorus, reflecting the fact that dissolved phosphorus constitutes a major constituent of total phosphorus. Total phosphorus and dissolved phosphorus concentrations at stations in the South Shore survey were positively correlated with chloride concentrations. This correlation may reflect the fact that these pollutants, to some extent, share common sources and modes of transport into Lake Michigan.

Metals

Arsenic

The mean concentration of arsenic in the nearshore Lake Michigan waters over the period of record was 1.91 μg/l. The data ranged from below the limit of detection to 13.00 μg/l. The mean concentration of arsenic at sampling stations in MMSD's South Shore survey was 1.75 μg/l. The data at these stations ranged from below the limit of detection to 12.00 μg/l. When the data were examined on an annual basis, increasing concentrations of arsenic over time were detected at most of the stations examined in MMSD's nearshore survey (see Table C-6 in Appendix C). At several stations, these trends accounted for a substantial portion of the variation in the data. When the data from the South Shore survey were examined on an annual basis, no trends were detected in arsenic concentration at most stations. When the data were examined on a seasonal basis, trends toward increasing arsenic concentrations during the summer were detected at most stations in both the nearshore and South Shore surveys. At most of these stations, the trends accounted for a substantial portion of the variation in the data. The trends toward increasing arsenic concentration in the nearshore areas of Lake Michigan represent a decrease in water quality.

Cadmium

The mean concentration of cadmium in the nearshore Lake Michigan areas over the period of record was 2.06 μg/l. A moderate amount of variability was associated with this mean. Concentrations in individual samples ranged from below the limit of detection to 82.00 μg/l. Concentrations were slightly higher at stations in the South Shore survey. At these stations, the mean concentration over the period of record was 2.31 μg/l and concentrations in individual samples ranged from below the limit of detection to 140.00 μg/l. Table C-6 in Appendix C shows the presence of strong decreasing trends in cadmium concentration at all stations in both surveys, both when the data were analyzed on an annual basis and when the data were analyzed on a seasonal basis. These declines in cadmium concentration may reflect changes in the number and types of industry present in the watersheds tributary to Lake Michigan, reductions due to treatment of industrial discharges, and reductions

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[74]*Holey and Trudeau, 2005,* op. cit.

in airborne deposition of cadmium to the Great Lakes region. The reduction in cadmium concentrations in the nearshore Lake Michigan areas represents an improvement in water quality.

Chromium
The mean concentration of chromium in the nearshore Lake Michigan areas over the period of record was 9.69 μg/l. Chromium concentration showed moderate variability, with individual sample concentrations ranging from below the limit of detection to 920.00 μg/l. Concentrations were slightly higher at stations in the South Shore survey. At these stations, the mean concentration over the period of record was 18.21 μg/l and concentrations in individual samples ranged from below the limit of detection to 970.00 μg/l. Table C-6 in Appendix C shows the presence of statistically significant decreasing trends in chromium concentrations at all sampling stations in both surveys. These trends toward decreasing chromium concentrations in the nearshore areas may reflect the loss of industry in some parts of the watersheds tributary to Lake Michigan and the decreasing importance of the metal plating industry in particular, as well as the establishment of treatment of discharges instituted for the remaining and new industries since the late 1970s. The decline in chromium concentrations represents an improvement in water quality.

Copper
The mean concentration of copper in the nearshore Lake Michigan areas during the period of record was 7.03 μg/l. Concentrations varied from below the limit of detection to 260.00 μg/l. Average concentrations of copper were slightly higher at the stations in MMSD's South Shore survey. The mean concentration over the period of record was 8.18 μg/l. Concentrations varied from below the limit of detection to 335.00 μg/l. Figure 350 shows copper concentrations at sampling stations along four transects through the nearshore area. At most stations, median (and mean) copper concentration increased from 1975 through 1997. Copper concentrations declined during the period 1998-2004. A similar pattern was observed along transects through stations in the South Shore survey (see Figure 351). Table C-6 in Appendix C shows that few long-term statistically significant trends in copper concentration were detected. At most stations in the nearshore and South Shore surveys, copper concentrations were positively correlated with zinc concentrations. This reflects the fact that many of the same sources release these two metals to the environment. The recent decreases in copper concentrations in the nearshore Lake Michigan areas represent improvements in water quality.

Lead
The mean concentration of lead in the nearshore Lake Michigan areas over the period of record was 38.9 μg/l. This mean is not representative of current conditions because lead concentrations in the water of the Lake have been decreasing since the late 1980s. During the period 1998-2004, the mean concentration of lead in the nearshore Lake Michigan areas was 0.5 μg/l. At all sampling stations for which sufficient data are available to assess trends in lead concentrations, baseline period monthly mean lead concentrations are quite low when compared to historical means and ranges. These decreases represent statistically significant decreasing trends (see Table C-6 in Appendix C). A major factor causing the decline in lead concentrations has been the phasing out of lead as a gasoline additive. From 1983 to 1986, the amount of lead in gasoline in the United States was reduced from 1.26 grams per gallon (g/gal) to 0.1 g/gal. In addition, lead was completely banned for use in fuel for on-road vehicles in 1995. The major drop in lead in water in the Lake followed this reduction in use.

In freshwater, lead has a strong tendency to adsorb to particulates suspended in water.[75] As these particles are deposited, they carry the adsorbed lead into residence in the sediment. Because of this, the lower concentrations of lead in the water probably reflect the actions of four processes: reduction of lead entering the environment, transport of lead from the nearshore areas of Lake Michigan to offshore areas through mixing, washing out of lead from Lake Michigan into Lake Huron, and deposition of adsorbed lead in the sediment. Lead concentrations in the nearshore areas show no evidence of patterns of seasonal variation. The decrease in lead concentrations over time in the nearshore Lake Michigan areas represents an improvement in water quality.

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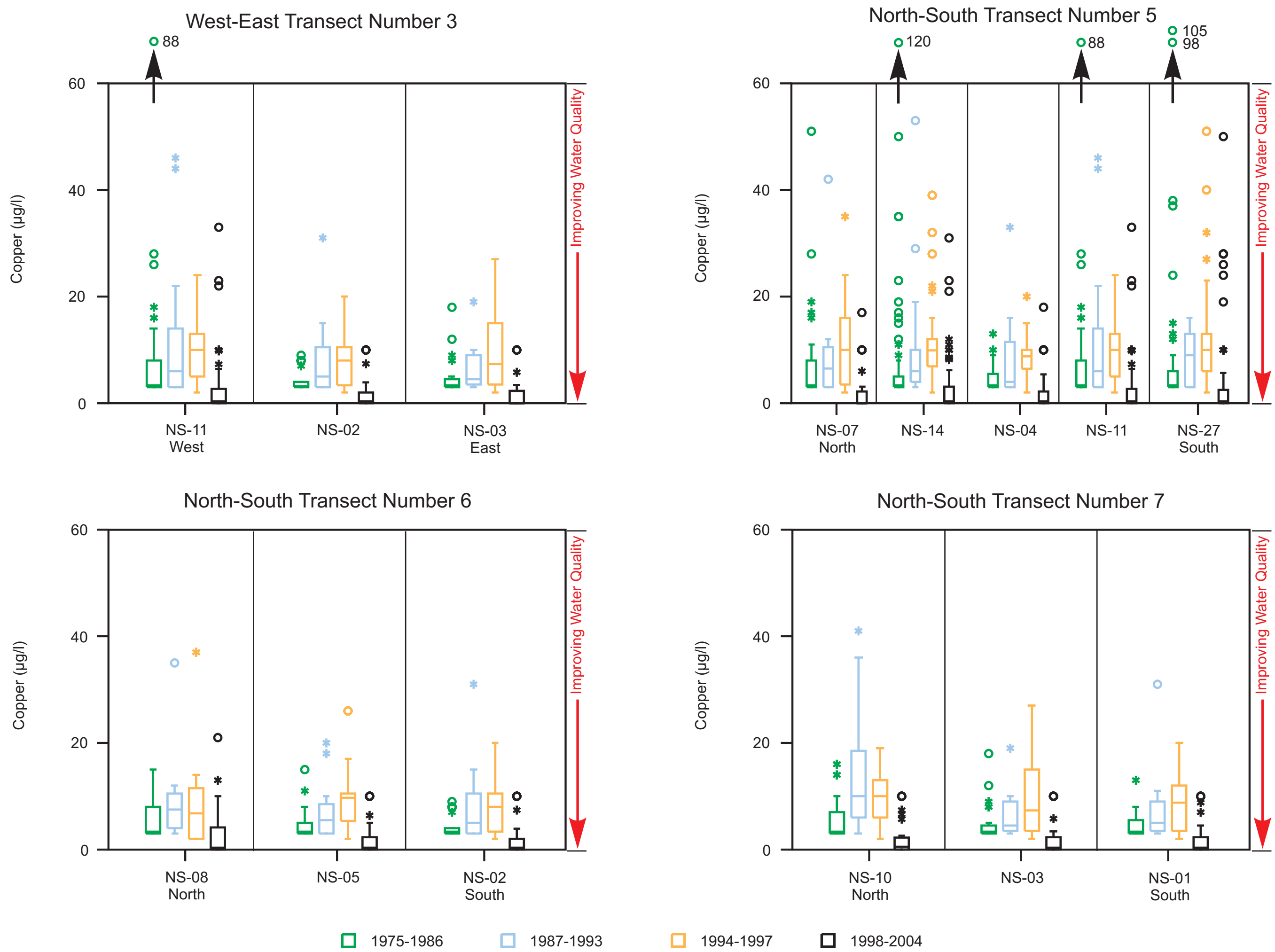
[75] *H.L. Windom, T. Byrd, R.G. Smith, and F. Huan, "Inadequacy of NASQUAN Data for Assessing Metal Trends in the Nation's Rivers,"* Environmental Science and Technology *Volume 25, 1991.*

Figure 350

COPPER CONCENTRATIONS AT SITES IN THE NEARSHORE LAKE MICHIGAN AREA: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

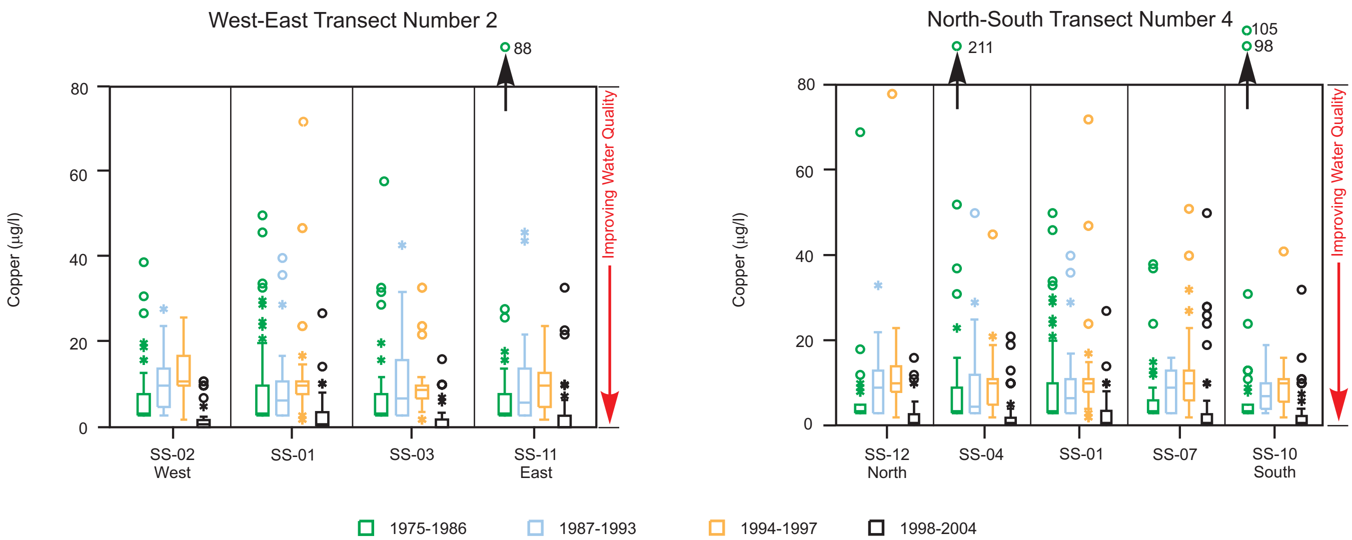
Mercury

Few historical data on the concentration of mercury in the water of the nearshore Lake Michigan areas exist. Most sampling for mercury in water in the nearshore area was taken during or after 1997 at four sampling stations: NS-12, NS-13, NS-14, and NS-28. No data were available from sampling stations in MMSD's South Shore survey. The mean concentration of total mercury in the nearshore area over the period of record was 0.010 μg/l. Mercury concentrations showed moderate variability, with a range from below the limit of detection to 0.220 μg/l. The mean concentration of mercury in the nearshore area is about 30 times greater than the mean concentration reported for offshore areas in Lake Michigan. Based on sampling conducted during 1994 and 1995 as part of the Lake Michigan Mass Balance Study, the USEPA found that the mean concentration of total mercury in the offshore area of the Lake was about 0.0003 μg/l.[76] The higher concentrations of mercury in the nearshore area

[76]*U.S. Environmental Protection Agency,* Results of the Lake Michigan Mass Balance Study: Mercury Data Report, *EPA 905 R-01-012, 2004.*

Figure 351

COPPER CONCENTRATIONS IN LAKE MICHIGAN OFF THE SOUTH SHORE SEWAGE TREATMENT PLANT: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

reflect the effect of inputs of mercury from tributaries mixing into the waters of the Lake. Mean concentrations of total mercury in the Milwaukee Harbor estuary, Fish Creek, Oak Creek, and the Root River reported in this study were 0.0535 μg/l, 0.0270 μg/l, 0.0590 μg/l, and 0.1030 μg/l, respectively (see Chapters VIII and IX of this report). By comparison, the USEPA reported mean total mercury concentration in the Milwaukee River during the period 1994-1995 of 0.0041 μg/l and mean total mercury concentrations in water from other Lake Michigan tributaries ranging between 0.0012 μg/l and 0.0203 μg/l.[77] The means from the data collected by the USEPA for the Lake Michigan Mass Balance Study are close enough to the means of the more recent data that the differences between them are likely to represent analytic differences between laboratories and not large differences in concentration in the Lake. While these data indicate that tributaries are contributing mercury to Lake Michigan, it is important to note that the major source of mercury to the Lake is atmospheric deposition.[78] Only one station in the nearshore area had sufficient data to examine for the presence of time-based trends in mercury concentration. When the data were analyzed on an annual basis, no trend was detected (see Table C-6 in Appendix C). A statistically significant trend toward decreasing mercury concentration during the summer was detected at this station; however, it is important to note that this is based on a small number of samples.

Nickel

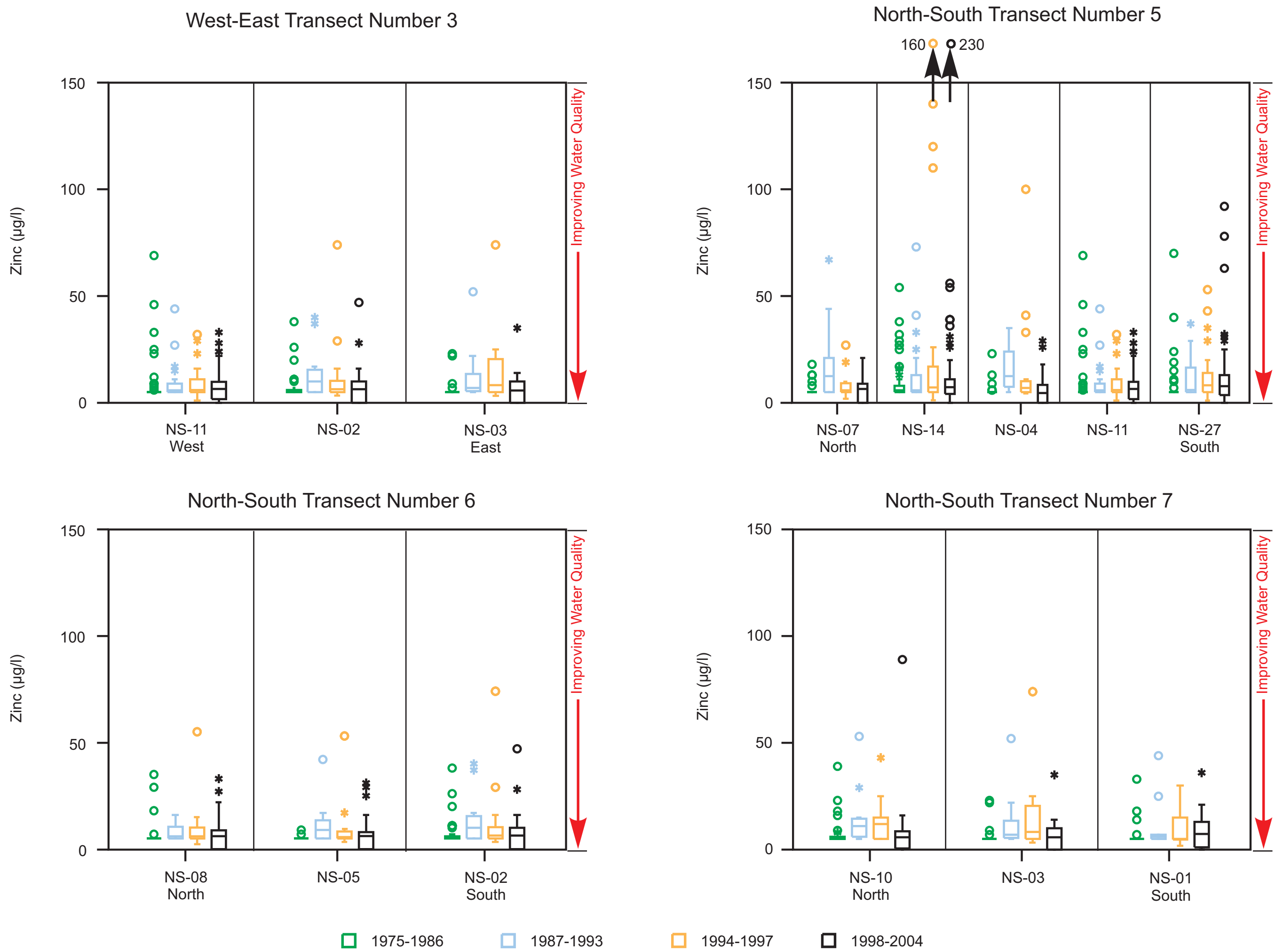
The mean concentration of nickel in the nearshore Lake Michigan areas over the period of record was 6.8 μg/l. Concentrations in individual samples ranged from below the limit of detection to 97.0 μg/l. The mean concentration of nickel at sampling stations in MMSD's South Shore survey was 6.8 μg/l. Concentrations in individual samples ranged from below the limit of detection to 39.0 μg/l. When examined on an annual basis, significant

[77]Ibid.

[78]Ibid.

Figure 352

ZINC CONCENTRATIONS AT SITES IN THE NEARSHORE LAKE MICHIGAN AREA: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

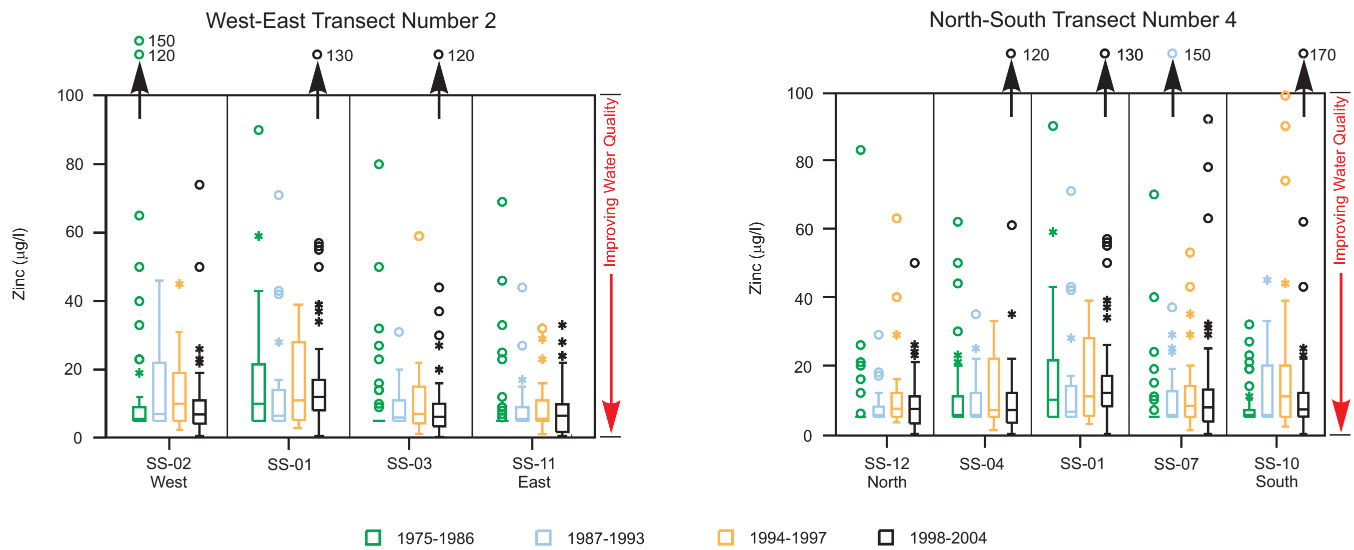
declines over time were observed at all sampling stations in the nearshore area (see Table C-6 in Appendix C). This may reflect changes in the amount and types of industry within the tributary watersheds. The decreases in nickel concentrations in the nearshore Lake Michigan areas represent an improvement in water quality.

Zinc

The mean concentration of zinc in the nearshore Lake Michigan areas during the period of record was 11.2 μg/l. Concentrations in individual samples ranged from below the limit of detection to 230.0 μg/l. The mean concentration of zinc at stations in MMSD's South Shore survey during the period of record was 12.2 μg/l. Concentrations in individual samples ranged from below the limit of detection to 198.0 μg/l. Figure 352 shows concentrations of zinc at sampling stations along four transects through the nearshore area. At most stations, zinc concentrations increased after 1986. They then decreased either after 1993 or after 1997. With the exception of one station, a similar pattern was observed at sampling stations in the South Shore survey (see Figure 353). Median concentrations of zinc at station SS-01 increased in every period after 1986. This station is located at the

Figure 353

ZINC CONCENTRATIONS IN LAKE MICHIGAN OFF THE SOUTH SHORE SEWAGE TREATMENT PLANT: 1975-2004



NOTE: See Figure 279 for description of symbols and Map 117 for locations of monitoring stations relative to the outer harbor and adjacent Lake Michigan area.

Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

outfall from the South Shore WWTP and may not be representative of ambient conditions in the nearshore area. Despite recent decreases in zinc concentrations, statistically significant trends toward increasing concentrations of zinc over the 1975 through 2004 time period were detected at several stations in both the nearshore and South Shore surveys (see Table C-6 in Appendix C). There is no evidence of seasonal variation in the concentration of zinc in the nearshore areas. The trends toward increasing zinc concentrations at some stations in the nearshore Lake Michigan areas represent a reduction in water quality.

Organic Compounds

No data were available on concentrations of organic compounds in the nearshore areas of Lake Michigan.

Pharmaceuticals and Personal Care Products

Few data are available on the presence or concentrations of pharmaceutical and personal care product compounds in the nearshore Lake Michigan areas. A recent study examined air samples from Lake Michigan and the City of Milwaukee and water samples from Lake Michigan for the presence and concentrations of six synthetic musk compounds—acetyldimethylbutyllindan (ADBI), acetylhexamethylindan (AHMI), acetylhexamethyltetrahydronaphthalene (AHTN), acetyltetramethylisopropylindan (ATII), dihydropentamethylindanone (DPMI), and hexahydrohexamethylcyclopentabenzopyran (HHCB)—and two nitro musk compounds—musk ketone and musk xylene.[79] With the exception of DMPI, all of these compounds were detected in water samples from the Lake. These compounds were found primarily in the dissolved phase. Average concentrations of AHTN and HHCB were 1.0 nanograms per liter (ng/l) and 4.7 ng/l, respectively. Concentrations of the others were between 0.03 ng/l and 0.52 ng/l. The concentrations of these compounds reported in Lake Michigan are several orders of magnitude

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[79] *Aaron M. Peck and Keri C. Hornbuckle, "Synthetic Musk Fragrances in Lake Michigan,"* Environmental Science and Technology, *Volume 38, 2004.*

Table 193

PONDS OF THE LAKE MICHIGAN DIRECT DRAINAGE AREA

Name	Area (acres)	Maximum Depth (feet)	Mean Depth (feet)	Lake Type	Public Access
Juneau Park Pond	15	6	4	Drainage lake	- -[a]
Sheridan Park Pond....................	1	8	4	Seepage lake	- -[a]

[a]*Private boats of any kind are not allowed on ponds in Milwaukee County Parks. Where available, commercial facilities provide boat liveries operated by the park.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

lower than what has been reported in wastewater treatment plant effluent.[80] A lakewide mass budget indicated that wastewater treatment plants were the major source of these compounds to the Lake. No other data were available on concentrations of pharmaceuticals and personal care products in the nearshore Lake Michigan areas.

Water Quality of Lakes and Ponds

While the Lake Michigan direct drainage area contains no lakes with a surface area of 50 acres or more, it contains two named ponds with surface areas of less than 50 acres: Juneau Park Pond and Sheridan Park Pond. Both of these ponds are in Milwaukee County. The physical characteristics of the ponds in the Lake Michigan direct drainage area are given in Table 193.

Rating of Trophic Condition

No data were available on the trophic status of ponds in the Lake Michigan direct drainage area.

Bacterial Parameters

No data on concentrations of fecal coliform bacteria or *E. coli* were available for ponds in the Lake Michigan direct drainage area.

Chemical and Physical Parameters

No data were available on water chemistry for ponds in the Lake Michigan direct drainage area.

TOXICITY CONDITIONS OF THE MILWAUKEE HARBOR ESTUARY, LAKE MICHIGAN DIRECT TRIBUTARY DRAINAGE AREA, AND THE ADJACENT NEARSHORE LAKE MICHIGAN AREAS: 1975-2004

Much of the data on toxic contaminants in the Milwaukee Harbor estuary, Lake Michigan direct drainage area, and the adjacent nearshore Lake Michigan area is related to the Milwaukee Estuary Area of Concern (AOC). This area includes the Milwaukee River downstream from the site of the former North Avenue dam, the Menomonee River downstream from 35th Street, the Kinnickinnic River downstream from Chase Avenue, the inner and outer harbors, and the nearshore waters of Lake Michigan bounded by a line extending north from Sheridan Park to the intake from the City of Milwaukee’s Linnwood water treatment plant. It is one of 43 sites in the Great Lakes area targeted for priority attention under the U.S.-Canada Great Lakes Water Quality Agreement (Annex 2 of the 1987 Protocol) due to impairment of beneficial use of the area's ability to support aquatic life. Eleven beneficial use impairments have been identified in the Milwaukee Estuary AOC including restrictions of fish and wildlife consumption, degradation of fish and wildlife populations, fish tumors or other deformities, bird or animal deformities or reproductive problems, degradation of benthos, restrictions on dredging activities, eutrophication or

[80]Ibid.

undesirable algae, beach closings, degradation of aesthetics, degradation of phytoplankton and zooplankton populations, and loss of fish and wildlife habitat.[81] While these impairments are the result of many causes, many are related, at least in part, to the presence of toxic substances in water, sediment, and the tissue of organisms.

Toxic Substances in Water

Data and analyses documenting historical and baseline period concentrations of toxic substances in water for the portions of the Kinnickinnic, Menomonee, and Milwaukee River comprising the estuary and inner harbor were presented in Chapters V, VI, and VII, respectively, of this report. This section summarizes the results presented in those chapters and presents comparisons of conditions among the three Rivers in order to characterize historical and baseline period conditions and toxicity trends within the estuary. In addition, these summaries are supplemented by data and analyses, also presented in this chapter, documenting historical and baseline period concentrations of toxic substances in the streams of the Lake Michigan direct drainage area, the outer harbor, and the nearshore Lake Michigan areas.

Pesticides

Relatively few data are available on concentrations of pesticides in water in the Milwaukee Harbor estuary, outer harbor, and nearshore Lake Michigan area. In 1993, four sites in the estuary portion of the Kinnickinnic River were sampled for chlordane isomers. Measurable concentrations of γ-chlordane were detected in one sample. In 2004, samples were collected from the Milwaukee River section of the estuary at Jones Island and examined for the presence of several pesticides. Atrazine and deethylatrazine were detected in one sample that was screened for these compounds at mean concentrations of 0.195 μg/l and 0.060 μg/l, respectively. Carbaryl and diazinon were detected in one sample each with mean concentrations of 0.011 μg/l and 0.011 μg/l, respectively. The concentrations of atrazine and diazinon reported were below the USEPA draft aquatic life criteria. The USEPA has not promulgated criteria for the other pesticides that were detected.

While no data were available on pesticide concentrations in water from the outer harbor or nearshore Lake Michigan area, data were available for Lake Michigan as a whole. These data should give some indications of conditions in the nearshore area. The Lake Michigan Mass Balance Study examined concentrations of the pesticide atrazine and two of its metabolites, deethylatrazine and deisopropylatrazine, in tributaries draining into Lake Michigan and the open waters of Lake Michigan.[82] Loadings from tributaries represent the major source of atrazine to the Lake, accounting for about 68 percent of contributions. Concentrations of atrazine in 16 samples collected from near the mouth of the Milwaukee River in 1994 and 1995 ranged between 0.011 μg/l and 0.058 μg/l, with a mean concentration of 0.030 μg/l. Concentrations of deethylatrazine ranged between 0.017 μg/l and 0.060 μg/l, with a mean concentration of 0.029 μg/l. Concentrations of deisopropylatrazine ranged between 0.015 μg/l and 0.056 μg/l, with a mean concentration of 0.028 μg/l. Concentrations of atrazine in the open waters of Lake Michigan ranged between 0.022 μg/l and 0.058 μg/l, with a mean concentration of 0.038 μg/l. Concentrations of deethylatrazine in the open waters of Lake Michigan ranged between 0.014 μg/l and 0.036 μg/l, with a mean concentration of 0.026 μg/l. Concentrations of deisopropylatrazine in the open waters of Lake Michigan ranged from below the limit of detection to 0.030 μg/l with a mean concentration of 0.015 μg/l. These observed concentrations are well below the USEPA biological effects threshold. The study estimated that in 1994 the Milwaukee River basin contributed 87 kg of atrazine to Lake Michigan. This represents less than 2 percent of the estimated tributary loading of 5,264 kg to the Lake. Assuming that atrazine loads to Lake Michigan continue at 1994 rates, concentrations of atrazine in the Lake were forecasted to increase to a concentration of 0.066 μg/l by 2263.[83] While data since 1994 on atrazine usage were not available by watershed, State-level data give some

[81]*Wisconsin Department of Natural Resources,* Milwaukee Estuary Remedial Action Plan Progress Through January 1994, *1995.*

[82]*U.S. Environmental Protection Agency,* Results of the Lake Michigan Mass Balance Study: Atrazine Data Report, *EPA 905R-01-010, December 2001.*

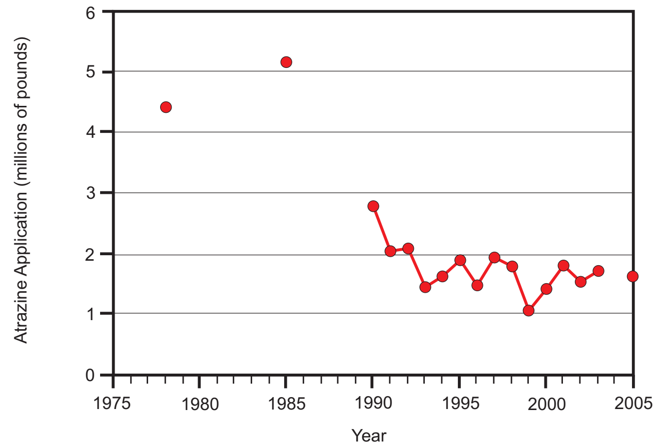
[83]Ibid.

indication of how current usage compares to usage since the mid-1990s. Figure 354 shows total applications of atrazine on corn, the major crop on which it is used, in Wisconsin since 1978. While the amount applied in the State has fluctuated since 1994, average usage in Wisconsin remains near 1994 levels. The combined usage of atrazine in the states containing watersheds tributary to Lake Michigan has followed a similar trend. While the amounts of atrazine applied in Illinois, Indiana, Michigan, and Wisconsin have fluctuated since 1994, average usage in these states remains near 1994 levels.

The Lake Michigan Mass Balance Study also examined concentrations of the pesticide trans-nonachlor, an isomer and constituent of the insecticide chlordane in tributaries draining into Lake Michigan and the open waters of Lake Michigan.[84] Concentrations of dissolved trans-nonachlor in 36 samples collected from near the mouth of the Milwaukee River in 1994 and 1995 ranged from below the limit of detection to 0.044 nanograms per liter (ng/l) with a mean concentration of 0.023 μg/l. Concentrations of particulate trans-nonachlor ranged between 0.011 ng/l and 0.22 ng/l with a mean concentration of 0.037 ng/l.

Figure 354

APPLICATION OF THE HERBICIDE ATRAZINE ON CORN IN WISCONSIN: 1978-2005



NOTE: Data include field corn and sweet corn; no data were available for seed corn.

Source: National Agricultural Statistics Service.

Polycyclic Aromatic Hydrocarbons (PAHs)

Between 1995 and 2001, MMSD conducted extensive sampling for 16 PAH compounds in unfiltered water at 12 sampling stations in the Milwaukee Harbor estuary. Sampling was done at three stations in the estuary portion of the Kinnickinnic River, four stations in the estuary portion of the Menomonee River, and five stations in the estuary portion of the Milwaukee River. The mean concentration of total PAHs in these samples was 1.00 μg/l. Analysis of variance detected no statistically significant differences among mean concentrations in the Kinnickinnic River, Menomonee River, and Milwaukee River portions of the estuary. The mean concentration in the estuary decreased slightly from 1.06 μg/l during the period 1995-1997 to 0.97 μg/l during the period 1998-2001. This decrease was not statistically significant. Some PAH compounds were more commonly detected in water samples from the estuary than others. The compounds benz(a)anthracene, chrysene, fluoranthene, and pyrene were frequently detected. The compounds acenaphthene, acenaphthylene, anthracene, and fluorene were rarely detected.

Between 2003 and 2005, MMSD conducted extensive sampling for 16 PAH compounds in unfiltered water at its two water quality sampling stations along Fish Creek. While PAHs were detected in every sample, concentrations of PAHs in most samples were less than the limit of quantitation. Measurable concentrations of PAHs were detected in about 20 percent of the samples. Concentrations of total PAHs in these samples ranged from below the limit of detection to 3.48 μg/l, with a mean concentration of 0.91 μg/l. Concentrations of total PAHs were higher at the sampling station farther upstream, at W. Port Washington Road and Katherine Lane, than at the station farther downstream, at Broadmoor Drive and the Union Pacific Railroad. Some PAH compounds were more

[84]*U.S. Environmental Protection Agency,* Results of the Lake Michigan Mass Balance Study: Polychlorinated Biphenyl and Trans-nonachlor Data Report, *EPA 905R-01-011, April 2004.*

commonly detected in measurable concentrations in water from Fish Creek than other PAH compounds. The compounds acenaphthylene, benzo(b)fluoranthene, chrysene, fluoranthene, phenanthrene, and pyrene were frequently detected in measurable concentrations.

No data were available for concentrations of PAHs in water from the outer harbor or the nearshore Lake Michigan area.

Polychlorinated Biphenyls (PCBs)

Between 1995 and 2001, 12 MMSD long-term sampling sites within the estuary were sampled for the presence and concentrations of 14 PCB congeners in water. Since concentrations of only 14 out of 209 congeners from this family of compounds were examined, the results should be considered minimum values. While in the majority of samples, the concentrations of these PCB congeners were below the limit of detection, when PCBs were detected they exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 nanograms per liter (ng/l). PCBs were detected at sampling stations in estuary portions of each of the three Rivers which make up the estuary.

In 1994, the USGS collected samples at Jones Island where the Milwaukee River flows into the outer harbor and analyzed these samples for the presence of polychlorinated biphenyls (PCBs) in water. These samples were divided by filtration into two portions: one portion consisting of PCBs dissolved in water and another portion consisting of PCBs associated with suspended sediment particles. These portions were analyzed on a congener-specific basis that examined 59 fractions representing 82 of the 209 individual PCB compounds.[85] Because only some congeners were analyzed, the results should be considered to represent minimum concentrations. In all of the samples collected, the sum of the PCB concentrations in the dissolved and suspended portions of the samples exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 nanograms per liter (ng/l). On average, 38 fractions representing 54 individual PCB compounds were detected in the dissolved portion of the samples. By contrast, 45 fractions representing 64 individual PCB compounds were detected in the suspended portion of the samples. Higher concentrations of PCBs were detected in the suspended portion of the samples than in the dissolved portion. These differences reflect the fact that PCBs are poorly soluble in water and tend to adsorb to sediment particles. The congener composition of the samples was examined to estimate what proportion of each sample consisted of PCB congeners that are considered to be of greatest environmental concern due to toxicity. Toxicity was judged by the ability of the congeners to induce toxic effects through mechanisms similar to those involved in the toxicity of dioxins.[86] It is important to note that toxic effects unrelated to dioxin-like toxicity have been reported; however, less information is available on nondioxin-like PCB congeners and their toxicology is not well understood.[87] On average, congeners considered to be of the greatest environmental concern represented about 6 percent and 16 percent of the mass of PCBs detected in the dissolved and suspended portions of the samples, respectively.

While no other data on PCBs concentrations in water were available from the outer harbor and no data on PCB concentrations in water were available from the nearshore Lake Michigan area, data were available for Lake Michigan as a whole. These data should give an indication of conditions in the nearshore area. The Lake Michigan Mass Balance Study examined concentrations of PCBs in tributaries draining into Lake Michigan and

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[85] *In several cases, the analytical method used is not able to distinguish between two or more specific congeners.*

[86] *Victor A. McFarland and Joan U. Clarke, "Environmental Occurrence, Abundance, and Potential Toxicity of Polychlorinated Biphenyl Congeners: Considerations for a Congener-Specific Analysis,"* Environmental Health Perspectives, *Vol. 81, 1989; Stephen Safe, "Toxicology, Structure-Function Relationships, and Human and Environmental Impacts of Polychlorinated Biphenyls: Progress and Problems,"* Environmental Health Perspectives, *Vol. 100, 1992*

[87] *Tala R. Henry and Michael J. DeVito, "Non-dioxin-like PCBs: Effects and Consideration in Ecological Risk Assessment", U.S. Environmental Protection Agency Ecological Risk Assessment Support Center, June 2003.*

in the open waters of Lake Michigan.[88] In 1994-1995, loadings from tributaries account for about 12 percent of contributions to the Lake. Concentrations of dissolved PCBs in 38 samples collected from near the mouth of the Milwaukee River in 1994 and 1995 ranged between 6.7 nanograms per liter (ng/l) and 28 ng/l, with a mean concentration of 13 ng/l. Concentrations of suspended PCBs in 38 samples collected from the same site during the same period ranged between 2 ng/l and 35 ng/l, with a mean concentration of 11 ng/l. Concentrations of dissolved PCBs in the open waters of Lake Michigan ranged from below the limit of detection to 0.95 ng/l, with a mean concentration of 0.18 ng/l. Concentrations of suspended PCBs in the open waters of Lake Michigan ranged from below the limit of detection to 0.74 ng/l, with a mean concentration of 0.07 ng/l. Concentrations of both dissolved and suspended PCBs tended to be higher in the southwestern portion of the Lake. The mean concentrations of dissolved and suspended PCBs at the sampling station nearest the Milwaukee Harbor were 0.19 ng/l and 0.09 ng/l, respectively. The study estimated that in 1994 and 1995 the Milwaukee River Basin contributed 11 kg per year of PCBs to Lake Michigan. The study found that concentrations of PCBs in the open water of Lake Michigan had decreased since earlier sampling.

In 2002, two sites along Fish Creek were sampled on two dates for the presence and concentrations of 14 PCB congeners in water. Since concentrations of only 14 out of 209 congeners from this family of compounds were analyzed, the results from the mainstem should be considered minimum values. PCBs were not detected in any of these samples.

Toxic Contaminants in Aquatic Organisms

The WDNR periodically surveys tissue from fish and other aquatic organisms for the presence of toxic and hazardous contaminants. Several surveys were conducted at sites within the Milwaukee Harbor estuary and nearshore Lake Michigan area between 1977 and 2002. These surveys screened for the presence and concentrations of several contaminants including metals, PCBs, and organochloride pesticides. The results of these surveys are documented in Chapters V, VI, and VII of this report. Because of potential risks posed to humans by consumption of fish containing high levels of contaminants, the WDNR has issued fish consumption advisories for several species of fish taken from Lake Michigan and tributaries of Lake Michigan up to the first dam (see Table 194). In addition due to tissue concentrations of PCBs in excess of the U.S. Food and Drug Administration's standard, the Wisconsin Division of Health has issued a do not eat consumption advisory for black ducks, mallard ducks, ruddy ducks, and scaup using the Milwaukee Harbor.

Mercury

Between 1977 and 2002 the WDNR sampled for mercury contamination of tissue from individuals from several species of aquatic organisms collected in the Milwaukee Harbor. The concentration of mercury reported in fish tissue ranged between 0.11 micrograms per gram (μg per g) tissue and 0.28 μg per g tissue. Species samples and concentrations detected in the portions of the Kinnickinnic River, Menomonee River, and Milwaukee River are included in the analyses given in Chapters V, VI, and VII, respectively, of this report.

While no data on tissue concentrations of mercury in organisms were available specifically for the outer harbor or nearshore Lake Michigan area, data were available for the Lake as a whole. These data give some indication of what tissue concentrations of mercury can be expected in these areas. The Lake Michigan Mass Balance Study examined tissue concentrations of the mercury in phytoplankton, zooplankton, and two species of predatory fish collected in the open waters of Lake Michigan.[89] Concentrations of mercury in phytoplankton samples collected from the open waters of Lake Michigan in 1994 and 1995 ranged between 0.011 μg/g tissue and 0.176 μg/g tissue, with a mean of 0.035 μg/g tissue. The bioaccumulation factor for phytoplankton, a measure of how many times higher tissue concentrations are than concentrations in water, was about 107,000. Concentrations of mercury in phytoplankton tended to increase throughout the summer and were highest in fall. Concentrations of

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[88]*U.S. Environmental Protection Agency, 2004, EPA 905 R-01-011,* op. cit.

[89]*U.S. Environmental Protection Agency, 2004, EPA 905 R-01-012,* op. cit.

Table 194

FISH CONSUMPTION ADVISORIES FOR LAKE MICHIGAN AND THE LAKE MICHIGAN DIRECT DRAINAGE AREA[a]

Species	Consumption Advisory Level			
	One Meal per Week	One Meal per Month	One Meal per Two Months	Do Not Eat
Lake Michigan and Its Tributaries Up to the First Dam				
Brown Trout	- -	Less than 22 inches	Larger than 22 inches	- -
Chinook Salmon	- -	Less than 32 inches	Larger than 32 inches	- -
Chubs	- -	All sizes	- -	- -
Coho Salmon	- -	All sizes	- -	- -
Lake Trout	- -	Less than 23 inches	23-27 inches	Larger than 27 inches
Rainbow Trout	Less than 22 inches	Larger than 22 inches	- -	- -
Smelt	All sizes	- -	- -	- -
Whitefish	- -	All sizes	- -	- -
Yellow Perch	All sizes	- -	- -	- -

[a]*The statewide general fish consumption advisory applies to fish species not listed in this table.*

Source: Wisconsin Department of Natural Resources.

mercury in zooplankton samples collected from the open waters of Lake Michigan in 1994 and 1995 ranged between 0.011 μg/g tissue and 0.376 μg/g tissue, with a mean of 0.054 μg/g tissue. The bioaccumulation factor for zooplankton was about 166,000. The biomagnification factor between phytoplankton and zooplankton, a measure of how tissue concentrations of a contaminant increase through the food chain, was about 1.55. Concentrations of mercury in zooplankton were higher in late summer and fall than in the spring.

Concentrations of mercury in the tissue of adult lake trout ranged between 0.019 μg/g tissue and 0.396 μg/g tissue, with a mean concentration of 0.139 μg/g tissue. Concentrations of mercury in the tissue of adult coho salmon ranged between 0.023 μg/g tissue and 0.127 μg/g tissue, with a mean concentration of 0.069 μg/g tissue. Concentrations of mercury in the tissue of coho salmon sampled in hatcheries ranged between 0.070 μg/g tissue and 0.088 μg/g tissue, with a mean concentration of 0.080 μg/g tissue. The reason for the higher tissue concentration in hatchery fish is unknown. It might reflect differences in exposure to mercury between hatchery and lake environments or differences between uptake and elimination rates of mercury between fish in hatcheries and fish in Lake Michigan. Alternatively, it may be a statistical anomaly related to the small number of hatchery samples in the study.[90] Tissue concentrations of mercury tended to increase with age and length of fish. Biomagnification factors for adult lake trout and adult coho salmon were about 1,140,000 and 758,000, respectively. Bioaccumulation factors could not be calculated for these species because they are top predator species and no data were collected on tissue concentrations of mercury in forage fish species.

PCBs

Between 1977 and 2002 the WDNR examined tissue taken from individuals of several species of aquatic organisms collected from sites in the Milwaukee Harbor estuary for contamination with PCBs. The results of these samplings are documented in Chapters V, VI, and VII of this report. Most of the samples collected were from the portion of the Milwaukee River in the estuary. Tissue concentrations of PCBs in fish collected in the estuary appear to have decreased since the 1970s, though time comparisons are complicated by the fact that different species were sampled on different dates (see Figure 155 in Chapter VII of this report).

While no data were available on tissue concentrations of PCBs in organisms collected from the outer harbor or nearshore Lake Michigan area, data were available for Lake Michigan as a whole. These data give some

[90]Ibid.

indications of likely conditions in the nearshore area. The Lake Michigan Mass Balance Study examined concentrations of PCBs in tissue of phytoplankton, zooplankton, aquatic invertebrates, and fish collected in the open waters of Lake Michigan.[91] Concentrations of PCBs in phytoplankton samples collected from the open waters of Lake Michigan in 1994 and 1995 ranged between 0.009 μg/g tissue and 0.24 μg/g tissue, with a mean concentration of 0.049 μg/g tissue. The bioaccumulation factor for phytoplankton was about 270,000. Concentrations of PCBs in zooplankton samples collected from the open waters of Lake Michigan in 1994 and 1995 ranged between 0.057 μg/g tissue and 0.33 μg/g tissue, with a mean of 0.17 μg/g tissue. The bioaccumulation factor for zooplankton was about 930,000. The biomagnification factor between phytoplankton and zooplankton was about 3.4. Concentrations of PCBs in samples of the opossum shrimp *Mysis* collected from the open waters of Lake Michigan in 1994 and 1995 ranged between 0.11 μg/g tissue and 0.410 μg/g tissue, with a mean of 0.25 μg/g tissue. The bioaccumulation factor for *Mysis* was about 1,400,000. The biomagnification factor between phytoplankton and *Mysis* was about 5.1. Concentrations of PCBs in samples of the amphipod *Diporeia* collected from the open waters of Lake Michigan in 1994 and 1995 ranged between 0.26 μg/g tissue and 0.62 μg/g tissue, with a mean of 0.42 μg/g tissue. The bioaccumulation factor for *Diporeia* was about 2,300,000. The biomagnification factor between phytoplankton and *Diporeia* was about 8.5. Concentrations of PCBs in forage fish ranged from 0.23 μg/g tissue to 5.0 μg/g tissue. Mean concentrations in deep water sculpin, smelt, slimy sculpin, and adult alewife were 1.7 μg/g tissue, 1.4 μg/g tissue, 1.7 μg/g tissue, and 2.1 μg/g tissue, respectively. Bioaccumulation factors for PCBs in forage fish ranged between 5,500,000 and 15,000,000. Tissue concentrations were lower in alewife under 120 millimeters in length, with a mean concentration of 0.99 μg/g tissue.

Piscivorous fish had higher body burdens of PCBs. Concentrations of PCBs in the tissue of adult lake trout ranged between 0.77 μg/g tissue and 37 μg/g tissue with a mean concentration of 7.8 μg/g tissue. Concentrations of PCBs in the tissue of adult coho salmon ranged between 0.57 μg/g tissue and 6.0 μg/g tissue, with a mean concentration of 2.9 μg/g tissue. Bioaccumulation factors for adult lake trout and coho salmon were 43,000,000 and 16,000,000, respectively. Tissue concentrations of PCBs in Lake Michigan fish were biomagnified through the food web. The biomagnification factor between forage fish and lake trout was 4.2. The biomagnification factor between forage fish and coho salmon was 1.6.

Comparison of tissue concentrations of PCBs in Lake Michigan lake trout from the 1994 and 1995 sampling to earlier studies indicate body burdens have decreased since the 1970s.[92] Forecasts from the Lake Michigan Mass Balance study indicate that if the rates of decrease observed in the 1994 to 1995 sampling continue, tissue concentrations of PCBs in lake trout may be low enough to permit unlimited consumption by sometime between 2039 and 2044.

Pesticides

Between 1977 and 2002 the WDNR sampled several species of aquatic organisms from the Milwaukee Harbor estuary for contamination by historically used, bioaccumulative pesticides and their breakdown products. Many of these compounds are no longer in use. For example, crop uses of most of these compounds were banned in the United States between 1972 and 1983. While limited uses were allowed after this for some of these substances, by 1988 the uses of most had been phased out. During the 1970s and 1980s, measurable concentrations of *p,p'*-DDT were occasionally detected in tissue of redhorse and *o,p'*-DDT was detected in the tissue of several species collected from the estuary. During the same period measurable concentrations of the DDT breakdown products of *p,p'*-DDD and *p,p'*-DDE were detected in the tissue of fish from most species that were examined. Since 1990, measurable concentrations of *p,p*'-DDD and *p,p'*-DDE have been detected in tissue from carp. During the 1970s and 1980s, measurable concentrations of α-chlordane and γ-chlordane were detected in the tissue of carp, goldfish, and northern pike. Since 1990, concentrations of chlordane isomers in the tissue of fish collected from the estuary have been below the limit of detection. Similarly, during the 1970s and 1980s, measurable

[91] *U.S. Environmental Protection Agency, 2004, EPA 905 R-01-011,* op. cit.

[92] Ibid.

concentrations of dieldrin were detected in tissue from carp, northern pike, and gizzard shad collected from the estuary. Since 1990, concentrations of this insecticide in fish tissue have been below the limit of detection. Tissue from carp, goldfish, and redhorse collected in the 1970s contained measurable concentrations of the insecticide methoxychlor. Tissue collected from a variety of species during the 1970s and 1980s contained measurable concentrations of the insecticide aldrin. During the 1980s, measurable concentrations of the fungicides 2,4,5-trichlorophenol, 2,4,6-trichlorophenol, and hexachlorobenzene were detected in carp and smallmouth bass collected in the estuary section of the Milwaukee River. It is important to recognize that the number of individual organisms and the range of species taken from the estuary that have been screened for the presence of pesticide contamination are quite small. Because of this, these data may not be completely representative of pesticide body burdens of pesticides carried by aquatic organisms in the estuary.

While no data were available on tissue concentrations of pesticides in organisms collected from the outer harbor or nearshore Lake Michigan area, data were available for one pesticide for Lake Michigan as a whole. These data give some indications of likely conditions in the nearshore area. The Lake Michigan Mass Balance Study examined concentrations of the chlordane isomer trans-nonachlor in tissue of phytoplankton, zooplankton, aquatic invertebrates, and fish collected the open waters of Lake Michigan.[93] This pesticide is a compound that tends to bioaccumulate and can be biomagnified through the food web. Concentrations of trans-nonachlor in phytoplankton samples collected from the open waters of Lake Michigan in 1994 and 1995 ranged from below the limit of detection to 0.0059 μg/g tissue, with a mean concentration of 0.0017 μg/g tissue. The bioaccumulation factor for phytoplankton was about 300,000. Concentrations of trans-nonachlor in zooplankton samples collected from the open waters of Lake Michigan in 1994 and 1995 ranged between 0.0022 μg/g tissue and 0.081 μg/g tissue, with a mean of 0.016 μg/g tissue. The bioaccumulation factor for zooplankton was about 2,800,000. The biomagnification factor between phytoplankton and zooplankton was about 9.5. Concentrations of trans-nonachlor in samples of the opossum shrimp *Mysis* collected from the open waters of Lake Michigan in 1994 and 1995 ranged between 0.0045 μg/g tissue and 0.049 μg/g tissue, with a mean of 0.025 μg/g tissue. The bioaccumulation factor for *Mysis* was about 4,400,000. The biomagnification factor between phytoplankton and *Mysis* was about 15. Concentrations of trans-nonachlor in samples of the amphipod *Diporeia* collected from the open waters of Lake Michigan in 1994 and 1995 ranged between 0.011 μg/g tissue and 0.069 μg/g tissue, with a mean of 0.032 μg/g tissue. The bioaccumulation factor for *Diporeia* was about 5,500,000. The biomagnification factor between phytoplankton and *Diporeia* was about 18. Concentrations of trans-nonachlor in forage fish ranged from 0.0098 μg/g tissue to 0.39 μg/g tissue. Mean concentrations in deep water sculpin, smelt, slimy sculpin, and adult alewife were 0.20 μg/g tissue, 0.087 μg/g tissue, 0.15 μg/g tissue, and 0.11 μg/g tissue, respectively. Bioaccumulation factors for trans-nonachlor in forage fish ranged between 8,500,000 and 35,000,000. Tissue concentrations were lower in alewife under 120 millimeters in length, with a mean concentration of 0.050 μg/g tissue.

Piscivorous fish species differed in their body burdens of trans-nonachlor. Concentrations of trans-nonachlor in the tissue of adult lake trout were higher than concentrations in the tissue of forage fish. They ranged between 0.048 μg/g tissue and 1.7 μg/g tissue, with a mean concentration of 0.48 μg/g tissue. By contrast, concentrations of trans-nonachlor in the tissue of adult coho salmon were similar to those observed in the tissue of forage fish species. They ranged between 0.024 μg/g tissue and 0.30 μg/g tissue, with a mean concentration of 0.14 μg/g tissue. Bioaccumulation factors for adult lake trout and coho salmon were 83,000,000 and 24,000,000, respectively. Transfer of trans-nonachlor through the food web differed between piscivorous fish species. The biomagnification factor between forage fish and lake trout was 3.4 and indicates that this pesticide is biomagnified in the trophic link between forage fish and lake trout. By contrast, the biomagnification factor between forage fish and coho salmon was 0.96, suggesting that no biomagnifications of trans-nonachlor occurs in the trophic link between forage fish and coho salmon. This difference may reflect the facts that trans-nonachlor tends to accumulate in lipids and lake trout tissue tends to have a higher lipid content than coho salmon tissue. Alternatively, it may reflect the fact that lake trout tend to have a varied diet while coho salmon tend to feed almost exclusively on alewife. Comparison of the mean tissue concentration of trans-nonachlor in coho salmon to

[93]Ibid.

the mean tissue concentration of trans-nonachlor in adult alewife indicates a biomagnification factor from alewife to coho salmon of about 1.3.

Toxic Contaminants in Sediment

Since the mid 1970s, a considerable number of sediment samples from the Milwaukee Harbor estuary and outer harbor have been examined for the presence and concentrations of toxic contaminants. Sampling during the late 1970s and early 1980s was conducted by a number of agencies, including the U.S. Army Corps of Engineers, the USEPA, the MMSD, and the Port of Milwaukee. The results of these samplings have been documented in a previous SEWRPC report.[94] More recently, sampling of sediment was conducted by the University of Wisconsin-Milwaukee in much of the estuary and outer harbor. The results of this study were documented in a series of reports and theses.[95] Additional sampling of sediment in the Kinnickinnic River portion of the estuary between the E. Becher Street Bridge and the 1st Street Bridge was conducted in 2002 as part of the concept design for remediation of the Kinnickinnic River.[96] Sample sites from the University of Wisconsin-Milwaukee studies and Kinnickinnic remediation studies are shown on Maps 124 and 125, respectively.

Sediment samples collected from the Milwaukee Harbor estuary during the period 1975 to 1985 showed detectable concentrations of cadmium, copper, lead, zinc, and PCBs. Mean concentrations of cadmium in sediment at sites in the estuary ranged from 5.3 mg/kg to 16.2 mg/kg. In the outer harbor, the mean concentration of cadmium in sediment samples was 18 mg/kg. These means were above the Probable Effect Concentration above which toxicity to benthic organisms is considered highly probable (see Table 13 in Chapter III of this report). Mean concentrations of copper in sediment samples from the estuary ranged between 86 mg/kg and 150 mg/kg. These means were between the Threshold Effect Concentrations (TEC) and the Probable Effect Concentrations (PECs), indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms. At a mean concentration of 293 mg/kg, copper concentrations in the outer harbor were above the PEC. Mean lead concentrations in samples from the estuary ranged between 380 mg/kg and 720 mg/kg. In the outer harbor, the mean concentration of lead in sediment was 140 mg/kg. All of these means were above the PEC. Mean concentrations of zinc in sediment samples from the estuary ranged between 220 mg/kg and 640 mg/kg. All of these means were above the TEC and some were above the PEC. Concentrations of PCBs in sediment samples from the estuary were highly variable. They ranged from below the limit of detection to 73.3 mg/kg, though

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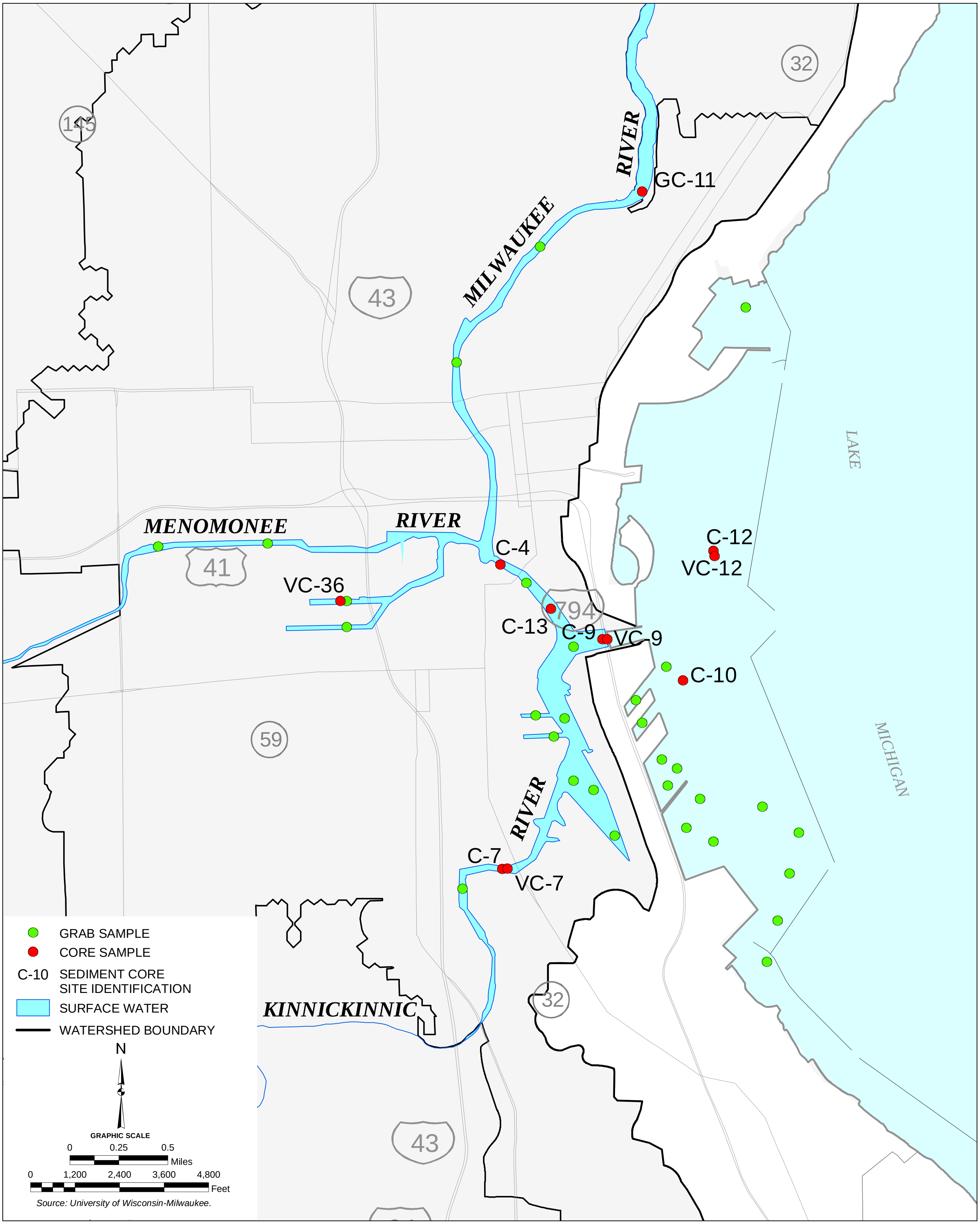
[94]*SEWRPC Planning Report No. 37,* A Water Resources Management Plan for the Milwaukee Harbor Estuary, Volume 1, Inventory Findings, *March 1987.*

[95]*Susan Chi,* PCB Congener Patterns of Sediments from the Milwaukee Harbor Estuary: Implications for Sources, Transport and Biodegradation, *M.S. Thesis, Department of Civil Engineering, University of Wisconsin-Milwaukee, 1996, Michael F. Gin,* Sedimentation Patterns of the Milwaukee Harbor Estuary Determined from TOC, Pb-210, and Cs-137, *M.S. Thesis, Department of Civil Engineering and Mechanics, University of Wisconsin-Milwaukee, 1992; Michael F. Gin and Erik R. Christensen,* Toxic Organic Contaminants in the Sediments of the Milwaukee Harbor Estuary Progress Report No. 3: Measurements of Porosity, TOC, and Loss on Ignition, *January 4, 1991; Fan Ni, Michael F. Gin, and Erik R. Christensen,* Toxic Organic Contaminants in the Sediments of the Milwaukee Harbor Estuary Final Report to the Milwaukee Metropolitan Sewerage Commission, *March 27, 1992; Fan Ni, Ashok K. Singh, and Erik Christensen,* Toxic Organic Contaminants in the Sediments of the Milwaukee Harbor Estuary Final Report to the Wisconsin Coastal Management Program, *September 1, 1992; Ashok K. Singh,* A Source Receptor Method for Determining Nonpoint Sources of PAHs to the Milwaukee Harbor Estuary, *M.S. Thesis, Department of Civil Engineering, University of Wisconsin-Milwaukee, 1992; Robert W. Taylor,* Toxic Organic Contaminants in the Sediments of the Milwaukee Harbor Estuary Progress Report No. 2: Geophysical Survey, *November 26, 1990.*

[96]*Altech Environmental Services, Inc.,* Sediment Sampling from the Kinnickinnic River, Milwaukee, Wisconsin, *March 2003.*

Map 124

SEDIMENT SAMPLING LOCATIONS IN THE MILWAUKEE HARBOR ESTUARY AND OUTER HARBOR: 1990-1991



Map 125

SEDIMENT SAMPLING LOCATION IN THE KINNICKINNIC RIVER PORTION OF THE MILWAUKEE HARBOR ESTUARY: 2002

concentrations at most sites were below 10.0 mg/kg. Concentrations of PCBs in sediment samples from the outer harbor ranged from below the limit of detection to 68.2 mg/kg.

The amount of organic carbon in sediment can exert considerable influence on the toxicity of nonpolar organic compounds such as PAHs, PCBs, and certain pesticides to benthic organisms. While the biological responses of benthic organisms to nonionic organic compounds has been found to differ across sediments when the concentrations are expressed on a dry weight basis, they have been found to be similar when the concentrations have been normalized to a standard percentage of organic carbon.[97] Because of this, the concentrations of PAHs, PCBs, and pesticides were normalized to 1 percent organic carbon prior to analysis.

Concentrations of PAHs in 293 sediment samples collected from the estuary and outer harbor between 1990 and 2002 ranged between about 20 micrograms PAH per kilogram sediment (μg PAH/kg sediment) and about 359,300 μg PAH/kg sediment (see Table 195). Mean concentrations for all sediment ranged from 38,500 μg PAH/kg sediment in the outer harbor to 94,580 μg PAH/kg sediment in the Kinnickinnic River portion of the estuary. Total organic carbon data were not available for two of the 79 samples of surface sediment.

In most sediment samples collected from the top 30 cm of sediment, the normalized concentrations of PAHs were between the TEC and the PEC, indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms. In a few samples, the normalized concentrations of PAHs exceed the PEC for total PAHs and are high enough to pose substantial risk of toxicity to benthic organisms. This was the case for all three sections of the estuary and the outer harbor. Figure 355 shows concentrations of PAHs in 12 sediment cores collected from the estuary and outer harbor during 1990 and 1991. PAH concentrations vary among cores and portions of the estuary. The data from several cores indicate PAH concentrations were higher in intermediate and deep sediment than in surface sediment. Figure 356 shows concentrations of PAHs in 13 sediment cores collected from the reaches of the Kinnickinnic River between E. Becher Street and 1st Street in 2002. Though high concentrations of PAHs were found in shallow sediment from some cores, highest concentrations of PAHs tended to occur between about 200 cm and 500 cm beneath the surface of the sediment.

Concentrations of PCBs in 293 sediment samples collected from the estuary and outer harbor between 1990 and 2002 ranged from below the limit of detection to about 35,500 micrograms PCB per kilogram sediment (µg PCB/kg sediment) (see Table 196). Mean concentrations for all sediment ranged between 271 µg PCB/kg sediment in the Menomonee River portion of the estuary and 3,846 µg PCB/kg sediment in the Kinnickinnic River portion of the estuary. Total organic carbon data were not available for two of the 79 samples of surface sediment. In most sediment samples collected from the top 30 cm of sediment, the normalized concentrations of PCBs were between the TEC and the PEC, indicating that these toxicants are likely to be producing some level of toxic effect in benthic organisms. In a few samples, the normalized concentrations of PCBs exceed the PEC for total PCBs and are high enough to pose substantial risk of toxicity to benthic organisms. This was the case for all three sections of the estuary and the outer harbor.

Figure 357 shows concentrations of PCBs in 12 sediment cores collected from the estuary and outer harbor during 1990 and 1991. PCB concentrations vary among cores and portions of the estuary. The data from several cores indicate PCB concentrations were higher in intermediate and deep sediment than in surface sediment.

Figure 358 shows concentrations of PCBs in 13 sediment cores collected from the reaches of the Kinnickinnic River between E. Becher Street and 1st Street in 2002. Though high concentrations of PCBs were found in shallow sediment from some cores, highest concentrations of PCBs tended to occur between about 200 cm and 500 cm beneath the surface of the sediment.

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[97]*U.S. Environmental Protection Agency,* Technical Basis for the Derivation of Equilibrium Partitioning Sediment Guidelines (ESGs) for the Protection of Benthic Organisms: Nonionic Organics*, USEPA Office of Science and Technology, Washington, D.C., 2000.*

Table 195

CONCENTRATIONS OF POLYCYCLIC AROMATIC HYDROCARBONS IN SEDIMENT SAMPLES FROM THE MILWAUKEE HARBOR ESTUARY AND OUTER HARBOR: 1990-2002[a]

Parameter	Surface Sediment (0-30 cm)	Intermediate Sediment (31-60 cm)	Deep Sediment (60-700 cm)	All Sediment (0-700 cm)
Kinnickinnic River				
Mean	93,400	99,580	92,850	94,580
Standard Deviation	71,240	93,560	70,790	70,560
Minimum	810	10,350	330	330
Maximum	255,900	243,200	359,300	359,300
Samples	40	5	97	141
Menomonee River				
Mean	58,540	72,200	67,430	64,520
Standard Deviation	36,160	5,491	42,980	35,780
Minimum	9,445	66,410	8,430	8,430
Maximum	117,700	79,640	116,700	117,700
Samples	7	4	9	20
Milwaukee River				
Mean	45,630	115,900	7,097	47,700
Standard Deviation	30,740	57,030	14,930	39,940
Minimum	7,440	47,050	20	20
Maximum	158,000	193,000	37,540	193,000
Samples	47	5	6	58
Outer Harbor				
Mean	33,300	65,750	88,950	38,500
Standard Deviation	24,210	1,761	9,285	27,060
Minimum	230	6,300	81,340	230
Maximum	140,000	6,756	102,000	140,000
Samples	65	5	4	74

[a]All concentrations expressed as µg/kg on a dry weight basis.

Source: Altech Environmental Services, Inc.; University of Wisconsin-Milwaukee; and Wisconsin Department of Natural Resources.

The combined effects of several toxicants in sediment of the Milwaukee River were estimated using the methodology described in Chapter III of this report. Table 197 shows overall mean PEC-Q values, a measure that integrates the effects of multiple toxicants on benthic organisms, for streams in the Milwaukee River watershed. Table 198 shows estimated incidences of toxicity to benthic organisms from sediment contaminants for the same streams. For sediments in the estuary, mean PEC-Q values range between 0.102 and 2.584. These mean PEC-Q levels suggest that benthic organisms in the estuary are experiencing moderate to high incidences of toxic effects. In these samples, the estimated incidence of toxicity ranges between about 2 percent and 94 percent. Higher mean PEC-Q values and estimated incidences of toxicity occurred in the Kinnickinnic River portion of the estuary. Mean PEC-Q values in the outer harbor ranged between 0.044 and 0.934, with associated estimated incidences of toxicity ranging between 5 percent and 62 percent. These values suggest that benthic organisms in the outer harbor are experiencing moderate to high incidences of toxic effects.

CURRENT NAVIGATIONAL DREDGING ACTIVITIES IN THE LAKE MICHIGAN INNER AND OUTER HARBOR AREAS

Dredging and the disposal of the dredged materials is presently carried out within the Milwaukee Harbor estuary for maintenance of adequate water depths for commercial navigation. Dredged materials are disposed of at the Jones Island Confined Disposal Facility (CDF) constructed by the U.S. Army Corps of Engineers (USCOE) in

Figure 355

CONCENTRATIONS OF POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) IN SEDIMENTS FROM THE MILWAUKEE HARBOR ESTUARY AND OUTER HARBOR: 1990-1991

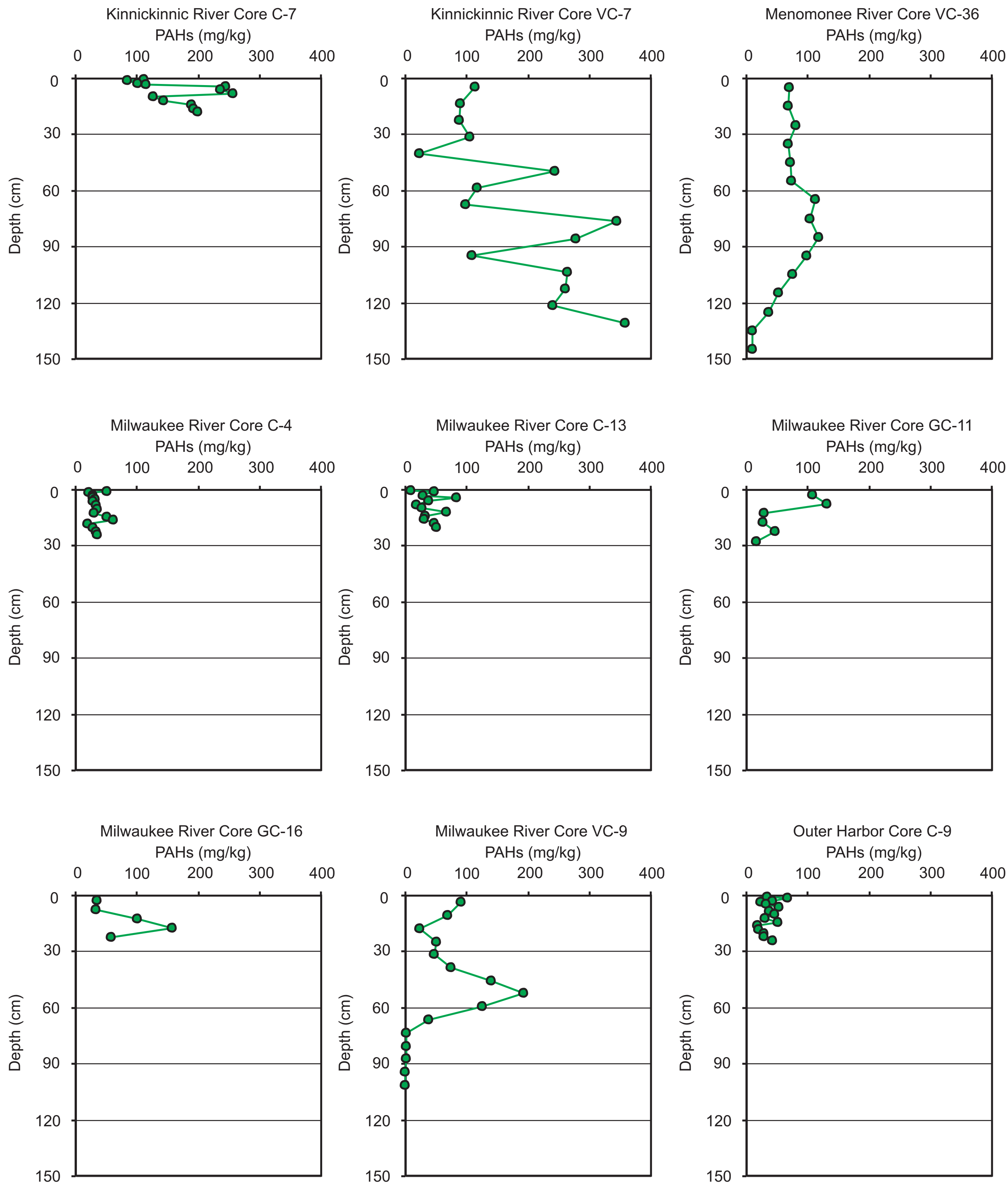
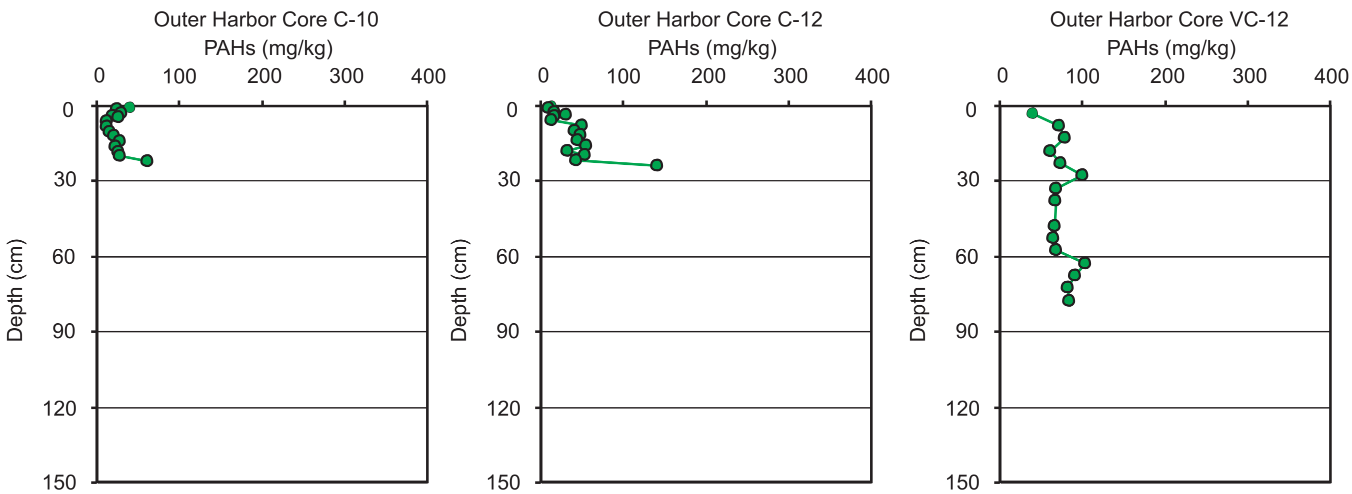


Figure 355 (continued)



Source: University of Wisconsin-Milwaukee and SEWRPC.

1975 along the shoreline of the southern portion of the outer harbor (see Map 126). As shown on Map 126, the current USCOE dredging program is focused on the outer harbor where a 28-foot depth below the established low water datum is authorized and maintained; the main gap from the outer harbor into Lake Michigan where a 30-foot depth is authorized and maintained; a short reach of the Milwaukee River downstream of E. Buffalo Street where a 21-foot depth is authorized and maintained; the Menomonee River from N. 20th Street extended to its confluence with the Milwaukee River where an 18-foot depth is currently maintained, although a 21-foot depth is authorized; the South Menomonee Canal where an approximately 16-foot depth is maintained, although a 21-foot depth is authorized; and the Kinnickinnic River from S. Kinnickinnic Avenue to the Union Pacific Railroad swing bridge, where a 21-foot depth is authorized and maintained and from the swing bridge to the confluence with the Milwaukee River where a 27-foot depth is authorized and maintained. The reach of the Milwaukee River estuary upstream of E. Buffalo Street that was historically dredged has now been Federally deauthorized and is no longer dredged. The reach of the Menomonee River from N. 25th Street downstream to N. 20th Street extended and the Burnham Canal, where 21-foot dredging depths are authorized, are part of the USCOE “backlog” and they have not been regularly maintained in recent years.

The Port of Milwaukee dredges within the municipal mooring basin along the Kinnickinnic River (27-foot-depth) and in the ship slips in the outer harbor, while the slips in the inner harbor are maintained by private concerns.

