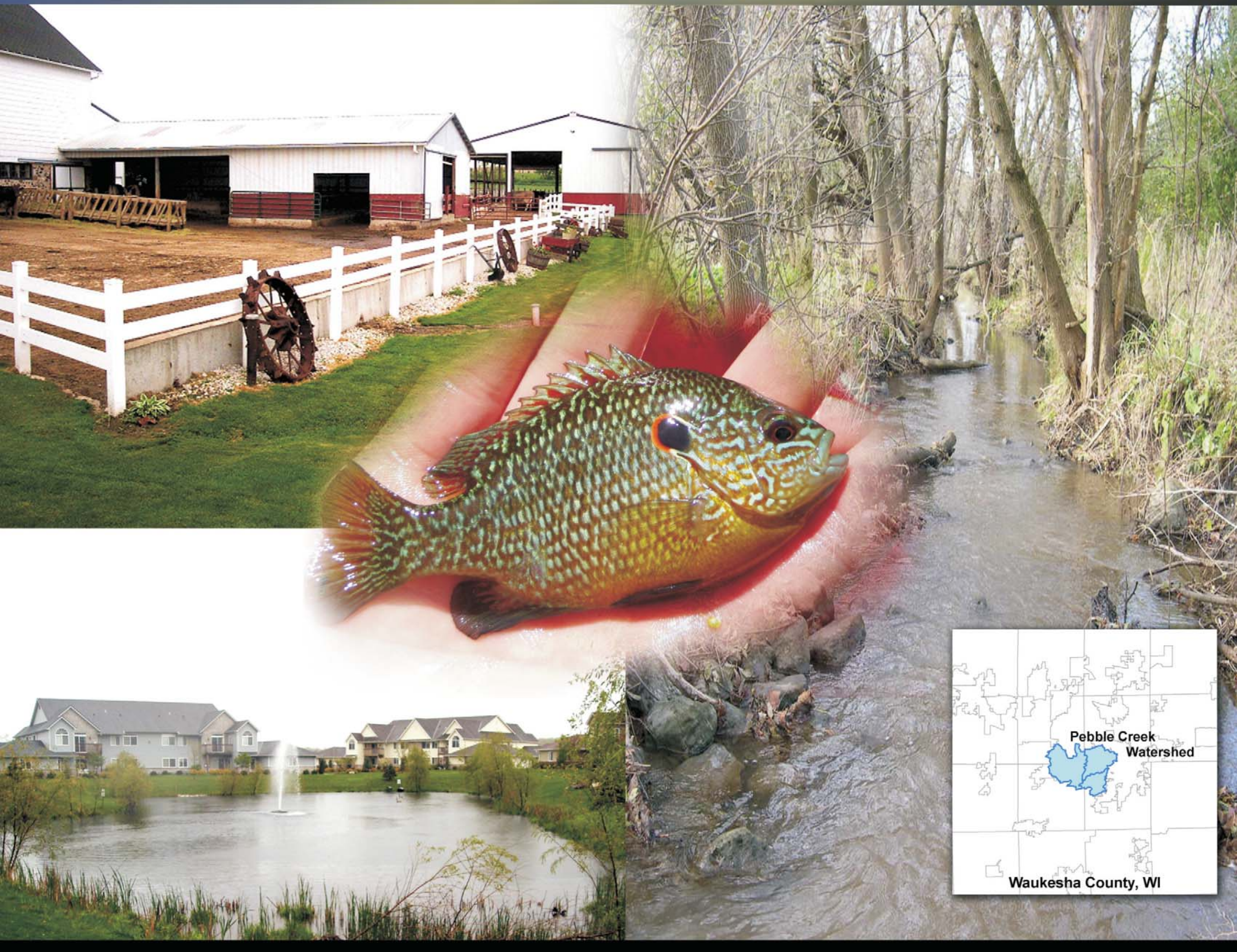
Community Assistance
Planning Report No. 284

Waukesha County
Wisconsin

Pebble Creek Watershed Protection Plan

Part One



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WATERSHED PROTECTION PLAN REPORT

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COMMUNITY ASSISTANCE PLANNING REPORT
NUMBER 284

PEBBLE CREEK WATERSHED PROTECTION PLAN WAUKESHA COUNTY, WISCONSIN

Part One

Prepared by the

Waukesha County Department of Parks and Land Use
and the
Southeastern Wisconsin Regional Planning Commission

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TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

Figure		Page

Chapter V

LIST OF MAPS

Map		Page

Chapter I

Chapter II

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EXECUTIVE SUMMARY

Pebble Creek, Brandy Brook, their tributaries, and associated wetlands constitute a unique cold and warmwater resource within a biologically diverse 18-square-mile watershed located in central Waukesha County, within the Cities of Pewaukee and Waukesha; the Village of Wales; and the Towns of Delafield, Genesee, and Waukesha. From the early 1900s to the 1980s, the most significant factors impacting the Pebble Creek system were nutrient loading and sedimentation from cropland and barnyard runoff, stream channelization, and the draining of wetlands for agricultural uses. In recent years, construction site erosion and stormwater discharges from urban development have also become significant pollution concerns. As a result, the stream system is showing signs of distress and degradation. The purpose of this plan is to provide a framework for communities in the area, and Waukesha County, to work together—*to protect and improve the water resources of Pebble Creek through the use and management of the watershed.*

The four major goals identified by the Pebble Creek Watershed Advisory Committee include:

- Protect and improve surface water and groundwater quality and aquatic life throughout the watershed.
- Control urban runoff pollution and flooding.
- Encourage the continuation of agricultural uses and control pollution from agricultural runoff.
- Educate the public about conservation issues and watershed protection.

KEY FINDINGS

While agricultural practices had the greatest impact on the Pebble Creek system in previous decades, that system is now most threatened by existing and planned urban development in the watershed. The level of human disturbance has significantly increased in recent years as historically agricultural lands have been converted to residential, commercial, and transportation uses. Under planned land use conditions, and in the absence of mitigating actions, stresses to the water resources of the study area will continue and potentially accelerate. A combination of good planning, stream restoration, and land management practices are needed to prevent further degradation of the stream and its associated riparian wetlands to achieve the following: improve water quality; reduce fragmentation and loss of natural areas; preserve and enhance wildlife habitat and species diversity; reduce existing flood damage and avoid increasing future damage; preserve the aesthetic value of the landscape; and maintain property values and quality of life. Doing nothing in this watershed is not an option if the stated goals of this plan are to be achieved. These are the prime motivations for the management actions presented in detail in Chapter V of this plan.

SELECTED PRINCIPAL PLAN RECOMMENDATIONS

Preserve and protect remaining high-quality environmentally sensitive areas. These are identified and delineated in Chapter V of this report and include designated natural areas, wetlands, fish and wildlife habitat, riparian buffers, and primary and secondary environmental corridors. Preservation and protection are to be accomplished through a combination of sound planning; ordinance development, refinement, and implementation; land purchase; sound land management; and effective educational programming.

- Local communities should endorse this plan as the first step in plan implementation.
- Local communities should review, update, and implement zoning standards to ensure preservation of targeted lands including wetlands, shorelands, and floodlands through ordinance enforcement.
- Landowners should be encouraged to adopt and utilize good housekeeping and land management practices, such as preserving and maintaining riparian buffers, planting rain gardens, implementing nutrient and pest management plans in both urban and agricultural areas, and participating in ongoing watershed activities such as volunteer water quality monitoring and storm sewer stenciling.
- County, local government, and citizen groups should restore, enhance, and/or rehabilitate stream channels to provide increased quality and quantity of available fisheries habitat. Appropriate management measures include: removal of trash and debris, and obstructions to flow; stabilize eroding banks; reconnect the stream to its floodplain; re-establish natural meandering stream channels; improve fish passage through removal or replacement of culverts and crossings; and minimize the number of new stream crossings.

Adopt and install stormwater and floodwater best management practices in urbanizing and urbanized areas. One of the most significant changes in this watershed in recent years has been the conversion of lands into urban uses as described in Chapter II of this report. Such changes in land use have resulted in modification of the hydrology and hydraulics of the stream system resulting in increased runoff volumes, streambank and channel erosion, sedimentation, and flooding. In addition to periodic review and update of ordinances and stormwater management plans and practices, local communities should install and maintain stormwater treatment facilities and increase infiltration where appropriate.

- Evaluate existing stormwater management facilities to determine the feasibility for retrofits to improve their effectiveness.
- Protect water resources when adding, improving and upgrading urban infrastructure, such as proposed sewer extensions and the completion of the CTH TT/STH 59 bypass.
- Coordinate activities for stormwater management and construction site erosion control throughout the watershed. Consider intergovernmental agreements and the formation of stormwater utility districts to improve the effectiveness of community efforts.
- Maximize stormwater infiltration and ensure adequate pretreatment to recharge and protect groundwater and maintain stream baseflows.
- Update local floodplain and stormwater ordinances to incorporate new data and discharge standards to be published in Part 2 of this report.

Adopt and install agricultural best management practices. Agricultural activities remain a significant component of the land use within this watershed as described in Chapter II of this report. These lands are largely located in the Towns of Genesee and Delafield portion of the watershed. There is also an active Drainage District in the center of the watershed, where the stream system has been subjected to significant channelization and riparian buffer loss. Consequently, these areas provide limited fisheries and wildlife habitats and the stream channel is too wide and overly deepened.

- Update land use plans and use zoning and other regulatory tools to preserve productive farmland and agricultural businesses. Consider the delineation of an Agricultural Enterprise Area and the use of purchase of development rights (PDR) or transfer of development rights (TDR) programs.
- Install permanent vegetative buffers along perennial, intermittent, and ephemeral waterways in accordance with WDNR and NRCS technical standards for filter strips where cropland or livestock pastures lie within 75 feet of the stream channel.
- Limit the number of stream crossings and configure any such crossings to minimize the fragmentation of stream habitat.
- Implement state nonpoint pollution performance standards and prohibitions on farmland within the watershed. Provide educational and technical assistance and secure cost-sharing needed to bring landowners into compliance.

Implement a watershedwide information and education program including monitoring and evaluation of management actions. Retzer Nature Center, which is centrally located within the watershed, is a logical focal point for these efforts. These activities should be integrated into County and local government initiatives and formal school-based and informal volunteer-based programs. All of these actions should be part of and fully integrated into the management measures described above.

CONCLUSION

This Watershed Protection Plan is designed to assist municipalities in protecting and improving the water resources of Pebble Creek and preserving sensitive habitats within the watershed. Future land use changes in the watershed are inevitable. How those changes impact the natural resources of Pebble Creek largely depends on local policy decisions. The actions recommended in this plan represent an extension of many ongoing program efforts and the refinement of others. Updating related plans, performance standards, and ordinances within the watershed, coupled with effective plan implementation, enforcement, monitoring and educational programs will contribute to enhanced and long-term protection of this valuable resource.

Chapter I

INTRODUCTION

PURPOSE OF THE PLAN

Research shows that the health of a stream is usually a direct reflection of the use and management of the land within its watershed. Pebble Creek, Brandy Brook, their tributaries, and associated wetlands are a unique cold and warmwater resource with a biologically diverse watershed located in the center of Waukesha County, located in southeastern Wisconsin (Map 1) that is showing signs of degradation. The purpose of this plan is to provide a framework for communities in the area to work together with a common goal—to protect and improve the water resources of Pebble Creek through the use and management of its watershed.

Wisconsin has been a leader in developing and implementing watershed-based plans aimed at abating water pollution from point and nonpoint sources. This watershed protection plan goes beyond pollution abatement by also focusing on what can be done to *prevent* future water pollution or resource degradation from occurring—and to *improve* on the existing resources where they are already suffering. This plan complements other existing programs and management actions in the Pebble Creek watershed and represents an ongoing commitment from government agencies and municipalities to diligent land use planning and natural resource protection. This plan presents appropriate and feasible watershed management recommendations for enhancing and preserving the water quality of Pebble Creek and Brandy Brook and for providing the public with opportunities for safe and enjoyable recreation within the Pebble Creek watershed.

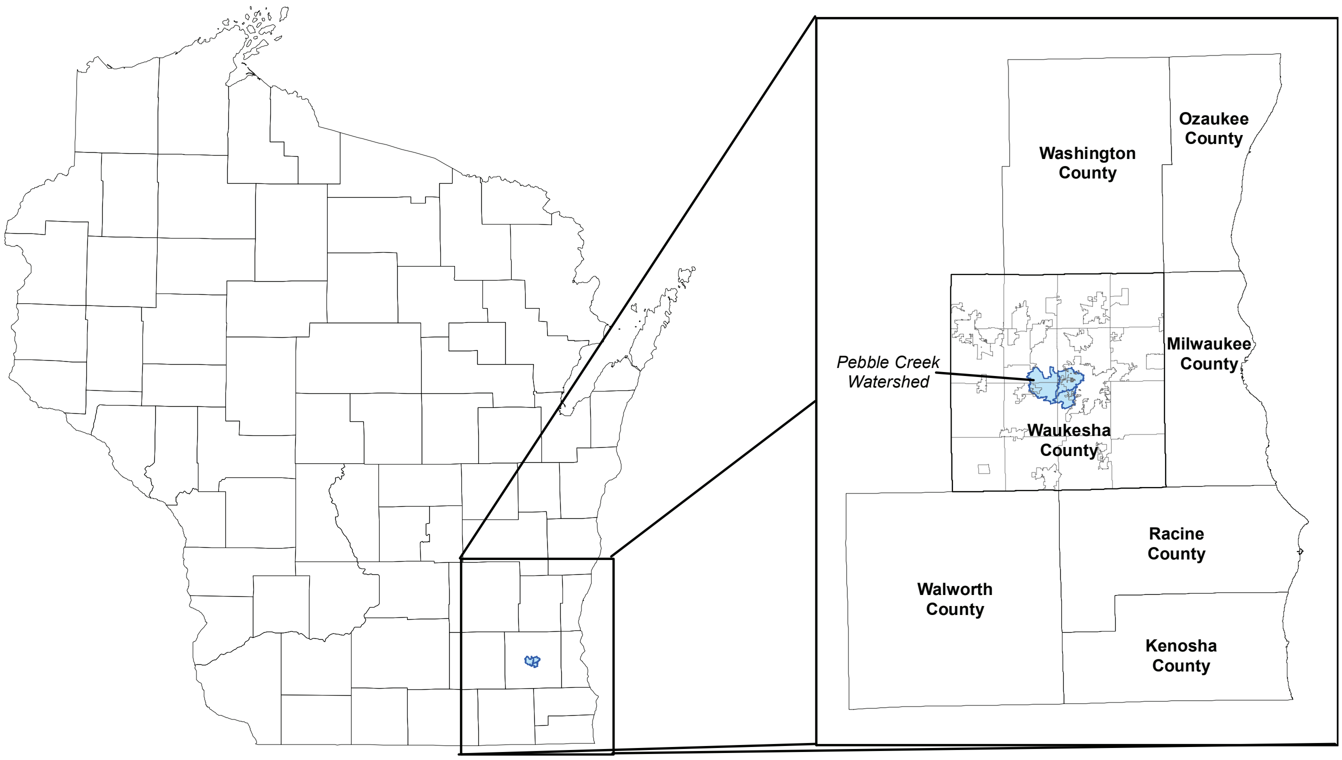
The Pebble Creek Watershed Protection Plan is designed to assist municipalities in developing strategies that will benefit the natural assets of Pebble Creek and protect sensitive habitats within the watershed. By using the planning strategies outlined in this plan, results will be achieved that enrich and preserve the natural environment. In addition, carefully planned urban development can create and maintain open space, groundwater recharge areas, and wildlife corridors for the benefit of Pebble Creek and the residents of the watershed. This protection plan should serve as a practical guide for the management of the water quality within the Pebble Creek watershed and for the management of the land surfaces that drain directly and indirectly to this body of water.

PLANNING PROCESS

The Waukesha County Department of Parks and Land Use, Land Resources Division (LRD), and the Southeastern Wisconsin Regional Planning Commission (SEWRPC) prepared this plan in cooperation with representatives from the Pebble Creek Watershed Protection Advisory Committee (see Appendix A). The Advisory Committee was assembled by the LRD and represents the diversity of interests and perspectives that affect the watershed, including farmers, developers, and environmental groups; the LRD; the Towns of Delafield, Genesee, and Waukesha; the Village of Wales; the Cities of Pewaukee and Waukesha; the Wisconsin Department of Natural Resources (WDNR); the Natural Resources Conservation Service (NRCS), and SEWRPC. During

Map 1

LOCATION OF THE PEBBLE CREEK WATERSHED STUDY AREA



Source: SEWRPC.

2006, the Advisory Committee met several times to define issues, develop goals, and established recommendations that would help manage local community growth while protecting the natural resources in the Pebble Creek watershed. It is important to note that the Advisory Committee devoted much time and thought to the development of the plan goals, which form the foundation for generating and evaluating the alternative and recommended plans and for implementing the recommendations. The Advisory Committee adopted the following general goals for the plan:

- Protect and improve surface water and groundwater quality and aquatic life throughout the watershed,
- Control urban runoff pollution and flooding,
- Encourage the continuation of agricultural uses and control pollution from agricultural runoff, and
- Educate the public about conservation issues and watershed protection.

Chapter V of this plan elaborates on each of these planning goals by outlining more-specific objectives and action items recommended to accomplish the goal. These were also derived from discussions with the Advisory Committee throughout the planning process.

This plan represents one component of implementation of the Waukesha County Land and Water Resource Management Plan's goal to protect and improve the natural resources of the County by applying a watershed protection planning approach.[1] The development of this plan was funded through a grant from the WDNR under Chapter NR 155 *Wisconsin Administrative Code*.

BACKGROUND

Pebble Creek and its major tributaries are a unique water resource located in central Waukesha County, within the Cities of Pewaukee and Waukesha; the Towns of Delafield, Genesee, and Waukesha; and the Village of Wales (Map 2). The system is a high-quality cold and warmwater stream system, sustained by groundwater recharge, seepage from wetlands and moraines, and precipitation runoff from about an 18-square-mile watershed. Pebble Creek discharges into the Fox River in the Town of Waukesha.

Pebble Creek has unique aesthetic value. The majority of the stream and adjacent riparian corridors exhibit a rural character within a rapidly urbanizing watershed. Recreational opportunities are also present within and adjacent to Pebble Creek. Utilized for fishing, wading, canoeing (lower sections) and wildlife watching, it provides ecological and recreational benefits for adjacent landowners and other users. In addition, the Retzer Nature Center and the Glacial Drumlin Trail offer enhanced educational and outdoor recreational opportunities.

Pebble Creek has been designated to potentially support a coldwater Class I and II brook and brown trout fishery extending from CTH D upstream to Upper Pebble Creek and Brandy Brook. Brook trout have never been recorded in this watershed. However, mottled sculpin, a coldwater indicator species, has been a significant component of the fishery community in the headwaters of this river system. Since the mid 1990s, the WDNR has annually stocked brown trout (Figure 1) at CTH TT and the trout have responded well to this effort. While the upper portions of the watershed contain coldwater species, the lower portions extending from CTH D to the confluence with the Fox River contain northern pike (Figure 2) among several other high-quality warmwater species. One of the key elements for the high-quality fishery is Pebble Creek's connection with the Upper Fox River (see Map 3). This connection likely functions as a seasonal refuge and source population for fish species in Pebble Creek,[2] because the Fox River contains a high abundance and diversity of warmwater fishes.

Limited aquatic habitat, sedimentation, and water quality, as related to dissolved oxygen content and water temperature, may continue to limit the maintenance and potential development of a high-quality coldwater sport fishery in the upper portion of this watershed and warmwater fishery in the lower portion. Generally, these limitations are related to urbanization within the watershed. From the early 1900s to 1980s, the most significant factors impairing the Pebble Creek system were nutrient loading and sedimentation from cropland and barnyard runoff, streambank erosion and streambed scour associated with stream channel straightening and modification, and the draining and/or filling of wetlands. More recently, construction site erosion and stormwater discharge from urban development have also become a significant pollution concern in the watershed. Urbanization increases the amount of impervious surfaces that contribute nonpoint source pollution (Figure 3) and in the past may have led to the loss of wetlands and natural riparian corridors. Increased impervious area may also reduce the potential for groundwater recharge, depending on its location in the watershed.

