

Chapter I

INTRODUCTION

BACKGROUND

This report documents inventory data and associated analyses of water quality 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 the design year 2020 and represents a major amendment to the regional water quality management plan for Southeastern Wisconsin.^{2,3}

This report documents inventories and analyses conducted as part of the regional water quality management plan update effort. The regional water quality management plan update is designed largely to meet Wisconsin Department of Natural Resources (WDNR) needs in developing watershed-based, total maximum daily pollution loading, and possibly water quality standard use attainability analyses and reports consistent with the policies of the WDNR and U.S. Environmental Protection Agency (USEPA).

This report is intended to serve as a planning tool and, in addition to being a component of the regional water quality management plan update, it forms part of the cooperative and coordinated efforts by the Milwaukee Metropolitan Sewerage District (MMSD) and the Southeastern Wisconsin Regional Planning Commission (SEWRPC) in MMSD’s 2020 facilities planning effort. The approach to carrying out the MMSD facilities planning program and the regional water quality management plan update program has been developed cooperatively by the WDNR, the MMSD (including its facilities plan consultant team), and the SEWRPC and has

¹The term “greater Milwaukee watersheds” is defined for 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.

²SEWRPC 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.

³SEWRPC Planning Report No. 50, A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds, December 2007.

been conceptually formalized under a February 19, 2003, Memorandum of Understanding among these agencies.⁴ Under the approach envisioned, the coordinated, collaborative planning programs will lead to the preparation of an update to the regional water quality management plan for the greater Milwaukee watersheds, and support the facilities planning program for the MMSD sewerage systems.

STUDY AREA

The study area for the regional water quality management plan update consists of 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, as shown on Map 1.

The watersheds involved in the study are those of the Kinnickinnic River, Menomonee River, Milwaukee River, Oak Creek, and the Root River. These watersheds cover approximately 1,127 square miles. About 861 square miles of these watersheds are located within the seven-county Region for which SEWRPC has planning authority, representing about 32.0 percent of the Region. In addition, approximately 266 square miles of the greater Milwaukee watersheds, or about 23.6 percent of the study area, are located outside of the Region. This portion of the study area consists of the upper reaches of the Milwaukee River watershed, and is located in Dodge, Fond du Lac, and Sheboygan Counties. The watersheds in the study area are drained by approximately 1,010 miles of stream.

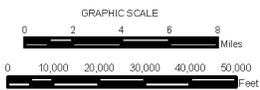
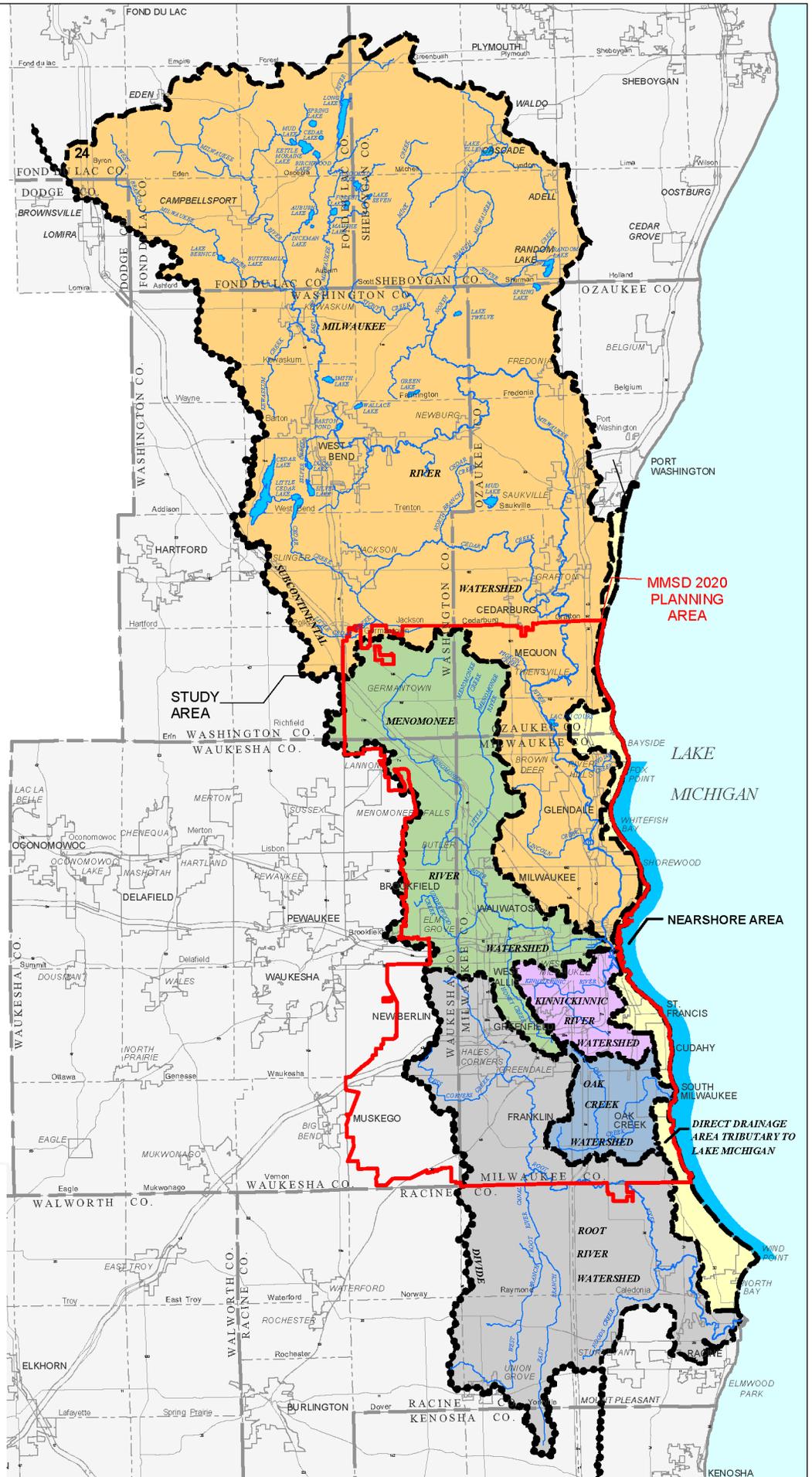
With regard to the Milwaukee Harbor estuary and nearshore Lake Michigan portion of the study area, it is important to make a physical distinction between the boundaries of the Milwaukee Harbor and the boundaries of the estuary itself. As shown on Map 2, the Milwaukee Harbor includes the outer harbor 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 reach of the Milwaukee River below the site of the former North Avenue dam, the 2.2-mile reach of the Menomonee River below the former Falk Corporation dam, and the 2.4-mile reach of the Kinnickinnic River below the Chase Avenue bridge along with the outer harbor to the breakwater structure. 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.

The Lake Michigan direct drainage area, as shown on Map 1, is a limited area drained by a number of small streams, drainage swales, and storm sewers discharging directly to Lake Michigan. The largest drainage system is Fish Creek located on the border of Milwaukee and Ozaukee Counties. The portion of the nearshore area of Lake Michigan included in the study area extends from Fox Point in Milwaukee County to a point approximated by Three Mile Road extended in Racine County. The land area draining directly to the Lake in this reach is included in the study area.

⁴*“Memorandum of Understanding between the Milwaukee Metropolitan Sewerage District (District), the Southeastern Wisconsin Regional Planning Commission (SEWRPC), and the Wisconsin Department of Natural Resources (DNR) for Cooperation in the Watershed Approach to Water Quality and Facilities Planning,” February 19, 2003.*