Additional information related to dredging in the Harbor estuary and the outer harbor is set forth in the regional water quality management plan update report.[98]

BIOLOGICAL CONDITIONS OF THE MILWAUKEE HARBOR ESTUARY AND ADJACENT NEARSHORE LAKE MICHIGAN AREAS

Aquatic and terrestrial wildlife communities have educational and aesthetic values, perform important functions in the ecological system, and are the basis for certain recreational and commercial activities. The location, extent, and quality of fishery and wildlife areas and the type of fish and wildlife characteristic of those areas are,

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[98]*SEWRPC Planning Report No. 50,* A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds, *December 2007.*

Figure 356

CONCENTRATIONS OF POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) IN SEDIMENTS FROM THE KINNICKINNIC RIVER PORTION OF THE MILWAUKEE HARBOR ESTUARY: 2002

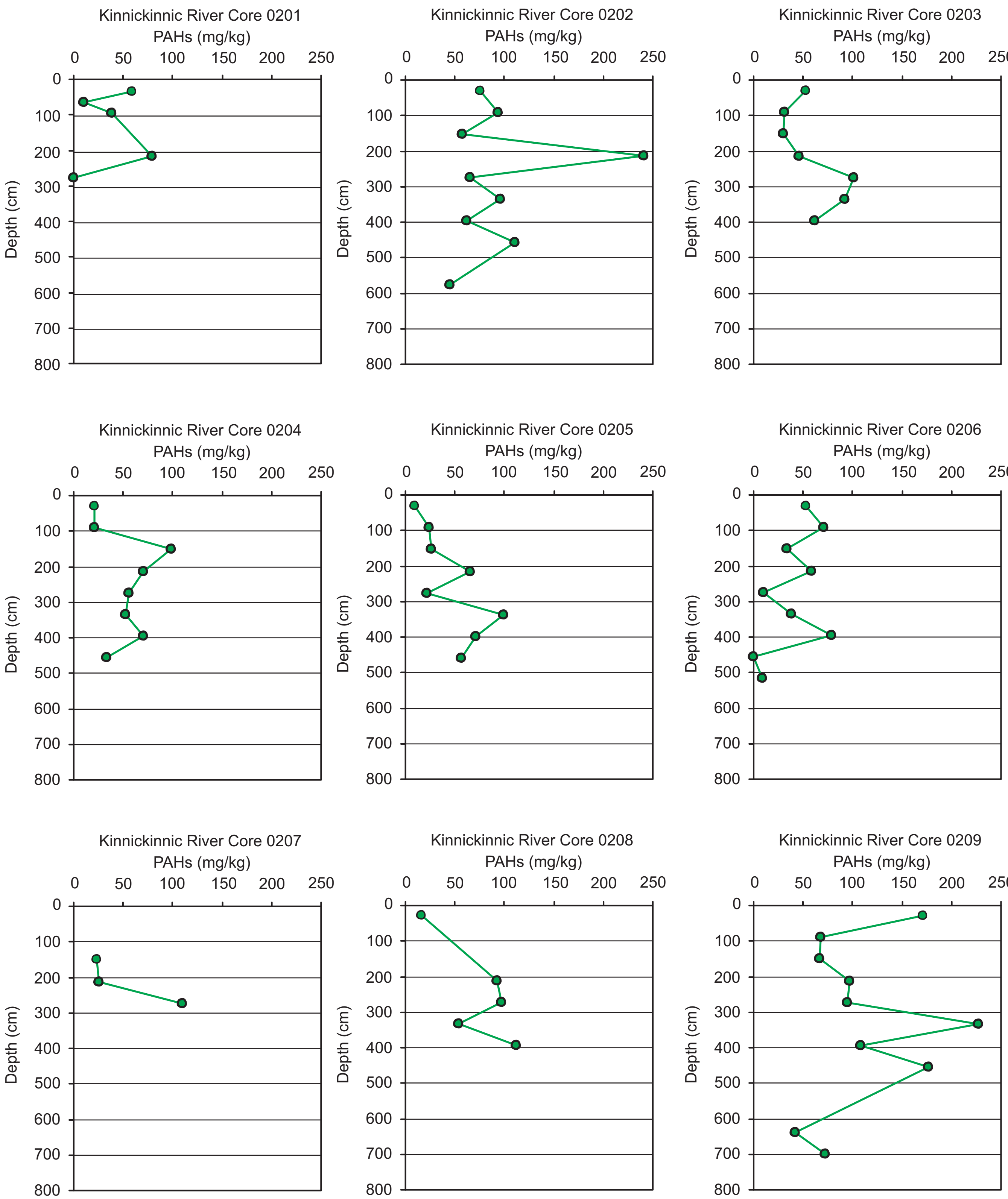
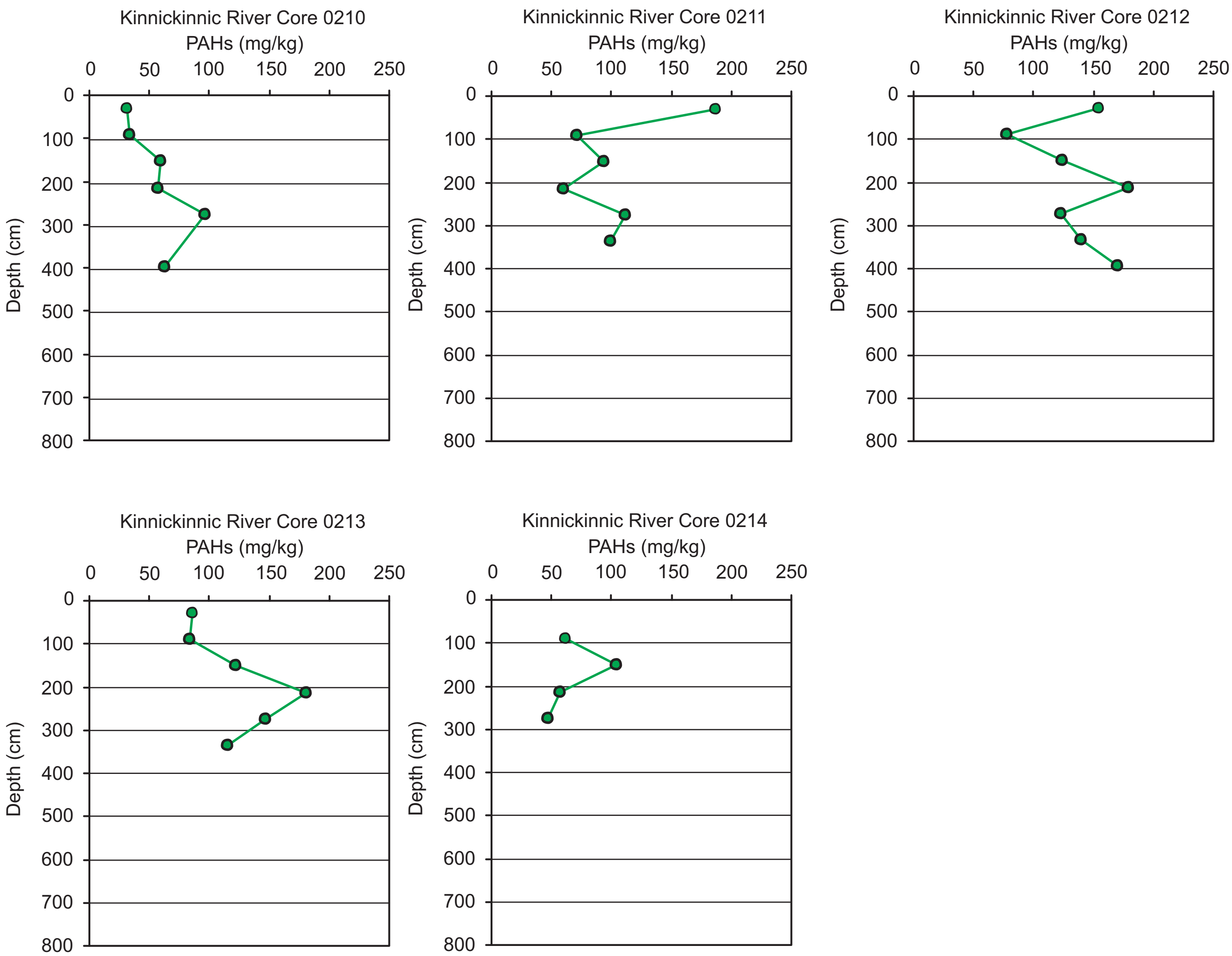


Figure 356 (continued)



Source: Altech Environmental Services, Inc., Wisconsin Department of Natural Resources, and SEWRPC.

therefore, important determinants of the overall quality of the environment in the Milwaukee Harbor estuary and adjacent nearshore Lake Michigan areas and important elements of the lake-based economy.

Lake Michigan Food Web Dynamics

Lake Michigan has undergone well-documented, significant changes in its fishery since the 1880s.[99] These changes have been linked to various factors that include eutrophication, fishery exploitation, and the invasions of exotic or nonnative species among several trophic levels of fishes, mussels, plankton, and aquatic plants. Although a complete history and description of the long term trends in the Lake Michigan fishery is beyond the scope of this report, it is important to note that the fishery in Lake Michigan is a critical element of a complex,

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[99]*L. Wells and A.L. McClain, Lake Michigan: effects of exploitation, introductions, and eutrophication on the salmonid community, Journal of Fisheries and Natural Resources Board of Canada, Volume 34, 1821-1829, 1972; L. Wells and A.L. McClain, Lake Michigan-man's effects on native fish stocks and other biota, Great Lakes Fishery Commission Technical Report No. 20, 1973; and Charles P. Madenjian and others, Dynamics of the Lake Michigan food web, 1970-2000, Canadian Journal of Fisheries and Aquatic Sciences, Volume 59: 736-753, 2002.*

Table 196

CONCENTRATIONS OF POLYCHLORINATED BIPHENYLS IN SEDIMENT SAMPLES FROM THE MILWAUKEE HARBOR ESTUARY AND OUTER HARBOR: 1990-2002[a]

Parameter	Surface Sediment (0-30 cm)	Intermediate Sediment (31-60 cm)	Deep Sediment (60-700 cm)	All Sediment (0-700 cm)
Kinnickinnic River				
Mean	1,180	1,133	5,038	3,846
Standard Deviation	1,264	1,037	5,666	5,064
Minimum	89	110	0	0
Maximum	6,100	2,768	35,500	35,500
Samples	38	5	97	141
Menomonee River				
Mean	272	318	251	271
Standard Deviation	282	44	197	204
Minimum	27	281	28	27
Maximum	860	368	459	860
Samples	7	4	9	20
Milwaukee River				
Mean	366	811	26	369
Standard Deviation	186	427	36	265
Minimum	24	398	3	3
Maximum	991	1,442	99	1,442
Samples	47	5	6	58
Outer Harbor				
Mean	478	141	11	430
Standard Deviation	651	132	9	624
Minimum	14	23	3	3
Maximum	4,692	335	20	4,692
Samples	65	5	4	74

[a]*All concentrations expressed as µg/kg on a dry weight basis.*

Source: Altech Environmental Services, Inc.; University of Wisconsin-Milwaukee; and Wisconsin Department of Natural Resources.

dynamic, and large ecosystem.[100] The Lake Michigan system has shaped entire communities and has significant influence on local economies, recreation, and quality of life, which is reflected in the number of recently published articles related to the Great Lakes as shown in Appendix I.

Most recently, there are several major trends throughout Lake Michigan that are important to note in order to understand the context of the estuary and nearshore fisheries. The findings summarized below are based upon some of the recent major studies and stock assessment activities carried out by the WDNR on Lake Michigan. They provide specific information about the major sport and commercial fisheries, and describe trends in some of the major fish populations. This compilation is not intended as a comprehensive overview of available information about Lake Michigan fisheries.[101]

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[100]*T. Edsall and M. Munawar, State of Lake Michigan: Ecology, Health and Management, Ecovision World Monograph Series, 2005.*

[101]*Additional information can be obtained from the WDNR Lake Michigan web page at http://dnr.wi.gov/org/water/fhp/fish/lakemich/index.htm.*

Figure 357

CONCENTRATIONS OF POLYCHLORINATED BIPHENYLS (PCBs) IN SEDIMENTS FROM THE MILWAUKEE HARBOR ESTUARY AND OUTER HARBOR: 1990-1991

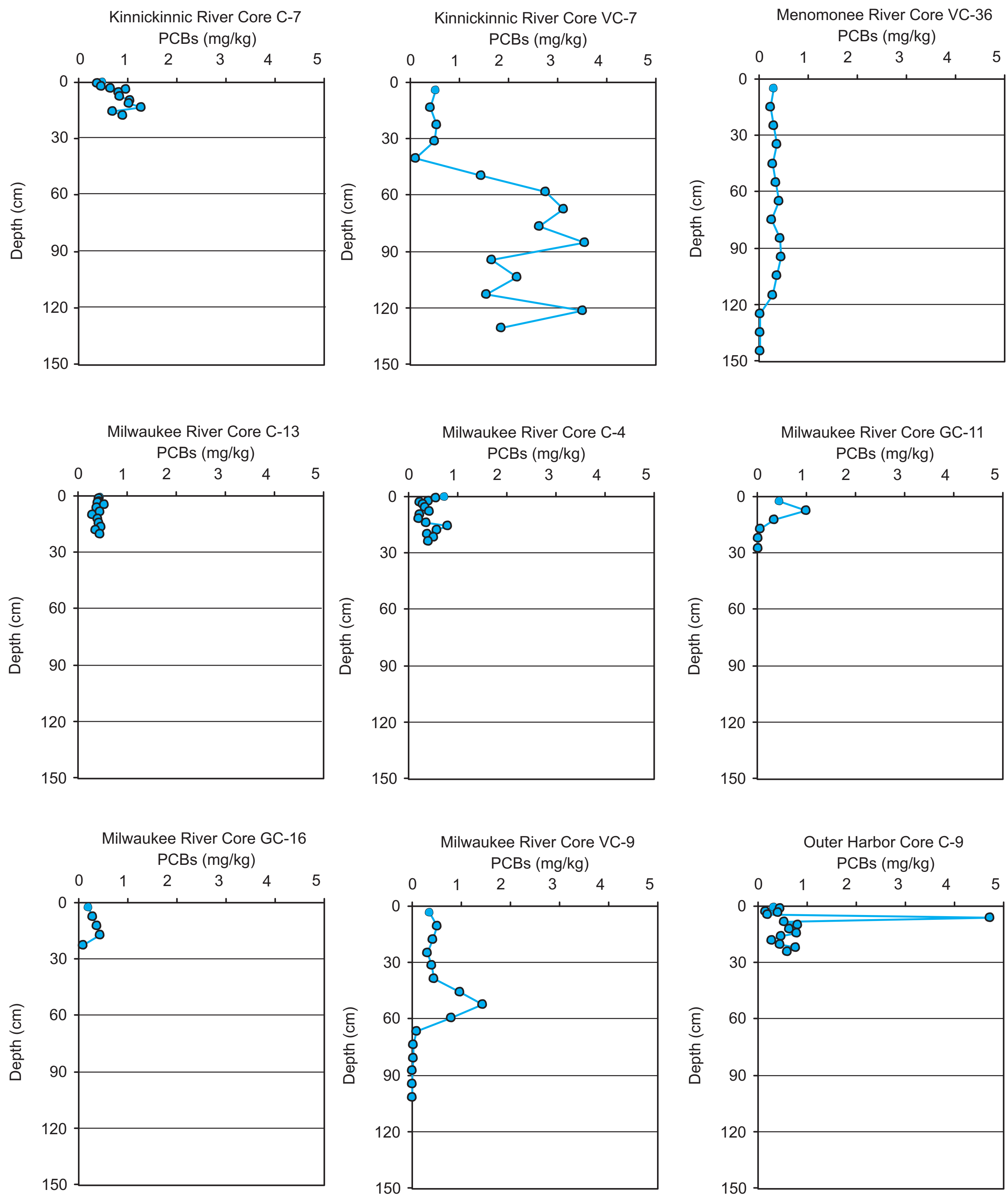
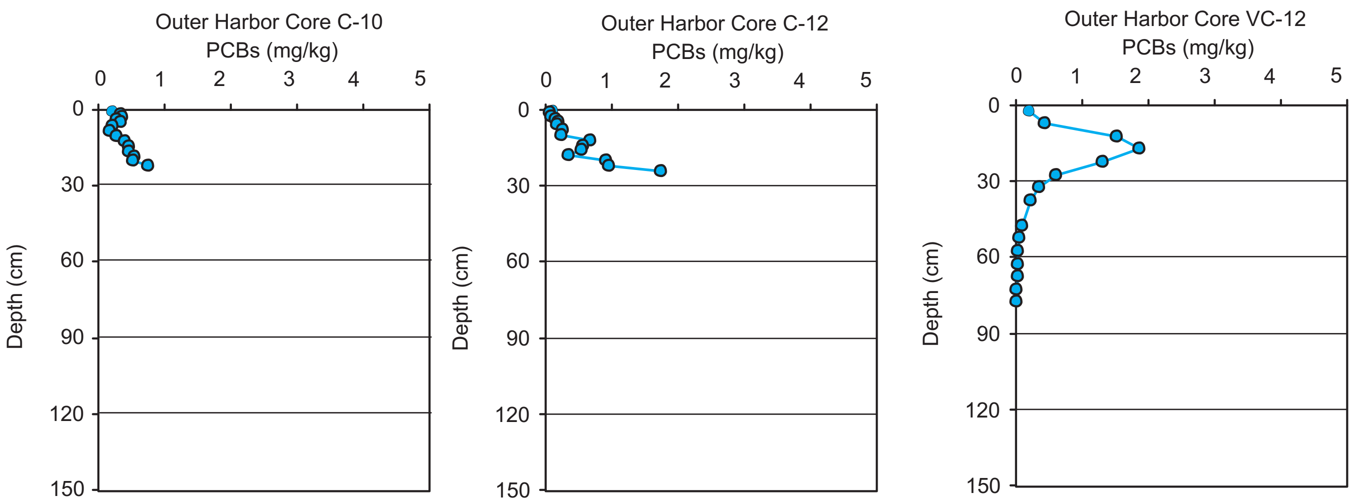


Figure 357 (continued)



Source: University of Wisconsin-Milwaukee and SEWRPC.

The management of Lake Michigan fisheries is conducted in partnership with other State, Federal, and tribal agencies, and in consultation with sport and commercial fishers. Major issues of shared concern are resolved through the Lake Michigan Committee, which is made up of representatives of the States of Michigan, Indiana, Illinois, Wisconsin, and the Chippewa Ottawa Resource Authority. The WDNR fisheries reports are presented to the Lake Michigan Committee as part of Wisconsin's contribution to that shared management effort. Specific points on fisheries trends as set forth in these reports include the following:

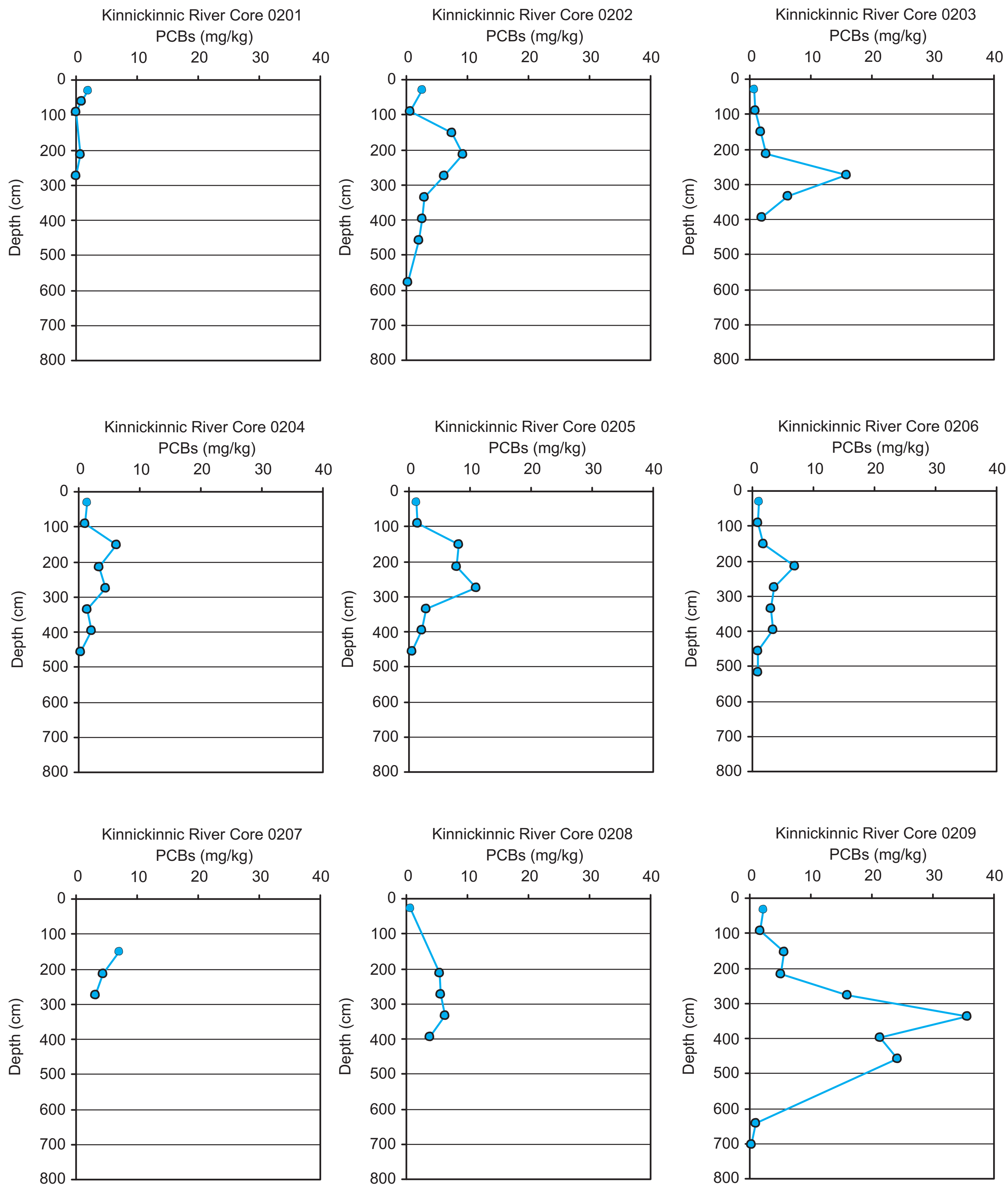
- The State of Wisconsin enjoyed a remarkable sport harvest of chinook salmon in 2005. Size-at-age of chinook salmon continued to decline in 2005, therefore, lakewide chinook stocking will be reduced 25 percent in 2006 in hopes of achieving a better match between the abundance of predators and the available biomass of their prey. The Milwaukee and Root Rivers will be affected by this reduction. The WDNR relies on lakewide forage surveys conducted by the U.S. Geological Survey (USGS) to keep track of trends in prey abundance. The survey completed in 2005 indicated that the biomass of alewives in 2005 was similar to that in 2004.

- Natural reproduction by yellow perch in Green Bay has been very good in recent years. Because of good prospects for the recovery of the Green Bay yellow perch population, in 2006 the allowable commercial harvest was increased to 60,000 pounds and the sport fishing daily bag limit was increased from 10 to 15.

- All yellow perch assessments and harvest data from the Wisconsin waters of Lake Michigan show weak year-classes beginning with the 1990 year class. However, the 1998 year-class was the strongest year-class in recent years which is the dominant group supporting the fishery. Although 2001 and 2002 year-classes are starting to appear in the fishery, the 1998 year-class continues to dominate, comprising 67 percent of the sport caught yellow perch, and 86 percent of the spawning population in 2004. The sport harvest of the 1998 year-class in Lake Michigan is gradually decreasing. These observations are consistent with data collected by other agencies throughout the Lake. Effective September 1996, commercial fishing for yellow perch was closed in the Wisconsin waters of Lake Michigan and the daily sport bag limit was reduced to five fish. Effective May 2002, the sport fishery for Lake Michigan yellow perch was closed from May 1 to June 15. These rule changes were implemented to benefit perch population recovery by reducing impact on spawning stocks. The yellow perch population in southern Lake Michigan is still dominated by the single year-class of

Figure 358

CONCENTRATIONS OF POLYCHLORINATED BIPHENYLS (PCBs) IN SEDIMENTS FROM THE KINNICKINNIC RIVER PORTION OF THE MILWAUKEE HARBOR ESTUARY: 2002



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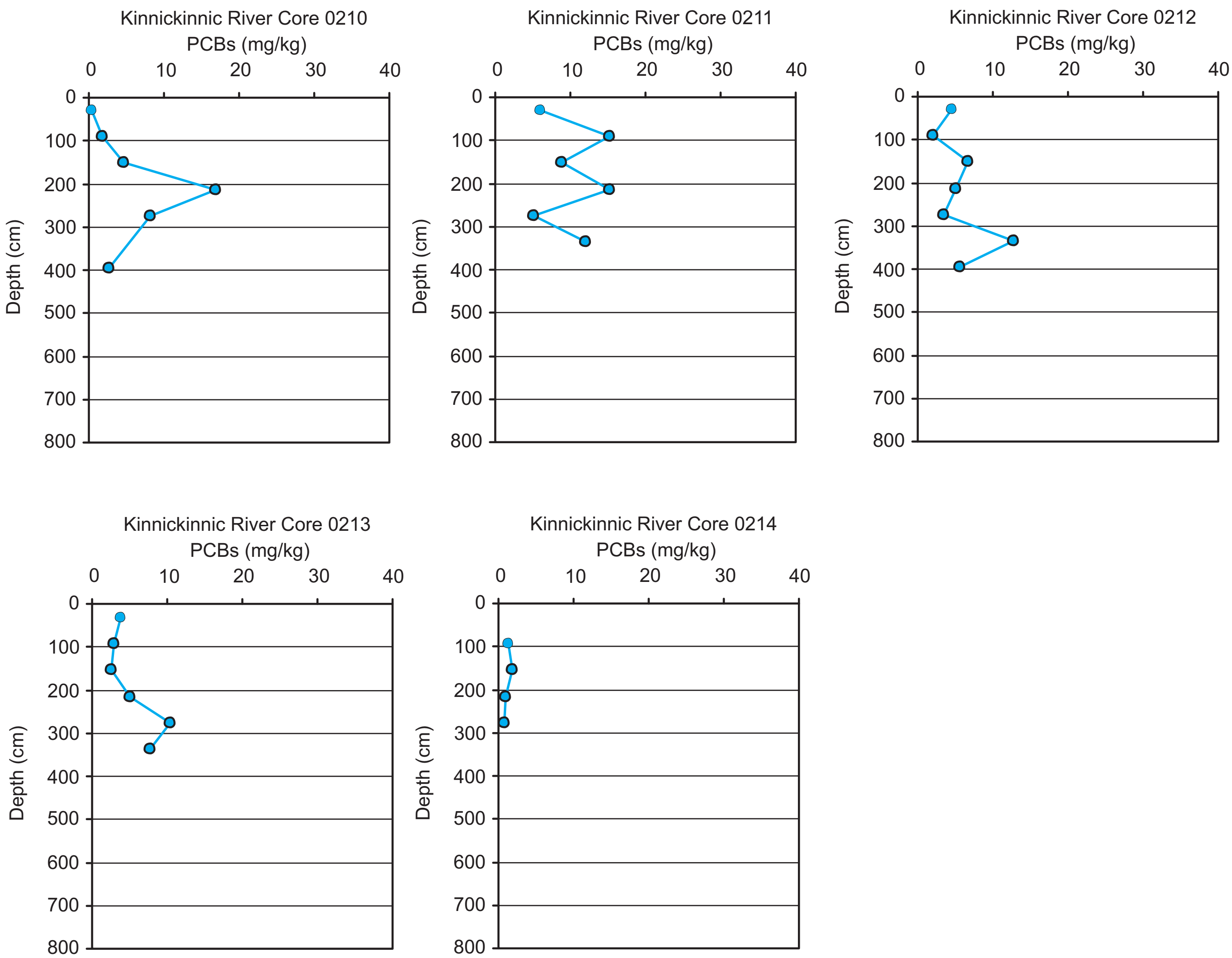


Source: Altech Environmental Services, Inc., Wisconsin Department of Natural Resources, and SEWRPC.

Table 197

MEAN PROBABLE EFFECT CONCENTRATION QUOTIENTS (PEC-Q) FOR SEDIMENT IN THE MILWAUKEE HARBOR ESTUARY AND OUTER HARBOR: 1990-2002

Statistic	Mean Probable Effect Concentration			
	Portion of the Estuary			Outer Harbor
	Kinnickinnic River	Menomonee River	Milwaukee River	
Mean	0.630	0.220	0.122	0.297
Standard Deviation	0.573	0.163	0.281	0.200
Minimum	0.102	0.016	0.107	0.044
Maximum	2.584	0.454	0.416	0.934
Number of Samples	20	5	6	46

Source: Altech Environmental Services, Inc.; University of Wisconsin-Milwaukee; Wisconsin Department of Natural Resources; and SEWRPC.

Table 198

ESTIMATED INCIDENCE OF TOXICITY TO BENTHIC ORGANISMS IN THE MILWAUKEE HARBOR ESTUARY AND OUTER HARBOR: 1990-2002

Statistic	Estimated Percent Benthic Organisms Experiencing Toxic Effects			
	Portion of the Estuary			Outer Harbor
	Kinnickinnic River	Menomonee River	Milwaukee River	
Mean	42	20	25	25
Standard Deviation	23	13	10	13
Minimum	10	2	11	5
Maximum	94	38	35	62
Number of Samples	20	5	6	46

Source: Altech Environmental Services, Inc.; University of Wisconsin-Milwaukee; Wisconsin Department of Natural Resources; and SEWRPC.

1998, which grew faster and attained larger size. There is some evidence for a strong 2005 year-class of yellow perch in Lake Michigan as shown in Figure 359, although the WDNR is not yet ready to recommend increased sport or commercial harvests of the adult fish. In contrast, natural reproduction by yellow perch in Green Bay has been very good in recent years. Prospects for the recovery of the Green Bay yellow perch population are encouraging, so in 2006 the allowable commercial harvest was increased to 60,000 pounds and the sport fishing daily bag limit was increased from 10 to 15.

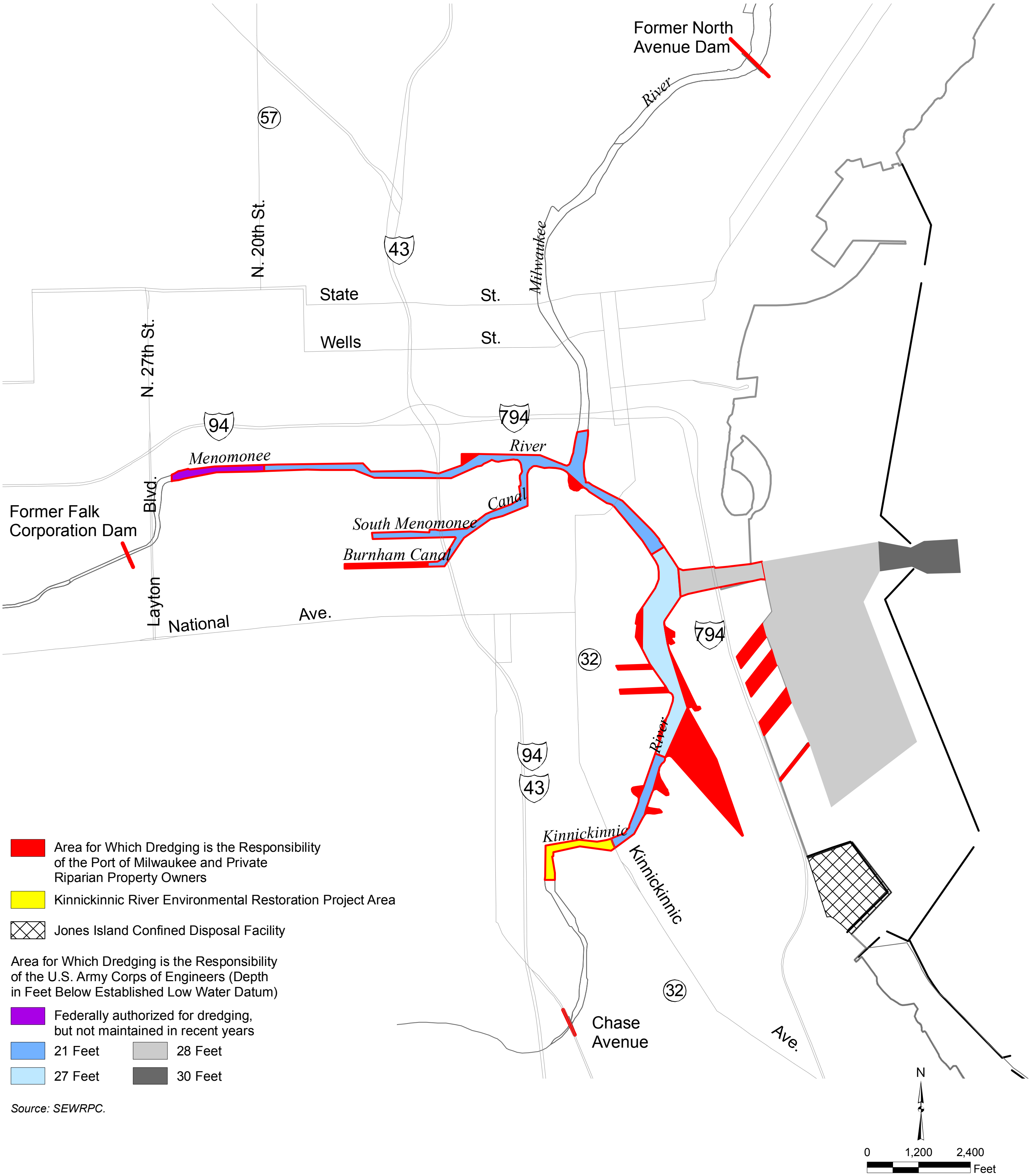
- During 2005, the reported commercial harvest of lake whitefish from the Wisconsin waters of Lake Michigan, including Green Bay, as shown in Figure 360, was up slightly from the annual harvests in 2002 through 2004 to 1,474,723 pounds with 2.4 percent of the total harvest from pound nets, 47.9 percent in trap nets, and 49.7 percent in gill nets. The total annual quota of whitefish for Wisconsin commercial fisherman has been increased four times since it was first established at 1.15 million pounds in quota year 1989-90 and is currently at 2.47 million pounds. However, the mean length and mean weight (i.e., size-at-age) of fish over this same time period has continued to decline. In spring 2005, whitefish mean length and weight at age as shown in Figure 361 (ages two through seven years) were the lowest values documented in the period from 1985 through 2005. As a result of the decreased length and weight at age, the age at which whitefish are recruited to the commercial fishery has increased from age four (as recently as the early to mid 1990s) to age six or seven. This may be related to lakewide declines in abundance of the amphipod *Diporeia* (see the following subsection on Declines in Lake Michigan *Diporeia*) and increases in abundance of the quagga mussel, which form the major food source and major competitor for the food source, respectively.

- Commercial smelt harvests have increased in recent years, reflecting a modest lakewide increase in smelt abundance. This reverses a declining trend of over 10 years that was experienced between 1995 and 2005.

In addition to these fisheries trends, there are two major food web changes that are also occurring in Lake Michigan—nuisance blooms of the filamentous alga *Cladophora* along much of the shoreline and the lakewide loss of the amphipod *Diporeia* (a major food base)—both of which are indicative of an ecosystem under stress. They are reminiscent of the vulnerability of Great Lakes ecosystems to previous disturbances from urban and agricultural runoff, introductions of exotic species, and changes in weather and climate. Although this is not meant to be a complete synopsis of the *Cladophora* or *Diporeia* problems, key elements of the changes being experienced and their possible linkages to those species are summarized below.

Map 126

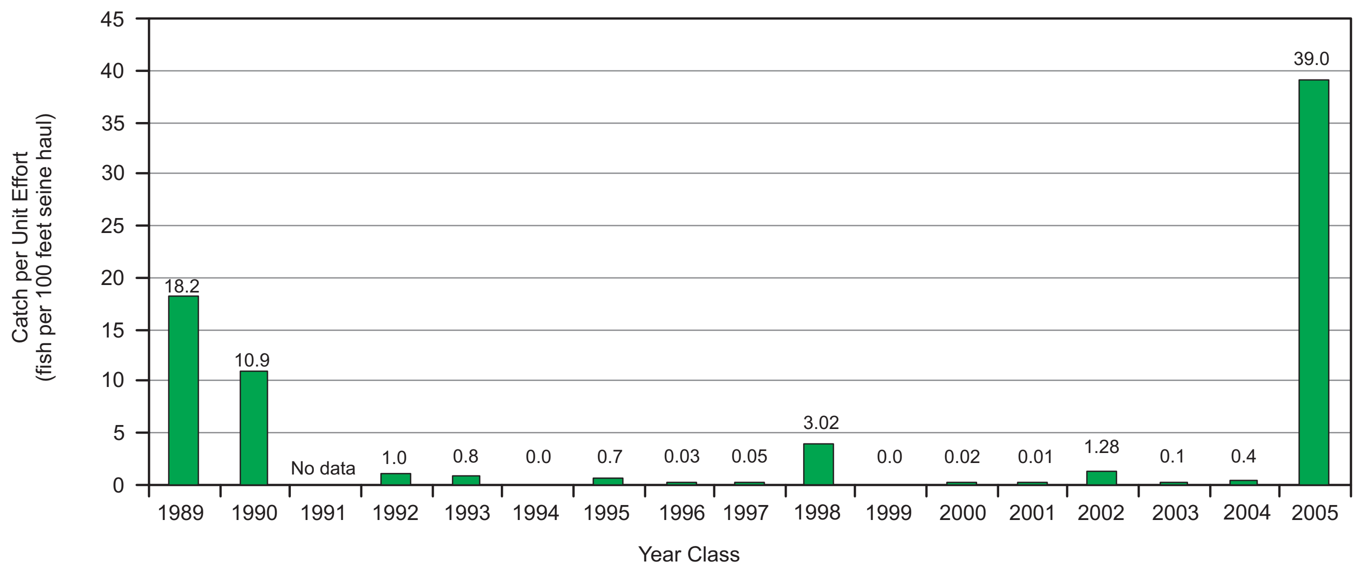
U.S. ARMY CORPS OF ENGINEERS' DREDGING PROGRAM IN THE MILWAUKEE HARBOR ESTUARY AND THE OUTER HARBOR: 2007



Source: SEWRPC.

Figure 359

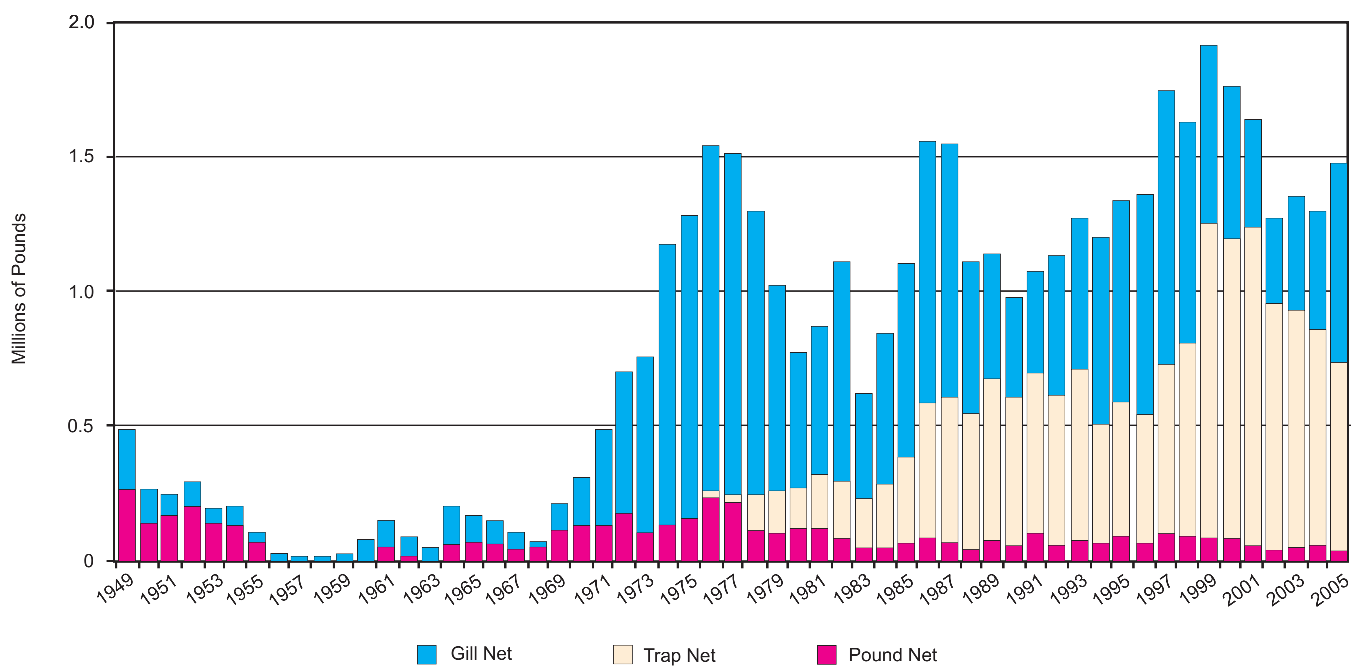
CATCH PER UNIT EFFORT OF YOUNG-OF-THE-YEAR YELLOW PERCH IN SUMMER BEACH SEINING: 1989-2005



Source: Wisconsin Department of Natural Resources.

Figure 360

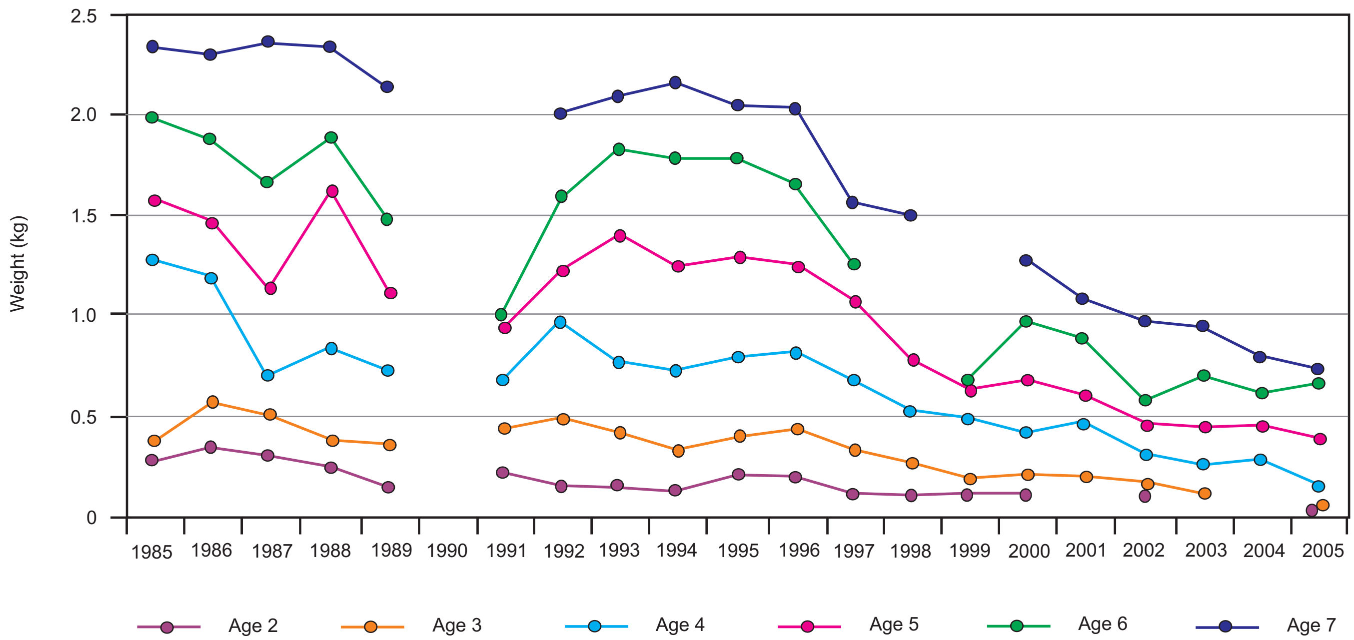
LAKE WHITEFISH REPORTED COMMERCIAL HARVEST BY GEAR IN POUNDS FROM WISCONSIN WATERS OF LAKE MICHIGAN, INCLUDING GREEN BAY: 1949-2005



Source: Wisconsin Department of Natural Resources.

Figure 361

MEAN ANNUAL WEIGHT AT AGE IN LAKE WHITEFISH FROM LAKE MICHIGAN: 1985-2005



Source: Wisconsin Department of Natural Resources.

Nuisance Algae (Cladophora) in Lake Michigan

In recent years large quantities of decaying algae have been fouling Wisconsin's Lake Michigan shoreline. As the bacteria and organisms trapped in the alga rot, they generate a pungent septic odor that many people confuse with sewage. Nutrient (phosphorus) sources, zebra mussels, and declining lake levels have been implicated in the recent increase in nuisance algae abundance. The presence of rotting *Cladophora* on Lake Michigan beaches presents aesthetic and odor problems that impair recreational uses of Lake Michigan. This alga, a green alga, does not present a risk to human health (unlike blue-green algae that can produce toxins). However, the rotting algae may provide adequate conditions for bacterial growth, and microcrustaceans deposited on the beach with the decaying *Cladophora* may attract large flocks of gulls resulting in increased bacteria concentrations from gull fecal material.

Cladophora is found naturally along the Great Lakes coastlines. It grows on submerged rocks, logs or other hard surfaces. Because of Lake Michigan's water clarity it has been observed growing in well over 30 feet of water depth. Wind and wave action cause the algae to break free from the lake bottom and wash up on shore. It is important to note that problems with *Cladophora* date back to the mid-1950s, when nutrient levels, particularly phosphorus, were higher throughout the Great Lakes. Nuisance levels of *Cladophora* were also a problem in the 1960s and 1970s. Research linked these blooms to high phosphorus levels in the water, mainly as a result of human activities such as fertilizing lawns, poorly maintained septic systems, inadequate sewage treatment, agricultural runoff, and detergents containing phosphorus. Following the 1972 Amendments to the Clean Water Act, wastewater discharges of phosphorus were limited. Phosphorus levels in the lakes declined and nuisance algae blooms in Lake Michigan largely subsided. *Cladophora* blooms were largely absent in the 1980s and 1990s. Phosphorus levels in Lake Michigan continue to remain below the thresholds set in the 1970s, but recent research suggests that the invasion of zebra and quagga mussels in the Great Lakes are responsible for increasing the availability of phosphorus as well as increasing water clarity.[102] This may be contributing to the increased abundance of *Cladophora* in recent years. Because there are no known effective means of controlling zebra mussel populations on a large scale, the only management option to date is to continue to reduce the mass of phosphorus entering Lake Michigan.

Possible Reasons for Excessive Growth
The causes of the *Cladophora* resurgence in the Great Lakes are not known for certain, but probably include changes in both dreissenid (zebra and quagga) mussels and phosphorus inputs and/or availability.

- Zebra and Quagga Mussels—During the past decade, water clarity in parts of the Great Lakes has increased substantially because dreissenid mussels filter suspended particles from the water as they feed. Light can penetrate to much greater depths, expanding the areas of hard substrate where *Cladophora* can grow. The vast beds of exotic mussels now found in the Great Lakes also provide *Cladophora* with new substrate on which to grow. In addition, as the mussels feed, they filter algae and other phosphorus-containing particles out of the water, and excrete excess phosphorus, which fertilizes the *Cladophora*.

- Phosphorus Inputs—Most of the phosphorus in Lake Michigan water comes from the internal recycling of nutrients from the lake bottom during spring and fall circulation, or turnover. While recent studies demonstrated that nearshore phosphorus concentrations are generally slightly greater than offshore concentrations and not as high as concentrations within tributary streams[103], phosphorus concentrations in the offshore waters of Lake Michigan have remained stable. It has been suggested that dreissenid mussels effectively capture and retain nearshore phosphorus inputs. This redirects nutrients away from offshore waters and retains them within the nearshore benthic community where *Cladophora* grows.

Limited evidence suggests that phosphorus inputs from some streams that flow into Lake Michigan may have increased in recent years. Total phosphorus concentrations in several watersheds in the study area have been increasing since 1997, which may be contributing to the local *Cladophora* problem, although such a link has not been established. Consequently, it is possible that levels in the nearshore waters may be higher. It is important to note that these phosphorus concentrations are being delivered to the streams via both point and nonpoint sources from agricultural as well as urban land areas. Modeled load comparisons of phosphorus from the 1970s versus 2000, however, indicate that overall phosphorus inputs have been substantially reduced.

Declines in Lake Michigan Diporeia
Populations of shrimp-like organisms called amphipods (i.e., *Diporeia*) that are normally found in bottom mud of the Great Lakes are declining in southern Lake Michigan. The NOAA Great Lakes Environmental Research Laboratory (GLERL) in Ann Arbor, Michigan, routinely monitors the abundance of these organisms at 40 sites in the southern basin of Lake Michigan. While the exact cause of the decline in the amphipod population is unknown, it may be linked to the introduction of zebra mussels in southern Lake Michigan in 1989. The two species compete for the same food supply, and as noted above, the zebra mussels are very efficient filter feeders that may be outcompeting the amphipods.

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[102] *Harvey A. Bootsma, Erica B. Young, and John A. Berges,* Cladophora Abundance and Physical/Chemical Conditions in the Milwaukee Region of Lake Michigan*, Great Lakes WATER Institute Technical Report No. 2005-2, February 17, 2006.*

[103] *Steve Greb, Paul Garrison, and Shaili Pfeiffer, Cladophora and Water Quality of Lake Michigan: A Systematic Survey of Wisconsin Nearshore Areas, WDNR Integrated Science Services and Office of the Great Lakes, December 2004.*

Since amphipods normally make up to 70 percent of the living biomass in a given area of a healthy lake bottom, their decline in Lake Michigan may impact a variety of fish species that depend heavily on them for food. It is hypothesized that the energy used to support amphipod growth is now being turned into zebra mussel and/or quagga mussel biomass. Many species of fish readily eat amphipods, but few species can use zebra mussels for food.

Amphipods have a much higher food value than zebra mussels. There is concern that the loss of amphipods in the food chain could lead to declines in several types of fish, including perch, alewives, sculpin, bloater, and smelt, with possible secondary effects on trout and salmon which use these forage fish species as food. Slimy sculpin and deepwater sculpin, for example, have shifted their diets from mostly *Diporeia* toward more fish eggs, insects and *Mysis* (the opossum shrimp). Commercially important lake whitefish in southern Lake Michigan are also consuming alternate food sources, primarily *Mysis*, chironomids (larval insects), and shelled prey including zebra mussels and quagga mussels. It is estimated that 40 percent of the diet of lake whitefish in southern Lake Michigan is now composed of quagga mussels, which may be a significant factor in the decline of the body size of whitefish as summarized above.

During the 1980s GLERL researchers were able to collect up to 20,000 amphipods per square meter of Lake Michigan bottom. Data collected in the early 1990s indicated that, in the far southern end of the lake, amphipod populations had declined by 60 to 90 percent. Since then, the average abundance of *Diporeia* dropped from about 5,200 per square meter in 1994 and 1995 to about 1,800 per square meter by 2000. The average abundance in 2005 was only 300 per square meter. *Diporeia* has declined in deeper waters, and the areas of the Lake with no *Diporeia* have expanded greatly.

While other organisms are still present in the bottom sediments of Lake Michigan, they are not as readily fed upon by fish as the amphipods. Prior to the appearance of zebra mussels in Lake Michigan, amphipods relied on a rich crop of microscopic plants called diatoms for growth and survival. Diatoms bloom in lake water in early spring and then eventually settle to the lake bottom where amphipods would feed on them. GLERL studies have shown that when amphipods feed on this rich material, their lipid (fat) content goes up. That stored energy fuels their growth and survival through the remaining year. Large concentrations of zebra mussels residing on rocky bottom areas of southern Lake Michigan may be filtering out diatoms and thereby depriving the amphipods of food. Research is being conducted to examine other possible reasons for the decline.

Comparison of Milwaukee Harbor Fishery to Other Southeastern Wisconsin Lake Michigan Harbor Fisheries

WDNR staff recorded 46 total fish species from five harbors in Southeastern Wisconsin, 10 of which were common to all harbors (see Table 199).[104] Alewife was the most abundant species among the harbor locations, which were probably moving in schools into the harbor areas. Four species of migratory stocked salmonid species were captured in the harbors. Most of them might have entered the harbor as they were staging for spawning migration. No pattern was seen in the distribution of species between the harbors north of Milwaukee and harbors south of Milwaukee, except that smallmouth bass were more abundant in the Sheboygan and Milwaukee Harbors, while largemouth bass were more abundant in the Kenosha Harbor. The greater abundance of fish in the Milwaukee, Sheboygan, and Racine harbors was likely due to including sampling upstream of the harbor on the Milwaukee, Sheboygan, and Root Rivers, respectively, which support a more abundant and diverse population of fishes. For example, Table 200 shows that the lower reaches of the Milwaukee River contain the highest abundance and diversity of fishes compared to other areas of the Milwaukee Harbor estuary. The Kenosha and Port Washington harbors contained the lowest abundance of fishes.

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[104] *Pradeep S. Hirethota and Thomas E. Burzynski,* Smallmouth bass distribution and abundance in selected harbors of Southeastern Wisconsin Lake Michigan, 2003-2005*, PUB-FH-512-2006, February 2006; and Pradeep S. Hirethota, Thomas E. Burzynski, and Bradley T. Eggold,* Changing Habitat and Biodiversity of the Lower Milwaukee River and Estuary*, PUB-FH-511-2005, August 2005.*

Table 199

FISH SPECIES OCCURRENCE AND RELATIVE ABUNDANCE AMONG FIVE LAKE MICHIGAN HARBORS IN SOUTHEASTERN WISCONSIN: 1997-2005

Species According to Their Relative Tolerance to Pollution	Relative Abundance[a]				
	Kenosha Harbor	Racine Harbor	Port Washington Harbor	Sheboygan Harbor	Milwaukee Harbor
Intolerant					
Greater Redhorse[b]	- -	- -	- -	Present	Common
Mottled Sculpin	- -	Present	- -	- -	Present
Rock Bass	Abundant	Common	Abundant	Present	Abundant
Smallmouth Bass[c]	Present	Common	Common	Abundant	Abundant
Spottail Shiner	Abundant	Common	Present	Common	Common
Tolerant					
Black Bullhead	Common	Abundant	Present	Common	Present
Blacknose Dace	- -	- -	- -	- -	Common
Bluntnose Minnow	Present	Present	- -	Present	Present
Brown Bullhead	- -	- -	- -	Present	- -
Common Carp	- -	- -	Present	Present	Common
Creek Chub	- -	- -	- -	- -	Common
Fathead Minnow	- -	- -	- -	- -	Common
Goldfish	Present	Present	- -	- -	Present
Golden Shiner	Present	Present	- -	- -	Present
Green Sunfish	Present	- -	- -	- -	Common
White Sucker	Common	Abundant	Common	Common	Abundant
Yellow Bullhead	- -	Present	- -	Present	Present
Intermediate					
Alewife	Abundant	Abundant	Abundant	Abundant	Abundant
Black Crappie	- -	Common	Present	Common	Common
Blackside Darter	- -	- -	- -	- -	Present
Bluegill	Abundant	Common	Present	Present	Present
Brook Trout[c]	- -	- -	- -	- -	Present
Brown Trout[c]	- -	Present	Present	Present	Present
Burbot	- -	- -	- -	Present	- -
Central Stoneroller	- -	- -	- -	- -	Present
Channel Catfish	- -	Present	- -	Present	Present
Chinook Salmon[c]	- -	- -	- -	- -	Present
Coho Salmon[c]	- -	Present	- -	Present	- -
Common Shiner	- -	- -	- -	- -	Common
Emerald Shiner	- -	- -	- -	- -	Common
Gizzard Shad	- -	Present	- -	- -	Abundant
Golden Redhorse	- -	- -	- -	- -	Common
Horneyhead Chub	- -	- -	- -	- -	Abundant
Johnny Darter	- -	- -	- -	- -	Common
Lake Trout	- -	- -	- -	- -	Present
Largemouth Bass	Common	Present	Present	Present	Common
Largescale Stoneroller	- -	- -	- -	- -	Common
Logperch	- -	- -	- -	- -	Present
Ninespine Stickleback	- -	Present	Present	Common	- -
Northern Pike	Present	Present	Present	Common	Common
Pumpkinseed	Common	Present	Common	- -	Present
Rainbow Smelt	- -	- -	- -	Present	- -
Rainbow Trout[c]	Present	Present	Present	Present	Present
Round Goby	- -	- -	Abundant	Common	Present
Shorthead Redhorse	- -	- -	- -	- -	Present
Silver Redhorse	- -	- -	- -	- -	Present
Spotfin Shiner	- -	- -	- -	- -	Common

Table 199 (continued)

Species According to Their Relative Tolerance to Pollution	Relative Abundance[a]				
	Kenosha Harbor	Racine Harbor	Port Washington Harbor	Sheboygan Harbor	Milwaukee Harbor
Intermediate (continued)					
Threespine Stickleback	Present	Present	- -	- -	Present
Trout-Perch	Present	Common	- -	- -	Present
Walleye[c]	- -	- -	- -	Present	Present
White Perch	- -	Present	- -	- -	- -
Yellow Perch	Common	Present	- -	Present	Present
Total Number of Species	18	26	16	25	46

[a]*Data was collected in the Milwaukee Harbor in 1997; all other harbors were sampled from 2002-2005.*

[b]*Designated threatened species.*

[c]*These species are stocked by Wisconsin Department of Natural Resources managers.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Several exotic fish species were also recorded in these harbors. Round goby are present in the Milwaukee Harbor, but were more common northward to Sheboygan and Port Washington Harbors. Other exotic species recorded in the survey included common carp, gold fish, smelt, white perch, and three-spine stickleback.

Milwaukee Harbor Estuary and Nearshore Lake Michigan Fisheries

The Lower Milwaukee River and Milwaukee Harbor estuary habitat and water quality have been heavily altered due to damming, channelization, streambank modification by installation of riprap and sheet piling, and urban stormwater discharges. The International Joint Commission (IJC) identified the Milwaukee Harbor estuary as one of 43 Areas of Concern (AOC) requiring clean up of toxic wastes and remedial action (see the section of this chapter entitled "Toxicity Conditions of the Milwaukee Harbor Estuary, Lake Michigan Direct Tributary Drainage Area, and the Adjacent Nearshore Lake Michigan Areas: 1975-2004" for a description).[105] The beneficial use impairments identified in the Milwaukee Harbor estuary AOC are the result of many causes. However, many are related, at least in part, to the presence of toxic substances in water, sediment, and the tissue of organisms. It is also important to note that the habitat in the lower reaches of each of the watersheds draining into the Milwaukee Harbor estuary is typical of that found in a highly urbanized environment, with extensive channelization and placement of sheet piling for bank stabilization. More natural habitat can be generally found in upstream areas of each of the major rivers.

Despite extensive habitat, water quality, and toxicity impacts, the Milwaukee Harbor estuary contains a fairly high abundance and diversity of fish species (Table 200). The quality of the fishery in the Milwaukee Harbor estuary is largely dependent upon the influx of fishes from the higher quality waters in the upstream areas of the Menomonee, Kinnickinnic, and Milwaukee Rivers that have been documented to support a full range of fish and aquatic life (see Chapters V, VI, and VII of this report), influx of fishes from Lake Michigan, and continued habitat improvement and species restoration projects as summarized below.

The 150-year old North Avenue dam, built on the Milwaukee River 3.2 miles upstream from the confluence with Lake Michigan, was removed in 1997. The dam, when it existed, created an impoundment approximately 2.3 miles in length and about 13.5 acres in surface area. Following many decades of impoundment, sediment

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[105]*Wisconsin Department of Natural Resources,* Milwaukee Estuary Remedial Action Plan Progress through January 1994, *1995.*

Table 200

FISH SPECIES OCCURRENCE AND RELATIVE ABUNDANCE IN THE MILWAUKEE HARBOR ESTUARY: 1998-2001

Species According to Their Relative Tolerance to Pollution	Relative Abundance[a]			
	Lower Milwaukee River	Menomonee River and South Menomonee and Burnham Canals	Kinnickinnic River	Milwaukee Harbor[b]
Intolerant				
Greater Redhorse[c]	Common	- -	Present	Common
Mottled Sculpin	- -	- -	- -	Present
Rock Bass	Abundant	- -	- -	- -
Smallmouth Bass[d]	Abundant	Present	- -	Common
Spottail Shiner	Common	- -	- -	- -
Stonecat	Present	- -	- -	- -
Tolerant				
Black Bullhead	Present	Present	Present	Present
Blacknose Dace	- -	Common	- -	- -
Bluntnose Minnow	- -	Present	- -	- -
Common Carp	Common	Present	Common	Present
Creek Chub	- -	Common	- -	- -
Fathead Minnow	Present	Common	Present	- -
Golden Shiner	Present	- -	Present	- -
Goldfish	- -	- -	Present	- -
Green Sunfish	Common	Common	- -	- -
White Sucker	Abundant	Abundant	Common	Abundant
Yellow Bullhead	Present	- -	- -	- -
Intermediate				
Alewife	Present	- -	Common	Abundant
Black Crappie	Present	- -	- -	Common
Blackside Darter	Present	- -	- -	- -
Bluegill	Present	Present	- -	- -
Brook Trout[d]	- -	- -	- -	Present
Brown Trout[d]	Present	Present	- -	Present
Central Stoneroller	Present	- -	- -	- -
Channel Catfish	Present	- -	- -	- -
Chinook Salmon[d]	- -	- -	- -	Present
Common Shiner	Common	- -	- -	- -
Emerald Shiner	Common	- -	- -	- -
Gizzard Shad	Abundant	- -	Abundant	Common
Golden Redhorse	Common	- -	- -	- -
Hornyhead Chub	Abundant	- -	- -	- -
Johnny Darter	Common	Present	- -	- -
Lake Trout	- -	- -	- -	Present
Largemouth Bass	Present	Present	- -	Common
Largescale Stoneroller	Common	- -	- -	- -
Logperch	Present	- -	- -	- -
Northern Pike	Common	- -	- -	Present
Pumpkinseed	Present	- -	Present	Present
Rainbow Trout[d]	Present	- -	- -	Present
Round Goby[e]	- -	- -	- -	Present
Shorthead Redhorse	Present	- -	- -	Present
Silver Redhorse	Present	- -	- -	- -
Spotfin Shiner	Common	- -	- -	- -
Threespine Stickleback	- -	- -	Present	Present
Trout-Perch	Present	- -	- -	- -
Walleye[d]	Present	Present	- -	Present
Yellow Perch	Present	- -	- -	- -
Total Number of Species	37	14	11	21

[a]*Data was collected for the Milwaukee Harbor site in 1997, all other sites were sampled in 1998-2001.*

[b]*The Milwaukee Harbor site includes data from the Summerfest Lagoon.*

[c]*Designated threatened species.*

[d]*These species are stocked by Wisconsin Department of Natural Resources managers.*

[e]*Presence of the round goby in the Milwaukee Harbor is based on gut content analysis study of large predator fishes by WDNR in 2005.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

deposition, and the consequences of historic discharges of rural and urban stormwater and poorly treated wastewater discharges from throughout the watershed, as well as sewer overflows into the River, the water quality and habitat within the impoundment were severely degraded. Low dissolved oxygen levels resulting from sediment oxygen demand and respiration by aquatic plants, and the deposition by about 18 acre-feet of fine-textured and contaminated sediment, contributed to reducing the fish community to only a few pollution tolerant species.

With the removal of the dam, improvements in sewage treatment and abatement of combined sewer overflow, riverine conditions quickly began to reestablish in the formerly impounded area. The removal of the dam not only provided an opportunity for migratory fish species to move further upstream, but also opened up opportunities for the rehabilitation of some of the native species that were extirpated or reduced to remnant populations. Details of the changes in the fishery community following the removal of the North Avenue dam are set forth in the section entitled “Influence of Dams/Dam Removal” in Chapter VII of this report.

In addition to the increased range available to Lake Michigan fishes, many habitat improvement measures have been implemented since the dam was removed. Streambanks were stabilized through the natural establishment of vegetation and placement of engineered materials, including riprap, geotextiles, and open-cell articulated concrete matting (ACM), utilized in conjunction with bioengineering techniques. Bioengineering techniques consisted mainly of the placement of live cuttings of willow within the open cells of the ACM and along the unarmored banks for stabilization. Exposed mud flats were revegetated using a combination of native grasses and forbs. Instream habitat improvements consisted of the placement of boulders and the construction of a series of bendway weirs to direct current flow away from those streambanks most susceptible to erosion. Natural meanders have also been reestablished within the former impoundment area, and scour has exposed much of the original substrate consisting of sand, gravel, cobble, and rubble. Riffles and shallow runs are the dominant stream features, although deeper runs and pools are more prominent in the downstream-most reach.

One of the most significant habitat improvements related to the removal of the North Avenue dam was that several miles of stream channel were made available to migratory as well as resident species whose movements were restricted prior to dam removal. This increase in migration along with the improvements in water quality and habitat allowed WDNR staff to initiate native walleye and lake sturgeon restoration projects in the Lower Milwaukee River and the Milwaukee Harbor estuary.

Since 1995, approximately 10,000 extended growth walleye fingerlings have been stocked annually into the Lower Milwaukee River downstream of the former North Avenue dam. These fishes are reported to be surviving and growing well, supporting a limited nearshore fishery. Mature and spent walleye were recorded during spring spawning assessments beginning in 1998. However, as yet, no successful natural reproduction of walleye has been documented in the system.

Radiotelemetry technology has been used by the WDNR to track the movement patterns of the stocked walleye. These studies indicated that walleye utilize areas as far upstream as the Estabrook dam as shown on Map 127 (which was not possible prior to removal of the North Avenue dam) as well as the Menomonee River canals, Milwaukee Harbor, and the Summerfest Lagoon. This pattern of habitat use by the walleye was tracked over multiple years and indicates a distinct and direct linkage between the nearshore Lake Michigan, Milwaukee Harbor, and lower reaches of the Milwaukee, Menomonee, and Kinnickinnic Rivers.

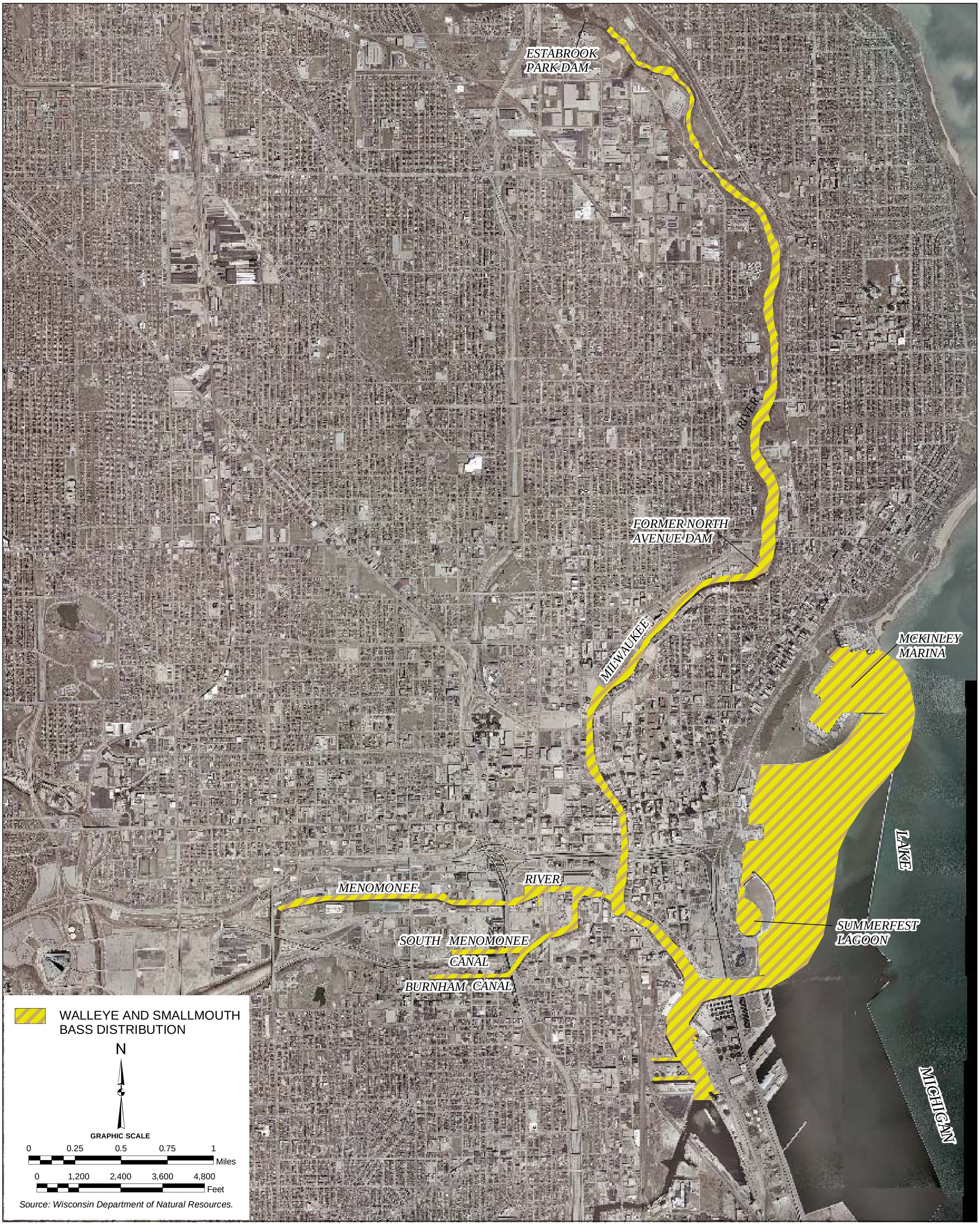
Stocking of lake sturgeon has also begun in the lower section of the Milwaukee River as part of the ongoing WDNR efforts to enhance this fishery community.

Lower Milwaukee River

The WDNR recorded nearly 30 resident native fish species, three trout species, migratory gizzard shad and alewife, and exotic carp species—including common carp, grass carp, and goldfish—within the lower portion of the Milwaukee River (see Table 200). There were also a few unidentified minnow and redhorse species. The greater

Map 127

MOVEMENT PATTERN OF WALLEYE AND SMALLMOUTH BASS IN THE MILWAUKEE RIVER AND THE INNER AND OUTER HARBORS AFTER INITIAL RELEASE BELOW THE FORMER NORTH AVENUE DAM: 2001



redhorse, which is a threatened species in the State of Wisconsin, has also been observed in this section of the River. White sucker was the most abundant species followed by golden redhorse, common carp, and smallmouth bass. Recently stocked walleye appeared in the catches, beginning in 1999.

Menomonee River and South Menomonee and Burnham Canals

The Menomonee River and South Menomonee and Burnham Canals were sampled infrequently between 1997 and 2000 by WDNR staff. Consequently, fewer records of fish have been obtained from this area than from other sampling sites within the Milwaukee Harbor estuary (see Table 200). There were more minnow and sunfish species in this reach, compared to downstream sites. The Canals and Lower Menomonee River also contained a high abundance and variety of panfish and suckers. Walleye captured by the WDNR were determined to be from the ongoing restoration effort. Because much of this area is channelized for shipping, and the canals have poor water circulation, the habitat and water quality is considered to be degraded from a fisheries point of view. In addition, the discharge of warm water into the River from an electric power company generating plant, and debris from storms entering from urban stormwater discharges, further degrade water quality. Despite the poor water quality and the degraded habitat, 14 native fish species were recorded from this area by the WDNR.

Milwaukee Harbor and Summerfest Lagoon

The Summerfest Lagoon is bordered by the Henry Maier Festival Park grounds to the west and was formed by the creation of Harbor Island in 1991. The flow of water from the outer harbor into and out of the lagoon occurs through a channel along the shoreline at the northern end of the lagoon and through culverts at the southern end of Harbor Island. The maximum depth of the Lagoon is approximately 20 feet. The riprap along the shoreline and thick submerged vegetation provides habitat for many species including smallmouth bass, largemouth bass, northern pike, and panfish. The Lagoon provides a unique year-round fishery, including winter ice fishing opportunities. The number of fish species captured in this area has ranged from six to almost 20 species, based upon annual surveys conducted between 1997 and 2000. Smallmouth bass dominated the catch followed by white sucker, and greater redhorse (see Table 200). The rocky habitat around the island provides suitable habitat for smallmouth bass to flourish. An underwater survey conducted by WDNR divers established that smallmouth bass spawning activity occurs in the Lagoon. Radiotelemetry studies also indicated that both walleye and smallmouth bass use this area extensively throughout the year. The results of the tracking studies are shown on Map 127.

Over 20 species of fish were recorded by the WDNR in the inner and outer harbor areas and at the upstream Menomonee and Milwaukee River stations, combined. Nevertheless, the fish diversity was lower than in the riverine sections of the Milwaukee River. Although the harbor is dredged periodically, and does not provide much habitat diversity, the fish community has not changed much since 1984, when 35 species of fish—including stocked salmonids—were reported. The harbor is reported to be dominated by carp, white suckers, greater redhorse, and alewife.

Exotic Invasive Species

The food web of Lake Michigan, and of the Great Lakes in general, is defined by, and complicated by, historic and continued additions of exotic invasive species. The entry and dispersal mechanisms which have acted singly or jointly in the movement of organisms into the Great Lakes basin include unintentional release (shipping traffic via discharge of ballast water; escape from cultivation, aquaculture and aquaria, and accidental releases due to fish stocking and from unused bait), deliberate releases (for example, the deliberate introduction of salmon species to enhance fisheries), canals, and disturbance linked to the construction of railroads and highways.[106] As shown in Table 201, scientists have identified 145 nonindigenous fishes, invertebrates, fish disease pathogens, plants, and

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[106]*Edward L. Mills and Kristen T. Holeck, Biological pollutants in the Great Lakes, Clearwaters, Vol. 31, No. 1, Spring 2001.*

Table 201

NUMBER OF INVASIVE AND INTRODUCED SPECIES ESTABLISHED IN THE GREAT LAKES BY TAXONOMIC GROUP AND TIME PERIOD: 1810-2000

Time	Fish	Invertebrates	Disease, Pathogens, and Parasites	Algae	Plants	Total
1810-1849	1	- -	- -	- -	9	10
1850-1899	6	4	- -	- -	23	33
1900-1949	7	8	1	6	18	40
1950-2000	12	20	2	19	9	62
Total	26	32	3	25	59	145
Percent	18	22	2	17	41	100

Source: E.L. Mills and K.T. Holeck, "Biological Pollutants in the Great Lakes," Clearwaters *Vol. 31 No. 1, 2001.*

algae established in the Great Lakes basin since the early 1800s.[107] Some taxonomic groups have not been studied as well as others, however, plants, algae, disease pathogens and parasites account for about 60 percent of new species established in the Great Lakes basin since 1810, followed by invertebrates that accounted for 22 percent, and fish that made up about 18 percent.

In cases where their introduction has caused or is likely to cause economic or environmental harm or harm to human health, exotic species may be considered invasive. Typically, populations of exotic invasive species can grow rapidly, due to both the high reproductive capacities of these organisms and the absence of predators, parasites, pathogens, and competitors from their new habitat. Once established in a waterbody, these species can rarely be eliminated. In addition, many of these species are capable of readily dispersing to other waterbodies, and as mentioned above their dispersal may be aided by direct or indirect human intervention. A complete list and description of relevant exotic invasive species and their current and potential impacts is provided in Chapter II of this report.

It is difficult if not impossible to predict how these species introductions will affect the existing or future foodweb dynamics in Lake Michigan. However, similar patterns of invasion and system responses have occurred among several of the Great Lakes. Sea lampreys, for example, have caused great damage to the lake trout, whitefish, and burbot populations in all the Great Lakes and similar impacts of zebra mussels have also been documented.

Lake Erie, like all of the Great Lakes, has had similar changes in food web dynamics, but because it is the shallowest and warmest of the Great Lakes, Erie is usually the first to show signs of stress. In other words, recent food web changes in Lake Erie may provide insight into trends that may also occur in Lake Michigan. In Lake Erie, zebra mussels have directly led to increased water clarity, clogging of municipal intakes, reduced recreation on beaches, and disappearance of many native mussel species.

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[107]*E.L. Mills, J.H. Leach, J.T. Carlton, and C.L. Secor, Exotic species in the Great Lakes: A history of biotic crises and anthropogenic introductions. Journal of Great Lakes Research 19(1): 1-54, 1993; and J.H. Leach, E.L. Mills, and M.A. Dochoda, Non-indigenous species in the Great Lakes: Ecosystem impacts, binational policies, and management, In Great Lakes Fishery Policy and Management: A Binational Perspective, Edited by W.W. Taylor, Michigan State University Press, 1998.*

Zebra mussels have indirectly led to:

- Creation of Algal Blooms and Dead Zones—Algal blooms have resulted from the enormous volumes of waste the mussels release as part of their feeding, which is high in algae-promoting phosphorus. The algal blooms have caused taste and odor problems for municipal water supplies. The combination of zebra mussel waste and clearer water allows algae to grow at greater depths, where there is less oxygen. When the mussels decay, oxygen is depleted, which creates a dead zone.

- Disappearance of Diporeia—Disappearance of Diporeia as summarized above through competition for phytoplankton. Diporeia are a vital food source for smaller fish like alewife, bloater, smelt, and sculpin, and reductions in the numbers of those fish results in less food for the bigger and commercially important fish such as trout, perch, whitefish, walleye, and salmon.

- Death of Thousands of Loons, Mergansers, Gulls, and Other Fish-Eating Birds—As the zebra mussels filter massive amounts of water, they also ingest and absorb toxins and contaminants. Diving ducks, such as the greater and lesser scaup, thrive on zebra mussels, and their population increased temporarily. For the past few years, scaup have been dying in large numbers as a result of type-E botulism, a toxin produced by a bacterium that concentrates inside the zebra mussels.

- Accelerated Bioaccumulation of Toxicants to Predatory Fishes and Birds—As gobies consume zebra mussels, they further concentrate the contaminants and bacteria that the mussels have filtered from the water. Fishes and birds that feed extensively on the gobies can become poisoned and die.

Except for indirect bird or fish deaths, the above consequences associated with the invasion of zebra mussels in Lake Erie have also occurred in Lake Michigan. However, it has been documented that round goby are increasing in abundance and that multiple predatory fishes are utilizing them as a major component of their diet, including brook trout, brown trout, northern pike, walleye, rainbow trout, smallmouth bass, and largemouth bass.

Synthesis
The Milwaukee Harbor estuary and nearshore areas of the Lake Michigan fishery are inextricably linked to the quality, diversity, and abundance of the fishery as well as the entire food web of Lake Michigan. In general, the removal of the North Avenue dam along with point source and combined sewer overflow pollution abatement has opened up many opportunities to enhance fishing in the area through improved water quality and increased river access for both resident and migratory fish.

Addition of instream structure and bank stabilization measures added to the complexity of structure and fish cover for both resident as well as migratory species. Dam removal and habitat improvements are key fisheries management tools that are pivotal if native species are to be restored in these once degraded areas. Because of the dam removal, WDNR initiated two native species restoration plans, walleye and lake sturgeon, in the Milwaukee Harbor estuary. These restoration efforts help to develop a more vital and diverse fish community. In addition, the removal of the North Avenue dam significantly enhanced fishing opportunities by opening up several river miles for migratory salmonids and resident native species.

CHANNEL CONDITIONS AND STRUCTURES

The conditions of the bed and bank of a stream are greatly affected by the flow of water through the channel. The great amount of energy possessed by flowing water in a stream channel is dissipated along the stream length by turbulence, streambank and streambed erosion, and sediment resuspension. Sediments and associated substances delivered to a stream may be stored, at least temporarily, on the streambed, particularly where obstructions or irregularities in the channel decrease the flow velocity or act as particle traps or filters. On an annual basis or a long-term basis, streams may exhibit net deposition, net erosion, or no net change in internal sediment transport, depending on tributary land uses, watershed hydrology, precipitation, and geology. From 3 to 11 percent of the annual sediment yield in a watershed in southeastern Wisconsin may by contributed by streambank erosion.[108] In the absence of mitigative measures, increased urbanization in a watershed may be expected to result in increased streamflow rates and volumes, with potential increases in streambank erosion and bottom scour, and flooding problems. In many of the communities in the Lake Michigan direct drainage area, the requirements of MMSD Chapter 13, "Surface Water and Storm Water," are applied to mitigate instream increases in peak rates of flow that could occur due to new urban development without runoff controls. In communities outside of the MMSD service area, local ordinances provide for varying degrees of control of runoff from new development. Also, where soil conditions allow, the infiltration standards of Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* are applied to limit increases in runoff volume from new development.

Data exist on channel conditions for only one stream in the Lake Michigan direct drainage area. The MMSD commissioned an assessment of geomorphic, hydrologic, and hydraulic conditions for Fish Creek and its watershed.[109] This study, conducted in 2000 to 2001, examined geomorphic and sediment characteristics and hydrologic and hydraulic conditions for about 3.5 miles of stream channel along Fish Creek. Major goals of this study were to evaluate the mechanisms driving flood control, erosion, valley stability, and environmental management for the Creek and to identify engineering and management options to be considered in future studies.

Map 128 shows the types of channel bed lining in streams within the Lake Michigan direct drainage area. Fish Creek is the only stream for which data were available. Fish Creek emerges from a storm sewer outfall at the south side of Donges Bay Road in the City of Mequon. Approximately 0.21 mile of the Creek are enclosed in conduit. Approximately 0.23 mile of Fish Creek is lined with concrete. The stream network has been substantially modified over much of the watershed, with many stretches having been straightened and channelized.