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[1] *Waukesha County Department of Parks and Land Use-Land Resources Division,* Waukesha County Land and Water Resources Management Plan: 2006-2010*, March 2006. The County land use plan is being updated under the ongoing comprehensive land use planning program and is scheduled for completion in 2008. That plan will present more detail than the regional land use plan, as set forth in SEWRPC Planning Report No. 48,* A Regional Land Use Plan for Southeastern Wisconsin: 2035*, June 2006.*

[2] *L.L. Osborne, and M.J. Wiley, "Influence of tributary spatial position on the structure of warmwater fish communities,"* Canadian Journal of Fisheries and Aquatic Sciences*, Volume 49, 1992, pp. 671-681.*

Map 2

CIVIL DIVISIONS WITHIN THE PEBBLE CREEK WATERSHED: 2006

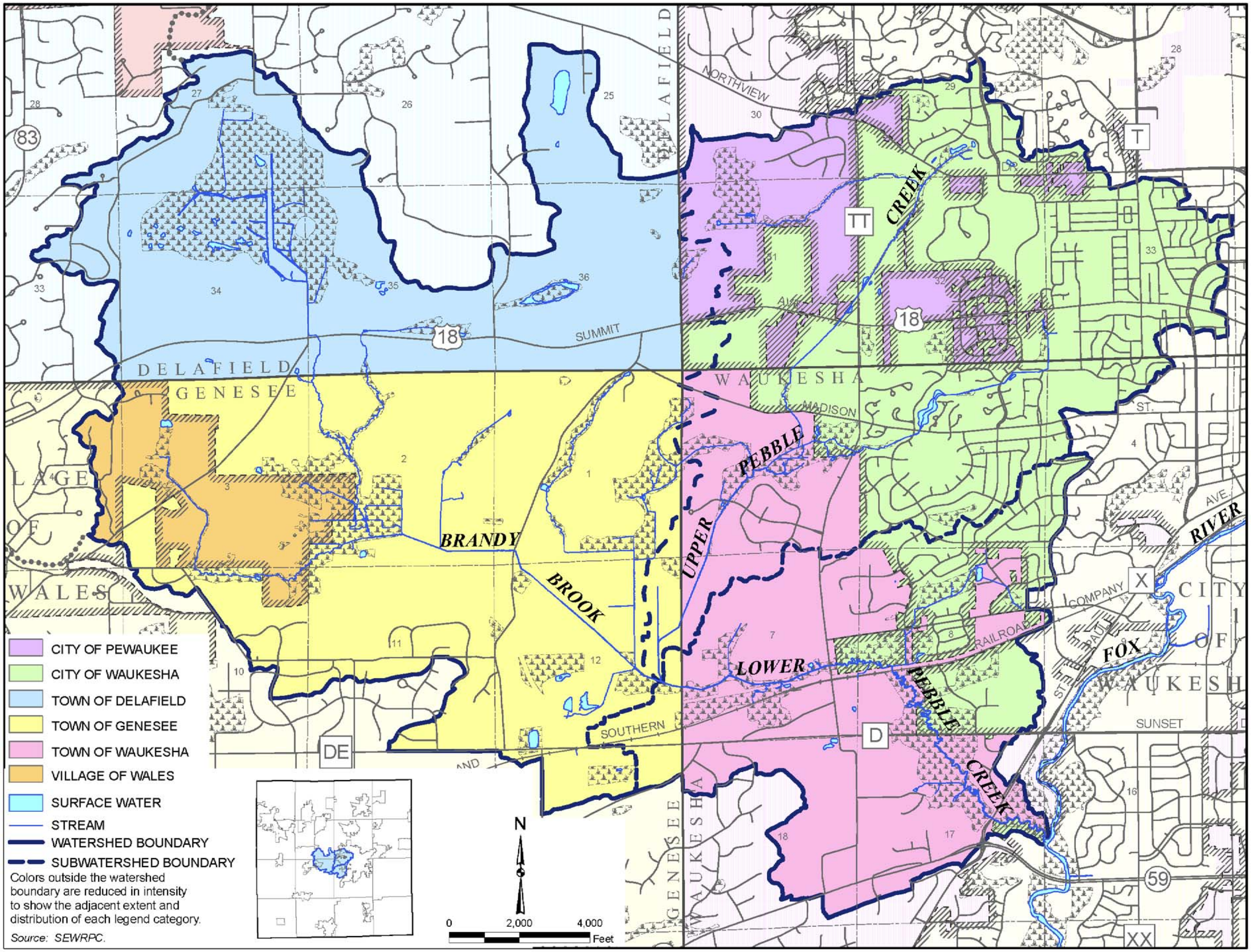

Figure 1

BROWN TROUT
(STOCKED COLDWATER GAMEFISH SPECIES)

Source: SEWRPC.

Figure 2

NORTHERN PIKE
(NATIVE WARMWATER GAMEFISH SPECIES)

Source: SEWRPC.

Riparian corridors help protect water quality, offer ecological and aesthetic benefits for recreational enjoyment, and provide the opportunity to protect and restore critical habitat for fish and wildlife (Figure 4). It is important to note that urban and agricultural encroachment into the riparian corridors has occurred in multiple areas throughout this watershed (Figure 5). This encroachment limits the ability of these buffers to filter out nutrients and sediments critical to protecting water quality, and reduces the quality of the buffer areas for fish and wildlife habitat.

PLAN FORMAT AND ORGANIZATION

This document is part one of a two part plan that incorporates land and stream management data and analyses compiled by the following sources: the WDNR Priority Watershed Project and State of the Basin Reports;[3] Harmony Homes, Inc.; and the Southeast Wisconsin Fox River Partnership Citizen Stream Monitoring Program.[4] In addition, this plan incorporates water quality and fishery data collected by the WDNR, Waukesha County Department of Parks and Land Use, and SEWRPC.

This report is divided into six chapters. Following this initial introductory chapter, the second chapter presents information on the natural and man-made features of the watershed, including a description of the natural resource base and environmentally sensitive areas, land use data, population demographics, and limitations to development. Chapter III briefly describes State and local plans, regulations, and programs that are related to the

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[3]*Wisconsin Department of Natural Resources, Publication No. PUBL-WR-255-90,* Nonpoint Source Control Plan for the Upper Fox River Priority Watershed Project*, June 1994; Wisconsin Department of Natural Resources,* Water Resource Appraisal Report and Stream Classification for the Upper Fox River Watershed, Upper Fox River Basin*, 1990; and Wisconsin Department of Natural Resources, Publication No. PUBL-WT-701-2002,* The State of the Southeast Fox River Basin*, February 2002.*

[4]*Mike Johnson, "Citizens Wade into Water Monitoring," Milwaukee Journal Sentinel, June 11, 2006; and Wisconsin's Water Action Volunteer website:* http://clean-water.uwex.edu/wav/*, last updated January 2006.*

Map 3

SURFACE WATER RESOURCES WITHIN THE PEBBLE CREEK WATERSHED: 2005

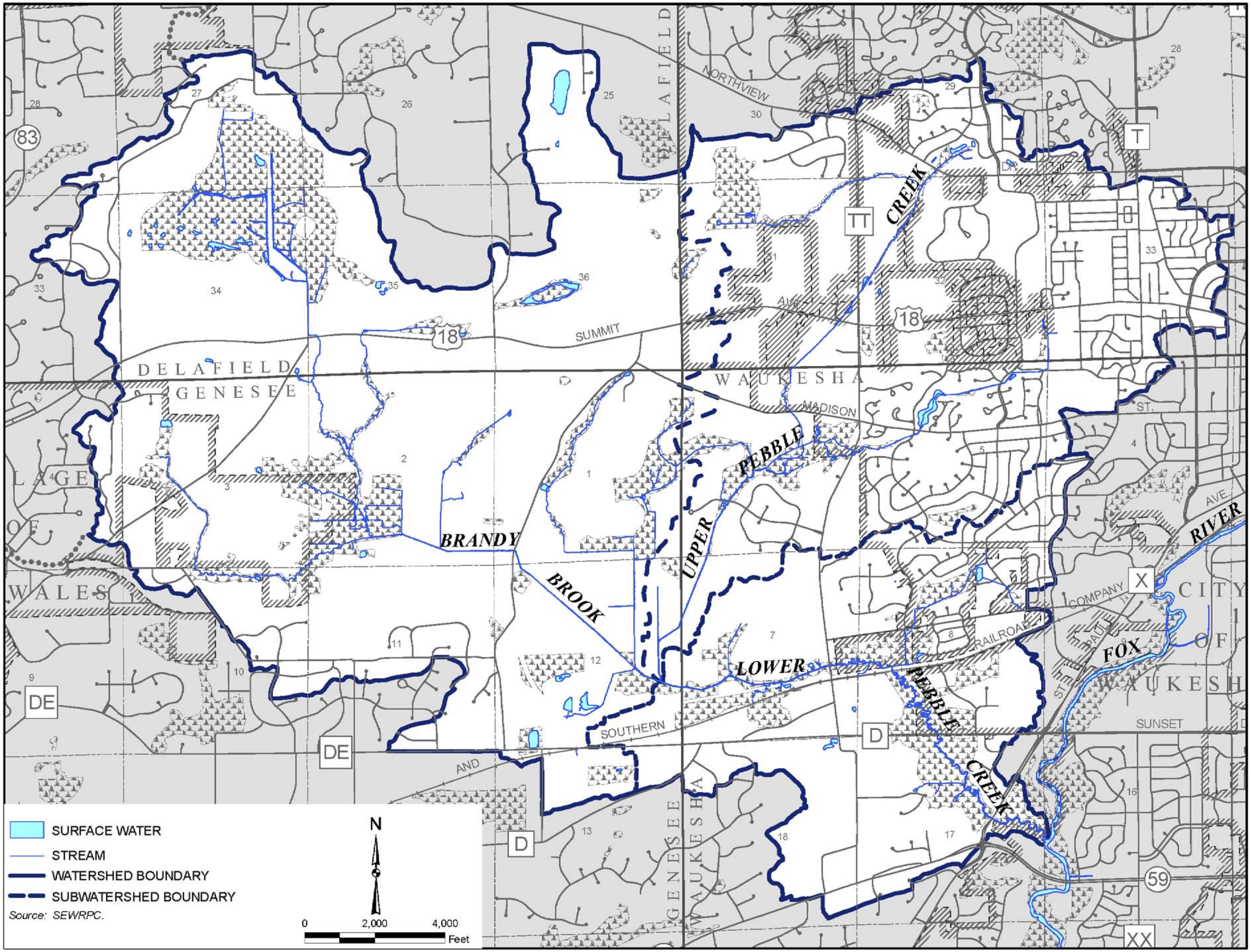


Figure 3

OIL, GREASE, AND SEDIMENT RUNOFF FROM IMPERVIOUS SURFACES TO STORM SEWERS, WHICH DRAIN INTO SURFACE WATERS

Source: Wisconsin Department of Natural Resources.

Figure 4

VEGETATIVE BUFFERS IN THE LOWER REACHES OF PEBBLE CREEK ABOUT 200 FEET DOWNSTREAM OF CTH X

Source: SEWRPC.

Figure 5

VEGETATIVE BUFFERS IN THE UPPER REACHES OF BRANDY BROOK ABOUT 200 FEET UPSTREAM OF CTH DT

Source: SEWRPC.

watershed protection plan. Chapter IV summarizes the physical conditions of the stream system, existing surface water quality, habitat and biological conditions in the Pebble Creek watershed. Chapters V and VI include the goals, objectives, alternative and recommended plan elements, and implementation steps to address the identified issues and problems of the watershed. These chapters contain recommendations regarding outreach and education, the methods of program performance review, and a summary of the estimated costs of plan implementation.

Part two of this Pebble Creek Watershed Protection Plan series will include a floodplain study and unit peak discharge analysis for the Pebble Creek watershed. More specifically, it will describe recent analyses for developing floodplain delineations along Pebble Creek and Brandy Brook under planned buildout conditions; place those analyses in context relative to County and local floodplain and stormwater management ordinances; address control of streambank erosion from a watershed perspective; and present, or reiterate, recommendations regarding ordinances and future planning work related to floodplain and streambank erosion issues. Finally, the report also sets forth the procedures for establishing the recommended stormwater management approach to limiting peak rates of runoff from areas of new development during storms with recurrence intervals ranging from two through 100 years.

Chapter II

NATURAL AND MAN-MADE FEATURES OF THE WATERSHED

INTRODUCTION

Information on natural and man-made features of the study area is essential to sound planning for water quality, stormwater management, and floodland management. Watershed topography and local hydrology influence rates and volumes of runoff, affecting instream water quality, the composition of plant and fish communities, and flooding conditions. Water pollution problems and their solutions are primarily a function of the human activities within a watershed, and of the ability of the natural resource base to sustain those activities. Streams are highly susceptible to water quality degradation due to human activities within the watershed which can interfere with desired water uses, and which is often difficult and costly to correct. Accordingly, the land uses and population levels in the watershed are important considerations in stream water quality and stormwater management.

LAND USE

Soil erosion problems, water pollution problems, recreational use conflicts, and the risk of damage to the environment, as well as the ultimate means for abatement of these problems, are primarily a function of human activities within the Pebble Creek watershed, and of the ability of the underlying natural resource base to sustain those activities. This becomes especially significant in areas that are in close proximity to lakes, wetlands, and rivers and streams.

Civil Divisions

Superimposed on the watershed boundary is a pattern of local political boundaries. As shown on Map 3 in Chapter I of this report, the watershed lies in central Waukesha County. A total of six civil divisions lie partially within the Pebble Creek watershed, as shown on Map 2 in Chapter I of this report and listed in Table 1. Geographic boundaries of the civil divisions are an important factor which must be considered in the watershed protection plan since the civil divisions form the basic foundation of the public decision making framework within which intergovernmental, environmental, and developmental problems must be addressed. The governmental units within the Pebble Creek watershed include portions of the Cities of Pewaukee and Waukesha, the Village of Wales, and the Towns of Delafield, Genesee, and Waukesha. The area and proportion of the watershed within the jurisdiction of each civil division is set forth in Table 1.

Historic Urban Growth

The type, intensity, and spatial distribution of land uses within Pebble Creek watershed are important elements in natural resource management. In this regard, the current and planned future land use patterns, placed in the context of the historical development of the area, are important considerations in developing and implementing this plan.

Table 1

AREAL EXTENT OF COUNTIES, CITIES, VILLAGES, AND TOWNS WITHIN THE PEBBLE CREEK WATERSHED

Civil Division	Area (acres)	Percent of Total
Waukesha		
City of Pewaukee	742.4	6.5
City of Waukesha	2,828.8	24.8
Town of Delafield	2,406.4	21.1
Town of Genesee	2,950.4	25.9
Town of Waukesha	1,913.6	16.8
Village of Wales	550.4	4.8
Total	11,392.0	100.0

Source: SEWRPC.

The historic urban growth within the Pebble Creek watershed is summarized on Map 4 and in Figure 6. Since 1970, much, though not all, of the urban growth in the watershed has occurred in the eastern half of the watershed. Comparison of 2000 and 2005 conditions indicates that most of the development in the 1996-2005 time period occurred at the outer perimeter of the watershed.

Population and Households

The Pebble Creek watershed generally experienced stable growth in population and number of households from 1963 to 2000 as shown in Figure 7. Over time, population and number of households in the watershed have grown at about the same rate as population and households on a countywide basis. The resident population approximated 7,032 persons in 1963. Since then, the Pebble Creek watershed has steadily continued to increase in population, with the greatest percentage of increase occurring between the years of 1970 and 1980. As of 2000, there were approximately 15,900 individuals residing in the watershed. The number of resident households has also continued to increase, although at a slower rate than the population. As of 2000, there were about 8,400 households in the watershed. Based upon the adopted regional land use plan, the population in the Pebble Creek watershed is projected to increase through the year 2035 by about 36 percent, while the number of resident households in the watershed is projected to increase by about 45 percent.

Existing and Planned Land Use

This section characterizes existing land use conditions as of the year 2005, describes changes in land use which have occurred within the Pebble Creek watershed since 2000, and examines changes anticipated to occur through 2035. Table 2 sets forth land use data for the entire Pebble Creek watershed for 2000, 2005, and planned year 2035 conditions. An apportionment of that land use data by subwatershed is provided in Appendix B. The data in Table 2 and shown on Map 5, indicate that, although a large portion of this watershed is urbanized, about 59 percent is still in rural and other open space land uses. The remaining approximately 41 percent of the watershed area was in urban uses.