Map 1

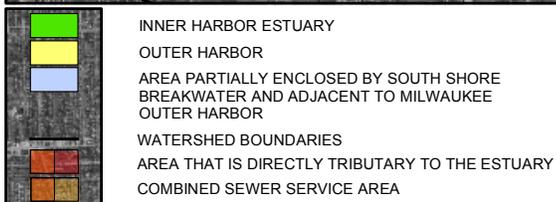
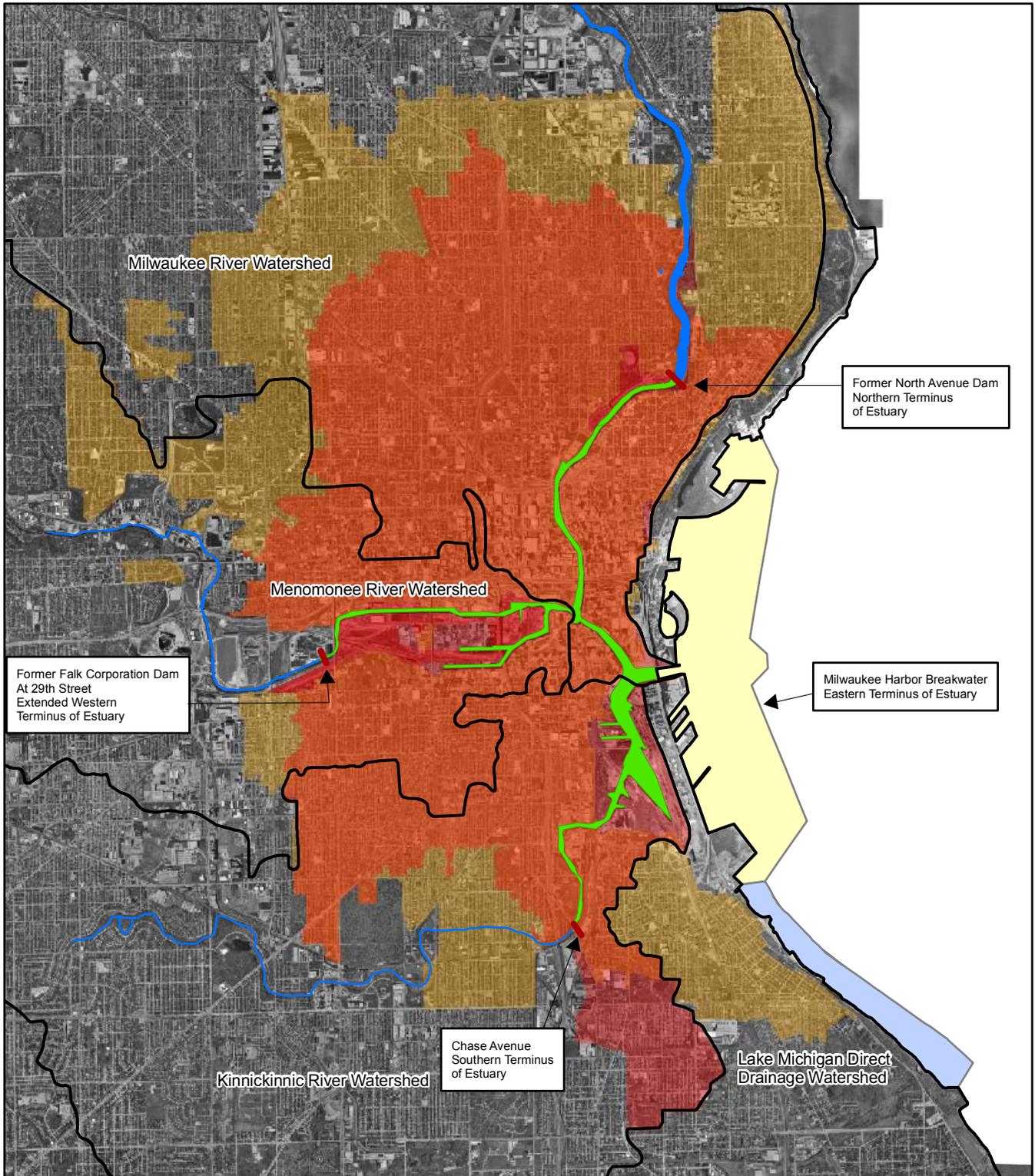
REGIONAL WATER QUALITY
MANAGEMENT PLAN UPDATE
STUDY AREA



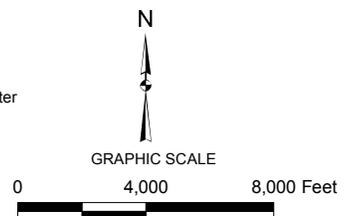
Source: SEWRPC.

Map 2

MILWAUKEE HARBOR ESTUARY



Note: The combined sewer service area would only contribute flow to the estuary during combined sewer overflow events and/or large storms when the combined sewers cannot convey all flow and excess stormwater runoff flows overland to the estuary.



Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

UNITS OF GOVERNMENT

Civil Divisions

Superimposed on the irregular study area boundary as defined by watershed boundaries is a pattern of local political boundaries. As shown on Map 3, the watersheds lie primarily within Fond du Lac, Milwaukee, Ozaukee, Racine, Sheboygan, Washington, and Waukesha Counties with small portions in northern Kenosha and northeastern Dodge Counties. Eighty-eight civil divisions lie in part or entirely within the greater Milwaukee watersheds, as also shown on Map 3 and in Table 1. Geographic boundaries of the civil divisions are an important factor which must be considered in any watershed-based planning effort like the regional water quality management plan update program, since the civil divisions form the basic foundation of the public decision-making framework within which intergovernmental, environmental, and developmental problems must be addressed.

Special-Purpose Units of Government

Special-purpose units of government are of particular interest to the water quality management update planning program. Among these are the MMSD; the legally established, active town sanitary and utility districts created to provide various urban-related services, such as sanitary sewerage, water supply, and solid waste collection and disposal, to designated portions of rural towns with urban service needs; and inland lake protection and rehabilitation districts.

Milwaukee Metropolitan Sewerage District

The Milwaukee Metropolitan Sewerage District is directed by an appointed Commission. The MMSD includes all of Milwaukee County, except the City of South Milwaukee and portions of the City of Franklin. In addition, sewage conveyance and treatment services are provided to portions of Ozaukee, Racine, Washington, and Waukesha Counties. The District, which exists pursuant to the provisions of Section 200.23 of the *Wisconsin Statutes*, has a number of important responsibilities in the area of water resources management, including the provision of floodland management programs for most of the major streams within the District and the collection, transmission, and treatment of domestic, industrial, and other sanitary sewage generated in the District and its contract service areas.

The MMSD has defined a series of interrelated projects which were designed to carry out its sewage management responsibilities, and which are collectively referred to as the Milwaukee water pollution abatement program. These projects were developed through facilities planning programs which were subregional in nature, the latest of which was completed in 1998 and had a design year of 2010. The present MMSD initiative, which is being conducted in coordination with the regional water quality management plan update, seeks to amend and extend its sewerage facilities plan to a design year of 2020.

Town Sanitary and Utility Districts

There are 11 active town sanitary and utility districts within the study area: the Brookfield Sanitary District No. 4 in the Town of Brookfield; the Caddy Vista Sanitary District, the Caledonia Utility District No. 1, the Crestview Sanitary District, and the North Park Sanitary District in the Town of Caledonia; the Lake Ellen Sanitary District in the Town of Lyndon; the Silver Lake Sanitary District in the Town of West Bend; the Town of Scott Sanitary District in the Town of Scott; the Wallace Lake Sanitary District in the Towns of Barton and Polk; the Waubeka Area Sanitary District in the Town of Fredonia; and the Yorkville Sewer Utility District No. 1 in the Town of Yorkville.

Inland Lake Protection and Rehabilitation Districts

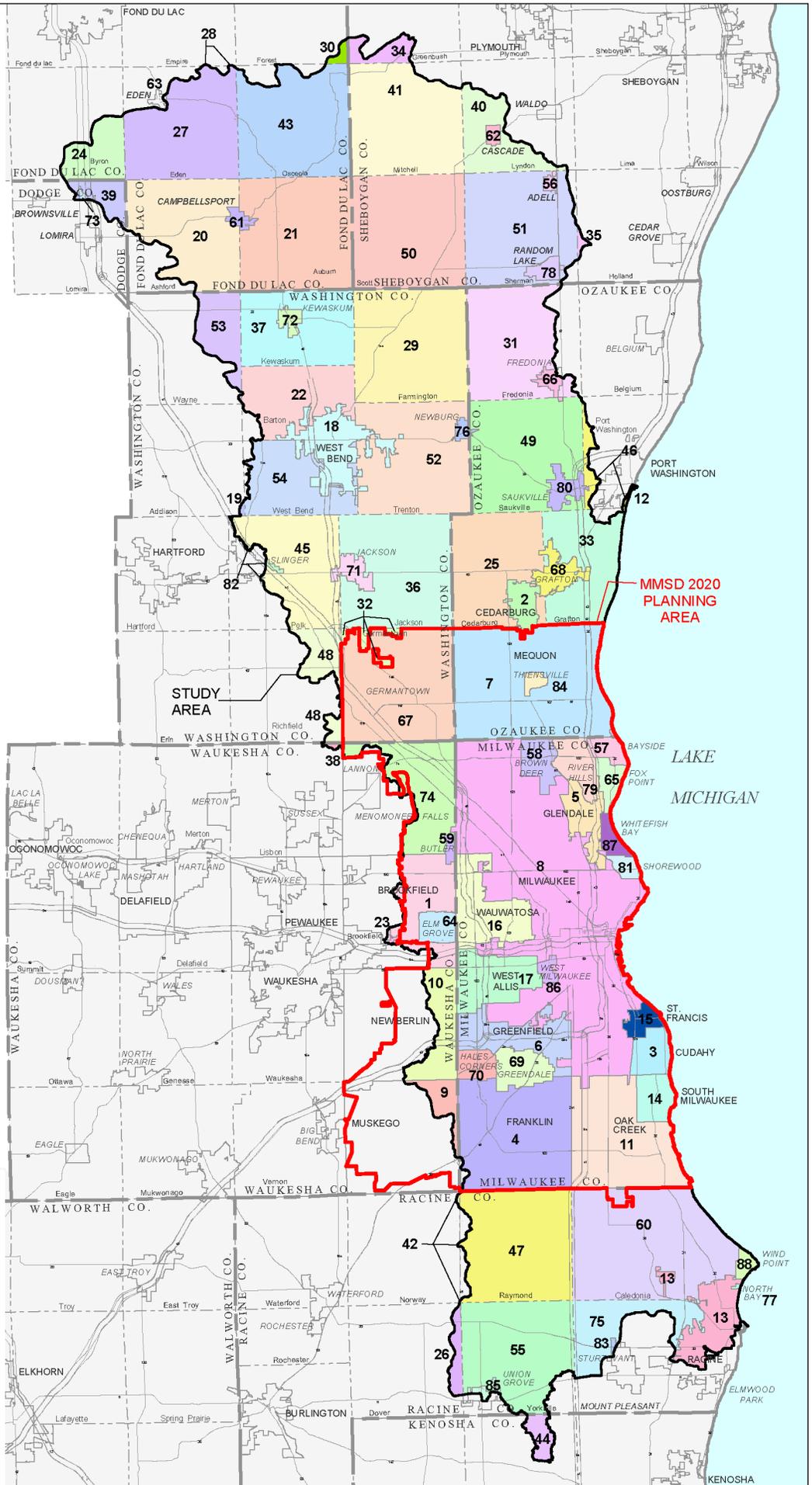
Inland lake protection and rehabilitation districts are special-purpose units of government created pursuant to Chapter 33 of the *Wisconsin Statutes*. There are three such districts in the watershed: the Big Cedar Lake Protection and Rehabilitation District, the Little Cedar Lake Protection and Rehabilitation District, and the Silver Lake Protection and Rehabilitation District. Lake protection and rehabilitation district powers include 1) study of existing water-quality conditions to determine the causes of existing or expected future water-quality problems, 2) control of aquatic macrophytes and algae, 3) implementation of lake rehabilitation techniques, including