Bed and Bank Stability

Alluvial streams within urbanizing watersheds often experience rapid channel enlargement. As urbanization occurs, the fraction of the watershed covered by impervious surfaces increases. This can result in profound changes in the hydrology in the watershed. As a result of runoff being conveyed over impervious surfaces to storm sewers which discharge directly to streams, peak flows become higher and more frequent and streams become "flashier," with flows increasing rapidly in response to rainfall events. The amount of sediment reaching the channel often declines. Under these circumstances and in the absence of armoring, the channel may respond by incising. This leads to an increase in the height of the streambank, which continues until a critical threshold for stability is exceeded. When that condition is reached, mass failure of the bank occurs, leading to channel widening. Typically, incision in an urbanizing watershed proceeds from the mouth to the headwaters.[110] Lowering of the downstream channel bed increases the energy gradient upstream and in the tributaries. This contributes to further destabilization. Once it begins, incision typically follows a sequence of channel bed lowering, channel widening, and deposition of sediment within the widened channel. Eventually, the channel returns to a stable condition characteristic of the altered channel geometry.

Map 128 summarizes bank and bed stability for Fish Creek, which is the only stream in the Lake Michigan direct drainage area for which data are available.[111] About 3.6 miles of channel were inventoried for stability as shown on Map 128. Beds along approximately 2.2 miles of stream appeared to be degrading and actively eroding. About

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[108]*SEWRPC Technical Report No. 21, Sources of Water Pollution in Southeastern Wisconsin: 1975, September 1978.*

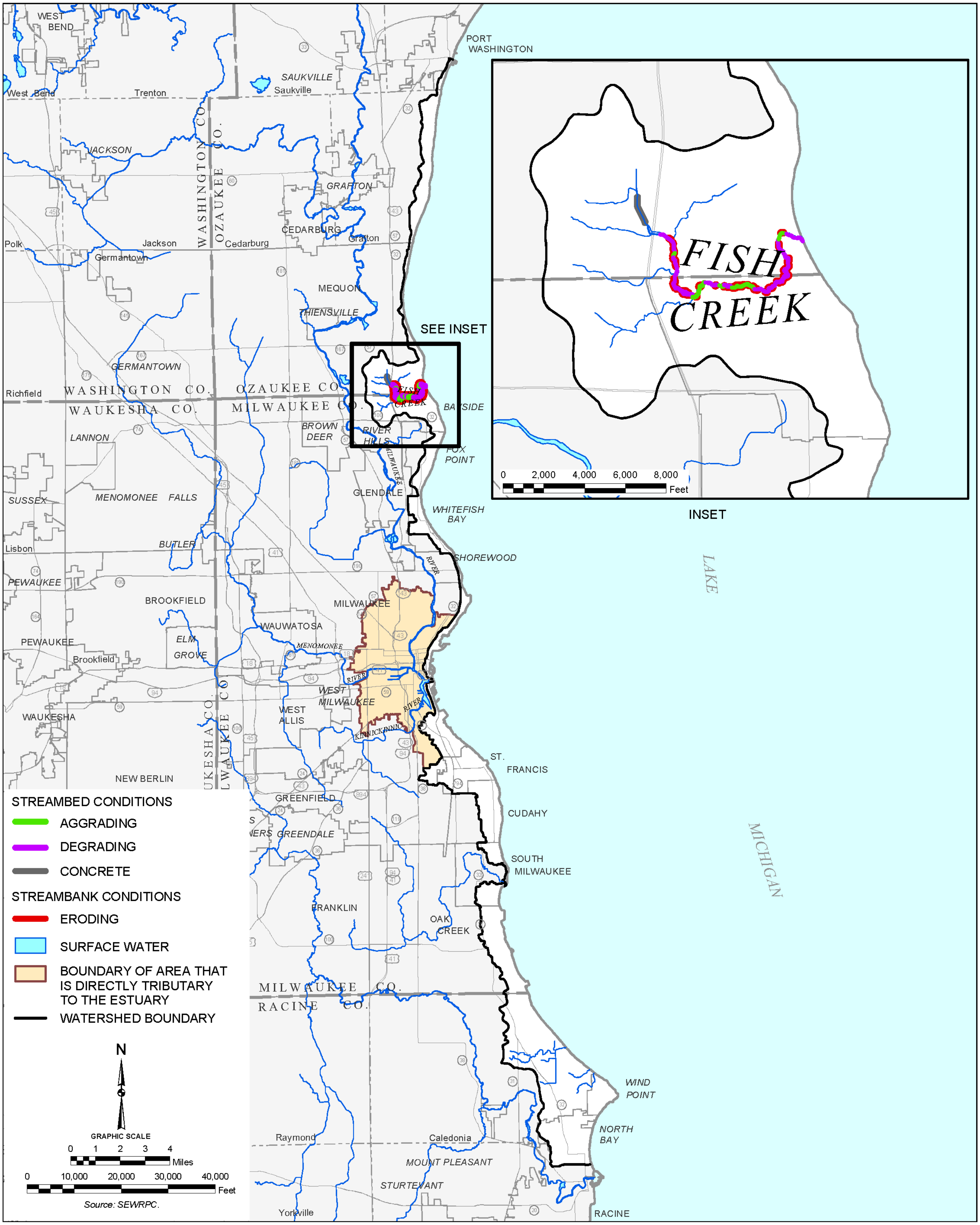
[109]*W.F. Baird & Associates,* Fish Creek Geomorphic Study: Final Study Report*, January 2002.*

[110]*S.A. Schumm, "Causes and Controls of Channel Incision," In: S. E. Darby and A. Simon (eds.),* Incised River Channels: Processes, Forms, Engineering and Management, *John Wiley & Sons, New York, 1999.*

[111]*W.F. Baird & Associates, 2002,* op. cit*.*

Map 128

STREAMBANK AND STREAMBED CHARACTERISTICS WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 2005



0.7 mile of stream was aggrading. Degradation was also observed along streambanks, with approximately 1.4 miles of bank that appeared to be actively eroding. Banks along about 0.8 mile of stream length were protected by cobble protection, retaining walls, riprap, or concrete.

Dams

There are currently two drop structures and one dam within the Lake Michigan direct drainage area. As shown on Map 129, the dam and drop structures are located on Fish Creek. A recent assessment reported that the low-head dam is failing.[112] Dams and drop structures can disrupt sediment transport and limit aquatic organism passage, fragmenting populations. Those factors can lead to a reduction in overall abundance and diversity of aquatic organisms.

Milwaukee Estuary Remedial Action Plan

The process of developing the Remedial Action Plan (RAP) for the Milwaukee Estuary Area of Concern (AOC) has been ongoing since 1988. The WDNR is the lead agency for development of the plan, and they have been advised by a Technical Advisory Committee, a Citizen's Advisory Committee, and a Citizen's Education and Participation Subcommittee. The RAP process has focused on issues related to remediation of contaminated sediments, eutrophication, nonpoint source pollution, beach water quality, fish and wildlife populations, and habitat.

The Milwaukee Estuary AOC includes the Milwaukee River downstream from the site of the former North Avenue dam, the Menomonee River downstream from S. 35th Street, the Kinnickinnic River downstream from S. Chase Avenue, the inner and outer harbors, and the nearshore waters of Lake Michigan bounded by a line extending north from Sheridan Park to the intake from the City of Milwaukee's Linnwood water treatment plant. Eleven beneficial use impairments have been identified in the Milwaukee Estuary AOC including restrictions on fish and wildlife consumption, degradation of fish and wildlife populations, fish tumors or other deformities, bird or animal deformities or reproductive problems, degradation of benthos, restrictions on dredging activities, eutrophication or undesirable algae, beach closings, degradation of aesthetics, degradation of phytoplankton and zooplankton populations, and loss of fish and wildlife habitat.[113] While these impairments are the result of many causes, many are related, at least in part, to the presence of toxic substances in water, sediment, and the tissue of organisms.

A joint WDNR/USEPA effort is currently underway to examine and assess the identified beneficial use impairments for the Milwaukee Estuary AOC, to eliminate those that no longer apply, and to develop restoration criteria to address the remaining beneficial use impairments, with the ultimate goal of delisting the AOC.[114]

Current Navigational Dredging Activities in the Lake Michigan Inner and Outer Harbor Areas

Dredging and the disposal of the dredged materials is presently carried out within the Milwaukee Harbor estuary for maintenance of adequate water depths for commercial navigation. Dredged materials are disposed of at the Jones Island Confined Disposal Facility (CDF) constructed by the U.S. Army Corps of Engineers (USCOE) in 1975 along the shoreline of the southern portion of the outer harbor. The current USCOE dredging program is focused on the outer harbor where a 28-foot depth below the established low water datum is authorized and maintained; the main gap from the outer harbor into Lake Michigan where a 30-foot depth is authorized and

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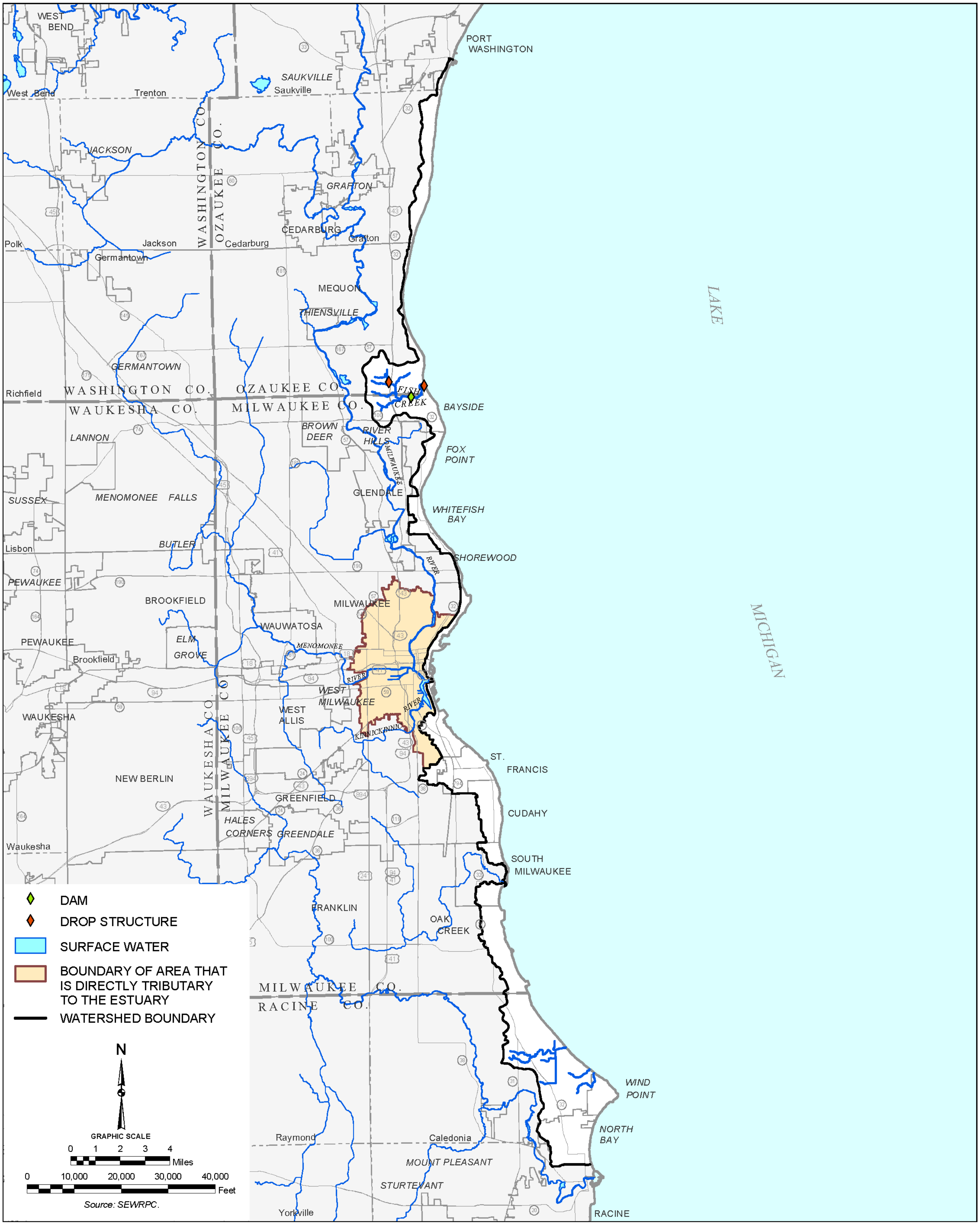
[112]Ibid.

[113]*Wisconsin Department of Natural Resources,* Milwaukee Estuary Remedial Action Plan Progress through January 1994, *1995.*

[114]*Short, Elliot and Hendrickson and Environmental Consulting & Technology, Inc.,* Restoration Criteria for the Milwaukee Harbor Estuary Area of Concern*, submitted to the Wisconsin Department of Natural Resources, in progress.*

Map 129

DAM AND DROP STRUCTURES WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 2005



maintained; a short reach of the Milwaukee River downstream of E. Buffalo Street where a 21-foot depth is authorized and maintained; the Menomonee River from N. 20th Street extended to its confluence with the Milwaukee River where an 18-foot depth is currently maintained, although a 21-foot depth is authorized; the South Menomonee Canal where an approximately 16-foot depth is maintained, although a 21-foot depth is authorized; and the Kinnickinnic River from S. Kinnickinnic Avenue to the Union Pacific Railroad swing bridge, where a 21-foot depth is authorized and maintained and from the swing bridge to the confluence with the Milwaukee River where a 27-foot depth is authorized and maintained. The reach of the Milwaukee River estuary upstream of E. Buffalo St. that was historically dredged has now been Federally deauthorized and is no longer dredged. The reach of the Menomonee River from N. 25th Street downstream to N. 20th Street extended and the Burnham Canal, where 21-foot dredging depths are authorized, are part of the USCOE "backlog" and they have not been regularly maintained in recent years.

Additional information related to dredging issues in the inner and outer harbors is provided in Chapter X of the 2007 regional water quality management plan update.[115]

HABITAT AND RIPARIAN CORRIDOR CONDITIONS

One of the most important tasks undertaken by the Commission as part of its regional planning effort was the identification and delineation of those areas of the Region having high concentrations of natural, recreational, historic, aesthetic, and scenic resources and which, therefore, should be preserved and protected in order to maintain the overall quality of the environment. Such areas normally include one or more of the following seven elements of the natural resource base which are essential to the maintenance of both the ecological balance and the natural beauty of the Region: 1) lakes, rivers, and streams and the associated undeveloped shorelands and floodlands; 2) wetlands; 3) woodlands; 4) prairies; 5) wildlife habitat areas; 6) wet, poorly drained, and organic soils; and 7) rugged terrain and high-relief topography. While the foregoing seven elements constitute integral parts of the natural resource base, there are five additional elements which, although not a part of the natural resource base per se, are closely related to or centered on that base and therefore are important considerations in identifying and delineating areas with scenic, recreational, and educational value. These additional elements are: 1) existing outdoor recreation sites; 2) potential outdoor recreation and related open space sites; 3) historic, archaeological, and other cultural sites; 4) significant scenic areas and vistas; and 5) natural and scientific areas.

The delineation of these 12 natural resource and natural resource-related elements on a map results in an essentially linear pattern of relatively narrow, elongated areas which have been termed "environmental corridors" by the Commission. Primary environmental corridors include a wide variety of the abovementioned important resource and resource-related elements and are at least 400 acres in size, two miles in length, and 200 feet in width. Secondary environmental corridors generally connect with the primary environmental corridors and are at the least 100 acres in size and one mile long. In addition, smaller concentrations of natural resource features that have been separated physically from the environmental corridors by intensive urban or agricultural land uses have also been identified. These areas, which are at least five acres in size, are referred to as isolated natural resource areas.

It is important to point out that, because of the many interlocking and interacting relationships between living organisms and their environment, the destruction or deterioration of any one element of the total environment may lead to a chain reaction of deterioration and destruction among the others. The drainage of wetlands, for example, may have far-reaching effects, since such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas of interconnecting lake and stream systems. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater. Groundwater serves as a source of domestic, municipal, and industrial water supply and provides a basis for low flows in rivers and streams. Similarly, the destruction of woodland cover, which may

[115]*SEWRPC Planning Report No. 50,* op. cit.

have taken a century or more to develop, may result in soil erosion and stream siltation and in more rapid runoff and increased flooding, as well as destruction of wildlife habitat. Although the effects of any one of these environmental changes may not in and of itself be overwhelming, the combined effects may lead eventually to the deterioration of the underlying and supporting natural resource base, and of the overall quality of the environment for life. The need to protect and preserve the remaining environmental corridors within the Lake Michigan direct drainage area thus becomes apparent.

Primary Environmental Corridors

The primary environmental corridors in southeastern Wisconsin generally lie along major stream valleys and around major lakes, and contain almost all of the remaining high-value woodlands, wetlands, and wildlife habitat areas, and all of the major bodies of surface water and related undeveloped floodlands and shorelands. As shown on Map 130, in the year 2000 primary environmental corridors in the Lake Michigan direct drainage area encompassed about 2,782 acres, or about 11 percent of the area. These environmental corridor lands are distributed along the entire length of the shoreline as shown in Map 130. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of primary environmental corridors within the direct drainage area. Primary corridors may be subject to urban encroachment because of their desirable natural resource amenities. Unplanned or poorly planned intrusion of urban development into these corridors, however, not only tends to destroy the very resources and related amenities sought by the development, but tends to create severe environmental and development problems as well. These problems include, among others, water pollution, flooding, wet basements, failing foundations for roads and other structures, and excessive infiltration of clear water into sanitary sewerage systems.

Secondary Environmental Corridors

Secondary environmental corridors are located generally along intermittent streams or serve as links between segments of primary environmental corridors. As shown on Map 130, secondary environmental corridors in the Lake Michigan direct drainage area encompassed about 68 acres, or about 0.25 percent of the area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of secondary environmental corridors within the direct drainage area. Secondary environmental corridors contain a variety of resource elements, often remnant resources from primary environmental corridors which have been developed for intensive agricultural purposes or urban land uses, and facilitate surface water drainage, maintain “pockets” of natural resource features, and provide for the movement of wildlife, as well as for the movement and dispersal of seeds for a variety of plant species.

Isolated Natural Resource Areas

In addition to the primary environmental corridors, other small concentrations of natural resource base elements exist within the Lake Michigan direct drainage area. These concentrations are isolated from the environmental corridors by urban development or agricultural lands and, although separated from the environmental corridor network, have important natural values. These isolated natural resource areas may provide the only available wildlife habitat in a localized area, provide good locations for local parks and nature study areas, and lend a desirable aesthetic character and diversity to the area. Important isolated natural resource features include a variety of isolated wetlands, woodlands, and wildlife habitat. These isolated natural resource features should also be protected and preserved in a natural state whenever possible. Such isolated areas five or more acres in size within the Lake Michigan direct drainage area also are shown on Map 130 and total about 486 acres, or about 2 percent of the area. In the period from the initial inventory in 1985 through 2000, there was no appreciable loss in the amount of isolated natural resource areas within the direct drainage area.

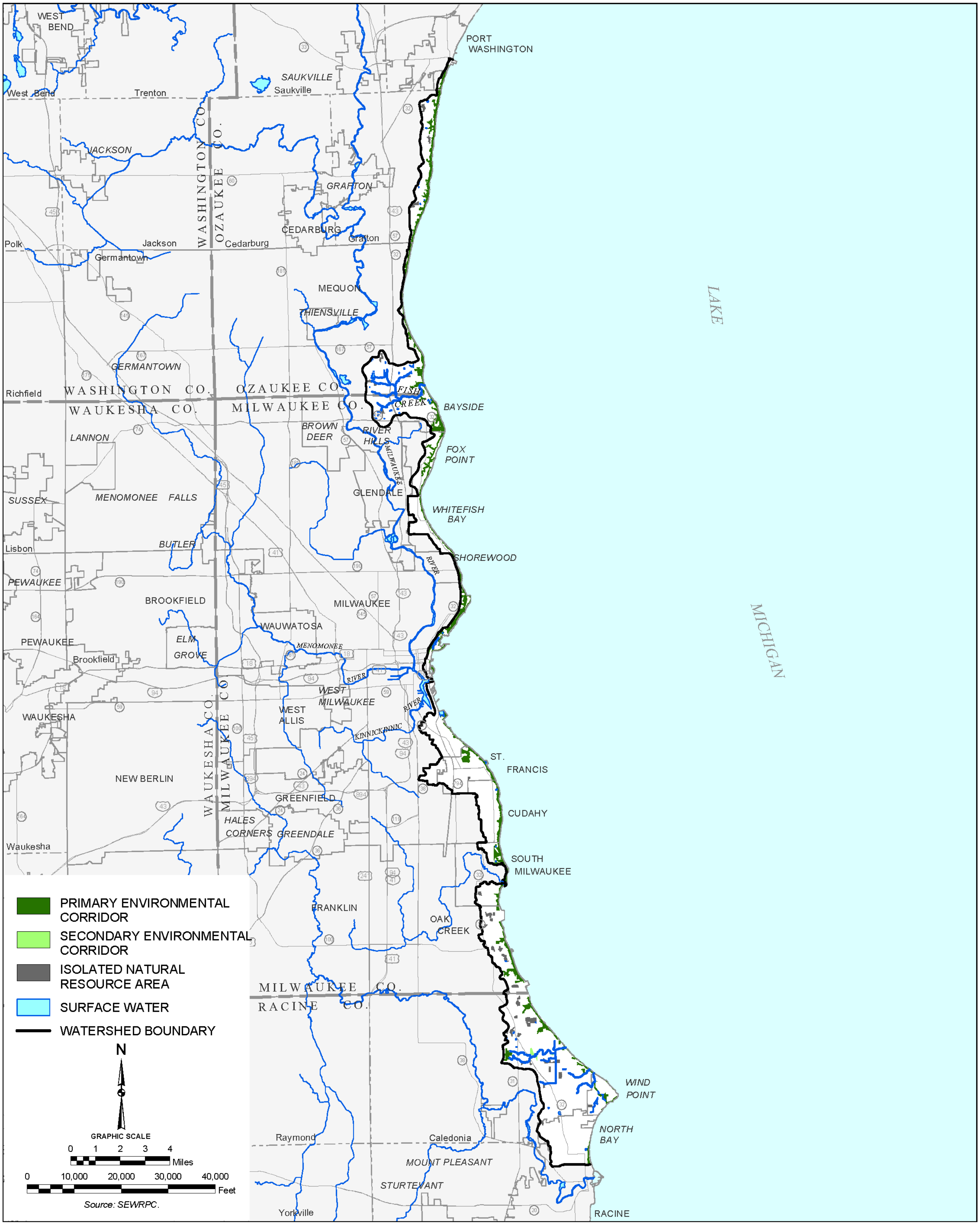
Natural Areas and Critical Species Habitat

The regional natural areas and critical species habitat protection and management plan[116] ranked natural resource features based upon a system that considered areas to be of statewide or greater significance, NA-1; countywide

[116]*SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*, September 1997.*

Map 130

ENVIRONMENTAL CORRIDORS WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 2000



or regional significance, NA-2; or local significance, NA-3. In addition, certain other areas were identified as critical species habitat sites. Within the Lake Michigan direct drainage area, as shown on Map 131 and in Table 202, 17 such sites were identified (based on the map), 10 of which were identified as critical species habitat sites. One site totaling 80 acres was identified as being of statewide or great significance (NA-1), about 25 percent of which is already in public ownership. Three sites were identified as natural areas of countywide or regional significance (NA-2) totaling about 40 acres. A further five sites, totaling about 200 acres, of natural area of local significance (NA-3) were identified. Of the approximately 425 acres of critical species habitat identified in the regional natural areas and critical species habitat protection and management plan, about 160 acres at eight sites are already in public ownership and the remaining lands are proposed to be acquired, as shown in Table 202.

There is limited information on endangered and threatened species and species of special concern within the Lake Michigan direct drainage area, however, one species of fish, the greater redhorse, which is a threatened species in the State of Wisconsin is known to inhabit this area. In 2002, it was documented that Lake Park, which is located within the central portion of the direct drainage area in the City of Milwaukee, contained more than 200 species of birds that consist of both resident breeding populations and migrant birds (Appendix E).[117] Eight of these bird species are listed as threatened or endangered Federally and in the State of Wisconsin and 28 bird species are listed as species of special concern within the State of Wisconsin (Appendix E). That park is also part of an important migration corridor for birds in the spring and fall, so it is a very popular location for bird watching. Habitat along the entire Lake Michigan shoreline is an important part of the Central Flyway.[118] For example, bird species, such as peregrine falcons which are Federally endangered, use the Park at some point as they move along the lakeshore in both resident pairs and migrants. Therefore, it is also likely that many of the corridor areas along the lakeshore also provide essential habitat and refuge for these bird species.

SUMMARY AND STATUS OF IMPLEMENTATION OF THE ELEMENTS OF THE REGIONAL WATER QUALITY MANAGEMENT PLAN IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA

The initial regional water quality management plan for the Southeastern Wisconsin Region, which was adopted in 1979, had five elements: a land use element, a point source pollution abatement element, a nonpoint source pollution abatement element, a sludge management element, and a water quality monitoring element.[119] For the purposes of documenting current conditions and trends in water quality and pollution sources, it is deemed important to redocument the point source and nonpoint source pollution abatement elements of the regional water quality management plan as amended. This section provides that redocumentation and describes the action taken to implement that plan. Those two specific elements of the plan as they relate to the Lake Michigan direct drainage area and actions taken to implement them are described below for those components of the plan elements most directly related to water quality conditions.

Point Source Pollution Abatement Plan Element

The point source pollution abatement element of the initial plan made several recommendations regarding sanitary sewerage service in the Lake Michigan direct drainage area. The plan recommended the abandonment of the public sewage treatment plant located in the North Park Sanitary District. By 1988, this plant had been abandoned. It also recommended abandonment of three privately-owned sewage treatment plants located in the

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[117]*Information provided by Brian Boldt, Tim Vargo, Paul Hunter, and others "Birds in Lake Park," http://home.wi.rr.com/phunter1/lakeparkbirds.html, August 2002.*

[118]Dr. Peter Dunn, Assistant Professor, Department of Biological Sciences, University of Wisconsin-Milwaukee.

[119]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume One,* Inventory Findings, *September 1978; Volume Two,* Alternative Plans, *February 1979; Volume Three,* Recommended Plan, *June 1979.*

Map 131

KNOWN NATURAL AREAS AND CRITICAL SPECIES HABITAT SITES WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 1994

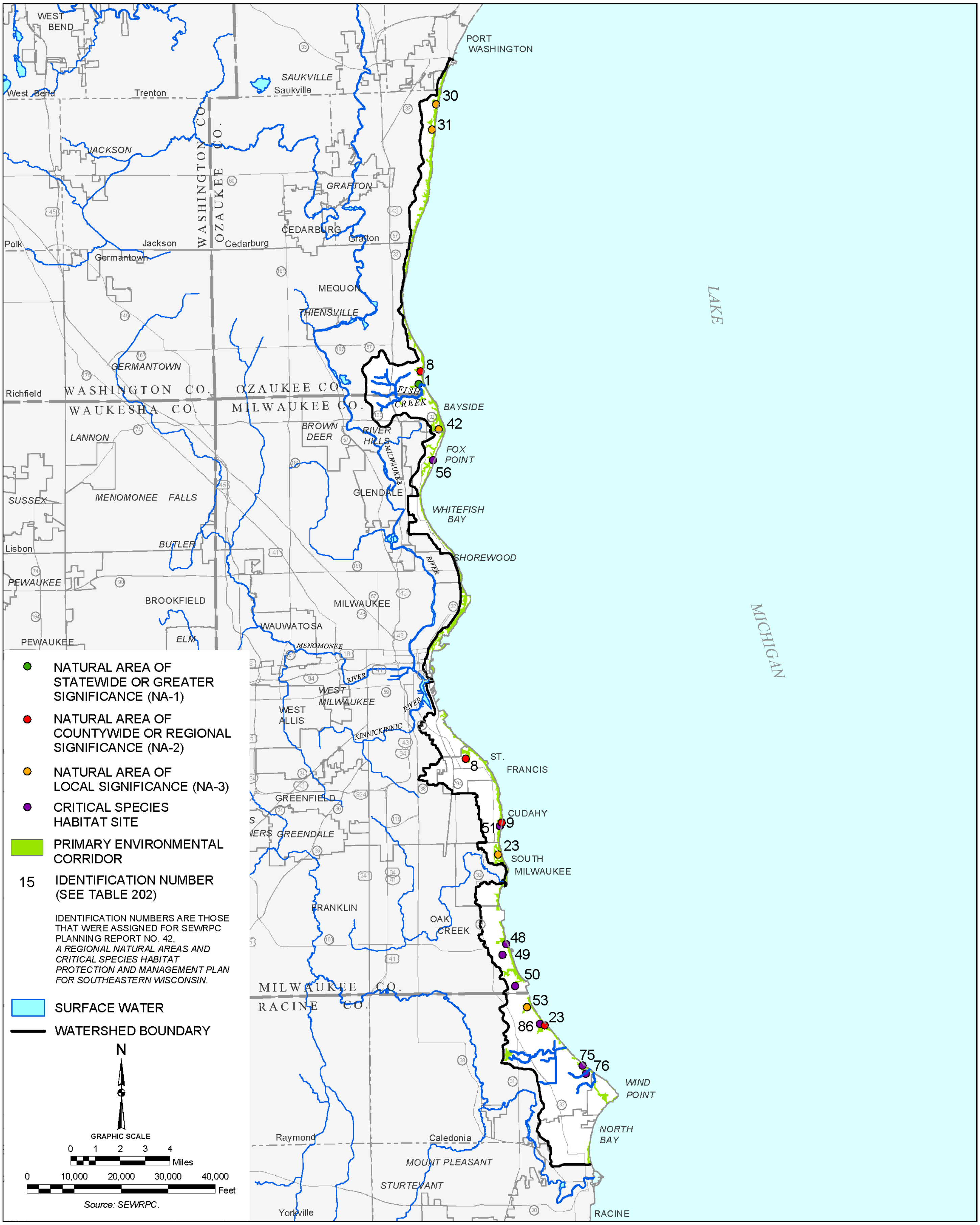

Table 202

NATURAL AREAS AND CRITICAL SPECIES HABITAT AREAS IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA

Number on Map 131	Name	Type of Area	Location	Owned	Proposed to Be Acquired[a]	Total	Proposed Acquisition Agency
	Natural Areas						
1	Fairy Chasm State Natural Area	NA-1, CSH	City of Mequon[b]	21	59	80	The Nature Conservancy
8	St. Francis Seminary Woods	NA-2	City of St. Francis	- -	37	37	Milwaukee County[c]
8	Donges Bay Gorge	NA-2, CSH	- -	- -	- -	- -	- -
9	Warnimont Park Fens	NA-2	City of Cudahy	2	- -	2	Milwaukee County
23	Grant Park Woods-Old Growth	NA-3	City of South Milwaukee	38	- -	38	Milwaukee County
30	Cedar Heights Gorge	NA-3	Town of Grafton	- -	9	9	Private conservancy organization
31	Lions Den Gorge	NA-3	Town of Grafton	- -	20	20	Private conservancy organization
42	Schlitz Audubon Center Woods and Beach	NA-3	Village of Bayside	54	- -	54	Schlitz Audubon Center
53	Power Plant Ravine Woods	NA-3	Village of Caledonia	-	32	32	Racine County
	Critical Species Habitat						
48	Bender Park Woods and Clay Banks	CSH	City of Oak Creek	13	- -	13	Milwaukee County
49	Bender Park Woods-South	CSH	City of Oak Creek	4	- -	4	Milwaukee County
50	Oak Creek Power Plant Woods	CSH					
51	Warnimont Park Woods	CSH	City of Cudahy	24	- -	24	Milwaukee County
56	Fox Point Clay Bluffs	CSH	Village of Fox Point	- -	86	86	Private conservancy organization
75	Breakers Woods	CSH	Village of Caledonia	- -	5	5	Private conservancy organization
76	Dominican Ravine	CSH	Village of Caledonia	- -	16	16	Private conservancy organization
86	Cliffside Park Old Fields	CSH	Village of Caledonia	5[d]	- -	5[d]	Racine County

[a]*Acquisition is recommended in SEWRPC Planning Report No. 42 (PR No. 42),* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, *September 1997.*

[b]*Site partly located in Milwaukee County.*

[c]*It is recommended that Milwaukee County acquire a conservation easement over this Natural Area.*

[d]*Does not include 55 acres of this Critical Species Habitat site located within the Cliffside Park Woods and Clay Banks Natural Area.*

Source: SEWRPC.

Cities of Mequon and Oak Creek. These plants were abandoned by 1998 and the attendant service areas for these plants were connected to the MMSD sewerage system for treatment purposes. Finally, the initial plan recommended the refinement of all sanitary sewer service areas in the Lake Michigan direct drainage area watershed. As of 2005, this had been done for all areas except for MMSD and the City of South Milwaukee, which, in the Lake Michigan Direct Drainage area, are entirely served by sanitary sewers.

A preliminary recommendation to abate separate sanitary sewer overflows and combined sewer overflows through the provision of large subterranean conveyance and storage facilities to contain separate and combined sewer peak flows in excess of sewage system capacity was originally made in the comprehensive plan for the Milwaukee River watershed.[120] The initial regional water quality management plan deferred recommendation on adoption of this alternative pending completion of the facility planning related to MMSD's Water Pollution

[120]*SEWRPC Planning Report No. 13,* A Comprehensive Plan for the Milwaukee River Watershed, *Volume One,* Inventory Findings and Forecasts, *December 1970; Volume Two,* Alternate Plans and Recommended Plan, *October 1971.*

Abatement Program. This planning effort, documented in a series of reports by MMSD,[121] recommended construction of a deep tunnel inline storage system in conjunction with construction of a shallow relief sewer system. These recommendations were adopted as an amendment to the regional water quality management plan as part of the water resources management plan for the Milwaukee Harbor estuary.[122] This system was subsequently constructed and began operation in 1994.

In 1975, there were three combined sewer outfalls located in the Lake Michigan direct drainage area. Overflows typically occurred over 50 times per year. Currently combined sewer bypasses have been reduced to less than three per year. Likewise, the number of sanitary sewer overflows has been markedly reduced from the 1975 conditions.

In 1975, there were 23 point sources of wastewater other than public and private sewage treatment plants. These sources discharged industrial cooling, process, rinse, and wash waters directly, or indirectly, to the surface water system. The initial regional water quality management plan included a recommendation that these industrial point sources of wastewater be monitored, and discharges limited to levels determined on a case-by-case basis under the Wisconsin Pollutant Discharge Elimination System (WPDES) permit process. Currently, this recommendation has been nearly fully implemented for the point sources that currently exist in the direct drainage area, the only exception being an unplanned discharge or spill.

Due to the dynamic nature of permitted point sources, it is recognized that the number of wastewater sources changes as industries and other facilities change locations or processes and as decisions are made with regard to the connection of such sources to public sanitary sewer systems. Many of the historic dischargers are now connected to the public sanitary sewer system.

Nonpoint Source Abatement Plan Element

The nonpoint source element of the original plan described a variety of methods and practices for abatement of nonpoint source pollution in urban and rural areas and estimated the percent reduction of released pollutants that could be achieved through implementation of these methods and practices. For urban areas, it recommended construction site erosion control and implementation of urban land practices sufficient to produce a 25 percent reduction in pollutants released to streams of the area. For rural areas, it recommended conservation practices sufficient to produce a 25 percent reduction in pollutants released to the streams of the area.

Several additional measures to abate nonpoint source pollution have been instituted since adoption of the initial plan. Facilities engaged in certain industrial activities have been required to apply for and obtain stormwater discharge permits under the WPDES program and to develop and follow stormwater pollution prevention plans. All the communities in the direct drainage area except the Village of North Bay and the Town of Port Washington have received WPDES stormwater discharge permits,[123] and all communities except the Villages of North Bay and Wind Point and the Town of Port Washington have adopted construction site erosion control ordinances and stormwater management plans or ordinances. These communities are required to develop new, or update existing,

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[121]*Milwaukee Metropolitan Sewerage District*, Combined Sewer Overflows, *June 1980*; *Milwaukee Metropolitan Sewerage District,* Inline Storage Facilities Plan, *February 1982*; *Milwaukee Metropolitan Sewerage District,* Combined Sewer Overflows Advanced Facilities Plan, *December 1983*.

[122]*SEWRPC Planning Report No. 37,* A Water Resources Management Plan for the Milwaukee Harbor Estuary, *Volume One,* Inventory Findings, *March 1987; Volume Two,* Alternative and Recommended Plans, *December*1987.

[123]*At this time, the Village of North Bay and the Town of Port Washington are not required to obtain WPDES stormwater discharge permits*

stormwater management ordinances to be consistent with the standards of Chapter NR 151 of the *Wisconsin Administrative Code*. Stormwater management measures are described more fully in the section on nonpoint source pollution in this chapter.

SOURCES OF WATER POLLUTION

An evaluation of water quality conditions in the Milwaukee Harbor Estuary, Lake Michigan direct drainage area, and adjacent Lake Michigan areas must include an identification, characterization, and where feasible, quantification of known pollution sources. This identification, characterization, and quantification are intended to aid in determining the probable causes of water pollution problems. Inventories identifying and characterizing known pollution sources and estimates of pollutant loadings for the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers comprising the estuary and inner harbor were presented in Chapters V, VI, and VII, respectively, of this report. This section identifies, characterizes, and where feasible, quantifies known pollution sources in the Lake Michigan direct drainage area.

Point Source Pollution

Point source pollution is defined as pollutants that are discharged to surface waters at discrete locations. Examples of such discrete discharge points include sanitary sewerage system flow relief devices, sewage treatment plant discharges, and industrial discharges.

Sewage Treatment Plants

The status of implementation in regard to the abandonment of public and private sewage treatment plants in the Lake Michigan direct drainage area, as recommended in the initial regional water quality management plan, is summarized in Table 203. In 1975, there were four public sewage treatment facilities located in the Lake Michigan direct drainage area and discharging to Lake Michigan. The MMSD South Shore plant and the plants for the City of South Milwaukee and the North Park Sanitary District discharged effluent to Lake Michigan. The MMSD Jones Island plant discharged effluent to Lake Michigan via the Milwaukee Outer Harbor. One of these plants, the North Park Sanitary District plant, was abandoned in 1988 and the attendant service area was connected to the City of Racine system for treatment purposes, as recommended in the initial regional water quality management plan. The initial plan recommended upgrading or upgrading and expanding each of the remaining plants. Dates of implementation of these recommendations are given in Table 203.

In 1975, there were three private sewage treatment facilities located in the Lake Michigan direct drainage area and discharging to Lake Michigan—the Chalet-on-the Lake Restaurant and Concordia University plants in the City of Mequon and the Wisconsin Electric Power Company plant in the City of Oak Creek. The initial regional water quality management plan recommended that all three of these plants be abandoned. By 1998, all three plants were abandoned. As of 2006, there were three sewage treatment plants located in the Lake Michigan direct drainage area. They are listed in Table 204.

The initial regional water quality management plan recommended that all of the sanitary sewer service areas identified in the plan be refined and detailed in cooperation with the local units of government concerned. There were five sewer service areas identified within, or partially within, the Lake Michigan direct drainage area: Mequon, MMSD, Port Washington, Racine, and South Milwaukee. As of 2005, all of these areas with the exception of the MMSD and South Milwaukee service areas had undergone refinements as recommended. In addition, the Oak Creek sewer service area, which was initially included as a part of the MMSD service area, was identified and refined since the completion of the initial plan. Table 205 lists the plan amendment prepared for each initial refinement, the date the Commission adopted the document as an amendment to the regional water quality management plan, and the date the Commission adopted the most recent refinement to the sewer service area. The table also identifies the original service area names and the relationship of these service areas to the service area names following the refinement process. The planned sewer service areas in the Lake Michigan direct drainage area, as refined through June 2006, total about 21.2 square miles, or about 52 percent of the total area. Planned sewer service areas in the direct drainage area are shown on Map 132.

Table 203

IMPLEMENTATION STATUS OF THE INITIAL REGIONAL WATER QUALITY MANAGEMENT PLAN RECOMMENDATIONS FOR PUBLIC SEWAGE TREATMENT PLANTS IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA: 2004

Plant	Receiving Water	Plan Recommendation	Implementation Status	Year of Implementation
Public				
Milwaukee Metropolitan Sewerage District-Jones Island Plant	Lake Michigan via Milwaukee outer harbor	Upgrade plant	Completed	1996
Milwaukee Metropolitan Sewerage District-South Shore Plant	Lake Michigan	Upgrade plant	Completed	1996
City of South Milwaukee	Lake Michigan	Upgrade plant	Completed	1996
North Park Sanitary District	Lake Michigan	Abandon plant	Plant abandoned	1988
Private				
Chalet-on-the-Lake Restaurant	Lake Michigan	Abandon plant	Plant abandoned	1981
Concordia University[a]	Lake Michigan	Abandon plant	Plant abandoned	1998
We Energies-Oak Creek Plant	Lake Michigan	Abandon plant	Plant abandoned	1986

[a] *Formerly Sisters of Notre Dame Academy.*

Source: SEWRPC.

Table 204

WASTEWATER TREATMENT FACILITIES IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA: 2004

Number on Map 133	Facility Name	Address	Municipality	Ownership
1	Milwaukee Metropolitan Sewerage District-Jones Island Plant	700 E. Jones Street	Milwaukee	Public
2	Milwaukee Metropolitan Sewerage District-South Shore Plant	8500 S. Fifth Avenue	Oak Creek	Public
3	City of South Milwaukee	3033 Fifth Avenue	South Milwaukee	Public

Source: SEWRPC.

Sanitary Sewer Overflow Sites in the Watershed

By 1993, work was completed by MMSD on its Water Pollution Abatement Program, including construction of the Inline Storage System and major relief sewers. As a result of this project, many flow relief devices within the direct drainage area were eliminated. Those which remain include combined sewer overflows and sanitary sewer overflows. During the period from August 1995 to August 2002, separate sanitary sewer overflows were reported at 22 locations in the Lake Michigan direct drainage area. Table 206 gives the locations of sanitary sewer overflow locations in the Lake Michigan direct drainage area for MMSD, five communities, and two sanitary districts. That table indicates the number of days during which overflows were reported as occurring at each location during the period from August 1995 to August 2002. The SSO sites which are being incorporated into the water quality model are indicated on Map 133.

Combined Sewer Overflows

Combined sewer overflows are potential sources of pollution within the direct drainage area. MMSD has two combined sewer overflow outfalls that discharge directly to Lake Michigan. These outfalls can convey diluted sewage from the combined sewer system to the Lake as a result of high water volume from stormwater, meltwater, and infiltration and inflow of clear water during wet weather conditions. This conveyance to surface

Table 205

PLANNED SANITARY SEWER SERVICE AREAS IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA: 2006

Name of Initially Defined Sanitary Sewer Service Area	Planned Sewer Service Area (square miles)	Name of Refined and Detailed Sanitary Sewer Service Area(s)	Initial Plan Amendment Document	Date of SEWRPC Adoption of Initial Plan Amendment	Date of SEWRPC Adoption of Most Recent Plan Amendment
Refined Sanitary Sewer Area					
Mequon	3.69	Mequon	SEWRPC CAPR No. 188, *Sanitary Sewer Service Area for the City of Mequon and the Village of Thiensville , Ozaukee County, Wisconsin*	January 15, 1992	June 12, 1995
Milwaukee Metropolitan Sewerage District (portion)	3.00	Oak Creek	SEWRPC CAPR No. 213, *Sanitary Sewer Service Area for the City of Oak Creek, Wisconsin*	September 7, 1994	- -
Port Washington	0.84	Port Washington	SEWRPC CAPR No. 95, *Sanitary Sewer Service Area for the City of Port Washington, Ozaukee County, Wisconsin*	December 1, 1983	December 3, 2003
Racine	13.66	Racine	SEWRPC CAPR No.147 *Sanitary Sewer Service Area for the City of Racine and Environs, Racine County, Wisconsin*	December 7, 1994	June 18, 2003
Subtotal	21.19	- -	- -	- -	- -
Unrefined Sanitary Sewer Service Areas					
Milwaukee Metropolitan Sewerage District (portion)	14.29	- -	- -	- -	- -
South Milwaukee	1.56	- -	- -	- -	- -
Subtotal	15.85	- -	- -	- -	- -
Total	37.04	- -	- -	- -	- -

Source: SEWRPC.

Map 132

PLANNED SEWER SERVICE AREAS WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 2006

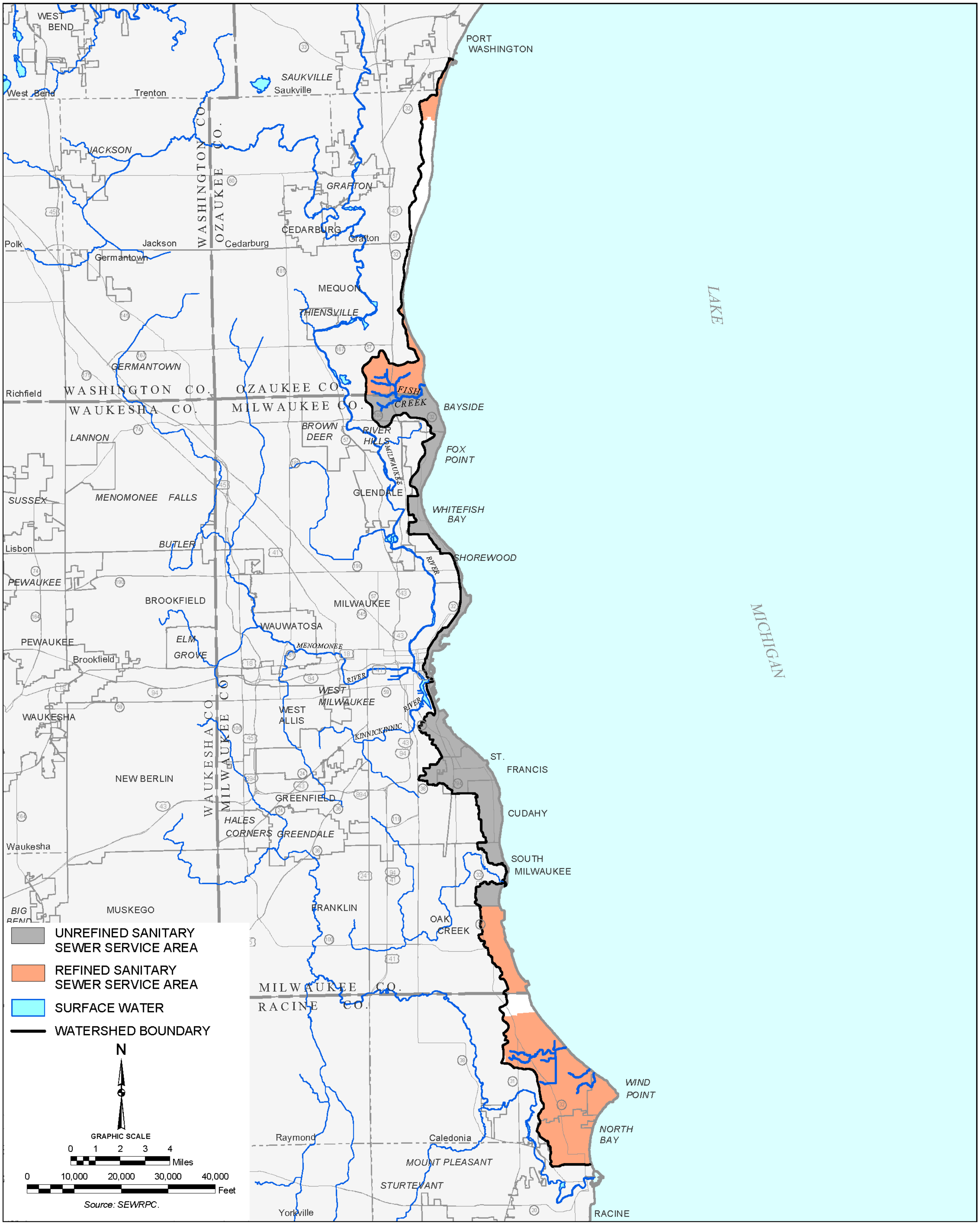

Table 206

SEPARATE SANITARY SEWER OVERFLOW LOCATIONS IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA

Identification Number on Map 133	Location	Community	Number of Days with Overflow: August 1995 to August 2002
206	Easement 500 feet south of the Milwaukee-Ozaukee County Line and 200 feet west of Waverly Road	MMSD	3
232	S. Kinnickinnic Avenue and E. St. Francis Avenue	MMSD	15
264	N. Lake Drive and E. Ravine Lane	Bayside	6
BA01	E. Fairy Chasm Road and N. Bayside Drive	Bayside	13
BA02	E. Hermitage Road and N. Bayside Drive	Bayside	10
BA03	E. Manor Circle and N. Pelham Parkway	Bayside	5
1	Manhole at Indian Trail and Elderberry Road	Crestview Sanitary District	5
CU01	S. Swift Avenue and E. Bottsford Avenue	Cudahy	2
CU02	S. Lake Drive and E. Allerton Avenue	Cudahy	2
CU03	S. Swift Avenue and E. Lunham Avenue	Cudahy	1
CU04	3950 E. College Ave Lift Station	Cudahy	1
CU05	Manhole at 3229 E. Lunham Avenue	Cudahy	1
FP06	8001 N. Beach Drive	Fox Point	1
MI03	439 E. Waterford Avenue	Milwaukee	3
MI06	N. Lincoln Memorial Drive and E. Belleview (extended)	Milwaukee	1
2	4-Mile Road and Hunt Club Road	North Park Sanitary District	1
3	468 E. 4-Mile Road	North Park Sanitary District	1
4	362 E. 4-Mile Road	North Park Sanitary District	1
5	4015 6-Mile Road	North Park Sanitary District	1
6	4129 6-Mile Road	North Park Sanitary District	1
7	4305 6-Mile Road	North Park Sanitary District	1
8	Lift Station at 6323 Douglas Avenue	North Park Sanitary District	2
9	5809 Erie Street	North Park Sanitary District	1
10	Birch Creek at Valley Trail	North Park Sanitary District	1
- -	Lodgewood Road and Lodgewood Court	River Hills	1
SM09	299 Edgewood Avenue	South Milwaukee	1
SM10	7th Avenue and Lakeview Avenue	South Milwaukee	2
SM11	Lake Drive and Brookdale Court	South Milwaukee	1
SM12	Lake Drive between Park Street and Oak Street	South Milwaukee	2
- -	South Milwaukee Sewage Treatment Plant	South Milwaukee	2
WB01	E. Circle Drive	Whitefish Bay	1
WB02	N. Lake Drive and E. Lake View Avenue	Whitefish Bay	3
WB03	N. Idlewild Avenue and E. Briarwood Place	Whitefish Bay	1
WB04	N. Newhall and E. Fairmount Avenue	Whitefish Bay	3

NOTE: For the MMSD Sanitary Sewer Overflow locations, the Identification Number corresponds to the WPDES permit number.

Source: Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, Triad Engineering, and SEWRPC.

waters occurs to prevent damage to buildings or the mechanical elements of the conveyance system during such events. The locations of these outfalls are shown on Map 133. Associated with these CSO outfalls is a set of sample collectors which obtain samples of effluent discharged during overflow events for chemical and bacteriological analysis. The assignment of collectors to outfalls is shown in Table 207. Over the period August 1995 to August 2002, the mean number of days during which individual outfalls discharged to streams in the watershed was 41. Associated with this mean was high variability among outfalls. The number of days over which an outfall discharged ranged between 34 and 47 days. There was also variation in the number of outfalls involved in particular discharge events. Some CSO events were quite localized, consisting of discharge from only one outfall. Others occurred over a larger portion of the CSO area, involving discharge from both outfalls into the Lake.

Other Known Point Sources

Industrial Discharges

The number of known industrial wastewater permitted dischargers in the Lake Michigan direct drainage area has increased over time. In 1975, there were a total of 23 known industrial wastewater permitted dischargers

Map 133

POINT SOURCES OF POLLUTION WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 2003

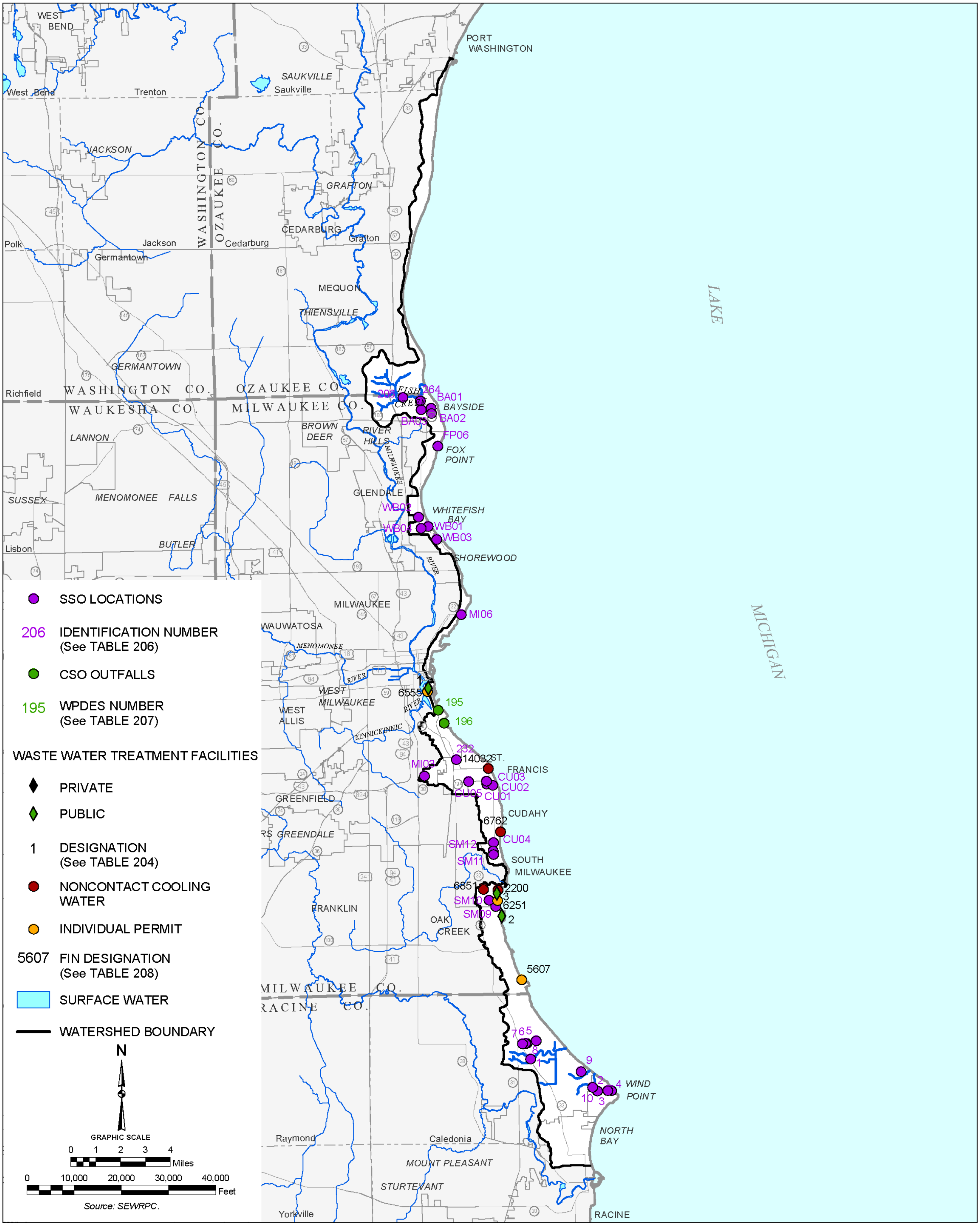

Table 207

COMBINED SEWER OVERFLOW OUTFALL LOCATIONS IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA

WPDES Number on Map 133	Location	Collector	Outfall Size (inches)	Number of Days with Overflow August 1995 to August 2002
195	E. Bay Street	LMN	90 x 78[a]	47
196	E. Russell Avenue	LMS	120	34

[a]*Double outfall.*

Source: Milwaukee Metropolitan Sewerage District, Triad Engineering, and SEWRPC.

identified in the area. These permitted facilities discharged industrial cooling, process, rinse, and wash waters to surface waters.[124] In 1990, 21 permitted facilities discharged wastewater to the Milwaukee River, its tributaries, or the groundwater system.[125]

Table 208 lists the industrial discharge permits in effect through the WPDES during February 2003 in the Lake Michigan direct drainage area. At that time, 37 WPDES industrial permits were in effect in the direct drainage area. Individual permits represent six of these permits, the rest are spread among seven categories of general permits. The most common category of general permit issued in this watershed was for noncontact cooling water which regulates the discharge of noncontact cooling water, boiler blowdown, and air conditioning condensate. There were 16 facilities in the watershed covered by permits in this category. The other common category of permits was for the discharge of hydrostatic test water. These types of facility represented seven permits. The other general permit categories were each represented by three or fewer facilities. Data from discharge monitoring reports for several facilities covered by individual permits or general permits for noncontact cooling water are being included in water quality modeling for the regional water quality management plan update and the MMSD 2020 Facility Plan. These sites are shown on Map 133.

Due to the dynamic nature of permitted point sources, it is recognized that the number of wastewater sources in the watershed will change as industries and other facilities change locations or processes and as decisions are made with regard to the connection of such sources to public sanitary sewer systems.

Nonpoint Source Pollution

Urban Stormwater Runoff

As shown in Table 186, as of the year 2000, about 66.4 percent of the land in the Lake Michigan direct drainage area was in urban uses. Urban land uses within the watershed were primarily residential (36.1 percent); followed by transportation, communication, and utilities (17.0 percent) and industrial and extractive, and governmental and institutional, commercial, and recreational each of which comprised less than 4.5 percent of the direct drainage area. Chapter II of this report includes descriptions of the types of pollutants associated with specific urban nonpoint sources.

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[124]*SEWRPC Technical Report No. 21,* Sources of Water Pollution in Southeastern Wisconsin: 1975, *September 1978.*

[125]*SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report*, March 1995.*

Table 208

PERMITTED WASTEWATER DISCHARGERS UNDER THE WPDES GENERAL PERMIT AND INDIVIDUAL PERMIT PROGRAMS IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA: FEBRUARY 2003

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number[a]
Carriage/Interstitial Water from Dredging	We Energies	4801 E. Elm Road	Oak Creek	0046588	241007690	5607
Concrete Products Operations[b]	- -	- -	- -	- -	- -	- -
Contaminated Groundwater Remedial Actions[c]	- -	- -	- -	- -	- -	- -
Hydrostatic Test Water and Water Supply System	Crestview Sanitary District	3120 Indian Trail	Racine	0057681	252086340	7308
	Cudahy Waterworks	5110 Lake Drive	Cudahy	0057681	241016930	13372
	North Park Sanitary District	333 4 1/2 Mile Road	Caledonia	0057681	252003180	6009
	South Milwaukee Water Utility	100 Marshall Avenue	South Milwaukee	0057681	241014400	6212
	Village of Wind Point Water Utility	215 E. Four Mile Road	Wind Point	0057681	- -	23654
	Whitefish Bay Water Utility	5300 N. Marlborough Drive	Whitefish Bay	0057681	241059720	14106
Land Applying Liquid Industrial Wastes[d]	- -	- -	- -	- -	- -	- -
Noncontact Cooling Water	Acmi Circon	3037 Mt. Pleasant Street	Racine	0044938	252014180	12855
	CNH Global, N. V.-Tractor Plant	25th Street and Mead Street	Racine	0044938	252004170	5572
	Cooper Power Systems, Inc.	2800 S. 9th Avenue	South Milwaukee	0044938	241362660	2200
	E. C. Styberg Engineering Company	1600 Goold Street	Racine	0044938	252009780	2299
	Everbrite, Inc.	315 Marion Avenue	South Milwaukee	0044938	241094700	6851
	Fontarome Chemical, Inc.	4170 S. Nevada Drive	St. Francis	0044938	241306670	14032
	Met Tek, Inc.	1800 Melvin Avenue	Racine	0044938	252189740	2308
	Modine Manufacturing Company	1500 DeKoven Avenue	Racine	0044938	252012090	9116
	Racine Stamping Corporation	3100 Rapids Drive	Racine	0044938	252009010	970
	S. C. Johnson and Son, Inc.	15 Four Mile Road	Racine	0044938	252083040	20553
	S. C. Johnson and Son, Inc.	1525 Howe Street	Racine	0044938	252006820	9043
	St. Luke's South Shore	5900 S. Lake Drive	Cudahy	0044938	241017150	6762
	Twin Disc, Inc.-Plant 3	4601 21st Street	Racine	0044938	252007140	2515
	Village of Whitefish Bay	Sanitary Overflows	Whitefish Bay	0044938	241004720	6129
	We Energies-Gas Operations	4500 E. Elm Road	Oak Creek	0044938	241020560	13034
Nonmetallic Mining Operations	Vulcan Materials Company-Racine	1501 Three Mile Road	Racine	0046515	252004480	3443
Petroleum Contaminated Water	Support Terminal Services	1626 S. Harbor Drive	Milwaukee	0046531	241005490	7728
Pit/Trench Dredging[e]	- -	- -	- -	- -	- -	- -
Potable Water Treatment and Conditioning	Cudahy Waterworks	5110 Lake Drive	Cudahy	0046540	241016930	13372
	Milwaukee Waterworks-Linnwood Plant	3000 N. Lincoln Memorial Drive	Milwaukee	0046540	241010000	14096
Swimming Pool Facilities	Milwaukee County Parks and Recreation-Sheridan Park Pool	4800 S. Lake Drive	Cudahy	0046523	241521060	14071
	Whitefish Bay High School Pool	1200 E. Fairmount Avenue	Whitefish Bay	0046523	241323280	14105

Table 208 (continued)

Permit Type	Facility	Address	Municipality	WPDES Permit Number	Facility Identification	Facility Identification Number[a]
Individual Permits	City of Cudahy	5050 S. Lake Drive	Cudahy	S049875	241206790	15778
	City of St. Francis	4235 S. Nicholson Avenue	St. Francis	S049875	241208990	15775
	MMSD Combined	700 E. Jones Street	Milwaukee	0036820	241487400	6555
	South Milwaukee Wastewater Treatment Facility	3003 Fifth Avenue	South Milwaukee	0028819	241004170	6251
	We Energies	4801 E. Elm Road	Oak Creek	914	241007690	5607
	University of Wisconsin Milwaukee Power Plant	3359 N. Downer Avenue	Milwaukee	0040282	241019900	6661

[a] *See Map 133 for the locations of point sources of pollution represented in the water quality model.*

[b] *There were no active WPDES general permits for Concrete Product Operations in the Lake Michigan direct drainage area during February 2003.*

[c] *There were no active WPDES general permits for Contaminated Groundwater Remedial Actions in the Lake Michigan direct drainage area during February 2003.*

[d] *There were no active WPDES general permits for Land Applying Industrial Wastes in the Lake Michigan direct drainage area during February 2003.*

[e] *There were no active WPDES general permits for Pit/Trench Dredging in the Lake Michigan direct drainage area during February 2003.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Regulation of Urban Nonpoint Source Pollution through the Wisconsin Pollutant Discharge Elimination System Permit Program

Facilities engaged in industrial activities listed in Section NR 216.21(2)(b) of Chapter NR 216 of the *Wisconsin Administrative Code* must apply for and obtain a stormwater discharge permit. The WDNR originally developed a three-tier system of industrial storm water permits. Tier 1 permits apply to facilities involved in heavy industry and manufacturing, including facilities involved in lumber and wood product manufacturing, leather tanning, and primary metal industries. Tier 2 permits apply to facilities involved in light industry and manufacturing and transportation facilities, including facilities involved in printing, warehousing, and food processing. Tier 3 permits used to be issued to facilities which have certified, with WDNR concurrence, that they have no discharges of contaminated stormwater. WDNR authority for Tier 3 permits no longer exists and the Tier 3 permits have been terminated. Facilities now submit a certificate of no exposure. In addition, the WDNR also issues separate permits for automobile parts recycling facilities and scrap recycling facilities. Associated with each category of permit are specific requirements for monitoring and inspection. For all categories of permits except Tier 3 industrial permits, the permit requires the facility to develop and follow a storm water pollution prevention plan (SWPPP). Specific requirements for the SWPPP are listed in Chapter NR 216.27 of the *Wisconsin Administrative Code*. They include provisions related to site mapping, implementation scheduling, conducting annual plan assessments, and monitoring of discharge.

As shown in Appendix G, "WPDES Permitted Stormwater Facilities," 43 industrial stormwater permits were in effect in the Lake Michigan direct drainage area in February 2003. A total of 28 of these were Tier 2 permits, representing slightly over 60 percent of the permitted facilities in the area. Tier 1 permits were the next most common in the watershed. In February 2003, eight of these were in effect. There were three or fewer each of Tier 3, Automobile Parts Recycling, and Scrap Recycling permits in effect in the watershed at this time.

The WDNR also issues and administers construction site stormwater permits through the WPDES General Permits program. All construction sites that disturb one acre of land or more are required to obtain coverage under the General Permit. Permitted construction sites are required to implement a construction erosion control plan, and a post-construction stormwater management plan as required in Chapter NR 216.46 and Chapter NR 216.47 of the *Wisconsin Administrative Code*. Owners of permitted construction sites are also required to conduct inspections of their construction erosion control measures on a weekly basis and within 24 hours of a precipitation event of 0.5 inches or more. Due to the dynamic nature of construction activities, it is recognized that the number of sites requiring Construction Site Storm Water permits in the watershed will change as construction projects are completed and new projects are initiated.

The WPDES stormwater permits for municipalities within the direct drainage area are described below and are listed in Table G-6 in Appendix G of this report.

Chapter NR 151 of the Wisconsin Administrative Code

Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* establishes performance standards for the control of nonpoint source pollution from agricultural lands, nonagricultural (urban) lands, and transportation facilities. The standards for urban lands apply to areas of existing development, redevelopment, infill, and construction sites. In general, the construction erosion control, post-construction nonpoint source pollution control, and stormwater infiltration requirements of NR 151 apply to projects associated with construction activities that disturb at least one acre of land.

The urban standards are applied to activities covered under the WPDES program for stormwater discharges. As noted below, communities with WPDES discharge permits must adopt stormwater management ordinances that have requirements at least as stringent as the standards of Chapter NR 151. Those communities must also achieve levels of control of nonpoint source pollution from areas of existing development (as of October 1, 2004), that are specified under Chapter NR 151.

Stormwater Management Systems

Stormwater management facilities are defined, for purposes of this report, as conveyance, infiltration, or storage facilities, including, but not limited to, subsurface pipes and appurtenant inlets and outlets, ditches, streams and engineered open channels, detention and retention basins, pumping facilities, infiltration facilities, constructed wetlands for treatment of runoff, and proprietary treatment devices based on settling processes and control of oil and grease. Such facilities are generally located in urbanized areas and constructed or improved and operated for purposes of collecting stormwater runoff from tributary drainage areas and conveying, storing, and treating such runoff prior to discharge to natural watercourses. In the larger and more intensively developed urban communities, these facilities consist either of complete, largely piped, stormwater drainage systems which have been planned, designed, and constructed as systems in a manner similar to sanitary sewer and water utility systems, or of fragmented or partially piped systems incorporating open surface channels to as great a degree as possible. In the Lake Michigan direct drainage area, the stormwater drainage systems provide the means by which a significant portion of the nonpoint sources pollutants reach the surface water system.

With the relatively recent application of the WPDES permitting program to stormwater discharges and the adoption of local stormwater management ordinances, controls on the quality of stormwater runoff prior to discharge to receiving streams have become more common. Table 209 indicates the status of stormwater management activities in each of the communities in the direct drainage area.

As indicated in Table G-6 in Appendix G, Milwaukee and Ozaukee Counties; the Cities of Cudahy, Glendale, Mequon, Milwaukee, Oak Creek, Port Washington, Racine, St. Francis, and South Milwaukee; the Villages of Bayside, Caledonia, Fox Point, Mt. Pleasant, River Hills, Shorewood, Whitefish Bay, and Wind Point; and the Town of Grafton have WPDES stormwater discharge permits. The Village of North Bay and the Town of Port Washington do not currently have stormwater discharge permits. Thus, communities comprising 99 percent of the direct drainage area have been issued WPDES stormwater discharge permits. In addition to specific nonpoint source pollution control activities recommended under their WPDES permits, the permitted communities will also all be required to develop new, or update existing, stormwater management ordinances to be consistent with the standards of Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*. As part of their permit application, each community prepared maps of the stormwater outfalls that are part of the municipal separate stormwater system.

Urban Enclaves Outside Planned Sewer Service Areas

Map 134 shows areas served by centralized sanitary sewer systems in the Lake Michigan direct drainage area in 2000. In that year, 19,095 acres of the direct drainage area were served by sanitary sewer systems. In addition, there were about 276 acres of urban-density enclaves that were not served by public sanitary sewer systems. As shown on Map 135, about 130 acres of these enclaves are in areas served by onsite sewage disposal systems that were developed prior to 1980. These older systems may be at particular risk for malfunctioning. As described in Chapter II of this report, failure of onsite disposal systems can contribute nonpoint source pollutants to streams and groundwater.

In 1978, the State of Wisconsin established the Private Onsite Wastewater Treatment System Replacement or Rehabilitation Financial Assistance Program under the Wisconsin Fund Program. That voluntary program annually awards grants to counties, Indian tribes, and municipalities to assist homeowners and small businesses in replacing or rehabilitating failing private, onsite systems. The program is administered by the Wisconsin Department of Commerce in cooperation with the counties and communities. Grant eligibility is subject to specific income, revenue, occupancy, and operation requirements. Onsite systems that are installed, replaced, or rehabilitated after the date on which the county or community elects to participate are required to have a maintenance program. Thus, given the 1978 date of establishment of the grant program, the determination of areas

Table 209

STORMWATER MANAGEMENT INFORMATION FOR CITIES, VILLAGES, AND TOWNS WITHIN THE LAKE MICHIGAN DIRECT DRAINAGE AREA

Civil Division	Stormwater Management Ordinance and/or Plan	Construction Erosion Control Ordinance	Stormwater Utility, General Fund, and/or Established Stormwater Fee Program
Milwaukee County			
City of Cudahy	X	X	X
City of Glendale	X	X	X
City of Milwaukee	X	X	X
City of Oak Creek	X	X	X
City of South Milwaukee	X	X	- -
Village of Bayside	X	X	- -
Village of Fox Point	X	X	- -
Village of River Hills	X	X	- -
Village of Shorewood	X	X	- -
Village of Whitefish Bay	X	X	- -
Ozaukee County			
City of Mequon	X	X	- -
City of Port Washington	X	X	X
Town of Grafton	X	X	- -
Town of Port Washington	- -	- -	- -
Racine County			
City of Racine	X	X	X
Village of Caledonia	X	X	X
Village of Mt. Pleasant	X	X	- -
Village of North Bay	- -	- -	- -
Village of Wind Point	- -[a]	- -[a]	- -

[a]*Will adopt ordinances as required under WPDES stormwater discharge permit.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

developed with onsite systems before 1980 and those developed in 1980 or later,[126] provides an indication of which systems are subject to the requirement of having formal maintenance programs and which are not. The counties, or communities in the case of Milwaukee County, are responsible for administering the maintenance program with the goal of assuring the onsite systems function properly. In the Lake Michigan direct drainage area, Ozaukee and Racine Counties currently participate in the program.

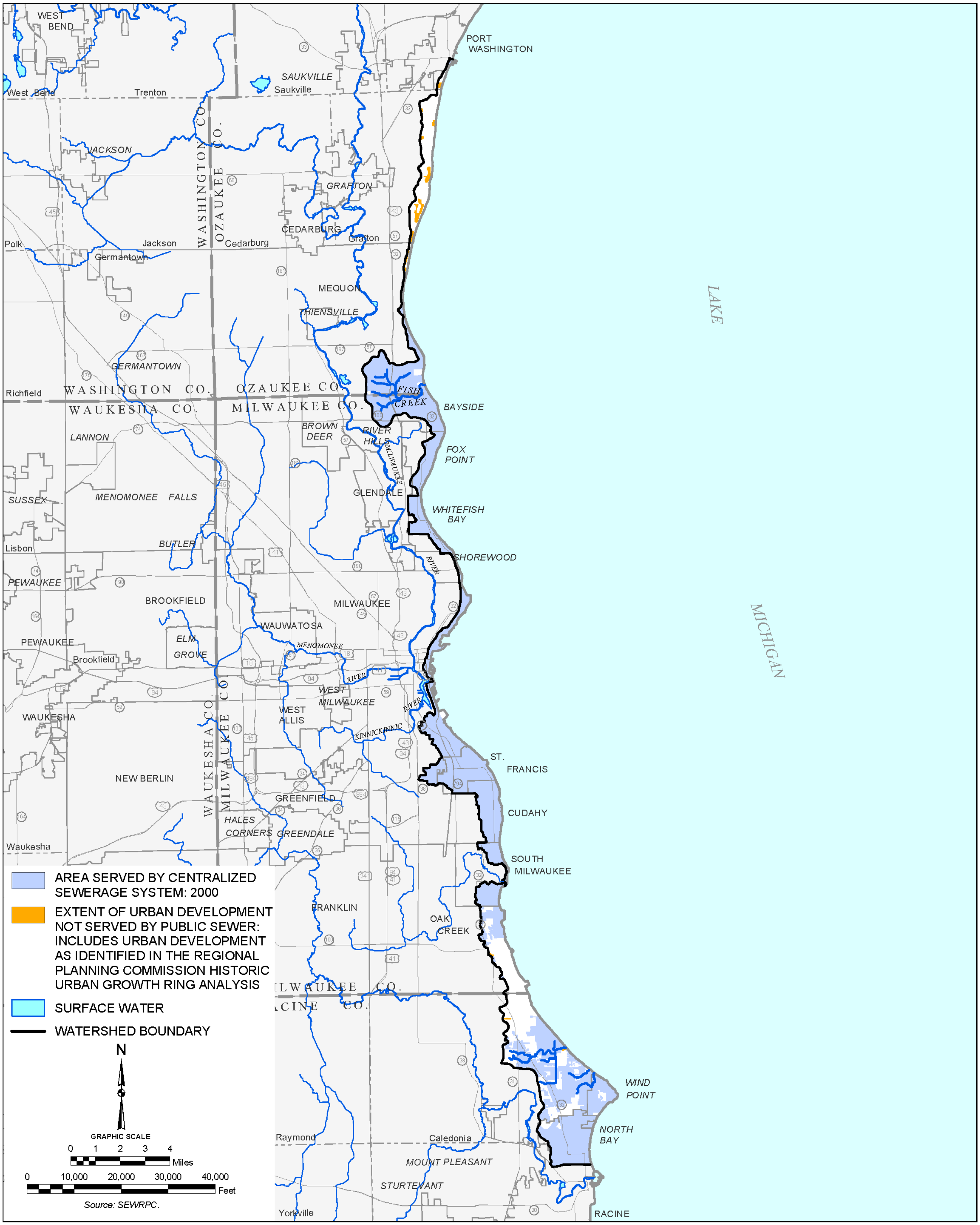
Solid Waste Disposal Sites

Solid waste disposal sites are a potential source of surface water, as well as groundwater, pollution. It is important to recognize, however, the distinction between a properly designed and constructed solid waste landfill and the variety of operations that are referred to as refuse dumps, especially with respect to potential effects on water quality. A solid waste disposal site may be defined as any land area used for the deposit of solid wastes regardless of the method of operation, or whether a subsurface excavation is involved. A solid waste landfill may be defined as a solid waste disposal site which is carefully located, designed, and operated to avoid hazards to public health or safety, or contamination of groundwaters or surface waters. The proper design of solid waste landfills requires careful engineering to confine the refuse to the smallest practicable area, to reduce the refuse mass to the smallest

[126]*Since 1970, the SEWRPC land use inventory has been conducted at five-year intervals. Thus the 1980 inventory was the best available information for establishing which systems have maintenance requirements.*

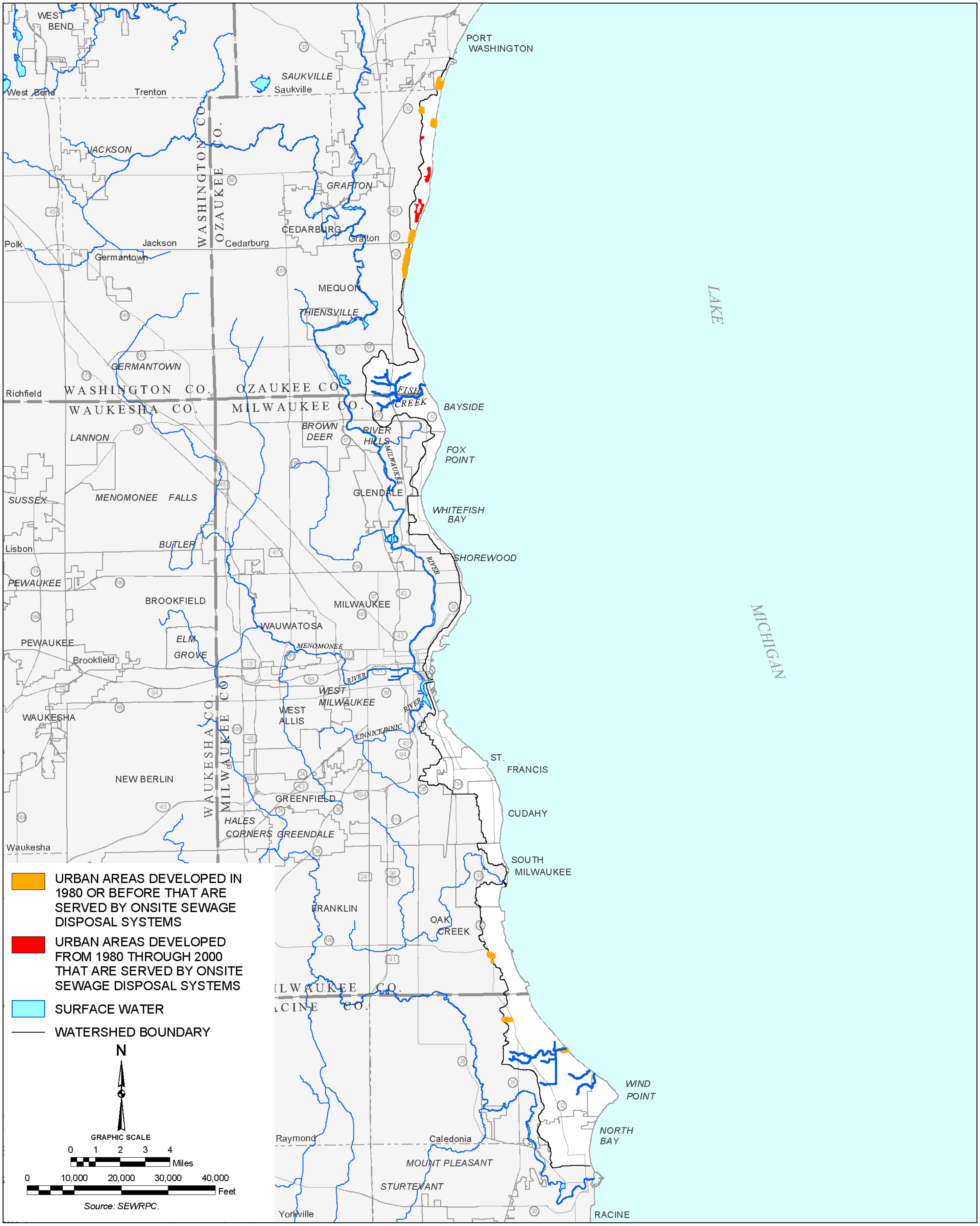
Map 134

AREAS SERVED BY CENTRALIZED SANITARY SEWERAGE SYSTEMS WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 2000



Map 135

URBAN AREAS WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN THAT ARE SERVED BY ONSITE SEWAGE DISPOSAL SYSTEMS: 1980 AND PRIOR AND 1981 THROUGH 2000



practicable volume, to avoid surface water runoff, to minimize leachate production and percolation into the groundwater and surface waters, and to seal the surface with a layer of earth at the conclusion of each day's operation or at more frequent intervals as necessary.