Urban Land Use

As indicated in Table 2, in 2005, urban land uses, which include residential, commercial, industrial, governmental, transportation, communication, utilities, and recreational lands, encompassed approximately 41 percent of the total watershed area. Residential land uses comprised the largest urban land use, covering about 2,960 acres, or about 25 percent of the total watershed. While urban development exists throughout much of the Pebble Creek watershed, it is especially concentrated in the eastern portion of the watershed in the Cities of Pewaukee and Waukesha and the Town of Waukesha. Between 2000 and 2005 about 760 acres (1.2 square miles) were converted from rural to urban uses. Under planned 2035 land use conditions, about 6,850 acres, or 60 percent of

Map 4

HISTORIC URBAN GROWTH WITHIN THE PEBBLE CREEK WATERSHED: 2005

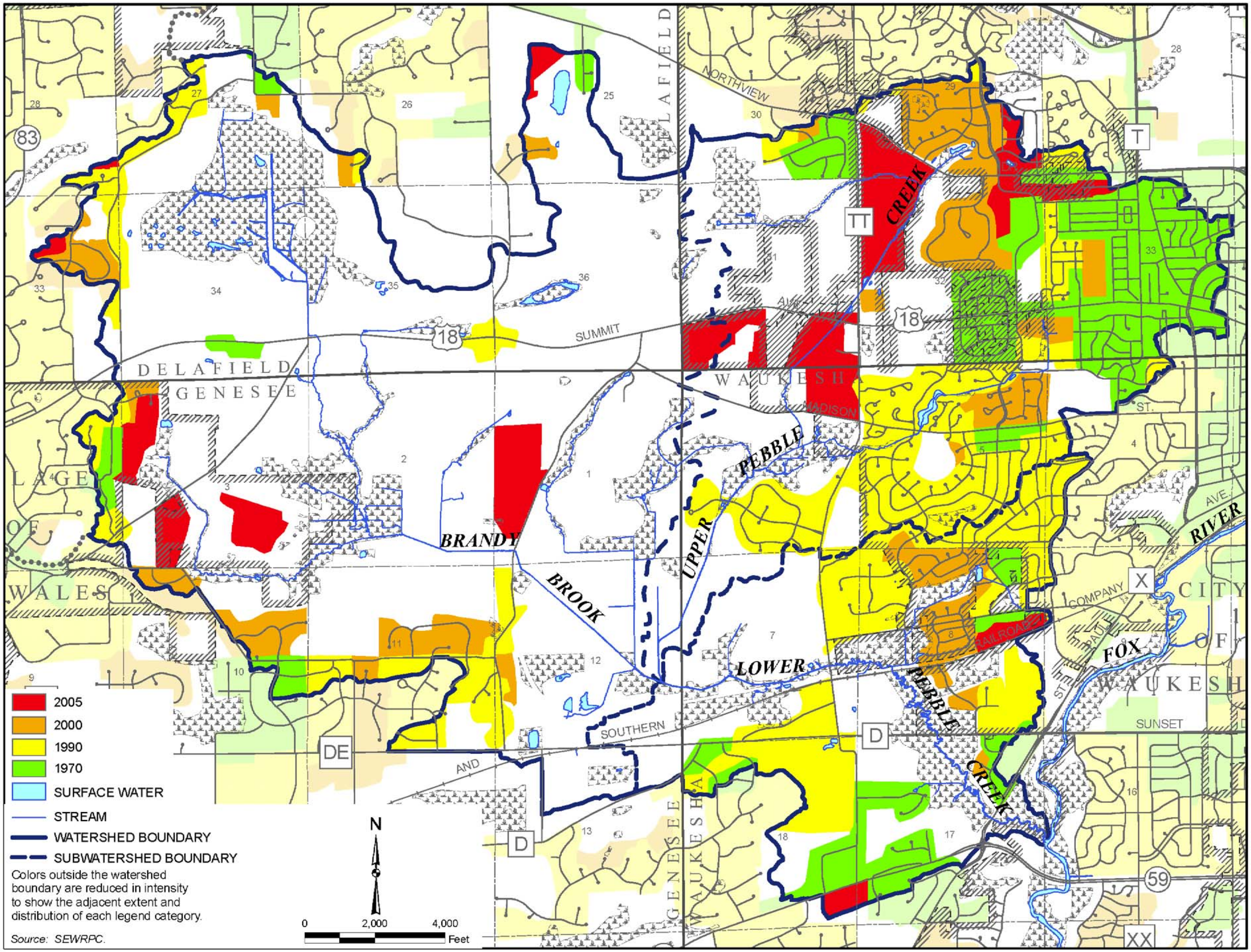
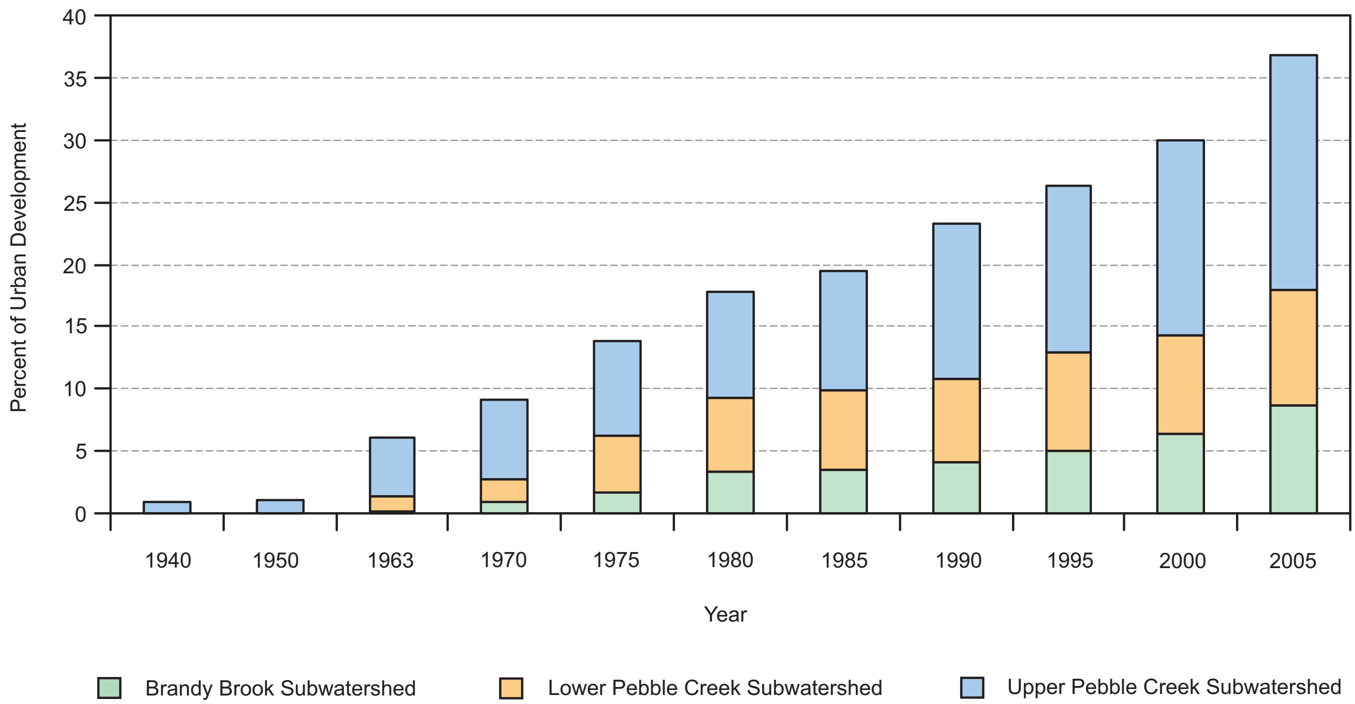


Figure 6

CUMULATIVE EXTENT OF URBAN DEVELOPMENT IN THE PEBBLE CREEK WATERSHED: 1940-2000



Source: SEWRPC.

the watershed, are anticipated to be in urban land uses.[1] Residential development is anticipated to comprise the majority of the increase in urban land use. Map 6 shows the recommended land use for the watershed, including an increase of about 1,480 acres of residential lands. Much of this is recommended at low densities.[2] Under State administrative rules, sanitary sewers may be extended only to areas located within planned sanitary sewer service areas identified in local sanitary sewer service area plans adopted as part of the Commission's regional water quality management plan, which is in turn based upon the regional land use plan. Sewer service area plans are long-range plans intended to guide the provision of sanitary sewer service over a 20-year period. Sewer service area plans are prepared through a cooperative planning process involving the local unit of government responsible for operation of the sewage treatment facility, the Regional Planning Commission, and the Wisconsin Department of Natural Resources (WDNR). Such plans may be amended in response to changing local conditions and needs, as well as in response to new population projections, subject to the provisions of *Wisconsin Administrative Code* Chapter NR 121. The planned incremental development through the year 2035 is generally located within currently adopted sanitary sewer service areas in the watershed as shown on Map 7.

Urban development would be accommodated within the areas identified on Map 6 as commercial; industrial; governmental; and high-, medium-, and low-density single-family residential areas. With the exception of some outlying low- and suburban-density enclaves, these areas are generally located within adopted sanitary sewer service areas.

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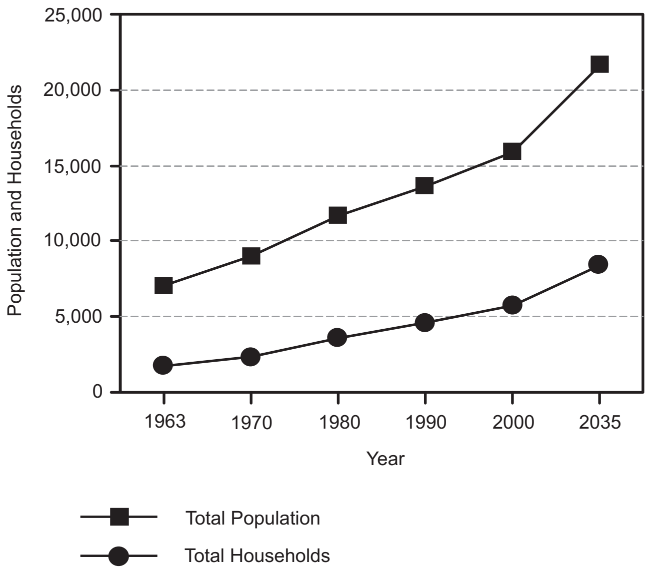
[1]*SEWRPC Planning Report No. 48,* A Regional Land Use Plan for Southeastern Wisconsin: 2035*, June 2006.*

[2]*Low-density is defined as 0.7 to 2.2 dwelling units per net residential acre (0.45- to 1.43-acre lots and single-family farm residences).*

Figure 7

TOTAL POPULATION AND NUMBER OF HOUSEHOLDS IN THE PEBBLE CREEK WATERSHED: 1963-2035



Source: SEWRPC.

Both refined and unrefined sanitary sewer service areas are shown on Map 7. Refined sewer service areas have been delineated through a local sewer service area planning process. As part of this process, the community concerned, assisted by the Regional Planning Commission, determines a precise sewer service area boundary consistent with local land use plans and development objectives. Reports documenting the sewer service areas include detailed maps of environmentally significant areas within the sewer service area. Following adoption by the designated management agency for the sewage treatment plant, local sewer service area plans are considered for adoption by the by the Regional Planning Commission as a formal amendment to the regional water quality management plan. The Commission then forwards the plans to the Wisconsin Department of Natural Resources for approval.

Unrefined sewer service areas in northwestern Waukesha County are additional areas where the regional water quality management plan envisions the eventual provision of sanitary sewer service. The areas are generalized in nature, the product of systems-level planning. Detailed local sewer service area planning processes would be carried out for these areas prior to the extension of sanitary sewer service.

At the request of the City of Waukesha, and with the concurrence of the Village of Wales, a portion of the sewer service area in the Village of Wales has recently been refined as shown on Map 7 and described in the SEWRPC report entitled *Amendment to the Regional Water Quality Management Plan, City of Waukesha/Village of Wales*, September 2006.

Rural Land Use

As shown in Table 2, in 2005, rural lands, consisting of woodlands, wetlands, surface water, agricultural croplands and other open lands, comprised about 59 percent of the total land area in the Pebble Creek watershed. Agricultural and other open land uses were the largest rural land use in the watershed, encompassing about 34 percent of the total land area. Agricultural land use is divided between active cropland and other open lands, which includes farm buildings, pasture, grasslands that have not succeeded to a wetland or woodland community, and lands adjacent to cropland, such as treelines and hedgerows. Surface water, wetlands, woodlands, and rural open lands comprised about 25 percent of the land area in the watershed. Most of the rural and open spaces in the watershed are located in the Brandy Brook subwatershed, with scattered areas throughout the Upper and Lower Pebble Creek subwatersheds. Between 2005 and 2035, rural lands in the watershed are anticipated to decrease by approximately 31 percent as indicated in Table 2. The majority of this loss is anticipated to be from the conversion of agricultural cropland and other open lands to urban lands for residential, commercial, and industrial uses. Wetlands, woodlands, and surface water are not anticipated to experience any significant losses due to current zoning ordinances within the watershed. Wetlands and woodlands are primarily located adjacent to Pebble Creek and are largely considered to be Class I and II wildlife habitat. In addition, the majority of this wildlife habitat is located within the primary and secondary environmental corridors, as well as the isolated natural resource areas.

Table 2

LAND USE IN THE PEBBLE CREEK WATERSHED: 2000-2035[a,b]

Category	2000		2005		2035		Change: 2005-2035	
	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent
Urban								
Suburban-Density Single-Family Residential	146	1	153	1	156	1	3	2
Low-Density Single-Family Residential	1,333	12	1,494	13	2,595	23	1,101	74
Medium-Density Single-Family Residential	993	9	1,178	10	1,530	13	352	30
High-Density Single-Family Residential	83	1	134	1	160	1	26	19
Commercial	32	<1	60	1	79	1	19	32
Industrial	68	1	84	1	91	1	7	8
Governmental and Institutional	150	1	146	1	232	2	86	59
Transportation: Motor Vehicle Related[c]	873	8	960	8	1,341[d]	12	340	40
Transportation: Rail Related	19	<1	19	<1	- -	- -	- -	- -
Communication, and Utilities	17	<1	22	<1	- -	- -	- -	- -
Recreational	285	2	510	4	666	6	155	30
Subtotal	4,000	35	4,760	41	6,850	60	2,090	44
Rural								
Agricultural and Related	4,532	39	3,938	34	2,264	20	-1,674	-43
Water	40	<1	40	<1	40	<1	0	0
Wetlands	1,419	12	1,409	12	1,387	12	-22	-2
Woodlands	727	6	691	6	691	6	0	0
Open Lands	809	7	687	6	294	2	-393	-57
Subtotal	7,526	65	6,766	59	4,676	40	-2,090	-31
Total	11,526	100	11,526	100	11,526	100	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 the increase to 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 projected 2035 land use combines transportation, communication, and utilities into one category.*

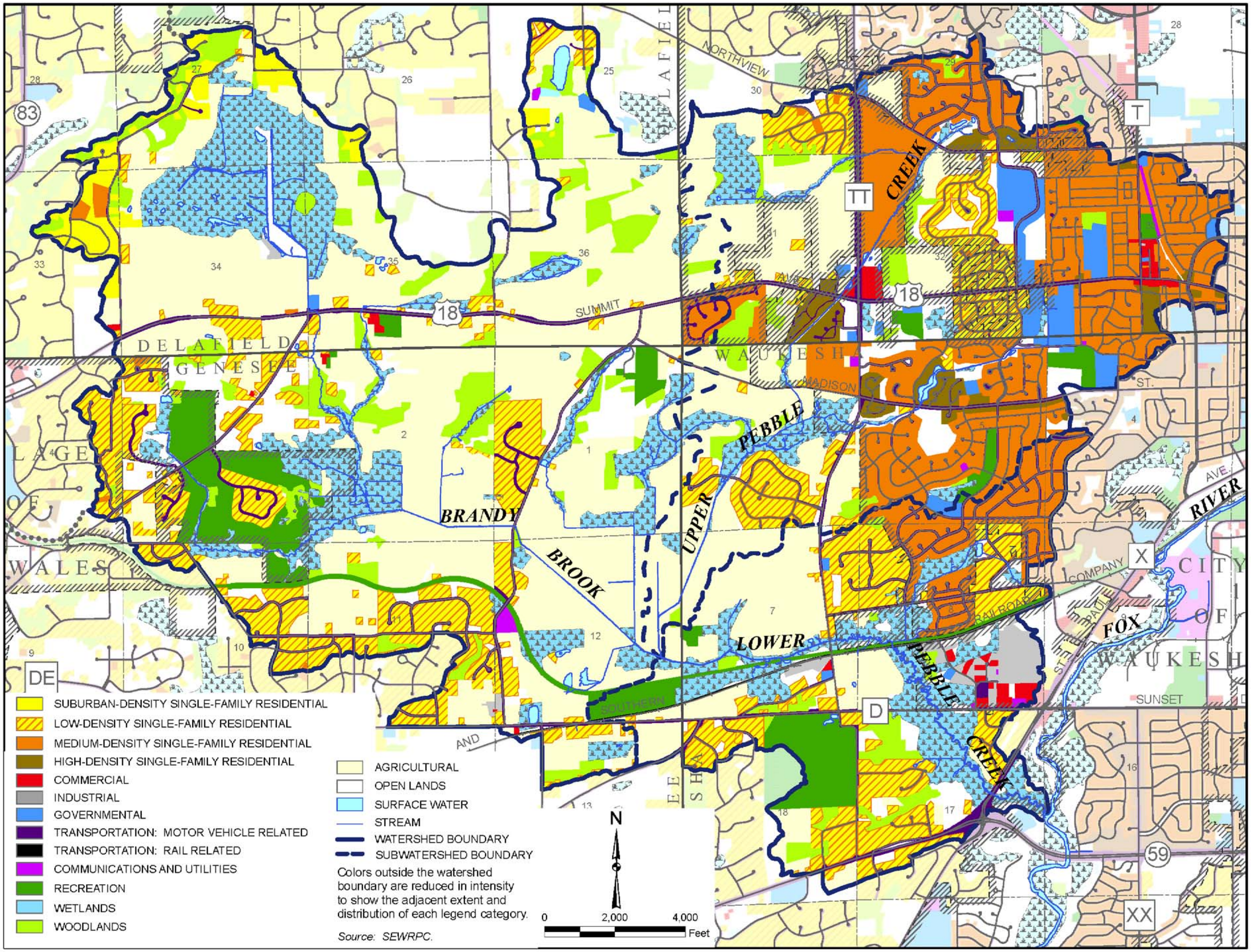
Source: SEWRPC.

CLIMATE

Long-term average annual air temperature and precipitation values for the Pebble Creek watershed are set forth in Figure 8. These averages were taken from official National Oceanic and Atmospheric Administration (NOAA) records for the weather recording station at Waukesha, Wisconsin. The records of this station may be considered typical of the entire watershed. The mean annual precipitation at Waukesha is about 32.8 inches, and the mean annual temperature is 47.1 degrees Fahrenheit. Figure 8 also shows that both mean temperature and mean precipitation has been increasing over this period of record, however, variability in each parameter remains unpredictably high from year to year. It is important to note that only the increasing mean annual temperature trend was shown to be statistically significant ($p \leq 0.009$; multiple $R^2 = 0.122$). More than half the normal yearly precipitation falls during the growing season, from May to September. During this time period, runoff volumes