Map 3

CIVIL DIVISIONS WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA: 2000

- | | |
|----------------------------|-------------------------------|
| 1 City of Brookfield | 45 Town of Polk |
| 2 City of Cedarburg | 46 Town of Port Washington |
| 3 City of Cudahy | 47 Town of Raymond |
| 4 City of Franklin | 48 Town of Richfield |
| 5 City of Glendale | 49 Town of Saukville |
| 6 City of Greenfield | 50 Town of Scott |
| 7 City of Mequon | 51 Town of Sherman |
| 8 City of Milwaukee | 52 Town of Trenton |
| 9 City of Muskego | 53 Town of Wayne |
| 10 City of New Berlin | 54 Town of West Bend |
| 11 City of Oak Creek | 55 Town of Yorkville |
| 12 City of Port Washington | 56 Village of Adell |
| 13 City of Racine | 57 Village of Bayside |
| 14 City of South Milwaukee | 58 Village of Brown Deer |
| 15 City of St. Francis | 59 Village of Butler |
| 16 City of Wauwatosa | 60 Village of Caledonia |
| 17 City of West Allis | 61 Village of Campbellsport |
| 18 City of West Bend | 62 Village of Cascade |
| 19 Town of Addison | 63 Village of Eden |
| 20 Town of Ashford | 64 Village of Elm Grove |
| 21 Town of Auburn | 65 Village of Fox Point |
| 22 Town of Barton | 66 Village of Fredonia |
| 23 Town of Brookfield | 67 Village of Germantown |
| 24 Town of Byron | 68 Village of Grafton |
| 25 Town of Cedarburg | 69 Village of Greendale |
| 26 Town of Dover | 70 Village of Hales Corners |
| 27 Town of Eden | 71 Village of Jackson |
| 28 Town of Empire | 72 Village of Kewaskum |
| 29 Town of Farmington | 73 Village of Lomira |
| 30 Town of Forest | 74 Village of Menomonee Falls |
| 31 Town of Fredonia | 75 Village of Mt. Pleasant |
| 32 Town of Germantown | 76 Village of Newburg |
| 33 Town of Grafton | 77 Village of North Bay |
| 34 Town of Greenbush | 78 Village of Random Lake |
| 35 Town of Holland | 79 Village of River Hills |
| 36 Town of Jackson | 80 Village of Saukville |
| 37 Town of Kewaskum | 81 Village of Shorewood |
| 38 Town of Lisbon | 82 Village of Slinger |
| 39 Town of Lomira | 83 Village of Sturtevant |
| 40 Town of Lyndon | 84 Village of Thiensville |
| 41 Town of Mitchell | 85 Village of Union Grove |
| 42 Town of Norway | 86 Village of West Milwaukee |
| 43 Town of Osceola | 87 Village of Whitefish Bay |
| 44 Town of Paris | 88 Village of Wind Point |

NOTE: MAP REFLECTS YEAR 2000 CORPORATE LIMITS. THE TOWNS OF CALEDONIA AND MOUNT PLEASANT INCORPORATED TO VILLAGES IN THE YEAR 2005 AND 2003 RESPECTIVELY.



Source: SEWRPC.

Table 1

**AREAL EXTENT OF COUNTIES, CITIES, VILLAGES, AND TOWNS IN THE
REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA: 2000**

Civil Division	Area (square miles)	Percent of Total
Dodge County		
Village of Lomira	0.2	0.02
Town of Lomira	4.4	0.39
Subtotal	4.6	0.41
Fond du Lac County		
Village of Campbellsport	1.1	0.10
Village of Eden	0.1	0.01
Town of Ashford	28.9	2.56
Town of Auburn	35.8	3.18
Town of Byron	8.9	0.79
Town of Eden	29.7	2.63
Town of Empire	<0.1	<0.01
Town of Forest	0.8	0.07
Town of Osceola	33.5	2.97
Subtotal	138.8	12.31
Kenosha County		
Town of Paris	2.8	0.25
Subtotal	2.8	0.25
Milwaukee County		
City of Cudahy	4.8	0.43
City of Franklin	34.2	3.04
City of Glendale	6.0	0.53
City of Greenfield	11.5	1.02
City of Milwaukee	96.7	8.58
City of Oak Creek	28.5	2.53
City of South Milwaukee	4.9	0.44
City of St. Francis	2.6	0.23
City of Wauwatosa	13.2	1.17
City of West Allis	11.4	1.01
Village of Bayside	2.3	0.20
Village of Brown Deer	4.4	0.39
Village of Fox Point	2.9	0.26
Village of Greendale	5.6	0.50
Village of Hales Corners	3.2	0.28
Village of River Hills	5.3	0.42
Village of Shorewood	1.6	0.14
Village of West Milwaukee	1.1	0.10
Village of Whitefish Bay	2.1	0.19
Subtotal	242.3	21.46
Ozaukee County		
City of Cedarburg	3.7	0.33
City of Mequon	47.0	4.17
City of Port Washington	0.1	0.01
Village of Bayside	0.1	0.01
Village of Fredonia	1.3	0.12
Village of Grafton	4.1	0.36
Village of Newburg	0.1	0.01
Village of Saukville	2.9	0.26
Village of Thiensville	1.1	0.10

Table 1 (continued)

Civil Division	Area (square miles)	Percent of Total
Ozaukee County (continued)		
Town of Cedarburg	26.0	2.31
Town of Fredonia	28.1	2.49
Town of Grafton	19.5	1.73
Town of Port Washington	2.6	0.23
Town of Saukville	33.4	2.96
Subtotal	170.0	15.09
Racine County		
City of Racine	10.6	0.94
Village of Caledonia	45.6	4.05
Village of Mt. Pleasant	13.5	1.20
Village of North Bay	0.1	0.01
Village of Sturtevant	0.2	0.02
Village of Union Grove	0.7	0.06
Village of Wind Point	1.3	0.12
Town of Dover	2.6	0.23
Town of Norway	0.1	0.01
Town of Raymond	34.0	3.02
Town of Yorkville	29.9	2.65
Subtotal	138.6	12.31
Sheboygan County		
Village of Adell	0.6	0.05
Village of Cascade	0.8	0.07
Village of Random Lake	1.7	0.15
Town of Greenbush	3.7	0.33
Town of Holland	0.5	0.04
Town of Lyndon	12.6	1.12
Town of Mitchell	33.5	2.97
Town of Scott	36.5	3.24
Town of Sherman	32.6	2.90
Subtotal	122.5	10.87
Washington County		
City of Milwaukee	>0.1	>0.01
City of West Bend	12.6	1.12
Village of Germantown	34.4	3.05
Village of Jackson	2.5	0.22
Village of Kewaskum	1.4	0.12
Village of Newburg	0.8	0.07
Village of Slinger	0.3	0.03
Town of Addison	0.2	0.02
Town of Barton	18.0	1.60
Town of Farmington	36.8	3.26
Town of Germantown	1.8	0.16
Town of Jackson	34.2	3.03
Town of Kewaskum	22.9	2.03
Town of Polk	24.2	2.15
Town of Richfield	7.2	0.64
Town of Trenton	33.5	2.97
Town of Wayne	9.1	0.81
Town of West Bend	17.2	1.53
Subtotal	257.1	22.81

Table 1 (continued)

Civil Division	Area (square miles)	Percent of Total
Waukesha County		
City of Brookfield.....	13.5	1.20
City of Milwaukee.....	0.1	0.01
City of Muskego.....	3.9	0.35
City of New Berlin.....	9.9	0.88
Village of Butler.....	0.8	0.07
Village of Elm Grove.....	3.3	0.29
Village of Menomonee Falls.....	18.5	1.64
Town of Brookfield.....	0.2	0.02
Town of Lisbon.....	0.3	0.03
Subtotal	50.5	4.49
Total	1,127.2	100.00

NOTE: The Town of Mt. Pleasant incorporated as a Village in 2003, and the Town of Caledonia incorporated as a Village in 2005.

Source: SEWRPC.

aeration, diversion, nutrient removal or inactivation, dredging, sediment covering, and drawdown, 4) construction and operation of water-level-control structures, 5) control of nonpoint source pollution, and 6) creation, operation, and maintenance of a water safety patrol unit.