In order for a landfill to produce leachate, there must be some source of water moving through the fill material. Possible sources included precipitation, the moisture content of the refuse itself, surface water infiltration, groundwater migrating into the fill from adjacent land areas, or groundwater rising from below to come in contact with the fill. In any event, leachate is not released from a landfill until a significant portion of the fill material exceeds its saturation capacity. If external sources of water are excluded from the solid waste landfill, the production of leachates in a well-designed and managed landfill can be effectively minimized if not entirely avoided. The quantity of leachate produced will depend upon the quantity of water that enters the solid waste fill site minus the quantity that is removed by evapotranspiration. Studies have estimated that for a typical landfill, from 20 to 50 percent of the rainfall infiltrated into the solid waste may be expected to become leachate. Accordingly, a total annual rainfall of about 35 inches, which is typical of the Lake Michigan direct drainage area, could produce from 190,000 to 480,000 gallons of leachates per year per acre of landfill if the facility is not properly located, designed, and operated.

As of 2005, there was one active solid waste landfill within the Lake Michigan direct drainage area, located in the Village of Caledonia. As set forth in Table 210 and shown on Map 136, there are three inactive landfills in the area. All are in the City of Oak Creek.

Rural Stormwater Runoff

Rural land uses within the Lake Michigan direct drainage area include agricultural—mostly crop production—and woodlands, wetlands, water, and other open lands as set forth in the beginning of this chapter. As previously noted, Chapter NR 151 of the *Wisconsin Administrative Code* establishes performance standards for the control of nonpoint source pollution from agricultural lands, nonagricultural (urban) lands, and transportation facilities. Agricultural performance standards are established for soil erosion, manure storage facilities, clean water diversions, nutrient management, and manure management. Those standards must only be met to the degree that grant funds are available to implement projects designed to meet the standards.

Livestock Operations

The presence of livestock and poultry manure in the environment is an inevitable result of animal husbandry and is a major potential source of water pollutants. Animal manure composed of feces, urine, and sometimes bedding material, contributes suspended solids, nutrients, oxygen-demanding substances, bacteria, and viruses to surface waters. Animal waste constituents of pastureland and barnyard runoff, and animal wastes deposited on pastureland and cropland and in barnyards, feedlots, and manure piles, can potentially contaminate water by surface runoff, infiltration to groundwater, and volatilization to the atmosphere. During the warmer seasons of the year the manure is often scattered on cropland and pastureland where the waste material is likely to be taken up by vegetative growth composing the land cover. However, when the animal manure is applied to the land surface during the winter, the animal wastes are subject to excessive runoff and transport, especially during the spring snowmelt period.

Based on data from 2002, animal operations in the Lake Michigan direct drainage area include 14 operations rearing a total of about 1,143 cattle and calves, 150 pigs, 58 sheep, and 2,543 chickens. Most of these operations are in the portions of the area in Ozaukee and Racine Counties.

No concentrated animal feeding operations (CAFO) are situated in the Lake Michigan direct drainage area.

Crop Production

In the absence of mitigating measures, runoff from cropland can have an adverse effect on water quality within the Lake Michigan direct drainage area by contributing excess sediments, nutrients, and organic matter, including pesticides to streams. Negative effects associated with soil erosion and transport to waterbodies includes reduced

Table 210

ACTIVE AND INACTIVE SOLID WASTE DISPOSAL SITES IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA: 2005

Number on Map 136	Facility Name	Address	Municipality	Facility Identification	Status
ML22	City of South Milwaukee	T5N R22E Section 14 NW SE	Oak Creek	241208770	Inactive
ML25	We Energies	T5N R22E Section 36 SW NE	Oak Creek	241219440	Inactive
ML26	James Manufacturing	3925 E. American Avenue	Oak Creek	241018800	Inactive
RA4	We Energies-Caledonia	8419 Douglas Avenue	Caledonia	252183690	Active

Source: Wisconsin Department of Natural Resources and SEWRPC.

water clarity, sedimentation on streambeds, and contamination of the water from various agricultural chemicals and nutrients that are attached to the individual soil particles. Some of these nutrients, in particular phosphorus, and to some extent nitrogen, are directly associated with eutrophication of water resources. The extent of the water pollution from cropping practices varies considerably as a result of the soils, slopes, and crops, as well as in the numerous methods of tillage, planting, fertilization, chemical treatment, and conservation practices. Conventional tillage practices, or moldboard plowing, involve turning over the soil completely, leaving the soil surface bare of most cover or residue from the previous year's crop, and making it highly susceptible to erosion due to wind and rain. The use of conservation tillage practices has become common in the area in recent years within areas most susceptible to erosion and surface water impacts.

Crops grown in Lake Michigan direct drainage area include row crops, such as corn and soybeans; small grains, such as winter wheat; hay, such as alfalfa; and vegetables, such as snap beans and sweet corn. Row crops and vegetable crops, which have a relatively higher level of exposed soil surface, tend to contribute higher pollutant loads than do hay and pastureland, which support greater levels of vegetative cover. Crop rotations typically follow a two- or three-year sequence of corn and soybeans and occasionally winter wheat in the third year. However, hay is periodically included as part of a long-term rotation of corn, oats, and alfalfa.

Since the early 1930s, it has been a national objective to preserve and protect agricultural soil from wind and water erosion. Federal programs have been developed to achieve this objective, with the primary emphasis being on sound land management and cropping practices for soil conservation. An incidental benefit of these programs has been a reduction in the amount of eroded organic and inorganic materials entering surface waters as sediment or attached to sediment. Some practices are effective in both regards, while others may enhance the soil conditions with little benefit to surface water quality. Despite the implementation of certain practices aimed at controlling soil erosion from agricultural land, and development of soil erosion plans and/or land and water resource management plans for Milwaukee,[127] Ozaukee,[128] and Racine[129] Counties, such erosion and the resultant deposition of sediment in the streams of the Lake Michigan direct drainage area remains a problem. Relative to urban nonpoint sources, soil erosion from agricultural lands is a relatively minor source of sediment and nutrients in the streams of the Lake Michigan direct drainage area.

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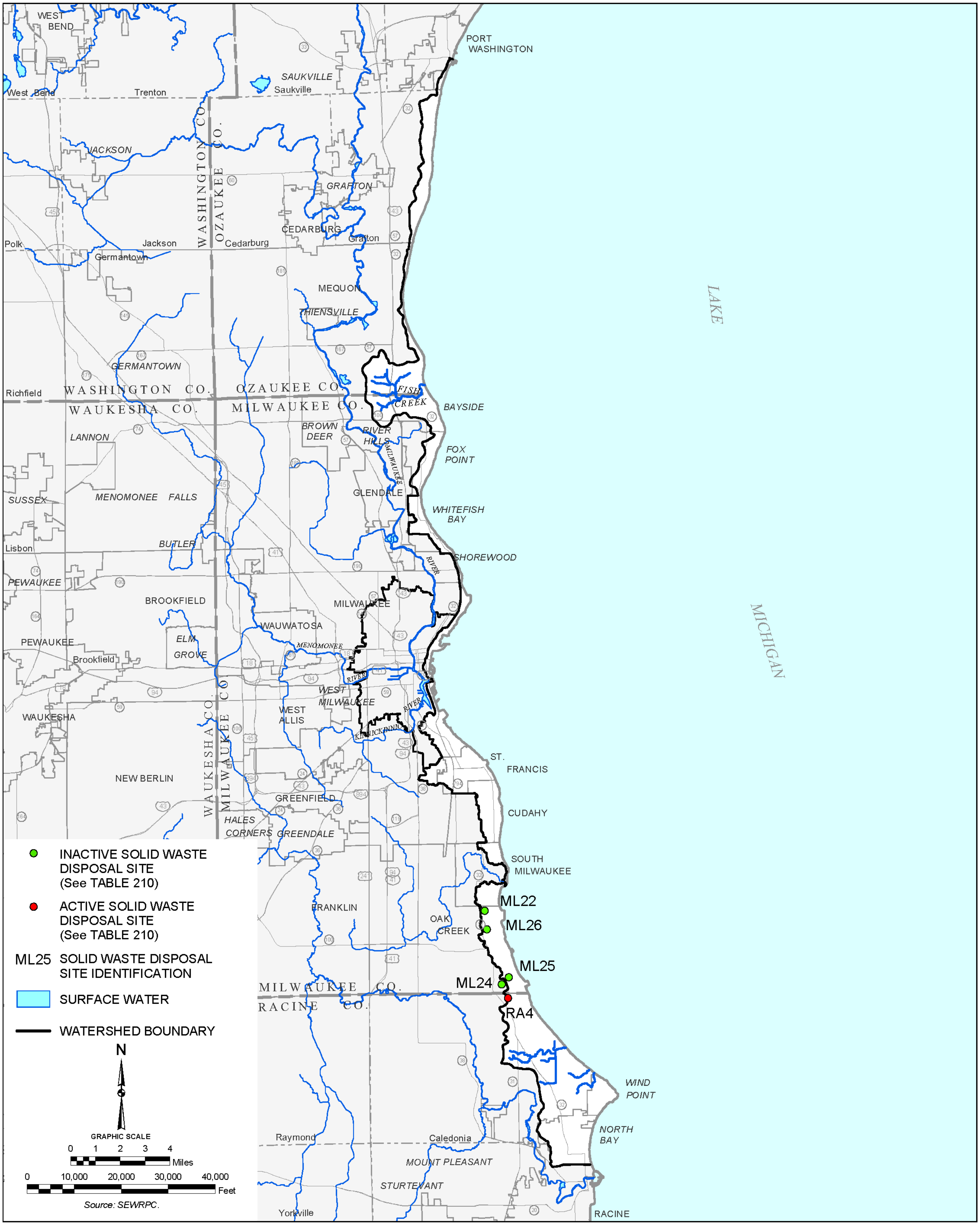
[127]*Milwaukee County Land Conservation Committee,* Milwaukee County Land and Water Resource Management Plan, *April 2001.*

[128]*SEWRPC Community Assistance Planning Report No. 171,* Ozaukee County Agricultural Soil Erosion Control Plan, *February 1989*

[129]*SEWRPC Community Assistance Planning Report No. 160,* Racine County Agricultural Soil Erosion Control Plan, *July 1988.*

Map 136

ACTIVE AND INACTIVE SOLID WASTE DISPOSAL SITES WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 2005



Nutrients, such as phosphorus and agri-chemicals, including herbicides and pesticides, are electrostatically attracted to silt sized particles and are transported to surface waters through soil erosion. As previously mentioned, phosphorus is one of the primary nutrients associated with eutrophication of water resources, and agri-chemicals can negatively impact the life cycles of aquatic organisms. In the eutrophication process, phosphorus enhances growth of aquatic vegetation and algae, which has the effect of accelerating the aging process of a water resource. Phosphorus is usually not susceptible to downward movement through the soil profile; instead, the majority of phosphorus reaches water resources by overland flow, or erosion. Nitrogen also is a nutrient that contributes to eutrophication; however, it is most often associated with subsurface water quality contamination. Nitrogen in the form of nitrate can be associated with respiration problems in newborn infants. Nitrogen is susceptible to downward movement through the soil profile; however, due to the nature of soils in the watershed, nitrogen is not as significant a threat due to various chemical reactions that occur within the soil.[130]

Woodlands

A well-managed woodland contributes few pollutants to surface waters. Under poor management, however, woodlands may have detrimental water quality effects through the release of sediments, nutrients, organic matter, and pesticides into nearby surface waters. If trees along streams are cut, thermal pollution may occur as the direct rays of the sun strike the water. Disturbances caused by tree harvesting, livestock grazing, tree growth promotion, tree disease prevention, fire prevention, and road and trail construction are a major source of pollution from silvicultural activities. Most of these activities are seldom practiced in the Lake Michigan direct drainage area.

Pollution Loadings

Annual Loadings

Annual average pollutant loads in the Lake Michigan direct drainage area are set forth in Tables 211 through 217. Average annual per acre loads are set forth in Table 218. These estimates represent point and nonpoint source loads delivered to the modeled stream reaches, after accounting for any trapping factors that would retain pollutants on the surface of the land. They include loads from groundwater. It is important to note that the stream channel pollutant loads may be expected to be different from the actual transport from the watersheds of the area, because physical, chemical, and biological processes may retain or remove pollutants or change their form during transport over the land surface or within the stream system. These processes include particle deposition or entrapment on the land surface or in floodplains, stream channel deposition or aggradation, biological uptake, and chemical transformation and precipitation. The total pollutant loads set forth in Table 211 are representative of potential pollutants moved from the Lake Michigan direct drainage area into stream channels, but are not intended to reflect the total amount of pollutants moving from those sources through the entire hydrologic-hydraulic system.

Point Source Loadings

Annual average total point source pollutant loads of six pollutants in the Lake Michigan direct drainage area are set forth in Tables 212 through 217. Contributions of most of these pollutants by point sources represent the major portion of the combined total average loads from point and nonpoint sources, generally about 94 percent or more, except for the TSS load, which is split evenly between point and nonpoint sources, and the fecal coliform bacteria load of which point sources represent about one third.

Average annual point source loads of total phosphorus in the Lake Michigan direct drainage area are shown in Table 212. The total average annual point source load of total phosphorus is about 316,750 pounds. Almost all of this is contributed by the portions of the Lake Michigan direct drainage area in Milwaukee County. Sewage treatment plants account for almost all of the contributions of total phosphorus from point sources, with small contributions from combined sewer overflows and separate sanitary sewer overflows.

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[130]*Soils that have a high clay content and stay wet for long periods of time, or even well-drained soils after a rainfall event, are susceptible to nitrogen losses to the atmosphere through a chemical reaction known as denitrification. This reaction converts nitrate,* NO_3^-*, to gaseous nitrogen,* N_2*, which is lost to the atmosphere.*

Table 211

AVERAGE ANNUAL TOTAL NONPOINT SOURCE POLLUTANT LOADS IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA[a]

County	Total Phosphorus (pounds per acre)	Total Suspended Solids (pounds per acre)	Fecal Coliform Bacteria (trillions of cells per acre)	Total Nitrogen (pounds per acre)	Biochemical Oxygen Demand (pounds per acre)	Copper (pounds per acre)
Ozaukee[b]	3,000	1,235,620	743.45	25,220	68,920	109
Milwaukee	6,650	2,897,030	2,015.44	46,590	177,750	315
Racine	5,770	2,636,300	1,303.68	53,580	151,090	246
Total	15,420	6,768,950	4,062.57	125,390	397,760	670

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

[b]These loads include those from the Fish Creek subwatershed, which is located in both Ozaukee and Milwaukee Counties, but discharges to Lake Michigan in Ozaukee County.

Source: HydroQual, Inc. and Tetra Tech, Inc.

Table 212

AVERAGE ANNUAL LOADS OF TOTAL PHOSPHORUS IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA[a]

County	Point Sources				Nonpoint Sources			Total (pounds)
	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Ozaukee[b]	10	0	0	10	2,370	630	3,000	3,010
Milwaukee	30	160	316,550	316,740	5,930	720	6,650	323,390
Racine	<10	0	0	<10	4,880	890	5,770	5,770
Total	40	160	316,550	316,750	13,180	2,240	15,420	332,170
Percent of Total Load	<0.1	<0.1	95.3	95.3	4.0	0.7	4.7	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

[b]These loads include those from the Fish Creek subwatershed, which is located in both Ozaukee and Milwaukee Counties, but discharges to Lake Michigan in Ozaukee County.

Source: HydroQual, Inc. and Tetra Tech, Inc.

Average annual point source loads of total suspended solids in the Lake Michigan direct drainage area are shown in Table 213. The total average annual point source load of total suspended solids is about 6,944,100 pounds. Amost all of this is contributed by the portions of the Lake Michigan direct drainage area in Milwaukee County. Sewage treatment plants represent the major source of TSS, contributing over 99 percent of the total load from point sources. Combined sewer overflows and separate sanitary sewer overflows contribute small amounts.

Average annual point source loads of fecal coliform bacteria in the Lake Michigan direct drainage area are shown in Table 214. The total average annual point source load of fecal coliform bacteria is about 2,209.06 trillion cells per year. Almost all of this is contributed by the portions of the Lake Michigan direct drainage area in Milwaukee County. Sewage treatment plants account for the majority of contributions of fecal coliform bacteria from point sources, contributing about 92 percent of the total load from point sources. Combined sewer overflows and separate sanitary sewer overflows contribute relatively small amounts.

Table 213

AVERAGE ANNUAL LOADS OF TOTAL SUSPENDED SOLIDS IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA[a]

County	Point Sources				Nonpoint Sources			Total (pounds)
	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Ozaukee[b]	310	0	0	310	838,280	397,340	1,235,620	1,235,930
Milwaukee	1,160	16,040	6,926,460	6,943,660	2,770,770	126,260	2,897,030	9,840,690
Racine	130	0	0	130	1,932,680	703,620	2,636,300	2,636,430
Total	1,600	16,040	6,926,460	6,944,100	5,541,730	1,227,220	6,768,950	13,713,050
Percent of Total Load	<0.1	0.1	50.5	50.6	40.4	9.0	49.4	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

[b]These loads include those from the Fish Creek subwatershed, which is located in both Ozaukee and Milwaukee Counties, but discharges to Lake Michigan in Ozaukee County.

Source: HydroQual, Inc. and Tetra Tech, Inc.

Table 214

AVERAGE ANNUAL LOADS OF FECAL COLIFORM BACTERIA IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA[a]

County	Point Sources				Nonpoint Sources			Total (trillions of cells)
	SSOs (trillions of cells)	CSOs (trillions of cells)	Sewage Treatment Plants (trillions of cells)	Subtotal (trillions of cells)	Urban (trillions of cells)	Rural (trillions of cells)	Subtotal (trillions of cells)	
Ozaukee[b]	5.87	0.00	0.00	5.87	682.50	60.95	743.45	749.32
Milwaukee	25.07	132.23	2,043.01	2,200.31	1,971.96	43.48	2,015.44	4,215.75
Racine	2.88	0.00	0.00	2.88	1,252.98	50.70	1,303.68	1,306.56
Total	33.82	132.23	2,043.01	2,209.06	3,907.44	155.13	4,062.57	6,271.63
Percent of Total Load	0.5	2.1	32.6	35.2	62.3	2.5	64.8	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

[b]These loads include those from the Fish Creek subwatershed, which is located in both Ozaukee and Milwaukee Counties, but discharges to Lake Michigan in Ozaukee County.

Source: HydroQual, Inc. and Tetra Tech, Inc.

Average annual point source loads of total nitrogen in the Lake Michigan direct drainage area are shown in Table 215. The total average annual point source load of total nitrogen is about 8,263,080 pounds. Almost all of this is contributed by the portions of the Lake Michigan direct drainage area in Milwaukee County. Sewage treatment plants account for close to all of the total nitrogen load, with very small contributions from combined sewer overflows and separate sanitary sewer overflows.

Average annual point source loads of BOD in Lake Michigan direct drainage area are shown in Table 216. The total average annual point source load of BOD is about 7,384,210 pounds. Almost all of this is contributed by the portions of the Lake Michigan direct drainage area in Milwaukee County. Sewage treatment plants contribute almost all of the BOD from point sources.

Table 215

AVERAGE ANNUAL LOADS OF TOTAL NITROGEN IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA[a]

County	Point Sources				Nonpoint Sources			Total (pounds)
	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Ozaukee[b]	10	0	0	10	15,310	9,910	25,220	25,230
Milwaukee	60	1,120	8,261,880	8,263,060	38,940	7,650	46,590	8,309,650
Racine	10	0	0	10	33,130	20,450	53,580	53,590
Total	80	1,120	8,261,880	8,263,080	87,380	38,010	125,390	8,388,470
Percent of Total Load	<0.1	<0.1	98.5	98.5	1.0	0.5	1.5	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

[b]*These loads include those from the Fish Creek subwatershed, which is located in both Ozaukee and Milwaukee Counties, but discharges to Lake Michigan in Ozaukee County.*

Source: HydroQual, Inc. and Tetra Tech, Inc.

Table 216

AVERAGE ANNUAL LOADS OF BIOCHEMICAL OXYGEN DEMAND IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA[a]

County	Point Sources				Nonpoint Sources			Total (pounds)
	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Ozaukee[b]	80	0	0	80	52,360	16,560	68,920	69,000
Milwaukee	320	2,980	7,380,790	7,384,090	162,330	15,420	177,750	7,561,840
Racine	40	0	0	40	119,170	31,920	151,090	151,130
Total	440	2,980	7,380,790	7,384,210	333,860	63,900	397,760	7,781,970
Percent of Total Load	<0.1	<0.1	94.9	94.9	4.3	0.8	5.1	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

[b]*These loads include those from the Fish Creek subwatershed, which is located in both Ozaukee and Milwaukee Counties, but discharges to Lake Michigan in Ozaukee County.*

Source: HydroQual, Inc. and Tetra Tech, Inc.

Average annual point source loads of copper in the Lake Michigan direct drainage area are shown in Table 217. The total average annual point source load of copper is about 10,449 pounds per year. Almost all of this is contributed by the portions of the Lake Michigan direct drainage area in Milwaukee County. Sewage treatment plants contribute essentially all of the copper from point sources.

Nonpoint Source Loads

Because nonpoint source pollution is delivered to streams in the watershed through many diffuse sources, including direct overland flow, numerous storm sewer and culvert outfalls, and swales and engineered channels, it would be prohibitively expensive and time-consuming to directly measure nonpoint source pollution loads to streams. Thus, the calibrated water quality model was applied to estimate average annual nonpoint source

Table 217

AVERAGE ANNUAL LOADS OF COPPER IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA[a]

County	Point Sources				Nonpoint Sources			Total (pounds)
	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	
Ozaukee[b]	<1	0	0	<1	96	13	109	109
Milwaukee	<1	4	10,445	10,449	298	17	315	10,764
Racine	<1	0	0	<1	228	18	246	246
Total	<1	4	10,445	10,449	622	48	670	11,119
Percent of Total Load	<0.1	<0.1	94.0	94.0	5.6	0.4	6.0	100.0

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

[b]*These loads include those from the Fish Creek subwatershed, which is located in both Ozaukee and Milwaukee Counties, but discharges to Lake Michigan in Ozaukee County.*

Source: HydroQual, Inc. and Tetra Tech, Inc.

Table 218

AVERAGE ANNUAL PER ACRE NONPOINT SOURCE POLLUTANT LOADS IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA[a]

County	Total Phosphorus (pounds per acre)	Total Suspended Solids (pounds per acre)	Fecal Coliform Bacteria (trillions of cells per acre)	Total Nitrogen (pounds per acre)	Biochemical Oxygen Demand (pounds per acre)	Copper (pounds per acre)
Ozaukee[b]	0.50	205	0.12	4.18	11.42	0.018
Milwaukee	0.63	275	0.19	4.42	16.85	0.030
Racine	0.62	283	0.14	5.74	16.20	0.026

[a]*Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.*

[b]*These loads include those from the Fish Creek subwatershed, which is located in both Ozaukee and Milwaukee Counties, but discharges to Lake Michigan in Ozaukee County.*

Source: HydroQual, Inc. and Tetra Tech, Inc.

pollutant loads delivered to the streams in the watershed. The results of that analysis are set forth in Tables 211 through 217. General water quality modeling procedures are described in Chapter V of SEWRPC Planning Report No. 50, *A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds.*

Table 211 shows the average annual total nonpoint source pollutant loads for the portions of the Lake Michigan direct drainage area in Milwaukee, Ozaukee, and Racine Counties. Average annual per acre nonpoint source pollution loads for the portions of the Lake Michigan direct drainage area in Milwaukee, Ozaukee, and Racine Counties are shown in Table 218.

The average annual nonpoint load of total phosphorus is estimated to be 15,420 pounds per year. About 4 percent of the total point and nonpoint source load is from urban nonpoint sources and 0.7 percent is from rural nonpoint sources (see Table 212). Contributions of total phosphorus vary among the counties (see Table 212) from about 3,000 pounds per year from Ozaukee County to about 6,650 pounds per year from Milwaukee County. The high load of total phosphorus from the portion of the Lake Michigan direct drainage area in Milwaukee County reflects both the high unit area load (pounds per acre) (see Table 218) and the proportionally large area in the County.

The average annual nonpoint load of total suspended solids is estimated to be 6,768,950 pounds per year. About 40.4 percent of the total point and nonpoint source load is from urban nonpoint sources and about 9.0 percent is from rural nonpoint sources (see Table 213). Contributions of total suspended solids vary among the counties (see Table 213) from about 1,235,620 pounds per year from Ozaukee County to about 2,897,030 pounds per year from Milwaukee County. The high load of total suspended solids from the portion of the Lake Michigan direct drainage area in Milwaukee County reflects both the relatively high unit area load (pounds per acre) and the proportionally large area in the County. The highest unit area loads occur in the portions of the Lake Michigan direct drainage area in Milwaukee and Racine Counties (see Table 218).

The average annual nonpoint source load of fecal coliform bacteria is estimated to be 4,062.57 trillion cells per year. About 62.3 percent of the total point and nonpoint source load is from urban nonpoint sources and about 2.5 percent is from rural nonpoint sources (see Table 214). Contributions of fecal coliform bacteria vary among the counties (see Table 214) from about 743.45 trillion cells per year from Ozaukee County to about 2,015.44 trillion cells per year from Milwaukee County. The high load of fecal coliform bacteria from the portion of the Lake Michigan direct drainage area in Milwaukee County reflects both the high unit area load (see Table 218) and the proportionally large area in the County.

The average annual nonpoint load of total nitrogen is estimated to be 125,390 pounds per year. About 1.0 percent of the total point and nonpoint source load is from urban nonpoint sources and 0.5 percent is from rural nonpoint sources (see Table 215). Contributions of total nitrogen vary among the counties (see Table 215) from about 25,220 pounds per year from Ozaukee County to about 53,580 pounds per year from Racine County. The high load of total nitrogen from the portion of the Lake Michigan direct drainage area in Racine County is due to that county having the highest unit area load (see Table 218).

The average annual nonpoint load of BOD is estimated to be 397,760 pounds per year. About 4.3 percent of the total point and nonpoint source load is from urban nonpoint sources and 0.8 percent is from rural nonpoint sources (see Table 216). Contributions of BOD vary among the counties (see Table 216) from a low of about 68,920 pounds per year from Ozaukee County to about 177,750 pounds per year from Milwaukee County. The high load of BOD from the portion of the Lake Michigan direct drainage area in Milwaukee County is due to both the proportionally large area in the County and to the high unit area load (see Table 218).

The average annual nonpoint load of copper is estimated to be 670 pounds per year. About 5.6 percent of the total point and nonpoint source load is from urban nonpoint sources and 0.4 percent is from rural nonpoint sources (see Table 217). Contributions of copper vary among the counties (see Table 217) from 109 pounds per year from Ozaukee County to 315 pounds per year from Milwaukee County. The high load of copper from the portion of the Lake Michigan direct drainage area in Milwaukee County is due to both the proportionally large area in the County and to the high unit area load (see Table 218).

Wet-Weather and Dry-Weather Loads

Because measured discharge data were unavailable for streams in the Lake Michigan direct drainage area, no estimates of wet-weather and dry-weather loads were made.

ACHIEVEMENT OF WATER USE OBJECTIVES IN THE MILWAUKEE HARBOR ESTUARY, LAKE MICHIGAN DIRECT TRIBUTARY DRAINAGE AREA, AND THE ADJACENT NEARSHORE LAKE MICHIGAN AREAS

The water use objectives and the supporting water quality standards and criteria for the Lake Michigan direct drainage area are documented in Chapter IV of this report. The stream reaches in the Lake Michigan direct drainage area are recommended for fish and aquatic life and full recreational uses. For the most part, the standards applying to Lake Michigan are less clear cut than those applying to inland waters. The Beach Act of 2000 requires that water quality advisories be issued at designated bathing beaches when concentrations of *E. coli* in a single sample exceed 235 cells per ml. This standard was used to assess whether water at beaches and in the nearshore Lake Michigan area were suitable for full recreational use. Because of its direct connection to the estuary and inner harbor, it was decided to compare water quality in the outer harbor to the standards and criteria applicable to the estuary. The estuary is subject to special variances under Chapter NR 104 of the *Wisconsin Administrative Code* under which dissolved oxygen is not to be less than 2.0 mg/l and counts of fecal coliform bacteria are not to exceed 1,000 cells per 100 ml.

An examination of achievement of water use objectives for the portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers that are in the estuary was presented in Chapters V, VI, and VII, respectively of this report. The estuary portions of these Rivers only partially met water use objectives due to exceedances of the variance standard for fecal coliform bacteria and the planning standard for dissolved phosphorus that was recommended under the regional water quality management plan.

For streams in the Lake Michigan direct drainage area, data for assessing achievement of water use objectives were available only for Fish Creek. Data were not available to assess whether Fish Creek met water quality standards associated with the recommended water use objectives during and prior to 1975, the base year of the initial regional water quality management plan, or during review of subsequent data that examined conditions as of 1995.[131]

During the 1998-2004 extended baseline period, the recommended water use objectives were only being partially achieved in Fish Creek. Table 219 shows the results of comparisons of water quality data from the baseline period to supporting water quality standards. Review of data from 1998 to 2004 shows the following:

- Ammonia concentrations in all samples taken at the two sampling stations were under the acute toxicity criterion for fish and aquatic life for ammonia, indicating compliance with the standard.

- Dissolved oxygen concentrations from two stations along Fish Creek were occasionally below the relevant standard, indicating a relatively small degree of noncompliance with the standard.

- Water temperatures in all samples taken from Fish Creek were at or below the relevant standard, indicating compliance with the standard.

- Fecal coliform bacteria standards were commonly exceeded at stations along Fish Creek, indicating frequent violation of the standard.

- Concentrations of total phosphorus in Fish Creek commonly exceeded the planning levels recommended in the initial regional water quality management plan.

Thus, during the baseline period, the stream reaches for which data are available substantially met the standards for ammonia, dissolved oxygen, and water temperature, but less frequently met the regulatory standard for fecal coliform bacteria and the planning standard for phosphorus. Fish Creek only partially achieved the recommended water use objectives. No data were available to assess whether other streams in the Lake Michigan direct drainage area met their recommended water use objectives.

During the 1998-2005 extended baseline period for which beach data were analyzed, the recommended water use objectives were only being partially achieved in public beaches in the Lake Michigan direct drainage area. Table 220 shows the results of comparisons of water quality data from the baseline period to supporting water

[131]*SEWRPC Memorandum Report No. 93,* op. cit.

Table 219

CHARACTERISTICS OF STREAMS IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA: 1998-2004

Stream Reach	Stream Length (miles)	Percent of Samples Meeting Water Quality Standards and Criteria[a]					Fish Biotic Index Rating[a,d]	Macroinvertebrate Biotic Index Rating (HBI)[a,d]	303(d) Impairments[e]
		Dissolved Oxygen	Temperature	NH_3[b]	Total Phosphorus[c]	Fecal Coliform Bacteria			
Fish Creek above W. Port Washington Road	2.3	88.2 (34)	100.0 (34)	100.0 (33)	60.6 (33)	28.1 (32)	- -	- -	- -
Fish Creek between W. Port Washington Road and Broadmoor Drive	0.6	97.1 (34)	100.0 (34)	100.0 (33)	51.5 (33)	33.3 (33)	- -	- -	- -
Unnamed Tributary to Lake Michigan T9N R22E S33	0.6	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Tributary to Lake Michigan T4N R23E S22 NW SW	1.5	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Tributary to Lake Michigan T4N R23E S17 NE SE	2.9	- -	- -	- -	- -	- -	- -	- -	- -

[a]*Number in parentheses indicates number of samples.*

[b]*Based upon the acute toxicity criterion for ammonia.*

[c]*Total phosphorus is compared to the concentration recommended in the regional water quality management plan.*

[d]*The State of Wisconsin has not promulgated water quality standards or criteria for biotic indices.*

[e]*As listed in the Approved Wisconsin 303(d) Impaired Waters List.*

Source: SEWRPC.

Table 220

CHARACTERISTICS OF PUBLIC BEACHES IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA: 1998-2005

Beach	Monitoring Priority in 2005[a]	Percent of Samples Meeting *E. coli* Standard	303(d) Impairments[b]
Lion's Den Nature Preserve	Not monitored	- -	- -
Virmond Park Beach	Not monitored	- -	- -
Doctors Park Beach	Medium	67.1 (108)	Bacteria
Klode Park Beach	Medium	76.4 (104)	- -
Big Bay Park Beach	Not monitored	- -	- -
Atwater Beach	Medium	82.1 (112)	- -
Bradford Beach	High	64.2 (1,130)	Bacteria
Watercraft Beach	High	81.7 (229)	- -
McKinley Beach	High	78.1 (777)	Bacteria
South Shore Beach	High	53.6 (786)	Bacteria
South Shore Beach Rocky Area	High	84.5 (232)	- -
Bay View Park Beach	Medium	81.1 (37)	- -
Sheridan Park Beach	Not monitored	- -	- -
Grant Park Beach	Medium	79.3 (115)	- -
Bender Park Beach	Medium	81.5 (92)	- -
Wind Point Lighthouse Beach	Not monitored	- -	- -
Shoop Park Beach	Not monitored	- -	- -
Parkway Beach	Not monitored	- -	- -
Michigan Boulevard Beach	Not monitored	- -	- -
Zoo Beach	High	87.1 (2,119)	- -
North Beach	High	85.4 (2,461)	- -

[a]Number in parentheses indicates number of samples.

[b]As listed in the Approved Wisconsin 303(d) Impaired Waters List.

Source: SEWRPC.

quality standards. Review of data from 1998 to 2005 shows that concentrations of *E. coli* occasionally exceeded 235 cells per ml at some beaches and frequently exceeded this standard at others.

During the 1998-2004 extended baseline period for which outer Harbor data were analyzed, the variance standards that apply to the estuary were, for the most part, being achieved in the outer harbor. Table 221 shows the results of comparisons of water quality data from the baseline period to supporting water quality standards. Review of data from 1998 to 2004 shows the following:

- Ammonia concentrations in all samples taken in the outer harbor were below the acute toxicity criterion for fish and aquatic life for ammonia, indicating compliance with the standard.

- Dissolved oxygen concentrations in vast majority of samples taken in the outer harbor were above the fish and aquatic life standard of 5.0 mg/l, indicating compliance with the standard.

- Water temperatures in all samples taken from the outer harbor were at or below the relevant standard, indicating compliance with the standard.

- Concentrations of fecal coliform bacteria at most sampling stations in the outer harbor occasionally exceeded 200 cells per 100 ml. At station OH-1 at the confluence with the Milwaukee River, concentrations of fecal coliform bacteria commonly exceeded 200 cells per 100 ml.

Table 221

CHARACTERISTICS OF SAMPLING STATIONS IN THE MILWAUKEE OUTER HARBOR: 1998-2004

Harbor Station	Percent of Samples Meeting Water Quality Standards and Criteria[a]						Fish Biotic Index Rating[a,d]	Macroinvertebrate Biotic Index Rating (HBI)[a,d]	303(d) Impairments[e]
	Dissolved Oxygen	Temperature	NH_3[b]	Total Phosphorus[c]	Fecal Coliform Bacteria	*E. Coli*			
OH-01	95.5 (381)	100.0 (381)	100.0 (366)	84.9 (358)	69.9 (123)	100.0 (29)	- -	- -	Aquatic toxicity, bacteria, fish consumption advisory
OH-02	97.2 (249)	100.0 (249)	100.0 (249)	74.0 (246)	86.3 (80)	88.0 (25)	- -	- -	Aquatic toxicity, bacteria, fish consumption advisory
OH-03	100.0 (441)	100.0 (441)	100.0 (441)	90.7 (421)	75.0 (136)	100.0 (10)	- -	- -	Aquatic toxicity, bacteria, fish consumption advisory
OH-04	100.0 (288)	100.0 (288)	100.0 (279)	96.7 (275)	88.0 (83)	80.0 (10)	- -	- -	Aquatic toxicity, bacteria, fish consumption advisory
OH-05	100.0 (249)	100.0 (249)	100.0 (251)	98.0 (249)	93.9 (66)	- -	- -	- -	Aquatic toxicity, bacteria, fish consumption advisory
OH-07	99.7 (363)	100.0 (363)	100.0 (263)	95.9 (362)	86.7 (113)	100.0 (25)	- -	- -	Aquatic toxicity, bacteria, fish consumption advisory
OH-09	100.0 (246)	100.0 (246)	100.0 (246)	97.5 (244)	88.4 (69)	92.0 (25)	- -	- -	Aquatic toxicity, bacteria, fish consumption advisory
OH-10	99.6 (246)	100.0 (246)	100.0 (246)	98.8 (245)	81.7 (71)	93.0 (25)	- -	- -	Aquatic toxicity, bacteria, fish consumption advisory
OH-11	99.4 (330)	100.0 (330)	100.0 (315)	94.9 (312)	83.2 (95)	90.0 (25)	- -	- -	Aquatic toxicity, bacteria, fish consumption advisory
OH-15	100.0 (132)	100.0 (132)	100.0 (132)	95.3 (129)	93.3 (60)	- -	- -	- -	Aquatic toxicity, bacteria, fish consumption advisory

[a] *Number in parentheses indicates number of samples.*

[b] *Based upon the acute toxicity criterion for ammonia.*

[c] *Total phosphorus is compared to the concentration recommended in the regional water quality management plan.*

[d] *The State of Wisconsin has not promulgated water quality standards or criteria for biotic indices.*

[e] *As listed in the Approved Wisconsin 303(d) Impaired Waters List.*

Source: SEWRPC.

- Concentrations of total phosphorus occasionally exceeded the planning levels recommended in the original regional water quality management plan. This was especially the case at stations located at the mouth of the Milwaukee River and the outfall from the Jones Island WWTP.

It is important to note that about 88 percent of samples of *E. coli* collected in the outer harbor had cell counts below 235 cells per 100 ml, the recreational use criterion promulgated for designated bathing beaches by the USEPA.

An additional issue to consider when examining whether stream reaches are achieving water use objectives is whether toxic substances are present in water, sediment, or tissue of aquatic organisms in concentrations sufficient to impair beneficial uses. Table 222 summarizes the limited data from 1998 to 2004 regarding toxic substances in water, sediment, and tissue from aquatic organisms for the Lake Michigan direct drainage area. For toxicants, the baseline period was extended to 2004 in order to take advantage of results from sampling conducted by the MMSD.

Water samples from the stations along Fish Creek were examined for concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. Detectable concentrations of each of these metals were present in samples from both of the stations. Concentrations of mercury in water in these samples commonly exceeded both the human threshold concentration for public health and welfare and the wildlife criterion for surface water quality. The percent of samples exceeding the lower of these two concentrations, which is the wildlife criterion, is given in Table 222. In addition, the concentration of copper in one water sample from Fish Creek exceeded the EPA's criterion maximum concentration (CMC) for copper, though it is important to note that this occurred when hardness in the stream was unusually low. Also, water samples from both stations along Fish Creek showed detectable concentrations of several PAH compounds.

As noted previously, sediment in the estuary and outer harbor contains concentrations of PCBs and PAHs known to cause impairments of beneficial uses.

The summary above suggests that some beneficial uses are being impaired by the presence of contaminants, especially PCBs and mercury. The fish consumption advisories in effect for Lake Michigan and its tributaries up to the first dam shown in Table 194 and the consumption advisories for waterfowl using the Milwaukee Harbor reflect this.

Section 303(d) of the Clean Water Act requires that the states periodically submit a list of impaired waters to the USEPA for approval. Wisconsin most recently submitted this list in 2004.[132] This list was subsequently approved by the USEPA. The Milwaukee Harbor estuary and outer harbor are classified as being impaired waters. The portions of the Kinnickinnic, Menomonee, and Milwaukee Rivers in the estuary are listed as impaired due to aquatic toxicity, high bacteria concentrations, low concentrations of dissolved oxygen, and fish consumption advisories necessitated by high concentrations of PCBs in the tissue of fish collected from this area. Bacteria, metals, phosphorus, and PCBs from contaminated sediment and a combination of point and nonpoint sources are cited as factors contributing to the impairment of the estuary. The outer harbor is listed as impaired due to aquatic toxicity, high bacteria concentrations, and fish consumption advisories necessitated by high concentrations of PCBs in the tissue of fish collected from this area. Bacteria, metals, and PCBs from contaminated sediment and a combination of point and nonpoint sources are cited as factors contributing to the impairment of the outer harbor.

As shown on Map 137, four public beaches along the Lake Michigan shore in the Lake Michigan direct drainage area are also listed as being impaired. Bradford Beach, Doctors Park Beach, McKinley Beach, and South Shore Beach are considered impaired due to bacteria counts exceeding standards from the Beach Act of 2000.

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[132] *Wisconsin Department of Natural Resources,* Approved 2004 Wisconsin 303(d) Impaired Waters List, *August 2004.*

Table 222

TOXICITY CHARACTERISTICS OF STREAMS IN THE LAKE MICHIGAN DIRECT DRAINAGE AREA: 1998-2004[a]

Stream Reach	Pesticides			Polychlorinated Biphenyls (PCBs)			Polycyclic Aromatic Hydrocarbons (PAHs)			Other Organic Compounds			Metals[b]		
	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue	Water	Sediment	Tissue
Fish Creek above W. Port Washington Road	- -	- -	- -	- -	- -	- -	D (26)[c]	- -	- -	- -	- -	- -	E-75 (8)	- -	- -
Fish Creek between W. Port Washington Road and Broadmoor Drive	- -	- -	- -	- -	- -	- -	D (26)[c]	- -	- -	- -	- -	- -	E-75 (8)	- -	- -
Unnamed Tributary to Lake Michigan T9N R22E S33	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Tributary to Lake Michigan T4N R23E S22 NW SW	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unnamed Tributary to Lake Michigan T4N R23E S17 NE SE	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

NOTE: E-X denotes exceedence of a water quality standard in X percent of the samples, D denotes detection of a substance in this class in at least one sample, N denotes that no substances in this class were detected in any sample.

[a]*Number in parentheses indicates sample size.*

[b]*Metals sampled were arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. For mercury, exceedances were determined based on the wildlife criterion of 1.3 nanograms per liter.*

[c]*This included samples for PAHs in water collected in 2005.*

Source: SEWRPC.

Map 137

IMPAIRED WATERS WITHIN THE AREA DIRECTLY TRIBUTARY TO LAKE MICHIGAN: 2004

SUMMARY

The water quality and pollution sources inventory for the Milwaukee Harbor estuary, outer harbor, Lake Michigan direct drainage area, and nearshore Lake Michigan area system has been summarized by answering five basic questions. This chapter provided detailed information needed to answer the questions. The information is presented below.

How Have Water Quality Conditions Changed Since 1975?

Water quality conditions in the Milwaukee Harbor estuary, outer harbor, Lake Michigan direct drainage area, and nearshore Lake Michigan area have both improved in some respects and declined in other respects since 1975.

Improvements in Water Quality

Concentrations of several pollutants associated with combined sewer overflows such as BOD, fecal coliform bacteria, total phosphorus, and ammonia have decreased in much of the estuary. These reductions in nutrients and oxygen-demanding wastes have produced improvements in concentrations of chlorophyll-*a* and dissolved oxygen at some sampling stations, especially in the estuary during the summer. Decreases in the concentrations of some pollutants have also been detected in the outer harbor. These include decreases in concentrations of ammonia, BOD, fecal coliform bacteria, total nitrogen, and total phosphorus which have resulted in some improvements in chlorophyll-*a* and Secchi depths at some stations in the outer harbor. Values of specific conductance have also decreased in the outer harbor suggesting that concentrations of dissolved materials have decreased. Decreases in the concentrations of some pollutants have also been detected in the nearshore area. Concentrations of ammonia and total nitrogen have decreased. At the same time, improvements in chlorophyll-*a* concentrations and Secchi depths have occurred. Improvements have also occurred in the concentrations of several toxic metals detected in the estuary, outer harbor, and nearshore area. The improvements in concentrations of toxic metals likely reflect both changes in the types of industries present in the watershed, the connection of most process wastewaters to the sanitary sewerage systems, and the implementation of treatment requirements for all industrial discharges.

No Change or Reductions in Water Quality

Water temperature has increased at most stations in the estuary and some stations in the outer harbor. Concentrations of suspended and dissolved pollutants typically associated with stormwater runoff and other nonpoint source pollution, such as chloride, copper and zinc have increased in the estuary and outer harbor. Increases in chloride concentration have also been observed in the nearshore area. Concentrations of some nutrients have increased in some areas. For instance, nitrate has increased at several stations in the estuary, outer harbor, and nearshore area. Total nitrogen has increased at several stations in the estuary. Organic nitrogen has increased at several stations in the outer harbor. In addition, specific conductance has increased at most stations in the estuary, suggesting that the total concentration of dissolved material in the water has increased.

How Have Toxicity Conditions Changed Since 1975?

Toxicity conditions in the Milwaukee Harbor estuary, outer harbor, Lake Michigan direct drainage area, and nearshore Lake Michigan area have both improved in some respects and declined in other respects since 1975.

Improvements in Toxicity Conditions

Tissue concentrations of some pesticides such as dieldrin and chlordane in fish collected from the estuary have decreased. Tissue concentrations of PCBs have decreased in fish collected from the estuary and in lake trout and coho salmon collected from Lake Michigan. Concentrations of PCBs in the open waters of Lake Michigan have decreased, suggesting a similar decrease in the waters of the nearshore area. As noted above, improvements have also occurred in the concentrations of several toxic metals detected in the estuary, outer harbor, and nearshore area.

Worsened Toxicity Conditions

Other toxicity conditions in the Milwaukee Harbor Estuary, outer harbor, and nearshore Lake Michigan area have become worse. Concentrations of the pesticide atrazine and its metabolites have increased in Lake Michigan and are expected to continue increasing. Concentrations of copper in water have increased at some stations in the estuary. Similarly, concentrations of zinc in water have increased at stations in the estuary, outer harbor, and nearshore Lake Michigan area.

Inconclusive Toxicity Data

In some cases, the available data were not adequate to address changes or show little evidence of change. For example, recent sampling shows that PAHs have been detected in water in Fish Creek, but historical data do not exist for this stream. While concentrations of PAHs in water in recent samples from the estuary were lower than concentrations in previous samples, the differences were not statistically significant. Consumption advisories remain in effect for fish from the estuary, outer harbor, and Lake Michigan, including fish from the nearshore Lake Michigan area. Waterfowl consumption advisories remain in effect for four species of ducks using the Milwaukee Harbor.

Sediment Conditions

In the most recent available data on sediment toxicity, the expected incidence of toxicity to benthic organisms at sites in the estuary ranged between 2 percent and 94 percent. Similarly, the expected incidence of toxicity to benthic organisms at sites in the outer harbor ranged between 2 percent and 94 percent. The overall quality of sediment, as measured by mean PEC-Q, remains poor. Sediment in the estuary and outer harbor contains concentrations of cadmium, lead, and copper at levels high enough to pose substantial risks of toxicity to benthic organisms. In addition, sediment in the estuary and outer harbor contains concentrations of other metals, PAHs, and PCBs high enough to likely produce some toxic effects in benthic organisms.

What Are the Sources of Water Pollution?

The Milwaukee River watershed contains several potential sources of water pollution. These fall into two broad categories: point sources and nonpoint sources.

Point Sources

Three public sewage treatment plants currently discharge to Lake Michigan, either directly or through the Milwaukee outer harbor. MMSD has three combined sewer overflow outfalls that discharge to Lake Michigan or the outer harbor. These outfalls convey a combination of stormwater runoff and sanitary sewage from the combined sewer system to the surface water system as a result of high water volume from stormwater, meltwater, and infiltration and inflow of clear water during wet weather conditions. Prior to 1994, overflows from these sites typically occurred around 50 times per year. Since MMSD's inline storage system came online in 1994, the number of combined sewer overflows per year has declined to about three. Since 1995, separate sanitary sewer overflows have been reported at 22 locations: two within MMSD's SSO area and 20 within local communities. The number of SSO events occurring per year has also declined compared to the time period prior to completion of the MMSD Water Pollution Abatement Program facilities in 1993. As of February 2003, 38 industrial dischargers and other point sources were permitted through the WPDES program to discharge wastewater to streams in the Lake Michigan direct drainage area. About two fifths of the permitted facilities discharged noncontact cooling water. The remaining discharges are of a nature which typically meets or exceeds the WPDES permit levels which are designed to meet water quality standards.

Nonpoint Sources

The Lake Michigan direct drainage area is comprised of combinations of urban land uses and rural land uses. As of 2000, about 33 percent of the watershed was in rural and other open land uses. About 94 percent of the watershed is contained within planned sewer service areas: about 38 percent within MMSD's planned service area, 16 percent within the sanitary sewer service areas of local communities that are connected to MMSD's conveyance and treatment systems, 2 percent within the City of Port Washington's planned sewer service area, about 34 percent within the City of Racine's planned sewer service area, and about 4 percent within the City of South Milwaukee's sewer service area. The status of adoption of stormwater management ordinances and/or plans and of construction erosion control ordinances in each community and county in the watershed is set forth in Table 209. That table also indicates which communities have established either stormwater utilities, general funds, or stormwater fee programs. As of 2005, there was one active solid waste landfill within the direct drainage area, located in the Village of Caledonia. As set forth in Table 210 and shown on Map 136, there are three inactive landfills in or adjacent to the direct drainage area. All are in the City of Oak Creek.

Quantification of Pollutant Loads

The annual average load of BOD to streams of the Lake Michigan direct drainage area and directly to Lake Michigan is estimated to be 7,781,970 pounds per year. Sewage treatment plants contribute about 94.9 percent of this load. Combined sewer overflows and separate sanitary sewer overflows each contribute less than 0.1 percent of this load. The rest of BOD load to streams in the Lake Michigan direct drainage area and directly to Lake Michigan, 5.1 percent, is contributed mainly by urban nonpoint sources.

The annual average load of TSS to streams of the Lake Michigan direct drainage area and directly to Lake Michigan is estimated to be 13,713,050 pounds per year. Sewage treatment plants, combined sewer overflows, and separate sanitary sewer overflows contribute 50.5 percent, 0.1 percent, and less than 0.1 percent, respectively, of this load. The rest of the TSS load to streams in the Lake Michigan direct drainage area and directly to Lake Michigan, about 49.4 percent, is contributed by nonpoint sources, with 40.4 percent from urban sources and 9.0 percent from rural sources.

The annual average load of fecal coliform bacteria to streams of the Lake Michigan direct drainage area and directly to Lake Michigan is estimated to be 6,271.63 trillion cells per year. Sewage treatment plants, combined sewer overflows, and separate sanitary sewer overflows contribute 32.6 percent, 2.1 percent, and about 0.5 percent, respectively, of this load. The rest of the fecal coliform bacteria load to streams in the Lake Michigan direct drainage area and directly to Lake Michigan, about 64.8 percent, is contributed by nonpoint sources, with 62.3 percent from urban sources and 2.5 percent from rural sources.

The annual average load of total phosphorus to streams of the Lake Michigan direct drainage area and directly to Lake Michigan is estimated to be 332,170 pounds per year. Sewage treatment plants contribute about 95.3 percent of this load. Combined sewer overflows and separate sanitary sewer overflows each contribute less than 0.1 percent of this load. The rest of total phosphorus loadings to streams in the Lake Michigan direct drainage area and directly to Lake Michigan, about 4.7 percent, are contributed by nonpoint sources, with 4.0 percent from urban sources and 0.7 percent from rural sources.

What is the Current Condition of the Fishery?

The Milwaukee Harbor estuary and nearshore areas of the Lake Michigan fishery are inextricably linked to the quality, diversity, and abundance of the fishery as well as the entire food web of Lake Michigan. In general, the removal of the North Avenue dam along with point source and combined sewer overflow pollution abatement has opened up many opportunities to enhance fishing in the area through improved water quality and increased river access for both resident and migratory fish.

Addition of instream structure and bank stabilization measures added to the complexity of structure and fish cover for both resident, as well as migratory species. Dam removal and habitat improvements are key fisheries management tools that are pivotal if native species are to be restored in these once degraded areas. Because of the dam removal, WDNR initiated two native species restoration plans, walleye and lake sturgeon, in the Milwaukee Harbor estuary. These restoration efforts help to develop a more vital and diverse fish community. In addition, the removal of the North Avenue dam significantly enhanced fishing opportunities by opening up several river miles for migratory salmonids and resident native species.

To What Extent Are Water Use Objectives and Water Quality Standards Being Met?

During the 1998 to 2004 extended study baseline period, the Milwaukee Harbor estuary partially met the water quality criteria supporting its recommended water use classification. In all of the samples taken from the estuary, concentrations of ammonia were in compliance with the relevant water quality standards. In almost all of the samples from the estuary, temperatures were in compliance with the relevant water quality standards. In the majority of samples, dissolved oxygen concentrations equaled or exceeded the 2.0 mg/l special variance standard applying to the estuary. Concentrations of fecal coliform bacteria in the estuary were usually less than or equal to the variance standard of 1,000 cells per 100 ml. While the rate of compliance varied among stations, it was generally between 20 percent and 77 percent. Compliance with the planning standard for total phosphorus recommended in the original regional water quality management plan was also low with the number of samples showing total phosphorus below the 0.1 mg/l planning standard ranging from 37 to 75 percent at stations in the estuary.

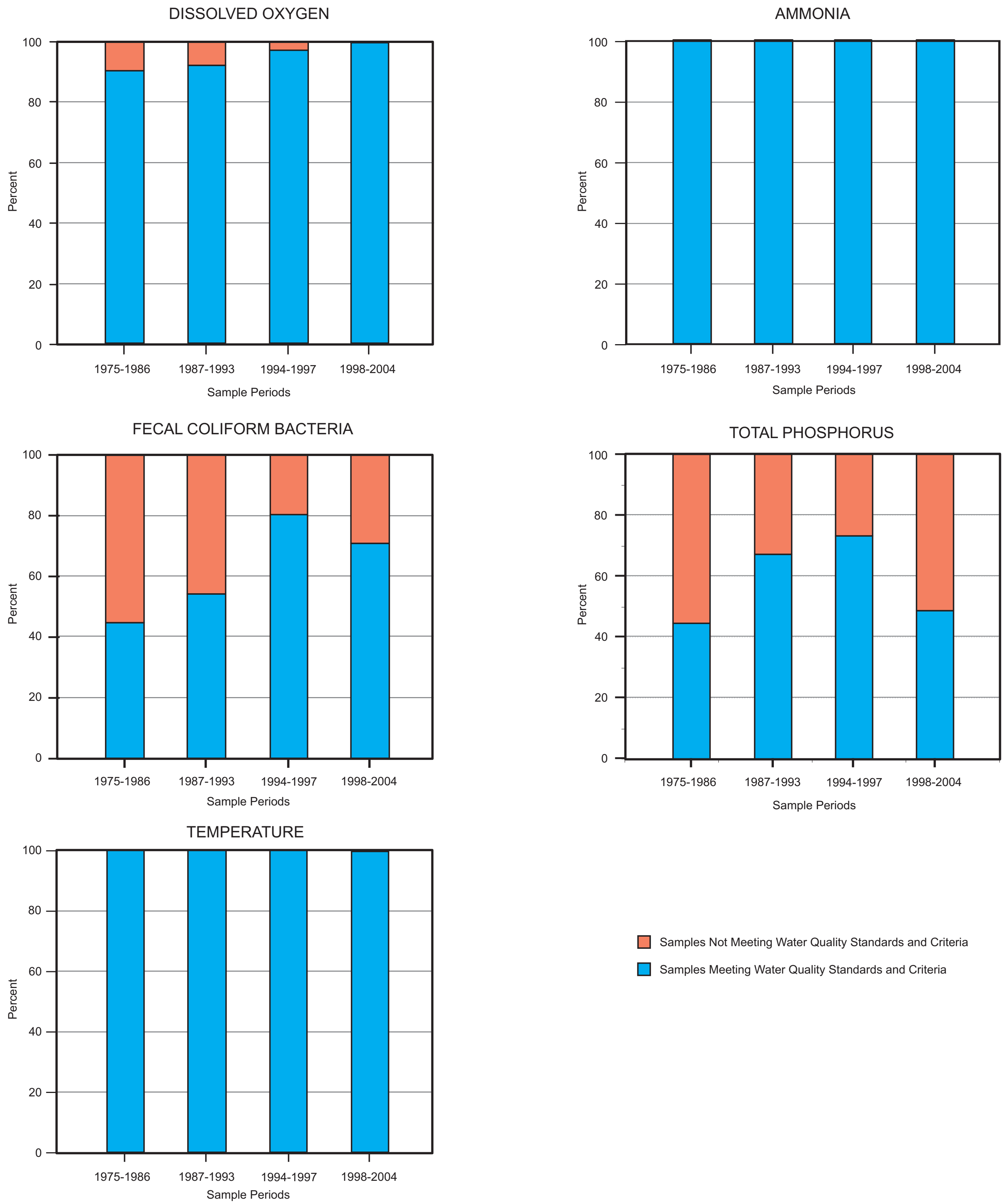
Figure 362 shows changes over the entire study period of 1975-2004 in the proportions of samples showing compliance with applicable water quality standards for the Milwaukee Harbor estuary. Over the entire study period, ammonia concentrations were in compliance with the applicable water quality standards in all of the samples. Over that same period, temperatures were in compliance with the applicable water quality standards in almost all of the samples. A small percentage of samples in each period had concentrations of dissolved oxygen that were not in compliance with the variance standard applicable to the estuary. Compliance with this standard increased from about 90 percent of samples during the period 1975-1986 to over 99 percent of samples during the period 1998-2004. By contrast, a significant percentage of samples collected in each period had concentrations of fecal coliform bacteria or total phosphorus that were not in compliance with the applicable regulatory or planning water quality standard. The rate of compliance with the planning standard recommended for total phosphorus increased over much of the study period, but showed a decrease in the 1998-2004 baseline period. During the period 1975-1986, total phosphorus concentrations were less than or equal to 0.1 mg/l in about 45 percent of the samples collected. By the period 1994-1997, this rate of compliance had increased to 73 percent. During the baseline period of 1998-2004, the rate of compliance with the recommended total phosphorus standard decreased to 49 percent. The rate of compliance with the applicable standards for fecal coliform bacterial followed a similar pattern. The percentage of samples in which the concentrations of fecal coliform bacteria were equal to or below the applicable standard increased from about 45 percent during the period 1975-1986 to about 80 percent during the period 1994-1997. During the 1998-2004 baseline period this rate of compliance decreased to about 71 percent.

During the 1998 to 2004 extended study baseline period, the Milwaukee outer harbor partially met the water quality criteria applicable to the Milwaukee Harbor estuary. In all of the samples taken from the outer harbor, concentrations of ammonia and temperatures were in compliance with the water quality standards applicable to the estuary. In almost all of the samples from the outer harbor, dissolved oxygen concentrations equaled or exceeded the 2.0 mg/l special variance standard applying to the estuary. Concentrations of fecal coliform bacteria in the estuary were usually less than or equal to the variance standard of 1,000 cells per 100 ml. Concentrations of total phosphorus were usually less than or equal to the 0.1 mg/l planning standard. In the majority of samples from the outer harbor, concentrations of *E. coli* bacteria were below the standard of 235 cells per 100 ml promulgated by the USEPA for coastal and Great Lakes recreation waters.

Figure 363 shows changes over time in the proportions of samples showing compliance with applicable water quality standards for the Milwaukee outer harbor. Over the entire study period of 1975-2004, ammonia concentrations were in compliance with the water quality standards applicable to the estuary in all of the samples. Over that same period, temperatures were in compliance with the applicable water quality standards in all of the samples. A small percentage of samples during the period 1987-1993 had concentrations of dissolved oxygen that were not in compliance with the variance standard applicable to the estuary. During all other periods, dissolved oxygen concentrations were above the variance standard applicable to the estuary in all samples. A small percentage of samples collected in each period had concentrations of fecal coliform bacteria or total phosphorus that were not in compliance with the water quality standard applicable to the estuary. The rate of compliance with the standard for fecal coliform bacteria increased after 1994 from about 94 percent of samples to about 99 percent of samples. During the period 1975-1986, total phosphorus concentrations were less than or equal to the 0.1 mg/l planning standard recommended in the original regional water quality management plan in about 93 percent of the samples collected. By the period 1994-1997, this rate of compliance had increased to 98 percent. During the baseline period of 1998-2004, the rate of compliance with the recommended total

Figure 362

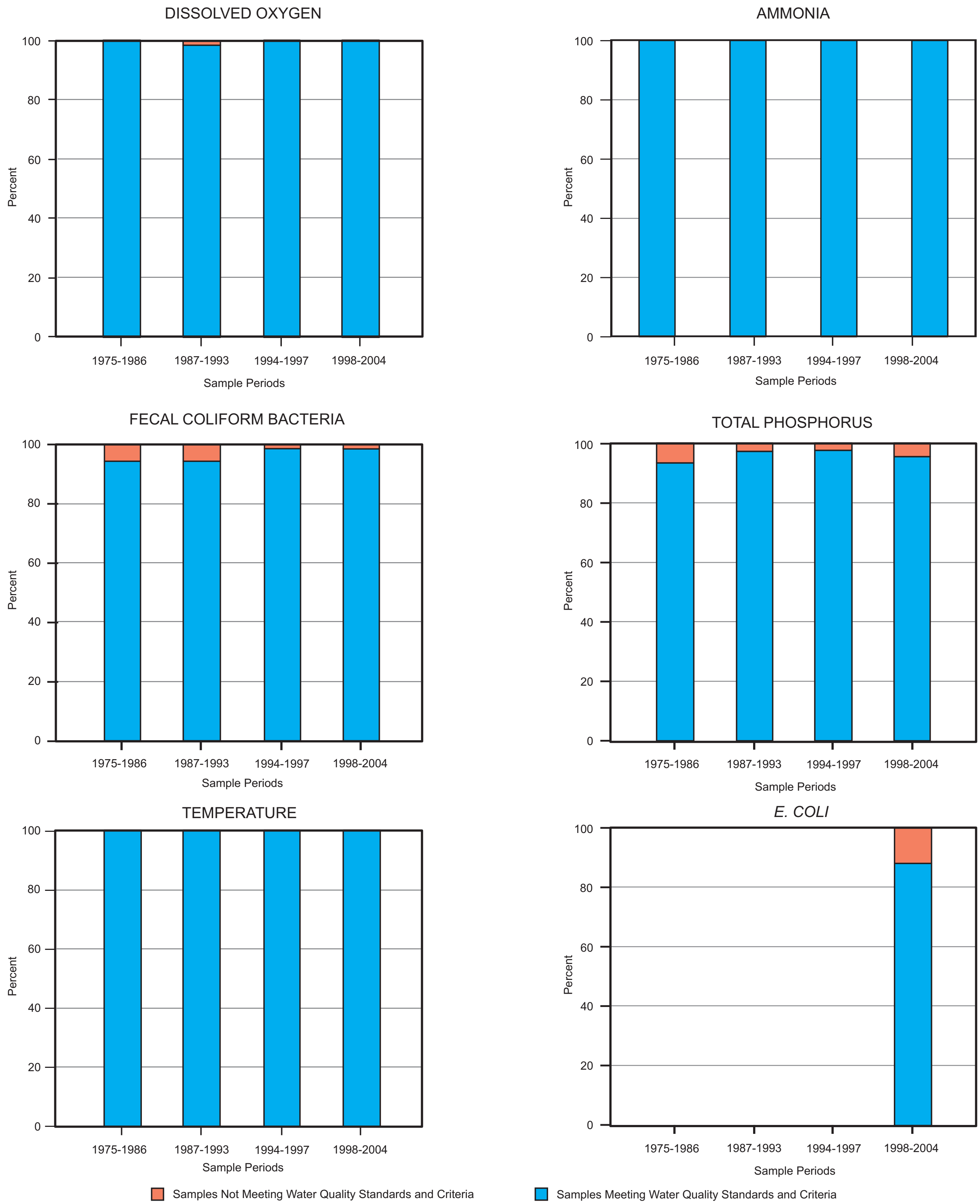
PROPORTION OF SAMPLES MEETING WATER QUALITY STANDARDS AND CRITERIA FOR SEVERAL CONSTITUENTS IN THE MILWAUKEE HARBOR ESTUARY: 1975-2004



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Milwaukee Metropolitan Sewerage District, and SEWRPC.

Figure 363

PROPORTION OF SAMPLES MEETING WATER QUALITY STANDARDS AND CRITERIA FOR SEVERAL CONSTITUENTS IN THE MILWAUKEE OUTER HARBOR: 1975-2004



Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

phosphorus standard decreased slightly to 96 percent. The rate of compliance with the applicable standards for *E. coli* during the period 1998-2004 was about 88 percent. No data were available for concentrations of *E. coli* from earlier periods.

The percentages of samples from public bathing beaches along Lake Michigan less than or equal to the standard of 235 cells per 100 ml promulgated by the USEPA for coastal and Great Lakes recreation waters, varied from about 54 percent to 87 percent.

The Milwaukee Harbor estuary and outer harbor are listed as impaired pursuant to Section 303(d) of the Clean Water Act. The estuary is considered impaired due to aquatic toxicity, bacterial contamination, concentrations of dissolved oxygen which do not meet the applicable water quality standard, and fish consumption advisories necessitated by the concentrations of PCBs in the tissue of fish collected from it. The outer harbor is considered impaired due to aquatic toxicity, bacterial contamination, and fish consumption advisories necessitated by the concentrations of PCBs in the tissue of fish collected from it. In addition, four Lake Michigan public beaches, Bradford Beach, Doctors Park Beach, McKinley Beach, and South Shore beach are considered impaired due to bacteria concentrations which often exceed the standard for recreational waters.

Chapter XI

GROUNDWATER QUALITY CONDITIONS AND SOURCES OF POLLUTION IN THE STUDY AREA

INTRODUCTION

The surface waters in lakes and streams and in the associated wetlands and floodlands and the groundwater aquifers underlying the Region, form important elements of the natural resource base of the Greater Milwaukee Watersheds study area. The contribution of these resources to social and economic development, to recreational activities, to ecology, and to aesthetic quality is immeasurable. Lake Michigan is a major source of water for municipal and industrial users in the most intensely developed areas of the study area, which lies entirely to the east of the subcontinental divide. The underlying groundwater aquifers constitute a major source of supply for domestic, municipal, and industrial water users in areas of the Region lying west of the subcontinental divide, as well as for some parts of the study area lying east of the subcontinental divide primarily in Dodge, Fond du Lac, Ozaukee, Sheboygan, and Washington Counties, and in portions of Racine and Waukesha Counties.

Understanding the interaction of the surface water and groundwater resources of the study area and the Region is essential to sound water quality management planning.[1] The surface and groundwater of the Region are interrelated components of, in effect, a single hydrologic system. The groundwater resources of the Region are hydraulically connected to the surface water resources inasmuch as the former provide the base flow of streams, and the water levels of wetlands and inland lakes. Surface waters interact with groundwater in three basic ways: surface waters gain water from inflow of groundwater; lose water from outflow to surface waters; or both gain and lose water from groundwater, depending upon the reaches and locations involved and other factors, such as precipitation patterns. Through those interactions, the quantity and quality of surface water affects the quantity and quality of groundwater and vice versa. Thus, the analyses of existing conditions, and the evaluation of alternative and recommended plans developed under this planning program recognize the existence of such impacts. Surface water conditions are described and evaluated in depth in the preceding chapters of this report.

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[1]*Although this chapter focuses on groundwater quality and sources of pollution in the Greater Milwaukee Watersheds study area, because groundwater movement is not constrained by the surface watershed boundaries that define the study area, references to the Southeastern Wisconsin Region are used to recognize that groundwater characteristics in the study area are influenced by factors occurring beyond the boundaries of that area. For example, significant groundwater recharge areas for the deep aquifer are located in the western parts of the Region and beyond.*

Water Supply Sources

As shown on Map 138, areas served by municipal water utilities in 2000 encompassed about 256 square miles, or about 23 percent of the total area of the regional water quality management plan study area. An estimated 1,155,683 persons, or about 90 percent of the population of the study area, were served by municipal water utilities in 2000. In addition, urban areas not served by municipal water supplies constitute about 61 square miles, or about 5 percent of the study area. Municipal water supply facilities in the study area, and the sources of that water supply, are listed in Table 223.

In addition to publicly owned municipal water utilities, there are numerous privately or cooperatively owned water systems operating in the study area that are not owned by municipalities or other public entities.[2] These water supply systems typically serve residential subdivisions, apartment or condominium developments, mobile home parks, and institutions. The areas served by such systems are shown on Map 138. This map distinguishes those municipal water supply systems which currently utilize Lake Michigan as a source of supply and those systems which utilize groundwater as a source of supply. In addition, all of the systems in the study area that are not owned by municipalities or other public entities utilize groundwater as a source of supply.

The entire study area is located within the Great Lakes-St. Lawrence River drainage basin. Thus, the use of Lake Michigan as a source of water supply is not a limitation from regulatory and policy considerations. However, given the distance from Lake Michigan and the availability of groundwater resources, much of the study area is expected to continue to rely upon groundwater as a source of supply.

Tables 224 and 225 illustrate the water uses and sources of supply for the nine counties within, or partially within, the study area. As can be seen by review of Table 224, the greatest use of water within the counties located within, or partially within, the study area is for electric power generation, comprising about 87 percent of the usage. Most of the water used for electric power generation is returned to Lake Michigan following use. As shown in Table 225, Lake Michigan supplies about 77 percent of the public water, while groundwater supplies the remaining 23 percent. Lake Michigan supplies 96 percent of total water use, while groundwater supplies the remaining 4 percent.

Regional Groundwater Studies

SEWRPC, working with the U.S. Geological Survey (USGS), Wisconsin Geological and Natural History Survey (WGNHS), the University of Wisconsin-Milwaukee (UWM), and the Wisconsin Department of Natural Resources (WDNR), recently completed two major groundwater studies for the Region that will be important resources for regional and local planning. These studies include a regional groundwater inventory and analysis and the development of a regional groundwater aquifer simulation model. The groundwater inventory and analysis findings are presented in SEWRPC Technical Report No. 37 (TR No. 37), *Groundwater Resources of Southeastern Wisconsin,* June 2002. The aquifer simulation model is documented in SEWRPC Technical Report No. 41 (TR No. 41), *A Regional Aquifer Simulation Model for Southeastern Wisconsin*, June 2005. In addition, the third, and final, component of the SEWRPC regional groundwater planning program is underway and is documented in SEWRPC Planning Report No. 52, *A Regional Water Supply Plan for Southeastern Wisconsin*, in progress. Important groundwater recharge areas will be identified under the regional water supply planning program. Delineation of those areas will utilize the results of the inventory and analysis work and the aquifer model. In addition, the WDNR in conjunction with local water utilities has undertaken an effort to identify areas of contribution to municipal wells that can be used for well protection planning.

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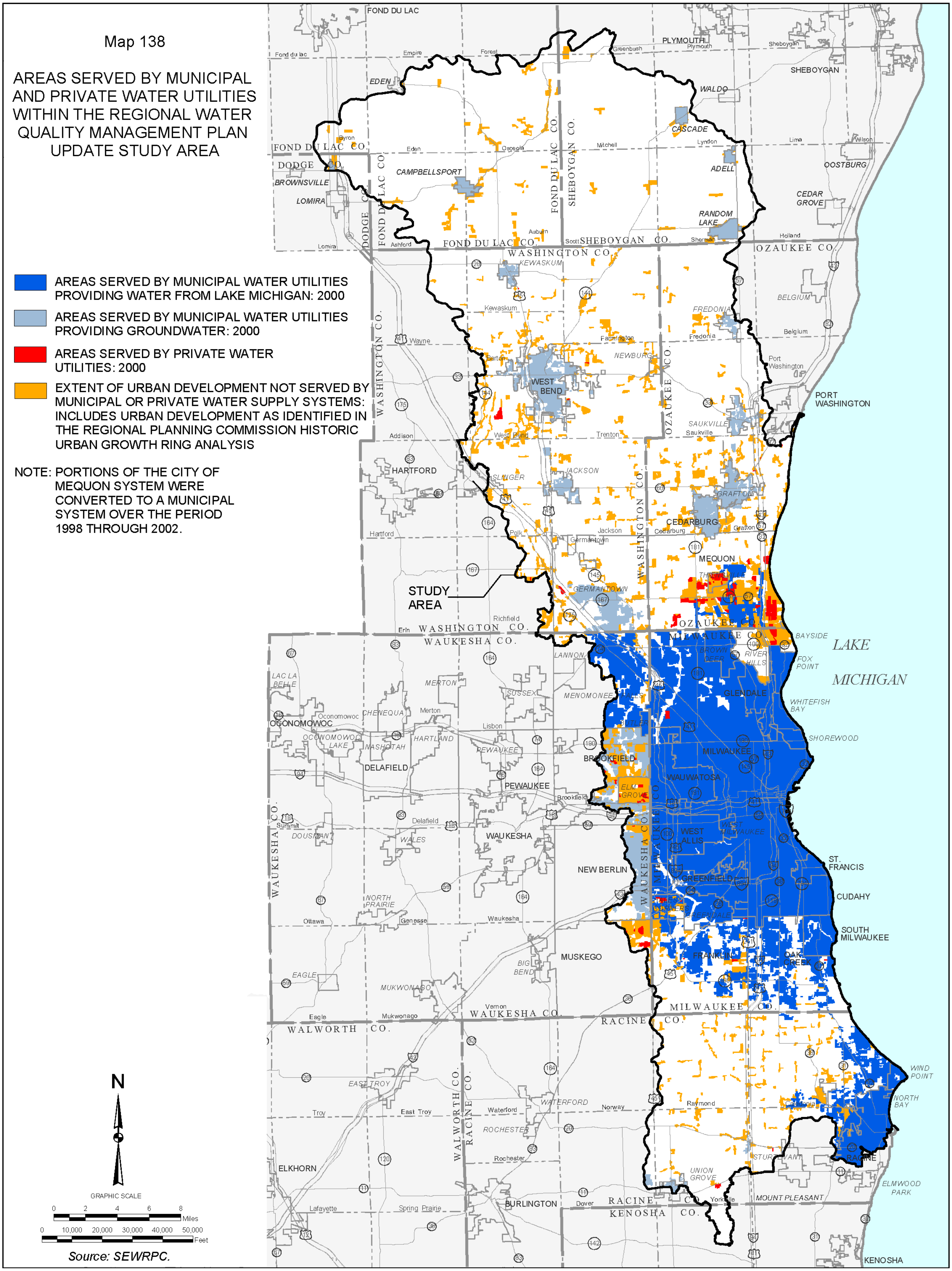
[2]*For regulatory purposes, a public water supply system is defined as one that provides drinking water to the public. This definition applies to both publicly owned and privately owned systems. For planning purposes, it is important to distinguish between such systems.*



Map 138

AREAS SERVED BY MUNICIPAL AND PRIVATE WATER UTILITIES WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA

- AREAS SERVED BY MUNICIPAL WATER UTILITIES PROVIDING WATER FROM LAKE MICHIGAN: 2000
- AREAS SERVED BY MUNICIPAL WATER UTILITIES PROVIDING GROUNDWATER: 2000
- AREAS SERVED BY PRIVATE WATER UTILITIES: 2000
- EXTENT OF URBAN DEVELOPMENT NOT SERVED BY MUNICIPAL OR PRIVATE WATER SUPPLY SYSTEMS: INCLUDES URBAN DEVELOPMENT AS IDENTIFIED IN THE REGIONAL PLANNING COMMISSION HISTORIC URBAN GROWTH RING ANALYSIS

NOTE: PORTIONS OF THE CITY OF MEQUON SYSTEM WERE CONVERTED TO A MUNICIPAL SYSTEM OVER THE PERIOD 1998 THROUGH 2002.

Source: SEWRPC.

Table 223

MUNICIPAL WATER UTILITY FACILITIES WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA

Water Utility Facility		Watershed						Water Supply Source		
								Local Municipal		
Name	Class[a]	Kinnickinnic River	Menomonee River	Milwaukee River	Oak Creek	Root River	Lake Michigan Direct Drainage Area	Groundwater	Lake Michigan	Other
Dodge County										
Village of Lomira Municipal Water Utility	D	- -	- -	X	- -	- -	- -	X	- -	- -
Fond du Lac County										
Campbellsport Municipal Water Utility	D	- -	- -	X	- -	- -	- -	X	- -	- -
Milwaukee County										
Village of Brown Deer Public Water Utility	AB	- -	- -	X	- -	- -	- -	- -	- -	X[b]
City of Cudahy Water Utility	AB	X	- -	- -	X	- -	X	- -	X	- -
City of Franklin Water Utility	C	- -	- -	- -	X	X	- -	- -	- -	X[c]
Village of Fox Point Water Utility	C	- -	- -	X	- -	- -	- -	- -	- -	X[d]
City of Glendale Water Utility	AB	- -	- -	X	- -	- -	- -	- -	- -	X[d]
Village of Greendale Water Utility	AB	- -	X	- -	- -	X	- -	- -	- -	X[b]
City of Milwaukee Water Works[e]	AB	X	X	X	X	X	X	- -	X	- -
City of Oak Creek Water and Sewer Utility	AB	- -	- -	- -	X	X	X	- -	X	- -
Village of Shorewood Municipal Water Utility	C	- -	- -	X	- -	- -	X	- -	- -	X[b]
Village of Bayside (We Energies Water Services)[f]	N/A	- -	- -	- -	- -	- -	X	- -	- -	X[d]
City of South Milwaukee Water Utility	AB	- -	- -	- -	X	- -	X	- -	X	- -
City of Wauwatosa Water Utility	AB	- -	X	- -	- -	- -	- -	- -	- -	X[b]
City of West Allis Water Utility	AB	X	- -	X	- -	X	- -	- -	- -	X[b]
Village of West Milwaukee	N/A	X	X	- -	- -	- -	- -	- -	- -	X[b]
Village of Whitefish Bay Water Utility	AB	- -	- -	X	- -	- -	X	- -	- -	X[d]
Ozaukee County										
City of Cedarburg Light & Water Commission	AB	- -	- -	X	- -	- -	- -	X	- -	- -
Village of Fredonia Municipal Water Utility	D	- -	- -	X	- -	- -	- -	X	- -	- -
Village of Grafton Water and Wastewater Commission	C	- -	- -	X	- -	- -	- -	X	- -	- -
City of Mequon Water Utility (We Energies Water Services)[f]	D	- -	- -	X	- -	- -	X	- -	- -	X[b]
Village of Saukville Municipal Water Utility	C	- -	- -	X	- -	- -	- -	X	- -	- -
Racine County										
Village of Caledonia Water Utility District No. 1	C	- -	- -	- -	- -	X	X	- -	- -	X[g]
City of Racine Water and Wastewater Utility	AB	- -	- -	- -	- -	X	X	- -	X	- -
Village of Union Grove Municipal Water Utility	C	- -	- -	- -	- -	X	- -	X	- -	- -
Village of Wind Point Municipal Water Utility	D	- -	- -	- -	- -	- -	X	- -	- -	X[g]
Town of Yorkville Water Utility District No. 1	D	- -	- -	- -	- -	X	- -	X	- -	- -
Caddy Vista Sanitary District	D	- -	- -	- -	- -	X	- -	- -	- -	X[h]
Crestview Sanitary District	D	- -	- -	- -	- -	- -	X	- -	- -	X[h]
North Park Sanitary District No. 1	C	- -	- -	- -	- -	X	X	- -	- -	X[g,h]

Table 223 (continued)

Water Utility Facility		Watershed						Water Supply Source		
								Local Municipal		
Name	Class[a]	Kinnickinnic River	Menomonee River	Milwaukee River	Oak Creek	Root River	Lake Michigan Direct Drainage Area	Groundwater	Lake Michigan	Other
Sheboygan County										
Village of Adell Water and Sewer Utility	D	- -	- -	X	- -	- -	- -	X	- -	- -
Village of Cascade Water Utility	D	- -	- -	X	- -	- -	- -	X	- -	- -
Village of Random Lake Municipal Water Department	D	- -	- -	X	- -	- -	- -	X	- -	- -
Washington County										
Village of Germantown Water Utility	AB	- -	X	- -	- -	- -	- -	X	- -	- -
Village of Jackson Water Utility	C	- -	- -	X	- -	- -	- -	X	- -	- -
Village of Kewaskum Municipal Water Utility	C	- -	- -	X	- -	- -	- -	X	- -	- -
City of West Bend Water Utility	AB	- -	- -	X	- -	- -	- -	X	- -	- -
Waukesha County										
City of Brookfield Municipal Water Utility	AB	- -	X	- -	- -	- -	- -	X	- -	- -
Village of Butler Public Water Utility	C	- -	X	- -	- -	- -	- -	- -	- -	X[b]
Village of Menomonee Falls Water Utility	AB	- -	X	- -	- -	- -	- -	- -	- -	X[b]
City of Muskego Public Water Utility	C	- -	- -	- -	- -	X	- -	X	- -	- -
City of New Berlin Water Utility	AB	- -	X	- -	- -	X	- -	X	- -	X[b]

[a]*The municipal water and combined water and sewer utilities are based upon the number of customers as follows: Class AB – 4,000 or more customers; Class C – From 1,000 to less than 4,000 customers; and Class D – Less than 1,000 customers.*

[b]*City of Milwaukee Water Works.*

[c]*City of Milwaukee Water Works and City of Oak Creek Water and Sewer Utility.*

[d]*North Shore Water Utility.*

[e]*Provides retail water supply services to the Cities of Greenfield and St. Francis, a portion of the City of Franklin and Village of Hales Corners.*

[f]*The We Energies Water Services, a private water utility, provides water supply service to portions of the Village of Bayside and the City of Mequon.*

[g]*City of Racine Water and Wastewater Utility.*

[h]*City of Oak Creek Water and Sewer Utility.*

Source: Public Service Commission of Wisconsin and SEWRPC.