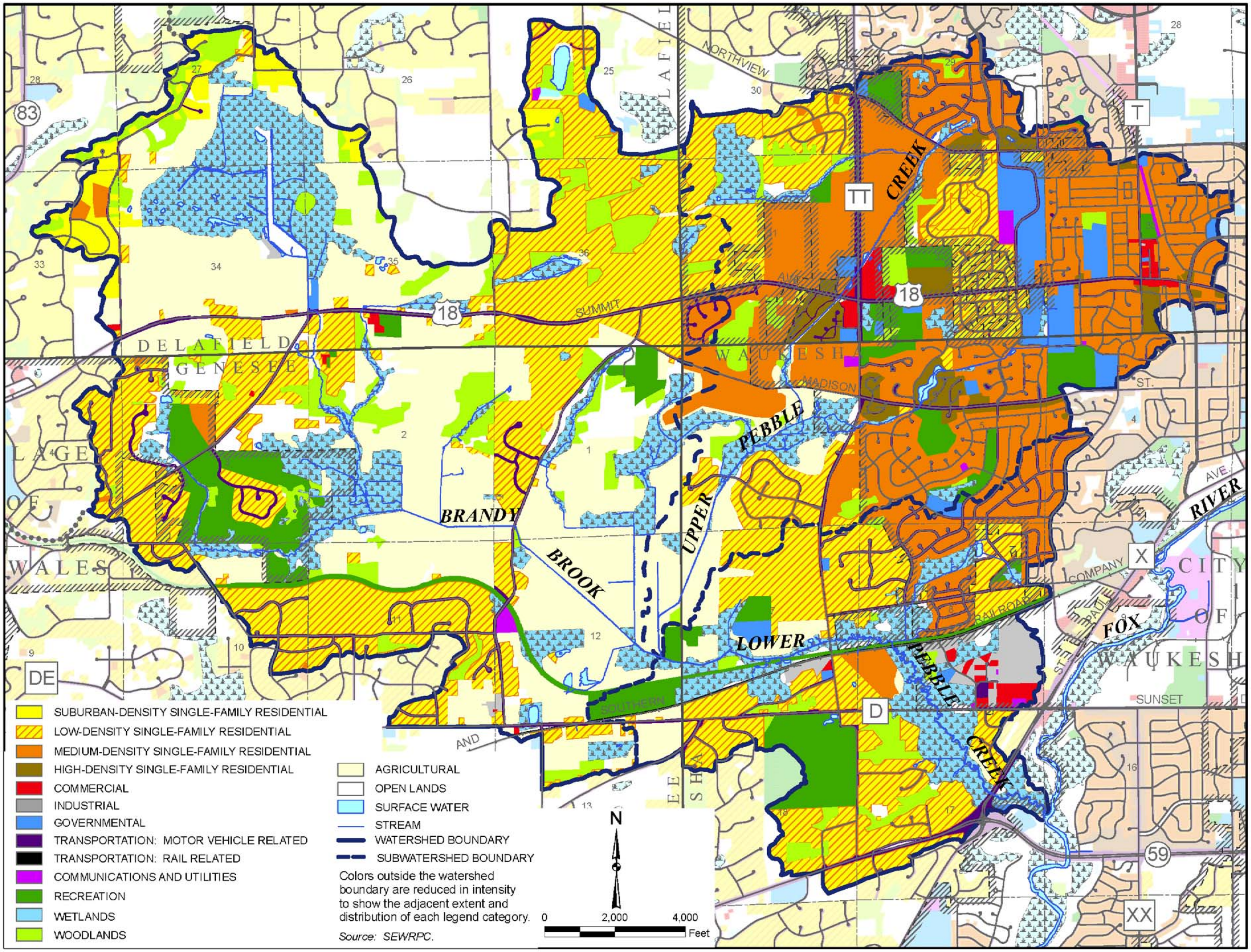
Map 5

EXISTING LAND USE WITHIN THE PEBBLE CREEK WATERSHED: 2005



Map 6

RECOMMENDED LAND USE WITHIN THE PEBBLE CREEK WATERSHED: 2035



Map 7

ADOPTED SANITARY SEWER SERVICE AREAS WITHIN THE PEBBLE CREEK WATERSHED: 2006

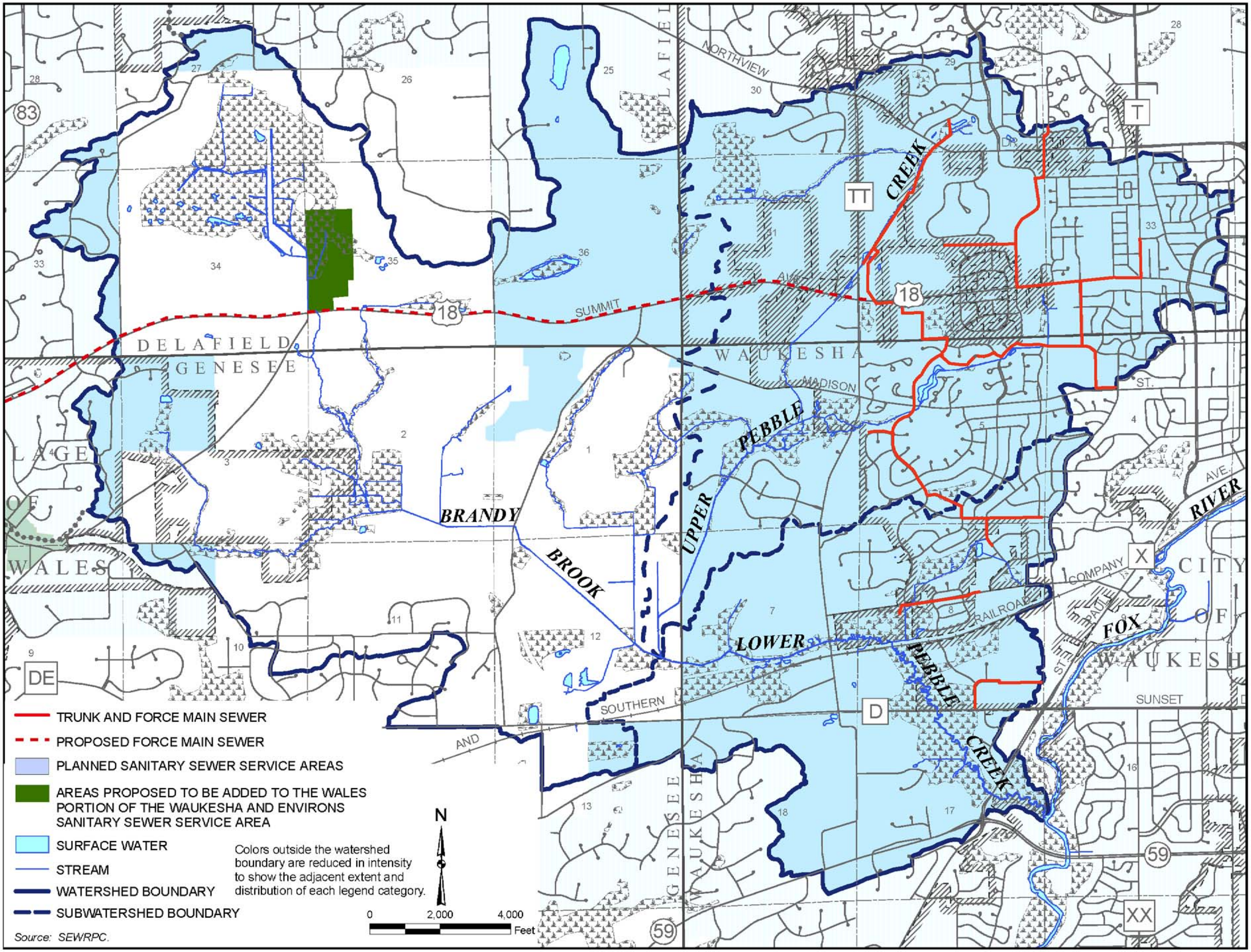
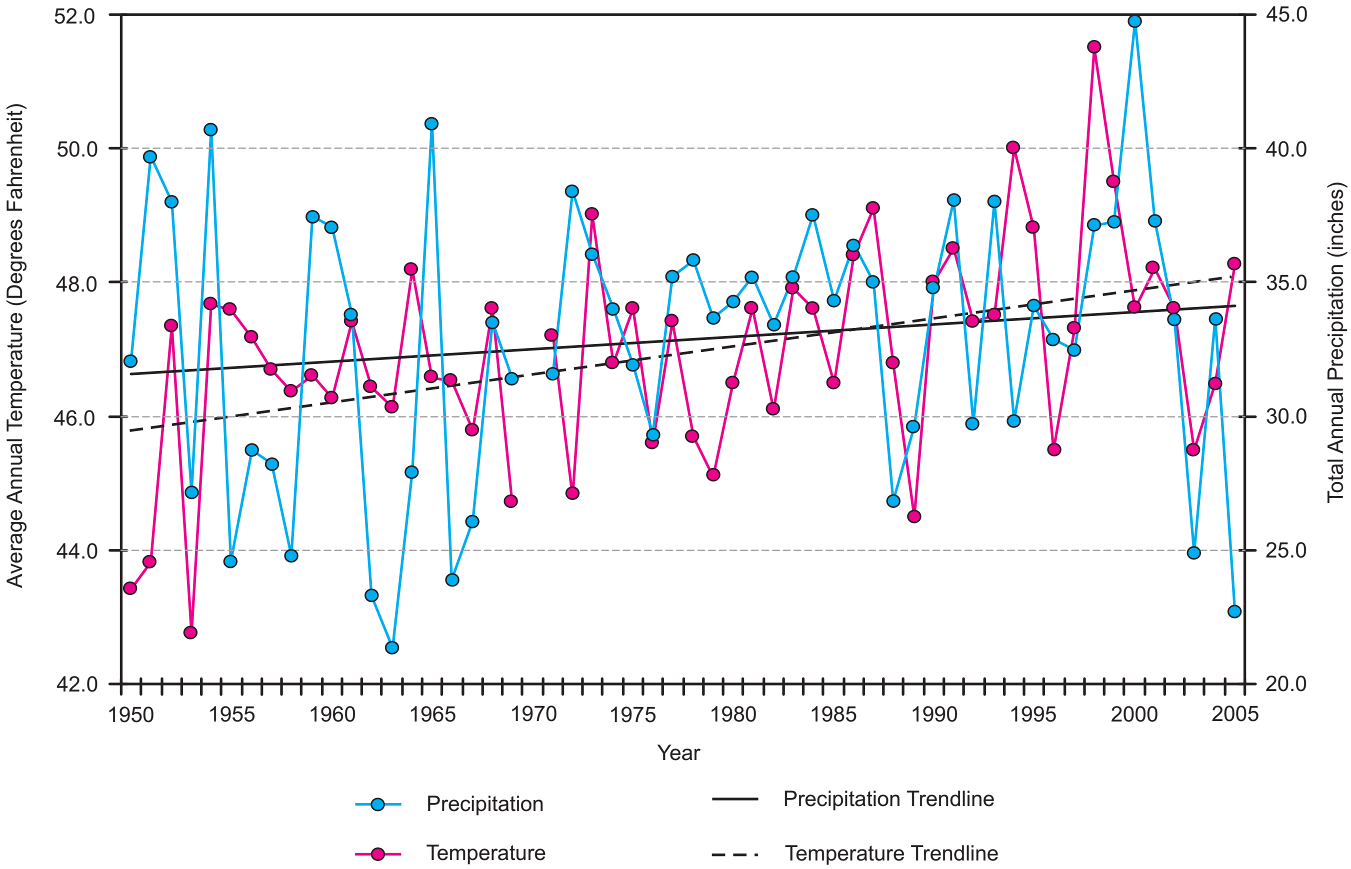


Figure 8

AVERAGE ANNUAL TEMPERATURE AND TOTAL ANNUAL PRECIPITATION FOR THE NOAA WAUKESHA WEATHER RECORDING STATION NEAR THE PEBBLE CREEK WATERSHED: 1950-2005



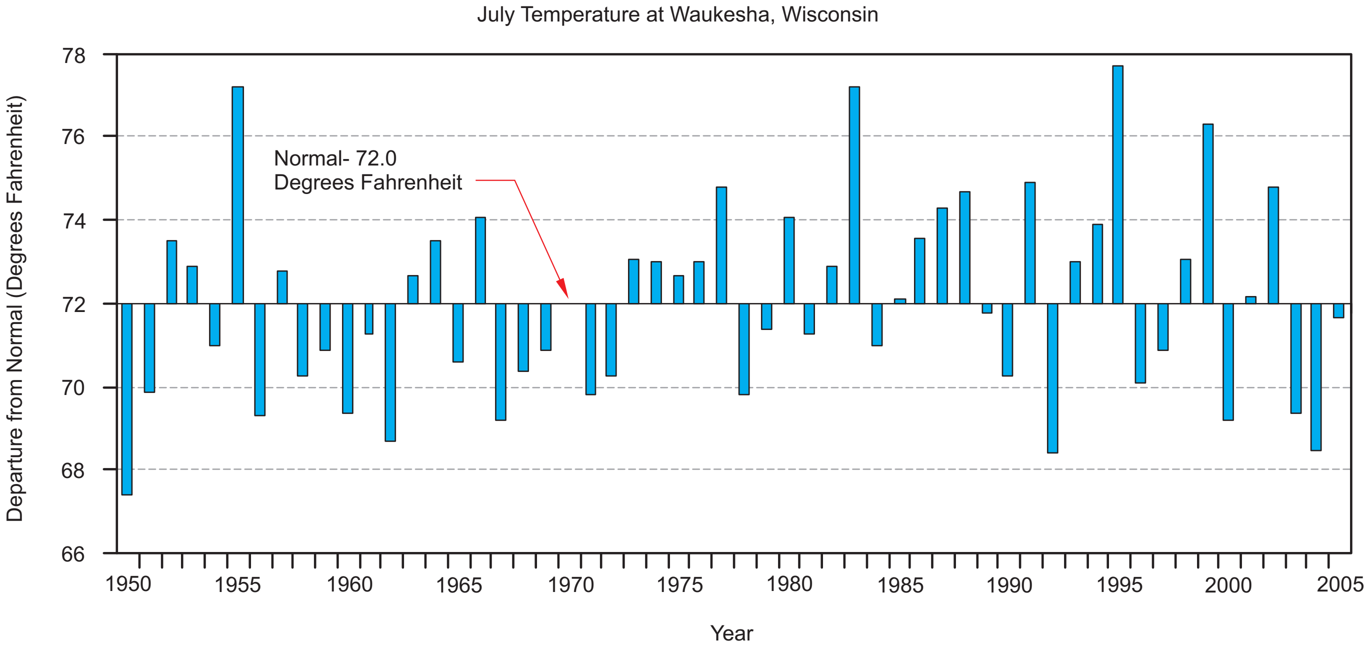
Source: National Oceanic and Atmospheric Administration, National Climatic Data Center, and SEWRPC.

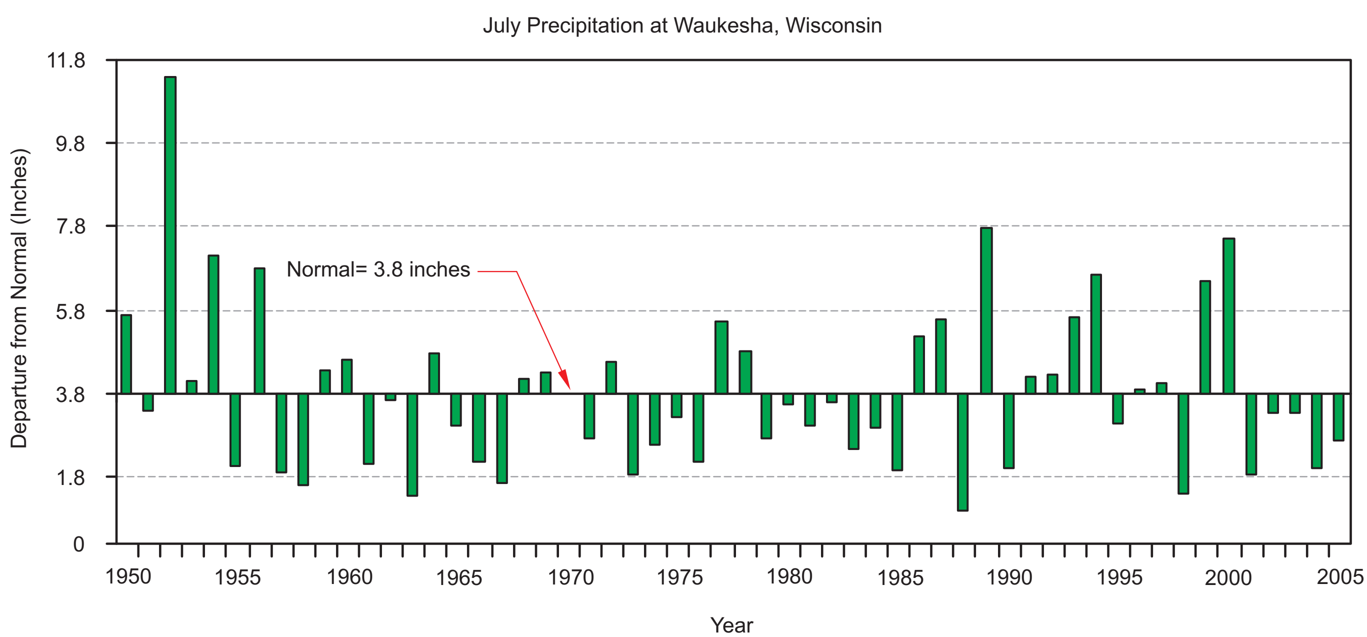
are moderated because evapotranspiration rates are high, vegetative cover is good, and the soils are not frozen, so infiltration can occur. However, the occurrence of intense thunderstorms during this period can result in high rates of runoff and associated flooding. Normally, about 20 percent of the summer precipitation is expressed as surface runoff. Approximately 45 percent of the annual precipitation occurs during the winter or early spring when the ground may be frozen, and may result in high surface runoff rates and/or volumes when air temperatures are high enough for the precipitation to fall as rain or as a result of rapid snowmelt or rainfall with snowmelt.

High air temperatures which warm water and land surfaces, when combined with periods of decreased precipitation during the summer, can negatively affect surface water dissolved oxygen concentrations (see the "Effects of Urbanization and Agriculture on Instream Biological Communities" subsection below). Hence, low dissolved oxygen concentrations are a major concern during the summer months, because even short periods of time where concentrations fall below 5.0 mg/L can cause significant decreases in the abundance and diversity of the aquatic organisms in streams. Figure 9 shows that the average temperature and precipitation for the month of July to be 72.0 degrees Fahrenheit and 3.8 inches, respectively, over the past 55 years. Similar to the annual trends above, variability in both July average temperature and precipitation remains unpredictably high from year to year. The deviation from normal air temperature can range from two to almost six degrees Fahrenheit and the deviation from normal precipitation can range from two to nearly eight inches. Fortunately, Pebble Creek's discharge is supplemented by a high proportion of cold, well oxygenated groundwater flow, which helps to mitigate critical summer periods that are warmer and/or dryer than normal. Figure 9 also shows that monthly average July

Figure 9

JULY AVERAGE TEMPERATURE AND PRECIPITATION DEPARTURES FROM NORMAL AT THE NOAA WAUKESHA WEATHER RECORDING STATION: 1950-2005





NOTE: Normal is defined as 3.8 inches, which is the average precipitation in the month of July from 1950-2005.

Source: National Oceanic and Atmospheric Administration, National Climatic Data Center, and SEWRPC.

temperature to be slightly increasing and average precipitation to be slightly decreasing over this 55-year period of record, which emphasizes the importance of protecting the quality and quantity of groundwater as future development occurs in this watershed (see the “Urban Development and Impervious Surfaces” subsection below).

GEOLOGY AND PHYSIOGRAPHY

The topographic elevations in the Pebble Creek watershed shown on Map 8 range from approximately 790 feet above mean sea level near the confluence of Pebble Creek with the Fox River in the southeastern portion of the watershed, to about 1,100 feet in the northern and western portions of the watershed, a variation of over 300 feet. Most of the high points in the watershed are located along the Kettle Moraine in the northwestern portion of the watershed and the Delafield Drumlin Fields in the northern and western portions of the watershed, which are two of the main physiographic and topographic features in the watershed. Both the Kettle Moraine and Drumlins are parts of much larger glacial landform features that were formed more than 10,000 years ago.[3]

Bedrock Geology

The bedrock and surfacial deposits overlying the bedrock directly and indirectly affect the quantity and quality of surface water and groundwater. The Pebble Creek watershed is underlain by Niagara limestone (dolomite bedrock) which typically is located between 50 and 100 feet below the ground surface. However, as shown on Map 9, there are some areas in the watershed where the bedrock is within six feet of the ground surface. Figure 10 shows some examples where the bedrock is exposed at the surface and makes up part of the streambed in the Upper Pebble Creek subwatershed. The northwestern portion of the watershed contains a portion of the Inter-Lobate Kettle Moraine, one of the most dominant topographic features in the County. The rest of the watershed occupies the pitted glacial outwash, rolling ground moraines, and glacial lake basin deposits south of Pewaukee Lake. The water from within the glacial sand and gravel deposits supplies the shallow wells and springs that occur within the watershed. The fissures in the dolomite provide groundwater storage and are frequently tapped by moderately deep wells for water supply purposes. Underlying the dolomite is an impervious layer of Maquoketa shale. Beneath the Maquoketa shale are dolomite and sandstone formations that constitute the “deep sandstone aquifer,” but which do not intersect the surface drainage system.

SOILS

The glaciers deposited a wide variety of soil-forming materials and sculpted many different landforms that influence soil type and stream hydrology. Soil type, along with land slope, land use, and vegetative cover, are important factors determining stream water quality conditions and affecting the rate, amount, and quality of stormwater runoff. Soil texture and soil particle structure influence the permeability, infiltration rate, and erodibility of soils. Land slopes are important determinants of stormwater runoff velocities and, therefore, significantly influence the susceptibility of soils to erosion. The erosivity of the runoff can be moderated or modified by vegetation.