Other Agencies with Resource-Management Responsibilities Related to Water Quality

Superimposed upon these local and special-purpose units of government are those State and Federal agencies with important responsibilities for water quality management and resource conservation and management. These include the WDNR; the University of Wisconsin-Extension; the State Board of Soil and Water Conservation Districts; the U.S. Department of the Interior, U.S. Geological Survey; the USEPA; the U.S. Department of Agriculture, Natural Resources Conservation Service; and the U.S. Army Corps of Engineers.

LAND USE

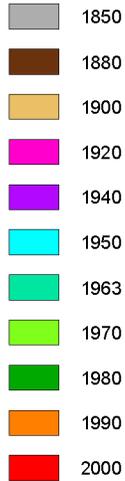
An important concept underlying the watershed planning effort is that land use development should be planned considering the ability of the underlying natural resource base to sustain such development. The type, intensity, and spatial distribution of land uses determine, to a large extent, the resource demands within a watershed. Water-resource demands can be correlated directly with the quantity and type of land use, as can water quality conditions. The existing land use pattern can best be understood within the context of its historical development. Thus, attention is focused here on historical, as well as existing, land use development.

Historical Growth Patterns

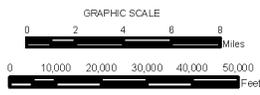
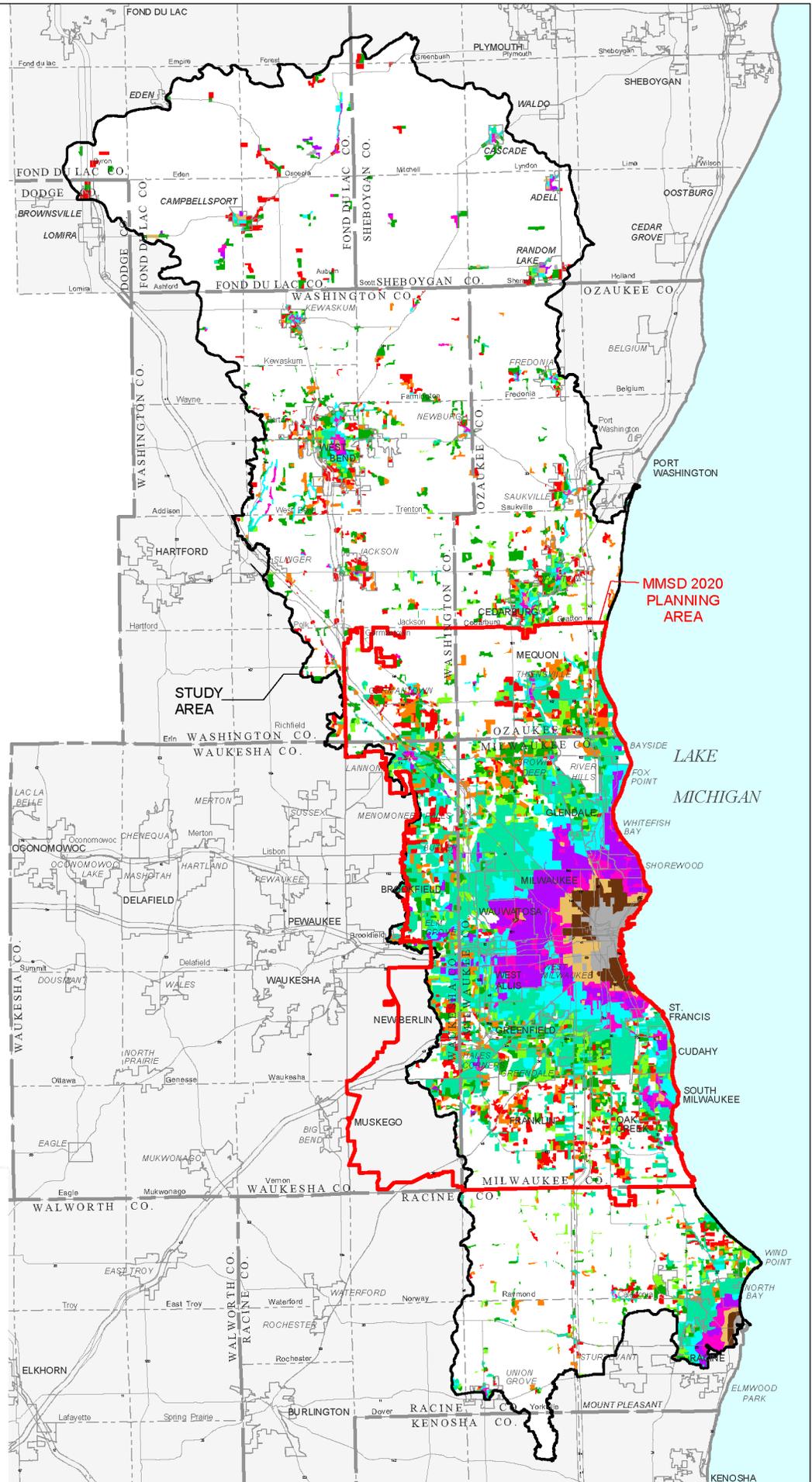
The movement of European settlers into the Southeastern Wisconsin Region began around 1830. Completion of the U.S. Public Land Survey in the Region in 1836 and the subsequent sale of public lands in Wisconsin brought an influx of settlers into the area. In 1850, the urban portions of the regional water quality management plan update study area was located at Cedarburg, Grafton, Milwaukee, Racine, and West Bend, along with many smaller settlements throughout the study area. Over the 100-year period from 1850 to 1950, urban development in the study area occurred in a pattern resembling concentric rings around existing urban centers, resulting in a relatively compact settlement pattern. After 1950, there was a significant change in the pattern and rate of urban development in the study area. While substantial amounts of development continued to occur adjacent to established urban centers, considerable development also occurred in isolated enclaves in outlying areas of the study area. Map 4 indicates a continuation of this trend during the 1990s, with significant development occurring adjacent to existing urban centers, but also with considerable development continuing to occur in scattered fashion in outlying areas. In Milwaukee and Waukesha Counties in the central portion of the study area, new

Map 4

**HISTORICAL URBAN GROWTH
IN THE REGIONAL WATER
QUALITY MANAGEMENT PLAN
UPDATE STUDY AREA**



NOTE: DATA NOT AVAILABLE FOR
1990 URBAN GROWTH ANALYSIS
FOR DODGE, FOND DU LAC,
AND SHEBOYGAN COUNTIES.



Source: SEWRPC.

urban development consists primarily of in-fill, which is the development of the last remaining lots and small subdivisions in an existing developed area, as well as redevelopment.

Table 2 summarizes the historic urban growth pattern in the study area for the period 1850 to 2000. The rate at which urban growth occurred in the study area increased gradually until 1940. After 1940, the rate of urban growth increased substantially, reaching a maximum average rate of approximately 4,500 acres converted to urban uses per year during the period 1950 to 1963. Since 1963, the average rate of urban growth in the study area has declined from this peak.

Land Use

The existing land use pattern within the study area is shown on Map 5, and the existing land uses are quantified by watershed in Table 3.

As indicated in Table 3, about 486,000 acres, or about 67 percent of the total study area, was still in rural uses in 2000, with agriculture and related open uses occupying about 304,000 acres, or about 42 percent of the total study area. In 2000, urban land uses occupied about 235,000 acres, or about 33 percent of the total study area. Residential land use accounted for over 113,000 acres, or about 16 percent of the total study area. Also of significance is the transportation, communication, and utilities land use category, which accounted for about 67,000 acres, or about 9 percent of the total study area.

Table 4 shows land use in those portions of the study area within the Southeastern Wisconsin Region for the years 1970, 1990, and 2000. During the period from 1970 to 2000, the amount of land devoted to agricultural and related uses declined from about 420 square miles to about 317 square miles. Much of this decrease resulted from the conversion of land from agricultural and related uses to urban uses. Over the same time period, the amount of land in urban land uses increased from about 259 square miles to about 347 square miles. In addition, the area represented by surface water increased from 10.1 square miles in 1970 to 11.5 square miles in 2000. This change represents the net effect of a number of changes, including refinements in watershed boundaries, changes in the water levels in inland lakes and ponds, and the construction of stormwater detention and infiltration basins. Over the same time period, the area represented by wetlands increased from 73.6 square miles to 78.2 square miles. This change represents the net effect of a number of changes, including reversion of prior-converted agricultural lands back to wetland, the creation or restoration of some wetlands, and the delineation of previously unidentified wetlands. The total area of the portion of the study area in the Region increased slightly by 0.5 square mile from 1970 to 2000. This increase represents the combined effects of refinements of watershed boundaries and the net effect of erosion and aggradation of land along the shore of Lake Michigan.

SURFACE WATER AND GROUNDWATER RESOURCES

Surface water resources, lakes and streams and their associated floodlands, form the most important element of the natural resource base of the regional water quality management plan update study area. Their contribution to the economic development, recreational activity, and aesthetic quality of the watersheds is immeasurable. Lake Michigan is a major source of water for domestic, municipal, and industrial users in the Greater Milwaukee watersheds. Understanding the interaction of the surface water and groundwater resources is essential to sound water resource planning. Surface water and groundwater are interrelated components of the hydrologic system.⁵ Accordingly, both these elements of the hydrologic system are described herein. The groundwater resources of the watersheds are hydraulically connected to the surface water resources inasmuch as the former provide the base flow of streams. The groundwater resources constitute the major source of supply for domestic, municipal, and industrial water users located in the northern portion of the study area and those resources are discussed below.