Table 224

ESTIMATED USE OF WATER WITHIN THE COUNTIES LOCATED WITHIN, OR PARTIALLY WITHIN, THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA (IN MILLION GALLONS PER DAY)[a]

County	Domestic	Agricultural	Irrigation	Industrial	Commercial	Thermo-Electric	Public Use and Losses	Total
Dodge	4.03	2.90	0.16	4.06	1.34	0.00	1.76	14.25
Fond du Lac	6.06	2.11	0.15	4.82	2.56	22.33	3.37	41.39
Kenosha	7.02	0.18	0.25	4.44	2.95	15.21	3.89	33.94
Milwaukee	54.06	0.01	0.81	57.92	33.14	1,867.56	43.60	2,057.10
Ozaukee	4.11	0.32	0.51	1.88	1.08	118.78	1.42	128.09
Racine	13.00	1.80	2.16	10.82	5.22	0.00	6.87	39.86
Sheboygan	8.12	2.02	0.40	6.21	3.75	487.55	4.94	512.99
Washington	5.64	0.62	0.31	2.55	1.84	2.89	2.42	16.26
Waukesha	14.12	0.27	2.68	9.10	5.07	0.00	6.67	37.90
Total	116.16	10.23	7.43	101.80	56.95	2,514.32	74.94	2,881.78
Percent of Total	4.03	0.35	0.26	3.53	1.98	87.25	2.60	100.00

[a] *Includes all water use for the entire counties, including those only partially within the study area.*

Source: B.R. Ellefson, G.D. Mueller, and C.A. Buchwald, U.S. Geological Survey, "Water Use in Wisconsin, 2000."

Table 225

ESTIMATED SOURCE OF WATER SUPPLY WITHIN THE COUNTIES LOCATED WITHIN, OR PARTIALLY WITHIN, THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA (IN MILLION GALLONS PER DAY)[a]

County	Public Water Supply Use[b]			Total Water Use		
	Surface Water	Groundwater	Total	Surface Water	Groundwater	Total
Dodge	0.00	7.04	7.04	0.30	13.95	14.25
Fond du Lac	0.00	13.47	13.47	22.52	18.87	41.39
Kenosha	15.47	0.08	15.55	31.25	2.69	33.94
Milwaukee	173.65	0.75	174.40	2,050.78	6.32	2,057.10
Ozaukee	1.43	4.24	5.67	120.29	7.80	128.09
Racine	23.72	3.75	27.47	26.23	13.63	39.86
Sheboygan	15.50	4.26	19.76	503.56	9.43	512.99
Washington	0.00	9.67	9.67	2.96	13.30	16.26
Waukesha	0.00	26.67	26.67	0.34	37.56	37.90
Total	229.77	69.93	299.70	2,758.23	123.55	2,881.78
Percent of Total	76.70	23.30	100.00	95.71	4.29	100.00

[a] *Includes all water use for the entire counties, including those only partially within the study area.*

[b] *Includes water delivered to residents, industry, and commerce within the served area.*

Source: B.R. Ellefson, G.D. Mueller, and C.A. Buchwald, U.S. Geological Survey, "Water Use in Wisconsin, 2000."

DESCRIPTION OF GROUNDWATER AQUIFERS

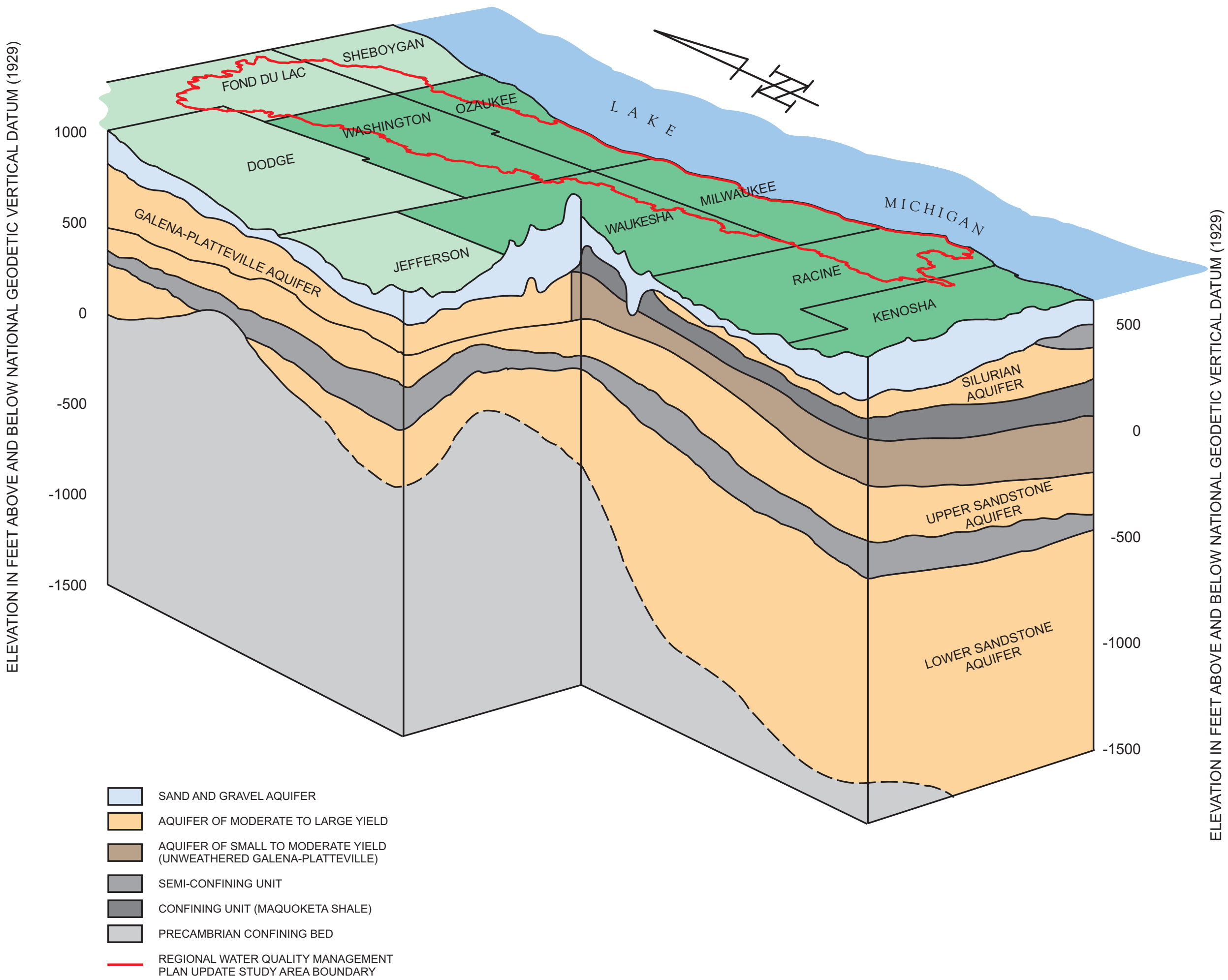
Geology and Groundwater Resources[3]

Individual hydrogeologic units within the Region differ widely in their ability to yield water to wells (see Figure 364 and Table 226). From the standpoint of groundwater occurrence, all rock formations that underlie the Region can be classified either as aquifers or as confining beds. An aquifer is a rock formation or sand and gravel

[3] *A more-detailed description of the areal extent and lithology of aquifers and confining units, including water table depth and elevation mapping can be found in SEWRPC Technical Report No. 37,* Groundwater Resources of Southeastern Wisconsin, *June 2002.*

Figure 364

AQUIFER SYSTEMS IN SOUTHEASTERN WISCONSIN



Source: Eaton, 1997; Mai and Dott, 1985; Peters, 1997; and Young, 1992.

unit that will yield water in a useable quantity to a well or spring. A confining bed, such as shale or siltstone, is a unit having relatively low permeability that restricts the movement of groundwater either into or out of adjacent aquifers and does not yield water in useable amounts to wells and springs.

In general, groundwater occurs within three major aquifers that underlie the study area. From the land's surface downward, they are: 1) the sand and gravel deposits in the glacial drift; 2) the shallow dolomite strata in the underlying bedrock; and 3) the deeper sandstone, dolomite, siltstone, and shale strata. Because of their proximity to the land's surface and hydraulic interconnection, the first two aquifers are commonly referred to collectively as the "shallow aquifer," while the latter is referred to as the deep aquifer. Within the study area, the shallow and deep aquifers are separated by the Maquoketa shale, which forms a relatively impermeable barrier between the two aquifers (see Figure 364).

The aquifers of southeastern Wisconsin extend to depths reaching in excess of 1,500 feet in the eastern parts of the Region, including the regional water quality management plan update study area. The general characterization of three major aquifers set forth above can be refined to group rock formations within the study area into five

Table 226

HYDROGEOLOGIC UNITS OF SOUTHEASTERN WISCONSIN

Geologic Age	Rock Unit		Hydrogeologic Unit	Water Yield
Quaternary	Undifferentiated		Sand and gravel aquifer	Small to large yields; thick sections yield several hundred gallons per minute
Devonian	Antrim Fm.[1]		Semi-confining unit	Yields little water
	Milwaukee Fm.[1]			
	Thiensville Fm.[1]		Silurian dolomite aquifer	Small to large yields (10s – 100s gpm) depending upon lithology and number and size of solution channels and fractures. Main water-producing units: Thiensville, basal member of Racine, and Mayville (Rovey and Cherkauer, 1994a)
Silurian	Waubekee Fm.[1]			
	Racine Fm.[2]			
	Waukesha Fm.[2]			
	Brandon Bridge beds[2]			
	Byron Fm.[2]			
	Mayville Fm.[2]			
Ordovician	Maquoketa Fm.[2]		Confining unit	Yields little or no water
	Sinnipee Group	Galena Fm.	Galena-Platteville aquifer	Yields little water where overlain by Maquoketa Formation. Commonly yields a few tens of gpm west of Maquoketa
		(Decorah Fm.)[3]		
		Platteville Fm.		
	Ancell Group	(Glenwood Fm.)[3]	Upper sandstone aquifer	Moderate to large yields (100-500 gpm)
		St. Peter Fm.		
	Prairie du Chien Group	Shakopee Fm.[2]		Small yields (10s of gpm)
		Oneota Fm.[2]		
Cambrian	Trempealeau Group	Jordan Fm.[2]		Moderate yields (100s gpm)
		St. Lawrence Fm.[2]	Semi-confining unit	Yields little water
	Tunnel City Group			Yields little water
	Elk Mound Group	Wonewoc Fm.[2]	Lower sandstone aquifer	Moderate to large yields (100s – 1,000s of gpm)
		Eau Claire Fm.		
		Mt. Simon Fm.		
Precambrian	Undifferentiated		Confining bed	Yields little or no water

NOTE: Fm. = Formation; gpm = gallons per minute; for description, see Chapter V; [1] only in eastern Milwaukee and Ozaukee Counties; [2] not always present in the entire Region; [3] thin or locally absent.

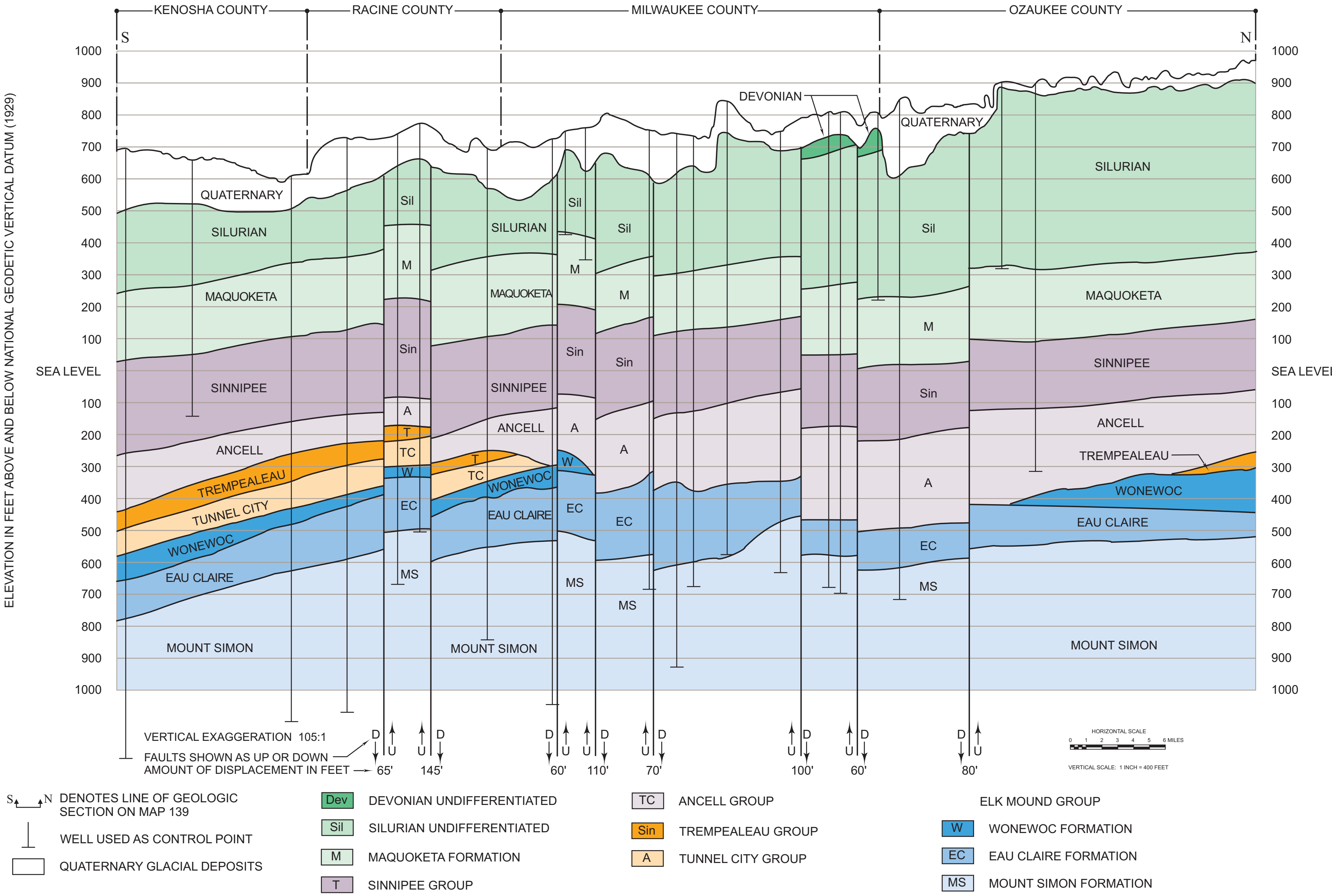
Source: A. Zaporozec, 1997.

aquifers, two confining beds, and two semi-confining beds (see Figure 364). The aquifers are, in descending order, the Quaternary sand and gravel; Silurian dolomite; Galena-Platteville; upper sandstone; and lower sandstone (see Table 226 and Figure 365). The confining beds are the Maquoketa Formation and the Precambrian crystalline rock. The shaly Antrim Formation and siltstone and shaly dolomite of the Milwaukee Formation constitute the uppermost semi-confining bed; and silty dolomite and fine-grained dolomitic sandstone of the St. Lawrence Formation-Tunnel City Group, the lower semi-confining bed in parts of the Region.

Recharge to the sand and gravel aquifer occurs primarily through infiltration of precipitation that falls on the land surface directly overlying the aquifer. Within the study area, the rate of recharge to the sand and gravel aquifer varies depending on the permeability of the overlying glacial till.

Figure 365

GEOLOGIC CROSS-SECTION OF THE SOUTHEASTERN WISCONSIN REGION, SOUTH-NORTH



Source: Roger M. Peters, 1997, and SEWRPC.

Recharge to the Silurian aquifer occurs primarily through infiltration of precipitation that seeps through the glacial drift above the aquifer. As with the sand and gravel aquifer, the rate of recharge varies with the permeability of the glacial drift. Some additional recharge to the Silurian aquifer occurs as lateral subsurface inflow from the west.

Recharge to the sandstone aquifer, located in the Cambrian and Ordovician strata occurs in the following three ways: 1) seepage through the relatively impermeable Maquoketa shale, 2) subsurface inflow from natural recharge areas located to the west in Waukesha, Jefferson, and Dodge Counties, and 3) seepage from wells that are hydraulically connected to both the Niagara and the sandstone aquifers. Although the natural gradient of groundwater movement within the sandstone aquifer is from west to east, concentrated pumping which has occurred over the years has reversed the gradient so that groundwater now flows from the east toward a cone of depression located in the vicinity of the Milwaukee-Waukesha county line in the west-central portion of the study area.

Like surface water, groundwater is susceptible to depletion in quantity and to deterioration in quality as a result of urban and rural development. Consequently, water quality management planning must appropriately consider the potential impacts of urban and rural development on this important resource. Water quality management and land use planning must also take into account, as appropriate, natural conditions which may limit the use of groundwater as a source of water supply, including the relatively high levels of naturally occurring radium in groundwater in the deep sandstone aquifer, found in certain parts of the study area. Other considerations which may limit the uses of groundwater include decreasing aquifer levels and increasing concentrations of dissolved solids and other constituents.

The aquifer systems in southeastern Wisconsin can be divided into two types: unconfined water table aquifers and semi-confined or confined deep bedrock aquifers. Water-table conditions generally prevail in the Quaternary deposits and Silurian dolomite aquifer above the Maquoketa Formation and in the Galena-Platteville aquifer west of the Maquoketa Formation (see Map 139 and Figures 365 and 366). These aquifers are interconnected and are commonly referred to collectively as the "shallow aquifer." These shallow aquifers provide water for most private domestic wells and some municipal wells within the Region. In 2005, approximately 60 registered wells were in use for municipal water supply by water utilities in the study area. Of these, 77 percent were supplied by groundwater from the shallow aquifers.

In the deep sandstone aquifer beneath the Maquoketa Formation, the water can be under artesian pressure. Deep high-capacity wells in the eastern part of the Region extract millions of gallons per day from the sandstone aquifer, creating a decline in water pressure within this aquifer that extends throughout most of the study area, except into the northern parts of Washington and Ozaukee Counties. Heavy pumping on the high-capacity wells has caused the gradual, steady decline in the artesian pressure and a reversal of the predevelopment, upward flow of groundwater. Flowing wells, still common within the Region in the late 1880s, ceased flowing at the beginning of the 1900s, and the potentiometric surface of the sandstone aquifer has been gradually declining and is now lower than the water table throughout most of the Region. On the average, water levels in deep observation wells have been declining at the rate of about four feet per year in the Milwaukee-Racine-Kenosha area and five feet per year around the City of Waukesha since the beginning of the record in the late 1940s.

Springs are areas of concentrated discharge of groundwater at the land surface. Alone, or in conjunction with numerous smaller seeps, they may provide the source of base flow for streams and serve as a source of water for lakes, ponds, and wetlands. Conversely, under certain conditions, streams, lakes, ponds, and wetlands may be sources of recharge that create springs. The magnitude of discharge from a spring is a function of several factors, including the amount of precipitation falling on the land surface, the occurrence and extent of recharge areas of relatively high permeability, and the existence of geologic and topographical conditions favorable to discharge of groundwater to the land surface.

Map 139

GENERAL HYDROGEOLOGY IN THE PORTION OF THE SOUTHEASTERN WISCONSIN REGION WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA

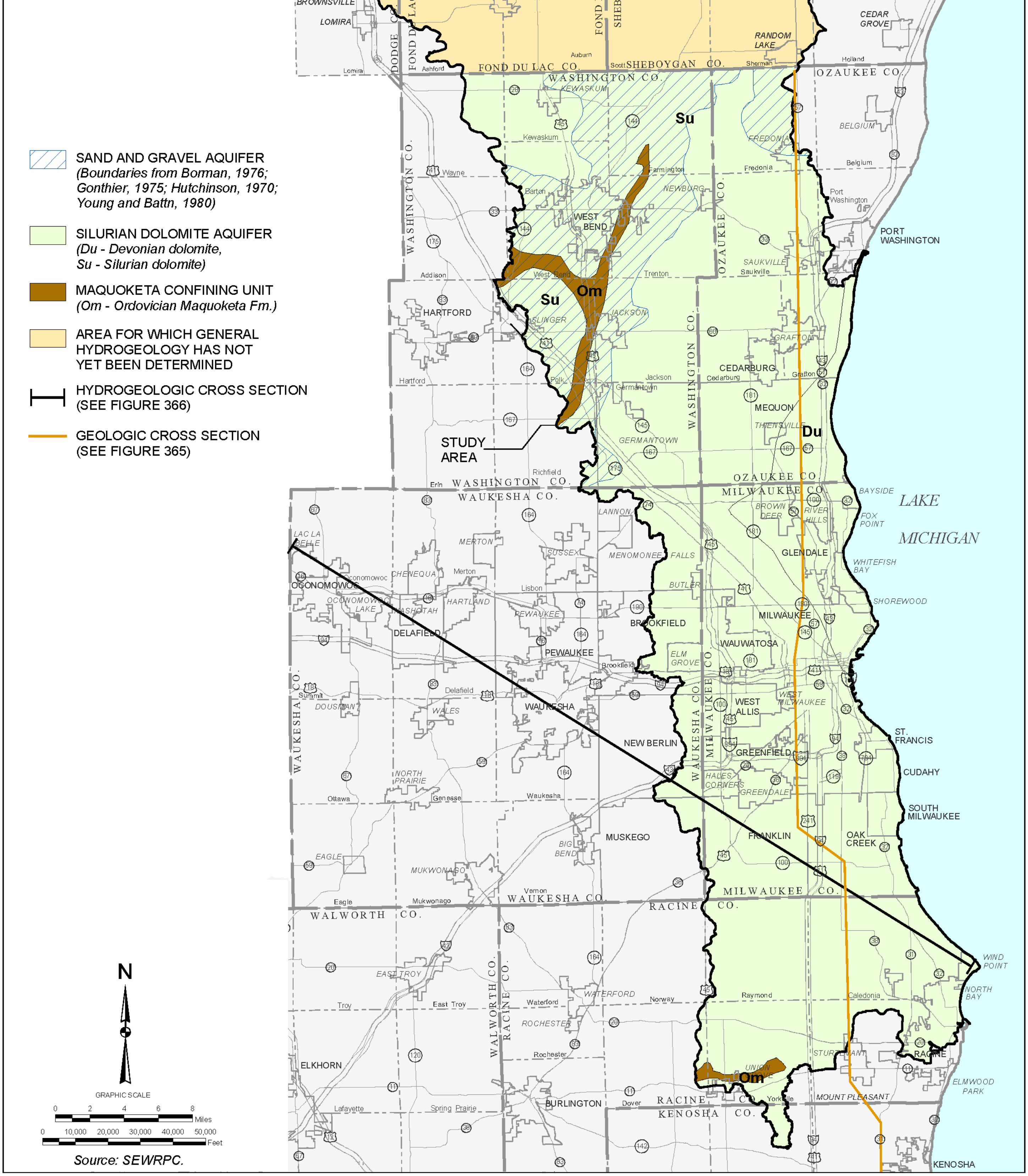
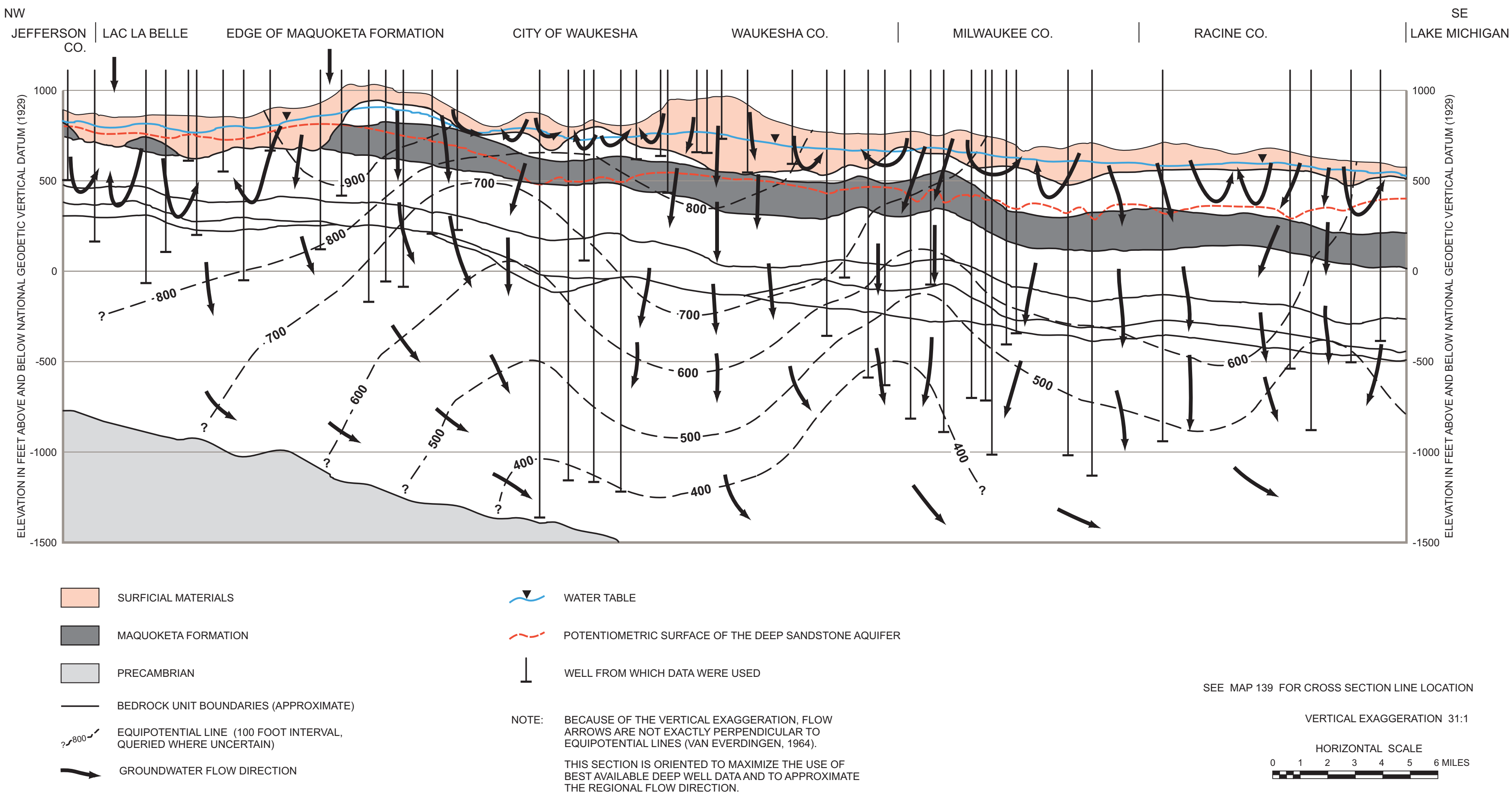


Figure 366

SCHEMATIC HYDROGEOLOGIC CROSS-SECTION FROM LAC LA BELLE, WAUKESHA COUNTY, TO WIND POINT, RACINE COUNTY: APPROXIMATELY 1990 CONDITIONS



Source: Wisconsin Geological and Natural History Survey.

GROUNDWATER QUALITY

Knowledge of the chemical character of groundwater and its variations is necessary for effective water quality management planning. The data available for the Region are provided in SEWRPC TR No. 37, *Groundwater Resources of Southeastern Wisconsin*.

The chemical composition of groundwater largely depends on the composition and physical properties of the soil and rock formations it has been in contact with, the residence time of the water, and the antecedent water quality. The chemical composition of groundwater in the Region and the study area is primarily a result of its movement through, and the interaction with, Pleistocene unconsolidated materials and Paleozoic rock formations. The latter contain large amounts of dolomite—$CaMg(CO_3)_2$—that is dissolved by water passing through the rock formations. In general, groundwater quality tends to be relatively uniform within a given aquifer, both spatially and temporally, but major differences in groundwater quality exist within the Region. The current quality of groundwater in both the shallow and deep aquifers underlying the Region is generally good and suitable for most uses, although localized water quality problems occur in some areas. The exception to this is the concentration of radium exceeding drinking water standards which occurs in portions of the deep sandstone aquifer underlying the Region, but which is not prevalent in wells in the study area.

Groundwater in the Region contains all the major ions that commonly dominate the composition of natural waters: calcium (Ca^{2+}), magnesium (Mg^{2+}), and sodium (Na^{+}) cations and bicarbonate (HCO_3^{-}), sulfate (SO_4^{2-}), and chloride (Cl^{-}) anions. The areal distribution and predominance of these major ions can be used to classify the groundwater into hydrochemical facies, i.e., the chemical type of water. Groundwater may be classified as a calcium-magnesium-bicarbonate(Ca-Mg- HCO_3) type in most of the Region. The water chemistry of the shallow and deep aquifer systems underlying the Region are very similar. The most pronounced geochemical changes occur in the confined parts of the deep aquifer system. From the western edge of the Maquoketa shale east toward Lake Michigan, water chemistry changes sequentially from Ca-Mg-HCO_3 to Ca-Na-SO_4-C1 to Na-SO_4-Cl type.[4]

Dissolved Solids

Dissolved solids concentration and hardness are good initial indicators of water quality. Concentrations of dissolved solids are primarily in the 300 to 400 milligrams per liter (mg/l) range within the Region. The recommended maximum concentration for drinking water of 500 mg/l is exceeded only locally in isolated areas, primarily in the east-central part of the Region, which includes part of the regional water quality management plan study area. The dissolved-solids concentration generally increases from west to east, generally in the direction of groundwater movement, and with depth and increased thickness of the aquifer. Available data show negligible differences between individual aquifers on a Regional basis:

- Sand and gravel aquifer: generally 300 to 400 mg/l; locally may exceed 400 mg/l;
- Silurian dolomite aquifer: generally 100 to 300 mg/l along the Lake Michigan shore; 400 to 500 mg/l in Ozaukee, Milwaukee, and eastern Waukesha County (all of which are locations within the study area); otherwise 300 to 400 mg/l; and
- Sandstone aquifer: generally 300 to 400 mg/l in the west, increasing toward the east to more than 600 mg/l; 200 to 300 mg/l in western Waukesha and northern Walworth and Racine Counties.

Map 140 shows the distribution of dissolved-solids concentration in the Silurian dolomite aquifer, the prevalent shallow aquifer in the Region and the study area. The map also shows those wells for which available data

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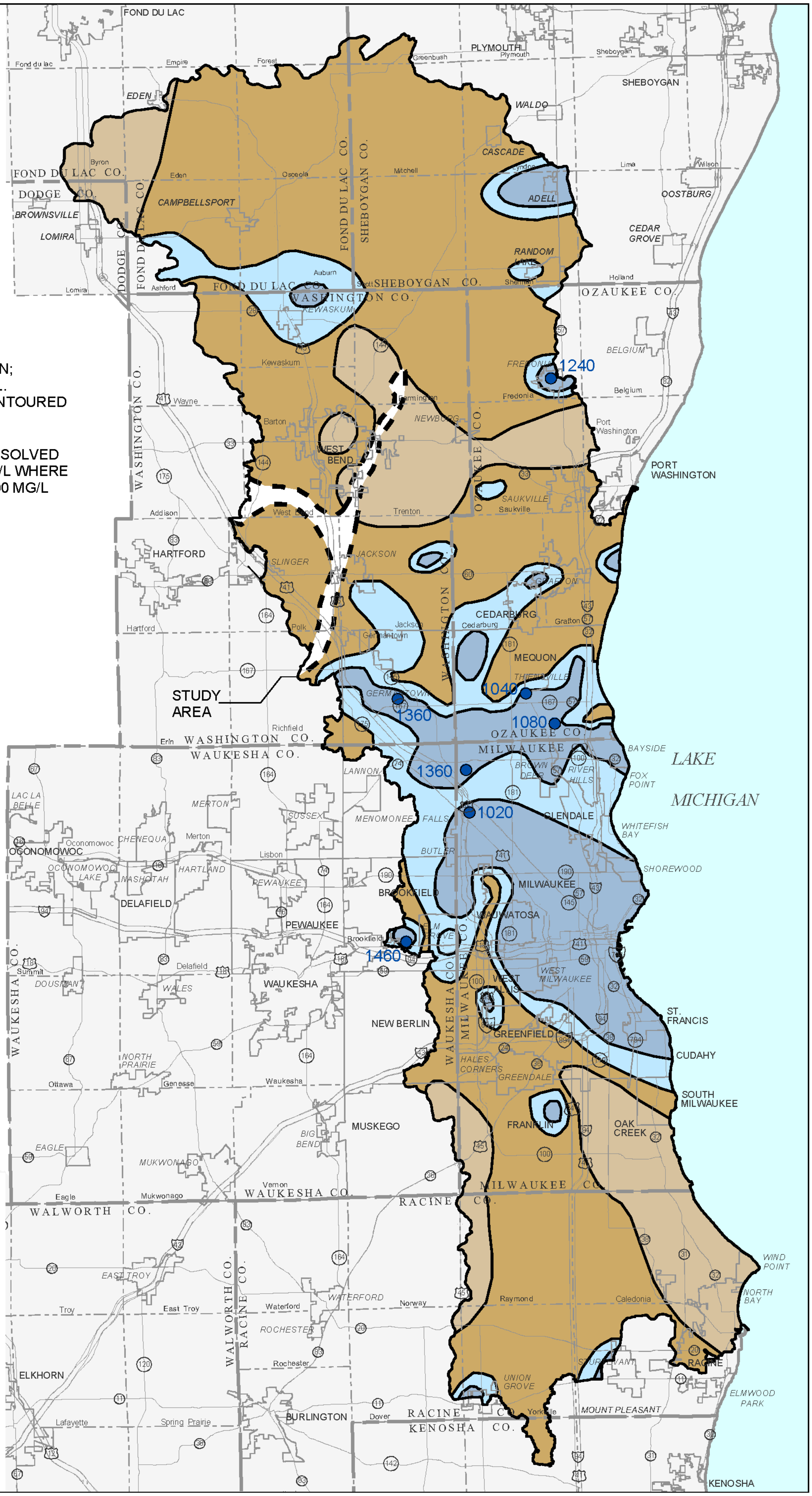
[4] *D.I. Siegel,* Geochemistry of the Cambrian-Ordovician Aquifer System in the Northern Midwest, United States*, (Regional Aquifer-System Analysis report), U.S. Geological Survey Professional Paper 1405-D, 1989.*

Map 140

GENERALIZED MAP OF TOTAL DISSOLVED SOLIDS CONCENTRATION IN THE SILURIAN DOLOMITE AQUIFER WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA



— LINE OF EQUAL CONCENTRATION; CONTOUR INTERVAL IS 100 MG/L. MAXIMUM CONCENTRATION CONTOURED IS 500 MG/L.

1460 ● WELL LOCATION AND TOTAL DISSOLVED SOLIDS CONCENTRATION IN MG/L WHERE CONCENTRATIONS EXCEED 1,000 MG/L

- - BOUNDARY OF SILURIAN DOLOMITE AQUIFER

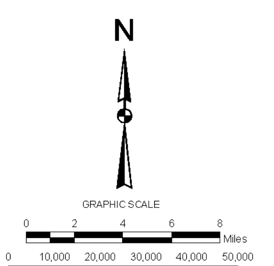
200 - 300 MG/L

300 - 400 MG/L

400 - 500 MG/L

500 MG/L AND MORE

NOTE: In general, the data within the Southeastern Wisconsin Region were developed by the Wisconsin Geological and Natural History Survey and the U.S. Geological Survey. The data in Dodge, Fond du lac, and Sheboygan Counties and in the vicinity of the northern boundaries of Washington and Ozaukee Counties were taken from the U.S. Geological Survey Hydrologic Investigations Atlas 432, "Water Resources of Wisconsin - Lake Michigan Basin, 1973".



Source: Wisconsin Geological and Natural History Survey, U.S. Geological Survey, and SEWRPC indicate concentrations above 1,000 mg/l. Water containing high dissolved solids is occasionally reported by drillers of new deeper wells in the aquifer. Water containing more than 1,000 mg/l of dissolved solids is considered saline water. The highest concentration of dissolved solids documented within the Region was 6,690 mg/l for a composite sample from a well tapping the Silurian dolomite, Galena-Platteville dolomite, and St. Peter Sandstone aquifers in northeastern Milwaukee County.

Hardness

Hardness in the groundwater underlying the Region and the study area is generally high due to the dominance of calcium-magnesium cations in the groundwater (see Map 141). Hardness is reported in terms of equivalent concentration of calcium carbonate ($CaCO_3$), in milligrams per liter. No Federal or State standards for hardness have been promulgated, but water with a hardness of less than 100 mg/l $CaCO_3$ is generally considered as suitable for domestic uses. Water having more than 180 mg/l $CaCO_3$ is considered very hard, and softening is required for most purposes. Hardness does vary somewhat between aquifers:[5]

- Sand and Gravel Aquifer: Hardness levels in the shallow aquifer are variable in the Region, varying from 164 mg/l $CaCO_3$ in Racine County to 353 mg/l $CaCO_3$ in Waukesha County.

- Silurian Dolomite Aquifer: Mean hardness levels varies from 241 mg/l $CaCO_3$ in Kenosha County to 722 mg/l $CaCO_3$ in Ozaukee County.

- Sandstone Aquifer: Mean hardness levels vary from 154 mg/l $CaCO_3$ in Kenosha County to 350 to 390 mg/l $CaCO_3$ in Milwaukee, Ozaukee, Washington, and Waukesha Counties.

Hardness in the Silurian dolomite aquifer generally ranges from 180 mg/l to 360 mg/l $CaCO_3$.

The hardest water in the Region is found in the regional water quality management plan study area in northern Milwaukee County and northeastern Waukesha County with values exceeding 360 mg/l. Hardness in excess of 360 mg/l, or even 500 mg/l $CaCO_3$ is common in wells in the Villages of Brown Deer and Menomonee Falls, and the Cities of Brookfield, Glendale, and Milwaukee. Wells ML 408 and ML 413 in the Village of River Hills have measured hardness exceeding 1,500 mg/l. The northeastern corner of Racine County has groundwater in the shallow aquifer containing less than 120 mg/l of hardness.

Trace Elements

Concentrations of some constituents, normally found in trace amounts, exceeded accepted limits in some areas of the Region and may limit the usefulness of groundwater for certain purposes. Barium concentrations may exceed the limit of one mg/l in a 30-mile broad band running through the western part of Washington County, most of Waukesha County, eastern Walworth County, and western Racine and Kenosha Counties. That band includes significant portions of the study area. The higher barium concentrations may be attributed to a zone of reducing conditions in the confined aquifer system, extending from northeastern Illinois to Wisconsin. Radium concentrations (226Ra and 228Ra combined) in some parts of the confined deep aquifer system exceed the current drinking water standard. The sources of the high radium concentrations in the groundwater may be attributed to the occurrence of uranium and thorium in the matrix of sandstones.

Water Quality Concerns

Some water quality problems are caused by natural factors, which cannot be controlled. For example, the abundant dolomite material in the Region releases calcium and magnesium, which form about one-half of all ions in groundwater and are the principal components of hardness. Therefore, hardness is objectionably high in the groundwater underlying most of the study area (see Map 141), and softening is required for almost all water uses.

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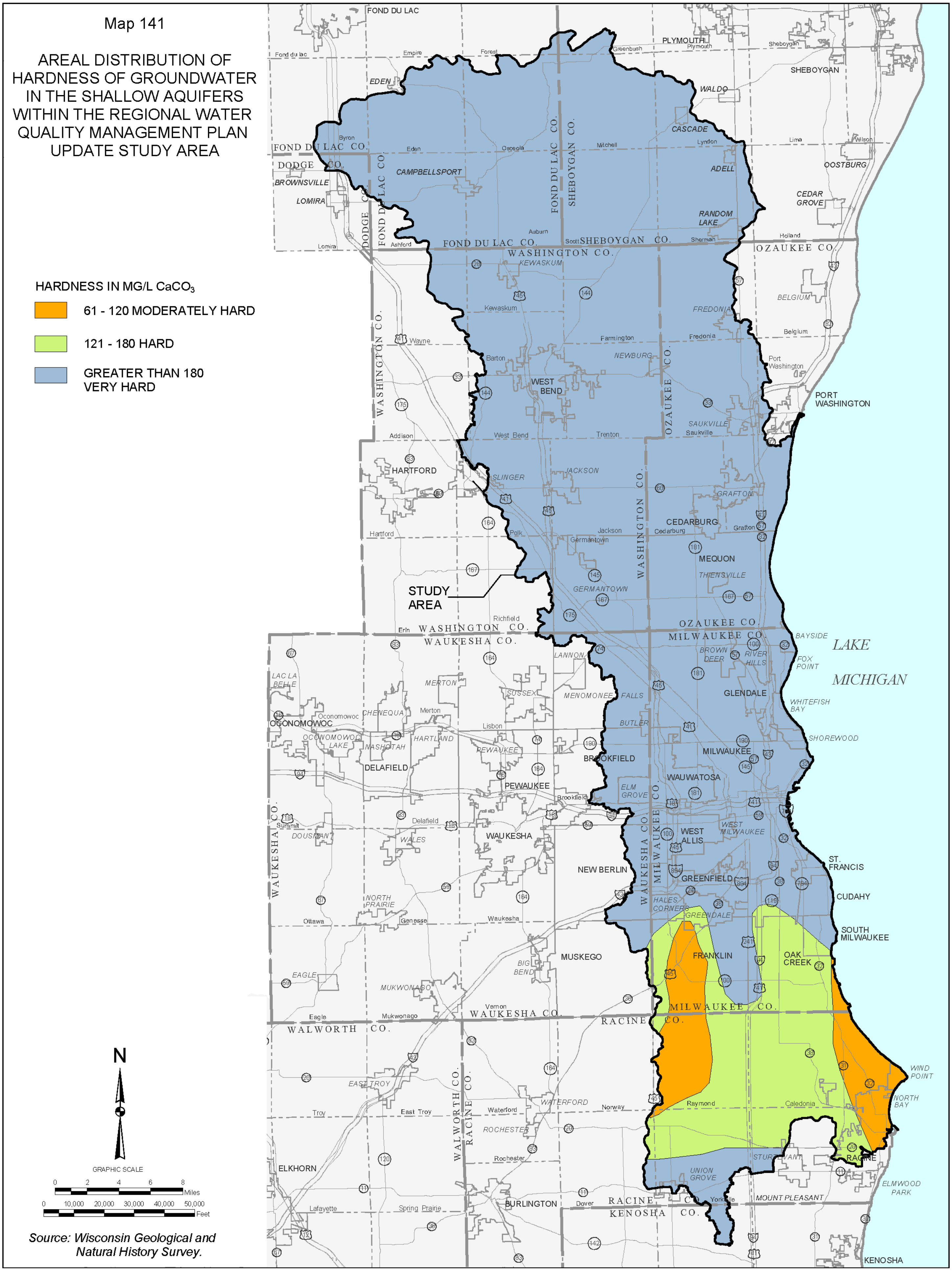
[5]*P.A. Kammerer, Jr.,* Groundwater Quality Atlas of Wisconsin*, U.S. Geological Survey and University of Wisconsin-Extension, Wisconsin Geological and Natural History Survey, Information Circular 39-1981.*



Map 141

AREAL DISTRIBUTION OF HARDNESS OF GROUNDWATER IN THE SHALLOW AQUIFERS WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA

The deep aquifer water in some parts of the Region contains saline water, that is, water with dissolved solids concentrations greater than 1,000 mg/l. But saline water also can occur in the shallow aquifer system through hydraulic connection between the deep and shallow aquifer systems. Dissolved solids levels in excess of 1,000 mg/l have been documented[6] in the study area in southeastern Ozaukee County and northeastern Milwaukee County. Several areas in southwestern Ozaukee, northeastern Waukesha, and northern Milwaukee Counties have been reported,[7] where saline water is suspected or has been found to be beneath the shallow aquifer system. Some locations of wells in the shallow aquifer system containing more than 1,000 mg/l of dissolved solids are shown on Map 140.

Naturally occurring radioactivity in groundwater, including radium and radon, has become a concern in Wisconsin in recent years. The State initiated several studies to examine the occurrence and extent of these naturally occurring contaminants. Radon does not appear to be a problem in the shallow aquifer of southeastern Wisconsin. The source of radium in groundwater is the naturally occurring radium content of certain types of rock formations in the deep sandstone aquifer. Based on the consumer confidence reports for 2005 issued by the WDNR, only one of the 18 water supply systems in the study area reported an exceedence of the current five picocuries per liter EPA and State maximum contaminant level (MCL) standard for radium (combined Radium-226 and Radium-228). The 2005 consumer confidence reports also indicated that four of the water supply systems in the study area reported an exceedence of the current MCL standard for radionuclides.

Another naturally occurring element, arsenic (As), is also a concern. The new Federal and State MCL standard is 10 micrograms per liter. The primary zone of arsenic mineralization is considered to be below the bottom of the Galena-Platteville-Dolomite formation (see Table 226). In 2005, none of the water supply systems in the study area reported exceedances of the arsenic standard.

Contaminants resulting from human activities, causing groundwater quality problems in the Region, include bacteria, nitrate, pesticides, and volatile organic compounds (VOCs). The first three can affect water quality in private wells, but generally do not cause major problems in the Region.

The coliform bacteria test has traditionally been used to measure the sanitary condition of well water. Although coliform bacteria are not known to usually cause disease, their presence in well-water samples may be an indication that more harmful bacteria also exist in a well. Bacteria can be introduced into wells from septic tanks, leaking sanitary sewer lines, feedlots, and manure pits and piles. Their presence usually indicates an improperly constructed well or a well too shallow for local conditions, such as thin soil or fractured bedrock. Coliform bacteria have been detected in, on average, 15 percent of the private wells in the Region, although there is a wide geographic and seasonal variability. In shallow, fractured bedrock aquifers, up to 73 percent of wells have been tested "unsafe." Protected aquifer wells average less that 6 percent unsafe.[8] Overall, coliform detection rates are three times higher in late summer months than midwinter.[9] *E. coli*, the coliform most strongly associated with

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[6]*R.W. Ryling,* A Preliminary Study of the Distribution of Saline Water in the Bedrock Aquifers of Eastern Wisconsin*, Wisconsin Geological and Natural History Survey, Information Circular 5, 1961.*

[7]*P.A. Kammerer, Jr.,* Ground-Water Flow and Quality in Wisconsin's Shallow Aquifer System*, U.S. Geological Survey Water-Resources Investigations Report 90-4171, 1995.*

[8]*Sharon Shaver,* Investigation of Bacteriological Water Quality in Private Water Supply Wells in Waukesha County*, WDNR Report 1996. Data from WDNR Groundwater Retrieval Network (GRN) and Waukesha County Environmental Health Department.*

[9]*Jon Standridge, Wisconsin State Laboratory of Hygiene data; Sharon Shaver, Ozaukee County GRN Data, 1990-1995.*

fecal contamination, is found in fewer than 2.6 percent of private wells.[10] Well bacterial contamination may not always be caused by poor aquifer conditions or substandard well construction. Incidental sources, such as insects under well caps, careless pumpwork, and iron biofilms are believed responsible for many coliform detects.

In Wisconsin, nitrate-nitrogen is the most commonly found groundwater contaminant that exceeds the State drinking water standard of 10 mg/l. Nitrate can enter groundwater from many sources, including nitrogen-based fertilizers, animal waste storage facilities, feedlots, septic tanks, and municipal and industrial wastewater and sludge disposal sites. Data from the WDNR Groundwater Retrieval Network (GRN) databases suggest that nitrate contamination is a relatively minor problem in the study area. In samples collected from 841 wells in the study area during the period 1998-2006, nitrate-nitrogen was found to exceed the enforcement standard of 10 mg/l in 1.3 percent of wells and the preventive action limit of 2.0 mg/l in 9.4 percent of wells. It is important to note that because the GRN databases do not include data from monitoring wells associated with some actions such as USEPA Superfund sites and some contaminated groundwater remediation actions, these percentages may underestimate the extent of nitrate-nitrogen contamination in groundwater in the study area.

Pesticide contamination of groundwater results primarily from agricultural field applications, spills, misuse, or improper storage and disposal of pesticides. In 1992 the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) initiated a rural well sampling program for testing of atrazine, the most widely used triazine herbicide in Wisconsin for weed control, primarily in corn. Triazine was detected in 63 of the 263 samples collected by DATCP in all of the counties within southeastern Wisconsin, except Milwaukee.[11] However, none of the samples were found to exceed the State drinking water standard. Data from the WDNR GRN databases indicate that during the period 1998-2006, wells in the study area were sampled for 24 different pesticides. The number of wells sampled varied by compound, ranging between 43 and 395 with a mean number of 193. Most compounds were detected in fewer than 15 percent of the wells sampled. Ten of these compounds were compared to preventative action limits and enforcement standards. Only one pesticide was found to exceed either standard. Pentachlorophenol exceeded its preventative action limit in slightly over 2 percent of the wells sampled. It did not exceed its enforcement standard in any well sampled. As noted previously, the GRN databases do not include data from monitoring wells associated with some actions such as USEPA Superfund sites and some contaminated groundwater remediation actions. Thus, these percentages may underestimate the extent of pesticide contamination in groundwater in the study area.

The presence in certain locations of VOCs is also a cause of concern. Sources of VOCs included landfills, leaking underground storage tanks, and spills of hazardous substances. Data from the WDNR GRN databases indicate that during the period 1998-2006, wells in the study area were sampled for 101 different VOCs. The number of wells sampled varied by compound, ranging between five and 1,089 with a mean number of 529. Most compounds were detected in fewer than 10 percent of the wells sampled. For most compounds, preventative action limits and enforcement standards were exceeded in less than 1 percent of the wells sampled. As noted previously, the GRN databases do not include data from monitoring wells associated with some actions such as USEPA Superfund sites and some contaminated groundwater remediation actions. Thus, these percentages may underestimate the extent of VOC contamination in groundwater in the study area.

Natural sources of chloride in potable water, other than weathering of minerals, include atmospheric deposition and connate water. Human and animal wastes, salt used for snow and ice removal, and water softening contributions to wastewater are important sources of chloride in some areas. Because chloride is, itself, a possible contaminant, and is also found in contaminants, such as wastewater and animal wastes, it is potentially useful as a general indicator of groundwater contamination when it is present in greater-than-ambient concentrations.

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[10]*Centers for Disease Control,* A Survey of the Quality of Water Drawn for Domestic Wells in Nine Midwestern States*, 1994.*

[11]*Charles A. Czarkowski, WDNR Drinking Water & Groundwater Expert, Public Water System database.*

Chloride concentrations in water from the aquifer systems in southeastern Wisconsin are commonly low. Wisconsin's secondary drinking water standards specify a maximum concentration of 250 mg/l for chloride in drinking water. The standard is based on aesthetic (taste) considerations.

Concentrations of chloride in water from the shallow aquifer is generally from 10 to 30 mg/l in the Region.[12] However, limited areas of the Silurian Dolomite aquifer have naturally occurring chloride concentrations which exceed 100 mg/l. In addition, isolated areas of the sand and gravel aquifer have been found to have levels exceeding the 250 mg/l standard due to contamination sources. As documented in the preceding chapters of this report, chloride concentrations in surface waters in the study area have been found to be increasing. However, no specific data on trends in the concentration chloride in groundwater are available.

Groundwater in the study area has also been examined for concentrations of inorganic compounds of public health and welfare concern and for values of groundwater quality indicator parameters. Data from the WDNR GRN databases indicate that during the period 1998-2006, wells in the study area were sampled for 47 different inorganic compounds and indicator parameters. The number of wells sampled varied by compound, ranging between one and 932 with a mean number of 277. On average, each compound or indicator parameter was detected in about 67 percent of the wells sampled. Of these compounds and indicator parameters, 25 were compared to preventative action limits and enforcement standards. Methodologies for establishing preventative action limits have been issued for an additional 11 of these compounds and indicator parameters; however, these standards were not computed in the GRN databases. Preventative action limits were exceeded in at least some wells in the study area for 20 inorganic compounds. The fraction of wells sampled that exceeded the preventative action limits varied among the compounds, ranging from less than 1 percent to 69 percent of wells, with a mean value of 9 percent. Enforcement standards were exceeded for at least some wells in the study area for 18 inorganic compounds. The fraction of wells sampled that exceeded the enforcement standards also varied among compounds, ranging from less than 1 percent to 56 percent of wells, with a mean value of about 4 percent. As noted previously, the GRN databases do not include data from monitoring wells associated with some actions, such as USEPA Superfund sites and some contaminated groundwater remediation actions. Thus, these percentages may underestimate the extent of inorganic compound contamination in groundwater in the study area.

The WDNR has recently tested all municipal water systems in the State and a large number of noncommunity and private wells for VOCs. During the contamination source inventory, collated by the Commission, data were obtained from the WDNR on areas of special well casing requirements, which indicate the presence of contaminants. The special well casing requirement program was created under Chapter NR 812 of the *Wisconsin Administrative Code* to provide additional protection of drinking water quality in areas where aquifers are known to be contaminated. Special well casing requirement areas in the regional water quality management plan update study area, based on detected or suspected contaminants, designated by the WDNR in the Region in 2005 are listed in Table 227 and the locations of the special well casing requirement areas are shown on Map 142. The most often found contaminants were VOCs and bacteria. Other contaminants included petroleum products, nitrates, and landfill leachate.

SOURCES OF GROUNDWATER CONTAMINATION

Potential sources of groundwater contamination are many and varied because, in addition to some natural processes, such as dissolved and particulate matter in precipitation, decay of organic matter, natural radioactivity and dissolution of arsenic-containing minerals, many types of facilities or structures and many human activities may eventually contribute to groundwater quality problems. This section characterizes the activities and practices that may affect groundwater quality in the Region and the study area and outlines the nature of contamination that may result from such activities. It also describes the nature and extent of potential groundwater contamination

[12]*P.A. Kammerer, Jr., Investigations Report 90-4171,* op. cit.

Table 227

SELECTED CHARACTERISTICS OF THE SPECIAL WELL CASING REQUIREMENT AREAS IN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA: 2005

Identification Number on Map 142	Location	Contaminant Found	Soil Type	Geologic Formation	Casing Recommendation
			Washington County		
2	Town of Barton Section 27 SE 1/4	VOC	Mucky peat, loam	Alluvial sand and silt, outwash sand and gravel	60 feet into bedrock
3	Town of Barton Sections 3, 4, 9, and 10	VOC	Loam, silt loam, mucky peat	Gravel; gravelly, silty sand; peat and muck	To base of Maquoketa shale
4	Town of West Bend Sections 15 and 16	VOC	Silt loam, loam	- -	Casing to base of Maquoketa shale
5	Town of West Bend Section 27 SE 1/4	Methane gas	Silt loam, loam	Sand and gravel	Bedrock well
7	Town of Jackson Sections 21, 22, 27, and 28	Bacteria, nitrate	Loam, silt loam	Clayey, sandy silt; lacustrine silt and sand	120 feet, plus sampling
8	Town of Jackson Section 27 NE 1/4 NW 1/4 Section 28 NE 1/4	Bacteria, nitrate	Silt loam	- -	220 feet
9	Town of Richfield Sections 12 and 13	Gasoline	Silt loam, silty clay loam	- -	100 feet into bedrock
10	Town of Richfield Section 36 SE 1/4	Gasoline	Silt Loam, silty clay loam	- -	220 feet
11	Town of Germantown Sections 9 and 10	Gasoline	Silt loam	Gravelly, clayey, sandy silt	100 feet
12	Town of Germantown Sections 9 and 10	Bacteria, nitrate, gasoline	Silt loam	Gravelly, clayey, sandy silt	80 feet
14	Village of Germantown Sections 29 and 30	Gasoline	Sand loam, silt loam, mucky peat	- -	150 feet
15	Village of Germantown Section 31 SW 1/4	Gasoline	Loam	- -	220 feet
			Ozaukee County		
16	Town of Cedarburg Section 14 SW 1/4	VOC, petroleum, gasoline	Silt loam	- -	130 feet
17	City and Town of Cedarburg Sections 22, 23, and 26	VOC	Loam, silt loam	- -	Special sampling
18	Village and Town of Grafton Section 25	VOC	Silt loam	- -	Special sampling
19	Village of Thiensville Sections 14,15, 22, and 23	VOC	Loam	Outwash sand and gravel	160 feet
20	Village of Thiensville Section 22, 23	VOC	Loam	Outwash sand and gravel	140 feet
			Waukesha County		
26	Villages of Menomonee Falls and Lannon within 0.5 mile of quarries or rock outcrops	Bacteria	- -	- -	100 feet or special approval
			Milwaukee County		
31	Village of River Hills Section 6 SE 1/4	Naturally occurring tar and asphaltum	Silt loam	Top of Silurian Dolomite	200 feet if tar and asphaltum are present
32	City of Franklin Section 6 NE 1/4	Petroleum	Silt loam	Silty till	Greater than 40 feet into bedrock

NOTE: VOC = Volatile Organic Compound.

[a] *The locations were inventoried under previous regional groundwater planning programs. Since only those sites within the study area are included in this table, there are gaps in the identification numbers.*

Source: Wisconsin Department of Natural Resources.

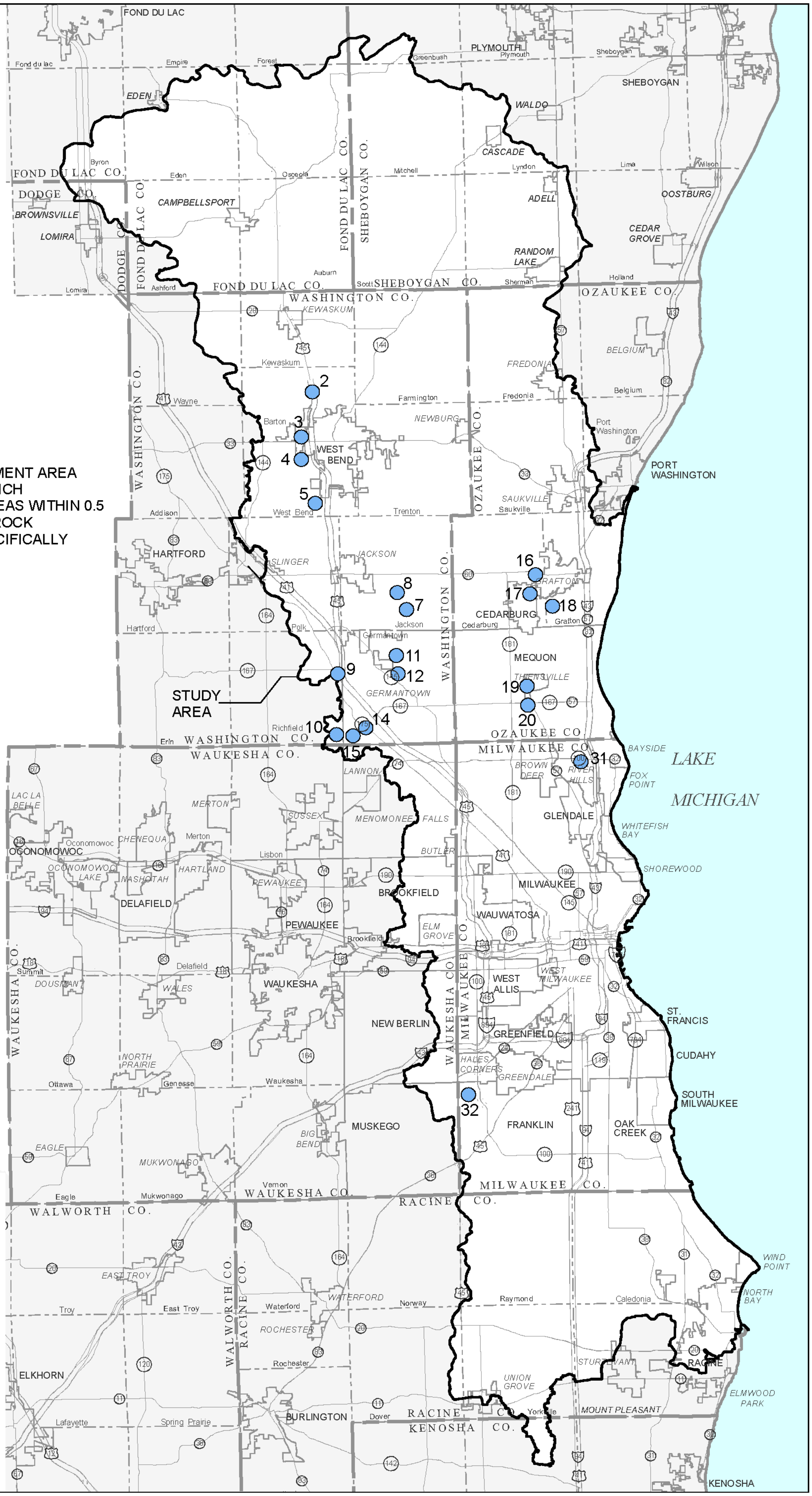
Map 142

LOCATION OF SPECIAL WELL CASING REQUIREMENT AREAS WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA

● SPECIAL WELL CASING REQUIREMENT AREA

21 IDENTIFICATION NUMBER (SEE TABLE 227)

NOTE: WELL CASING REQUIREMENT AREA NO. 26 IN TABLE 227, WHICH INCLUDES MULTIPLE AREAS WITHIN 0.5 MILE OF QUARRIES OR ROCK OUTCROPS, IS NOT SPECIFICALLY SHOWN ON THIS MAP.



N

GRAPHIC SCALE

0 2 4 6 8 Miles

0 10,000 20,000 30,000 40,000 50,000 Feet

Source: Wisconsin Department of Natural Resources.

sources in the Region. No attempt has been made, however, to rank quantitatively the various potential contamination sources. For the purposes of this study, the sources that were considered to have potential to create contamination problems in the study area are summarized according to their location in Table 228.[13]

In 1997 and 1998, SEWRPC and the WGNHS, in cooperation with the Wisconsin Departments of Natural Resources, Agriculture, Trade and Consumer Protection, and Transportation, conducted, as a part of the study documented in SEWRPC TR No. 37, an inventory of potential sources of contamination in order to assess their extent and potential impact on groundwater. No attempt was made to include all possible human activities that may affect groundwater quality in the Region, as listed in Table 228. The primary emphasis of the inventory was on the clusters of onsite sewage disposal systems, landfills, leaking underground storage tanks, and abandoned wells. Also identified were wastewater sludge application sites, agricultural activities (major farm animal operations, fertilizer and pesticide storage facilities) and other potential sources of contamination, such as the stockpiles of salt for highway de-icing, salvage yards, and bulk fuel storage sites. Because of the nature of the sources of groundwater contamination, the location and number of each source can change over time. Thus, for the most up-to-date inventory data, it is recommended that the agency noted as the source of information be contacted.

Onsite Sewage Disposal Systems

Private wastewater systems are used to dispose of sanitary wastes in unsewered areas. A conventional onsite system consists of a septic tank and a soil absorption field. Most solids, called septic sludge, settle at the bottom of the tank where they are partially digested by bacteria. The liquid waste, called septic tank effluent, flows from the tank to the soil absorption field where it is purified as it moves through the soil. If these systems are properly installed in suitable soils and located a sufficient distance from a water supply source, most contaminants are removed or attenuated before they can reach the water supply. However, local groundwater contamination may occur in areas of concentrated suburban or rural residential development where individual onsite systems are densely spaced. This may be of most concern where older systems are in place, which may not meet current design criteria. Specifically, the amount of nitrate and chloride may not be significantly reduced.

In addition to conventional onsite systems, newer alternative onsite sewage disposal systems designed to overcome certain types of soil limitations are in use in the Region and the study area. Such systems include "mound-type systems," which pump septic tank effluent through a distribution piping system placed in sand or other fill material on top of the natural soil. Other types of soil absorption systems include in-ground pressure distribution systems and at-grade systems. In addition, holding tanks to temporarily store wastewater prior to pumping out to a tank truck and transport to a sewage treatment plant are used.

During 2000, the Wisconsin Legislature amended Chapter Comm 83 of the *Wisconsin Administrative Code* (a health and safety code, which regulates private sewage systems statewide) and adopted new rules governing onsite sewage disposal systems. These rules, which had an effective date of July 1, 2000, increased the number of types of onsite sewage disposal systems that legally could be used from four to nine. These rules significantly altered the previous regulatory framework and increased the area in which onsite sewage disposal systems may be utilized.

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[13] *The WDNR provides resources where more specific information on groundwater contamination is available. The Remediation and Redevelopment Sites Map is a map-based system for finding property in Wisconsin that is or was contaminated with hazardous substances. The status of cleanup actions of these sites is tracked through the Bureau for Remediation and Redevelopment Tracking System. The GIS Registry of Closed Remediation Sites provides a means of public notice for several types of completed environmental cleanups. The Source Water Assessment Program provides basic information of the degree to which drinking water sources may be impacted by potential sources of contamination. These resources may be accessed through the WDNR's website at* http://dnr.wi.gov/.

Table 228

HUMAN ACTIVITIES THAT MAY CREATE GROUNDWATER QUALITY PROBLEMS IN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA

Originating on the Land	Originating Below Land Surface
Above-ground storage tanks (bulk fuel storage)	Above Water Table
Accidental spills	Animal waste storage facilities
Agricultural activities:	Landfills
Animal feedlots	Leakage:
Fertilizer and pesticide storage, mixing, and loading	Underground storage tanks
Fertilizer and pesticide application	Underground pipelines
Irrigation return flow	Sewers
Silage and crop residue piles	Onsite sewage disposal systems
Dumps	Surface wastewater impoundments
Highway de-icing, including material storage sites	Sumps, dry wells
Waste spreading or spraying (sewage, sludge, septage, whey)	Waste disposal in dry excavations
Stockpiles (chemicals and waste)	Below Water Table
Infiltration of contaminated surface water or precipitation	Ground water development:
Salvage yards	Improperly abandoned wells and holes
Application of fertilizers and pesticides to urban lawns and gardens	Improper well construction
Urban runoff	Overpumping
	Drainage or disposal wells
	Waste disposal in wet excavations

Source: Wisconsin Geological and Natural History Survey and SEWRPC.

It is estimated that less than 5 percent of the study area population was served by individual onsite systems as of 2000. The individual chapters on surface water quality conditions and sources of pollution in this report include maps showing areas served by onsite sewage disposal systems. The potential contamination sources inventory conducted for the SEWRPC regional groundwater study[14] focused on areas of clustered onsite sewage disposal systems, defined as areas with more than 32 housing units per U.S. Public Land Survey section. In the study area, onsite systems tend to be concentrated in Fond du Lac, Racine, Ozaukee, and Washington Counties. Significant portions of Fond du Lac, Ozaukee, and Washington Counties within the study area tend to have relatively permeable soils, especially in the major river valleys. Therefore, clustered onsite systems in these areas are a potential source of contamination to the groundwater. However, sites located in southern and eastern Ozaukee County and in much of Racine County have less permeable soils, thus groundwater contamination is not as great a concern in those locations.

Land Disposal of Solid Waste

Solid waste disposal is an important potential groundwater contamination source. Continuous or intermittent contact between deposited waste and water produces a liquid called leachate, which contains high concentrations of potential contaminants. Landfill leachate is defined as a contaminated liquid characterized by high concentrations of dissolved chemicals, high chemical and biological oxygen demand, and high hardness. Its composition is extremely variable, and is a function of the composition of waste and the volume of water. The threat to groundwater from solid waste disposal sites depends on the nature of leachate, the availability of moisture, the type of soil through which the leachate passes, and the hydrogeology of the site. Because the Region lies in a humid climatic zone, most waste disposal sites will eventually produce leachate. Disposal site success depends on how leachate production and movement is managed either by engineering design or by locating the

[14]*SEWRPC Technical Report No. 37,* op. cit.

site in a more protective environment. Detailed information on active and inactive solid waste disposal sites is set forth in Chapters V through X of this report. The sites inventoried in those chapters have been documented based upon information from WDNR and SEWRPC files. In addition, there are other known solid waste disposal sites for which only limited information is available. Some of these sites are still under review by the WDNR. Because of the nature of these facilities, the inventory information changes periodically. The WDNR maintains an up-to-date inventory of the landfill sites. It is recommended that WDNR be contacted for the most recent inventory data.

Underground Storage Tanks

Storage and transmission of a wide variety of fuels and chemicals are inherent in many industrial, commercial, agricultural, and individual activities. Petroleum and petroleum products are the most common potential contaminants. Throughout the study area and the Region, underground storage tanks for gasoline, oil, and other liquids were installed during the 1950s and 1960s and have now reached or exceeded their expected 20- to 30-year life. The large volume and high concentration of hazardous materials that can leak or can be released from a storage tank or associated piping in a small area creates an onsite, and sometimes offsite, contamination risk. The majority of the existing tanks are in urban areas and, as a result, are relatively close to municipal water supply wells. Leaks in petroleum-product conveyance and transmission lines also are a potential source of groundwater contamination.

SEWRPC Technical Report No. 37 used WDNR file data to develop an inventory of underground storage tank sites within the Region, where there has been a release of contaminants. The number of sites per county were tabulated and the site density in sites per square mile was mapped.

The majority of the sites were located in the regional water quality management plan update study area with the highest concentration in Milwaukee County. The WDNR's classification system considers a leaking underground storage tank to be a high priority when it is known that the site is causing contamination to the groundwater, or where there is a high potential for such contamination. Additionally, those sites that are assigned a medium priority, have known soil contamination or a potential for groundwater contamination. Where high- and medium-priority leaking underground storage tanks occur within the study area, their density generally ranges from one to 10 sites per square mile. In Milwaukee County, the site density ranges from one to 10 sites per square mile up to 41 to 50 sites per square mile. Because of the nature of these potential contamination sites, the number and location are subject to frequent change. The Wisconsin Department of Natural Resources should be contacted for the most recent inventory data.

Land Application of Liquid Waste and Sewage Sludge

Sludge and biosolids are organic, by-products of treated wastewater. Most of the land application of such materials in southeastern Wisconsin involves biosolids which are treated residuals from sewage treatment plants that can be used beneficially. They are composed mostly of water and organic matter. Both industrial sludges or residual solids and municipal biosolids may contain hazardous chemicals and metals removed by the wastewater treatment process. Metals often found in biosolids at variable concentrations include arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. The types and concentrations of metals found in sludge depend upon the source of the wastewater. Other constituents of sludge that may have an impact on the groundwater are nitrate, chloride, and pathogenic bacteria and viruses.

The land application of municipal sludge is regulated under Chapter NR 204 of the *Wisconsin Administrative Code* and 40 CFR Part 503. Industrial sludges are also applied in the Region although the majority of the wastewater biosolids is domestic sewage sludge. Industrial sludge is regulated under Chapter NR 214. Wastewater biosolids must meet the requirements of the above regulations before being applied to any lands. The requirements include ceiling concentrations for contaminants, pathogen reduction requirements, and vector reduction options.

Sites for storage and land application of wastewater and sludge in the Region were inventoried under SEWRPC TR No. 37. As of 1999, for counties within the both study area and the Region, WDNR-approved sites were located in Washington (1,065 sites), Ozaukee (408 sites), Waukesha (400 sites), Racine (275 sites), and Kenosha (127 sites) Counties. The number and location of these sites is constantly changing and the WDNR should be contacted for the latest information on the approved sites.

Some land application of wastewater from other sources such as vegetable processing and dairy operation by-products (whey), septage and, in some cases, holding tank waste are also practiced. Sludge and wastewater are only applied to agricultural land in the study area. Biosolids are land-applied to improve the structure of the soil, or as a fertilizer to supply nutrients to crops and other vegetation in the soil. Land application in the study area is done by spreading, spraying, injection, or incorporation of sewerage sludge onto or below the surface of the land to take advantage of the soil enhancing qualities of the biosolids. Almost all of the sludge and wastewater is injected or incorporated into the soil, although there are some spray irrigation systems.

Contamination of groundwater from land application of sludge and wastewater depends upon the concentration of contaminants, application rate, physical and chemical soil properties, amount of precipitation, and distance to the water table. Coarse-textured soils, a shallow water table, and high rates of precipitation favor groundwater contamination. Currently, the wastewater biosolids are applied in such a manner that there should be no impact on the groundwater. All of the municipal residuals that are land-applied in the study area and in southeastern Wisconsin have been treated to meet the appropriate quality parameters. The type of soil, application rate, distance to bedrock and groundwater, slopes, porosity of the soils, percolation rates, solum depth (depth of the A and B horizons), and distance to lakes, streams, ponds, and other water sources are evaluated for every site approved for land application prior to application.

Major Livestock Operations

Major livestock operations are not common in the study area. Within the study area, the Milwaukee and Root River watersheds have six farm operations with more than 1,000 animal units as described in Chapters VII and IX of this report. The principal contaminants associated with animal farm operations and feedlots are nitrogen, phosphorus, chloride, oxygen-demanding material, and microorganisms. Feedlots may also cause objectionable odor. The potential for groundwater contamination will depend on the volume of waste produced at a given site, waste handling practices, and general farm operations. Typically, animal waste is stored in a storage facility such as a manure pile, lagoon, or holding tank, and then periodically applied to the land as a source of plant nutrients. Unless livestock manure is applied to sandy soils that are prone to rapid internal drainage, most nutrient loss, especially phosphorus, occurs by erosion from overland runoff, and presents the greatest potential environmental threat to surface waters.

As noted in Chapters VII and IX of this report, the WDNR regulates livestock operations with greater than 1,000 animal units through the Wisconsin Pollution Discharge Elimination System (WPDES) permit program. One animal unit (AU) is equivalent to a single mature beef unit weighing 1,000 pounds, e.g., 200,000 chickens (broilers) equal 1,000 animal units. Proper plant nutrient management plays a critical role in assuring that large livestock operations manage the large volumes of animal waste they generate, and minimizes detrimental effects on the environment. Because of the nature of these facilities, the number and location changes periodically.

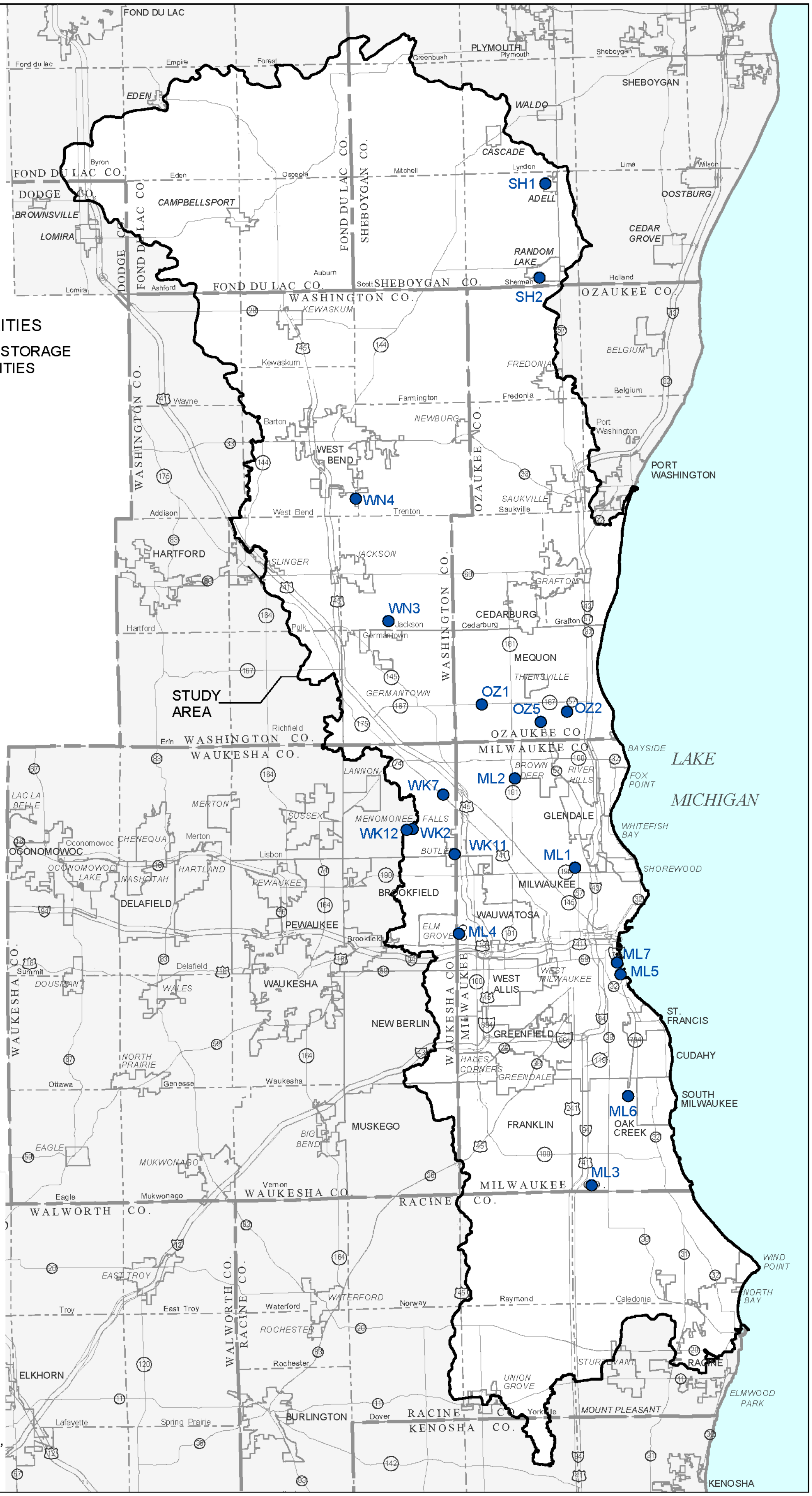
Agricultural Chemical Facilities

Selected information on bulk agricultural chemical (fertilizers and pesticides) storage and loading facilities in the study area is set forth on Map 143 and in Table 229. Commercial fertilizers include a variety of types and concentrations of nitrogen, phosphorus, potassium, and trace elements, most of which are intended to improve plant growth and market value. While both nitrogen and phosphorus may contribute to eutrophication of surface waters, the nitrogen component of fertilizer has generated the most concern regarding groundwater quality.

Storage and handling of large amounts of agricultural chemicals in a small area presents a potential for contamination of groundwater in the case of an accident or mismanagement.

Map 143

AGRICULTURAL CHEMICAL FACILITIES WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA



AGRICULTURAL CHEMICAL FACILITIES

- ● BULK AGRICULTURAL CHEMICAL STORAGE AND MIXING AND LOADING FACILITIES
- WK7 IDENTIFICATION NUMBER (SEE TABLE 229)

N

GRAPHIC SCALE

0 2 4 6 8 Miles

0 10,000 20,000 30,000 40,000 50,000 Feet

Source: Wisconsin Department of Agriculture, Trade, and Consumer Protection and SEWRPC.