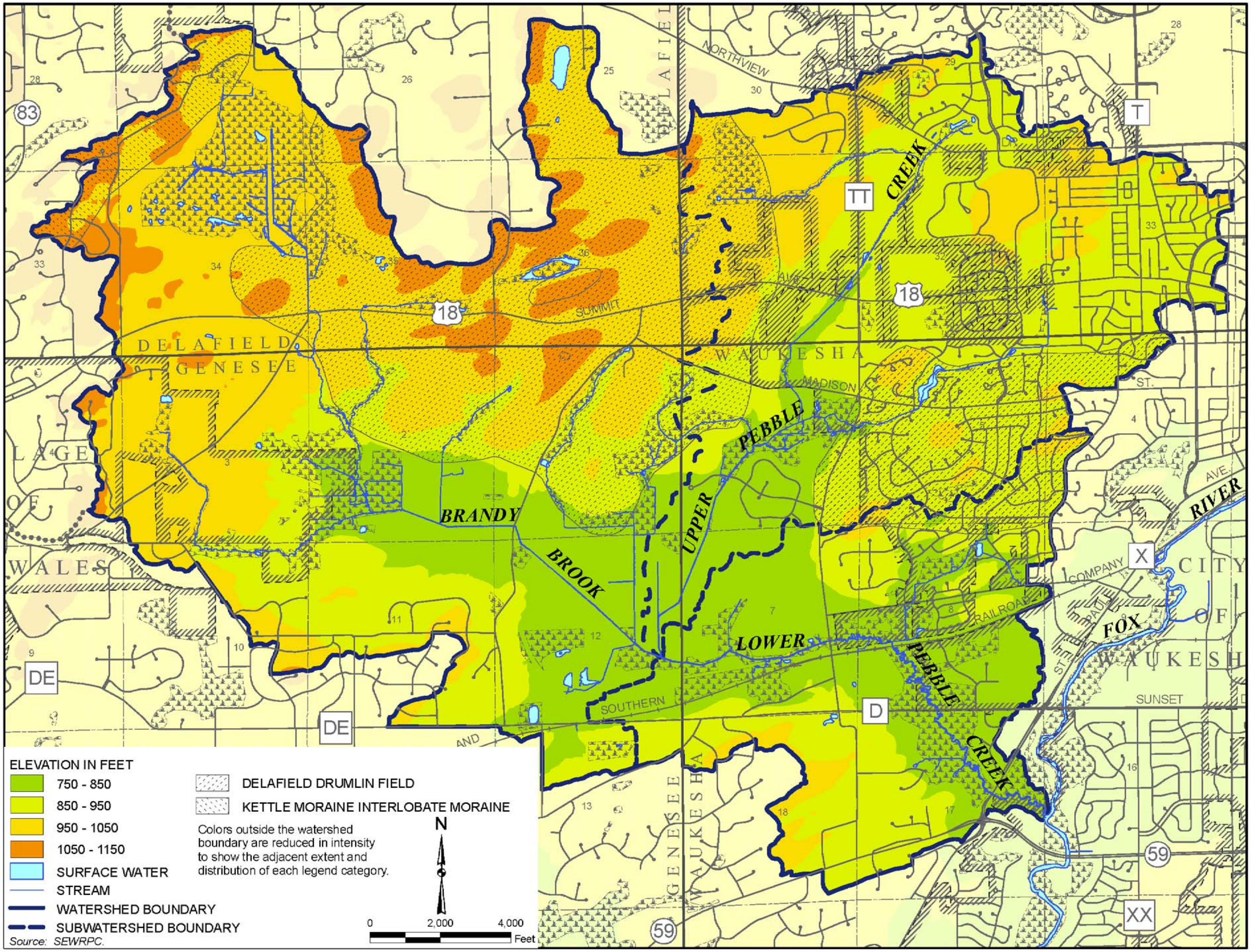
Agricultural Classifications

Agricultural lands in the watershed include cropland, pastureland, and open fields (not woodlands or wetlands), and make up 4,463 acres, or 39 percent of the watershed, as shown in Table 3. Map 10 shows these lands based on their use for growing agricultural crops. The first category is agricultural land that meets the Federal (NRCS) definition of “prime” agricultural soils which includes those lands that would meet the prime classification if artificially drained or protected from flooding. The second category includes agricultural land that does not meet the Federal prime definition, but is classified by the State as being “soils of statewide importance.” In this watershed, the agricultural lands placed in the second category do not meet the Federal definition due to steeper slopes (6 to 12 percent) or poor drainage (water table at zero to three foot depth). However, with the application of

[3]*Waukesha County Department of Parks and Land Use-Land Resources Division,* Waukesha County Land and Water Resources Management Plan: 2006-2010*, March 2006.*

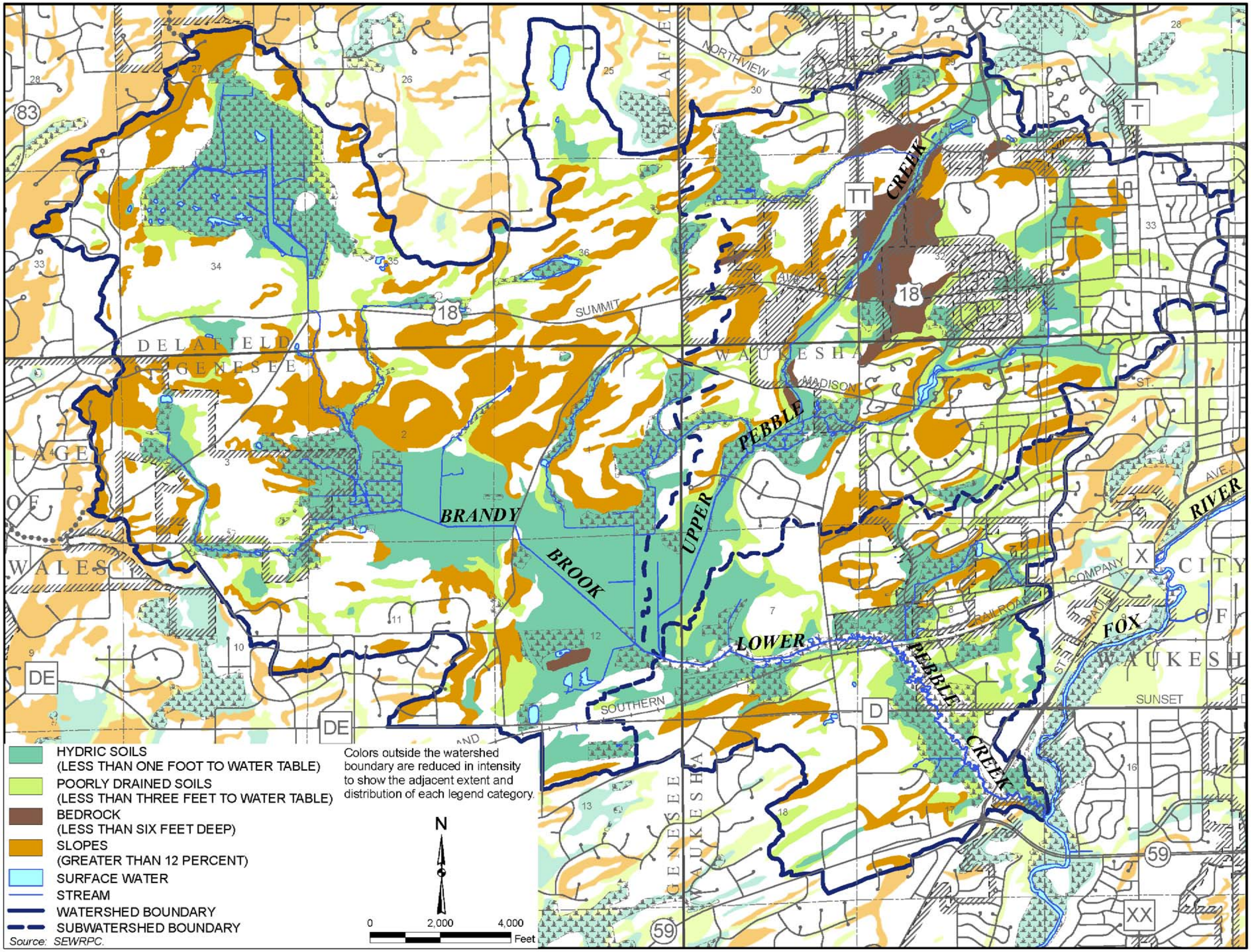
Map 8

TOPOGRAPHIC AND PHYSIOGRAPHIC CHARACTERISTICS WITHIN THE PEBBLE CREEK WATERSHED: 2005



Map 9

SOIL LIMITATIONS/CONSIDERATIONS FOR DEVELOPMENT WITHIN THE PEBBLE CREEK WATERSHED: 2005



Source: SEWRPC.

Figure 10

BEDROCK OUTCROPPING IN THE HEADWATER AREAS OF UPPER PEBBLE CREEK NEAR CTH TT

Source: SEWRPC.

soil conservation or drainage practices, these soils have proven to be very productive in Wisconsin. The third category, shown on Map 10, are other agricultural lands that do not meet either the State or Federal definitions, and primarily include fields with slopes greater than 12 percent, or a total of about 810 acres.

Soil Limitations/Considerations for Development

Map 9 shows the primary soil features that present potential limitations for land development, including depth to water table, bedrock and steep slopes. Hydric soils generally have seasonal depth to water table of one foot or less and are capable of supporting wetland vegetation. There are 2,570 acres of hydric soils in the watershed (Table 4), with the largest area being an organic complex located at the confluence of Brandy Brook and Pebble Creek, where an agricultural drainage district is still active. Poorly drained soils have seasonal depth to water table of three feet, and are generally concentrated in lower areas or adjacent to the hydric soils, demonstrating a transition zone for the water table. Some of these soils may have a high clay content in subsoils causing a perched water table condition. Shallow water table conditions present a risk of groundwater contamination from onsite septic systems and could cause wetness problems for dwellings with basements. Shallow bedrock conditions (less than six feet) pose higher construction costs for basements and also pose a risk of groundwater contamination from onsite septic systems because of the lack of a filtering soil layer. Slope steepness has a direct bearing on the potential for soil erosion and the sedimentation of surface waters. Slope steepness affects the velocity and the erosive potential of runoff. As a result, steep slopes place moderate to severe limitations on urban development and agricultural activities in areas with highly erodible soil types. Development or cultivation of steeply sloped lands is also likely to impact surface water quality negatively through related erosion and sedimentation. Steep slopes may also limit the use of certain stormwater management practices and represent possible increased grading costs and higher risks for soil erosion during land development activities. It should be noted that steep slopes are concentrated near the Kettle Moraine and Delafield Drumlin Field areas. Shallow bedrock is concentrated near the northeast part of the watershed in the Upper Pebble Creek subwatershed, with examples of surface exposures shown in Figure 10.

Table 4 shows a summary of the acreages in each category described above. It should be noted that there is a small amount of overlap between a few of these soils limitations. For example, the largest area of overlap occurs in 48 acres of soils that are both greater than 12 percent slope and have bedrock less than six feet. To simplify the analysis, a hierarchy of the limitations was created, which assumes that a high water table is more of a restriction

Table 3

STATE AND FEDERAL CLASSIFICATIONS FOR AGRICULTURAL LANDS IN THE PEBBLE CREEK WATERSHED: 2005

Classification	Acres	Percent of Watershed
Federal (NRCS) Prime Agricultural Soils Group (includes prime if drained or protected from flooding)	2,370	21
Soils of Statewide Importance (not in NRCS prime group)	1,283	11
Other Agricultural Lands (not meeting abovenoted State or Federal categories)	810	7
Total	4,463	39

Source: Waukesha County Land Resources Division and SEWRPC.

than shallow bedrock, which in turn is more restrictive than steep slopes. Using this method, only the most restrictive limitation is shown in Map 9, and each soil map unit is only counted once in Table 4. The hierarchy that was used is the same order that each soil limitation is shown in the Table 4 and on Map 9. For the example given above, the 48 acres of overlap is shown under bedrock less than six feet category, but not under the slopes greater than 12 percent, because bedrock is above slope in the hierarchy.

WATER RESOURCES

The Pebble Creek watershed contains three major subwatersheds designated as Brandy Brook and Upper and Lower Pebble Creek (Map 3 in Chapter I of this report). As described in Chapter III of this report, Pebble Creek upstream of CTH D and Brandy Brook are assigned coldwater sport fish and partial water recreation use objectives.[4] Downstream of CTH D, Pebble Creek is assigned a warmwater sport fish use objective. Should Waukesha County adopt the single criterion stream classification system proposed in the Waukesha County Lake and Stream Classification report, it is likely that Brandy Brook would be rated as a Class I waterbody and the Upper and Lower portions of Pebble Creek as a Class II waterbody, both of which would suggest that this stream system as a whole should be protected to a degree that exceeds minimum statewide requirements for streambank setbacks, riparian buffer widths, and other management measures, as appropriate.[5]

Surface Water

The mainstem of Pebble Creek is 6.5 miles in length, ending at the confluence with the Fox River in the Town of Waukesha (Map 3 in Chapter I of this report). Pebble Creek contains a large number of intermittent and perennial tributaries totaling more than 20 miles, the longest being Brandy Brook at about 4.8 miles in length.[6] The total drainage area of the Pebble Creek watershed is 17.8 square miles (about 11,500 acres). The watershed is one of several subwatersheds that comprise the Upper Fox River watershed and it represents about 12 percent of the land area of that entire basin. Despite its relatively smaller size compared to the Upper Fox River watershed, the problems or threats to the water resources in the Pebble Creek watershed are similar to the Upper Fox, namely, channelization, streambank erosion, excessive sediment and nutrient inputs, cropland and urban runoff, pesticides,

[4]*Wisconsin Department of Natural Resources, Publication No. PUBL-FH-806-2002,* Wisconsin Trout Streams*, April 2002.*

[5]*SEWRPC Memorandum Report No. 145, A* Lake and Stream Classification System for Waukesha County, Wisconsin*, June 2006.*

[6]*Wisconsin Department of Natural Resources, Publication No. PUBL-WR-255-90,* Nonpoint Source Control Plan for the Upper Fox River Priority Watershed Project*, June 1994.*

Map 10

STATE AND FEDERAL SOIL CLASSIFICATIONS FOR AGRICULTURAL USES WITHIN THE PEBBLE CREEK WATERSHED: 2005

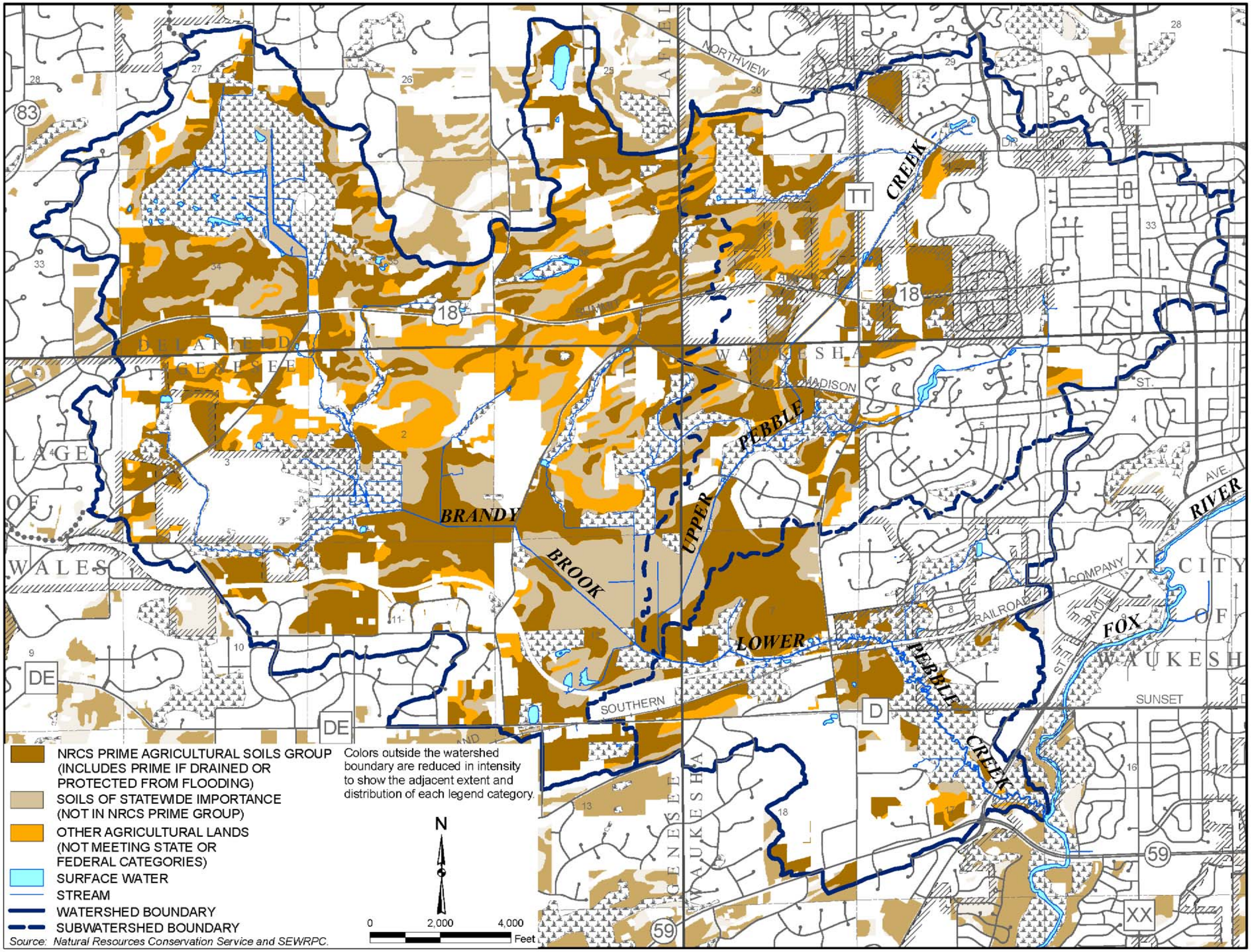


Table 4

SOIL LIMITATIONS FOR DEVELOPMENT IN THE PEBBLE CREEK WATERSHED

Soil Limitation	Acres	Percent of Watershed
Hydric Soils (seasonal high water table less than one foot)	2,570	22
Poorly Drained Soils (seasonal high water table less than three feet)	1,283	11
Bedrock (less than six feet)	250	2
Slopes (greater than 12 percent)	1,951	17
Total	6,054	52

Source: Waukesha County Land Resources Division and SEWRPC.

herbicides, wetland filling, stream flow fluctuation or low flow, temperature extremes, low dissolved oxygen, loss of fish and macroinvertebrate habitat, and fish migration barriers.[7]

Urban Development and Impervious Surfaces

As indicated above, urban land use in the Pebble Creek watershed is expected to increase between the present and 2035. In the absence of planning, such urbanization can create negative impacts on streams and lakes. Urbanization itself is not the main factor driving the degradation of the local waterbodies. Lakes and streams can survive and flourish in urban settings. The main factors leading to the degradation of urban waterbodies are the creation of large areas of connected impervious surfaces, the lack of adequate stormwater management facilities to control the quantity and quality of runoff, proximity of development to waterbodies, loss of natural areas, and inadequate construction erosion controls. These factors increase the potential for the occurrence of the negative water quality/quantity effects associated with urbanization. Good land use planning, creative site design and the application of best management practices for construction site erosion control and post-construction stormwater management can greatly reduce the potential for urban development to negatively affect the surrounding environment.

Industrial and commercial land uses have significantly more impervious area than residential land uses. Furthermore, smaller residential lots create more impervious surfaces than larger residential lots. Table 5 lists the approximate amount of impervious surfaces created by residential, industrial, commercial, and governmental and institutional development.