⁵Thomas C. Winter, Judson W. Harvey, O. Lehn Franke, William M. Alley, Ground water and surface water; a single resource, *USGS Circular 1139*.

Table 2

**EXTENT OF URBAN GROWTH WITHIN THE REGIONAL WATER
QUALITY MANAGEMENT PLAN UPDATE STUDY 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	4,617	4,617	0.6
1880	5,063	9,680	1.3
1900	4,479	14,159	2.0
1920	11,101	25,260	3.5
1940	18,331	43,591	6.0
1950	21,651	65,242	9.0
1963	57,944	123,186	17.1
1970	18,966	142,152	19.7
1980	15,360	168,494	23.4
2000	10,177	202,632	28.1

^aUrban development, as defined for the purposes of this table, 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. The quantification of urban lands set forth in Table 3 includes scattered urban development.

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

Lakes and Ponds

There are more than 120 named lakes and ponds greater than two acres in area within the regional water quality management plan update study area, of which 21 lakes are greater than 50 acres in area and are capable of supporting a variety of recreational uses.⁶ The total surface area of these 21 lakes is 3,438 acres, or less than 1 percent of the total study area. More than 75 percent of the 3,438 acres is comprised of nine lakes all greater than 100 acres in size that include: Silver, Big Cedar, and Little Cedar Lakes in Washington County; Auburn, Kettle Moraine, and Long Lakes in Fond du Lac County; Mud Lake in Ozaukee County; and Ellen and Random Lakes in Sheboygan County. Ponds and other surface waters are present in relatively smaller proportions, totaling less than 200 acres in area throughout the study area. These lakes and smaller bodies of water provide residents of the regional water quality management plan update study area and persons from outside the study area with a variety of aesthetic and recreational opportunities and also serve to stimulate the local economy by attracting recreational users.

Rivers and Streams

Water from rainfall and snowmelt flows into stream systems by one of two pathways; either directly flowing overland as surface water runoff or infiltrating into the soil surface and eventually flowing underground into streams as groundwater. Ephemeral streams generally flow only during the wet season. Streams that flow year-round are called perennial streams and are primarily sustained by groundwater during dry periods. The surface water drainage systems and the 1,010 miles of mapped streams are shown on Map 6 on a study area basis. More-detailed mapping and information on the stream system is presented in Chapters V through X of this report.

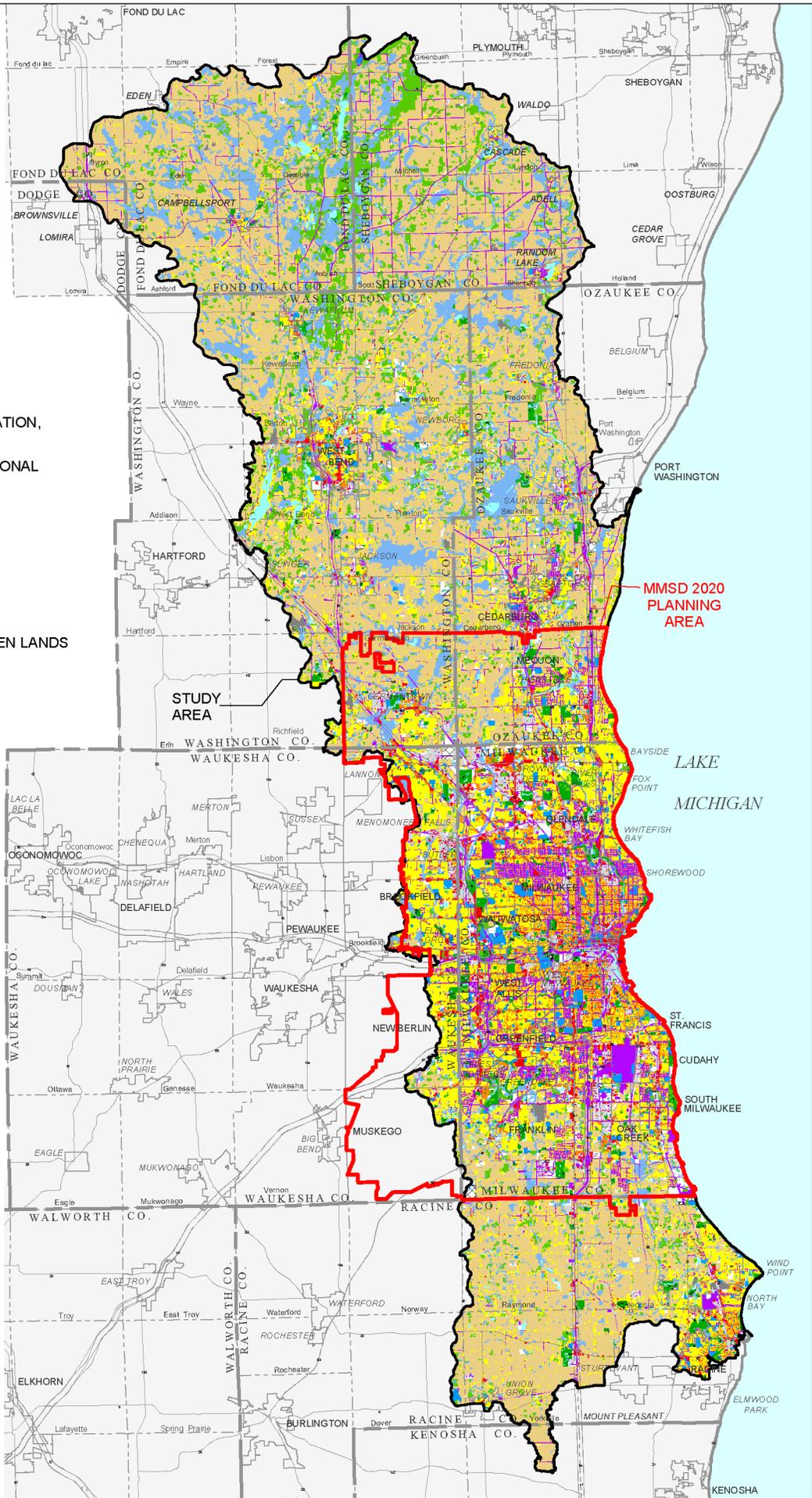
Viewed from above, the network of water channels that form a river system displays a branchlike pattern as shown in Figure 1. A stream channel that flows into a larger channel is called a tributary of that channel. The

⁶Wisconsin Department of Natural Resources Publication No. PUBL WT 704-2001, State of the Milwaukee River Basin, August 2001; Wisconsin Department of Natural Resources Publication No. PUBL WT-700-2002, State of the Root-Pike River Basin, May 2002.

Map 5

EXISTING LAND USE IN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA: 2000

-  SINGLE-FAMILY RESIDENTIAL
-  MULTI-FAMILY RESIDENTIAL
-  COMMERCIAL
-  INDUSTRIAL
-  TRANSPORTATION, COMMUNICATION, AND UTILITIES
-  GOVERNMENTAL AND INSTITUTIONAL
-  RECREATIONAL
-  SURFACE WATER
-  WOODLANDS
-  WETLANDS
-  AGRICULTURAL AND OTHER OPEN LANDS
-  EXTRACTIVE
-  LANDFILL



MMSD 2020
PLANNING
AREA

Source: SEWRPC.

Table 3

EXISTING LAND USE IN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA: 2000^{a,b}

Category	Watershed												Total	
	Lake Michigan Direct Drainage		Kinnickinnic River		Menomonee River		Milwaukee River		Oak Creek		Root River			
	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total
Urban														
Residential	9,322	35.6	5,741	34.7	25,928	29.8	45,848	10.2	4,599	25.5	22,215	17.6	113,384	15.7
Commercial.....	520	2.0	913	5.8	3,510	4.0	4,045	0.9	638	3.5	1,812	1.4	11,438	1.6
Industrial	844	3.2	1,154	7.3	4,417	5.1	5,688	1.3	865	4.8	1,639	1.3	14,608	2.0
Transportation, Communication, and Utilities ^c	4,519	17.3	5,175	32.8	14,546	16.8	28,504	6.4	3,516	19.5	10,645	8.4	66,904	9.3
Governmental and Institutional	971	3.7	1,201	7.6	3,647	4.2	4,415	0.9	652	3.6	1,956	1.5	12,841	1.8
Recreational.....	1,200	4.6	646	4.1	3,409	3.9	6,593	1.5	555	3.1	3,361	2.7	15,763	2.2
Subtotal	17,376	66.4	14,560	92.3	55,457	63.8	95,093	21.2	10,825	60.0	41,628	32.9	234,938	32.6
Rural														
Agricultural and Related	2,801	10.7	70	0.4	14,978	17.3	219,168	48.9	2,919	16.2	64,012	50.6	303,948	42.1
Water	127	0.5	153	1.0	542	0.6	7,715	1.7	28	0.2	1,017	0.8	9,583	1.3
Wetlands.....	415	1.6	57	0.3	6,741	7.8	67,110	15.0	920	5.1	6,793	5.4	82,036	11.4
Woodlands.....	1,464	5.6	92	0.6	2,110	2.4	39,836	8.9	760	4.2	4,936	3.9	49,199	6.8
Landfill, Extractive, Unused, and Other Open Land	3,983	15.2	847	5.4	7,062	8.1	19,080	4.3	2,587	14.3	8,104	6.4	41,662	5.8
Subtotal	8,790	33.6	1,219	7.7	31,433	36.2	352,909	78.8	7,214	40.0	84,862	67.1	486,428	67.4
Total	26,166	100.0	15,779	100.0	86,890	100.0	444,802	100.0	18,039	100.0	126,490	100.0	721,366	100.0

^aAs approximated by whole U.S. Public Land Survey one-quarter sections.