Table 229

BULK AGRICULTURAL CHEMICAL STORAGE AND MIXING/LOADING FACILITIES WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA: 2005

Identification Number on Map 143	Name and Site Address	Location by U.S. Public Land Survey
Milwaukee County		
ML1	Happy Lawns, Inc. 4220 N. Teutonia Ave. Milwaukee, WI	T7N, R22E, Section 6, NE 1/4 of the SW 1/4
ML2	Hydrite Chemical Company 7300 W. Bradley Road Milwaukee, WI	T6N, R21E, Section 10, SW 1/4 of the SW 1/4
ML3	PPG Industries, Inc. 10800 13th Street Oak Creek, WI	T5N, R22E, Section 32, NW 1/4 of the SW 1/4
ML4	Hawks Nursery Company 12217 Watertown Plank Road Wauwatosa, WI	T7N, R21E, Section 30, NW 1/4 of the NW 1/4
ML5	Kinder Morgan Energy Partners 1900 S. Harbor Drive Milwaukee, WI	T6N, R22E, Section 4, SW 1/4 of the NE 1/4
ML6	Kujawa Enterprises, Inc. 824 E. Rawson Ave. Oak Creek, WI	T5N, R22E, Section 3, SW 1/4 of the SW 1/4
ML7	Milwaukee Metropolitan Sewerage District 700 E. Jones Street Milwaukee, WI	T7N, R22E, Section 33, SW 1/4 of the SE 1/4
Ozaukee County		
OZ1	Walter Baehmann Farms 9919 W. Mequon Road Mequon, WI	T9N, R21E, Section 29, NE 1/4 of the NW 1/4
OZ2	North Shore Country Club 10757 Range Line Road Mequon, WI	T9N, R21E, Section 25, NE 1/4 of the SE 1/4
OZ5	Buckley Tree Service, Inc. 10351 N. Cedarburg Road Mequon, WI	T9N, R21E, Section 35, NW 1/4 of the NE 1/4
Sheboygan County		
SH1	Adell Cooperative Union 707 Mill Street Adell, WI	T13N, R21E, Section 2, NE 1/4 of the SW 1/4
SH2	Kettle Lakes Cooperative 403 1st Street Random Lake, WI	T13N, R21E, Section 34, NE 1/4 of the SE 1/4
Washington County		
WK2	Associated American Landscape N60 W16073 Kohler Lane Menomonee Falls, WI	T8N, R20E, Section 27, SE 1/4 of the SE 1/4
WN3	Vogel Seed & Fertilizer, Inc. 1891 Spring Valley Road Jackson, WI	T10N, R20E, Section 33, NW 1/4 of the SE 1/4

Table 229 (continued)

Identification Number on Map 143	Name and Site Address	Location by U.S. Public Land Survey
Waukesha County WN4	Gundrum Brothers Farm Supply, Inc. 1095 Rusco Drive West Bend, WI	T11N, R19E, Section 36, NE 1/4 of the NE 1/4
WK7	North Hills Country Club N73 W13430 Appleton Ave. Menomonee Falls, WI	T8N, R20E, Section 13, NE 1/4 of the SW 1/4
WK11	LCS Lawn Service 4908 N. 125th Street Butler, WI	T8N, R20E, Section 36, SE 1/4 of the SE 1/4
WK12	Scotts Lawn Service N59 W16600 Greenway Circle Menomonee Falls, WI	T8N, R20E, Section 27, NE 1/4 of the SW 1/4

NOTE: The inventory data in this table are subject to periodic change due to the nature of the facilities. For the most recent data, the Wisconsin Department of Agriculture, Trade and Consumer Protection should be contacted.

Source: Wisconsin Department of Agriculture, Trade and Consumer Protection and SEWRPC.

Salvage Yards

Salvage yards are a minor potential source of contamination. The danger of groundwater contamination increases if the sites handle hazardous materials from various automotive parts and accessories, such as grease, oil, solvents, and battery acids. Well-operated salvage yards present a minimal threat to groundwater. Salvage yards within the Region were inventoried for SEWRPC TR No. 37. Within the study area, the majority of these sites are located in Milwaukee County and eastern Waukesha County.

Salt Storage Facilities

Salt storage, road salting, and snow dumping are all common practices used in the Region in relation to road de-icing and improvement of winter driving conditions. These activities may contribute to high salt concentrations in both groundwater and surface water. Of these activities, salt storage in uncovered piles appears to be the most critical with respect to potential groundwater contamination. Rainfall can dissolve the salt, which may then seep into shallow aquifers.

Salt storage sites in the study area are shown on Map 144. Table 230 sets forth an inventory of salt storage facilities in the study area. Nearly all of these facilities are covered. Most of these sites are located in counties with a dense network of highways such as Milwaukee and Waukesha. The WDNR has reported documented cases of groundwater contamination due to past salt storage and handling practices. However, current design and maintenance of storage facilities minimizes the potential for infiltration of salt into groundwater.

Temporary Solid and Hazardous Waste Storage Sites

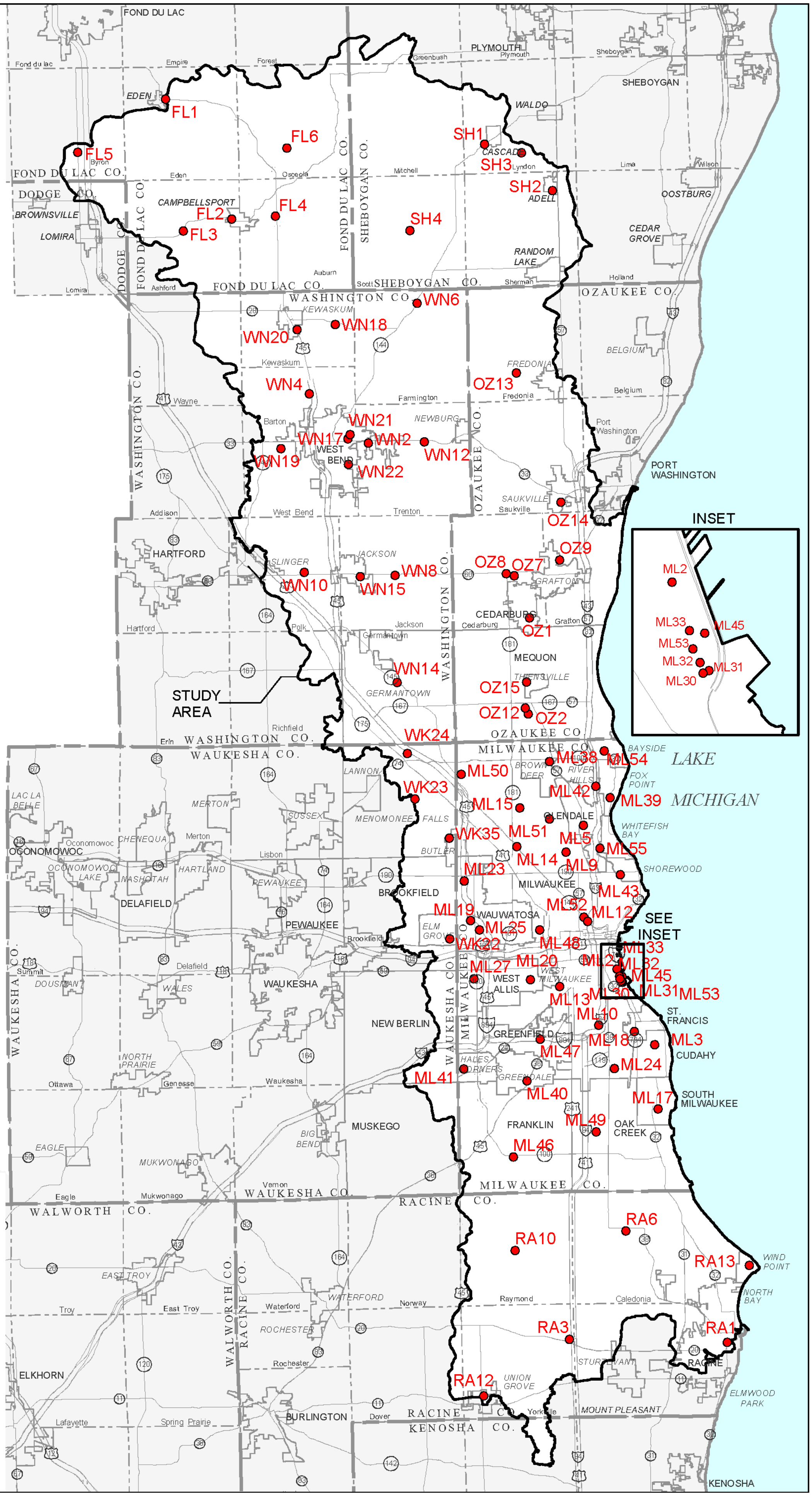
Temporary storage of solid and hazardous waste represents a minor threat to the groundwater. If the waste is handled correctly and regularly transferred to a long-term facility, contamination from these areas should not be significant. An inventory of these sites was made for SEWRPC TR No. 37. Within the study area, these sites are generally located in urban areas, with the greatest concentration occurring in Milwaukee County. Due to the nature of these facilities, data on the facilities is subject to periodic change. The WDNR should be contacted for the most recent data.

Map 144

SALT STORAGE SITES WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA: 2006

● SALT STORAGE FACILITY SITES

ML52 SALT STORAGE FACILITY IDENTIFICATION NUMBER (SEE TABLE 230)



N

GRAPHIC SCALE

0 2 4 6 8 Miles

0 10,000 20,000 30,000 40,000 50,000 Feet

Source: SEWRPC.

Table 230

SALT STORAGE FACILITIES WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA: 2005

Identification Number on Map 144	Owner	Site Location
Fond du Lac County		
FL1	Baumhardt Sand & Gravel	W3998 State Road 45, Eden, WI
FL2	Fond du Lac County	203 Railroad St. Campbellsport, WI
FL3	Town of Ashford	N1410 Rolling Drive, Ashford, WI
FL4	Town of Auburn	W1728 Sunset Drive, Auborn, WI
FL5	Town of Byron	N3097 State Road 175, Byron, WI
FL6	Town of Osceola	1476 County Road F, Osceola, WI
Milwaukee County		
ML2	Cargill Salt, Inc.	1531 S. Carferry Drive, Milwaukee, WI
ML30	Cargill Salt, Inc.	2225 S. Carferry Drive, Milwaukee, WI
ML45	Cargill Salt, Inc.	1902 S. Harbor Drive, Milwaukee, WI
ML32	Cargill Salt, Inc.	2175 S. Carferry Drive, Milwaukee, WI
ML3	City of Cudahy	3555 E. Pabst Avenue, Cudahy, WI
ML46	City of Franklin	7979 W. Ryan Road, Franklin, WI
ML5	City of Glendale	5930 N. Glen Park, Glendale, WI
ML47	City of Greenfield	4551 S. 52nd Street, Greenfield, WI
ML10	City of Milwaukee	4031 S. 6th Street, Milwaukee, WI
ML12	City of Milwaukee	1600 N. 14th Street, Milwaukee, WI
ML14	City of Milwaukee	7222 W. Fond du Lac Avenue, Milwaukee, WI
ML9	City of Milwaukee	2931 W. Cameron Avenue, Milwaukee, WI
ML15	City of Milwaukee	6732 N. Industrial Road, Milwaukee, WI
ML13	City of Milwaukee	2363 S. 35th Street, Milwaukee, WI
ML48	City of Milwaukee	5230 W. State Street, Milwaukee, WI
ML49	City of Oak Creek	800 W. Puetz Road, Oak Creek, WI
ML18	City of St. Francis	2125 E. Bolivar Avenue, St. Francis, WI
ML17	City of South Milwaukee	910 Marshall Avenue, South Milwaukee, WI
ML19	City of Wauwatosa	11100 W. Walnut Road, Wauwatosa, WI
ML20	City of West Allis	6300 W. McGeoch Avenue, West Allis, WI
ML23	Deluca & Hartman	12001 W. Capitol Drive, Wauwatosa, WI
ML27	Metropolitan Maintenance and Landscaping	11020 W. Rogers Street, West Allis, WI
ML24	Milwaukee County	5800 S. Howell Avenue, Milwaukee, WI
ML50	Milwaukee County	12300 W. Bradley Road, Milwaukee, WI
ML51	Milwaukee County	6270 N. Hopkins Street, Milwaukee, WI
ML52	Milwaukee County	1525 W. Vine Street, Milwaukee, WI
ML25	Milwaukee County	10190 W. Watertown Plank Road, Wauwatosa, WI
ML31	North American Salt, Inc.	2061 S. Harbor Drive, Milwaukee, WI
ML33	North American Salt, Inc.	1830 S. Carferry Drive, Milwaukee, WI
ML53	North American Salt, Inc.	1000 E. Bay Street, Milwaukee, WI
ML40	Village of Greendale	6351 Industrial Loop, Greendale, WI
ML54	Village of Bayside	9075 N. Regent Road, Bayside, WI
ML38	Village of Brown Deer	8717 N. 43rd Street, Brown Deer, WI
ML39	Village of Fox Point	7200 N. Santa Monica Boulevard, Fox Point, WI
ML41	Village of Hales Corners	5635 S. New Berlin Road, Hales Corners, WI
ML42	Village of River Hills	7650 N. Pheasant Lane, River Hills, WI
ML43	Village of Shorewood	3801 N. Morris Boulevard, Shorewood, WI
ML55	Village of Whitefish Bay	5055 N. Lydell Avenue, Whitefish Bay, WI
Ozaukee County		
OZ1	City of Cedarburg	W59 N306 Johnson Avenue, Cedarburg, WI
OZ2	City of Mequon	10800 N. Industrial Drive, Mequon, WI
OZ12	LaRosa Landscaping	10950 Buntrock, Mequon, WI
OZ7	Ozaukee County	1221 Hilltop Drive, Cedarburg, WI
OZ13	Ozaukee County	W4074 County Road Z, Fredonia, WI
OZ8	Town of Cedarburg	1293 Washington Avenue, Cedarburg, WI
OZ9	Village of Grafton	1300 Hickory Street, Grafton, WI
OZ14	Village of Saukville	649 S. Main Street, Saukville, WI
OZ15	Village of Thiensville	132 Freistadt Road, Thiensville, WI
Racine County		
RA1	City of Racine	820 Racine Street, Racine, WI
RA3	Racine County	14200 Washington Avenue, Yorkville, WI
RA6	Village of Caledonia	6922 Nicholson Road, Caledonia, WI
RA10	Town of Raymond	2563 76th Street, Raymond, WI
RA12	Village of Union Grove	1015 State Street, Union Grove, WI
RA13	Village of Wind Point	215 E. 4 Mile Road, Wind Point, WI

Table 230 (continued)

Identification Number on Map 144	Owner	Site Location
Sheboygan County		
SH1	Sheboygan County	W6451 State Road 28, Lyndon, WI
SH2	Sheboygan County	234 Edgewood Street, Adell, WI
SH3	Town of Lyndon	W5672 County Road F, Lyndon, WI
SH4	Town of Scott	N1320 Boltonville Road, Scott, WI
Washington County		
WN2	City of West Bend	251 Municipal Drive, West Bend, WI
WN4	Town of Barton	3482 Town Hall Road, Barton, WI
WN6	Town of Farmington	9422 State Road 144, Farmington, WI
WN8	Town of Jackson	3685 Division Road, Jackson, WI
WN18	Town of Kewaskum	9019 Kettle Moraine Drive, Kewaskum, WI
WN10	Town of Polk	3680 State Road 60, Polk, WI
WN12	Town of Trenton	1071 State Road 33, Trenton, WI
WN19	Town of West Bend	6355 County Road Z, West Bend, WI
WN14	Village of Germantown	W172 N12205 Fond du Lac Road, Germantown, WI
WN15	Village of Jackson	W204 N16690 Jackson Drive South, Jackson, WI
WN20	Village of Kewaskum	US Highway 45 at County Road H, Kewaskum, WI
WN17	Washington County	620 E. Washington Street, West Bend, WI
WN21	Washington County	900 Lang Street, West Bend, WI
WN22	West Bend School District	1065 S. Indiana Avenue, West Bend, WI
Waukesha County		
WK35	Village of Butler	12975 Old Silver Spring Road, Butler, WI
WK22	Village of Elm Grove	900 Wall Street, Elm Grove, WI
WK24	Village of Menomonee Falls	W164 N9183 Water Street, Menomonee Falls, WI
WK23	Village of Menomonee Falls	N72 W15920 Good Hope Road, Menomonee Falls, WI

NOTE: The inventory data on this table is subject to periodic change due to the nature of the facilities. For the most recent data, the Wisconsin Department of Transportation should be contacted.

Source: Wisconsin Department Transportation and SEWRPC.

Bulk Fuel Storage Facilities

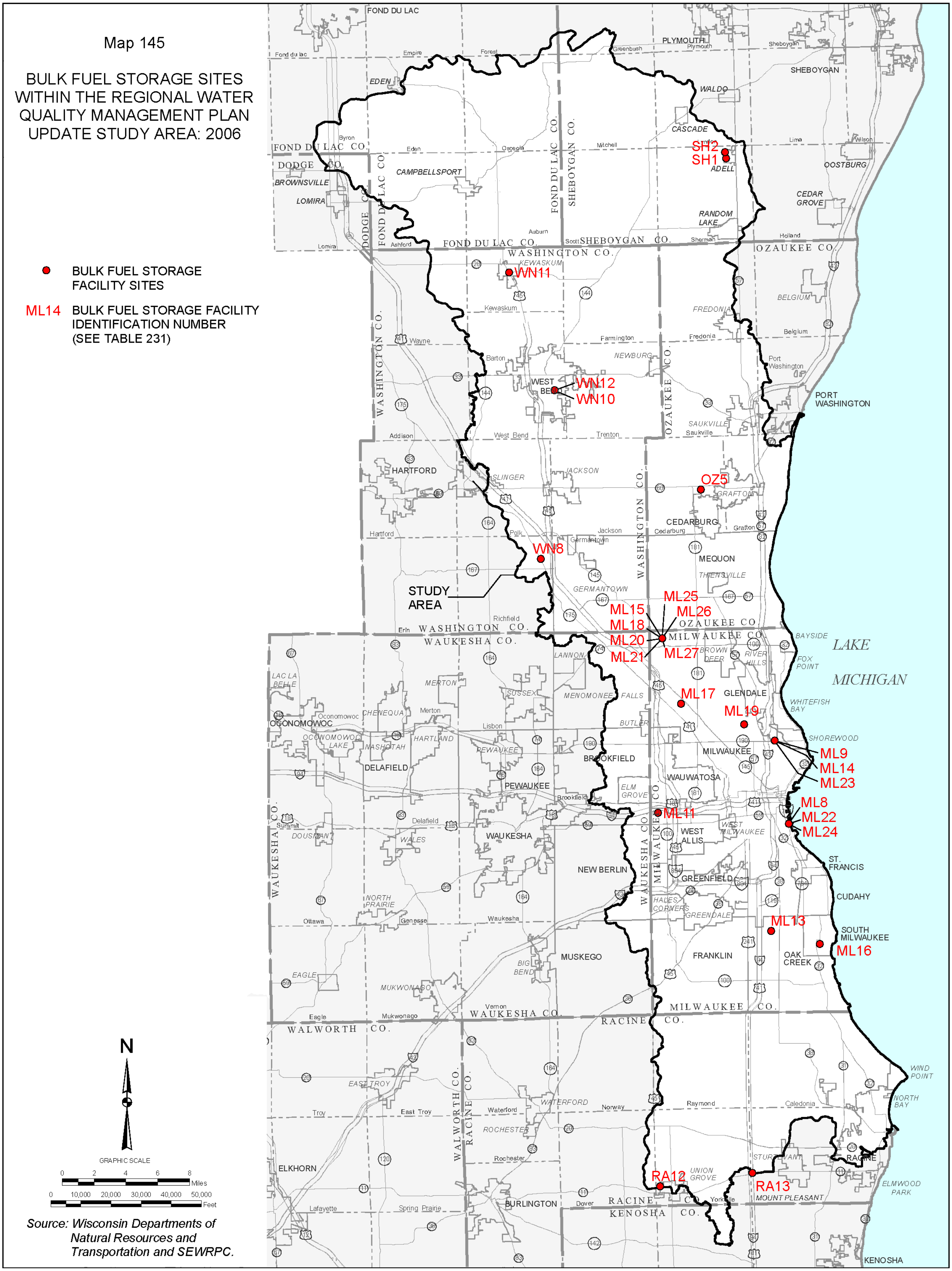
Bulk fuel storage sites are a potential source of groundwater contamination in the event of a spill or leak at the storage facility. Known bulk fuel storage sites in the study area are shown on Map 145 and listed in Table 231. Should a spill or leak occur, sites overlying sand and gravel materials would cause the greatest threat to contamination of the groundwater. In other areas, such incidents could also be potential sources of contamination to both the groundwater and surface water. Installation of containment structures under and around the storage tanks minimizes the risk of contamination due to ruptures or spills.

Spills of Hazardous Materials

Approximately 1,200 accidental or unintentional spills of hazardous materials are reported in Wisconsin every year, with nearly one-third of these spills occurring within the Region. An undetermined number of additional spills and illegal dumping of hazardous materials go unreported. Fortunately, many spills are small and can be cleaned up quickly before much of the substance can reach the groundwater. The types of spills vary, and have included substances such as fuel, mineral spirits, mineral oil, heating oil, hydraulic fluid, transformer fluid, chlorinated solvents, lubricants, hydrocarbons, as well as other unknown substances. By far, petroleum products are the contaminants most commonly involved in spills. The sites are scattered throughout the Region, but most of them have occurred along highways and within urban areas near storage tanks. The spills that required a major cleanup effort have been primarily centered around urban areas, with most occurring in the eastern portion of the Region within the water quality management plan update study area in areas underlain by clay tills with restricted permeability. Sites located on more permeable soils in the study area would be more susceptible to groundwater contamination. Spills of hazardous materials are also a potential hazard to surface waters, especially if the contaminant enters the storm sewer system.

Map 145

BULK FUEL STORAGE SITES WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA: 2006



Source: Wisconsin Departments of Natural Resources and Transportation and SEWRPC.

Table 231

BULK FUEL STORAGE SITES IN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA: 2006

Identification Number on Map 145	Name and Site Address	Location by U.S. Public Land Survey
Milwaukee County		
ML8	Jacobus Energy, Inc. 1726 S. Harbor Drive Milwaukee, WI 53207	T6N, R22E, Section 4, SW 1/4 of the NE 1/4
ML9	Bliffert North Side Coal and Oil 250 W. Capitol Drive Glendale WI, 53212	T7N, R22E, Section 5, SW 1/4 of the SE 1/4
ML11	Jacobus Energy, Inc. 435 S. 116th Street West Allis, WI 53214	T7N, R21E, Section 31, SE 1/4 of the NW 1/4[a]
ML13	Bioversal USA, Inc. 610 W. Rawson Avenue Oak Creek, WI 53154	T5N, R22E, Section 5, SE 1/4 of the SW 1/4
ML14	Bliffert North Side Coal and Oil 4061 N. Lydell Avenue Glendale WI, 53212	T7N, R22E, Section 5, SE 1/4 of the SE 1/4
ML15	BP Products of North America 9101 N. 107th Street Milwaukee, WI 53224	T8N, R21E, Section 6, NE 1/4 of the SE 1/4
ML16	Coveney & Company 900 Marion Avenue South Milwaukee, WI 53172	T5N, R22E, Section 11, SW 1/4 of the SE 1/4
ML17	Kaul Oil Co. 5931 N. 91st Street Milwaukee, WI 53225	T8N, R21E, Section 29, NE 1/4 of the SW 1/4
ML18	Koch Petroleum 9343 N. 107th Street Milwaukee, WI 53224	T8N, R21E, Section 6, SE 1/4 of the NE 1/4
ML19	Lakeside Oil Co. 2817 W. Stark Street Milwaukee, WI 53209	T8N, R21E, Section 36, SE 1/4 of the SE 1/4
ML20	Marathon Oil Co. 9125 N. 107th Street Milwaukee, WI 53224	T8N, R21E, Section 6, NE 1/4 of the SE 1/4
ML21	Milwaukee Petroleum Products 9135 N. 107th Street Milwaukee, WI 53224	T8N, R21E, Section 6, SE 1/4 of the NE 1/4
ML22	PTW, Inc. 1414 S. Harbor Drive Milwaukee, WI 53207	T6N, R22E, Section 4, NE 1/4 of the NE 1/4
ML23	Riverside BP 122 W. Capitol Drive Milwaukee, WI 53212	T7N, R22E, Section 5, SE 1/4 of the SE 1/4
ML24	ST Services 1626 S. Harbor Drive Milwaukee, WI 53207	T6N, R22E, Section 4, NW 1/4 of the NE 1/4
ML25	US Oil Company, Inc. 9135 N. 107th Street Milwaukee, WI 53224	T8N, R21E, Section 6, SE 1/4 of the NE 1/4

Table 231 (continued)

Identification Number on Map 145	Name and Site Address	Location by U.S. Public Land Survey
Milwaukee County (continued)		
ML26	US Oil Company, Inc. 9521 N. 107th Street Milwaukee, WI 53224	T8N, R21E, Section 6, NE 1/4 of the NE 1/4
ML27	US Oil Company, Inc. 9451 N. 107th Street Milwaukee, WI 53224	T8N, R21E, Section 6, SE 1/4 of the NE 1/4
Ozaukee County		
OZ5	Filter Oil, Inc. 1206 Hilltop Road Cedarburg, WI 53012	T10N, R21E, Section 22, NE 1/4 of the NW 1/4
Racine County		
RA12	Cooperative Plus, Inc. 20412 10th Avenue Union Grove, WI 53182	T3N, R21E, Section 30, SE 1/4 of the SW 1/4
RA13	Pugh Oil Company, Inc. 13709 Old Highway 11 Sturtevant, WI 53177	T3N, R22E, Section 30, NW 1/4 of the NW 1/4
Sheboygan County		
SH1	Adell Cooperative 607 Mill Street Adell, WI 53001	T13N, R21E, Section 2, NE 1/4 of the SW 1/4
SH2	Co-Energy Alliance 647 County Highway BB Adell, WI 53001	T13N, R21E, Section 2, SE 1/4 of the NW 1/4
Washington County		
WN8	Wolf Brothers Fuel 1985 Highway 175 Richfield, WI 53076	T9N, R19E, Section 12, SE 1/4 of the NW 1/4
WN10	Yahr Oil Company 106 W. Decorah Road West Bend, WI 53095	T11N, R19E, Section 13, SE 1/4 of the SW 1/4[a]
WN11	Herriges Oil, Inc. 1245 Fond du Lac Avenue Kewaskum, WI 53040	T12N, R19E, Section 9, NE 1/4 of the SE 1/4
WN12	Jacobus Petroleum Producers 111 E. Decorah Road West Bend, WI 53095	T11N, R19E, Section 24, NE 1/4 of the NW 1/4

NOTE: The inventory data on this table is subject to periodic change due to the nature of the facilities. For the most recent data, the Wisconsin Department of Commerce should be contacted.

[a]*Location differs from that of the inventory in TR-37, however these locations are based on aerial photos showing actual storage tanks.*

Source: Wisconsin Department of Commerce and SEWRPC.

Improperly Abandoned Wells

One of the most important, yet overlooked, sources of groundwater contamination are old wells that are no longer used, but have not been properly sealed when abandoned. Proper well abandonment means filling the well from the bottom up with cement grout or bentonite.[15] The locations of old wells are often long-forgotten, and buildings or roads may have been built over the top of open boreholes. These wells can serve as a means for transmission of contaminants from the land surface to an aquifer and can permit contaminated water to migrate freely from one aquifer to another (see Figure 367). This is particularly critical in southeastern Wisconsin where the open intervals of most wells penetrate many different aquifer units. Even in areas where groundwater contamination potential is ordinarily considered low because of favorable soil and geological properties, such as in Milwaukee and eastern Waukesha Counties, large numbers of improperly abandoned or unaccounted-for old wells create a significant threat to groundwater quality. In addition, an abandoned well can become a convenient receptacle for disposal of trash or a safety hazard.

Figure 367 illustrates the possible pathways that contaminants can take through improperly abandoned wells to threaten water quality in multiple aquifer systems. Wells B and D are improperly abandoned or poorly grouted wells, which enable contaminants from the land surface or from leaking underground storage tanks to migrate either to shallow production wells (C) in the upper aquifer or to deep production wells (A) in lower aquifers. If deep wells such as B are improperly abandoned or poorly grouted, they provide a conduit for contaminants to migrate below confining units, such as the Maquoketa shale, and contaminate deep sandstone aquifers normally considered to be protected from surface activities.

More than 100,000 private domestic and other wells have been drilled in southeastern Wisconsin since the turn of the century, particularly before municipal water supply systems were established. Since 1936, well drillers have submitted Well Constructor's Reports (WCRs) for most of these wells to the WDNR, and these WCRs are subsequently filed and sorted by reported location at the WGNHS. Densities of wells drilled between 1936 and 1979 in Milwaukee County and the easternmost townships in Waukesha County were determined based on these records. Densities of wells for which records exist range from less than 10 per square mile in central and southern parts of Milwaukee County to more than 500 per square mile along the Milwaukee-Waukesha county line. Areas with at least 300 old well or boring records per square mile are located primarily in Brookfield, Wauwatosa, and Hales Corners.

Most of Milwaukee County was converted to municipal water supply by 1963. Thus, the 1936-1979 data represent a reasonable count of potentially improperly sealed wells for which there are historical records. However, the areas in Milwaukee County with relatively low densities of historic well records undoubtedly contain many wells drilled prior to 1936, for which no historic records exist. In eastern Waukesha County, numerous wells have been drilled since 1979, thus the numbers of WCRs and boring records per U.S. Public Land Survey section between 1936 and 1979 probably are a significant underestimate of the total number of wells actually drilled.

Recently, the WDNR has introduced well abandonment forms, which should be submitted when unused, abandoned wells are properly sealed. The WDNR maintains files of these forms. Unfortunately, it is not possible to match well abandonment records with the original WCRs.[16]

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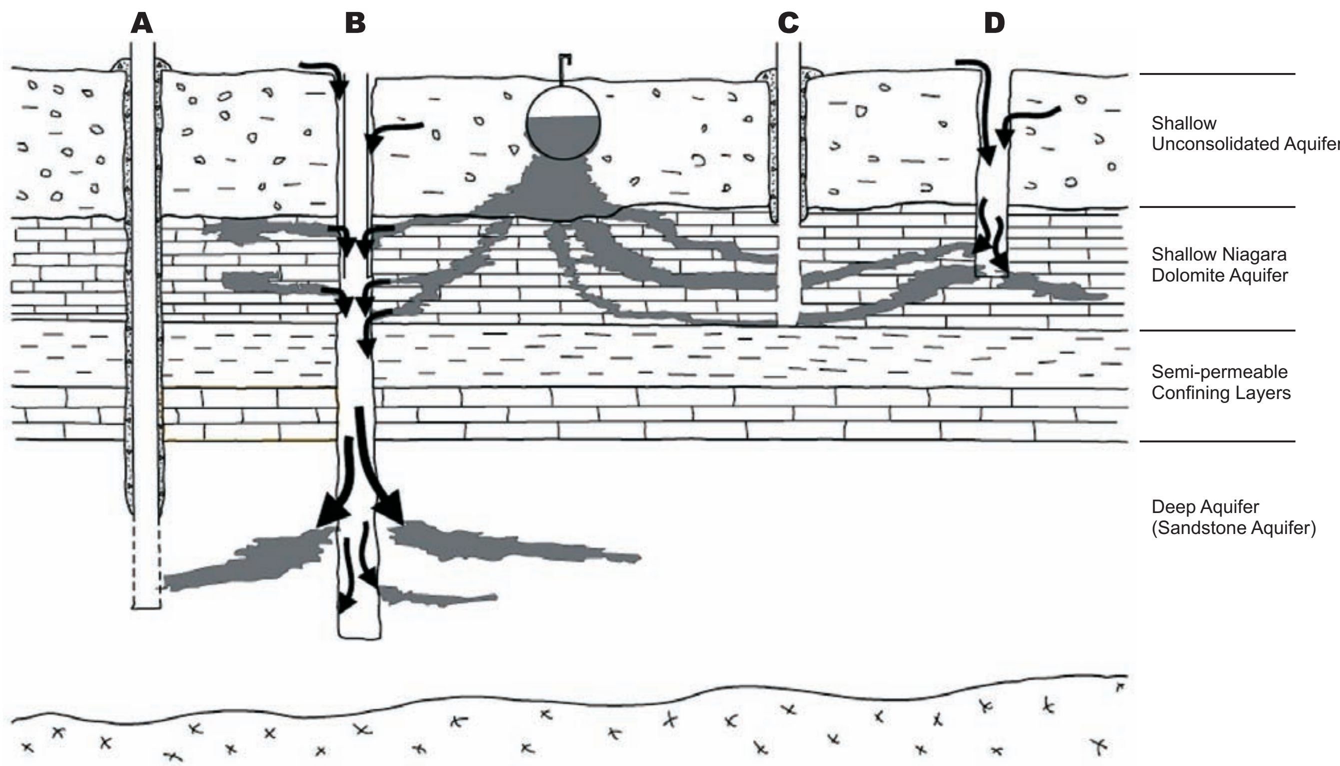
[15] *Wisconsin Department of Natural Resources Publication No. PUBL-WS-016 94 rev.,* Well Abandonment*, 1994.*

[16] *The WDNR has increased its surveillance of abandoned wells. As of February 2007, the Department was in the process of developing a centralized database containing information on abandoned wells.*

Figure 367

AQUIFER CONTAMINATION THROUGH IMPROPERLY ABANDONED WELLS



Source: Adapted from DiNovo and Jaffe, 1984.

It would be difficult to accurately estimate the number of improperly abandoned wells in the study area. As municipal water supply service areas expanded, existing private domestic wells may have been sealed, or remain improperly abandoned, or are used for a secondary purpose, such as lawn watering, for which owners may or may not have been granted a permit. By comparing numbers from various sources, the WDNR has estimated that within the study area, three areas: Milwaukee County, eastern Waukesha County, and eastern Racine County, have the most abandoned wells.[17] The WDNR has estimated that Milwaukee County had up to 8,000 improperly abandoned wells; eastern Waukesha County within the study area, less than 3,000 improperly abandoned wells; and eastern Racine County within the study area less than about 1,000 improperly abandoned wells.

The existence of unused, abandoned wells represents a significant contamination threat to both shallow and deep groundwater. It is not an intention of this report to show an accurate, absolute number of such wells, but rather to point out improperly abandoned wells as a serious problem in the study area.

[17]*Peter Wood, Wisconsin Department of Natural Resource-Southeast Region, written communication, 1997.*

APPROACH TO THE EVALUATION OF VULNERABILITY OF GROUNDWATER TO CONTAMINATION FOR THE REGION

Processes Affecting the Fate and Transport of Contaminants in the Subsurface
The potential for groundwater contamination depends on the attenuation processes that take place between the source of contamination and the aquifer. Attenuation of most contaminants, as they travel through the unsaturated zone and groundwater system, is affected by a variety of naturally occurring chemical reactions and biological and physical processes that often cause the contaminant to change its physical state or chemical form. These changes may lessen the severity of contamination or amounts of contaminants. Once contaminants reach the saturated zone (an aquifer), fewer processes attenuate contaminant concentrations than in the unsaturated zone. Although the importance of these processes in attenuation of contaminants is well recognized, predicting how much attenuation will take place in a particular environment is still difficult.[18] The degree of attenuation that occurs depends upon: 1) the grain size and physical and chemical characteristics of the material through which the contaminant passes, 2) the time the contaminant is in contact with the material through which it passes, and 3) the distance which the contaminant has traveled. However, attenuation processes can be bypassed completely if a contaminant is introduced directly into an aquifer.

Evaluation System
Many methods have been developed to evaluate the groundwater contamination potential. The most commonly used ones are the overlay methods combining several major physical factors considered most important for the evaluation of a given area. The factors typically include soil characteristics, lithology and thickness of the unsaturated zone, and depth to groundwater. The methods often rely on a numerical rating system to assess the importance of and relationship among the individual parameters. A numerical rating is assigned to each of the selected parameters, and the final numerical score is calculated for each hydrogeologic setting present in the area by summing the numerical scores of the individual parameters.[19]

The system for the evaluation of contamination potential in the study area is based on the following five parameters:

1. Soil characteristics.
2. Unsaturated zone thickness.
3. Permeability of vertical sequences in the unsaturated zone.
4. Recharge to groundwater, represented by soil percolation.
5. Aquifer characteristics.

In the approach used for this report, the evaluation of the physical environment in the study area was separated into three independent components according to the intended use or activity and the fate of contaminants in the subsurface:

1. Evaluation of the capacity of soils to attenuate contaminants.
2. Evaluation of the contamination potential of shallow groundwater.
3. Evaluation of the contamination potential of deeper aquifers.

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[18]*L. Aller, and Others,* DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings*, U.S. Environmental Protection Agency, Ada, OK, EPA/600/2-87-036, 1987.*

[19]Ibid.

Each of these components can be mapped separately, and the maps can be used individually or combined into a composite map. Using three independent components makes the system use-specific. However, at this point, the third component—the contamination potential of deeper aquifers—can be considered only generally, because of limitations in the currently available information. Components 1 and 2 are presented on Maps 146 and 147.

The capacity of soils to attenuate contaminants has been evaluated by the Soil Contamination Attenuation Model (SCAM), using seven physical and chemical characteristics of soils. The system evaluates the ability of the soil solum (the A and B horizons) to attenuate potential contaminants resulting from activities above and within the soil zone. It was developed by F.W. Madison in 1985 and it is described in Chapter III of SEWRPC TR No. 37.

The evaluation of the contamination potential of shallow groundwater is based on three parameters: thickness of the unsaturated zone, permeability of vertical sequences in the unsaturated zone, and estimated annual soil percolation rate as an approximation of recharge. This component of the system evaluates the capacity of the subsurface environment to attenuate contaminants resulting from activities within the unsaturated zone or contaminants that penetrated the soil zone as described in the next section.

The contamination potential of the deeper aquifers is based upon consideration of the geologic and groundwater-flow characteristics, such as bedrock lithology; presence of the Maquoketa shale unit; location, extent and character of the recharge areas; and general direction of groundwater flow. This component of the system helps evaluate the general movement of contaminants that reach the deep groundwater-flow systems and also helps define protection zones related to water supply sources.

The procedures for evaluation of contamination potential of shallow groundwater are set forth in detail in Appendix J.

CONTAMINATION POTENTIAL ANALYSIS

A comprehensive assessment of the vulnerability of groundwater to contamination in the Region had not been carried out previous to that conducted for SEWRPC TR No. 37. Previous studies either considered only a part of the Region or a single contamination source, or were done at a limited, Statewide scale. In 1971, the first study that addressed the potential for contamination of groundwater in the Region[20] investigated geologic factors important to determine the suitability of land for liquid waste disposal. In that study, four general maps were used to develop the final suitability map: soil permeability, thickness of surficial deposits, nature of surficial deposits, and nature of the bedrock. In 1979,[21] a map was constructed showing contamination potential in the Silurian dolomite aquifer at the scale of 1:250,000, based on three factors: the relative permeability of unconsolidated materials, the thickness of those materials, and the depth to the water table. In 1987, the Wisconsin Department of Natural Resources completed a statewide map of groundwater contamination susceptibility at the scale of 1:1,000,000.[22] Five factors were considered in the preparation of the map: soil characteristics, depth to the water table, characteristics of surficial deposits, depth to bedrock, and type of bedrock.

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[20]*M.J. Ketelle, "Hydrogeologic Considerations in Liquid Waste Disposal, with a Case Study in Southeastern Wisconsin," SEWRPC* Technical Record*, Vol. 3, No. 3, 1971.*

[21]*M.G. Sherrill,* Contamination Potential in the Silurian Dolomite Aquifer, Eastern Wisconsin*, U.S. Geological Survey Water Resources Investigations 78-108 (4 maps on 2 plates), 1979.*

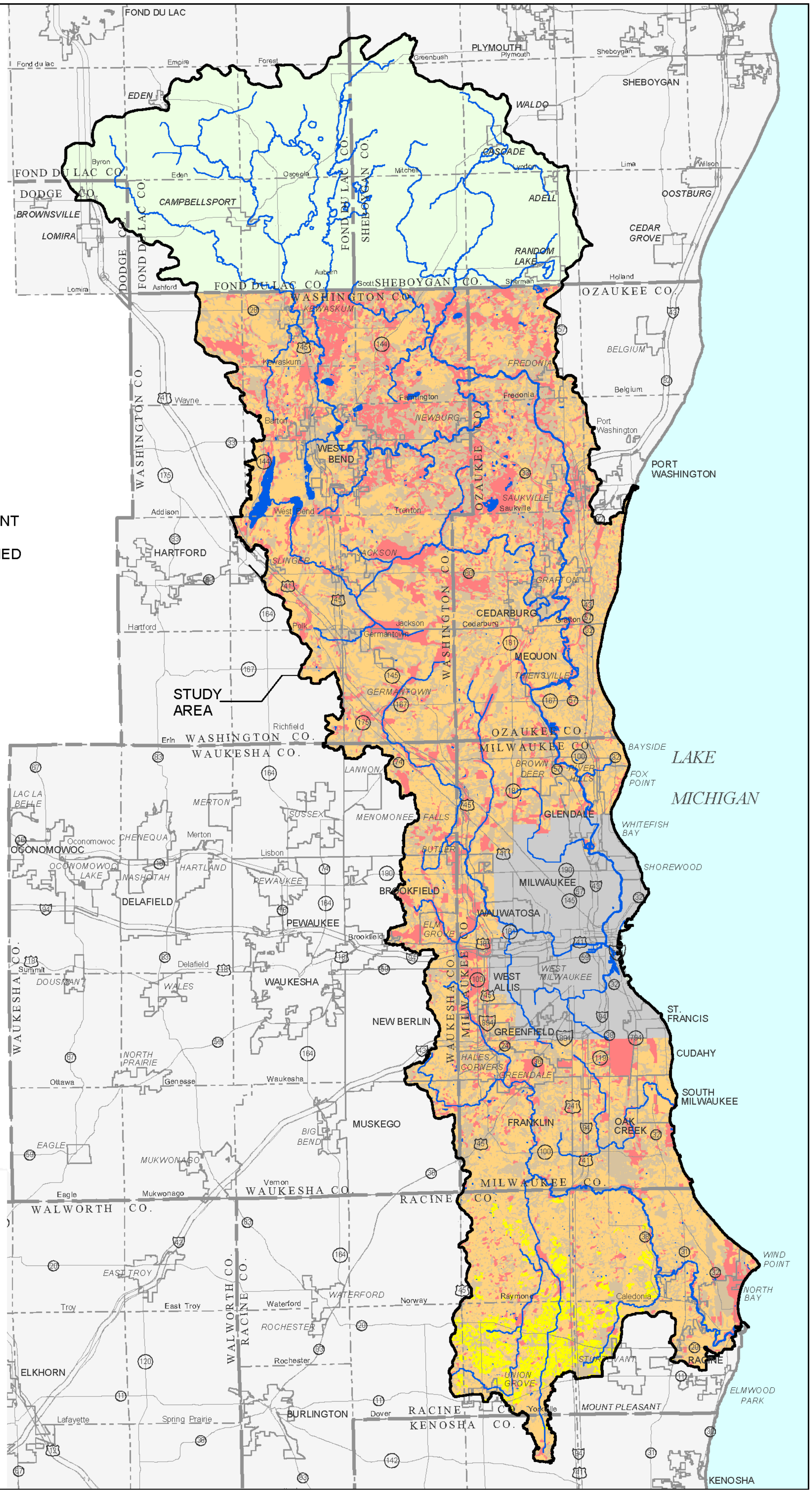
[22]*R. Schmidt, and K. Kessler,* Groundwater Contamination Susceptibility in Wisconsin*, Wisconsin Geological and Natural History Survey Other Contributions 9, map 1:1,000,000, full color, 1987.*

Map 146

CONTAMINANT ATTENUATION POTENTIAL OF SOILS IN THE PORTION OF THE SOUTHEASTERN WISCONSIN REGION WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA

SOIL ATTENUATION CATEGORY

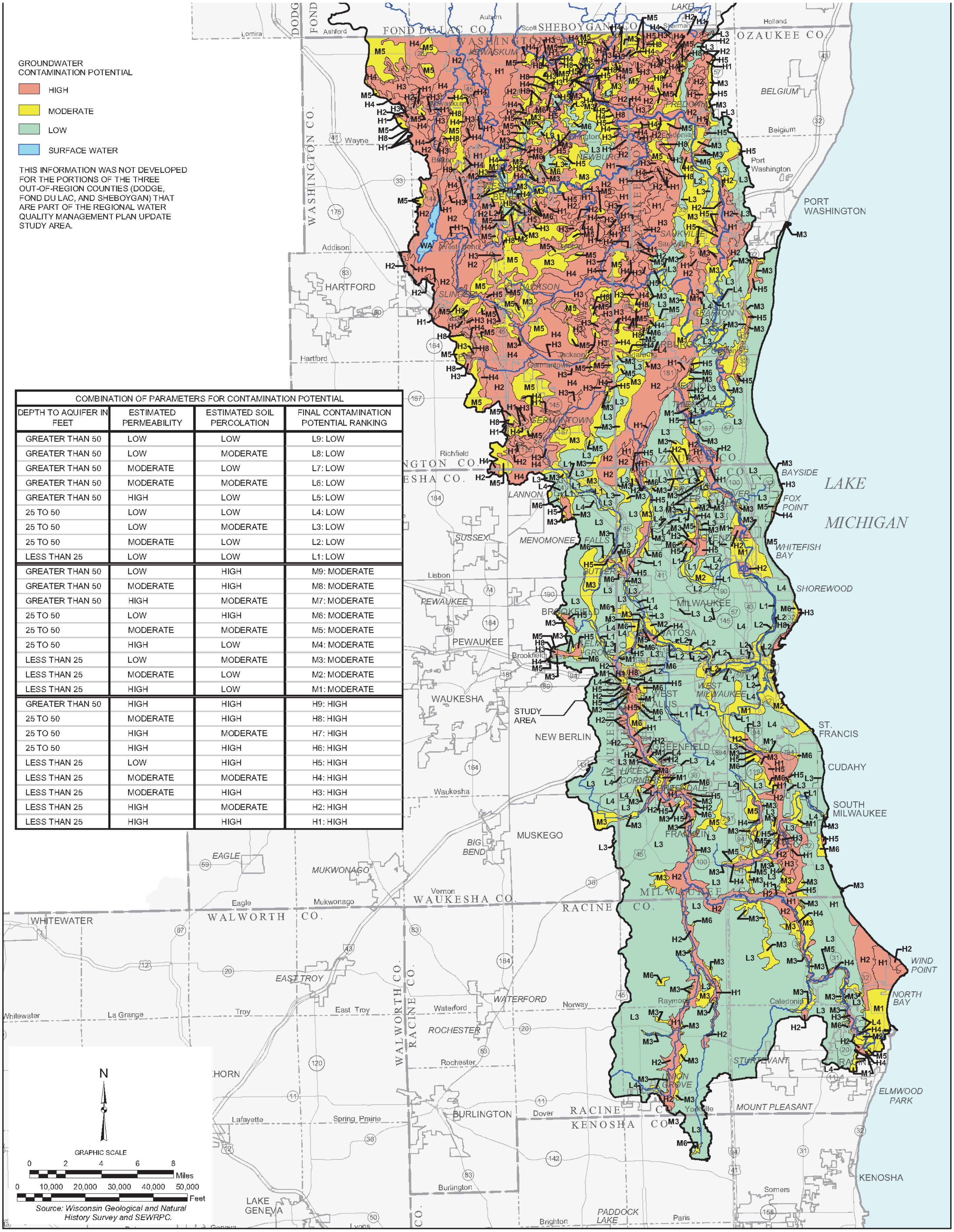
- BEST
- GOOD
- MARGINAL
- LEAST
- NO SURVEY DATA
- AREA FOR WHICH CONTAMINANT ATTENUATION POTENTIAL HAS NOT YET BEEN DETERMINED
- SURFACE WATER



Source: Wisconsin Geological and Natural History Survey, University of Wisconsin-Extension, and SEWRPC.

Map 147

GROUNDWATER CONTAMINATION POTENTIAL OF SHALLOW AQUIFERS IN THE PORTION OF THE SOUTHEASTERN WISCONSIN REGION WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA



COMBINATION OF PARAMETERS FOR CONTAMINATION POTENTIAL

DEPTH TO AQUIFER IN FEET	ESTIMATED PERMEABILITY	ESTIMATED SOIL PERCOLATION	FINAL CONTAMINATION POTENTIAL RANKING
GREATER THAN 50	LOW	LOW	L9: LOW
GREATER THAN 50	LOW	MODERATE	L8: LOW
GREATER THAN 50	MODERATE	LOW	L7: LOW
GREATER THAN 50	MODERATE	MODERATE	L6: LOW
GREATER THAN 50	HIGH	LOW	L5: LOW
25 TO 50	LOW	LOW	L4: LOW
25 TO 50	LOW	MODERATE	L3: LOW
25 TO 50	MODERATE	LOW	L2: LOW
LESS THAN 25	LOW	LOW	L1: LOW
GREATER THAN 50	LOW	HIGH	M9: MODERATE
GREATER THAN 50	MODERATE	HIGH	M8: MODERATE
GREATER THAN 50	HIGH	MODERATE	M7: MODERATE
25 TO 50	LOW	HIGH	M6: MODERATE
25 TO 50	MODERATE	MODERATE	M5: MODERATE
25 TO 50	HIGH	LOW	M4: MODERATE
LESS THAN 25	LOW	MODERATE	M3: MODERATE
LESS THAN 25	MODERATE	LOW	M2: MODERATE
LESS THAN 25	HIGH	LOW	M1: MODERATE
GREATER THAN 50	HIGH	HIGH	H9: HIGH
25 TO 50	MODERATE	HIGH	H8: HIGH
25 TO 50	HIGH	MODERATE	H7: HIGH
25 TO 50	HIGH	HIGH	H6: HIGH
LESS THAN 25	LOW	HIGH	H5: HIGH
LESS THAN 25	MODERATE	MODERATE	H4: HIGH
LESS THAN 25	MODERATE	HIGH	H3: HIGH
LESS THAN 25	HIGH	MODERATE	H2: HIGH
LESS THAN 25	HIGH	HIGH	H1: HIGH

In order to comprehensively assess the contamination potential of groundwater in the Region, the study documented in SEWRPC TR No. 37 developed the evaluation system described in Appendix J, which is designed to specifically assess the potential for contamination of shallow groundwater; that is, the threat of contamination to the water table aquifer. As already noted, this threat to groundwater quality varies according to possible sources of contamination. The subsurface environment can provide three levels of protection against such sources. In general, for contaminants spilled at the land surface, the soil layer itself provides the first barrier to groundwater contamination. For contaminants that have penetrated the soil layer or for shallow subsurface sources of contamination such as onsite sewage disposal systems and leaking underground storage tanks, the nature of the unlithified geology and hydrogeology, as assessed in the groundwater contamination potential system, form the next barrier. If the shallow aquifer becomes contaminated, this constitutes a possible contamination source for deeper aquifers, because of the hydrologic interconnection of aquifer systems. The nature of the deeper bedrock geology and groundwater-flow systems constitute the final barrier to more extensive, deep groundwater contamination.

The contamination potential of groundwater in the study area is described at all three levels in the following sections. It is important to note, however, that any of the three barriers to groundwater contamination can be bypassed by various mechanisms. For instance, in areas where numerous leaking underground storage tanks, quarries, or gravel pits exist, it is clearly inappropriate to use the soil contaminant attenuation map to assess contamination potential, because contaminants from these sources have already bypassed the soil barrier. In addition, soils have only a limited capacity to attenuate contaminants. If there is a large spill of a contaminant, such as a rupture of a high-volume petroleum storage tank, it is likely that the soil attenuation capacity at that location will be quickly overwhelmed. Furthermore, where there is reason to believe that numerous improperly abandoned wells exist, as previously noted, the contamination potential map for shallow groundwater may be misleading, because improperly abandoned wells are direct conduits that bypass the second barrier created by the unlithified geology and hydrogeology.

Potential for Contamination By Surface Sources

Since the first barrier to groundwater contamination is the soil, the threat of groundwater contamination from surface sources in southeastern Wisconsin depends on the nature of soils and their ability to attenuate or neutralize contaminants. Map 146 shows the distribution of soils with differing attenuation properties based on a system described in Chapter III of SEWRPC TR No. 37. The better the soil attenuation rating for a given area, the more likely it is that the soil can help neutralize small contaminant spills before they reach the groundwater, thus reducing the contamination threat to groundwater from surface activities. Conversely, the lower the soil attenuation rating, the greater the contamination threat to groundwater from surface activities.

The system for evaluating the ability of soils to attenuate contaminants is designed to assess soils in their natural, undisturbed state. There are some areas in all counties where soils may have been extensively modified, in which case mapped attenuation ratings may not be accurate. Over time, soil properties change as land is put into intensive agricultural production and eroded, or land use changes from rural to suburban or urban uses. Therefore, soil properties for attenuating contaminants must be verified by field examination for any specific area.

Map 146 indicates that about 43 percent of the portion of the study area in the Region is covered by soils that have good and best potential for attenuating contaminants, and thus may be considered less susceptible to contamination from surface sources and well suited for a variety of land uses. These soils appear to be fairly evenly distributed across the portion of the study area in the Region on upland till surfaces. Areas where soils are best suited for attenuating contaminants, and therefore, contamination potential is the lowest, have good loamy or clayey soil texture; and thick, well-drained soils. Soils with the best attenuation potential cover about 1 percent of the portion of the study area in the Region (see Appendix K) and are found only in Racine County. Soils with good attenuation potential cover about 42 percent of the portion of the study area in the Region (see Appendix K).

Approximately 46 percent of the portion of the study area in the Region is covered by soils with poor—marginal and least—attenuation potential (see Appendix K). Soils that have the least attenuation potential, and thus, may be considered most susceptible to contamination by surface sources, account for about 16 percent of the study area in the Region. Areas where soil attenuation is least tend to be concentrated in terminal moraine areas, where the surface drainage has been extensively disrupted by glacial debris, and in areas of poorly drained organic soils in land depressions with standing water and near lakes and rivers (see Map 146). For example, within the study area, the Cedarburg Bog in Ozaukee County is an example of this setting. Other major areas of least soil attenuation in the study area are sandy soils along the Lake Michigan shoreline.

Due to their disturbance, soils have not been mapped in the urban areas of Milwaukee County, so it is not possible to determine attenuation potential for that area, which is shown in gray on Map 146 and which comprises about 10 percent of the study area in the Region. The remaining 1 percent of the study area in the Region is surface water.

Contamination Potential of Shallow Aquifers

The contamination potential of shallow groundwater is illustrated for that portion of the study area in the Southeastern Wisconsin Region on Map 147 and is quantified in Table 232.[23] Areas of differing relative contamination potential are shown in red (high contamination potential), yellow (moderate contamination potential), and green (low contamination potential). Groundwater vulnerability factors used in assigning contamination potential rankings can be identified by using the map labels to refer to the table presented adjacent to the map. Map 147 and Table 232 indicate that approximately 36 percent of the study area in the Region has a high potential for contamination of shallow aquifers, especially in the inland areas. Therefore, there is a need for careful planning of activities that may affect shallow aquifers. Moderate and low contamination potential occur over 19 and 45 percent of the study area in the Region, respectively.

The most noticeable feature of the regional groundwater contamination potential map is the west-east dichotomy between primarily high and moderate contamination potential areas in the west and primarily low contamination potential areas in the east, including much of the regional water quality management plan update study area. This is a reflection of the heavy influence of the Pleistocene glacial materials on groundwater vulnerability. The inland counties are dominated by sandier sediment and the lakeshore counties are dominated by less permeable silty sediment. Depth to the groundwater table is also an important groundwater vulnerability factor, which accounts for most of the additional variations in contamination potential.

Inland Areas

In the inland areas of Ozaukee and Washington Counties a large portion of the land area has a high contamination potential (see Map 147). Of the counties within the study area and the Region, Washington County has the largest area with high contamination potential. Areas most vulnerable to contamination are those that have shallow depths to groundwater and high permeability (H2), or those underlain by outwash deposits with shallow depths to aquifer and high or moderate soil percolation (H3, H4). Many of these areas are found in river valleys where the water table is close to the surface. Much of the areas of northeastern Waukesha and southeastern Washington Counties are vulnerable to groundwater contamination because the bedrock aquifer is close to the surface. In addition, some upland areas, particularly in the Kettle Moraine, have high contamination potentials (H1, H2) because estimated permeabilities are high due to the presence of extensive sand and gravel deposits.

The moderate contamination potential classification (primarily M5), is attributable to shallow to average depth to groundwater, moderate permeability, and moderate soil percolation (see Table J-6 in Appendix J of this report). M1 and M2 areas are found primarily in areas of urban development, where low soil percolation compensates for shallow depth to the aquifer. M3 areas are found primarily in eastern Waukesha and Washington Counties, where

[23]*This type of inventory has not been developed for the three counties within the study area that are outside the Southeastern Wisconsin Region (Dodge, Fond du Lac, and Sheboygan Counties).*

Table 232

GROUNDWATER CONTAMINATION POTENTIAL AREAS BY COUNTY IN THE PORTION OF THE SOUTHEASTERN WISCONSIN REGION WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA

County	High Potential		Moderate Potential		Low Potential		Total
	Area (acres)	Percent	Area (acres)	Percent	Area (acres)	Percent	
Kenosha	0	0	90	5	1,670	95	1,760
Milwaukee	18,370	12	24,710	16	111,800	72	154,880
Ozaukee	47,440	44	24,110	22	37,000	34	108,550
Racine	11,850	13	8,370	10	68,510	77	88,730
Washington	116,140	71	41,070	25	6,520	4	163,730
Waukesha	2,480	8	5,620	17	24,240	75	32,340
Total	196,280	36	103,970	19	249,740	45	549,990

Source: Wisconsin Geological and Natural History Survey and SEWRPC.

low permeability compensates for shallow depth to aquifer. Areas of low contamination potential labeled L1 and L2 are found in urban areas due mainly to low soil percolation. Some areas in eastern Washington and Waukesha Counties have low contamination potential rankings (L3) due to the low permeabilities of the soils.

Lakeshore Areas

The situation in the lakeshore areas of the study area within the Region—Ozaukee, Milwaukee, and Racine Counties—is somewhat different. In these areas there is generally low groundwater contamination potential. Close to the lakeshore, areas of high and moderate contamination potential are limited to river valleys and portions of the shoreline, with labels of H1 and H2 indicating shallow depth to aquifer.

The moderate contamination potential areas in the lakeshore areas are mostly labeled M3 and, in Milwaukee County, also M2. This is because moderate and low soil percolation and permeability compensates for shallow depths to aquifer (see Table J-6 in Appendix J). The central urban area of Racine is classified as moderate contamination potential because of the low soil percolation (primarily M1).

The large area of low contamination potential in the lakeshore counties is due to the ridges of the lakeshore moraines constituted of silty till. These areas are labeled mostly L3 and L4 indicating low permeabilities, low to moderate soil percolation, and moderate depths to aquifer. Ranking of large areas of Milwaukee County as low contamination potential is influenced by low soil percolation in this mostly urban area with large portions of impervious surfaces.

Summary

Areas most vulnerable to contamination constitute approximately 36 percent of the study area within the Region (see Table 232) and are located primarily in inland areas. Generally, the lakeshore areas contain more areas with low contamination potential, which are more suitable for the location of activities that may affect shallow groundwater. These areas cover about 45 percent of the study area within the Region. Within the study area in the Region, these areas can be found in the eastern portion of Racine County, in the majority of Milwaukee County, and in eastern Ozaukee County. The remaining 19 percent of the study area within the Region has moderate contamination potential (see Table 232).

Contamination potential of shallow groundwater varies widely across the study area depending on the presence of the various combinations of the factors determining groundwater vulnerability. Mapped rankings of contamination potential can be misleading under specific circumstances such as improperly abandoned wells or open quarries, which can provide direct access to shallow aquifers. The groundwater contamination potential maps are intended to be used in conjunction with an inventory of potential contamination sources as an aid to sound land use and water quality management planning.

Contamination Potential of Deeper Aquifers

The vulnerability of the deeper aquifers of southeastern Wisconsin and the study area to contamination is more difficult to assess; and a complete evaluation of such vulnerability was beyond the scope of SEWRPC TR No. 37, which is the source for much of the information presented in this report and which is focused on the shallow groundwater system. In general, the greater thickness of overburden and the first two barriers to contamination—the soil layer and the underlying unlithified geologic conditions, provide an effective shield against contamination of the deeper aquifers. In addition, the deeper aquifers are protected by the ability of shallow aquifers to dilute contaminants. The possibility of contamination of deeper aquifers, however, is very real, although very difficult to detect, and may be impossible to reverse. In addition, the importance of the deeper aquifers as a source of municipal and industrial water supply within the study area cannot be understated. In some cases, these aquifers represent the only practical source of such supply.

A conceivable contamination scenario is the discharge of a large amount of liquid, such as petroleum, in an area where the shallow aquifer is relatively thin, unprotected, and directly interconnected with the deeper aquifers. A more insidious possibility is a smaller surface spill in the immediate vicinity of an old, forgotten deep well or open borehole that has not been properly abandoned (see Figure 367). Another contamination scenario is the drilling of a deep borehole through a shallow contaminated aquifer into the deeper aquifers. Contaminated shallow groundwater can contaminate the deeper aquifers through the borehole before a casing is installed. Other than the possibility of deep open boreholes, if the shallow aquifer is indeed significantly contaminated in a given area, the potential that such contamination will eventually reach the deeper aquifers depends on the nature of the deep bedrock lithology and the direction of flow between aquifers. These factors can be considered to be the third and final barrier to deep groundwater contamination.

Unfortunately, the nature of the deep bedrock lithology of the Region and the study area is not well understood at present, particularly with regard to the distribution of different units and the importance of regional faulting. A major confining unit plays the most significant role in the protection of the deeper aquifers: the Maquoketa Formation, which is continuous over all of the study area. In general, in areas to the west of this edge and outside of the study area, where the Maquoketa Formation is absent, the deeper aquifers are more vulnerable to contamination. However, the variability of lithology of the Maquoketa Formation is not known in detail. The dominant lithology is shale, which is relatively impermeable, but significant proportions of the thickness of this unit in some areas may be dolomite, which is much more permeable.

The other factor that determines vulnerability of the deeper groundwater to contamination is the direction of flow in deep groundwater systems. In the very thick deep aquifers, groundwater flow is three-dimensional, depending on differences of pressure and gradient. Under steady state, nonpumping conditions gradients are downward in recharge areas and upward in discharge areas. If there is a source like a contaminated shallow aquifer in a regional recharge area, such as to the west of the Maquoketa confining unit, then deeper aquifers can be contaminated. However, downward gradients can also be caused by pumping from the deeper aquifers and can induce leakage from shallow to deep aquifers through the Maquoketa confining unit (see Figure 367). If areas of downward gradients between aquifers near pumping centers coincide with locations of more permeable, dolomitic lithology in the Maquoketa shale, contaminants can penetrate into deeper aquifers over time. For this reason, protective measures for the deep aquifer recharge areas, as well as measures to avoid potential contamination routes through the confining unit, should be an important consideration in land use and water quality management planning.

GROUNDWATER QUALITY PROTECTION

Groundwater is a valuable resource in the study area. As indicated in Table 225, it comprises about 23 percent of the municipal water supply use and about 4 percent of the total water use in counties within the study area. Unfortunately, certain land uses and facility development activities can result in contamination of groundwater. About 36 percent of the study area within the Region is highly vulnerable to groundwater contamination (see Table 232). Cleaning contaminated groundwater can be costly and, in some cases, almost impossible. Therefore, the prevention of contamination before it occurs is a prudent step that should be taken in the development of the Region and the study area.

This section identifies specific areas, which should be afforded high priority for groundwater protection efforts.

Special Management Areas
Groundwater quality protection can be pursued either by addressing particular sources of contamination, or by focusing on specific areas that require special attention, in which all the existing or potential sources of contamination are of concern. Considering the high contamination potential present in certain parts of the study area, the second option provides a more effective approach. These specific areas, sometimes called special management areas, can be delineated and designated for special groundwater protection measures.[24]

Special management areas can be divided into three categories:

1. Naturally vulnerable areas.

2. Potential problem areas.

3. Wellhead protection areas.

Naturally Vulnerable Areas
Areas vary in terms of their vulnerability to groundwater contamination. Certain locations are naturally more susceptible to contamination than others because the soils, unlithified materials, or bedrock do not provide adequate protection, and the potential exists for a rapid movement of contaminants into groundwater. To identify these locations, the most vulnerable categories from the soil attenuation potential map (see Map 146) and groundwater contamination potential map (see Map 147) were combined, as shown on Map 148. The areas where these two categories overlap each other have no significant potential for the attenuation of contaminants and require special attention because certain land uses, accidents, or mishandling of hazardous materials may create serious contamination problems.

The critical recharge areas are another type of naturally vulnerable area. These are the recharge areas of the deeper aquifers located in areas of high groundwater contamination potential. These areas were delineated by superimposing the category of the high contamination potential from Map 147 on the significant recharge areas of the lower sandstone aquifer and are shown by crosshatching on Map 148. These areas are located in the western part of the Region, thus, there are no critical recharge areas in the portion of the study area within the Region. However, if a contaminant is released in a critical recharge area, resulting contamination may eventually spread to large areas of the deep aquifer, as well as the overlying aquifers. The remaining portion of the deep aquifer recharge area is considered as a naturally vulnerable area.

Delineating naturally vulnerable areas does not mean that the introduction of contaminants in other areas should be of no concern. The delineation is intended to focus needed management efforts on especially critical areas, and permits screening and priority-setting for areas that most need protection. By delineating the most vulnerable areas, it is possible to relate the stringency of protection controls to the severity of the threat of groundwater contamination.

Finally, naturally vulnerable areas also include dominant recharge areas in the shallow aquifer system. Recharge to the Galena-Platteville aquifer and the upper sandstone aquifer takes place within the recharge area for the lower sandstone aquifer. Recharge to the Silurian dolomite aquifer will primarily occur where highly permeable layers (Thiensville and Mayville) subcrop or where traces of fracture zones reach the surface (in the areas of shallow depth to bedrock). Recharge to the sand and gravel aquifer is controlled by hydraulic conductivity of glacial

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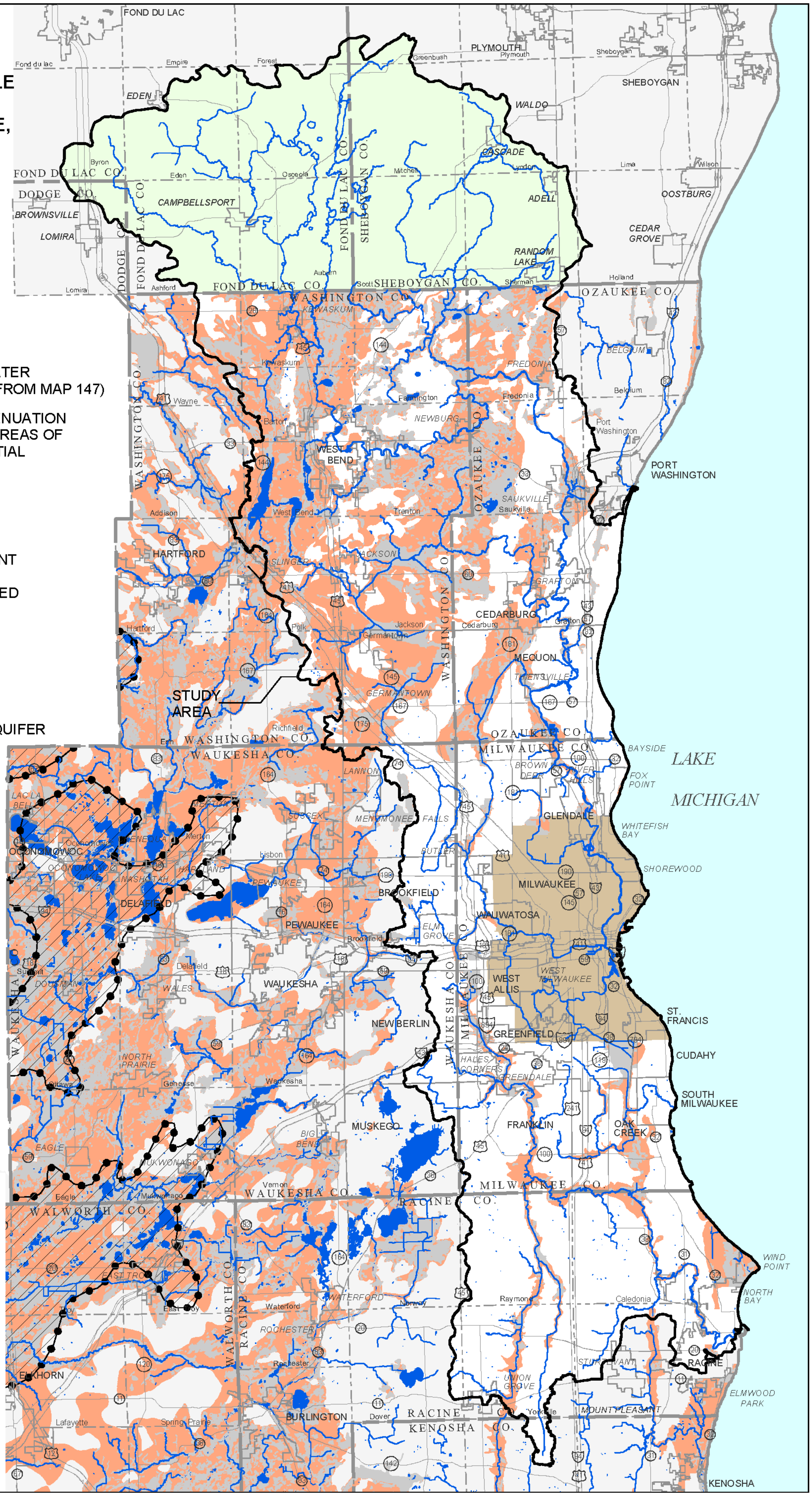
[24]*S.M. Born, D.A., Yanggen, and A. Zaporozec,* A Guide to Groundwater Quality Planning and Management for Local Governments*, Wisconsin Geological and Natural History Survey Special Report 9, 1987.*

Map 148

AREAS NATURALLY VULNERABLE TO GROUNDWATER CONTAMINATION IN MILWAUKEE, OZAUKEE, WASHINGTON, AND WAUKESHA COUNTIES, AND PORTIONS OF KENOSHA AND WALWORTH COUNTIES

- AREAS WITH HIGH GROUNDWATER CONTAMINATION POTENTIAL (FROM MAP 147)
- AREAS WHERE LOW SOIL ATTENUATION OF CONTAMINANTS OVERLIE AREAS OF HIGH CONTAMINATION POTENTIAL
- CRITICAL RECHARGE AREA
- NO SOIL SURVEY DATA
- AREA FOR WHICH CONTAMINANT ATTENUATION POTENTIAL HAS NOT YET BEEN DETERMINED
- REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA BOUNDARY
- SURFACE WATER
- LIMIT OF DEEP SANDSTONE AQUIFER RECHARGE AREA

NOTE: WITHIN THE PORTION OF THE STUDY AREA IN THE REGION, THIS MAP DEPICTS THE VULNERABILITY TO CONTAMINATION OF THE SHALLOW AQUIFER.



Source: Wisconsin Geological and Natural History Survey and SEWRPC.

materials and topography. Further information necessary to define the important recharge areas for the shallow aquifer system and their vulnerability to groundwater contamination has to be collected and interpreted.

Potential Problem Areas
Potential problem areas are places where potentially contaminating sources are located in the naturally vulnerable areas or places where contaminants have already entered groundwater. Overlaying the most vulnerable categories from the soil and groundwater contamination potential maps (see Map 146 and Map 147, respectively) with maps showing the location of individual potential contamination sources would indicate areas of highest contamination potential. This is not intended to suggest, however, that such places are the only areas in which groundwater quality problems may occur. Inventoried contamination sources, such as those shown on Maps 143, 144, and 145, have a potential to create groundwater contamination problems. The potential problem area map would only show the areas of greatest concern, because of the high potential for contaminants to reach the groundwater system if released into the soil or underlying materials. A map of potential problem areas can be used as a guide in the identification of areas that should be given a high priority in regional and local groundwater management planning. The potential problem areas can be determined by correlating the map of naturally vulnerable areas (see Map 148) with maps of identified contamination sources.

Potential problem areas, including the naturally vulnerable areas, are located primarily in the northern part of the portion of the study area within the Region, where in general, there is only a very limited potential for attenuating contaminants due to natural soil and geologic conditions (see Map 148). This is the primary area that should be given the highest priority for protection from contamination of groundwater.

At present, the known existing sources of contamination, as determined in the contamination source inventory, do not present a widespread threat to groundwater quality. The major anthropogenic sources of groundwater contamination in the Region and the study area include abandoned landfills containing hazardous waste materials, leaking underground storage tanks, uncontrolled spills, improperly abandoned wells, and clusters of onsite sewage disposal systems. Construction and operational procedures at these sources should be examined to determine if potential threats to groundwater quality exist and if control measures are needed. Most of the special well casing requirement areas, in which contamination of shallow aquifers may have already occurred, are located in the most vulnerable parts of the study area within the Region.

Wellhead Protection Areas
Drinking-water supplies may be protected by delineating wellhead protection (WHP) areas, in which potentially contaminating land uses are regulated. This type of planning is most appropriate for protecting municipal wells sunk into the shallow aquifers of the study area. Wellhead protection areas identify the land areas contributing groundwater to a well and are determined by hydrogeologic analysis. The WDNR is the regulatory State agency for developing and implementing the Wisconsin Wellhead Protection Plan. The first part of the plan is mandatory. *Wisconsin Administrative Code* NR 811 requires that a WHP plan be developed and submitted to the WDNR for any municipal water supply well constructed after May 1, 1992. The second part of the plan, applicable to any public water supply well approved prior to May 1, 1992, is voluntary. In 1996, the WDNR completed the delineation of WHP areas for all municipalities in the State using the EPA-approved calculated fixed radius method. This simple method results in a circular WHP area around each well and is a good first approximation of the WHP area.[25] However, more advanced delineations are desirable, to provide more accurate WHP areas. The capability to prepare greatly improved WHP area delineations was developed under the regional aquifer performance modeling project involving the Wisconsin Geological and Natural History Survey, the U.S. Geological Survey, and SEWRPC, in cooperation with the water utilities of the Region.[26]

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[25]*U.S. Environmental Protection Agency,* Guidelines for Delineation of Wellhead Protection Areas, *USEPA Office of Ground-Water Protection, 1987.*

[26]*SEWRPC Technical Report No. 41,* A Regional Aquifer Simulation Model for Southeastern Wisconsin, *June 2005.*

ARTIFICIAL GROUNDWATER RECHARGE AND MANAGEMENT[27]

Artificial recharge is defined as any engineered system designed to introduce and store water in an aquifer.[28] Artificial recharge can be accomplished by a number of methods that can be broadly classified into the following categories:

- Surface infiltration, which uses infiltration basins, or impoundments, to percolate water into the ground;
- Subsurface infiltration, which uses vadose zone (unsaturated zone) wells or trenches to introduce water into the unsaturated zone below the ground surface to facilitate infiltration;
- Direct injection, including aquifer storage and recovery, which uses wells or other structures to inject water directly into an aquifer. The water is recovered by the same well in typical aquifer storage and recovery systems;[29,30]
- Enhanced recharge, which uses man-made changes to the land surface to increase the amount of water recharged from natural sources;
- Riverbank filtration, including induced recharge, which uses well fields placed near surface waterbodies with the intention of inducing surface water into the aquifer to provide some or all of the water produced by the well field; and
- Water banking under which an aquifer is recharged by one of the foregoing methods with the intent of recovery of the water in some future, possibly undefined, timeframe.

Figure 368 illustrates several different types of groundwater recharge. A comparison of artificial groundwater recharge technology is presented in Appendix L.

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[27]*Additional information on artificial groundwater recharge and management is provided in SEWRPC Technical Report No. 43,* State-of-the-Art of Water Supply Practices*, in progress.*

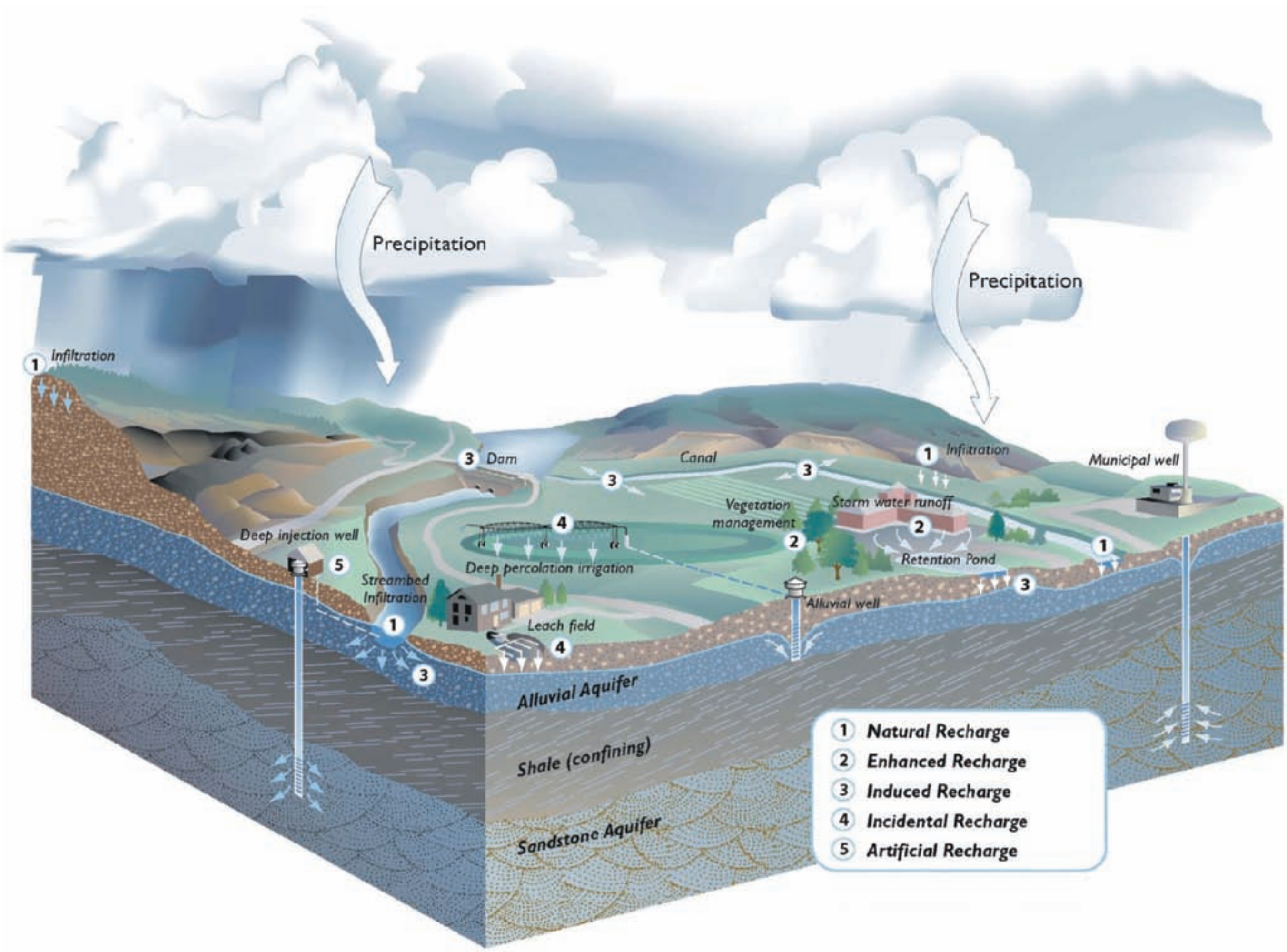
[28]*Ralf Topper, Peter E. Barkmann, David R. Bird, and Matthew A. Sares, Colorado Geological Survey Department of Natural Resources,* Artificial Recharge of Ground Water In Colorado - A Statewide Assessment*, 2004.*

[29]*The water stored in the aquifer is generally treated drinking water although systems using treated wastewater have been developed and systems using partially treated stormwater have been proposed. The water is stored in the aquifer around the well and recovered, typically by pumping the same well, to reuse the water with minimal additional treatment.*

[30]*The City of Oak Creek is operating a municipal well as an aquifer storage and recovery (ASR) well and has approval to operate their municipal water supply system as an ASR system. This approval was granted by the WDNR after a series of pilot studies by the City. As a result of this operation, some effects have been observed on groundwater chemistry. According to the WDNR, concentrations of manganese in groundwater associated with this well have been increasing. It is possible that other geochemical changes may occur as oxygenated water is added to a fairly anoxic deep aquifer system. These changes may mean that Oak Creek would need to reduce the concentration of manganese in recovered water. In addition, these changes could result in groundwater quality standards from Chapter NR 140 of the* Wisconsin Administrative Code *not being met at the point of standards application.*

Figure 368

SCHEMATIC DIAGRAM OF GROUNDWATER RECHARGE METHODS



Source: Ralf Topper, Peter E. Barkmann, David R. Bird, and Matthew A. Sares, Colorado Geological Survey Department of Natural Resources, Artificial Recharge of Ground Water In Colorado - A Statewide Assessment*, 2004.*

Artificial recharge is distinguished from incidental recharge, which is defined as recharge that reaches an aquifer from human activities not designed specifically for recharge.[31] Incidental recharge includes septic tank leach fields, stormwater retention ponds, percolation from irrigation, or leaking water or wastewater facilities.