Although commercial and industrial developments create a larger percentage of impervious surfaces, residential developments, where lawns are the single largest use of land area, present different concerns. Lawns are considered pervious, but they do show some similarities to impervious surfaces. When lawns are compared to woodlands and cropland, they are found to contain less soil pore space (up to 15 percent less than cropland and 24 percent less than woodland) available for the infiltration of water. In many instances, considerable soil compaction occurs during grading activities, significantly reducing the perviousness of lawns. Native grasses, forbs, and sedges have significantly deeper root systems than turf grass, which loosen the soil and create flow channels that increase infiltration capacity. Also, owing to excessive application of fertilizers and pesticides on urban lawns, they typically produce higher unit loads of nutrients and pesticide than does cropland.[8]

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[7]*Wisconsin Department of Natural Resources, Publication No. PUBL-WR-255-90,* Nonpoint Source Control Plan for the Upper Fox River Priority Watershed Project*, June 1994; and Wisconsin Department of Natural Resources, Publication No. PUBL-WT-701-2002,* The State of the Southeast Fox River Basin*, February 2002.*

[8]*Center for Watershed Protection,* Impacts of Impervious Cover on Aquatic Systems, *Watershed Protection Research Monograph No.1, March 2003, p. 7.*

Table 5

APPROXIMATE PERCENTAGE OF CONNECTED IMPERVIOUS SURFACES CREATED BY URBAN DEVELOPMENT

Type of Urban Development	Impervious Surface (percent)
Two-Acre Residential	10-15
One-Acre Residential	15-25
One-Half-Acre Residential	20-30
One-Third-Acre Residential	25-35
One-Fourth-Acre Residential	35-45
One-Eighth-Acre Residential	60-70
Industrial	70-80
Commercial	85-95

Source: B.K. Ferguson, Introduction to Stormwater: Concept, Purpose, Design, *New York: John Wiley & Sons, 1998.*

When a new commercial or residential development is built near a stream, the area in driveways, rooftops, sidewalks, and lawns increases; while native plants and undisturbed soils decrease; and the ability of the shoreland area to perform its natural functions (flood control, pollutant removal, wildlife habitat, and aesthetic beauty) is decreased. In the absence of mitigating measures, urbanization impacts the watershed, not only by altering the ratio between stormwater runoff and groundwater recharge, but also through the changing of stream hydrology (i.e., increasing stormwater runoff volumes and peak flows and altering the baseflow regime) and through divergence of the seasonal thermal regimes away from their historical patterns. These changes further influence other characteristics of the stream, such as channel morphology, water quality/quantity, and biological diversity. When urban development increases, the amount of surfaces impervious to water increases proportionately to the decrease in the amount of surfaces pervious to water. For this reason alone, many researchers throughout the United States, including researchers at the WDNR, report that the amount of connected impervious surfaces is the best indicator of the level of urbanization in a watershed.[9] Connected impervious surfaces have a direct hydraulic connection to a stormwater drainage system, and, ultimately, to a stream. The studies mentioned above have found that relatively low levels of urbanization, 8 to 12 percent connected impervious surface, can cause subtle changes in physical (increased temperature and turbidity) and chemical properties (reduced dissolved oxygen and increased pollutant levels) of a stream that may lead to a decline in the biological components of the stream. For example, each 1 percent increase in watershed imperviousness can lead to an increase in water temperature of about 0.25 degrees Celsius.[10] This temperature increase is small in magnitude, but even this small increase can have significant impacts to fish, such as trout, and other members of the biological community.

In the absence of mitigating measures, one of the consequences of urban development is the increase in the amount of stormwater, which runs off the land, instead of infiltrating into the groundwater. A parking lot or driveway produces much more runoff than an undisturbed meadow or agricultural hay field. Furthermore, runoff traveling over a parking lot or driveway will pick up more heavy metals, bacteria, pathogens, and other stream pollutants than runoff traveling over surfaces that allow some of the stormwater to be filtered or to infiltrate. Runoff traveling over impervious surfaces bypasses the filtering action of the soil particles, soil microbes, and vegetation present above (stems and leaves) and below (roots) the soil surface. Therefore, location of these impervious surfaces determines the degree of direct impact they will have upon a stream. There is a greater impact from impervious surfaces located closer to a stream, due to the fact that less time and distance exists where the polluted runoff can be naturally treated before entering into the stream. A study of 47 watersheds in southeastern Wisconsin found that one acre of impervious surface located near a stream could have the same negative effect on aquatic communities as 10 acres of impervious surface located further away from the stream.[11] Because urban lands located adjacent to the stream have a greater impact on the biological community, an

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[9]*L. Wang, J. Lyons, P. Kanehl, and R. Bannerman, "Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spatial Scales,"* Environmental Management*, Vol. 28, 2001, pp. 255-266.*

[10]*L. Wang, J. Lyons, and P. Kanehl, "Impacts of Urban Land Cover on Trout Streams in Wisconsin and Minnesota,* Transactions of the American Fisheries Society, *Vol. 132, 2003, pp. 825-839.*

[11]*Wang, L., J. Lyons, P. Kanehl, and R. Bannerman, "Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spatial Scales,"* Environmental Management*, Vol. 28, 2001, pp. 255-266.*

assumption might be made that riparian buffer strips located along the stream could absorb the negative runoff effects attributed to urbanization. Yet, riparian buffers may not be the complete answer in the watershed since most urban stormwater is delivered directly to the stream via a storm sewer or engineered channel and, therefore, enters the stream without first being filtered by the buffer. Riparian buffers need to be combined with other management practices, such as infiltration facilities, detention basins, and grass swales, in order to adequately mitigate the effects of urban stormwater runoff. Combining practices into such a "treatment train" can provide a much higher level of pollutant removal, than single, stand-alone practices could ever achieve. Stormwater and erosion treatment practices vary in their function, which in turn influences their level of effectiveness. Location of a practice on the landscape, as well as proper construction and continued maintenance, greatly influences the level of pollutant removal. Chapter IV of this report presents a general evaluation of the effectiveness of existing stormwater best management practices in the watershed, and Chapter V sets forth recommendations regarding the need for additional controls.

Effects of Urbanization and Agriculture on Instream Biological Communities

Researchers evaluated 134 sites on 103 streams throughout the State of Wisconsin and have found that the amount of urban land use upstream of sample sites had a negative relationship with biotic integrity scores, and that there appeared to be a threshold of about 10 percent directly connected impervious cover in the areas tributary to the streams beyond which where Index of Biotic Integrity (IBI) scores declined dramatically.[12,13] The IBI is a measure of the quality of the fishery community and combines elements, such as abundance, diversity (number of different species), tolerance (ability of a species to tolerate pollution), feeding or trophic classifications (e.g., top carnivores, or fish that feed on other fish, vertebrates, or large aquatic insects), and healthy appearance (e.g., no deformities, eroded fins, lesions). Fish IBI scores were found to be good to excellent below this threshold, but were consistently rated as poor to fair above this threshold. They also found that habitat scores were not closely associated with degraded fish community attributes in the studied streams. Wisconsin researchers also found that the number of trout per 100 meters in coldwater streams dramatically decreased at a threshold of 6 percent imperviousness, and no trout were observed in coldwater streams in watersheds with greater than 11 percent imperviousness (Figure 11).[14] Wang and others also studied 47 small streams in 43 watersheds in southeastern Wisconsin to retrospectively analyze fisheries and land use data from between 1970-1990.[15] Historical changes in land uses were determined from data provided by SEWRPC and the changes in the fishery were evaluated over the two decades. Streams that were already extensively urbanized as of 1970, had fish communities characterized as highly tolerant with low species richness.[16] As these areas urbanized even more, the fish communities changed little since they were already degraded. In contrast, stream sites that had little urbanization (characterized by connected imperviousness) in 1970 that were urbanizing by 1990, showed decreases in the fishery community quality. This study further supported major differences at the 10 percent connected impervious cover threshold,

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[12]*L. Wang, J. Lyons, P. Kanehl, and R. Gatti, "Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams,"* Fisheries*, Volume 22, 1997.*

[13]*Directly connected impervious area is area that discharges directly to the stormwater drainage system without the potential for infiltration through discharge to pervious surfaces or facilities specifically designed to infiltrate runoff.*

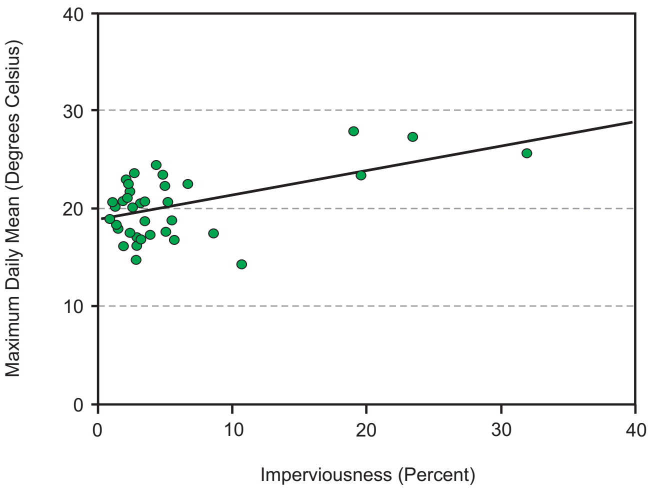
[14]*Personal communication, L. Wang, Wisconsin Department of Natural Resources.*

[15]*L. Wang, J. Lyons, P. Kanehl, R. Bannerman, and E. Emmons, "Watershed Urbanization and Changes In Fish Communities In Southeastern Wisconsin Streams,"* Journal of the American Water Resources Association*, Volume 36, No. 5, 2000.*

[16]*Highly tolerant fishes can survive under degraded conditions, particularly low dissolved oxygen and high temperatures. More detail on tolerance and characterization of the fishery community in this watershed is provided in Chapter IV of this report.*

Figure 11

MAXIMUM DAILY WATER TEMPERATURES AND PERCENT IMPERVIOUS SURFACES AMONG COLDWATER STREAM WATERSHEDS WITHIN WISCONSIN



Source: Wisconsin Department of Natural Resources.

with poorer fisheries quality generally reported for stream sites above this threshold. In addition, numerous studies over different eco-regions and using various techniques have revealed that as watersheds become highly urban, aquatic diversity becomes extremely degraded.[17]

In addition to increases in the amount of impervious land cover that are associated with urbanization, urban development has also often been accompanied by alteration, or loss of wetlands; disturbance or reductions in the sizes of riparian corridors; stream channel modification, including straightening and lining with concrete; and occasional spills of hazardous materials. All of these factors contribute to degradation of fish communities and of aquatic diversity, however, there are various approaches to mitigating the adverse effects of these factors (see Chapter IV of this report).

An additional important concern related to urban development is thermal pollution. Thermal pollution results when stormwater flows over heated surfaces, such as roads, rooftops, and parking lots, before it enters the stream. The main consequence of thermal pollution is oxygen depletion, because warm water cannot hold as much oxygen as cold water. Rainfall events that occur during the warmer summer months are more stressful on fish and other water dwelling organisms, due to runoff being heated as it flows over sun-warmed impervious surfaces. As these oxygen-deficit events increase, aquatic organisms living in the stream become more stressed. Any increase in the level of thermal and oxygen stress can lead to decreased growth and reproduction, migration out of the system, or death of the aquatic organisms. When coupled with the chronic affects of reduced infiltration on baseflows to streams, these events can lead to significantly elevated temperatures. There is a direct relation between a coldwater stream's maximum daily water temperatures and the percent of impervious surfaces (i.e., urban development) in the watershed (Figure 12). Coldwater fish, such as brown trout, survive best in water temperatures less than 20 degrees Celsius. Temperatures a few degrees below the lethal limit of 25 degrees Celsius can still cause significant stress, eventually leading to illness, infection, and death.[18]

As summarized above, 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 Pebble Creek watershed had about 6 percent urban land use by 1970, which approximately corresponds to 2 percent directly connected imperviousness in the watershed and, as of 2005, it had about 41 percent urban land overall, corresponding to about 9 percent directly connected imperviousness. That level of imperviousness is just below the threshold level of 10 percent at which the previously cited studies indicate that negative biological impacts have been observed (see Table 6).

However, given the pattern of development in the Pebble Creek watershed, the Upper Pebble Creek and the Lower Pebble Creek subwatersheds contain higher proportions of urban land uses, and contain about 14 and 12 percent, respectively, directly connected imperviousness (Table 6). These areas are just above the threshold

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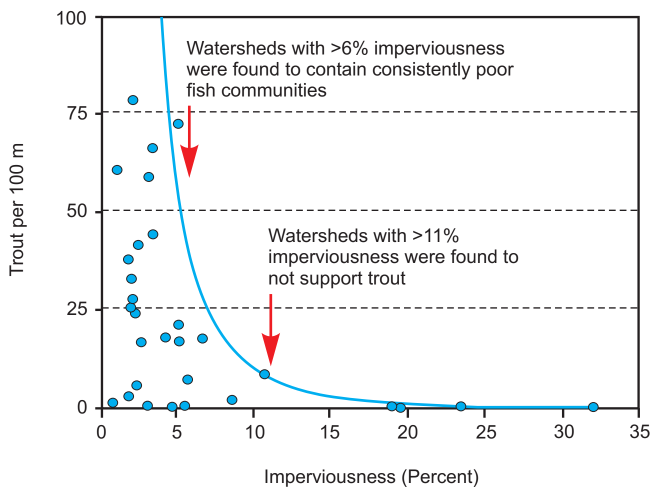
[17]*Center for Watershed Protection,* op. cit.

[18]*G.S. Becker,* Fishes of Wisconsin, *University of Wisconsin Press, 1983.*

Figure 12

TROUT ABUNDANCE PER 100 METERS OF LINEAR STREAM DISTANCE AND PERCENT IMPERVIOUS SURFACES AMONG COLDWATER STREAM WATERSHEDS WITHIN WISCONSIN



Source: Wisconsin Department of Natural Resources.

level of 10 percent where negative biological impacts are expected. This may be the reason that brown trout are not found in the Upper Pebble Creek subwatershed and also indicates that the Lower Pebble Creek subwatershed is potentially at the threshold of being able to support a coldwater trout species. Urban development has proceeded at accelerated rates in the Upper and Lower Pebble Creek subwatersheds compared to the Brandy Brook subwatershed, and development is expected to continue to occur throughout the watershed.

Researchers in Wisconsin have also found that the amount of agricultural land use upstream of sample sites had a negative relationship with biotic integrity scores, and there appeared to be a threshold of about 50 percent for agricultural land use where IBI scores declined dramatically.[19] A separate study looking at the effects of multi-scale environmental characteristics on agricultural stream biota in eastern Wisconsin demonstrated a strong negative correlation between fisheries IBI and increased proportion of agricultural land ranging from 0 to 80 percent within watersheds, which indicates that, as the percent of agricultural land increased, the resultant fishery community decreased in abundance and diversity.[20]

About 50 percent of the Pebble Creek watershed was in agricultural land use in 1970 and the watershed currently has about 34 percent agricultural land. Agricultural land use has dominated the Brandy Brook subwatershed and it currently has about 46 percent agricultural land, whereas the Upper and Lower Pebble Creek subwatersheds have been dominated by urban development. The Brandy Brook subwatershed is near the threshold of 50 percent agricultural land use where declines in fishery abundance and diversity may be expected.

The study of the effects of agricultural land use on biotic integrity scores also discovered a positive relationship between Fisheries IBI and increased agricultural riparian buffer vegetation width, which implies that, by analogy, the impacts of increased urban land use may also be mitigated by an increased riparian buffer that acts to protect the stream aquatic biota. A follow-up study investigating the influence of watershed, riparian corridor, and reach scale characteristics on aquatic biota in agricultural watersheds found that land use within the watershed, the presence of riparian corridors, and fragmentation of vegetation were the most important variables influencing fish and macroinvertebrate abundance and diversity.[21] In addition, combined upland best management practices (BMPs) that included barnyard runoff controls; manure storage; contour plowing and reduced tillage; and riparian

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[19] *L. Wang, J. Lyons, P. Kanehl, and R. Gatti, "Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams,"* Fisheries*, Volume 22, 1997.*

[20] *F. Fitzpatrick, B. Scudder, B. Lenz, and D. Sullivan, "Effects of Multi-Scale Environmental Characteristics on Agricultural Stream Biota in Eastern Wisconsin,"* Journal of the American Water Resources Association*, Volume 37, No. 6, 2001.*

[21] *J. Stewart, L. Wang, J. Lyons, J. Horwatich, and R. Bannerman, "Influence 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, 2001.*

Table 6

ESTIMATED HISTORICAL AND EXISTING PERCENT CONNECTED IMPERVIOUS SURFACE WITHIN THE PEBBLE CREEK WATERSHED

Subwatershed Area	Historical 1940	Historical 1970	Historical 1990	Historical 2000	Existing 2005	Planned 2035
Upper Pebble Creek	<1	5	10	12	14	18
Lower Pebble Creek	0	2	9	10	12	15
Brandy Brook	0	<1	1	2	3	6
Total Average	<1	2	5	7	8	11

Source: Wisconsin Department of Natural Resources and SEWRPC.

BMPs that included streambank fencing, streambank sloping, and limited streambank riprapping, were shown to significantly improve overall stream habitat quality, bank stability, instream cover for fishes, and fish abundance and diversity.[22] Improvements were most pronounced at sites with riparian BMPs. At sites with limited upland BMPs installed in the watershed there were no improvements in water temperature or the quality of fish community.

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,[23] the resultant poor to good IBI scores observed throughout this watershed are not surprising (see Chapter IV of this report). Consequently, the WDNR has recently concluded that the quality of the fishery remains impaired throughout the Pebble Creek watershed primarily due to the impacts of instream habitat loss, namely channelization, fish migration interference, eutrophication, cropland and urban runoff, pesticides, herbicides, flow modifications, temperature extremes, dissolved oxygen, and turbidity.[24]

Groundwater Resources

Groundwater is a vital natural resource of southeastern Wisconsin. Groundwater not only sustains lake levels and wetland and provides the perennial base flow of the streams, but is also a major source of water supply. In general, there is an adequate supply of groundwater to support the growing population, agriculture, commerce, and a viable and diverse industry. However, overproduction and water shortages may occur in areas of concentrated development and intensive water demand, especially in the sandstone aquifer. The amount, recharge, movement, and discharge of the groundwater is controlled by several factors, including precipitation, topography, drainage, land use, soil, and the lithology and water-bearing properties of rock units. Recharge to groundwater is derived almost entirely from precipitation. Waukesha County is almost fully dependent on groundwater for its potable water supply and for many industrial water supplies. Groundwater resources, thus, constitute an extremely valuable element of the natural resource base. The continued growth of population and industry within the County

[22]*L. Wang, J. Lyons, and P. Kanehl, "Effects of Watershed Best Management Practices on Habitat and Fish in Wisconsin's Streams,"* Journal of the American Water Resources Association*, Volume 38, No. 3, 2002.*

[23]*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.*

[24]*Wisconsin Department of Natural Resources, Publication No. PUBL-WR-255-90,* Nonpoint Source Control Plan for the Upper Fox River Priority Watershed Project*, June 1994; and Wisconsin Department of Natural Resources, Publication No. PUBL-WT-701-2002,* The State of the Southeast Fox River Basin*, February 2002.*

necessitates the wise development and management of groundwater resources. Because groundwater is recharged from the surface, certain land uses can result in pollution of groundwater, requiring costly or environmentally difficult cleanups.

The amount of precipitation and snowmelt that infiltrates at any location depends mainly on the permeability of the overlying soils, bedrock or other surface materials, including man-made surfaces. As development occurs, stormwater management practices can be installed that encourage infiltration of runoff. To be effective, these practices need to be located on soils with permeable subsoils and adequate groundwater separation to allow infiltration, but minimize the potential for contamination. This is described in more detail in Chapter V. Most of the precipitation that does infiltrate, either naturally or through a stormwater management practice, will generally only migrate within the shallow aquifer system and may discharge in a nearby wetland or stream system. This process helps support base flows, wetland vegetation, and wildlife habitat in these water resources.

Vulnerability to Contamination

Groundwater quality conditions can be impacted by such sources of pollution on the surface as infiltration of stormwater runoff, landfills, agricultural fertilizer, pesticides, manure storage and application sites, chemical spills, leaking surface or underground storage tanks, and onsite sewage disposal systems. The potential for groundwater pollution in the shallow aquifer is dependent on the depth to groundwater, the depth and type of soils through which precipitation must percolate, the location of groundwater recharge areas, and the subsurface geology. The Pebble Creek watershed exhibits moderate to high potential for contamination of groundwater in the shallow glacial drift and Niagara aquifers.[25] Generally, the areas of the watershed most vulnerable to groundwater contamination are where both Niagara dolomite and the water table are near the surface.