^bAs 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 this change, however, year 2000 land use inventory data are not strictly comparable with data from the 1990 and prior inventories. At the watershed and study area level, the most significant effect of the change is to increase the transportation, communication, and utilities categories, as a 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.

^cOff-street parking of more than 10 spaces is included with the associated land use.

Source: SEWRPC.

Table 4

LAND USE IN THE SOUTHEASTERN WISCONSIN PORTION OF THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA : 1970-2000^{a,b,c}

Category	1970		1990		2000 ^c		Change 1970-2000	
	Square Miles	Percent of Total	Square Miles	Percent of Total	Square Miles	Percent of Total	Square Miles	Percent of Total
Urban								
Residential	123.5	14.4	152.4	17.7	169.0	19.7	45.5	36.8
Commercial	9.7	1.1	15.2	1.8	17.6	2.0	7.9	81.4
Industrial.....	14.7	1.7	18.5	2.1	21.6	2.5	6.9	46.9
Transportation, Communication, and Utilities ^c	77.1	9.0	84.8	9.9	96.0	11.2	18.9	24.5
Governmental and Institutional	17.1	2.0	18.7	2.2	19.4	2.2	2.3	13.5
Recreational	17.3	2.0	20.7	2.4	23.7	2.8	6.4	37.0
Subtotal	259.4	30.2	310.3	36.1	347.3	40.4	87.9	33.9
Rural								
Agricultural and Related	419.8	48.8	362.2	42.1	317.2	36.9	-102.6	-24.4
Water.....	10.1	1.2	11.2	1.3	11.5	1.3	1.4	13.9
Wetlands	73.6	8.6	75.6	8.8	78.2	9.1	4.6	6.2
Woodlands	42.2	4.9	43.4	5.1	43.6	5.1	1.4	3.3
Land, Extractive, Unused, and Other Open Lands	54.4	6.3	57.0	6.6	62.2	7.2	7.8	14.3
Subtotal	600.1	69.8	549.4	63.9	512.7	59.6	-87.4	-14.6
Total	859.5	100.0	859.7	100.0	860.0	100.0	0.5	--

^aAs approximated by whole U.S. Public Land Survey one-quarter sections.

^bAs 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, as a 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.

^cBecause data are unavailable for Dodge, Fond du Lac, and Sheboygan Counties for 1970 and 1990, these data include only those portions of the study area that are within the Southeastern Wisconsin Region.

^dOff-street parking of more than 10 spaces are included with the associated land use.

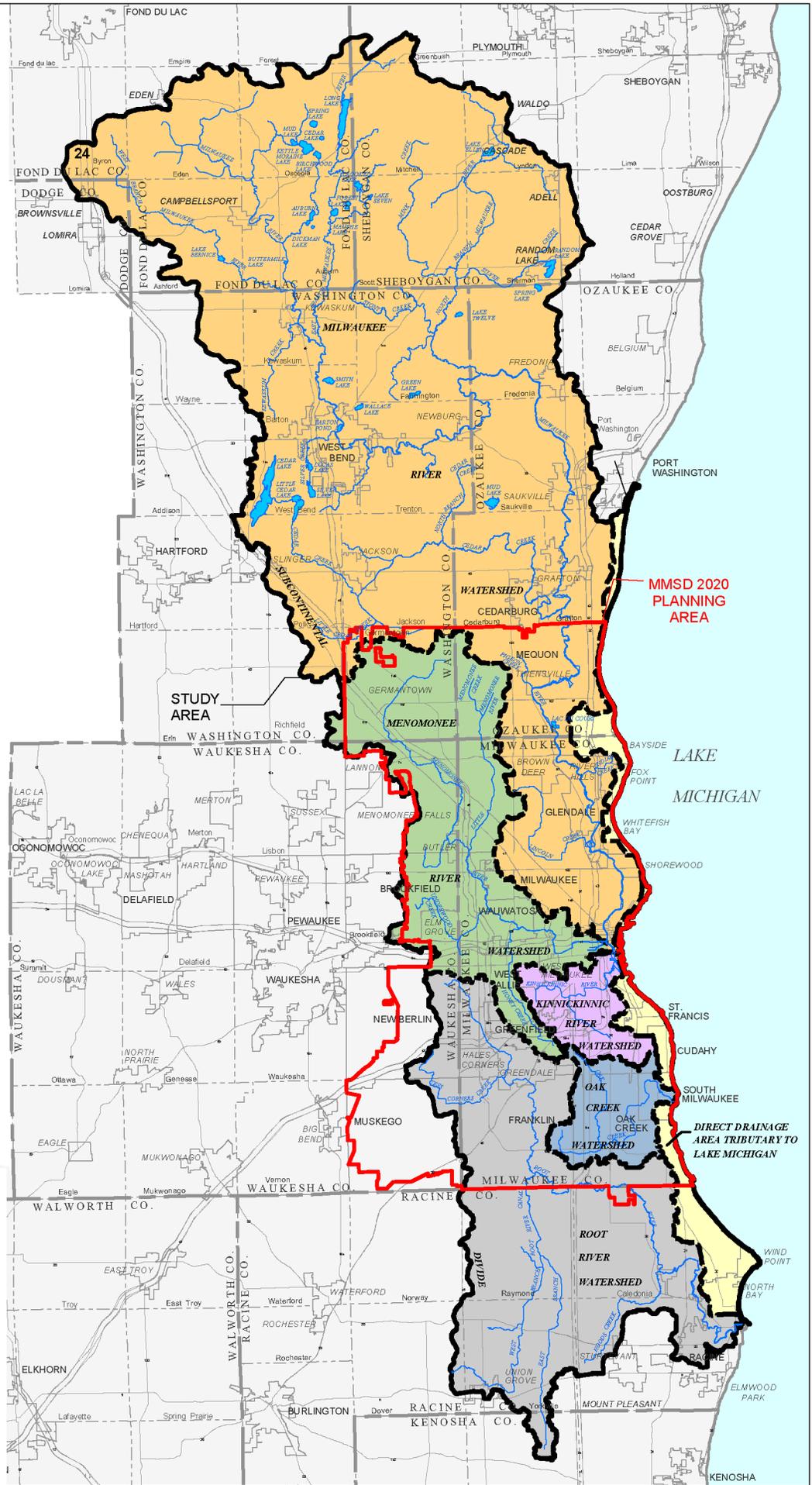
Source: SEWRPC.

entire area drained by a single river system is termed a drainage basin, or watershed. Stream size increases downstream as more and more tributary segments enter the main channel. A classification system based on the position of a stream within the network of tributaries, called stream order, was developed by Robert E. Horton and later modified by Arthur Strahler. In general, the lower stream order numbers correspond to the smallest headwater tributaries and are shown as the Order 1, or first-order, streams in Figure 1. Second-order streams (Order 2) are those that have only first-order streams as tributaries, and so on (Figure 1). As water travels from headwater streams toward the mouth of larger rivers, streams gradually increase their width and depth and the amount of water they discharge also increases. Over 80 percent of the total length of rivers and streams worldwide are headwater streams (first- and second-order), which is also the case in terms of the watersheds within the regional water quality management plan update study area.

To better understand stream systems and what shapes their conditions, it is important to understand the effects of both spatial and temporal scales. Streams can be theoretically subdivided into a continuum of habitat sensitivity to

Map 6

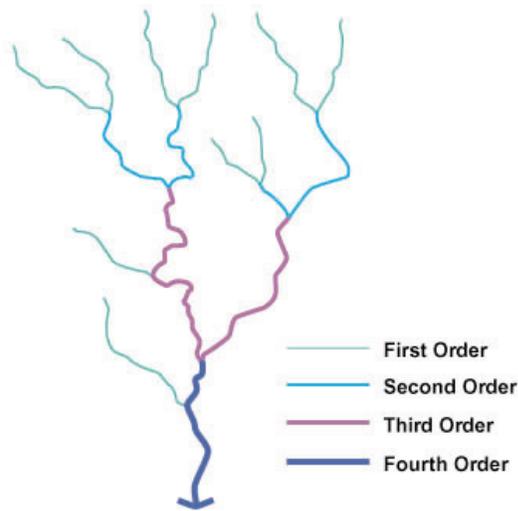
SURFACE DRAINAGE AND SURFACE WATER IN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA



Source: SEWRPC.