Land use development and associated stormwater management and wastewater disposal practices typically have impacts on groundwater and surface water hydrology. Such impacts typically include increases in runoff and reductions in infiltration of precipitation due to the development of impervious surfaces. When public sanitary sewerage systems are developed to support development, water supplies used may be exported from the source of

[31]*Herman Bouwer, "Artificial Recharge of Groundwater: Hydrogeology and Engineering,"* Hydrogeology Journal *Vol. 10, 2002, pp. 121-142.*

supply areas as treated wastewater. These changes in the natural hydrology can be minimized by developing land in a manner which reduces the hydrologic impacts, such as conservation subdivision design. In addition, preservation of important recharge areas can reduce the impacts of development on the natural hydrology. In areas where development occurs with onsite sewage disposal systems, the export of spent groundwater is minimized. Those management practices for maintaining the natural hydrology were considered in developing alternative water quality management plans and the recommended plan as set forth in SEWRPC Planning Report No. 50. This section focuses on information related to artificial groundwater recharge technologies which can be considered to offset groundwater withdrawal and recharge losses and provide other benefits. Information is presented on selected stormwater management measures which are considered as a means of artificial surface infiltration technologies. However, information is not presented on development practices, natural recharge area protection, and the use of onsite sewage disposal systems.

For southeastern Wisconsin and the regional water quality management plan update study area, the most likely objectives of a potential artificial recharge project would be to:

- Restore water levels in a partially depleted aquifer;
- Increase the sustainable yield of a well field;
- Supplement the base flow to a stream, wetland, spring, or lake;
- Manage stormwater to limit peak flows in streams;
- Moderate temperature changes in sensitive waterbodies such as trout streams; or
- Offset down-gradient impacts caused by impermeable surfaces or well fields.

Runoff from urban and some rural lands can contain contaminants that could be detrimental to groundwater quality. Furthermore, recharge of treated wastewater into aquifers has a potential for transmitting regulated and unregulated contaminants into the groundwater system. Thus, the potential contamination of aquifers is an important factor in the consideration of artificial recharge projects.

Source Water Considerations

The quality and quantity of recharge water is another important factor controlling the performance of a recharge system. Many sources of water have been used for recharge systems. These sources include:[32]

- Surface water from streams, canals, lakes, reservoirs;
- Reclaimed wastewater;
- Rainfall and stormwater runoff;
- Imported water from other areas;
- Groundwater from other aquifers; and
- Treated drinking water.

[32]*American Society of Civil Engineers,* Standard Guidelines for Artificial Recharge of Ground Water, *2001*.

Several factors must be considered when choosing the most desirable source of water for a recharge system. The two most significant factors are availability and quality. It is important to note that for many water sources the quality of the water is variable. In many cases the water quality is poorest when the water is most abundant. This is true for river sources, where turbidity is often highest during high flow events, or for surface water runoff when road salt or agricultural chemicals can be highest during spring runoff or major storm events.

Pretreatment for Artificial Recharge

Most water sources for artificial recharge require some form of treatment prior to recharge. This may include normal drinking water treatment for aquifer storage and recovery systems, simple sedimentation for river water systems, or extensive tertiary treatment for wastewater. Many water quality problems for surface water sources can be corrected with simple sedimentation basins to remove silt and turbidity, and by avoiding recharge when high levels of pollutants, such as chlorides or agricultural chemicals, are present.

The generally consistent supply of sewage effluent makes wastewater an attractive source for recharge water. However, wastewater presents several important challenges, including poor quality, the presence of human pathogens, pharmaceuticals and personal care products, and other dissolved chemicals, and significant issues of public acceptance. Wastewater sources generally require primary and secondary treatment with disinfection for use in a surface infiltration system. In situations where groundwater quality will not be degraded, primary treatment may be sufficient for surface infiltration systems that use a process known as soil aquifer treatment to provide additional treatment during the recharge process.[33]

When wastewater is used for direct injection or subsurface recharge, higher levels of treatment are generally needed to protect the groundwater quality and prevent clogging of the recharge structures. In some places, such as California, pretreatment can include microfiltration, reverse osmosis and carbon filtration,[34] which significantly increase costs. The quality of the recharge water may, in some situations, exceed the quality of the native groundwater or the water that will be recovered by the well field. In these cases the aquifer is actually used as a barrier to avoid the direct reuse of wastewater. This provides both a buffer to protect against the accidental break through of contaminants and a buffer against the public objections towards the direct reuse of wastewater.

No Federal guidelines have been established for groundwater recharge with reclaimed wastewater in the United States. Consequently, standards for recharge with reclaimed wastewater are established by State agencies and local water districts. When determining pretreatment requirements, public health and safety and public acceptance are the most important concerns. Removal of pathogenic microorganisms are the primary concerns, but trace metals and organic compounds can also be important issues. Pretreatment processes may be required to reduce synthetic organic compounds (SOC), higher molecular weight organic compounds called natural organic matter (NOM), disinfection byproducts (DBPs), and emerging compounds such as nitrosdimethylamine (NDMA), endocrine disrupting compounds (EDCs), and pharmaceutically active compounds (PhACs). If an underground injection well is used, the injectate must meet primary drinking water maximum contaminant levels and health advisory levels if the fluid is directly placed into a saturated aquifer. No injection is allowed to endanger the quality of an underground source of drinking water.

Soil Aquifer Treatment

A process that uses the soil layer, unsaturated zone, and the aquifer itself to improve the quality of the recharged water prior to use has been developed to reduce the cost of using recharge water of marginal quality. This process, called soil aquifer treatment, reduces synthetic organic compounds and nitrates, removes and degrades bacteria

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[33] *American Society of Civil Engineers,* op. cit.

[34] *Asano and Cotruvo, Groundwater recharge with reclaimed municipal wastewater: health and regulatory considerations,* Water Research *38, 2004.*

and viruses, reduces BOD and biodegradable organic compounds, volatilizes some volatile and semi-volatile organic compounds, and removes metals, phosphate and fluoride.[35] Most of the processes are sustainable, but phosphate, metals, fluoride, and some organic compounds may accumulate in the treatment zone and may cause an eventual reduction in treatment efficiency.

Wastewater recovered from aquifers after soil aquifer treatment is usually suitable for nonpotable uses such as irrigation. Potable use is also possible if sufficient blending with native groundwater has occurred to meet drinking water standards. The long term efficacy of such systems is not well known. The American Society of Civil Engineers recommends that these systems use higher levels of monitoring and that additional pretreatment be added as needed to avoid undesired effects. In addition, accumulation of some compounds in the recharge area could be an environmental concern when a soil aquifer treatment system is decommissioned and the land is to be returned to some other use.

Advanced Wastewater Treatment

When wastewater is used for subsurface or direct recharge the ability of the unsaturated zone to reduce compounds of concern is reduced or eliminated. This is because much of the biological and geochemical degradation and adsorption of metals, organic compounds, bacteria and viruses occurs in the shallow soil zone and unsaturated zone, and those zones are partially or completely bypassed when recharge occurs directly to the aquifer. It is often necessary to use higher levels of treatment prior to injection to protect the quality of the groundwater and avoid clogging the recharge structure. Advanced wastewater treatment generally involves tertiary water treatment and may include chemical clarification, air stripping, membrane treatment (including reverse osmosis), and carbon filtration.[36] Chlorine used for disinfection may form undesirable and persistent disinfection byproducts and make the water more reactive with the aquifer and native groundwater. In these cases, ultraviolet disinfection or advanced oxidation using hydrogen peroxide may be more desirable disinfection systems. Where reverse osmosis is included, the water will have low total dissolved solids and may be more chemically aggressive.

Source Water Considerations for Aquifer Storage and Recovery Systems

Most aquifer storage and recovery systems use treated surface water as their source water.[37] The source water generally has a higher redox (oxidation/reduction) potential than the native groundwater, which can cause undesirable chemical reactions with the groundwater and aquifer matrix. Aquifer storage and recovery systems have mobilized several metals from the aquifer matrix, most notably arsenic, iron, and manganese. Iron and manganese have limited health concerns, but arsenic exposure has been linked to several forms of cancer and other serious diseases. Such systems have also had problems with precipitation of several minerals, deflocculation of clay minerals, and swelling clay minerals. All of these problems are generally less significant when groundwater is used as the source water due to the greater similarity between the chemical properties of the injected water and the groundwater in the storage zone. Pretreatment with caustic chemicals to increase pH has been used to stabilize metals in the formation by forming oxidized coatings to encapsulate minerals and immobilize metals. Pretreatment with calcium chloride has also been used to control clay dispersion in an injection test.[38]

Treated surface water frequently contains halogenated compounds called disinfection byproducts created by a reaction between organic carbon in the surface water and chlorine used as a disinfectant. Disinfection byproducts

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[35]*American Society of Civil Engineers,* op. cit.

[36]*Asano and Cotruvo,* op. cit.

[37]*R. David G. Pyne,* op. cit.

[38]Ibid.

are a health concern due to their carcinogenic properties. Aquifer storage and recovery systems have been shown to significantly reduce or eliminate disinfection byproducts during the storage and recovery cycle.[39] The reduction achieved is greater than can be explained by simple mixing and dilution. At least some of the reduction appears to be associated with microbial degradation, usually under reducing conditions and accompanied by nitrate reduction. In some cases brominated disinfection byproducts have proven to be more resistant to degradation than chlorinated species.

Regulatory Issues

Stormwater Infiltration Systems

Stormwater infiltration structures are currently regulated by Chapters NR 110, 140, 151, 815, and 216 of the *Wisconsin Administrative Code*. Chapter NR 815 prohibits recharge of stormwater directly into groundwater through a well but allows injection of stormwater through a well into unsaturated formations of an aquifer. This injection must be permitted under Chapter NR 216 and satisfy groundwater quality standards of Chapter NR 140.

The recharge system is required, to the extent that is technically and economically feasible, to minimize the level of pollutants entering the groundwater and maintain compliance with Chapter NR 140 preventive action limits at the point of standards application. The recharge system is also required to meet Chapter NR 140 enforcement standards (ES) at the point of standards application. Pretreatment is required for parking lot runoff and for runoff from new road construction in commercial, industrial, and institutional areas that will enter an infiltration system. Pretreatment may include oil and grease separation, sedimentation, biofiltration, filtration, and filter strips or swales. The systems are intended to infiltrate the runoff water from land uses which are considered to have the least contamination in runoff to prevent groundwater contamination. This may require greater infiltration rates from low pollution sources, such as roofs, and lower infiltration rates from higher pollution sources, such as roadways or parking lots. It should be noted that rooftops and other “cleaner” surfaces may, in fact, be contaminated from sources, such as road salting and bird activity on rooftops.

These regulations provide a starting point for artificial recharge in Wisconsin, but they are not designed to regulate recharge for potable water systems. Significant additional restrictions would be needed before a large-scale infiltration system could be developed to safely supplement potable water resources. These restrictions would need to consider the characteristics of the recharge source water, the buffering capacity of the soils and aquifer, and the time the water will be sequestered in the aquifer prior to reuse. As is currently the case in most states, these restrictions will probably need to be developed on a case-by-case basis to effectively protect the public and the environment.

Wastewater Infiltration Systems

Wastewater infiltration systems are regulated by the *Wisconsin Administrative Code*. Chapter NR 206 prohibits underground injection of municipal or domestic wastewater through a well. Land treatment systems, including soil absorption systems designed to infiltrate wastewater must treat the water to meet Chapter NR 206 effluent standards and may require additional treatment to meet Chapter NR 140 water quality standards as approved by the WDNR.

The WDNR has determined that it is not technically and economically feasible for wastewater absorption pond systems to meet Chapter NR 140 preventive action limits for nitrate, total dissolved solids, and chloride with secondary wastewater treatment. Thus, a tertiary treatment level designed to remove these contaminants would have to be provided or variances to the regulations obtained.

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[39] *R. David G. Pyne, Philip C. Singer and Cass T. Miller,* Aquifer Storage and Recovery of Treated Drinking Water*, American Water Works Association Research Foundation, 1996.*

Spray irrigation systems, ridge and furrow systems, and overland flow systems are all regulated to prevent or minimize infiltration to the groundwater by restricting application rates based on soil types and requiring minimum thicknesses of unsaturated soil above the water table. Without modification, these regulations essentially eliminate the possibility of using these systems for artificial recharge because the regulations are designed to prevent application of wastewater at a rate that allows recharge to groundwater.[40]

All of these regulations are designed to facilitate disposal of wastewater with minimal degradation of the groundwater. The Wisconsin Department of Natural Resources regulations have attempted to place barriers between drinking water sources and pollution sources. As with the stormwater infiltration regulations, these regulations are not intended to develop safe artificial recharge systems for potable use. Protection of human health must be the first priority when using water of impaired quality for artificial recharge. Experience has shown that these regulations often allow significant degradation of the groundwater quality down-gradient of the infiltration system. In their present form, these regulations would not be adequate to develop a safe artificial recharge system using a wastewater source. Significant additional restrictions would be needed before a large-scale infiltration system could be developed to safely supplement potable water resources. These restrictions would need to include higher levels of pretreatment of the wastewater, consider the buffering capacity of the soils and aquifer, and consider the time the water will be sequestered in the aquifer prior to reuse. As is currently the case in most states, these restrictions will need to be developed on a case-by-case basis to effectively protect the public and the environment.

Aquifer Storage and Recovery System Regulations

Aquifer storage and recovery system wells fall under the broad category of Class V injection wells under the U.S. Environmental Protection Agency underground injection control program.[41] Class V injection wells include a wide variety of structures, most pertaining to waste disposal. Aquifer storage and recovery systems are unlike these other Class V injection wells in that the intent is to inject and recover treated drinking water. Many states, including Wisconsin, have adopted specific regulations to manage aquifer storage and recovery systems.

In Wisconsin, aquifer storage and recovery systems are regulated by Chapter NR 811, subchapter XIV, of the *Wisconsin Administrative Code*. Chapter NR 811 mandates WDNR approval before any water can be recovered through an aquifer storage and recovery system. The source water must comply with Chapter NR 809 drinking water standards and the water in the storage zone must comply with Chapter NR 140 groundwater standards at the property boundary of the well site. The Chapter NR 140 groundwater standards for disinfection byproducts are much lower than the Chapter NR 809 drinking water standards, which means that stored water with disinfection byproducts over Chapter NR 140 standards cannot move past the well site property.

[40]*Wastewater infiltration can also be considered as a means of wastewater disposal as opposed to aquifer recharge. In such cases, the infiltrated wastewater typically is infiltrated in the vicinity of a river or stream to which the groundwater, including the infiltrated wastewater, discharges. Wastewater could also be reused for irrigation purposes, with the intention being focused on being a source of water for vegetation and the wastewater being applied in a manner which is consistent with vegetation needs and uptakes, rather than for aquifer recharge. The intended use and means of such wastewater infiltration or irrigation system would be a factor in determining requirements for such systems.*

[41]*American Water Works Association,* Survey and Analysis of Aquifer Storage and Recovery (ASR) Systems and Associated Regulatory Programs in the United States, *August 2002.*

Chapter XII

SUMMARY AND CONCLUSIONS

INTRODUCTION

This report documents inventory data and associated analyses of water quality conditions and sources of pollution used in an update to the regional water quality management plan for the greater Milwaukee watersheds.[1] The plan update is for design year 2020 and represents a major amendment to the regional water quality management plan for Southeastern Wisconsin.[2,3]

This report sets forth the factual findings of the extensive inventories conducted under the study. It identifies and, to the extent possible, quantifies historical and existing water quality conditions, toxicity conditions, biological conditions, channel conditions, habitat and riparian corridor conditions, sources of water pollution, and pollutant loading, as well as evaluating the achievement of designated water use objectives for waters of the greater Milwaukee watersheds in order to provide a scientifically sound basis for the development of alternative plans and selection of a recommended plan.

WATER USE OBJECTIVES AND STANDARDS

The water use objectives and supporting water quality standards and criteria for the greater Milwaukee watersheds are documented in Chapter IV of this report. As shown in Table 15 and on Maps 7 through 12 in Chapter IV of this report, most of the stream reaches in these watersheds are recommended for fish and aquatic life and full recreational uses and are subject to standards under which dissolved oxygen concentrations are not to be less than 5.0 milligrams per liter (mg/l) and fecal coliform bacteria counts may not exceed 200 cells per 100 milliliter (ml) as a geometric mean based on not less than five samples per month, nor exceed 400 cells per 100 ml in more than 10 percent of all samples during any month.

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[1]*The term "greater Milwaukee watersheds" is defined for the purposes of this report as all five watersheds which lie entirely or partially in the greater Milwaukee area, as well as the Milwaukee Harbor estuary and a portion of nearshore Lake Michigan and its direct drainage area. The watersheds included are those of the Kinnickinnic River, Menomonee River, Milwaukee River, Oak Creek, and Root River.*

[2]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume One,* Inventory Findings, *September 1978; Volume Two,* Alternative Plans, *February 1979; and Volume Three,* Recommended Plan, *June 1979.*

[3]*SEWRPC Planning Report No. 50,* A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds, *December 2007.*

A few streams are recommended for coldwater uses. Auburn Lake Creek upstream from Auburn Lake, Chambers Creek, Gooseville Creek, Melius Creek, Nichols Creek, and Watercress Creek are all considered coldwater streams and subject to standards under which dissolved oxygen concentrations are not to be less than 7.0 mg/l during spawning and 6.0 mg/l during the rest of the year. These streams are all in the Milwaukee River watershed.

The other exceptions to the fish and aquatic life and full recreational use designations are subject to variances under Chapter NR 104 of the *Wisconsin Administrative Code*. The mainstem of the Kinnickinnic River in the Kinnickinnic River watershed; Honey Creek, Underwood Creek from Juneau Boulevard in the Village of Elm Grove downstream to the confluence with the Menomonee River, and the mainstem of the Menomonee River downstream from the confluence with Honey Creek in the Menomonee River watershed; and Indian Creek, Lincoln Creek, and the mainstem of the Milwaukee River downstream from the site of the former North Avenue dam in the Milwaukee River watershed are subject to special variances under which dissolved oxygen is not to be less than 2.0 mg/l and counts of fecal coliform bacteria are not to exceed 1,000 cells per 100 ml. Burnham Canal and the South Menomonee Canal in the Menomonee River watershed are subject to special variances that impose the same requirements with the additional requirement that the water temperature shall not exceed 31.7 degrees Celsius (ºC). In the Milwaukee River watershed, Silver Creek (Sheboygan County) downstream from the Random Lake sewage treatment plant to the first crossing of Creek Road is recommended for limited forage fish and is subject to a variance under which dissolved oxygen concentrations are not to be less than 3.0 mg/l. The East Branch of the Root River Canal from STH 20 to the confluence with the West Branch of the Root River Canal, Hoods Creek, Tess Corners Creek, the West Branch of the Root River Canal between STH 20 and CTH C, and Whitnall Park Creek downstream from the site of the former Hales Corners sewage treatment plant are recommended for limited forage fish and subject to variances under which dissolved oxygen concentrations are not to be less than 3.0 mg/l. The East Branch of the Root River, the East Branch of the Root River Canal upstream from STH 20, Ives Grove Ditch, the West Branch of the Root River Canal upstream from CTH C, and an unnamed tributary of the Root River downstream from the site of the former New Berlin Memorial Hospital sewage treatment plant in the Root River watershed are recommended for limited aquatic life and are subject to variances under which dissolved oxygen concentrations are not to be less than 1.0 mg/l.

The standards that apply to the Milwaukee outer harbor and adjacent nearshore Lake Michigan area are not as specifically defined as are the standards for the riverine areas. The Beach Act of 2000 requires that water quality advisories be issued at designated bathing beaches when the concentration of *E. coli* in a single sample exceeds 235 cells per 100 ml. This standard was used to assess whether the quality of water at beaches and in the nearshore Lake Michigan area was suitable for full recreational use. For other water quality parameters, it was decided to compare water quality in the outer harbor to the standards for fish and aquatic life.

WATER QUALITY CONDITIONS AND TRENDS

Kinnickinnic River Watershed

Bacterial and Biological Parameters

Concentrations of fecal coliform bacteria at sampling stations along the mainstem of the Kinnickinnic River commonly exceed the variance standard that applies to River. After 1993, fecal coliform bacteria concentrations in the section of the River in the estuary decreased, at least in part as a result of MMSD's Inline Storage System coming online. Long-term trends toward decreasing concentrations of fecal coliform bacteria have been detected at most sampling stations.

Concentrations of chlorophyll-*a* at sampling stations in the estuary section of the Kinnickinnic River decreased after 1993, with the reductions at these stations representing long-term decreasing trends. The timing of these reductions suggest that they were probably caused, at least in part, by nutrient reductions related to the reduction in combined sewer overflows resulting from MMSD's Inline Storage System coming online.

Chemical and Physical Parameters

During the period 1998 through 2001, the annual median water temperatures at sampling stations along the mainstem of the Kinnickinnic River ranged from 15.3ºC to 20.3ºC. Water temperatures at sampling stations along the Kinnickinnic River did not exceed the 31.7ºC standard for fish and aquatic life. While water temperatures in the estuary section of the River were cooler than those in upstream areas, trends toward water temperatures increasing over time were detected in the estuary section of the River.

Concentrations of biochemical oxygen demand (BOD) were higher in the upstream reaches of the Kinnickinnic River than in the estuary portion of the River. BOD concentrations at most sampling stations along the mainstem of the River decreased after 1993. This decrease coincided with the reductions in combined sewer overflows that resulted from MMSD's Inline Storage System coming online. Trends toward BOD concentrations decreasing over time were detected at all sampling stations along the mainstem of the River. High concentrations of BOD were detected in samples from Wilson Park Creek, especially at the sampling station where this stream emerges from conduit at General Mitchell International Airport. These high concentrations may be related to deicer usage at the airport. Though concentrations of BOD in Wilson Park Creek were lower during the period 1998-2001 than they were during the period 1994-1997, they were still high.

Concentrations of chloride in samples collected from the mainstem of the Kinnickinnic River occasionally exceeded the State acute toxicity criterion for fish and aquatic life of 757 mg/l and/or chronic toxicity criterion for fish and aquatic life of 395 mg/l. Trends toward increasing chloride concentrations were found at all sampling stations along the River. The highest chloride concentrations tended to occur during winter and early spring. This is likely to be related to the application of deicing salts on streets and highways during winter months.

Dissolved oxygen concentrations at sampling stations in the estuary section of the Kinnickinnic River were lower than concentrations at stations in the section of the River upstream from the estuary. Concentrations in occasional samples from stations in the estuary were lower than the 2.0 mg/l variance standard that applies to the estuary. A trend toward dissolved oxygen concentrations increasing over time was detected at one sampling station in the estuary. Few other time-based trends in dissolved oxygen concentration were detected.

Suspended Material

Concentrations of total suspended solids (TSS) in the Kinnickinnic River showed considerable variability with variability tending to be higher at upstream sites than at downstream sites. Mean concentrations of TSS were lower at sampling stations in the estuary than in the sections of the River upstream from the estuary, probably as a result of settling of suspended material in sections of the estuary. Trends toward TSS concentrations increasing over time were detected at three sampling stations.

Nutrients

While concentrations of total nitrogen at sampling stations along the Kinnickinnic River have not changed much over time, several differences among stations and changes over time in nitrogen chemistry are apparent. There are distinct differences with respect to forms of nitrogen between the estuary and sections of the River upstream from the estuary, with concentrations of total nitrogen, nitrate and ammonia being higher in the estuary. The relative proportions of different nitrogen compounds in the River appear to be changing over time. Concentrations of ammonia have decreased at most sampling stations along the mainstem of the River. At the same time, concentrations of organic nitrogen appear to be increasing over time at most stations along the mainstem of the River. Similarly, concentrations of nitrate in the estuary and nitrite in the sections of the River upstream from the estuary appear to be increasing.

Total phosphorus concentrations in samples collected from sampling stations along the Kinnickinnic River frequently exceeded the 0.1 mg/l standard recommended in the original regional water quality management plan. Conflicting trends were detected among sampling stations with respect to how phosphorus concentrations in the River changed over time. At some stations, trends toward total phosphorus concentrations increasing over time were detected. At other stations, trends toward total phosphorus concentrations decreasing over time were detected. Conflicting trends were also observed with respect to how dissolved phosphorus concentrations changed over time. Overall, annual mean total phosphorus concentrations in the Kinnickinnic River increased sharply after 1996. A likely cause of this is phosphorus loads from facilities discharging noncontact cooling water drawn from municipal water utilities that use orthophosphate or polyphosphate as anticorrosion agents.

Metals
Concentrations of some metals have decreased in the Kinnickinnic River. Trends toward decreasing concentrations of arsenic, cadmium, lead, and mercury were detected at all sampling stations along the mainstem of the Kinnickinnic River. In addition, trends toward decreasing concentrations of chromium were detected at stations in the estuary. These declines may reflect changes in the number and types of industries in the watershed, as well as reductions due to treatment of industrial discharges. In addition, the reductions in cadmium concentrations reflect reductions in atmospheric deposition of this metal in the Great Lakes region and the reductions in lead concentrations reflect the phasing out of the use of lead as a gasoline additive.

Concentrations of other metals have increased in the Kinnickinnic River. Trends toward increasing copper concentrations were detected at all sampling stations along the mainstem of the River and trends toward increasing zinc concentrations were detected at stations in the estuary. These increases may be related to increases in vehicle traffic and corrosion of galvanized building materials.

Organic Compounds
Ethylene glycol and propylene glycol, compounds used in airport deicing operations, were occasionally detected in samples collected from Wilson Park Creek, in some instances at high concentrations.

Pharmaceuticals and Personal Care Products
The stimulant caffeine was detected in some samples from the Kinnickinnic River.

Menomonee River Watershed
Bacterial and Biological Parameters
Concentrations of fecal coliform bacteria at sampling stations along the mainstem of the Menomonee River commonly exceed the applicable standards. After 1993, fecal coliform bacteria concentrations in the section of the River in the estuary decreased, at least in part as a result of MMSD's Inline Storage System coming online. Long-term trends toward decreasing concentrations of fecal coliform bacteria have been detected at all sampling stations in the estuary.

Concentrations of chlorophyll-*a* at most sampling stations in the estuary section of the Menomonee River decreased after 1993, with the reductions at these stations representing long-term decreasing trends. The timing of these reductions suggest that they were probably caused, at least in part, by nutrient reductions related to the reduction in combined sewer overflows resulting from MMSD's Inline Storage System coming online.

Chemical and Physical Parameters
During the period 1998 through 2001, the annual median water temperatures at sampling stations along the mainstem of the Menomonee River ranged from 14.3ºC to 19.0ºC. Water temperatures in some samples collected at the Burnham Canal sampling station exceeded the 31.7ºC fish and aquatic life standard.

BOD concentrations at most sampling stations along the mainstem of the Menomonee River decreased after 1993, especially in the estuary sections of the River. This decrease coincided with the reductions in combined sewer overflows that resulted from MMSD's Inline Storage System coming online. Trends toward BOD concentrations decreasing over time were detected at all sampling stations along the mainstem of the River.

Concentrations of chloride in samples collected from the mainstem of the Menomonee River occasionally exceeded the State chronic and/or acute toxicity criteria for fish and aquatic life. Trends toward increasing chloride concentrations were found at most sampling stations along the River. The highest chloride concentrations tended to occur during winter and early spring. This is likely to be related to the application of deicing salts on streets and highways during winter months.

Dissolved oxygen concentrations at sampling stations in the estuary section of the Menomonee River were lower than concentrations at stations in the section of the River upstream from the estuary. Concentrations in occasional samples from stations along the mainstem of the River were lower than the applicable standards. Trends toward dissolved oxygen concentrations increasing over time were detected at most sampling stations in the estuary. This may be related to the reductions in loadings of organic material resulting from the reductions in combined sewer overflows that accompanied the Inline Storage System coming online in 1994. Few other time-based trends in dissolved oxygen concentration were detected.

Suspended Material
Concentrations of TSS in the Menomonee River showed considerable variability. Mean concentrations of TSS were lower at sampling stations in the estuary than in the sections of the River upstream from the estuary, probably as a result of settling of suspended material in sections of the estuary. Trends toward TSS concentrations increasing over time were detected at four sampling stations, mostly in the estuary.

Nutrients
While concentrations of total nitrogen at sampling stations along the Menomonee River have not changed much over time, several differences among stations and changes over time in nitrogen chemistry are apparent. There are distinct differences with respect to forms of nitrogen between the estuary and sections of the River upstream from the estuary, with concentrations of all forms of nitrogen except organic nitrogen being higher in the estuary. The relative proportions of different nitrogen compounds in the River appear to be changing over time. Concentrations of ammonia have decreased at all sampling stations along the mainstem of the River. At the same time, concentrations of organic nitrogen appear to be increasing over time at those stations along the mainstem of the River where trends exist. Similarly, concentrations of nitrate appear to be decreasing over time in upstream areas, but increasing over time in the estuary.

Total phosphorus concentrations in samples collected from sampling stations along the Menomonee River frequently exceeded the 0.1 mg/l standard recommended in the original regional water quality management plan. Conflicting trends were detected among sampling stations with respect to how phosphorus concentrations in the River changed over time. At one station, a trend toward total phosphorus concentrations increasing over time was detected. At other stations, trends toward total phosphorus concentrations decreasing over time were detected. Conflicting trends were also observed with respect to how dissolved phosphorus concentrations changed over time, though for this form of phosphorus several stations showed increasing trends. Despite these ambiguous results, annual mean total phosphorus concentrations in the Menomonee River increased sharply after 1996. A likely cause of this is phosphorus loads from facilities discharging noncontact cooling water drawn from municipal water utilities that use orthophosphate or polyphosphate as anticorrosion agents.

Metals
Concentrations of some metals have decreased in the Menomonee River. Trends toward decreasing concentrations of arsenic, cadmium, and lead were detected at all sampling stations along the mainstem of the River. In addition, trends toward decreasing concentrations of chromium, mercury, and nickel were detected at most stations along the mainstem of the River. These declines may reflect changes in the number and types of industries in the watershed, as well as reductions due to treatment of industrial discharges. In addition, the reductions in cadmium concentrations reflect reductions in atmospheric deposition of this metal in the Great Lakes region and the reductions in lead concentrations reflect the phasing out of the use of lead as a gasoline additive.

Concentrations of other metals have increased in the Menomonee River. Trends toward increasing copper and zinc concentrations were detected at all sampling stations along the mainstem of the River. These increases may be related to increases in vehicle traffic and corrosion of galvanized building materials.

Organic Compounds
The deodorizer 1,4-dichlorobenzene and the solvent isophorone were detected in water samples from the Menomonee River and some tributary streams.

Pharmaceuticals and Personal Care Products

The Menomonee River and some tributary streams were sampled for the antibacterial agent triclosan. However, triclosan was not detected in any samples. No other data on pharmaceuticals and personal care products were available from the Menomonee River watershed.

Milwaukee River Watershed

Bacterial and Biological Parameters

Concentrations of fecal coliform bacteria at sampling stations along the mainstem of the Milwaukee River commonly exceeded the applicable standards. Concentrations of fecal coliform bacteria exceeding applicable standards were also detected in Lincoln and Southbranch Creeks. After 1993, fecal coliform bacteria concentrations in the section of the Milwaukee River in the estuary decreased, at least in part as a result of MMSD's Inline Storage System coming online. Long-term trends toward decreasing concentrations of fecal coliform bacteria have been detected at all sampling stations in the estuary and at some sampling stations in the sections of the River upstream from the estuary.

While concentrations of chlorophyll-*a* decreased after 1997 at most sampling stations along the mainstem of the Milwaukee River, long-term trends in chlorophyll-*a* concentration were detected only at the two most downstream stations. Trends toward decreasing concentrations were detected at these stations.

Chemical and Physical Parameters

During the period 1998 through 2004, the annual median water temperatures at sampling stations along the mainstem of the Milwaukee River ranged from 15.0ºC to 19.0ºC. Water temperatures did not exceed the 31.7ºC standard for fish and aquatic life. Trends toward water temperatures increasing over time were detected in the estuary section of the River.

While BOD concentrations at some sampling stations along the mainstem of the Milwaukee River decreased after 1993, at most sampling stations BOD concentrations decreased after 1997. Trends toward BOD concentrations decreasing over time were detected at all sampling stations along the mainstem of the River.

Concentrations of chloride in samples collected from the mainstem of the Milwaukee River were generally below the State chronic and/or acute toxicity criteria for fish and aquatic life. Trends toward increasing chloride concentrations were found at all sampling stations along the River. In addition, evidence of increasing chloride concentrations was found in those tributary streams and lakes in the Milwaukee River watershed for which sufficient data exist to assess trends. The highest chloride concentrations tended to occur during winter and early spring. This is likely to be related to the application of deicing salts on streets and highways during winter months.

Dissolved oxygen concentrations at sampling stations in the estuary section of the Milwaukee River were lower than concentrations at stations in the section of the River upstream from the estuary. Concentrations in occasional samples from stations in reaches upstream from the estuary were lower than the 5.0 mg/l fish and aquatic life standard. Trends toward dissolved oxygen concentrations decreasing over time were detected at some sampling stations in reaches upstream from the estuary. These trends appear to result from lower dissolved oxygen concentrations during the summer. Few other time-based trends in dissolved oxygen concentration were detected.

Suspended Material

Concentrations of TSS in the Milwaukee River showed considerable variability. Mean concentrations of TSS were lower at sampling stations in the estuary than in the sections of the River upstream from the estuary, probably as a result of settling of suspended material in sections of the estuary. Trends toward TSS concentrations increasing over time were detected at most sampling stations.

Nutrients

Concentrations of total nitrogen have increased at several sampling stations along the mainstem of the Milwaukee River. There are differences with respect to forms of nitrogen between the estuary and sections of the River upstream from the estuary, with concentrations of nitrite and ammonia being higher in the estuary. The relative proportions of different nitrogen compounds in the River appear to be changing over time. Concentrations of ammonia have decreased at most sampling stations along the mainstem of the River. At the same time, concentrations of nitrate appear to be increasing over time at most stations along the mainstem of the River.

Total phosphorus concentrations in samples collected from sampling stations along the Milwaukee River frequently exceeded the 0.1 mg/l standard recommended in the original regional water quality management plan. Trends toward total phosphorus concentrations increasing over time were detected at most sampling stations along the mainstem of the River. By contrast, trends toward dissolved phosphorus concentrations decreasing over time were detected at a few stations. Although the change was not as dramatic as those in the Kinnickinnic and Menomonee Rivers, annual mean total phosphorus concentrations in the Milwaukee River increased after 1996. A likely cause of this is phosphorus loads from facilities discharging noncontact cooling water drawn from municipal water utilities that use orthophosphate or polyphosphate as anticorrosion agents.

Metals

Concentrations of some metals have decreased in the Milwaukee River. Trends toward decreasing concentrations of arsenic, cadmium, and lead were detected at all sampling stations along the mainstem of the River. In addition, trends toward decreasing concentrations of chromium and nickel were detected at most stations along the mainstem of the River and trends toward decreasing concentrations of mercury were detected at stations in the estuary. These declines may reflect changes in the number and types of industries in the watershed, as well as reductions due to treatment of industrial discharges. In addition, the reductions in cadmium concentrations reflect reductions in atmospheric deposition of this metal in the Great Lakes region and the reductions in lead concentrations reflect the phasing out of the use of lead as a gasoline additive.

Concentrations of other metals have increased in the Milwaukee River. Trends toward increasing copper and zinc concentrations were detected at most sampling stations along the mainstem of the River. These increases may be related to increases in vehicle traffic and corrosion of galvanized building materials.

Organic Compounds

Several organic compounds were detected in water samples collected from the mainstem of the Milwaukee River and Lincoln Creek including the solvent isophorone, the dye component carbazole, the plasticizer triphenyl phosphate, and the flame retardants tri(2-chloroethyl) phosphate, tri(dichloroisopropyl) phosphate, and tributyl phosphate. In addition, the disinfectant byproduct bromoform, the nonionic detergent metabolite p-nonylphenol, and the industrial chemical vinyl chloride were detected in water samples collected from Lincoln Creek.

Pharmaceuticals and Personal Care Products

Several pharmaceuticals and personal care products were detected in water samples collected from the mainstem of the Milwaukee River and Lincoln Creek including the stimulant caffeine; DEET, the active ingredient from insect repellants; the flavoring and fragrance compounds camphor, acetophenone, AHTN, and HHCB; the perfume fixative benzophenone; and triethyl citrate, a component of some cosmetics. In addition, the fragrance and flavoring compounds menthol and d-limonene were detected in water samples collected from Lincoln Creek.

Oak Creek Watershed

Bacterial and Biological Parameters

Concentrations of fecal coliform bacteria in most samples collected along the mainstem of Oak Creek exceeded the full recreational use standard. Few time-based trends were detected in fecal coliform bacteria in Oak Creek.

Chlorophyll-*a* concentrations at most sampling stations along the mainstem of Oak Creek increased after 1994, though this was followed by decreases at some stations. Trends toward chlorophyll-*a* concentrations increasing over time were detected at some sampling stations. At other stations, no trends were apparent.

Chemical and Physical Parameters

During the period 1998 through 2001, the annual median water temperatures at sampling stations along the mainstem of Oak Creek ranged from 13.0ºC to 15.7ºC. Water temperatures did not exceed the 31.7ºC standard for fish and aquatic life. Few time-based trends were detected in water temperatures in the Creek.

BOD concentrations at most sampling stations along the mainstem of Oak Creek decreased after 1993. Trends toward BOD concentrations decreasing over time were detected at most sampling stations along the mainstem of the Creek.

Concentrations of chloride in samples collected from the mainstem of the Oak Creek occasionally exceeded the State chronic toxicity criterion for fish and aquatic life. Trends toward increasing chloride concentrations were found at all sampling stations along the Creek. The highest chloride concentrations tended to occur during winter and early spring. This is likely to be related to the application of deicing salts on streets and highways during winter months.

Concentrations of dissolved oxygen collected from sampling stations in upstream reaches of Oak Creek were occasionally to frequently lower than the 5.0 mg/l fish and aquatic life standard. Trends toward dissolved oxygen concentrations decreasing over time were detected at three sampling stations along the Creek. Few other time-based trends in dissolved oxygen concentration were detected.

Suspended Material

Concentrations of TSS in Oak Creek showed considerable variability. Mean concentrations of TSS tended to decrease from upstream to downstream along the mainstem of the Creek, probably as a result of settling or dilution along the Creek. No time-based trends were detected in TSS concentrations in Oak Creek.

Nutrients

While concentrations of total nitrogen at sampling stations along Oak Creek have not changed much over time, some differences among stations and changes over time in nitrogen chemistry are apparent. Nitrate concentrations in the Creek tend to increase from upstream to downstream. By contrast, ammonia concentrations in the Creek tend to decrease from upstream to downstream. The relative proportions of different nitrogen compounds in the Creek appear to be changing over time. Concentrations of ammonia have decreased at most sampling stations along the mainstem of the Creek. At the same time, concentrations of organic nitrogen appear to be increasing over time at those stations along the mainstem of the Creek for which trends exist.

Total phosphorus concentrations in samples collected from sampling stations along Oak Creek occasionally exceeded the 0.1 mg/l standard recommended in the original regional water quality management plan. Trends toward total phosphorus concentrations increasing over time were detected at some stations. Similarly, trends toward dissolved phosphorus concentrations decreasing over time were detected at some stations.

Metals

Concentrations of some metals have decreased in Oak Creek. Trends toward decreasing concentrations of arsenic, cadmium, and lead were detected at all sampling stations along the mainstem of the Creek. These declines may reflect changes in the number and types of industries in the watershed, as well as reductions due to treatment of industrial discharges. In addition, the reductions in cadmium concentrations reflect reductions in atmospheric deposition of this metal in the Great Lakes region and the reductions in lead concentrations reflect the phasing out of the use of lead as a gasoline additive.

Concentrations of other metals have increased in Oak Creek. Trends toward increasing copper and zinc concentrations were detected at all sampling stations along the mainstem of the Creek. These increases may be related to increases in vehicle traffic and corrosion of galvanized building materials.

Organic Compounds
Several organic compounds were detected in water samples collected from Oak Creek including the solvent isophorone; the dye component carbazole; the plasticizer triphenyl phosphate; and the flame retardants tri(2-chloroethyl) phosphate, tri(dichloroisopropyl) phosphate, and tributyl phosphate; and the nonionic detergent metabolites p-nonylphenol and diethoxynonylphenol.

Pharmaceuticals and Personal Care Products
Some pharmaceuticals and personal care products were detected in water samples collected from Oak Creek including the stimulant caffeine, the nicotine metabolite cotinine, and the flavoring and fragrance compounds camphor and menthol.

Root River Watershed
Bacterial and Biological Parameters
Concentrations of fecal coliform bacteria at sampling stations along the mainstem of the Root River commonly exceed the full recreational use standard. Few time-based trends were detected in fecal coliform bacteria in the Root River.

Historical data for chlorophyll-*a* concentration were available at only one sampling station along the Root River, Johnson Park. At this station, chlorophyll-*a* concentrations increased after 1993 and decreased after 1997. A long-term trend toward decreasing chlorophyll-*a* concentration was detected at this station.

Chemical and Physical Parameters
During the period 1998 through 2001, the annual median water temperatures at sampling stations along the mainstem of the Root River ranged from 14.1ºC to 19.5ºC. Water temperatures did not exceed the 31.7ºC standard for fish and aquatic life. Few time-based trends were detected in water temperatures in the River.

Trends toward BOD concentrations decreasing over time were detected at those sampling stations along the mainstem of the Root River for which sufficient data were available to evaluate long-term trends.

Concentrations of chloride in samples collected from the mainstem of the Root River occasionally exceeded the State chronic toxicity criterion for fish and aquatic life and rarely exceeded the acute toxicity criterion for fish and aquatic life. Trends toward increasing chloride concentrations were found at all sampling stations along the River for which sufficient data were available to assess long-term trends. The highest chloride concentrations tended to occur during winter and early spring. This is likely to be related to the application of deicing salts on streets and highways during winter months.

Concentrations of dissolved oxygen collected from sampling stations along the Root River were occasionally lower than the 5.0 mg/l fish and aquatic life standard. Few time-based trends in dissolved oxygen concentration were detected at sampling stations along the Root River.

Suspended Material
Concentrations of TSS in the Root River showed considerable variability. Mean concentrations of TSS tended to decrease from upstream to downstream along the mainstem of the River, probably as a result of settling or dilution along the River. Trends toward increasing TSS concentrations were detected at two sampling stations and trends toward decreasing TSS concentrations were detected at two sampling stations.

Nutrients
While concentrations of total nitrogen at sampling stations along the Root River have not changed much over time, some differences among stations and changes over time in nitrogen chemistry are apparent. Concentrations of all forms of nitrogen, except ammonia, tend to increase from upstream to downstream along the River. At several stations along the mainstem of the River, concentrations of ammonia have decreased over time.

Total phosphorus concentrations in samples collected from sampling stations along the Root River commonly exceeded the 0.1 mg/l standard recommended in the original regional water quality management plan. Few time-based trends were detected for total or dissolved phosphorus concentrations at sampling stations along the Root River.

Metals
Concentrations of some metals have decreased in the Root River. Trends toward decreasing concentrations of arsenic, chromium, copper, and nickel were detected at sampling stations in upstream reaches along the mainstem of the River. These declines may reflect changes in the number and types of industries in the watershed, as well as reductions due to treatment of industrial discharges.

Organic Compounds
Several organic compounds were detected in water samples collected from the mainstem of the Root River including the solvent isophorone, the dye component carbazole, the plasticizer triphenyl phosphate, the flame retardants tri(2-chloroethyl) phosphate, tri(dichloroisopropyl) phosphate, and tributyl phosphate, and the nonionic detergent metabolite p-nonylphenol.

Pharmaceuticals and Personal Care Products
Several pharmaceuticals and personal care products were detected in water samples collected from the mainstem of the Root River including the stimulant caffeine; DEET, the active ingredient from insect repellants; the nicotine metabolite cotinine; the flavoring and fragrance compounds camphor, acetophenone, and menthol; and the perfume fixative benzophenone.

Milwaukee Harbor Estuary and Adjacent Nearshore Lake Michigan Area
Bacterial and Biological Parameters
Concentrations of fecal coliform bacteria at sampling stations in the Milwaukee Harbor estuary commonly exceeded the variance standard that applies to the estuary. While fecal coliform bacteria concentrations in the outer harbor were generally about an order of magnitude lower than those in the estuary, they occasionally exceeded the standard for full recreational use. After 1993, fecal coliform bacteria concentrations in the estuary and outer harbor decreased, at least in part as a result of MMSD's Inline Storage System coming online. Long-term trends toward decreasing concentrations of fecal coliform bacteria were detected at most sampling stations in the estuary and outer harbor. Although high concentrations of fecal coliform bacteria were detected at some sampling stations nearest the shore, concentrations of these bacteria in the nearshore Lake Michigan area tended to be low. High concentrations of *E. coli* were detected at some Lake Michigan public beaches and resulted in beach water quality advisories and closings. The frequency of this varies among the beaches, with the highest frequency of advisories and closings occurring at Bradford Beach, McKinley Beach, and South Shore Beach in Milwaukee County.

Concentrations of chlorophyll-*a* at most sampling stations in the estuary sections of the Kinnickinnic and Menomonee Rivers and the Milwaukee outer harbor decreased after 1993, with the reductions at these stations representing long-term decreasing trends. Reductions also occurred at sampling stations in the estuary sections of the Milwaukee River after 1997. Trends toward decreasing chlorophyll-*a* concentrations were also detected in the nearshore Lake Michigan areas. Several factors probably contribute to these reductions, including nutrient reductions related to the reduction in combined sewer overflows resulting from MMSD's Inline Storage System coming online and filtering activities by zebra mussels and quagga mussels.

Chemical and Physical Parameters
With the exception of samples from the Burnham Canal station noted above, water temperatures in the estuary did not generally exceed the 31.7ºC standard for fish and aquatic life. Water temperatures in the outer harbor and nearshore area did not exceed this standard. Mean water temperatures in the Menomonee River portion of the estuary were higher than mean water temperatures in the Kinnickinnic River and Milwaukee River portions of the estuary. Water temperatures in the estuary were warmer than those in the outer harbor and water temperatures in the outer harbor were warmer than those in the nearshore area. Trends toward water temperatures increasing over

time were detected at several sampling stations in the estuary and outer harbor. In part, the trends in the outer harbor appear to result from the annual warming of the water occurring earlier in the year and the annual cooling of the water occurring later in the year in recent years than they did during the past. While few time-based trends were detected at stations in the nearshore area, some evidence suggests that recent changes in the prevailing wind direction during the summer are causing warmer epilimnetic water to be moved toward the western shore of Lake Michigan and piling up in the nearshore area. This may be a factor in the recent resurgence of *Cladophora* as a nuisance alga along the shoreline of Lake Michigan.

Trends toward decreasing concentrations of BOD were detected at all sampling stations in the estuary. The fact that all of the estuary sampling stations are also in the area served by combined sewers suggests that this decrease is being caused, at least in part, by reductions in inputs from combined sewer overflows resulting from operation of the Inline Storage System. At most sampling stations in the outer harbor and nearshore area for which sufficient data are available, the concentration of BOD also decreased over time.

Concentrations of chloride in samples collected from the Milwaukee Harbor estuary rarely exceeded the State chronic toxicity criterion for fish and aquatic life, and never exceeded the acute toxicity criterion. Chloride concentrations in samples from the outer harbor and nearshore areas were below these criteria. Trends toward increasing chloride concentration were found at all sampling stations in the estuary and outer harbor and most sampling stations in the nearshore area. In addition, concentrations of chloride in Lake Michigan have increased.

Concentrations of dissolved oxygen in samples collected from the Milwaukee Harbor estuary were occasionally below the 2.0 mg/l variance standard that applies to the estuary. At four sampling stations in the estuary, trends were detected toward increasing dissolved oxygen concentration over time. This may be related to the reductions in loadings of organic material resulting from the reductions in combined sewer overflows that accompanied the Inline Storage System coming online in 1994. Few other time-based trends in dissolved oxygen concentration were detected at stations in the estuary. Dissolved oxygen concentrations in occasional samples from the outer harbor were lower than the fish and aquatic life standard. In the nearshore area, concentrations of dissolved oxygen were generally above this standard. Trends toward decreasing dissolved oxygen concentration were detected at several sampling stations in and adjacent to the outer harbor and in the nearshore area. Particularly in the nearshore area, these changes appear to be driven by changes in water temperature.

Secchi depths in the outer harbor and nearshore area have increased since 1975. Much of the increase is probably attributable to filtering activities by zebra mussels and quagga mussels. In addition, reduced nutrient loads to the outer harbor, resulting from both reductions in combined sewer overflows since the Inline Storage System came online and nonpoint source pollution control efforts, have contributed to reductions in chlorophyll-*a* concentrations in the outer harbor and, consequently, have contributed to increased Secchi depths. Similarly, basinwide reductions in total phosphorus concentrations in Lake Michigan have contributed to reductions in chlorophyll-*a* concentrations in the Lake leading to increased Secchi depths in the nearshore area.

Suspended Material

Concentrations of TSS were lower in the estuary than in the sections of the Kinnickinnic, Menomonee, and Milwaukee Rivers upstream of the estuary, probably as a result of settling of suspended material within the estuary. Trends toward TSS concentration increasing over time were detected at most sampling stations in the estuary. Concentrations of TSS were lower in the outer harbor than in the estuary, probably as a result of both settling within the outer harbor and dilution with water from Lake Michigan. Trends toward TSS concentration increasing over time were detected at several sampling stations in the outer harbor.

Nutrients

Concentrations of total nitrogen have increased at several sampling stations in the estuary, outer harbor and nearshore Lake Michigan area. The relative proportions of different nitrogen compounds in the estuary, outer harbor, and nearshore area seem to be changing over time. Ammonia concentrations at all stations in the estuary and outer harbor and several stations in the nearshore area have decreased over time. Concentrations of nitrate have increased over time at most stations in the estuary and outer harbor and several stations in the nearshore area.

Similarly, concentrations of organic nitrogen compounds have increased over time at a few stations in the estuary and several stations in the outer harbor.

Total phosphorus concentrations in samples collected from sampling stations in the Milwaukee Harbor estuary frequently exceeded the 0.1 mg/l standard recommended in the original regional water quality management plan. Similarly, total phosphorus concentrations in samples collected from the outer harbor occasionally exceeded the recommended standard. Conflicting trends were detected among forms of phosphorus in how phosphorus concentrations in the estuary and outer harbor changed over time. While trends toward total phosphorus concentrations decreasing over time were detected at several sampling stations, trends toward dissolved phosphorus concentrations increasing over time were detected at some stations. Despite these ambiguous results, annual mean total phosphorus concentrations increased in the estuary and outer harbor after 1996. A likely cause of this is phosphorus loads from facilities discharging noncontact cooling water drawn from municipal water utilities that use orthophosphate or polyphosphate as anticorrosion agents. Trends toward increasing concentrations of total phosphorus were also detected at most sampling stations in the nearshore area. Trends toward increasing concentrations of dissolved phosphorus were also detected at several sampling stations in the nearshore area.

Metals

Concentrations of some metals have decreased in the Milwaukee Harbor estuary. Trends toward decreasing concentrations of cadmium, lead, and mercury were detected at all sampling stations in the estuary. In addition, trends toward decreasing concentrations of arsenic and chromium were detected at most stations in the estuary and trends toward decreasing concentrations of nickel were detected at several stations in the estuary. These declines may reflect changes in the number and types of industries in the watershed, as well as reductions due to treatment of industrial discharges. In addition, the reductions in cadmium concentrations reflect reductions in atmospheric deposition of this metal in the Great Lakes region and the reductions in lead concentrations reflect the phasing out of the use of lead as a gasoline additive.

Concentrations of other metals have increased in the estuary. Trends toward increasing copper and zinc concentrations were detected at most sampling stations. These increases may be related to increases in vehicle traffic and corrosion of galvanized building materials.

Concentrations of some metals have also decreased in the outer harbor and nearshore area. Trends toward decreasing concentrations of cadmium, chromium, lead, and nickel were detected at sampling stations in the outer harbor and nearshore area. These declines may reflect changes in the number and types of industries in the watershed, as well as reductions due to treatment of industrial discharges. In addition, the reductions in cadmium concentrations reflect reductions in atmospheric deposition of this metal in the Great Lakes region and the reductions in lead concentrations reflect the phasing out of the use of lead as a gasoline additive.

Concentrations of other metals have increased in the outer harbor and nearshore area. Trends toward increasing arsenic concentrations were detected at all sampling stations in the outer harbor and nearshore area for which adequate data for assessing trends are available. In addition, trends toward increasing zinc concentrations were detected at some sampling stations in the outer harbor and nearshore area.

Organic Compounds

Several organic compounds were detected in water samples collected from the Milwaukee Harbor estuary and outer harbor including the solvent isophorone; the dye component carbazole, the plasticizer triphenyl phosphate; the flame retardants tri(2-chloroethyl) phosphate, tri(dichloroisopropyl) phosphate, and tributyl phosphate; and the nonionic detergent metabolite p-nonylphenol. In addition, the flame retardant tri(2-butoxyethyl) phosphate and the nonionic detergent metabolite diethoxynonylphenol were detected in samples collected from the outer harbor.

Pharmaceuticals and Personal Care Products

Several pharmaceuticals and personal care products were detected in water samples collected from the Milwaukee Harbor estuary and outer harbor including the stimulant caffeine; DEET, the active ingredient from insect repellants; the nicotine metabolite cotinine; the flavoring and fragrance compounds camphor, acetophenone, AHTN, and HHCB; triethyl citrate, a component of some cosmetics; and the perfume fixative benzophenone. In addition, the flavoring agent and fragrance menthol and the sterol related to steroid hormones cholesterol were detected in samples collected from the outer harbor.

TOXICITY CONDITIONS OF THE GREATER MILWAUKEE WATERSHEDS

Much, though not all of the data on toxic contaminants in the greater Milwaukee watersheds is related to four sites with contaminated sediments: The Moss-American U.S. Environmental Protection Agency (USEPA) Superfund site on the Little Menomonee River in the Menomonee River watershed, the Cedar Creek USEPA Superfund site in the Milwaukee River watershed, Estabrook Impoundment on the Milwaukee River in the Milwaukee River watershed, and the Milwaukee Estuary Area of Concern (AOC) in the Milwaukee River estuary, outer harbor, and adjacent Lake Michigan area.

Toxic Substances in Water

Pesticides

Since the 1970s, streams in the greater Milwaukee watersheds have been sampled for the presence of pesticides in water on several occasions. Most of the sampling was conducted on the mainstems of the major rivers and streams. Few tributaries have been sampled. It is important to note that the suite of pesticides sampled for has changed over the years.

Since the 1970s, the Kinnickinnic River has been sampled for the presence of pesticides in water on several occasions. While several pesticides were sampled for, concentrations of many were found to be below their limits of detection. In samples collected in 1984, detectable concentrations of lindane and toxaphene were each found in one sample. In 1993, measurable concentrations of γ-chlordane were detected in one sample. During sampling conducted in 2004, the insecticides carbaryl and diazinon were occasionally detected as were the herbicide atrazine and its metabolite deethylatrazine. Where detectable concentrations of diazinon and atrazine were reported, they were below the USEPA draft aquatic life criteria.

Since the 1970s, the Menomonee River has been sampled for the presence of pesticides in water on several occasions. While several pesticides were sampled for, concentrations of many were found to be below their limits of detection. Several pesticides were detected in sampling conducted during the 1990s, including the insecticides DDT, chlordane, endosulfan, lindane, and toxaphene and the herbicides 2,4-D and atrazine. DDT metabolites were also detected. During sampling conducted in 2004, the insecticides carbaryl and diazinon were occasionally detected as were the herbicide atrazine and its metabolite deethylatrazine. Where detectable concentrations of diazinon and atrazine were reported, they were below the USEPA draft aquatic life criteria.

Since the 1970s, the Milwaukee River has been sampled for the presence of pesticides in water on several occasions. While several pesticides were sampled for, concentrations of many were found to be below their limits of detection. Atrazine was detected in samples collected during the early 1980s. Several pesticides were detected in sampling conducted between 1993 and 2002, including the insecticides dieldrin, lindane, and malathion and the herbicide atrazine. In addition the DDT metabolite DDE and the atrazine metabolites deethylatrazine and deisopropylatrazine were detected in some of these samples. During sampling conducted in 2004, the insecticides carbaryl and diazinon were occasionally detected as were the herbicide atrazine and its metabolite deethylatrazine. Where detectable concentrations of diazinon and atrazine were reported, they were below the USEPA draft aquatic life criteria. Some of these pesticides have also been detected in tributaries to the Milwaukee River.

Since the 1970s, Oak Creek has been sampled for the presence of pesticides in water on several occasions. While several pesticides were sampled for, concentrations of many were found to be below their limits of detection. The insecticide toxaphene was detected in samples from the Creek collected in 1982 and 1993. During sampling conducted in 2004, the insecticide carbaryl was occasionally detected as were the herbicide atrazine and its metabolite deethylatrazine. Where detectable concentrations of atrazine were reported, they were below the USEPA draft aquatic life criteria.

The Root River has been sampled for the presence of pesticides in water on several occasions. While several pesticides were sampled for, concentrations of many were found to be below their limits of detection. During sampling conducted in 2004, the insecticides carbaryl and diazinon were occasionally detected as were the herbicides atrazine and glyphosate and the atrazine metabolite deethylatrazine. Where detectable concentrations of atrazine were reported, they were below the USEPA draft aquatic life criteria.

Polycyclic Aromatic Hydrocarbons (PAHs)
Since 1995, sampling has been conducted for PAHs in the mainstems of the major streams and rivers of the greater Milwaukee watersheds. Measurable concentrations of PAHs were detected at all of the sampling stations surveyed. Between the periods 1995-1997 and 1998-2001, mean concentrations of total PAHs increased in the estuary portions of the Kinnickinnic and Menomonee Rivers. These increases in mean PAH concentrations in the estuary were accompanied by decreases in mean PAH concentrations in the sections of these Rivers upstream from the estuary.

Polychlorinated Biphenyls (PCBs)
Streams in the greater Milwaukee watersheds have been sampled for the presence of PCBs in water on several occasions. While most of the sampling was conducted on the mainstems of the major rivers and streams, a few tributaries have been sampled.

Between 1995 and 2001, the MMSD long-term sampling sites along the mainstems of the Kinnickinnic, Menomonee, and Milwaukee Rivers, including sampling stations within the estuary, were sampled for the presence and concentrations of 14 PCB congeners in water. Since concentrations of only 14 out of 209 congeners from this family of compounds were examined, the results should be considered minimum values. While in the majority of samples, the concentrations of these PCB congeners were below the limit of detection, when PCBs were detected they exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 nanograms per liter (ng/l). PCBs were detected at sampling stations in estuary portions of each of the three Rivers which make up the estuary.

Between 1993 and 1995, congener-specific analyses of PCBs in water examining 62 PCB fractions representing 85 of the 209 PCB compounds were conducted that examined samples collected at some additional sites along the Milwaukee River and at the confluence of the Milwaukee River with the outer harbor. In all of these samples, the concentrations of PCBs in water exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 nanograms per liter. Congeners of the greatest environmental concern represented between 0 and 32 percent of the mass of dissolved PCBs and between 11 and 57 percent of the mass of PCBs associated with suspended sediment in these samples.

In 1975, water samples from Oak Creek were sampled for the presence and concentrations of PCBs. In all of the samples, the concentrations of PCBs were below the limit of detection.

Between 1998 and 2001, the MMSD long-term sampling sites along the mainstem of the Root River were sampled for the presence and concentrations of 14 PCB congeners in water. Since concentrations of only 14 out of 209 congeners from this family of compounds were examined, the results should be considered minimum values. In all of these samples, the concentrations of PCBs were below the limit of detection.

Only a few tributary streams have been sampled for PCBs in the greater Milwaukee watersheds.

Between 1995 and 2001, the MMSD long-term sampling sites along Lincoln Creek in the Milwaukee River watershed were sampled for the presence and concentrations of 14 PCB congeners in water. Since concentrations of only 14 out of 209 congeners from this family of compounds were examined, the results should be considered minimum values. While in the majority of samples, the concentrations of these PCB congeners were below the limit of detection, when PCBs were detected they exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 ng/l.

Similar sampling was conducted between 1999 and 2001 at sites along Southbranch Creek in the Milwaukee River watershed and in 2002 at sites along Fish Creek in the Lake Michigan direct drainage area. In all of these samples, concentrations of PCBs in water were below the limit of detection.

Between 1991 and 2001, congener-specific analyses were conducted on water samples collected from Cedar Creek. PCBs were detected in all of these samples. In all but one sample, the concentrations detected exceeded Wisconsin's wildlife criterion for surface water quality of 0.12 ng/l. At the two sites where sufficient data were available to assess trends in PCB concentrations, the concentrations of PCBs detected in water decreased over the period 1991 to 2001.

Toxic Contaminants in Aquatic Organisms

The Wisconsin Department of Natural Resources (WDNR) periodically surveys tissue from fish and other aquatic organisms for the presence of toxic and hazardous contaminants. Several surveys were conducted at sites within the greater Milwaukee watersheds between 1976 and 2002. These surveys screened for the presence and concentrations of several contaminants including metals, PCBs, and organochloride pesticides. Because of the potential risks posed to humans by consumption of fish containing contaminants, the WDNR has issued a general fish consumption advisory for fish caught from most of the surface waters of the State. The details of this advisory are shown in Table 6 in Chapter II of this report. In addition, when tissue from fish caught in a particular waterbody is found to contain higher levels of mercury, PCBs, or dioxins, the WDNR issues more restrictive consumption recommendations. Additional consumption advisories of this sort have been issued for several waterbodies in the greater Milwaukee watersheds. These are documented in Chapters V through X of this report. In addition, due to tissue concentrations of PCBs in excess of the U.S. Food and Drug Administration's standard, the Wisconsin Division of Health has issued a do not eat consumption advisory for black ducks, mallards, ruddy ducks, and scaup using the Milwaukee Harbor.

Tissue concentrations of mercury are generally low in fish collected from the greater Milwaukee watersheds. Fish from only one waterbody in the study area, Mauthe Lake, are subject to a special fish consumption advisory due to high concentrations of mercury.

High tissue concentrations of PCBs were found in several species, especially carp, in samples collected from the Kinnickinnic and Menomonee River watersheds. High tissue concentrations of PCBs were found in several species of fish collected from the Milwaukee River watershed, especially from sites along the mainstem of the Milwaukee River downstream from the Village of Grafton, Cedar Creek, Lincoln Creek, Jackson Park Pond, and Zeunert Pond. High tissue concentrations of PCBs were also detected in several species of fish collected from the Root River, especially at sites below Horlick dam. In addition, high tissue concentrations of PCBs were found in both forage fish and piscivorous fish collected from Lake Michigan. Comparisons of tissue concentrations of PCBs in recent samples to concentrations in samples collected in the 1970s suggest that at some locations tissue concentrations of PCBs in fish have decreased. Time comparisons in many of these locations are complicated by the fact that different species were collected at different dates. Several waterbodies in the greater Milwaukee watersheds are subject to special fish consumption advisories due to high tissue concentrations of PCBs detected in fish. These advisories are documented in Chapters V through X of this report.

Since the mid 1980s and early 1990s, concentrations of DDT isomers in fish tissue in samples collected from the Menomonee and Milwaukee Rivers and Oak Creek have been below the limit of detection. DDT has been detected in fish tissue in samples collected from the Root River, Oak Creek Parkway Pond, and some tributaries of the Milwaukee River. While DDT metabolites were still detected in fish tissue at most locations that were sampled, concentrations found in some streams were lower than those detected during the late 1970s and early 1980s. Concentrations of dieldrin in fish tissue were below the limit of detection in many streams, though measurable concentrations were still being detected in some fish collected from the Root River. Concentrations of chlordane isomers in fish tissue were below the limit of detection in many streams, though measurable concentrations were still being detected in some fish collected from Cedar Creek and the Root River.

Toxic Contaminants in Sediment

Since 1973, sediment samples from streams in the greater Milwaukee watersheds have been examined for the presence and concentrations of toxic substances on several occasions. Toxicants that have been sampled for include metals, PAHs, PCBs, and pesticides. Most of the sites sampled in the Kinnickinnic River watershed are from the mainstem of the Kinnickinnic River within the estuary. Most of the sites sampled in the Menomonee River watershed are from the Little Menomonee River and are related to the Moss-American USEPA Superfund site. A variety of sites were sampled in the Milwaukee River watershed. Sampling has been especially intensive along Cedar Creek and Lincoln Creek and in Estabrook Impoundment. The sites sampled in the Oak Creek watershed are from the mainstem of Oak Creek and Oak Creek Parkway Pond. The sites sampled in the Root River watershed include sites along the mainstem of the Root River, Crayfish Creek, Whitnall Park Creek, and an unnamed tributary to Crayfish Creek. Considerable sampling has been conducted within the Milwaukee Harbor estuary and outer harbor.

Several toxic metals have been detected in sediment samples collected in the greater Milwaukee watersheds. Detectable concentrations of arsenic, cadmium, copper, lead, and zinc have been frequently reported in sediment samples collected from most of the watersheds and the estuary and outer harbor. Chromium, iron, mercury, and nickel have also been detected in sediment samples from several watersheds. The mean concentrations of cadmium, chromium, copper, lead, mercury, and zinc reported for the watersheds in which they have been detected are generally at levels such that these toxicants are likely to be producing some level of toxic effect in benthic organisms. In some watersheds, concentrations of cadmium, copper, lead, and zinc are at levels high enough that toxic effects to benthic organisms are highly probable.

While PAHs were detected in sediment samples collected from all of the watersheds, particularly high concentrations were found in sediment from sites in the Little Menomonee River in the Menomonee River watershed, the mainstem of the Kinnickinnic River in the estuary, and Estabrook Impoundment and Lincoln Creek in the Milwaukee River watershed. Concentrations of PAHs at some sites along the Little Menomonee River, the Kinnickinnic River, Lincoln Creek, the Root River, and in the estuary and outer harbor were high enough that benthic organisms at those sites may be experiencing substantial incidences of toxic effects. While concentrations of PAHs were lower at other locations, they were still at levels that are likely to produce some level of toxic effects in benthic organisms.

While PCBs were detected in sediment from a number of locations, particularly high concentrations were found in sediment from sites in Cedar Creek and Zeunert Pond in Cedarburg, Estabrook Impoundment and Lincoln Creek in the Milwaukee River watershed, and the Milwaukee Harbor estuary. At several sites, including sites in Cedar Creek, Zeunert Pond, Estabrook Impoundment, and the estuary and outer harbor, concentrations of PCBs in sediment are high enough to cause substantial incidences of toxic effects in benthic organisms. At other sampling locations, concentrations of PCBs in sediment are lower, but still high enough to likely produce some level of toxic effect in benthic organisms.

Analysis of sediment quality using indices that estimate the combined effect of multiple toxicants in sediment suggest that sediment quality at several locations in the greater Milwaukee watersheds is poor enough that benthic organisms are likely experiencing high incidences of toxic effects.

BIOLOGICAL CONDITIONS OF THE GREATER MILWAUKEE WATERSHEDS

Aquatic and terrestrial wildlife communities perform important functions in the ecological system, have educational and aesthetic values, and are the basis for certain recreational activities. The location, extent, and quality of the fishery and wildlife areas and the type of fish and wildlife characteristic of those areas are, therefore, important determinants of the overall quality of the environment in the greater Milwaukee watersheds.

Streams and Rivers

Review of fishery data collected in the greater Milwaukee watersheds since the beginning of the twentieth century show apparent net losses of species in the Kinnickinnic River, Milwaukee River, and Oak Creek watersheds, no apparent net loss in the Root River watershed, and an apparent net gain in the Menomonee River watershed. Some, though not all, of these apparent changes appear to be due to decreased sampling effort.

Historically, low numbers of fish species were detected in samples from the Kinnickinnic River and Oak Creek watersheds, with 24 species having been reported in the Kinnickinnic River watershed and 29 species having been reported in the Oak Creek watershed over the past century. Current species diversity remains low in these watersheds. During the period 1998-2004, only one species was reported as being present in samples collected from the Kinnickinnic River and its tributaries and 20 species were reported as being present in samples collected from Oak Creek and its tributaries. It is important to note that during the period 1998-2004 only one sample was collected from the Kinnickinnic River. It is likely that a greater sampling effort would have resulted in the detection of more species. For the Kinnickinnic River watershed, this total represents a decrease from the number of species collected during 1994-1997. For the Oak Creek watershed, this total represents an increase from the number of species detected during 1994-1997.

By contrast, higher numbers of fish species were historically detected in the Milwaukee River and Root River watersheds, with 81 species having been reported in the Milwaukee River watershed and 64 species having been reported in the Root River watershed over the past century. Current species diversity is also higher in these watersheds. During the period 1998-2004, 63 species were reported as being present in samples collected from the Milwaukee River and its tributaries and 46 species were reported as being present in samples collected from the Root River and its tributaries. For both these watersheds, these totals represent increases from the numbers detected during 1994-1997.

Historically, an intermediate number of fish species was detected in the Menomonee River watershed, with a total of 46 species having been reported as being present in samples collected over the last century. During the period 1998-2004, 31 species were reported in this watershed. This is the highest number of species detected in this watershed during any sampling period and represents an increase over the number of species detected during 1994-1997.

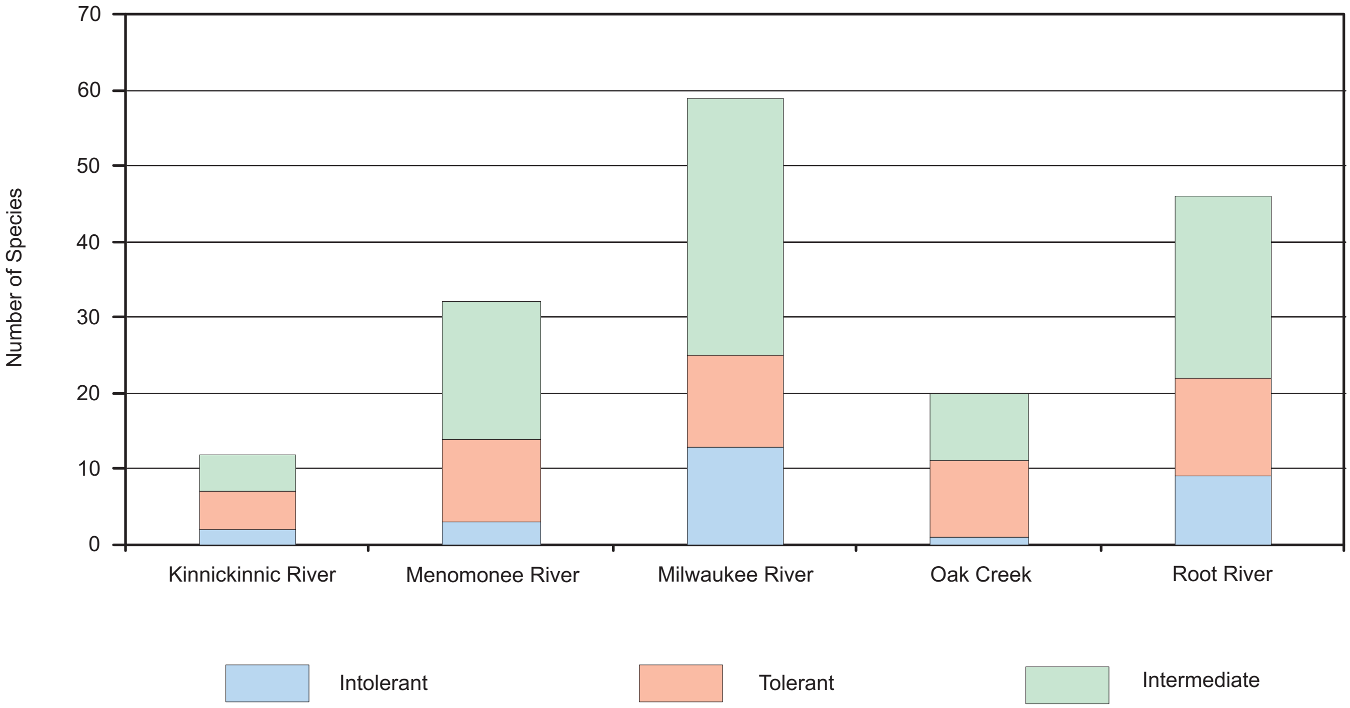
In each watershed the composition of the fish community appears to be changing. In each watershed, several species have not been observed since 1986. In addition, with the exception of the Kinnickinnic River watershed, there have been recent observations of fish species that have not been historically detected in each watershed. In the Oak Creek and Root River watersheds, some of these new observations have occurred in reaches of the mainstems between the confluence with Lake Michigan and the first dam, suggesting that some of these observations reflect the influence of Lake Michigan’s fish community on the fish communities in the lower reaches of these Rivers.

Figure 369 shows the number of fish species by tolerance class in each of the watersheds of the study area. All of the watersheds contain high proportions of species that are tolerant of low dissolved oxygen conditions. These tolerant species tend to be present at high prevalence in the fish communities in the Kinnickinnic River, Menomonee River, and Oak Creek watersheds. Low numbers of native species and species that are intolerant of low dissolved oxygen conditions are also present in these watersheds. This is indicative of a poor quality fishery. The proportion of tolerant species has increased in many parts of the study area. For example, the proportion of fish collected from the Menomonee River watershed represented by common carp increased from about 2 percent in 1975 to 40 percent in 2004. Other stream reaches sustain good proportions of top carnivore species and good balances of predatory fishes to forage fishes, indicating a high quality fishery.

Because of its size, the situation is more complicated in the Milwaukee River watershed. Some stream reaches in this watershed are dominated by low dissolved oxygen tolerant fish, especially in the North Branch Milwaukee River, Lincoln Creek, and Lower Milwaukee River subwatersheds. Other stream reaches sustain good proportions of top carnivore species and good balances of predatory fishes to forage fishes, indicating a high quality fishery. Although the fisheries in portions of the watershed are high quality, most notably in the northern part of the watershed and in the portions of the mainstem that are directly connected to Lake Michigan, there are many areas where the fishery quality is poor to fair or where the quality of the fishery has declined.

Figure 369

NUMBER OF FISH SPECIES BY TOLERANCE CLASS IN THE GREATER MILWAUKEE WATERSHEDS: 1998-2004



Source: SEWRPC.

The apparent stagnation of the fishery communities within much of the greater Milwaukee watersheds can be attributed to habitat loss and degradation as a consequence of human activities primarily related to the historical and current agricultural and land use development that has occurred within these watersheds. Agricultural and/or urban development can cause numerous changes to streams that have the potential to alter aquatic biodiversity. Impacting factors that have been observed to varying degrees in the greater Milwaukee watersheds are described in Chapters V through IX of this report.

Chapter II of this report includes a description of the correlation between urbanization in a watershed and the quality of the aquatic biological resources. The amount of imperviousness in a watershed that is directly connected to the stormwater drainage system can be used as a surrogate for the combined impacts of urbanization in the absence of mitigation. The overall percentages of urban land in the watersheds in 2000 ranged from about 21 percent in the Milwaukee River watershed to about 93 percent in the Kinnickinnic River watershed, corresponding to levels of directly connected imperviousness that range between 10 percent and 30 percent. Some portions of the study area have even higher percentages of imperviousness, with the amounts in the lower reaches of the Milwaukee River, for example, approaching 50 to 60 percent. Many areas have levels of imperviousness above the threshold level of 10 percent at which studies cited in Chapters V through IX of this report indicate that negative biological impacts have been observed. The Milwaukee River, Root River, and Oak Creek watersheds still have high proportions of agricultural land use. Based upon the amounts of agricultural and urban lands in these watersheds and, in the past, a lack of measures to mitigate the adverse effects of those land uses, it is not surprising that indices of fish community quality in many areas of these watersheds indicate poor to fair quality fisheries.[4]

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[4]*The standards and requirements of Chapter NR 151, "Runoff Management," and Chapter NR 216, "Storm Water Discharge Permits," of the* Wisconsin Administrative Code *are intended to mitigate the impacts of existing and new urban development and agricultural activities on surface water resources through control of peak flows*
(Footnote Continued on Next Page)

Habitat data for sites in the greater Milwaukee watersheds have been collected as part of the WDNR baseline monitoring program and by the WDNR Fish and Habitat Research Section in the Milwaukee River watershed. Based on limited habitat data, habitat conditions in the Kinnickinnic River watershed have generally been described as being degraded due, in large part, to more than 60 percent of the entire river network being comprised of either enclosed conduit or concrete-lined channel. A small data set suggests that habitat conditions in the Menomonee River watershed are fair to good. Based upon the available data, the results suggest that fisheries habitat conditions in the Oak Creek watershed are poor to fair. Limited data suggest habitat conditions in the Root River watershed may be fair to good. It is important to note that many of the streams have been channelized within the greater Milwaukee watersheds. Such channelization impacts habitat quality by reducing instream and riparian vegetation cover, increasing sedimentation, decreasing diversity of flow, decreasing water depths, and decreasing substrate diversity, among others.

Despite the habitat classification of fair to good, the WDNR recently concluded that instream habitat is impaired in many stream reaches in the greater Milwaukee watersheds, primarily due to the impacts of hydrologic modification, streamflow fluctuations caused by unnatural conditions, stream bank erosion, urban stormwater runoff, cropland erosion, and roadside erosion emanating from both agricultural and urban land use areas of these watersheds.[5]

The macroinvertebrate communities in the Kinnickinnic River, Oak Creek, and Root River watersheds were found to be depauperate and dominated by tolerant taxa. The macroinvertebrate communities in the Menomonee River watershed were found to have improved substantially since 1993, especially in the Lower Menomonee River subwatershed. Results from the Milwaukee River watershed show that current macroinvertebrate diversity and abundances are indicative of fair to good-very good water quality. They also indicate long-term improvement in the abundance and diversity of macroinvertebrates.

Lakes and Ponds

There are 20 major lakes, i.e., lakes greater than 50 acres in size, within the greater Milwaukee watersheds. All of them are located within the Milwaukee River watershed. In addition, there are more than 130 lakes and ponds of less than 50 acres in size in the greater Milwaukee watersheds.

The last recorded fishery surveys for many of the lakes and ponds were completed in the late 1970s and early 1980s. The surveys indicated that these waterbodies contained a typical urban fish species mixture mostly dominated by tolerant species such as green sunfish, black bullhead, carp, and white sucker. Largemouth bass, northern pike, and yellow perch were also reported to occur in several of these waterbodies. Information from WDNR staff indicates that many of these lakes and ponds provide various recreational fishing opportunities for gamefish and/or panfish species; however, some of these waterbodies are stocked to supplement these fisheries.