Compared to the deep aquifer, the shallow aquifers are more susceptible to pollution from the surface because they are nearer to the source, thus minimizing the potential for dilution, filtration, and other natural processes that tend to reduce the potential detrimental effects of pollutants. Such problems can often be traced to runoff pollution sources, septic system discharges, and chemical spills or leakage.

Radium Concentrations

Certain formations within the Cambrian sandstones in southeastern Wisconsin are known to produce relatively high concentrations of naturally occurring radium, a radioactive metallic element. This naturally occurring radium has been found to exceed U.S. Environmental Protection Agency standards in approximately 22 of the 80 municipal water supplies in the Southeastern Wisconsin Region. All of the water supplies which exceed the radium standard draw water from the deep sandstone aquifer and lie in a narrow band from the Illinois-Wisconsin border through Kenosha, Racine, and Waukesha Counties and extends north through Green Bay.

Currently, all water systems that exceed the radium standards in Waukesha County have a consent order agreement with the WDNR that details how the water systems will come into compliance with the radium standards. Within the watershed, systems serving portions of the Cities of Pewaukee and Waukesha have reported exceedances of the current radium standard. This issue is being further discussed on a regionwide basis as part of the regional water supply plan that is projected to be completed in 2009.[26]

NATURAL RESOURCE BASE RELATED ELEMENTS

Many important interlocking and interacting relationships occur between living organisms and their environment, the destruction or deterioration of any one element may lead to a chain reaction of deterioration and destruction among the others. The drainage of wetlands, for example, may have far-reaching effects. Such drainage may

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[25]*SEWRPC Technical Report No. 37,* Groundwater Resources of Southeastern Wisconsin*, June 2002.*

[26]*SEWRPC Planning Report No. 52,* A Regional Water Supply Plan for Southeastern Wisconsin*, ongoing, for more information see* http://www.sewrpc.org/watersupplystudy/.

destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas. 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 in isolation may not 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 thus becomes apparent.

Primary Environmental Corridors

Primary environmental corridors include a wide variety of important resource and resource-related elements and are at least 400 acres in size, two miles in length, and 200 feet in width.[27] Primary environmental corridors encompassed about 1,830 acres, or about 16 percent of the Pebble Creek subwatershed, in 2000. These primary environmental corridors contain almost all of the best remaining woodlands, wetlands, and wildlife habitat areas in the watershed, and represent a composite of the best remaining elements of the natural resource base. Primary environmental corridors in the watershed are shown on Map 11. It is also important to note that the majority of the primary environmental corridor area is in the Brandy Brook and Lower Pebble Creek subwatersheds.

Secondary Environmental Corridors

Secondary environmental corridors generally connect with the primary environmental corridors and are at least 100 acres in size and one-mile long. In 2000, secondary environmental corridors encompassed about 335 acres, or about 3 percent of the watershed. 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 agriculture purposes. Secondary environmental corridors facilitate surface water drainage, maintain pockets of natural resource features, and provide corridors for the movement of wildlife, as well as for the movement and dispersal of seeds for a variety of plant species. Secondary environmental corridors in the Pebble Creek watershed are shown on Map 11.

Isolated Natural Resource Areas

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 natural areas, which are at least five acres in size, are referred to as isolated natural resource areas. Widely scattered throughout the watershed, isolated natural resource areas included about 400 acres, or about 4 percent of the total study area in 2000. Isolated natural resource areas in the watershed are shown on Map 11.

Natural Areas and Critical Species Habitat Sites

Natural areas, as defined by the Wisconsin Natural Areas Preservation Council, are tracts of land or water so little modified by human activity, or sufficiently recovered from the effects of such activity, that they contain intact native plant and animal communities believed to be representative of the pre-European settlement landscape. Natural areas have been identified for the entire seven county Southeastern Wisconsin Region in the SEWRPC Planning Report No. 42, "*A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*," September 1997. This report was developed to assist Federal, State, and local units and agencies of government, and nongovernmental organizations, in making environmentally sound land use decisions including acquisition of priority properties, management of public lands, and location of development in appropriate localities that will protect and preserve the natural resource base of the Region.

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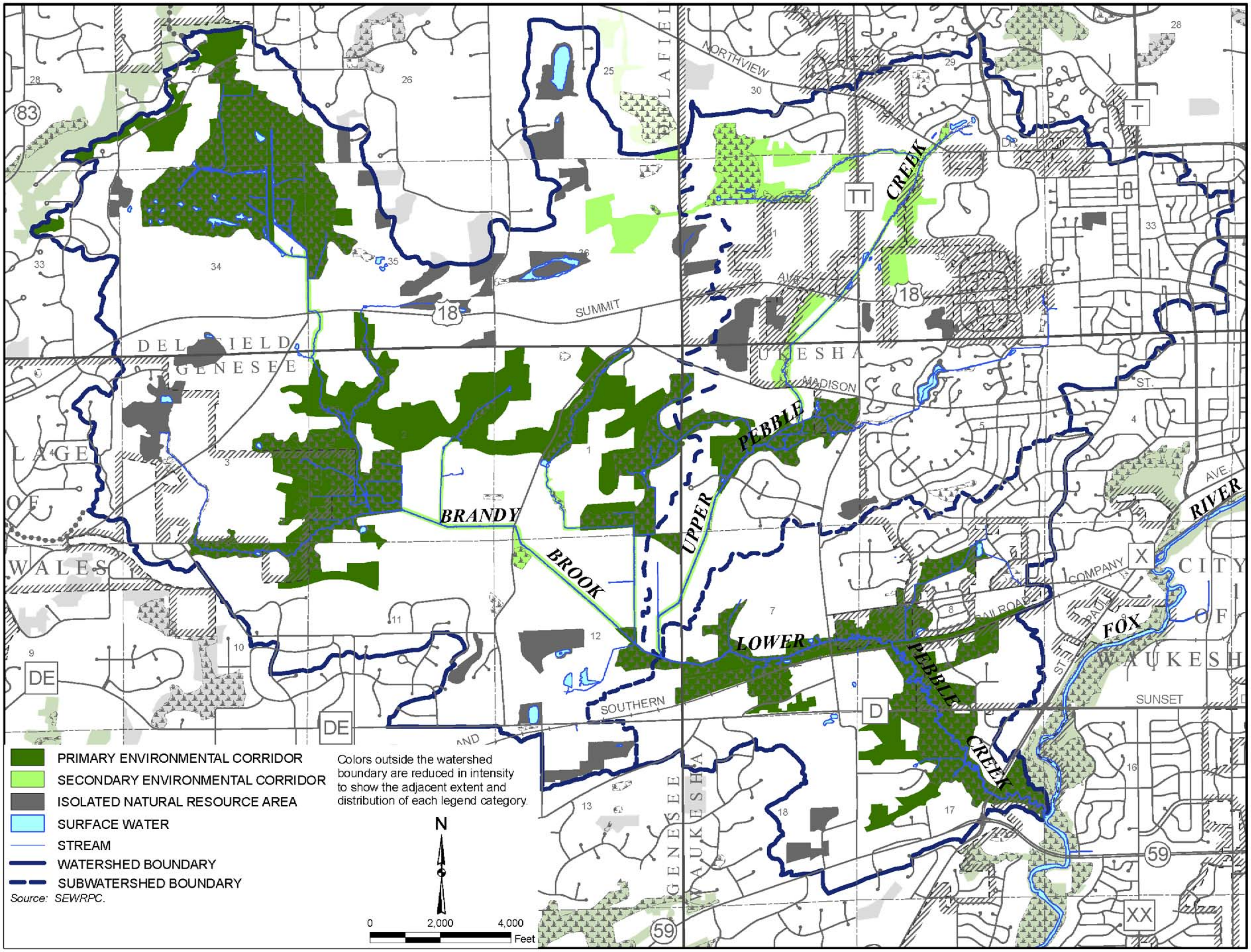
[27]*SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*, September 1997.*

Map 11

ENVIRONMENTAL CORRIDORS WITHIN THE PEBBLE CREEK WATERSHED: 2000



Waukesha County uses this document to guide land use decisions for the benefit of critical species and key natural resource areas. Natural areas are classified into one of the following three categories:[28]

1. Natural area of statewide or greater significance (NA-1);

2. Natural area of countywide or regional significance (NA-2); or

3. Natural area of local significance (NA-3).

Classification of an area into one of these three categories is based upon consideration of several factors. These include the diversity of plant and animal species and community types present; the structure and integrity of the native plant or animal community; the extent of disturbance by human activity, such as logging, grazing, water level changes, and pollution; the commonness of the plant and animal communities present; any unique natural features within the area; the size of the area; and the educational value. However, it is important to note that although agricultural lands are not designated as natural areas, the majority of the designated Class I, II, and III wildlife habitat areas in the watershed lie adjacent to agricultural croplands that provide food, cover, and traveling corridors for many of the animal wildlife species that reside within the designated wildlife habitat areas. Natural areas form an element of the wildlife habitat base of the study area. Natural areas and critical species habitat locations in the Pebble Creek watershed and are shown on Map 12 and inventoried in Tables 7 and 8. Critical species are those species of plants and animals that are considered endangered, threatened or of special concern. Such species that are known to occur in the watershed are listed in Table 9. These critical species include the longear sunfish (Figure 13), Blanding's turtle (Figure 14), Butler's garter snake (Figure 15), and Henslow's sparrow (Figure 16). All of the critical species habitat sites are located within identified primary environmental corridor areas adjacent to the mainstem of Lower and Upper Pebble Creek. The Blanding's turtle, longear sunfish, and Henslow's sparrow are new records in this watershed identified by Waukesha County Land Resources Division and SEWRPC staff as part of this planning effort.

Wetlands

Wetlands perform an important set of natural functions, which make them particularly valuable resources lending to overall environmental health and diversity. Wetlands contribute to the maintenance of good water quality by serving as traps that retain nutrients and sediments, thereby preventing them from reaching streams and lakes. They act to hold water during flooding events and retain it during dry periods, thus keeping the water table high and relatively stable. Some wetlands provide seasonal groundwater recharge or discharge. Those wetlands that provide groundwater discharge often provide base flow to surface waters. They provide essential breeding, nesting, resting, and feeding grounds and predator escape cover for many forms of fish and wildlife. These attributes have the net effect of improving general environmental health; providing recreational, research, and educational opportunities; maintaining opportunities for hunting and fishing; and adding to the aesthetics of an area.

Wetlands pose severe limitations for urban development. In general, these limitations are related to the high water table, and the high compressibility and instability, low bearing capacity, and high shrink-swell potential of wetland soils. These limitations may result in flooding, wet basements, unstable foundations, failing pavements, and failing sewer and water lines. There are significant and costly onsite preparation and maintenance costs associated with the development of wetland soils, particularly in connection with roads, foundations, and public utilities. As indicated on Map 13, wetlands are scattered throughout the Pebble Creek watershed and total approximately 1,390 acres, or about 12 percent of the watershed area.

[28]Ibid.

Map 12

KNOWN NATURAL AREAS AND CRITICAL SPECIES HABITAT SITES WITHIN THE PEBBLE CREEK WATERSHED: 2005

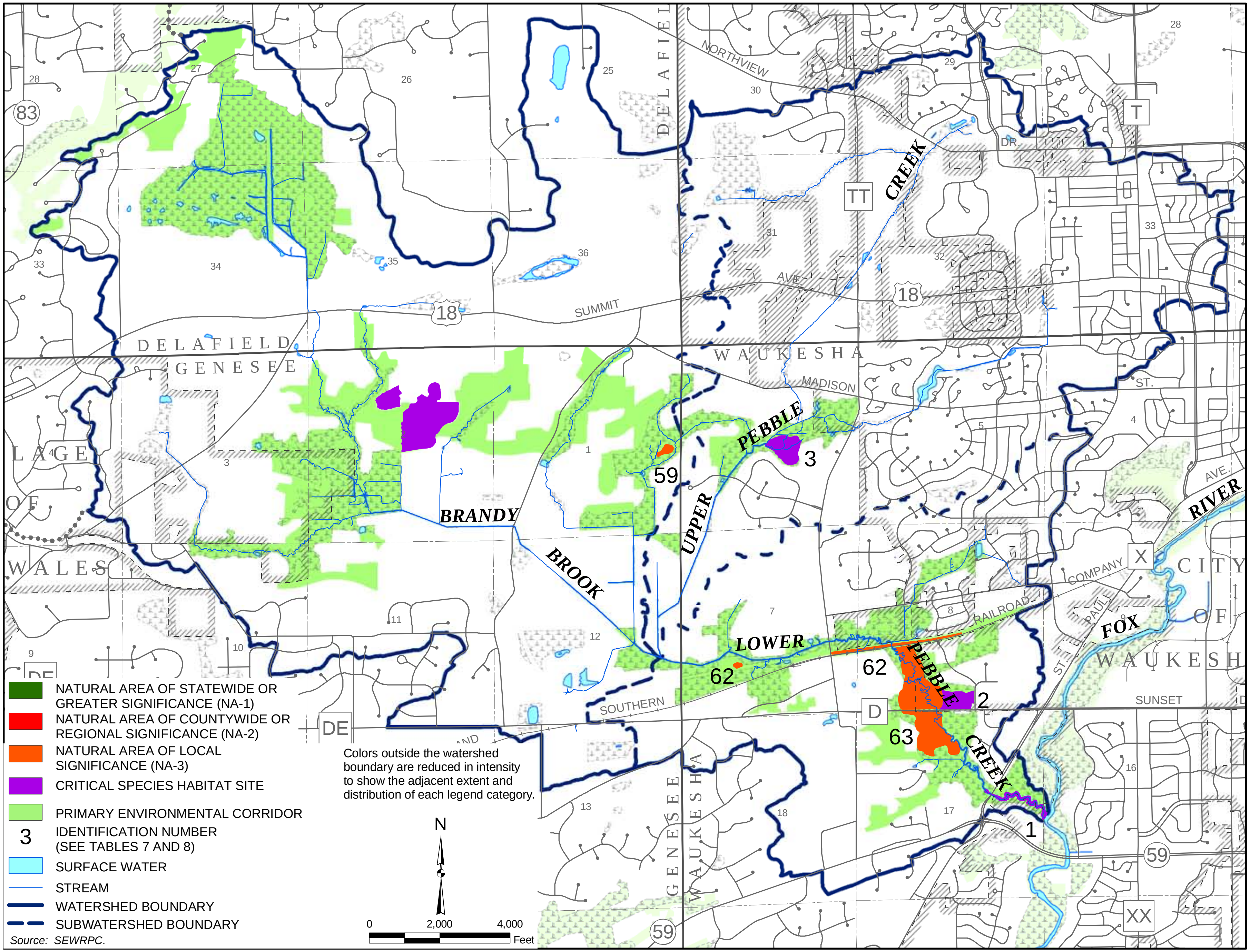


Table 7

NATURAL AREAS IN THE PEBBLE CREEK WATERSHED

Number on Map 12	Name	Type of Area	Location	Acres Owned	Acres Proposed to Be Acquired	Total	Proposed Acquisition Agency
	Natural Areas						
- -	Fruits Pond Fen	NA-3	City of Waukesha	16	- -	16	City of Waukesha
63	Pebble Creek Wetlands	NA-3	City and Town of Waukesha	12	48[a]	60	City of Waukesha
59	Brown's Fen	NA-3	Town of Genesee	2	- -	2	Waukesha County
62	Pebble Creek Railroad Prairie	NA-3	Town of Waukesha	7	- -	7	Wisconsin Department of Natural Resources[a]

[a]*This natural area is located between the Glacial Drumlin State Trail, owned by the Wisconsin Department of Natural Resources and the Wisconsin & Southern Railroad right-of-way, owned by the Wisconsin Department of Transportation. The SEWRPC natural areas plan proposes that the Wisconsin Department of Natural Resources assume responsibility of managing this natural area.*

Source: SEWRPC.

Table 8

CRITICAL SPECIES HABITAT SITES LOCATED OUTSIDE OF NATURAL AREAS IN THE PEBBLE CREEK WATERSHED

Number on Map 12	Site Description	Acres	Classification	Status
	Critical Species Habitat			
1	Fox-Pebble Confluence Floodland	6.68 (8.93[a])	Aquatic species	Threatened
2	Pebble Creek Wetland	10.31	Reptile species	Threatened
3	Kame Terrace Marsh	13.35	Reptile species	Threatened
4	Davies Drumlin Grassland	50.92	Bird species	Threatened

[a]*This area is located within the Fox River and is outside of the Pebble Creek watershed boundary.*

Source: SEWRPC.

Woodlands

Woodlands have both economic and ecological value and can serve a variety of uses providing multiple benefits. Located primarily on ridges and slopes and along streams, woodlands provide an attractive natural resource, accentuating the beauty of streams and the topography of the watershed. Under balanced use and sustained yield management, woodlands can, in many cases, serve scenic, wildlife, educational, recreational, environmental protection, and forest production benefits simultaneously. In addition to contributing to clean air and water, groundwater recharge and soil conservation, woodlands contribute to the maintenance of a diversity of plant and animal life and provide for important recreational opportunities. Woodlands cover about 730 acres, or about 6 percent of the watershed area, as shown on Map 13.

Wildlife Habitat

Wildlife in the Pebble Creek watershed include upland game and nongame species, such as rabbits, squirrels, shrews, mice, and woodchucks; predators, such as fox and mink; game birds, including pheasant and turkey; and marsh furbearers, such as muskrats and beaver. In addition, waterfowl and deer are present. The remaining habitat and wildlife residing therein provide opportunities for recreational, educational, and scientific activities, and constitute an aesthetic asset to the watershed.

Table 9

ENDANGERED AND THREATENED SPECIES AND SPECIES OF SPECIAL CONCERN IN THE PEBBLE CREEK WATERSHED: 2006

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			
Great Copper	*Lycaena dione*	Not listed	Special concern
Mottled Darner	*Aeshna clepsydra*	Not listed	Special concern
Mulberry Wing	*Poanes massasoit*	Not listed	Special concern
Fish			
Banded Killifish[a]	*Fundulus diaphanus*	Not listed	Special concern
Longear Sunfish	*Lepomis megalotis*	Not listed	Threatened
Starhead Topminnow[a]	*Fundulus dispar*	Not listed	Special concern
Weed Shiner	*Notropis texanus*	Not listed	Special concern
Reptiles and Amphibians			
Butler's Garter Snake	*Thamnophis butleri*	Not listed	Threatened
Blanding's Turtle	*Emydoidea blandingii*	Not listed	Threatened
Blanchard's Cricket Frog	*Acris crepitans blanchardi*	Not listed	Endangered
Birds			
Henslow's Sparrow	*Ammodramus henslowii*	Not listed	Threatened
Black-Crowned Night-Heron	*Nycticorax nycticorax*	Not listed	Special concern
Plants			
American Gromwell	*Lithospermum latifolium*	Not listed	Special concern
Autumn Coral-Root	*Corallorhiza odontorhiza*	Not listed	Special concern
Beaked Spikerush	*Eleocharis rostellata*	Not listed	Threatened
Canada Horse-Balm	*Collinsonia canadensis*	Not listed	Endangered
Common Bog Arrow-Grass	*Triglochin maritima*	Not listed	Special concern
Cuckooflower	*Cardamine pratensis*	Not listed	Special concern
False Hop Sedge	*Carex lupuliformis*	Not listed	Endangered
Great Indian-Plantain	*Cacalia muehlenbergii*	Not listed	Special concern
Hairy Beardtongue	*Penstemon hirsutus*	Not listed	Special concern
Hairy Wild-Petunia	*Ruellia humilis*	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
Innocence	*Houstonia caerulea*	Not listed	Special concern
Kentucky Coffee-Tree	*Gymnocladus dioicus*	Not listed	Special concern
Kitten Tails	*Besseya bullii*	Not listed	Threatened
Leafy White Orchis	*Platanthera dilatata*	Not listed	Special concern
Lesser Fringed Gentian	*Gentianopsis procera*	Not listed	Special concern
Low Nutrush	*Scleria verticillata*	Not listed	Special concern
Marsh Blazing Star	*Liatris spicata*	Not listed	Special concern
Marsh Horsetail	*Equisetum palustre*	Not listed	Special concern
Ohio Goldenrod	*Solidago ohioensis*	Not listed	Special concern
Prairie Indian Plantain	*Cacalia tuberosa*	Not listed	Threatened
Prairie White-Fringed Orchid	*Platanthera leucophaea*	Not listed	Endangered
Purple Meadow-Parsnip	*Thaspium trifoliatum var. Flavum*	Not listed	Special concern
Purple Milkweed	*Asclepias purpurascens*	Not listed	Endangered
Reflexed Trillium	*Trillium recurvatum*	Not listed	Special concern
Rock Stitchwort	*Minuartia dawsonensis*	Not listed	Special concern
Rough Rattlesnake-Root	*Prenanthes aspera*	Not listed	Endangered
Seaside Crowfoot	*Ranunculus cymbalaria*	Not listed	Threatened
Showy Lady's-Slipper	*Cypripedium reginae*	Not listed	Special concern
Small White Lady's-Slipper	*Cypripedium candidum*	Not listed	Threatened
Small Yellow Lady's-Slipper	*Cypripedium parviflorum*	Not listed	Special concern
Sticky False-Asphodel	*Tofieldia glutinosa*	Not listed	Threatened
Tufted Club-Rush	*Scirpus cespitosus*	Not listed	Threatened
Wafer-Ash	*Ptelea trifoliata*	Not listed	Special concern
Waxleaf Meadowrue	*Thalictrum revolutum*	Not listed	Special concern
Wild Hyacinth	*Camassia scilloides*	Not listed	Endangered
Yellow Gentian	*Gentiana alba*	Not listed	Threatened

[a] *This species was observed in the Fox River directly downstream of the Pebble Creek confluence and are also likely to be found in Pebble Creek.*

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

Figure 13

LONGEAR SUNFISH

Wisconsin Status: Threatened.