Figure 1

TYPICAL STREAM NETWORK PATTERNS BASED ON HORTON'S CLASSIFICATION SYSTEM



Source: Oliver S. Owen and others, *Natural Resource Conservation: Management for a Sustainable Future*.

disturbance and recovery time as shown conceptually in Figure 2.⁷ Microhabitats, such as a handful-sized patch of gravel, are most susceptible to disturbance and river systems and watersheds, or drainage basins, are least susceptible. Furthermore, events that affect smaller-scale habitat characteristics may not affect larger-scale system characteristics, whereas large disturbances can directly influence smaller-scale features of streams. For example, on a small spatial scale, deposition at one habitat site may be accompanied by scouring at another site nearby, and the reach or segment does not appear to change significantly. In contrast, a large-scale disturbance, such as a debris flood, is initiated at the segment level and reflected in all lower levels of the hierarchy (reach, habitat, microhabitat). Similarly, on a temporal scale, siltation of microhabitats may disturb the biotic community over the short term. However, if the disturbance is of limited scope and intensity, the system may recover quickly to pre-disturbance levels.⁸ In contrast, extensive or prolonged disturbances, such as the stream channelization practices of ditching and tile drainage, have resulted in longer-term impacts throughout the study area.

The most important fundamental aspects of stream systems are that 1) the entire fluvial system is a continuously integrated series of physical gradients in which the downstream areas are longitudinally linked and dependent upon the upstream areas and 2) that streams are intimately connected to their adjacent terrestrial setting, in other words the land-stream interaction is crucial to the operation of stream ecosystem processes. In this regard, land uses have a significant impact on stream channel conditions and associated biological responses.⁹

Groundwater Resources

Groundwater is a key element of the natural resource base that not only sustains lake levels and wetlands and provides the base flows of streams in the study area, but also comprises the major source of water supply in the northern portion of the study area.

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

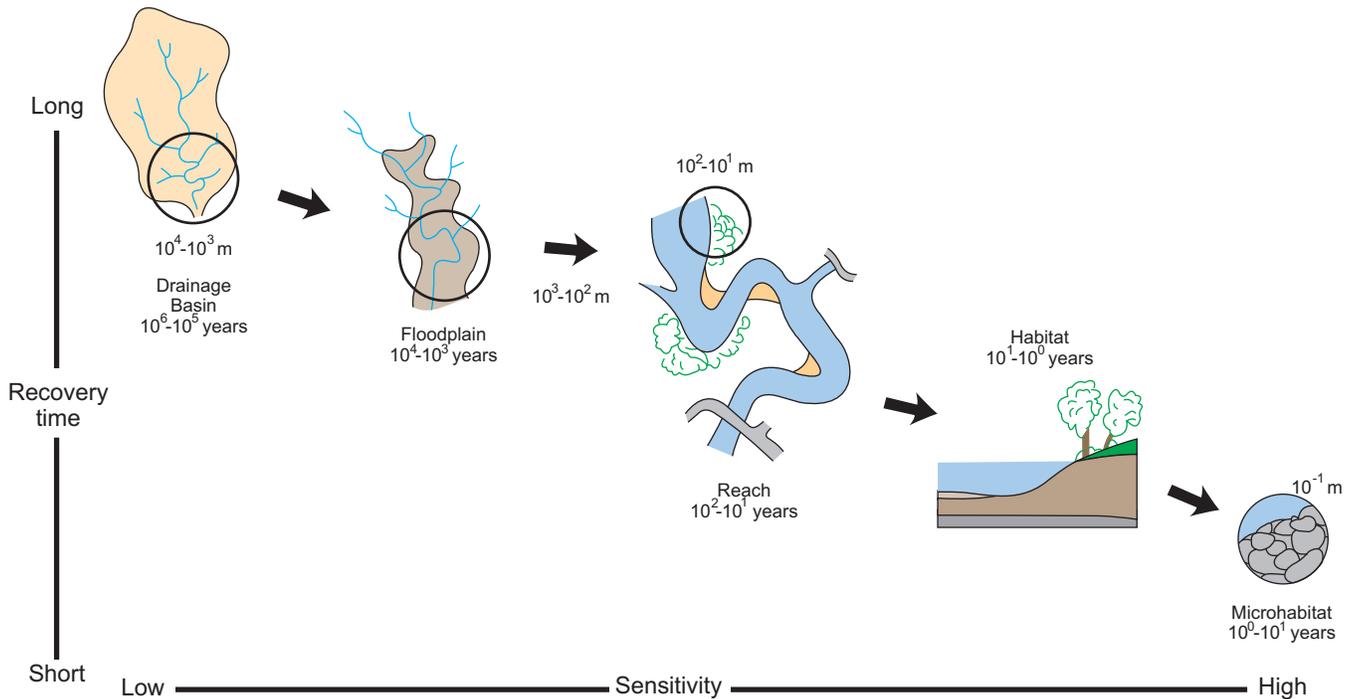
⁷C.A. Frissell and others, "A Hierarchical Framework for Stream Classification: Viewing Streams in a Watershed Context," *Environmental Management*, Volume 10, pages 199-214, 1986.

⁸G.J. Niemi and others, "An Overview of Case Studies on Recovery of Aquatic Systems From Disturbance," *Journal of Environmental Management*, Volume 14, pages 571-587, 1990.

⁹Lizhu Wang and others, "Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams," *Fisheries*, Volume 22, No. 6, June 1997; Jana S. Stewart and others, "Influences of Watershed, Riparian-Corridor, and Reach-Scale Characteristics on Aquatic Biota in Agricultural Watersheds," *Journal of the American Water Resources Association*, Volume 37, No. 6, December 2001; Faith A. Fitzpatrick and others, "Effects of Multi-Scale Environmental Characteristics on Agricultural Stream Biota in Eastern Wisconsin," *Journal of the American Water Resources Association*, Volume 37, No. 6, December 2001.

Figure 2

RELATION BETWEEN RECOVERY TIME AND SENSITIVITY TO DISTURBANCE FOR DIFFERENT HIERARCHICAL SPATIAL SCALES ASSOCIATED WITH STREAM SYSTEMS



Source: C.A. Frissell and others, "A Hierarchical Framework for Stream Habitat Classification: Viewing Streams in a Watershed Context," Environmental Management, Vol. 10.

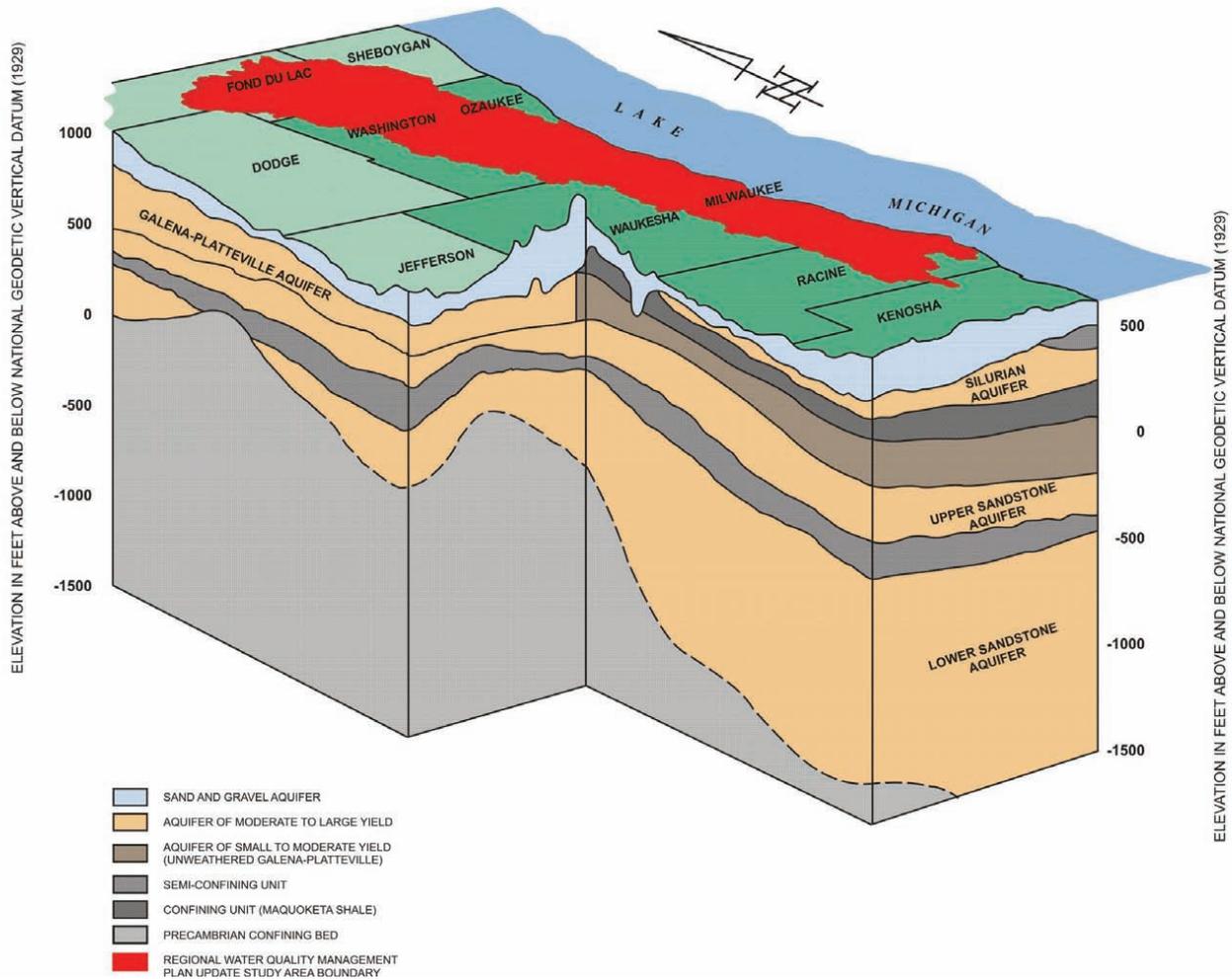
bedrock; and 3) the deeper sandstone, dolomite, siltstone, and shale strata. Because of their proximity to the land's surface and hydraulic interconnection, the first two aquifers are commonly referred to collectively as the "shallow aquifer," while the latter is referred to as the deep aquifer. Within the study area, the shallow and deep aquifers are separated by the Maquoketa shale, which forms a relatively impermeable barrier between the two aquifers (Figure 3).