More-recent comprehensive fishery surveys have been completed by the WDNR for Erler, Little Cedar, Long, and Random Lakes. In 2003, a fish community survey of Erler Lake found 11 fish species including bluegill, carp, largemouth bass, and yellow perch. More restrictive fishing regulations on panfish and bass were proposed to protect the populations from collapse when public access is developed. A fish community survey on Little Cedar Lake during 1999 found that fish habitat conditions in this lake were good to very good. The species found in this

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(Footnote Continued from Previous Page)

in the channel-forming range, promotion of increased baseflow through infiltration of stormwater runoff, and reduction in sediment loads to streams and lakes. The implementation of those rules is intended to mitigate, or improve, water quality and instream/inlake habitat conditions.

[5]*Wisconsin Department of Natural Resources,* The State of the Milwaukee River Basin, *WT-704-2001, August 2001; Wisconsin Department of Natural Resources,* The State of the Root-Pike River Basin, *WT-700-2002, May 2002.*

lake included bluegills, bluntnose minnows, crappies, largemouth bass, northern pike, and yellow perch. While some populations, such as those of bluegills and northern pike consisted mostly of small individuals, other populations, such as largemouth bass, had good size structure. A comprehensive fish community survey of Long Lake in eastern Fond du Lac County conducted during 2004 found 15 native species of fish, including bluegill, northern pike, walleye, yellow bullhead, and yellow perch. The Long Lake largemouth bass population was in exceptional condition. An electrofishing survey of the shoreline of Random Lake during the fall of 2004 found several species, including black crappies, bluegills, largemouth bass, muskellunge, walleye, and yellow perch. While panfish were abundant, they were generally small in size and appeared to be growing slowly. By contrast, walleye in this lake were generally plump, an indication that they were feeding well.

Exotic invasive species have been recorded in several lakes and ponds within the greater Milwaukee watersheds. Carp are found in at least 26 lakes and ponds. Zebra mussels have been recorded in seven lakes. Eurasian water milfoil is known to exist in 20 lakes and ponds. Curly-leaf pondweed is known to exist in each of the Counties within the greater Milwaukee watersheds.

Lake Michigan

Biological conditions in the estuary, outer harbor, and nearshore areas are strongly linked to the conditions in Lake Michigan.

Lake Michigan Fishery

Lake Michigan has undergone well-documented, significant changes in its fishery since the 1880s. These changes have been linked to various factors that include eutrophication, fishery exploitation, and the invasions of exotic or nonnative species among several trophic levels of fishes, mussels, plankton, and aquatic plants. Most recently, there are several major trends throughout Lake Michigan that are important to note in order to understand the context of the estuary and nearshore fisheries. The findings summarized below are based upon some of the recent major studies and stock assessment activities carried out by the WDNR on Lake Michigan.[6]

While sport harvests of chinook salmon have been good in recent years, size-at-age of these fish has continued to decline. In response to this, lakewide chinook stocking levels were reduced by 25 percent in 2006. As of 2005, the yellow perch population in southern Lake Michigan was still dominated by the 1998 year class. The sport harvest of this year class is decreasing. Effective May 2002, the sport fishery for Lake Michigan yellow perch was closed between May 1 and June 15 to reduce fishing impacts on spawning stocks. While the reported commercial harvest of lake whitefish from Wisconsin waters of Lake Michigan has increased slightly, the size-at-age of these fish has continued to decrease. This may be related to lakewide declines in the abundance of the amphipod *Diporeia* and increases in the abundance of quagga mussels, which form the major food source for lake whitefish and the major competitor for the food source, respectively.

Nuisance Algae* (Cladophora) *in Lake Michigan

In recent years large quantities of decaying algae, mostly from the genus *Cladophora,* have been fouling Wisconsin's Lake Michigan shoreline. As the bacteria and organisms in the alga rot, they generate a pungent septic odor that many people confuse with sewage. While the presence of rotting *Cladophora* on Lake Michigan beaches does not present a risk to human health, the rotting algal mats may provide adequate conditions for bacterial growth, and microcrustaceans deposited on the beach with the decaying algae may attract large flocks of gulls resulting in increased bacteria concentrations from gull fecal material.

Cladophora is naturally found along the Great Lakes coastline. It grows on submerged rocks, logs, or other hard surfaces. Because of the Lake's water clarity, it has been observed growing at depths below 30 feet. Wind and wave action cause the algae to break free from the lake bottom and wash up on shore. Nuisance levels of

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[6]*Additional information on the Lake Michigan fishery can be obtained from the WDNR Lake Michigan web page at* http://dnr.wi.gov/org/water/fhp/fish/lakemich/index.htm.

Cladophora were previously a problem during the mid-1950s and during the 1960s and 1970s. The causes of the *Cladophora* resurgence in the Great Lakes are not known for certain, but probably include changes in phosphorus loadings from the rivers discharging into the Great Lakes and changes in water clarity and phosphorus availability related to the presence of zebra mussels and quagga mussels in the nearshore area.

Milwaukee Harbor Estuary and Nearshore Lake Michigan Fisheries

The Lower Milwaukee River and Milwaukee Harbor estuary habitat and water quality have been heavily altered due to damming, channelization, streambank modification by installation of riprap and sheet piling, and urban stormwater discharges. The International Joint Commission identified the Milwaukee Harbor estuary as one of 43 Areas of Concern (AOC) requiring clean up of toxic wastes and remedial action. While the beneficial use impairments identified in the Milwaukee Harbor estuary AOC are the result of many causes, many are related, at least in part, to the presence of toxic substances in water, sediment, and the tissue of organisms. It is also important to note that the habitat in the lower reaches of each of the watersheds draining into the estuary is typical of that found in a highly urbanized environment, with extensive channelization and placement of sheet piling for bank stabilization. More natural habitat can be generally found in upstream areas of each of the major rivers.

Despite extensive habitat, water quality, and toxicity impacts, the Milwaukee Harbor estuary contains a fairly high abundance and diversity of fish species. The quality of the fishery in the estuary is largely dependent upon the influx of fishes from the higher quality waters in the upstream areas of the Menomonee, Kinnickinnic, and Milwaukee Rivers that have been documented to support a full range of fish and aquatic life, influx of fishes from Lake Michigan, and continued habitat improvement and species restoration projects.

The 1997 removal of the North Avenue dam on the Milwaukee River 3.2 miles upstream from the confluence with Lake Michigan reconnected the estuary with the Milwaukee River system. With the removal of the dam, improvements in sewage treatment, and abatement of combined sewer overflows, riverine conditions quickly began to reestablish in the formerly impounded area. The removal of the dam not only provided an opportunity for migratory fish species to move further upstream, but also opened up opportunities for the rehabilitation of some of the native species that were extirpated or reduced to remnant populations. Many habitat improvement measures have been implemented including streambank stabilization, revegetation of mud flats, and reestablishment of meanders within the former impounded area. As a result of these efforts, several miles of stream channel were made available to migratory as well as resident species whose movements were restricted prior to dam removal. This increase in migration along with improvements in water quality and habitat allowed WDNR staff to initiate native walleye and lake sturgeon restoration projects in the Lower Milwaukee River and the Milwaukee Harbor estuary.

Exotic Invasive Species

The food web of Lake Michigan and of the Great Lakes in general is defined and complicated by historical and continued additions of exotic invasive species. The entry and dispersal mechanisms which have acted singly or jointly in the movement of organisms into the Great Lakes basin include unintentional release (shipping traffic via discharge of ballast water; escape from cultivation, aquaculture, and aquaria; and accidental releases due to fish stocking and from unused bait), deliberate releases (for example, the deliberate introduction of salmon species to enhance fisheries), canals, and disturbances linked to the construction of railroads and highways. Scientists have identified 145 nonindigenous fishes, invertebrates, fish disease pathogens, plants, and algae that have established in the Great Lakes since the early 1800s. Some taxonomic groups have not been studied as well as others; however, plants, algae, disease pathogens, and parasites account for about 60 percent of new species established in the Great Lakes basin since 1810, followed by invertebrates that account for 22 percent, and fish that make up about 18 percent.

It is difficult, if not impossible, to predict how these species introductions will affect the existing or future food web dynamics in Lake Michigan. Similar patterns of invasion and system responses have occurred among several of the Great Lakes. Sea lamprey, for example, have caused great damage to the lake trout, whitefish, and burbot populations in all the Great Lakes and similar impacts of zebra mussels have been documented in all of the Great Lakes.

Lake Erie, like all of the Great Lakes, has had similar changes in food web dynamics, but because it is the shallowest and warmest of the Great Lakes, Erie is usually the first to show signs of stress. In other words, recent food web changes in Lake Erie may provide insight into trends that may also occur in Lake Michigan. In Lake Erie, zebra musses have directly led to increased water clarity, clogging of municipal water intakes, reduced recreation on beaches, and disappearance of many native mussel species. Indirect effects of zebra mussels in Lake Erie include creation of algal blooms and dead zones, disappearance of *Diporeia*, deaths of fish-eating birds, and accelerated bioaccumulation of toxicants to predatory fishes and birds. Except for indirect bird or fish deaths, the above consequences associated with the invasion of zebra mussels in Lake Erie have also occurred in Lake Michigan.

Other Wildlife

Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of this study, it is possible, by polling naturalists and wildlife managers familiar with the area, to compile lists of species which may be expected to be found in the area under existing conditions. These species lists are presented in Appendices D, E, and F of this report.

These appendices show that 57 species of mammals, ranging in size from large animals like the white-tailed deer, to small animals like the meadow vole, are likely to be found within the greater Milwaukee watersheds. At least 180 species of birds have been reported to breed in this area. Some of these species are resident throughout the year. An additional 108 bird species visit the area only during the annual migration periods or winter in the area. Species reported include game birds, songbirds, waders, and raptors. Amphibians and reptiles are vital components of the ecosystem within an environmental unit like that of the greater Milwaukee watersheds area. Examples of amphibians native to the area include frogs, toads, and salamanders. Turtles and snakes are examples of reptiles common to the area. Eighteen species of amphibians and 24 species of reptiles have been reported to occur in the greater Milwaukee watersheds area.

Endangered and threatened species and species of special concern present in the greater Milwaukee watersheds area include 74 species of plants, 16 species of birds, 13 species of fish, five species of herptiles, and 21 species of invertebrates.

The complete spectrum of wildlife species originally native to the watersheds, along with their habitat, has undergone significant change in terms of diversity and population size since the European settlement of the area. This change is a direct result of the conversion of land by the settlers from its natural state to agricultural and urban uses, beginning with the clearing of the forest and prairies, the draining of wetlands, and ending with the development of urban land in some areas. Successive cultural uses and attendant management practices, primarily urban, have been superimposed on the land use changes and have also affected the wildlife and wildlife habitat. In urban areas, cultural management practices that affect wildlife and their habitat include the use of fertilizers, herbicides, and pesticides; road salting for snow and ice control; heavy motor vehicle traffic that produces disruptive noise levels and air pollution and nonpoint source water pollution; and the introduction of domestic pets.

CHANNEL CONDITIONS AND STRUCTURES

While a comprehensive evaluation of channel conditions within the greater Milwaukee watersheds has not been conducted, data are available on channel conditions in portions of the study area from several studies. Stream reaches for which data are available include about 60 miles of stream channel along the mainstems of the Kinnickinnic River, Milwaukee River, Root River, Oak Creek, and several tributary streams in Milwaukee County; about 63 miles of stream channel along the mainstem of the Menomonee River and several of its tributaries in MMSD's service area; the Root River within the City of Racine; 3.5 miles of stream channel along Fish Creek; Quaas Creek in Washington County; and an unnamed tributary to the Milwaukee River.

Some streams of the greater Milwaukee watersheds show substantial modification of streambeds and banks. The percentages of streambed and bank modifications tend to differ among the watersheds. The Kinnickinnic River watershed has a high proportion of bed and bank modification with about 58 percent of the portions of the stream channel which was examined being lined with concrete or enclosed in conduit. The Menomonee River watershed also has a high proportion of this sort of modification with about 22 percent of the stream channel examined being lined with concrete or riprap, or enclosed in conduit. Lower proportions of stream channel show these sorts of modifications in the other watersheds. About 7 percent of the stream channel examined in the Oak Creek watershed is lined with concrete or enclosed in conduit. Less than 1 percent of the stream channel in the Root River watershed is enclosed in conduit and none is concrete-lined. About seven miles of stream channel in the Milwaukee River watershed are lined with concrete or enclosed in conduit, representing about 2 percent of the perennial stream length in this watershed.

There are some areas where stream channel modification has not been as significant. Examples of this include the designated exceptional water resource areas in the East Branch of the Milwaukee River and Lake Fifteen Creek subwatersheds in the upper portions of the Milwaukee River watershed.

Bed and Bank Stability

Degrading channels and eroding banks are common along streams in some portions of the greater Milwaukee watersheds. Locations of aggrading, degrading and stable stream reaches are inventoried in Chapters V through X of this report.

Since a large portion of the Kinnickinnic River watershed contains channels which are concrete-lined or enclosed in conduit, only six miles of channel were inventoried for stability. Most alluvial reaches that were examined appeared to be degrading and actively eroding. Less than 5 percent of the total 6.1 miles assessed were observed to be stable.

About 63 miles of channel in the Menomonee River watershed were inventoried for stability. Lateral erosion is relatively uncommon in this watershed, comprising about 5 percent of total bank conditions. Streambeds in this watershed showed similar trends toward stability. Only about 5 percent of alluvial reaches were observed to be unstable. In particular, the lower portions of the Menomonee River have experienced relatively little bed and bank degradation. This appears to be the result of armoring of the channel by bedrock, large bed materials, and manmade structures. Aggrading alluvial reaches are uncommon in the portions of this watershed which were assessed.

About 43 miles of channel in the Milwaukee River watershed were inventoried for stability including about 31 miles of channel in Milwaukee County, and about 2.4 miles of channel in the unnamed tributary to the Milwaukee River and Quaas Creek systems. Approximately half of the alluvial reaches that were examined appeared to be degrading and actively eroding. About 9.5 percent of the stream length assessed was observed to be stable.

About 24 miles of channel in the Oak Creek watershed were inventoried for stability. Most alluvial reaches that were examined appeared to be degrading and actively eroding. Less than 8 percent of the lengths of bank assessed were observed to be stable.

About 55.4 miles of channel in the Root River watershed were inventoried for stability, including about 48 miles of channel in Milwaukee County and about 7.4 miles of channel in the City of Racine. Most alluvial reaches that were examined appeared to be degrading and actively eroding. About 34 percent of the stream length assessed was observed to be stable. Less than 2 percent of the assessed channel was observed to be aggrading.

About 3.6 miles of channel of Fish Creek in the Lake Michigan direct drainage area were inventoried for stability. Most alluvial reaches that were examined appeared to be degrading and actively eroding. Beds along approximately 61 percent of the examined sections of the stream appeared to be degrading and actively eroding. Degradation was also observed along stream banks, with about 39 percent of the length of banks that were examined appearing to be actively eroding. Aggradation was occurring in about 19 percent of the stream.

Dams

In 2005, there were about 88 dams and 62 drop structures located within the greater Milwaukee watersheds. These include one dam and 14 drop structures within the Kinnickinnic River watershed, seven dams and 28 drop structures within the Menomonee River watershed, 70 dams and six drop structures within the Milwaukee River watershed, one dam and six drop structures in the Oak Creek watershed, eight dams and six drop structures in the Root River watershed, and one dam and two drop structures in the Lake Michigan direct drainage area. Between 1988 and 2005 at least nine dams were removed within the greater Milwaukee watersheds.

HABITAT AND RIPARIAN CORRIDOR CONDITIONS

Environmental Corridors, Natural Areas, and Critical Species Habitat Sites

The primary environmental corridors in the greater Milwaukee watersheds are primarily located along major stream valleys, around major lakes, and along the northern Kettle Moraine. In 2000, primary environmental corridors encompassed about 185 square miles, or about 16 percent of the study area. These primary environmental corridors contain almost all of the best remaining woodlands, wetlands, and wildlife habitat areas in the study area, and represent a composite of the best remaining elements of the natural resource base.

Secondary environmental corridors are generally located along the small perennial and intermittent streams within the greater Milwaukee watersheds. In 2000, secondary environmental corridors encompassed about 27 square miles, or about 2 percent of the study area. Secondary environmental corridors also contain a variety of resource elements, often remnant resources from primary environmental corridors which have been developed for intensive urban or agricultural purposes. Secondary environmental corridors facilitate surface water drainage, maintain pockets of natural resource features, and provide corridors for movement of wildlife, as well as for the movement and dispersal of seeds of a variety of plant species.

Widely scattered throughout the greater Milwaukee watersheds, isolated natural resource areas encompassed about 28 square miles, or about 3 percent of the study area, in 2000. These smaller pockets of wetlands, woodlands, surface water, or wildlife habitat may provide the only available wildlife habitat in an area, provide good locations for local parks and nature study areas, and lend unique aesthetic character or natural diversity to an area.

There are about 227 natural area sites encompassing about 20,700 acres, or about 3 percent of the greater Milwaukee watersheds. In addition, the regional natural areas and critical species habitat protection and management plan identified critical species habitat sites in the study area,[7] except for areas located within Sheboygan, Fond du Lac, and Dodge Counties. The majority of critical species habitat sites are located within identified natural areas; however, 47 critical species habitat sites are located outside the abovementioned natural area sites. Natural areas and critical species habitat sites are inventoried in Chapters V through X of this report.

Measures for Habitat Protection

Varying approaches to the protection of stream corridor have been adopted within the greater Milwaukee watersheds. In Milwaukee County, stream corridor protection has focused on public acquisition of the lands adjacent to the stream banks and their preservation as river parkways. These lands are frequently incorporated into public parks and other natural areas. Racine County has acquired some lands adjacent to the mainstem of the Root River and preserved it as river parkway. In Washington County, the City of West Bend has also acquired some lands adjacent to the Milwaukee River, at the site of the former Woolen Mills dam, and has preserved it as a park. The Washington County comprehensive shoreland and floodland protection ordinance requires setbacks of principal structures and places limits upon removal of shoreland vegetation cover, excavation of shoreland, and

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[7]*SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, *September 1997.*

encroachment into shorelands by structures based upon a lake and stream classification system designed to protect those waters most sensitive to human encroachment. In Waukesha County, a comprehensive shoreland and floodland protection ordinance requires setbacks of principal structures and places limits upon removal of shoreland vegetation cover, excavation of shoreland, and encroachment into shorelands by structures.

The provision of buffer strips along waterways represents an important intervention that addresses anthropogenic sources of contaminants, with even the smallest buffer strip providing environmental benefit.[8] Figure 370 shows the current status of buffer widths around streams of the greater Milwaukee watersheds, ranging from less than 25 feet, 25 to 50 feet, 50 to 75 feet, and greater than 75 feet. Buffers of greater than 75 feet width were the most common category, accounting for 56 percent of the buffer widths observed in the study area. Buffer widths less than 25 feet were the next most common category, accounting for about 25 percent of the buffer widths in the study area. Depending on the watershed, buffers of greater than 75 feet in width accounted for between 10 and 67 percent of buffers in the watershed, with the greatest percentage of buffers in this width category being found in the Milwaukee River watershed and the smallest percentage of buffers in this width category being found in the Kinnickinnic River watershed. Enclosed conduits, which comprise about 34 miles of the greater Milwaukee watersheds stream system, essentially eliminate opportunities for the installation of buffers. Maps showing buffer widths along streams in the greater Milwaukee watersheds area are presented in Chapters V through IX of this report.

ACHIEVEMENT OF WATER USE OBJECTIVES, STANDARDS, AND CRITERIA

Achievement of water use objectives was assessed by comparing observed values of five water quality parameters—ammonia concentration, dissolved oxygen concentration, concentration of fecal coliform bacteria, temperature, and total phosphorus concentration—to the water quality criteria supporting the codified water use classification for the stream or stream reach being assessed. Fairly large data sets for the assessment of achievement of water use objectives were available along the mainstems of the Menomonee and Kinnickinnic Rivers and Oak Creek and from large portions of the mainstems of the Milwaukee and Root Rivers. Far fewer data were available from tributary streams. In the inventories contained in Chapters V through X of this report, 119 tributary streams were identified in the Kinnickinnic River, Menomonee River, Milwaukee River, Oak Creek, and Root River watersheds and in the Lake Michigan direct drainage area for assessing compliance with water quality standards and criteria during the baseline period.[9] Observed data were available to assess compliance with standards or criteria for all five parameters for only eight tributary streams. Data were available for assessing compliance with standards or criteria for at least one of these parameters for another 20 tributary streams. It is important to note that these numbers reflect the tributaries for which any data were available. For many tributaries, these assessments were based upon small numbers of samples. For about half the tributaries assessed, the assessment of compliance was based on 15 or fewer samples. In some cases, the assessments were based on five or fewer samples.

Major Rivers and Streams

During the study baseline period, the Kinnickinnic, Menomonee, Milwaukee, and Root Rivers and Oak Creek only partially met the water quality criteria supporting their recommended water use classifications. In almost all samples collected from the mainstems of these streams, concentrations of ammonia were in compliance with the

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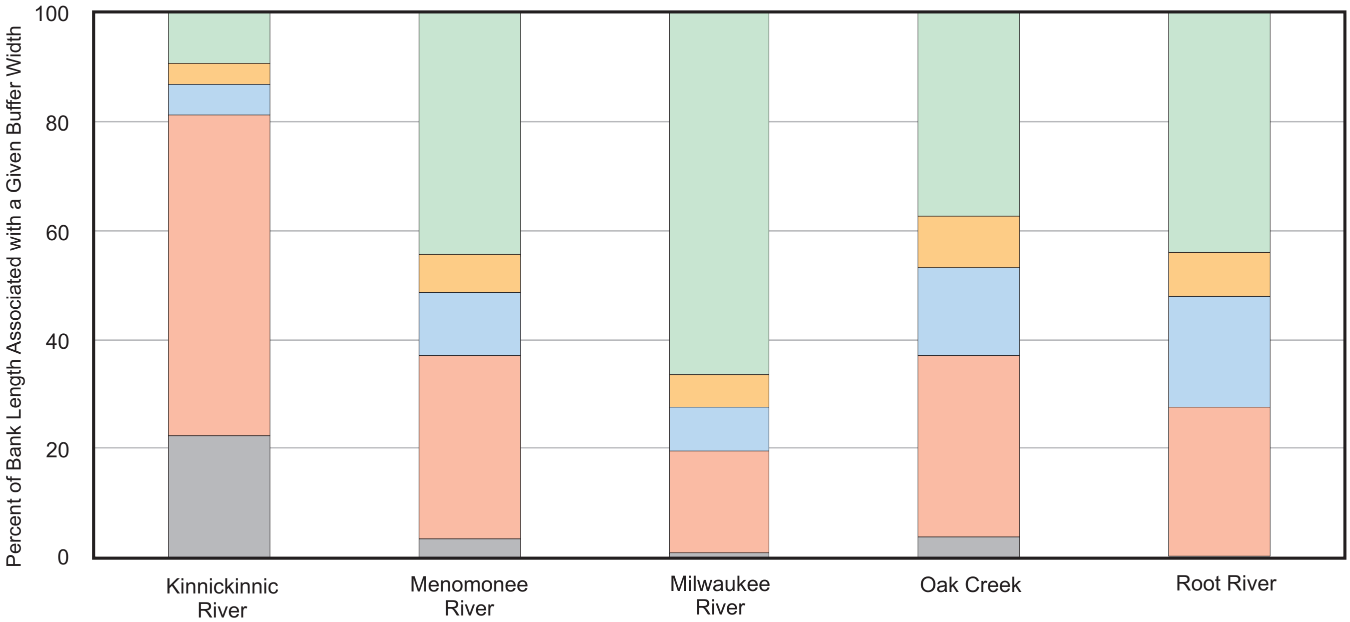
[8]*See Chapter II of this report.*

[9]*The baseline period was initially set as 1998-2001. During the course of the study, more recent data were incorporated into analyses as they became available. Thus, the baseline period used for these assessments in the Menomonee River, Kinnickinnic River, and Oak Creek watersheds was 1998-2001. Because more recent data were available when the analyses were conducted, the baseline period used for these assessments in the Milwaukee River and Root River watersheds and the Lake Michigan direct drainage area was 1998-2004.*

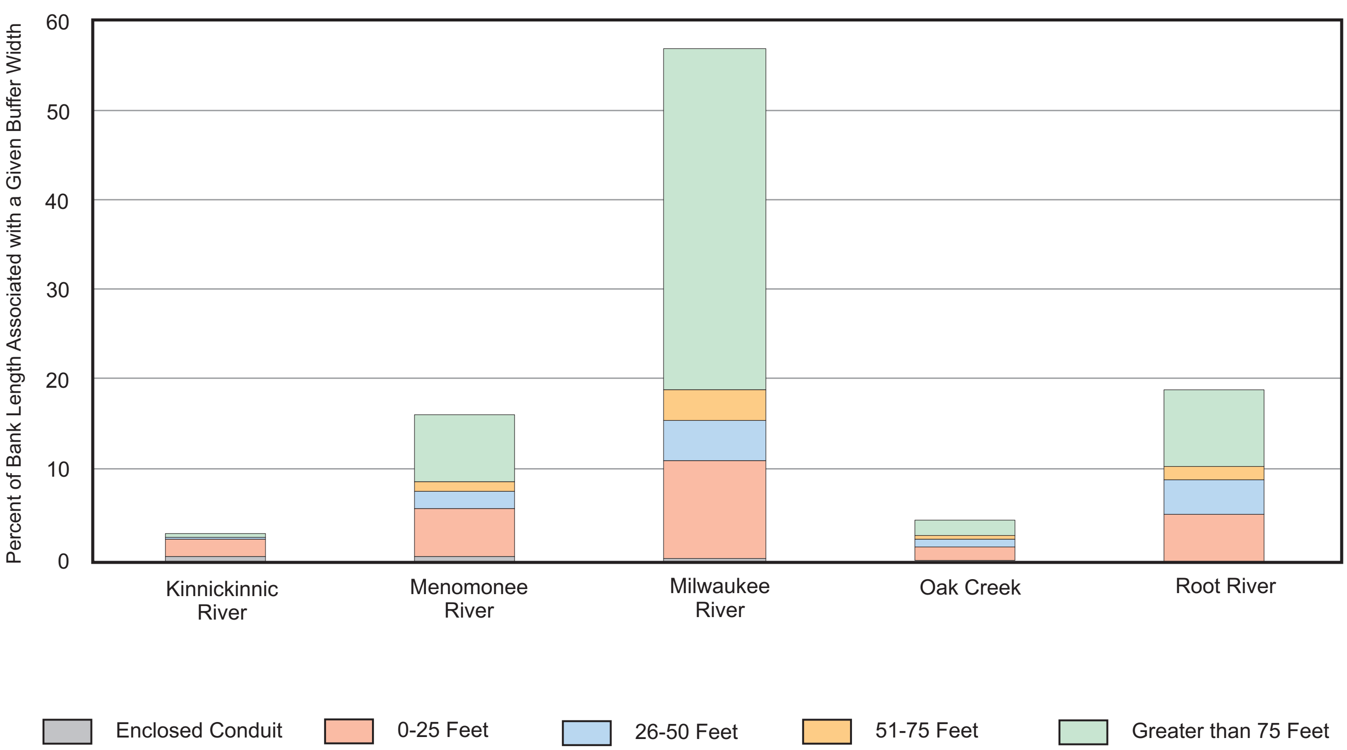
Figure 370

RIPARIAN CORRIDOR BUFFER WIDTHS IN THE GREATER MILWAUKEE WATERSHEDS: 2005

PERCENT OF BUFFER WIDTH CATEGORIES WITHIN EACH WATERSHED



PERCENT OF BUFFER WIDTH CATEGORIES WITHIN THE STUDY AREA



Source: SEWRPC.

relevant water quality standards. In almost all samples collected from the mainstems of these streams water temperatures were in compliance with the relevant water quality standard. Only in occasional samples in some reaches in the Kinnickinnic and Menomonee Rivers were temperatures above 31.7ºC.

While high levels of compliance with the applicable standards for dissolved oxygen were observed in many stream reaches, some sections of these streams showed lower compliance with dissolved oxygen standards. In the vast majority of the samples taken from the mainstem of the Kinnickinnic River, concentrations of dissolved oxygen were in compliance with the relevant water quality standards. Only in occasional samples in the reaches between S. 27th Street and S. 1st Street were dissolved oxygen concentrations below the special variance standard of 2.0 mg/l that applies to the Kinnickinnic River. In the vast majority of the samples taken from the mainstem of the Menomonee River, concentrations of dissolved oxygen were in compliance with the relevant water quality standards. In occasional samples collected in the reaches upstream from W. Hampton Avenue, dissolved oxygen concentrations were below the standard of 5.0 mg/l that applies to fish and aquatic life waters. At most stations along the mainstem of the Milwaukee River, concentrations of dissolved oxygen in all samples equaled or exceeded the applicable standard. There were three exceptions to this: concentrations of dissolved oxygen occasionally fell below 5.0 mg/l in the sections of the River above the dam at Kewaskum in Washington and Fond du Lac Counties, between Silver Spring Drive and Port Washington Road in Milwaukee County, and between Estabrook Park and the site of the North Avenue dam, also in Milwaukee County. At most stations along the mainstem of Oak Creek, dissolved oxygen concentrations were above the standard for fish and aquatic life in the majority of samples. In the upstream reaches above Ryan Road, dissolved oxygen concentrations were below the standard of 5.0 mg/l in about 43 percent of the samples. The proportion of samples from the mainstem of the Root River in which dissolved oxygen concentrations equaled or exceeded the 5.0 mg/l standard for fish and aquatic life varied considerably among stations, with compliance being lowest at the upstream stations and at the station near the mouth of the River. For example, in the upstream reaches above W. Grange Avenue, dissolved oxygen concentrations were below the standard in about 21 to 56 percent of samples, depending upon the location of the sampling station.

Lower levels of compliance were seen with the applicable standards for fecal coliform bacteria. Concentrations of fecal coliform bacteria in the Kinnickinnic River often exceeded the special variance standard of 1,000 cells per 100 ml which applies to the River. The rate of compliance with this standard increased from upstream to downstream from about 30 percent to about 77 percent of samples. Concentrations of fecal coliform bacteria in the estuary portion of the Menomonee River often exceeded the special variance standard of 1,000 cells per 100 ml which applies to the estuary. Similarly, in the vast majority of samples collected from the section of the River upstream from the estuary, the concentrations of fecal coliform bacteria exceeded the standard of 200 cells per 100 ml. The rate of compliance with this standard varied among reaches from about 24 percent to 60 percent of samples. Concentrations of fecal coliform bacteria in the estuary sections of the Milwaukee River were usually less than or equal to the special variance standard of 1,000 cells per 100 ml. While the rate of compliance varied among stations, it was generally between 65 percent and 77 percent. In the section of the Milwaukee River upstream from the estuary, concentrations of fecal coliform bacteria usually exceeded the recreational use standard of 200 cells per 100 ml. Between Pioneer Road in Cedarburg and the site of the former North Avenue dam, concentrations of fecal coliform bacteria exceeded this standard in the majority of samples. Depending upon the station, the percentage of samples in this section of the River that complied with the standard ranged between 20 percent and 55 percent. Upstream from Pioneer Road, fecal coliform bacteria concentrations equaled or were below the standard in the majority of samples at the stations at Waubeka, Newburg, and above the dam at Kewaskum, although at Newburg and Kewaskum, concentrations occasionally exceeded the standard. Concentrations of fecal coliform bacteria in the mainstem of Oak Creek usually exceeded the recreational use standard of 200 cells per ml which applies to the Creek. Compliance varied among stations with concentrations of fecal coliform bacteria meeting or being below the standard in between 15 percent and 35 percent of samples. Concentrations of fecal coliform bacteria in the mainstem of the Root River usually exceeded the recreational use standard of 200 cells per 100 ml which applies to the River. While the rate of compliance varied among stations, it was generally low.

Lower levels of compliance were also seen with the standard for total phosphorus recommended in the original regional water quality management plan. In the Kinnickinnic River, compliance with the recommended 0.1 mg/l standard increased from upstream to downstream from a low of about 30 percent to a high of about 74 percent. Compliance with the recommended total phosphorus standard also varied among reaches in the Menomonee River, with the number of samples with total phosphorus concentrations below the recommended standard ranging between about 32 percent and about 66 percent. Compliance with the recommended standard for total phosphorus was also low in the Milwaukee River with the number of samples showing total phosphorus below the 0.1 mg/l planning standard ranging from 37 percent to 79 percent along the mainstem. Low levels of compliance with the planning standard for total phosphorus were also observed in Oak Creek, with the number of samples showing total phosphorus below 0.1 mg/l ranging from 58 percent to 79 percent at stations along the mainstem of the Creek. The levels of compliance with the recommended standard for total phosphorus in the Root River were also low with the number of samples showing total phosphorus below the 0.1 mg/l standard ranging from 8 percent to 79 percent at stations along the mainstem.

Tributary Streams

As noted above, relatively few data are available for assessing whether tributary streams in the greater Milwaukee watersheds area meeting water use objectives and water quality standards.

In the Kinnickinnic River watershed, data were available to assess this for only one stream: Wilson Park Creek. Based on available data, Wilson Park Creek is only partially meeting its water use objectives. While ammonia concentrations in this stream were below the acute toxicity standard for fish and aquatic life in almost all samples, total phosphorus concentrations exceeded the recommended standard in about 30 percent of the samples.

In the Menomonee River watershed, data were available to assess achievement of water use objectives for four streams: Butler Ditch, Honey Creek, the Little Menomonee River, and Willow Creek. Based on available data, Honey Creek, the Little Menomonee River, and Willow Creek are only partially meeting their water use objectives. In all samples collected from each of these streams, ammonia concentrations were below the acute toxicity standard for fish and aquatic life, water temperatures were under the 31.7ºC standard, and dissolved oxygen concentrations were above the applicable standard. Concentrations of fecal coliform bacteria in Honey Creek generally exceeded the variance standard of 1,000 cells per 100 ml which applied to this stream. Total phosphorus concentrations in the Little Menomonee River and Willow Creek exceeded the recommended concentration in about 20 percent of the samples. Based on limited sampling, Butler Ditch appears to be meeting water use objectives and water quality standards. In all of the samples taken, dissolved oxygen concentrations and temperatures were in compliance with the applicable water quality standards.

In the Milwaukee River watershed, data were available to evaluate whether one or more standard was met for 19 out of 76 tributary streams. In 16 tributary streams temperatures in all samples were at or below the 31.7ºC fish and aquatic life standard. In one other tributary, Cedar Creek, temperatures were at or below the standard in the vast majority of samples. In the 15 tributaries for which data were available, ammonia concentrations were at or below the applicable standard in all samples. Dissolved oxygen concentrations in 11 tributaries equaled or exceeded the applicable standard in all samples, indicating compliance with the standard. In four tributaries, Lincoln Creek, the North Branch Milwaukee River, Quaas Creek, and Southbranch Creek, dissolved oxygen concentrations occasionally dropped below the standard. In only one tributary, the West Branch Milwaukee River, dissolved oxygen concentrations were frequently below the standard. Fecal coliform bacteria concentrations frequently exceeded the applicable standard in four tributaries: Indian Creek, Lincoln Creek, the North Branch Milwaukee River, and Southbranch Creek. In the North Branch Milwaukee River and Southbranch Creek, concentrations of fecal coliform bacteria were out of compliance with the standard in the majority of samples. By contrast, concentrations of fecal coliform bacteria only occasionally exceeded the applicable standard in Cedar Creek. Concentrations of fecal coliform bacteria in the East Branch Milwaukee River were at or below the applicable standard in all samples collected. Total phosphorus concentrations exceeded the 0.1 mg/l planning standard recommended in the original regional water quality management plan in most tributaries for which data were available. In three tributaries, Polk Springs Creek, Southbranch Creek, and Wallace Creek, total phosphorus concentrations exceeded the recommended planning standard in the majority of samples. In eight more tributaries, Batavia Creek, Indian Creek, Kewaskum Creek, Lincoln Creek, the North Branch Milwaukee River, Parnell Creek, Quaas Creek, and the West Branch Milwaukee River, total phosphorus concentrations frequently exceeded the recommended standard. In three more tributaries, Cedar Creek, the East Branch Milwaukee River, and Friedens Creek, total phosphorus concentrations occasionally exceeded the recommended standard. In only four tributaries, Crooked Lake Creek, Mole Creek, Pigeon Creek, and Stony Creek, were total phosphorus concentrations at or below the recommended standard in all samples.

In the Oak Creek watershed, data were available to assess whether water use objectives and water quality standards are being met for only one tributary stream: the Mitchell Field Drainage Ditch. Based on available data, this tributary is only partially meeting its water use objectives. While ammonia concentrations in this stream were below the acute toxicity standard for fish and aquatic life in all samples, total phosphorus concentrations exceeded the recommended standard in about 55 percent of the samples.

In the Root River watershed, data were available to assess whether water use objectives and water quality standards are being met for only two tributary streams: Husher Creek and the Root River Canal. Based on available data, these streams are only partially meeting their water use objectives. While ammonia concentrations in Husher Creek were below the acute toxicity standard for fish and aquatic life in all samples and dissolved oxygen concentrations and temperatures were in compliance with applicable standards in all samples, total phosphorus concentrations exceeded the recommended standard in about 67 percent of the samples. While temperatures in the Root River Canal were in compliance with the relevant standard in all samples, dissolved oxygen concentrations were below the standard for fish and aquatic life in about 23 percent of samples and concentrations of fecal coliform bacteria exceeded the recreational use standard of 200 cells per 100 ml in about 40 percent of samples. In the vast majority of samples collected from the Root River Canal, total phosphorus concentrations exceeded the standard recommended in the original regional water quality management plan.

Milwaukee Harbor Estuary, Outer Harbor, and Nearshore Lake Michigan Area

During the 1998 to 2004 extended study baseline period, the Milwaukee Harbor estuary partially met the water quality criteria supporting its recommended water use classification. In all of the samples taken from the estuary, concentrations of ammonia were in compliance with the relevant water quality standards. In almost all of the samples from the estuary, water temperatures were in compliance with the relevant water quality standards. In the majority of samples, dissolved oxygen concentrations equaled or exceeded the 2.0 mg/l special variance standard applying to the estuary. Concentrations of fecal coliform bacteria in the estuary were usually less than or equal to the variance standard of 1,000 cells per 100 ml. While the rate of compliance varied among sampling stations, it was generally between 20 percent and 77 percent. Compliance with the planning standard for total phosphorus recommended in the original regional water quality management plan was low with the number of samples showing total phosphorus below the 0.1 mg/l planning standard ranging between 37 and 75 percent in the estuary.

During the 1998 to 2004 extended study baseline period, the water quality criteria for fish and aquatic life were, for the most part, being achieved in the Milwaukee outer harbor. In all of the samples taken from the outer harbor, concentrations of ammonia and temperatures were in compliance with the fish and aquatic life standards. In almost all of the samples from the outer harbor, dissolved oxygen concentrations equaled or exceeded the 5.0 mg/l fish and aquatic life standard. Concentrations of fecal coliform bacteria in the outer harbor occasionally exceeded 200 cells per 100 ml. Concentrations of total phosphorus were usually less than or equal to the 0.1 mg/l planning standard. In the majority of samples from the outer harbor, concentrations of *E. coli* bacteria were below the standard of 235 cells per 100 ml promulgated by the U.S. Environmental Protection Agency for coastal and Great Lakes recreational waters.

Lake Michigan beaches partially met applicable water use objectives. The percentages of samples from public bathing beaches along Lake Michigan in which the concentration of *E. coli* bacteria were less than or equal to the standard of 235 cells per 100 ml promulgated by the U.S. Environmental Protection Agency for coastal and Great Lakes recreational waters varied among beaches from about 54 percent to 87 percent.

Impaired Waters
As shown on Maps 27, 46, 72, 91, 112, and 137 in Chapters V, VI, VII, VIII, IX, and X, respectively, of this report, a number of sections of streams and other waterbodies in the greater Milwaukee watersheds are listed as impaired pursuant to Section 303(d) of the Clean Water Act. The Milwaukee Harbor estuary and outer harbor are listed as impaired. Reaches of the mainstems of the Kinnickinnic, Menomonee, and Milwaukee Rivers upstream from the estuary are listed as impaired. Some sections of the mainstem of the Root River and the entire mainstem of Oak Creek are listed as impaired. Eleven tributary streams, including one in the Menomonee River watershed, eight in the Milwaukee River watershed, and two in the Root River watershed are listed as impaired. Three lakes and one pond in the Milwaukee River watershed, as well as one pond in the Kinnickinnic River watershed are listed as impaired. Four Lake Michigan public beaches are listed as impaired. The causes of these impairments vary among the waterbodies. They include aquatic toxicity, high concentrations of bacteria, low concentrations of dissolved oxygen, degraded habitat, high temperatures, and fish consumption advisories necessitated by high concentrations of PCBs or mercury in the tissues of fish collected in the waterbodies.

SOURCES OF WATER POLLUTION

The greater Milwaukee watersheds contain several potential sources of surface water pollution. These sources fall into two broad categories: point sources and nonpoint sources.

Point Sources
Fourteen public and three private sewage treatment plants currently discharge into streams of the greater Milwaukee watersheds. In addition, three public sewage treatment plants discharge into Lake Michigan, either directly into the Lake or indirectly into the Lake through the Milwaukee outer harbor. MMSD has 121 combined sewer outfalls that discharge to the streams of the greater Milwaukee watersheds or to Lake Michigan. These outfalls convey a combination of stormwater runoff and sanitary sewage from the combined sewer system to the surface water system as a result of high water volume from stormwater, meltwater, and infiltration and inflow of clear water during wet weather conditions. Prior to 1994, overflows from these sites typically occurred around 50 times per year. Since MMSD's Inline Storage System came online in 1994, the number of combined sewer overflows per year has declined to less than three. Since 1995, separate sanitary sewer overflows (SSOs) have been reported at 133 locations: 28 within MMSD's SSO area and 105 in local communities. The number of SSO events occurring per year has also declined compared to the time prior to completion of the MMSD Water Pollution Abatement Program facilities in 1994. As of February 2003, 398 industrial dischargers and other point sources were permitted through the WPDES program to discharge wastewater to streams in the greater Milwaukee watersheds. About two-fifths of the permitted facilities discharged noncontact cooling water. The remaining discharges are of a nature which typically meets or exceeds the Wisconsin Pollutant Discharge Elimination System permit levels which are designed to meet water quality standards.

Nonpoint Sources
The greater Milwaukee watersheds are comprised of combinations of urban and rural land uses. As of 2000, about 67 percent of the area in the greater Milwaukee watersheds was in rural or other open land uses. About 39 percent of the study area is contained within planned sewer service areas: about 22 percent of the study area is within planned sewer service areas in the Southeastern Wisconsin Region which have been refined, about 16 percent within planned sewer service areas in the Southeastern Wisconsin Region which have not been refined, and about 1 percent within planned sewer service areas in counties outside the Region. As of 2000, 190,664 acres of the watersheds were served by sanitary sewer systems. In addition, there were about 25,242 acres of urban-density enclaves that were not served by public sanitary sewer systems. About 17,354 acres of these enclaves are in areas served by onsite sewage disposal systems that were developed prior to 1980. These older systems may be at particular risk of malfunctioning.

As described in Chapters V through X of this report, 68 cities, villages, and towns in the study area have adopted stormwater management ordinances and/or plans or are covered under stormwater ordinances enacted by their County. Similarly, 76 cities, villages, and towns in the study area have adopted erosion control ordinances or are covered under erosion control ordinances enacted by their County. In addition, 34 communities comprising about 42 percent of the area of the greater Milwaukee watersheds have been issued or will be issued WPDES stormwater discharge permits and 18 communities have established stormwater utilities, general funds, or stormwater fee programs. Facilities engaged in certain types of industrial activities are required to apply for and obtain a stormwater discharge permit under the WPDES program. As of February 2003, 677 industrial stormwater discharge permits were in effect in the greater Milwaukee watersheds.

As of 2005, there were six active sanitary landfills in the greater Milwaukee watersheds, two located in the Milwaukee River watershed, and one each located in the Menomonee River, Oak Creek, and Root River watersheds and the Lake Michigan direct drainage area. There are also 78 inactive solid waste disposal sites in the greater Milwaukee watersheds. While they are spread throughout the area, the majority are located in the Milwaukee River watershed.

Quantification of Pollutant Loads

The annual average load of biochemical oxygen demand (BOD) to streams of the greater Milwaukee watersheds and directly to Lake Michigan is estimated to be 18,337,410 pounds. Nonpoint sources and sewage treatment plants contribute about 55 percent and 43 percent of this load, respectively. Industrial dischargers contribute about 2 percent of this load. The rest of the BOD load to the streams of the greater Milwaukee watersheds and Lake Michigan, less than 1 percent, is contributed by separate sanitary sewer overflows and combined sewer overflows. The annual average load of BOD to streams of the greater Milwaukee watersheds only is estimated to be 10,555,440 pounds per year. Nonpoint sources contribute about 91 percent of this load. Industrial dischargers and sewage treatment plants each contribute about 4 percent of this load. The rest of the BOD load to the streams of the greater Milwaukee watersheds, about 1 percent, is contributed by combined sewer overflows and separate sanitary sewer overflows.

The annual average load of total suspended solids (TSS) to streams of the greater Milwaukee watersheds and directly to Lake Michigan is estimated to be 184,435,700 pounds per year. Nonpoint sources and sewage treatment plants contribute 96 percent and 4 percent of this load, respectively. The rest of the TSS load to streams of the greater Milwaukee watersheds and directly to Lake Michigan, less than 1 percent, is contributed by combined sewer overflows, industrial dischargers, and sanitary sewer overflows. The average annual load of TSS to streams of the greater Milwaukee watersheds only is estimated to be 170,722,650 pounds per year. Nonpoint sources contribute about 99 percent of this load. The rest of the TSS load to the streams of the greater Milwaukee watersheds, about 1 percent, is contributed by industrial dischargers, combined sewer overflows, sewage treatment plants, and sanitary sewer overflows.

The annual average load of total nitrogen to streams of the greater Milwaukee watersheds and directly to Lake Michigan is estimated to be 12,280,230 pounds per year. Sewage treatment plants and nonpoint sources contribute about 68 percent and 30 percent of this load, respectively. The rest of the total nitrogen load to streams of the greater Milwaukee watersheds and Lake Michigan, less than 2 percent, is contributed by combined sewer overflows, industrial dischargers, and sanitary sewer overflows. The annual average load of total nitrogen to streams of the greater Milwaukee watersheds only is estimated to be 3,891,760 pounds per year. Nonpoint sources contribute about 92 percent of this load. Sewage treatment plants and industrial dischargers each contribute just under 4 percent of this load. The rest of the total nitrogen load to the streams of the greater Milwaukee watersheds, about 1 percent, is contributed by combined sewer overflows and sanitary sewer overflows.

The annual average load of fecal coliform bacteria to streams of the greater Milwaukee watersheds and directly to Lake Michigan is estimated to be 83,435.07 trillion cells per year. Nonpoint sources and combined sewer overflows contribute about 90 percent and 5 percent of this load, respectively. Sewage treatment plants and sanitary sewer overflows each contribute about 2.5 percent of this load. The rest of the fecal coliform bacteria load to the streams of the greater Milwaukee watersheds and Lake Michigan, much less than 1 percent, is contributed by industrial dischargers. The annual average load of fecal coliform bacteria to streams of the greater Milwaukee watersheds only is estimated to be 77,163.44 trillion cells per year. Nonpoint sources contribute about

92 percent of this load. Combined sewer overflows and sanitary sewer overflows contribute 5 percent and 3 percent, respectively, of this load. The rest of the fecal coliform bacteria load to the streams of the greater Milwaukee watersheds, much less than 1 percent, is contributed by sewage treatment plants and industrial dischargers.

The annual average load of total phosphorus to streams of the greater Milwaukee watersheds and to Lake Michigan is estimated to be 767,230 pounds per year. Sewage treatment plants and nonpoint sources contribute about 48 percent and 36 percent of this load, respectively. Industrial dischargers contribute about 15 percent of this load. The rest of the total phosphorus load to streams of the greater Milwaukee watersheds and Lake Michigan, less than 1 percent, is contributed by combined sewer overflows and sanitary sewer overflows. The annual average load of total phosphorus to the streams of the greater Milwaukee watersheds only is estimated to be 435,060 pounds per year. Nonpoint sources contribute about 60 percent of this load. Industrial dischargers and sewage treatment plants contribute about 26 percent and 13 percent, respectively, of this load. The rest of the total phosphorus load to the streams of the greater Milwaukee watersheds, slightly more than 1 percent, is contributed by combined sewer overflows and sanitary sewer overflows.

CONCLUSIONS

The conclusions from the water quality inventory for the greater Milwaukee watersheds have been presented by answering seven basic questions. This report provides the information needed to answer these questions. The information is presented below.

How Have Water Quality Conditions Changed Since 1975?

Water quality conditions in the greater Milwaukee watersheds have both improved in some respects and declined in other respects since 1975.

Improvements in Water Quality

Concentrations of several pollutants associated with combined sewer overflows, such as BOD, fecal coliform bacteria, and ammonia, have decreased in much of the Kinnickinnic, Menomonee, and Milwaukee Rivers and in much of the Milwaukee Harbor Estuary. In addition, total phosphorus concentrations in much of the estuary have also decreased. These reductions in nutrients and oxygen-demanding wastes have produced some improvements, such as higher dissolved oxygen concentrations and lower chlorophyll-*a* concentrations in the estuary. One important, though not the only, factor responsible for these decreases is the reduction in combined and separate sanitary sewer overflows resulting from construction and operation of MMSD’s Inline Storage System. These improvements also likely reflect changes in the types of industries present in the watersheds, the connection of most process wastewaters to the MMSD sewerage system, and implementation of treatment requirements for all industrial discharges. Concentrations of ammonia and BOD in Oak Creek and portions of the Root River have also decreased. Decreases in the concentrations of some pollutants have also been detected in the outer harbor and nearshore area. These include decreases in concentrations of ammonia, BOD, fecal coliform bacteria, total nitrogen, and total phosphorus in the outer harbor and decreases in ammonia and total nitrogen in the nearshore area. These reductions in pollutant concentrations have resulted in some improvements in chlorophyll-*a* concentrations and Secchi depths at some stations in the outer harbor and nearshore area. Improvements have also occurred in the concentrations of several toxic metals. The improvements in toxic metal concentrations likely reflect changes in the types of industry present in the watersheds, the connection of most process wastewaters to the sanitary sewerage systems, the implementation of treatment requirements for all industrial dischargers, and the phasing out of the use of lead as an additive to gasoline.

No Changes or Reductions in Water Quality

Concentrations of suspended and dissolved pollutants typically associated with stormwater runoff and other nonpoint source pollution, such as chloride, copper, total suspended solids, and zinc have remained unchanged or increased at sampling stations along the major streams and rivers of the greater Milwaukee watersheds. In addition, specific conductance has increased in several stream reaches, suggesting that the total concentration of dissolved material in the water has increased. In other reaches, the concentration of dissolved material, as indicated by specific conductance, has remained unchanged. At some locations, concentrations of fecal coliform bacteria have increased. Water temperatures at most stations in the estuary and some stations in the outer harbor have increased, especially during the summer.

How Have Toxicity Conditions Changed Since 1975?

In some respects, toxicity conditions in the greater Milwaukee watersheds have improved since 1975; in other respects, the have declined or not changed.

Improvements in Toxicity Conditions

There have been several improvements in toxicity conditions since 1975. Concentrations of some toxic metals in water have decreased at many sampling locations. Concentrations of PAHs in water have decreased in the portions of Kinnickinnic and Menomonee Rivers upstream from the estuary. Concentrations of PCBs in the tissue of fish appear to have decreased; however, fish consumption advisories remain in effect for PCB contamination in Lake Michigan and much of the greater Milwaukee watersheds. Concentrations of PCBs in water have decreased at two sampling stations along Cedar Creek. Concentrations of some pesticides in fish tissue have decreased. Remediation of sediment contaminated with PAHs in the Little Menomonee River and with PCBs in Ruck Pond and the former Hamilton Pond along Cedar Creek should reduce toxic effects related to toxic sediment. Other remediation efforts for toxic sediment are ongoing or in planning stages. While this does not constitute a change, concentrations of mercury in the tissue of fish collected from the Kinnickinnic and Menomonee Rivers remain low.

Worsened Toxicity Conditions

Other toxicity conditions have worsened in the greater Milwaukee watersheds. Concentrations of copper and zinc in water are increasing. Concentrations of the pesticide atrazine and its metabolites have increased at several locations. Concentrations of PAHS in water have increased in the estuary portions of the Kinnickinnic and Menomonee Rivers.

Inconclusive Toxicity Data

In some cases, the data are not adequate to assess changes. Various pesticides have been detected in water in the greater Milwaukee watersheds, but different compounds were screened for in recent samplings than in historical samplings. Changes in methodology and the number of compounds screened for make it difficult to compare concentrations in some recent samplings of PCBs and PAHs in water to concentrations in earlier samplings. In some locations, no recent data are available on tissue concentrations of some bioaccumulative contaminants. At other locations, concentrations of mercury and PCBs in tissue of aquatic organisms appear to have decreased since 1975, but the fact that different species were assessed in different years makes it unclear whether these trends represent actual reductions or interspecies differences.

Sediment Conditions

Sediment quality, as measured by mean PEC-Q, remains poor. At several locations, sediment contains concentrations of PCBs, PAHs, pesticides, or heavy metals high enough to pose substantial risks to benthic organisms. At other locations concentrations of contaminants are high enough to be likely to produce toxic effects in benthic organisms. As a result of recent remediation efforts, sediment contaminated with PCBs has been removed from Ruck Pond and the banks of the former Hamilton Pond along Cedar Creek and sediment contaminated with PAHs has been removed from the Little Menomonee River. This should reduce toxicity in these locations. Deposits of contaminated sediment are still present at a number of locations, including Cedar Creek below the Ruck dam, Zeunert pond in Cedarburg, Thiensville millpond and Estabrook impoundment along the mainstem of the Milwaukee River, Lincoln Creek, the Milwaukee Harbor estuary, and the Milwaukee outer harbor. Remediation efforts for some of these are ongoing or in planning stages.

What is the Current Condition of the Fishery?

The Kinnickinnic River, Oak Creek, and Root River watersheds appear to have very poor fisheries and macroinvertebrate communities at present. The fish communities contain relatively few species of fishes, are trophically unbalanced, contain few or no top carnivores, and are dominated by tolerant fishes. The macroinvertebrate communities are equally depauperate and dominated by tolerant taxa. Since water quality has generally been improving in these watersheds for some constituents, habitat seems to potentially be the most important factor limiting both the fishery and macroinvertebrate communities.

In general, the Milwaukee River watershed contains a poor to fair quality fishery; however, some areas within the watershed contain higher quality fisheries. These higher quality areas are mostly located within six of the 20 subwatersheds, those being the Upper Milwaukee River, West Branch Milwaukee River, East Branch Milwaukee River, Middle Milwaukee River, Upper Lower Milwaukee River, and Lower Milwaukee River watersheds. Within those subwatersheds, areas of good to excellent fishery conditions have been identified. On a watershed basis, the fish community contains a high abundance of both warmwater and coldwater species of fishes, seems trophically balanced in the highest quality areas, contains a good percentage of top carnivores (except for those species stocked), and is not dominated by tolerant fishes. The quality of the macroinvertebrate community has improved substantially since 1993 and is generally indicative of fair to very good water quality. Since water quality has generally been improving in the watershed and habitat seems to be adequate, it is likely that some other factor, such as periodic stormwater loads, is limiting the fish community.

Except for some areas within the Upper Milwaukee River, West Branch of the Milwaukee River, East Branch of the Milwaukee River, Middle Milwaukee River, Upper Lower Milwaukee River, and Lower Milwaukee River subwatersheds that contain good and in some cases excellent fishery quality, the Milwaukee River watershed in general contains a poor to fair fishery. The fish community contains a high abundance of both warmwater and coldwater species of fishes, seems trophically balanced in the highest quality areas, contains a good percentage of top carnivores (except for those species stocked), and is not dominated by tolerant fishes. Macroinvertebrate communities are classified as good-very good at present. The macroinvertebrate community is also generally trophically balanced and not dominated by tolerant taxa. Overall, the fish and macroinvertebrate communities in the Milwaukee River watershed are of a better quality than those communities in the other watersheds in the study area.

To What Extent Are Water Use Objectives and Water Quality Standards Being Met?

Major Rivers and Streams

During the study baseline period, the major streams and rivers of the greater Milwaukee watersheds only partially met the water quality criteria supporting their water use objectives. High levels of compliance were attained with the acute toxicity standards for fish and aquatic life for ammonia in all of the major streams and rivers of the study area. Although water temperatures in some reaches in the Kinnickinnic and Menomonee Rivers occasionally exceeded the standard for fish and aquatic life, high levels of compliance were also attained with the applicable standard for water temperature in all of the major streams and rivers of the study area. Lower levels of compliance with the applicable standards for dissolved oxygen, fecal coliform bacteria, and total phosphorus were attained by these streams. While many reaches of the major streams and rivers of the study area achieved high levels of compliance with the applicable standards for dissolved oxygen concentration, other reaches occasionally to frequently experienced dissolved oxygen concentrations that were below the standard supporting the reaches' water use classifications. Stream reaches in which this occurred include reaches in the upstream areas of the Menomonee and Root Rivers and Oak Creek, reaches in the central section of the Kinnickinnic River, reaches near the mouth of the Root River, and reaches in several locations along the Milwaukee River. Concentrations of fecal coliform bacteria commonly exceeded applicable standards at sampling stations along the Kinnickinnic, Menomonee, Milwaukee, and Root Rivers, indicating frequent violations of the standards. Concentrations of fecal coliform bacteria generally exceeded the full recreational use standard at sampling stations along Oak Creek, indicating general violation of the standard. Concentrations of total phosphorus at sampling stations along the mainstems of the Kinnickinnic, Menomonee, Milwaukee, and Root Rivers and Oak Creek commonly exceeded the concentration recommended in the original regional water quality management plan.

Tributary Streams

Relatively few data are available for assessing whether tributary streams in the greater Milwaukee watersheds area meeting water use objectives and water quality standards. Out of 119 tributary streams identified in the study area for assessing compliance with water quality standards and criteria, data were available to assess compliance with standards or criteria for all five of the parameters examined for only eight tributary streams. Data were available for assessing compliance with standards or criteria for at least one of these parameters for another 20 tributary streams. In addition, for many of these tributaries, only small numbers of samples were available upon which to base these assessments.

As a group, the tributary streams of the greater Milwaukee watersheds for which data were available only partially met the water quality criteria supporting their water use objectives during the study baseline period. In all samples from the 23 tributary streams for which data were available, concentrations of ammonia were at or below the acute toxicity standard for fish and aquatic life, indicating compliance with the standard. Similarly, with the exception of a single sample, water temperatures sampled in 25 tributary streams were always at or below the applicable standard, indicating compliance with the standard. Lower levels of compliance with the applicable standards for dissolved oxygen, fecal coliform bacteria, and total phosphorus were attained by some of the tributary streams which were assessed. While concentrations of dissolved oxygen were at or above the relevant standards in the vast majority of samples collected from 15 tributary streams, dissolved oxygen concentrations were occasionally below the relevant standards in four streams and commonly to frequently below the relevant standards in six streams. Concentrations of fecal coliform bacteria were generally below the full recreational use standard in two tributary streams, indicating substantial compliance with the standard in these streams. In nine other tributary streams, concentrations of fecal coliform bacteria commonly exceeded the relevant standard, indicating frequent violation of the standard. Concentrations of total phosphorus in four tributary streams were at or below the level recommended in the original regional water quality management plan. Total phosphorus concentrations in four tributary streams occasionally exceeded the recommended concentration. In another 20 tributary streams, total phosphorus concentrations commonly exceeded the recommended concentration.

Milwaukee Harbor Estuary, Outer Harbor, and Nearshore Lake Michigan Area

During the study baseline period, the Milwaukee Harbor estuary partially met the water quality criteria supporting its recommended water use classification. Concentrations of ammonia in all of the samples taken from the estuary and water temperatures in almost all of the samples from the estuary were in compliance with the relevant water quality standards. In the majority of samples, dissolved oxygen concentrations equaled or exceeded the 2.0 mg/l special variance standard applying to the estuary. While exceedances occurred, concentrations of fecal coliform bacteria in the estuary were usually less than or equal to the variance standard of 1,000 cells per 100 ml. Compliance with the planning standard for total phosphorus recommended in the original regional water quality management plan was low.

During the study baseline period, the water quality criteria for fish and aquatic life were, for the most part, being achieved in the Milwaukee outer harbor. Concentrations of fecal coliform bacteria in the outer harbor occasionally exceeded 200 cells per 100 ml. In the majority of samples from the outer harbor, concentrations of *E. coli* bacteria were below the standard of 235 cells per 100 ml promulgated by the U.S. Environmental Protection Agency for coastal and Great Lakes recreational waters.

Lake Michigan beaches partially met applicable water use objectives. The percentages of samples from public bathing beaches along Lake Michigan in which the concentration of *E. coli* bacteria were less than or equal to the standard of 235 cells per 100 ml promulgated by the U.S. Environmental Protection Agency for coastal and Great Lakes recreational waters varied among beaches from about 54 percent to 87 percent.

Impaired Waters

A number of sections of streams and other waterbodies in the greater Milwaukee watersheds are listed as impaired pursuant to Section 303(d) of the Clean Water Act. The Milwaukee Harbor estuary and outer harbor are listed as impaired. Reaches of the mainstems of the Kinnickinnic, Menomonee, and Milwaukee Rivers upstream from the estuary are listed as impaired. Some sections of the mainstem of the Root River and the entire mainstem of Oak Creek are listed as impaired. Eleven tributary streams are listed as impaired. Three lakes and two ponds are listed as impaired. Four Lake Michigan public beaches are listed as impaired. The causes of these impairments vary among the waterbodies. They include aquatic toxicity, high concentrations of bacteria, low concentrations of dissolved oxygen, degraded habitat, high temperatures, and fish consumption advisories necessitated by high concentrations of PCBs or mercury in the tissues of fish collected in the waterbodies.

What Are the Sources of Surface Water Pollution?

There are currently 17 public and three private sewage treatment plants discharging to streams of the greater Milwaukee watersheds or to Lake Michigan. Other point sources include 121 combined sewer outfalls, 133 sanitary sewer overflow sites, and 398 industrial dischargers. About 39 percent of the study area is within planned sanitary sewer service areas and nearly 191,000 acres are served by sanitary sewers. The study area also contains about 25,242 acres of urban-density enclaves that are not served by public sanitary sewer systems. About 17,354 acres of these enclaves are in areas served by onsite sewage disposal systems that were developed prior to 1980 and which may be at particular risk for malfunctioning.

How Have the Sources of Water Pollution Changed Since 1975?

Since 1975, the numbers and types of point sources present in the greater Milwaukee watersheds have changed. In 1975, there were 26 public sewage treatment facilities in the study area discharging treated wastewater to streams, groundwater, and Lake Michigan. By 2003, this number had decreased to 17. In 1975, 15 private sewage treatment plants discharged to streams, groundwater, and Lake Michigan in the study area. By 2003, this number had decreased to three. In 1975, there were 121 combined sewer outfalls and 352 known separate sewer overflow relief devices located in the greater Milwaukee watersheds. In 2003, there were 121 combined sewer outfalls. Between 1995 and 2002 separate sanitary sewer overflows were reported at 133 locations. In 1975, overflows typically occurred over 50 times per year. Currently, combined sewer overflows have been reduced to less than three per year on average. Likewise, the number of sanitary sewer overflows has been markedly reduced from the 1975 condition. In 1975, there were 190 point sources of wastewater other than public and private sewage treatment plants that discharged industrial cooling, process, and wash waters directly, or indirectly, to the surface water system. In 2003, there were 400 of these point sources.

Figure 371 shows how the relative contributions of four pollutants by six pollution sources to the greater Milwaukee watersheds changed between 1975 and 2000. The graphs show comparisons of the percentages of total pollutant load contributed by various classes of sources. These percentages reflect estimates of point and nonpoint source loads delivered to the modeled stream reaches, after accounting for any trapping factors that would retain pollutants on the surface of the land. These include loads from groundwater. It is important to note that the stream channel pollutant loads may be expected to be different from the actual transport from the watershed, because physical, chemical, and biological processes may retain or remove pollutants or change their form during transport over the land surface or within the stream system. Two cautions must be kept in mind when interpreting these graphs. First, the breakdowns between 1975 and 2000 were estimated using different water quality models and modeling procedures. The assumptions underlying these models are somewhat different and categorization of nonpoint source loads as rural or urban may have been based on somewhat different criteria. Because of this, the estimates are not strictly comparable and comparisons based on them should be considered to be approximate. Second, between 1975 and 2000, pollutant loadings to streams in these watersheds decreased over time. Depending on the pollutant, total 1975 loads of these four pollutants, as estimated by the model developed for the 1979 regional water quality management plan, were 1.7 to 4.4 times the total 2000 loads, as estimated by the model. One consequence of this is that an increase in the relative contribution from a source to the total load does not necessarily represent an absolute increase in load from the source.

Keeping these caveats in mind, three differences are apparent between the relative contributions of these sources in 1975 and 2000.

First, the fraction of total pollutant contributions represented by combined sewer overflows has decreased dramatically. The most dramatic example of this change occurred for fecal coliform bacteria in the Kinnickinnic River watershed. Combined sewer overflows were estimated to account for 97 percent of contributions of fecal coliform bacteria to streams in this watershed in 1975. They were estimated to account for 5 percent of

Figure 371

CHANGES IN POLLUTANT LOADINGS IN THE GREATER MILWAUKEE WATERSHEDS: 1975-2000

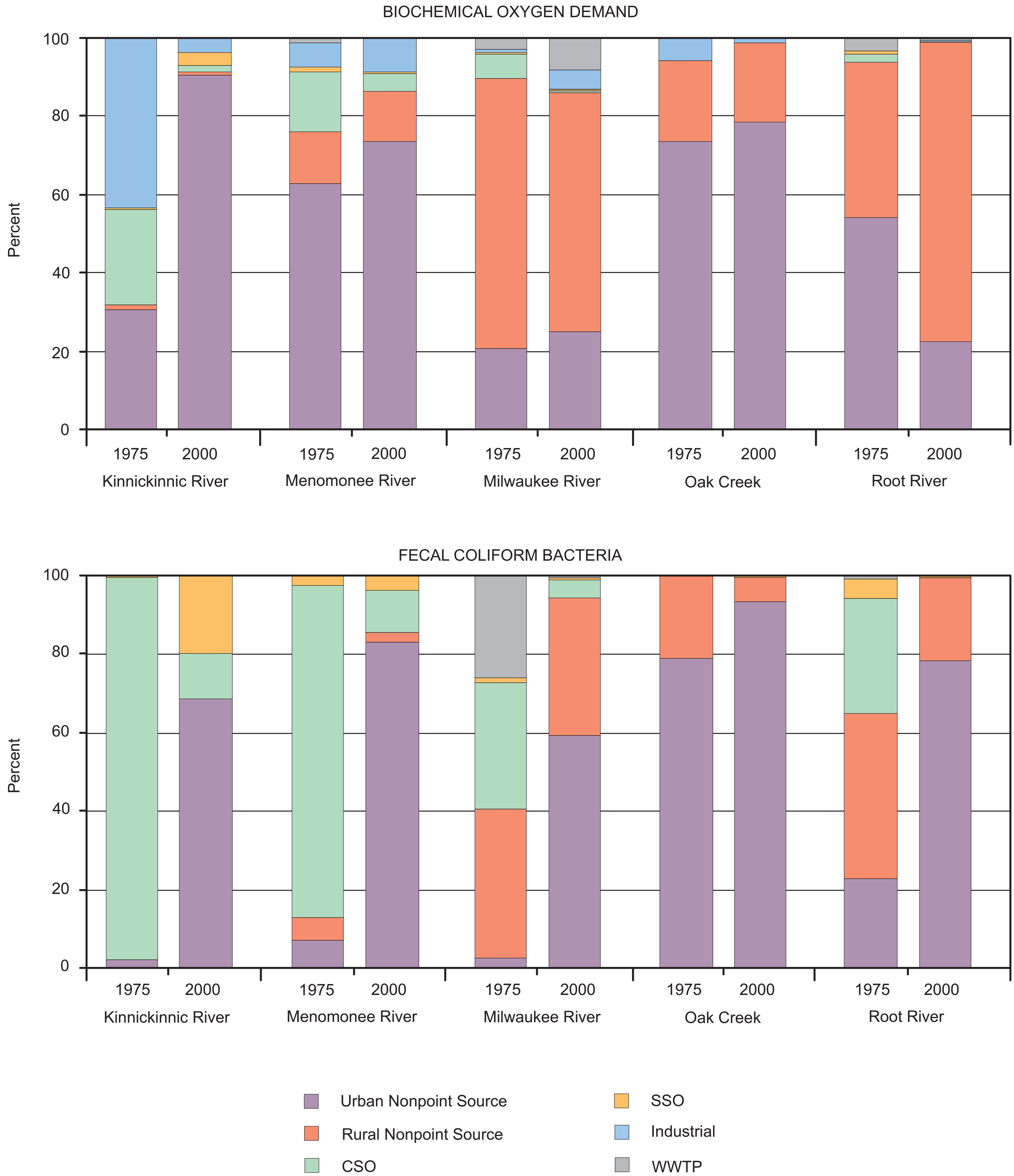
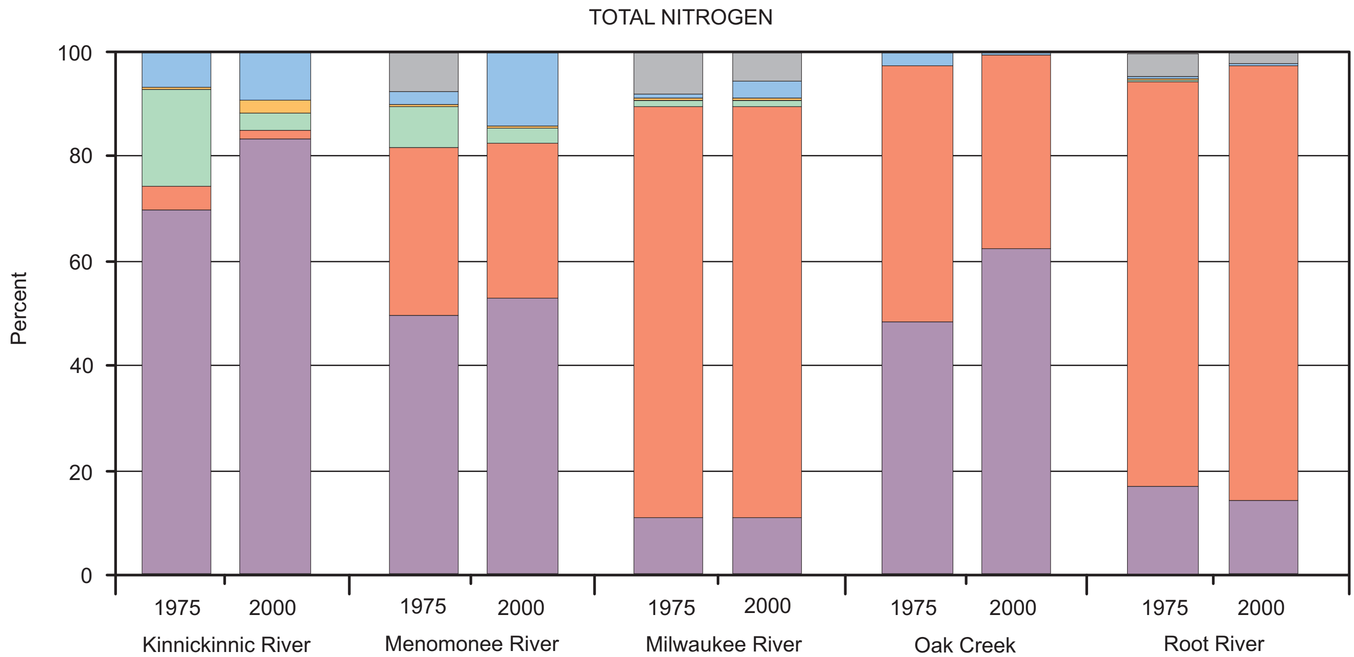
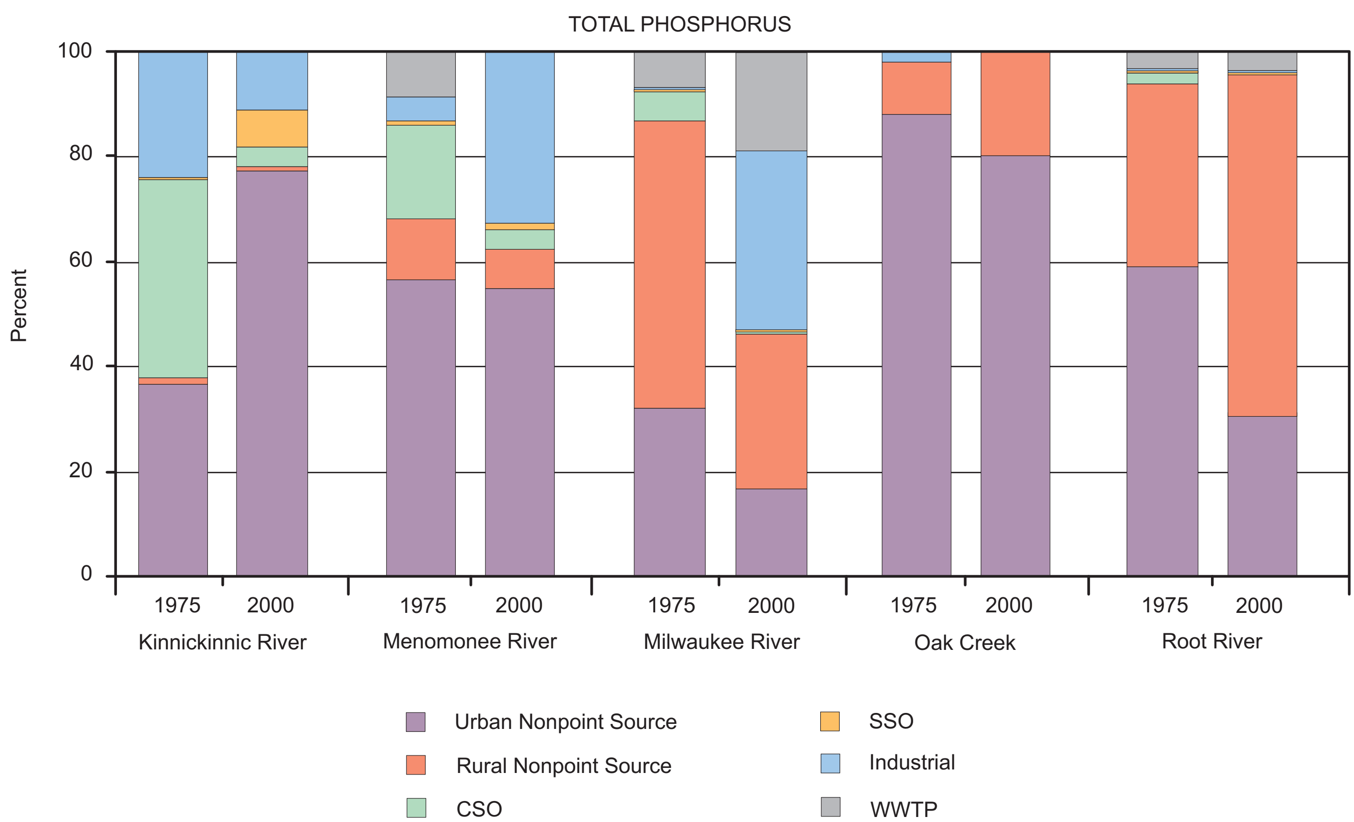


Figure 371 (continued)





Source: SEWRPC.

contributions of fecal coliform bacteria in 2000. While the magnitudes of the changes are generally not this large, the fraction of total pollutant contributions represented by combined sewer overflows decreased in all the watersheds in which combined sewer overflows were occurring in 1975. While several factors may account for this change, two deserve special mention. For the Kinnickinnic River, Menomonee River, and Milwaukee River watersheds, completion of MMSD's Water Pollution Abatement Program, including construction of the Inline Storage System, resulted in a reduction in the frequency of combined sewer overflows in the combined sewer area in the City of Milwaukee and the Village of Shorewood from over 50 per year before the Inline Storage System came online to less than three per year on average after the Inline Storage System came online. For the Root River watershed, separation of the remaining combined sewers in the City of Racine during the 1980s eliminated combined sewer overflows.

Second, for most pollutants in most watersheds the fraction of contributions accounted for by nonpoint sources has increased. For all four pollutants shown in Figure 371, in 2000, nonpoint source pollution sources constituted the major sources of pollutant loads in all of these watersheds, except the Milwaukee River watershed, where point sources contribute about 64 percent of the total phosphorus. In the Kinnickinnic River, Menomonee River, and Oak Creek watersheds, the fractions of total contributions accounted for by urban nonpoint sources have generally increased and currently tend to predominate. Total phosphorus breakdowns in the Menomonee River and Oak Creek watersheds are exceptions to this generalization. While the fractions of total contributions accounted for by urban nonpoint sources decreased in these watersheds between 1975 and 2000, urban nonpoint sources still represent the dominant source of phosphorus. In the Milwaukee River, 1) the urban and rural nonpoint source fractions of biochemical oxygen demand and total nitrogen did not change greatly between 1975 and 2000; 2) the fecal coliform load fraction contributed by urban nonpoint sources increased significantly from 1975 to 2000, but the rural fraction was similar in each of those years; and 3) the phosphorus load fraction from industrial sources increased substantially and the fraction from sewage treatment plants increased somewhat, while the fractions from urban and rural nonpoint sources both decreased. In the Root River watershed, for all the pollutants shown except fecal coliform bacteria, the fractions of total contributions accounted for by rural nonpoint sources have apparently increased and currently tend to predominate.

Third, for most watersheds, the fraction of contributions from industrial dischargers decreased or did not change much. In the Menomonee River watershed, the fraction of contributions of total nitrogen and total phosphorus increased. These increases are due to absolute increases in the loadings of these nutrients and may reflect the fact that between 1975 and 2003 the number of permitted industrial dischargers increased from 48 to 150. This increase represents about one half of the increase in the number of industrial dischargers in the greater Milwaukee watersheds since 1975.

What Are the Potential Sources of Groundwater Pollution?

Assessments of the groundwater contamination potential of shallow aquifers within the portions of the greater Milwaukee watersheds located in the Southeastern Wisconsin Region indicate that areas most vulnerable to contamination constitute about 36 percent of the study area within the Region and are located primarily in inland areas and major river valleys (see Map 147 in Chapter XI of this report). Areas with low contamination potential cover about 45 percent of the study area within the Region and can be found in eastern Ozaukee County, eastern Racine County, and the majority of Milwaukee County. The remaining 19 percent of the study area within the Region has moderate contamination potential.

The vulnerability of deeper aquifers to contamination is more difficult to assess. Several barriers to contamination from the surface can serve to protect the integrity of deeper groundwater in portions of the study area. These include the soil layer, the unlithified geologic conditions, the presence of relatively impermeable geologic strata, and upward groundwater flow in groundwater discharge areas. The degree of protection that these factors provide may be compromised by both natural factors, such as faulting in the deep bedrock, and anthropogenic factors, such as the presence of improperly abandoned wells and downward gradients in groundwater movement induced by pumping from deeper aquifers.

Most types of facilities or structures and many human activities have the potential to contribute to groundwater quality problems. These include onsite sewage disposal systems, solid waste disposal sites, leaking underground storage tanks, land application of liquid wastes, major livestock operations, salvage yards, hazardous material spills, and bulk storage of agricultural chemicals, fuels, and salt. Proper design and operation can reduce the risks of groundwater contamination associated with some of these activities.