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.

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 southern portion of the study area.

Figure 3
AQUIFER SYSTEMS IN SOUTHEASTERN WISCONSIN



Source: Eaton, 1997; Mai and Dott, 1985; Peters, 1997; and Young, 1992.

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 areas of the Region. Other considerations which may limit the uses of groundwater include decreasing aquifer levels and increasing concentrations of dissolved solids and other constituents.

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.

SEWRPC, working with the U.S. Geological Survey, the Wisconsin Geological and Natural History Survey, the University of Wisconsin-Milwaukee, and the 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, *Groundwater Resources of Southeastern Wisconsin*. The aquifer simulation model will be documented in a SEWRPC technical report to be published in 2005.

REGIONAL WATER QUALITY MANAGEMENT PLAN

SEWRPC is, pursuant to State legislation, the official planning agency for the seven-county Southeastern Wisconsin Region. The Commission is charged by law with the duty of preparing and adopting a comprehensive plan for the development of the Region. SEWRPC is also the State-designated and Federally recognized areawide water quality management planning agency for Southeastern Wisconsin.

Pursuant to the provisions of section 208 of the Federal Clean Water Act, the Commission prepared and adopted an areawide water quality management plan for the Southeastern Wisconsin Region in 1979.¹⁰ That plan was subsequently adopted by the Wisconsin Natural Resources Board and approved by the USEPA. That plan provided the necessary framework for the preparation and adoption of the 1980 MMSD facilities plan. Although certain elements of the areawide plan have been updated since 1979, and although many key recommendations of that plan have been implemented, the plan has now been updated to provide a needed framework for the preparation of the new MMSD facilities plan.

The previously cited initial regional water quality management plan was designed, in part, to meet the Congressional mandate that the waters of the United States be made to the extent practicable “fishable and swimmable.” In accordance with the requirements of Section 208 of the Federal Clean Water Act, the plan provides recommendations for the control of water pollution from such point sources as sewage treatment plants, points of separate and combined sewer overflow, and industrial waste outfalls and from such nonpoint sources as urban and rural stormwater runoff.

An important amendment to the regional water quality management plan, adopted in 1987, addressed water quality issues in the Milwaukee Harbor estuary.¹¹ The estuary plan set forth recommendations to abate water pollution from combined sewer overflows, including a determination of the level of protection to be provided by such abatement, and from other point and nonpoint sources of pollution in the tributary watersheds, including recommendations for instream measures, that might be needed to achieve established water use objectives.

Since completion of the initial regional water quality management plan, SEWRPC and the WDNR have cooperatively conducted a continuing water quality management planning effort. That effort has been severely limited by fiscal constraints, however, with work confined largely to sanitary sewer service area planning, groundwater inventories and analyses, and selected plan implementation activities.

In 1995, SEWRPC completed a report documenting the implementation status of the regional water quality management plan as amended over the approximately first 15 years since the initial adoption of the plan. This

¹⁰SEWRPC *Planning Report No. 30*, op. cit.

¹¹SEWRPC *Planning Report No. 37*, A Water Resources Management Plan for the Milwaukee Harbor Estuary, *Volume 1*, Inventory Findings, *March 1987*; *Volume Two*, Alternative and Recommended Plans, *December 1987*.

report, SEWRPC Memorandum Report No. 93, *A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report*, March 1995, provides a comprehensive restatement of the regional water quality management plan as amended. The plan status report reflects implementation actions taken and plan amendments adopted since the initial plan was completed. The status report also documents, as available data permitted, the extent of progress which had been made toward meeting the water use objectives and supporting water quality standards set forth in the regional water quality management plan.

All of the regional water quality management planning efforts were conducted using the watershed as the primary planning unit. In addition to providing clear and concise recommendations for the control of water pollution, the adopted areawide plan provides the basis for the continued eligibility of local units of government for Federal and State grants and loans in partial support of sewerage system development and redevelopment, for the issuance of waste discharge permits by the WDNR, for the review and approval of public sanitary sewer extensions by that Department, and for the review and approval of private sanitary sewer extensions and large onsite sewage disposal systems and holding tanks by the Wisconsin Department of Commerce. The WDNR also permits large farm animal operations. However, these permits are not directly related to the regional water quality plan recommendations.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES BASIN PLANNING

The WDNR conducts program management and planning for the Milwaukee River basin, comprised of the Kinnickinnic, Menomonee, and Milwaukee River watersheds and for the Root-Pike basin, which includes the Root River and Oak Creek watersheds, as well as the Pike River watershed. The Department has prepared state-of-the-basin plans for each basin.¹² These plans include resource management recommendations related to the WDNR programmatic activities, including surface water use objectives (classifications), sewerage system management, and related water resources programs. The regional water quality management plan updating program includes review, coordination, and a specific plan implementation strategy for integrating the current regional planning with the WDNR basin planning.

MILWAUKEE METROPOLITAN SEWERAGE DISTRICT FACILITY PLANNING

The MMSD is a special-purpose unit of government directed by an appointed Commission. The MMSD includes all of Milwaukee County, except the City of South Milwaukee and portions of the City of Franklin. In addition, sewage conveyance and treatment services are provided to portions of Ozaukee, Racine, Washington, and Waukesha Counties. The District, which exists pursuant to the provisions of Section 200.23 of the *Wisconsin Statutes*, has a number of important responsibilities in the area of water resources management, including the provision of floodland management programs for most of the major streams within the District and the collection, transmission, and treatment of domestic, industrial, and other sanitary sewage generated within the District and its contract service areas.

During 2002, the MMSD initiated work on a third-generation sewerage facilities planning effort. This effort is responsive to a court-ordered stipulation requiring the facilities plan to be completed by June 30, 2007, and is consistent with Section 201 of the Federal Clean Water Act. As the facilities planning program was conceptualized, the MMSD proposed to utilize the watershed approach to plan development consistent with evolving USEPA policies. That approach was further defined to be conducted cooperatively with a coordinated and integrated comprehensive regional water quality management planning effort. Such an approach is sound public planning practice, as well as being consistent with the requirements of Section 208 of the Federal Clean Water Act and evolving USEPA facilities planning guidance.

¹²*Wisconsin Department of Natural Resources Publication No. PUBL WT 704-2001*, op. cit.; *Wisconsin Department of Natural Resources Publication No. PUBL WT-700-2002*, op. cit.

As previously noted, a cooperative approach to carrying out the MMSD facilities planning program and the regional water quality management plan update program has been developed by the WDNR, the MMSD, and the SEWRPC.

PURPOSE OF REPORT

Reliable engineering and planning data available on a uniform, areawide basis are essential to the formulation of watershed water resources management plans. This report documents current objectives and historic and existing conditions to provide a factual basis for updating the regional water quality management plan for the study area described above. To accomplish this, this report documents current water use objectives and supporting standards, describes existing water quality, sediment quality, and biological conditions, documents water quality trends, and identifies factors causing impairments or degradation to water quality. The inventories and analyses contained within this report will serve as a basis for developing elements of the update to the regional water quality management plan, including the point source pollution abatement and nonpoint source pollution abatement elements.

SCHEME OF PRESENTATION

The major findings of the regional water quality management planning study for the greater Milwaukee watersheds, Milwaukee Harbor, estuary, and the associated nearshore portions of Lake Michigan are presented in the planning report that documents the water quality management plan update.¹³ This report complements the planning report and sets forth the basic concepts underlying the study and the factual findings of the extensive inventories and analyses conducted under the study. Toward these ends, the remainder of this report has been organized as follows: Chapter II, “Water Quality Definitions and Issues,” provides an overview of technical issues related to water quality; Chapter III, “Data Sources and Methods of Analysis,” describes the data sources and analytical procedures used to characterize the state of water quality and to evaluate the degree to which water use objectives are being met in the waters of the study area; Chapter IV, “Water Use Objectives and Water Quality Standards,” describes the regulatory setting and recommended water use objective and supporting water quality standards for the waters of the study area; Chapters V through X, “Surface Water Quality Conditions and Sources of Pollution,” in each of the six watersheds, present inventories and analyses of historic and existing water quality, sediment quality, and biological conditions, inventories of sources of water pollution, and describe riparian corridor conditions for each of the watersheds in the study area and for the Milwaukee Harbor Estuary and adjacent nearshore Lake Michigan Area; Chapter XI, “Groundwater Quality Conditions and Sources of Pollution in the Study Area,” presents inventories and analyses for groundwater resources in the study area; and Chapter XII, “Summary and Conclusions,” provides a summary of the information presented in this report.

¹³*SEWRPC Planning Report No. 50, op. cit.*