The longear sunfish population found in Pebble Creek and the Fox River is one of less than six locations where they exist in southeastern Wisconsin. Their presence indicates areas of high water quality and fisheries habitat. This species requires clear, shallow, and moderately warm still water from relatively wide streams or rivers with native submergent and emergent aquatic vegetation adjacent to the streambank.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 14

BLANDING'S TURTLE

Wisconsin Status: Threatened.

Blanding's turtles can be found throughout the State of Wisconsin where they live in shallow marshy habitats, as well as shallow, slow-moving rivers and streams with abundant native submerged vegetation. This species is semi-aquatic. While it prefers open, grassy marshes containing shallow water, it will, on occasion, move to ground adjacent to water to forage or to bask in the sun. This species is easy to identify by it's bright yellow chin and throat and highly domed shell.

Source: Wisconsin Department of Natural Resources, Waukesha County Land Resources Division, and SEWRPC.

Wildlife habitat areas remaining in the Southeastern Wisconsin Region were inventoried in 1985 as part of the regional classification of the natural areas and critical species for southeast Wisconsin[29] and again in 2005 by SEWRPC staff as part of this planning effort. The five major criteria used to determine the value of these wildlife habitat areas are listed below:

1. Diversity: An area must maintain a high, but balanced, diversity of species for a temperate climate, balanced in such a way that the proper predatory-prey (consumer-food) relationships can occur. In addition, a reproductive interdependence must exist.

2. Territorial Requirements: The maintenance of proper spatial relationships among species, allowing for a certain minimum population level, can occur only if the territorial requirements of each major species within a particular habitat are met.

3. Vegetative Composition and Structure: The composition and structure of vegetation must be such that it meets the required levels for nesting, travel routes, concealment, and protection from weather are met for each of the major species.

4. Location with Respect to Other Wildlife Habitats: It is very desirable that a wildlife habitat maintain proximity to other wildlife habitats.

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[29]Ibid.

Figure 15

BUTLER'S GARTER SNAKE

Wisconsin Status: Threatened.

The Butler's garter snake is a medium-sized snake that occurs in only a few counties in southeastern Wisconsin. This species occurs in many colors, ranging from brown, black, or olive, with or without a double row of black spots between the stripes that range from light yellow to a rich orange-yellow color. This species lives in wet-mesic prairies, marshes, and roadside grassy areas, and get isolated from other populations due to wetland loss and habitat fragmentation.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 16

HENSLOW'S SPARROW

Wisconsin Status: Threatened.

Henslow's sparrows can be found throughout most of the State of Wisconsin where they live in undisturbed pastures and meadows, timothy hayfields, and uncultivated fields, generally preferring mesic or wet habitats with relatively tall and dense vegetation. They are identified by their flat olive-colored and striped head and reddish wings.

Source: Wisconsin Department of Natural Resources and SEWRPC.

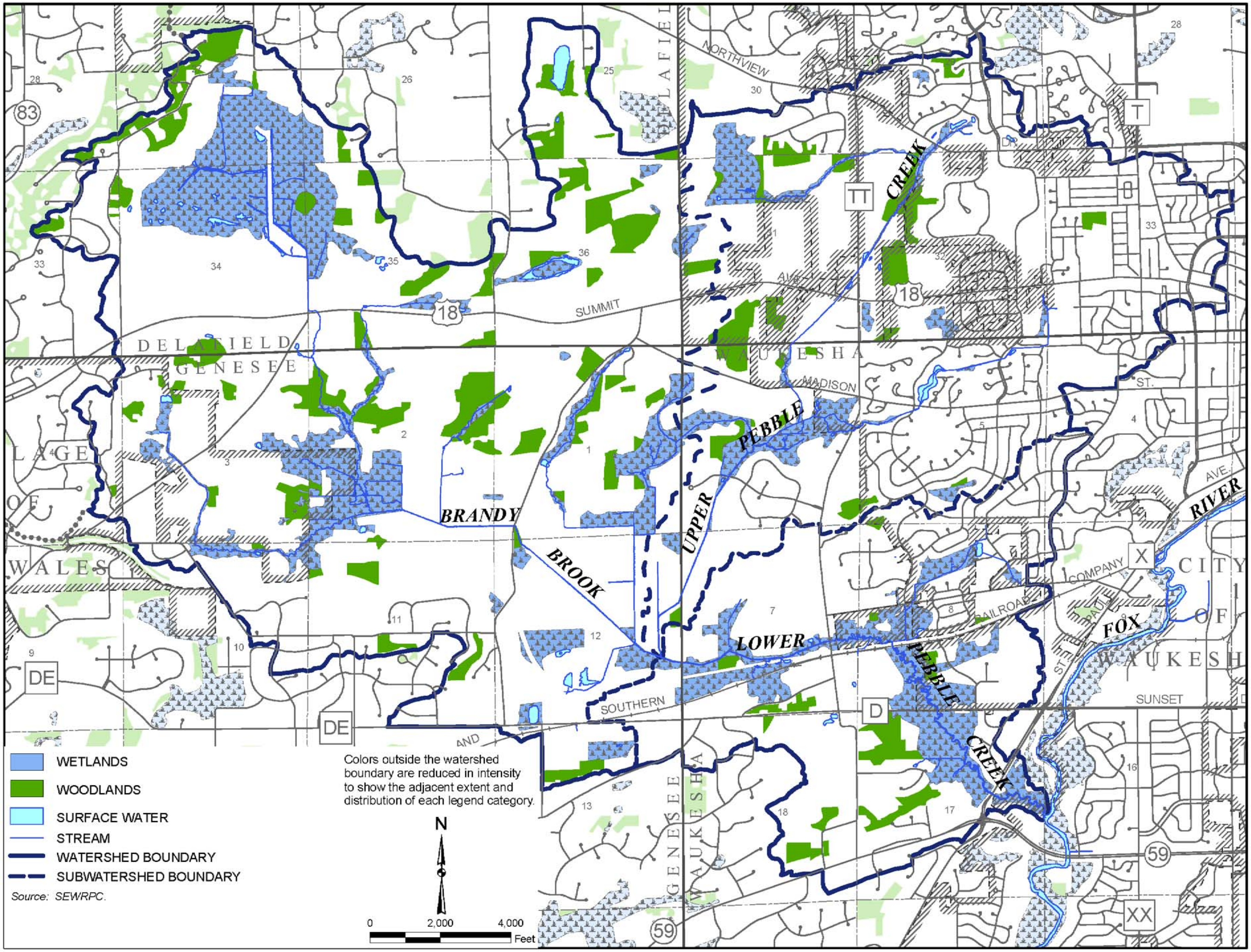
5. Disturbance: Minimum levels of disturbance from human activities are necessary, other than those activities of a wildlife management nature.

On the basis of these five criteria, the wildlife habitat areas in the Pebble Creek watershed were categorized as Class I, High-Value; Class II, Medium-Value; or Class III, Good-Value habitat areas. Class I wildlife habitat areas contain a good diversity of wildlife, are adequate in size to meet all of the habitat requirements for the species concerned, are generally located in proximity to other wildlife habitat areas, and meet all five criteria listed above. Class II wildlife habitat areas generally fail to meet one of the five criteria in the preceding list for a high-value wildlife area. However, they do retain a good plant and animal diversity. Class III wildlife habitat areas are remnant in nature, and they generally fail to meet two or more of the five criteria for a high-value wildlife habitat. These areas may be important if located in proximity to medium- or high-value habitat areas, especially if they provide corridors linking wildlife habitat areas of higher value or if they provide the only available range in an area.

As illustrated on Map 14, the 2005 inventory identified about 3,605 acres of wildlife habitat, covering approximately 32 percent of the land area of the watershed. This indicates that there has been an approximate net loss of about 360 acres of wildlife habitat compared to 1985 conditions when the original WDNR-SEWRPC net wildlife habitat inventory plan was considered. Losses in wildlife habitat since 1985, primarily as a result of residential land development and related uses, were partially offset by the creation of new wildlife habitat due to both natural succession as a result of farm abandonment and pond construction. Analysis of the mapping data indicates that there has been a net loss of approximately 180 acres of Class I habitat; 220 acres of Class II habitat; and 290 acres of Class III habitat compared to 1985.

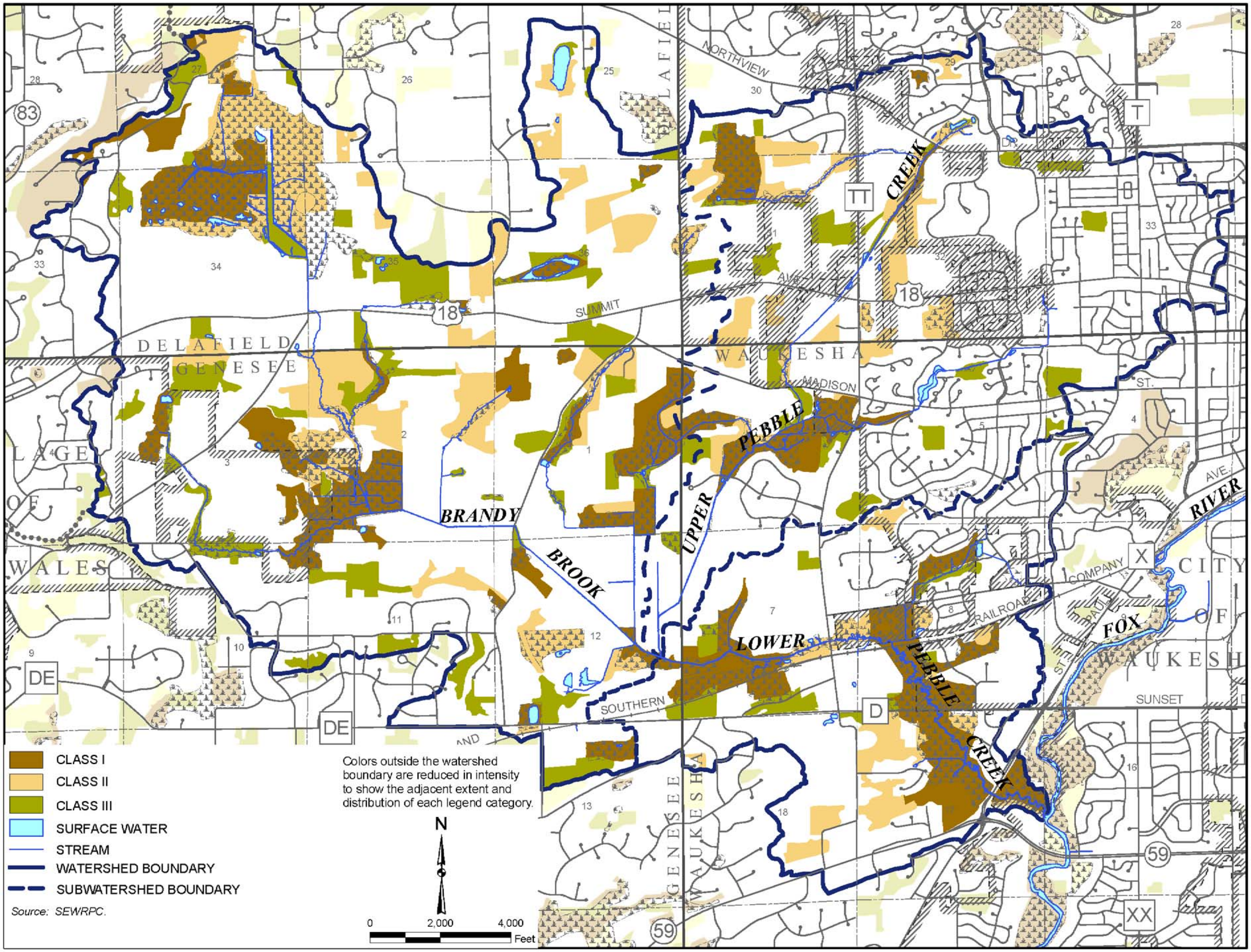
Map 13

WETLANDS AND WOODLANDS WITHIN THE PEBBLE CREEK WATERSHED: 2000



Map 14

WILDLIFE HABITATS WITHIN THE PEBBLE CREEK WATERSHED: 2005



Source: SEWRPC.

Based on 2005 conditions, approximately 1,341 acres, or about 12 percent of the watershed area, were classified as Class I habitat; 1,362 acres, or 12 percent of the watershed area, were classified as Class II habitat; and 903 acres or, 8 percent of the watershed area, were classified as Class III wildlife habitat. It is also important to note that the majority of the wildlife habitat areas are located in the Brandy Brook and Lower Pebble Creek subwatersheds.

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Chapter III

RELATED PLANS, REGULATIONS, AND PROGRAMS

RELATIONSHIP TO OTHER PLANS

The Pebble Creek Watershed Protection Plan is built upon preceding planning and resource management efforts, linking regional- and watershed-level plans with local level planning. This plan will, therefore, provide an integrated framework within which future efforts to protect and rehabilitate the land and water resources within the Pebble Creek watershed can occur. This planning effort contributes to the environmentally sound management of these valuable resources in a coordinated and compatible manner with watershedwide needs and resource management programs. One of the first steps to be undertaken in the watershed planning process is the inventory, collation, and review of the recommendations of relevant previously prepared reports and plans.

These plans include recommendations and programs which address the interconnectedness of the natural resources of this basin with those of the towns, cities, and villages, Waukesha County, and the Southeastern Wisconsin Region, and which focus on the immediacy and importance of natural resources at the community level. The plans collated and reviewed for input into this current planning program were generally most relevant to actions undertaken by Waukesha County or potentially to be undertaken by Waukesha County. In addition, selected plans prepared at the local level, including development plans, land use plans, park and open space plans, and water quality management plans, were all considered. These plans and reports, which are described below, are listed in Table 10 and provide the basis for developing an integrated scheme for the sustainable management of the natural resources of the Pebble Creek watershed through the coordinated efforts of State, County, and local governments, special-purpose units of government, and community groups.

Land Use Plans

The areawide concerns which necessitate a regional planning effort in southeastern Wisconsin have their source in the changes in population size, composition, and distribution, and in the attendant urban development, occurring within the Region. These areawide problems and issues include, among others: drainage and flooding; air and water pollution; increased demand for park and outdoor recreation facilities; the need to provide for adequate sewerage and water supply facilities; traffic congestion; and, underlying all of the foregoing, rapidly changing land use development. The year 2035 comprehensive regional land use plan, SEWRPC Planning Report No. 48 (PR No. 48), provides an adopted framework for coordinating and guiding growth and development within the multijurisdictional urbanizing Region (Table 10). A summary of the existing and planned land use conditions within the Pebble Creek watershed is set forth in Chapter II of this report.

The Waukesha County Development Plan refines and focuses the regionwide land use recommendations. This plan, published in 1996 as SEWRPC Community Assistance Planning Report No. 209 (CAPR No. 209), is being updated under the County's ongoing comprehensive land use planning program and is scheduled for completion in 2008.

Table 10

LAND USE, STORMWATER, SANITARY SEWER, AND ENVIRONMENTAL PLANS PREPARED BY COUNTY AND LOCAL GOVERNMENTS IN WAUKESHA COUNTY: 2006

Plan Type	Community	Plan and Date of Publication	Adoption Date by Governing Body[a]
Land Use	Regional	SEWRPC Planning Report No. 48, *A Regional Land Use Plan for Southeastern Wisconsin: 2035*, June 2006	- -
	Waukesha County	SEWRPC Community Assistance Planning Report No. 209, *A Development Plan for Waukesha County, Wisconsin*, August 1996	1996
	City of Waukesha	SEWRPC Community Assistance Planning Report No. 169, A *Land Use Plan for the City of Waukesha Planning Area: 2010, Waukesha County, Wisconsin*, September 1993	1993
	City of Pewaukee	SEWRPC Community Assistance Planning Report No. 76, *A Land Use Plan for the Town and Village of Pewaukee, Waukesha County, Wisconsin,* December 1982	1982
	City and Village of Pewaukee	Ruekert & Mielke, *City and Village of Pewaukee Consolidation Study,* January 2002	- -
	Village of Pewaukee	The Bradlee Group, *Village of Pewaukee Master Plan*, November 1998	1998
	Village of Wales	SEWRPC Community Assistance Planning Report No. 256, *A Master Plan for the Village of Wales: 2020, Waukesha County, Wisconsin,* April 2004	2003
	Town of Delafield	Planning and Design Institute, Inc., and R. A. Smith and Associates, Inc., *Land Use Plan, Town of Delafield,* June 1999	1999
	Town of Genesee	SEWRPC Community Assistance Planning Report No. 22, *Alternative and Recommended Land Use Plans for the Town of Genesee-2000, February 1978*	- -[c]
	Town of Waukesha	*Town of Waukesha Master Land Use Plan*, November 1994	1994
Stormwater and Drainage	City of Waukesha	Hey & Associates, Inc., *East Branch of Pebble Creek Stormwater Management Plan, Waukesha County, Wisconsin,* September 2002	- -[d]
		Hey & Associates, Inc., *City of Waukesha Stormwater Management Plan, Waukesha County, Wisconsin,* August 2003	- -[e]
	Drainage District	Ayres & Associates, Inc. *Waukesha Genesee Drainage District #1 Flood Study Maintenance Plan,* October 2005	- -
Sanitary Sewer	Waukesha County	Black & Veatch, *Sanitary Sewerage System Plan for the Northwestern Waukesha County Area,* April 2000	- -
	City of Delafield	SEWRPC Community Assistance Planning Report No. 127, *Sanitary Sewer Service Area for the City of Delafield and the Village of Nashotah and Environs, Waukesha County, Wisconsin,* November 1992	- -
	City of Waukesha	SEWRPC Community Assistance Planning Report No. 100, 2nd Edition, *Sanitary Sewer Service Area for the City of Waukesha and Environs, Waukesha County, Wisconsin,* March 1999	- -
	Village of Pewaukee	SEWRPC Community Assistance Planning Report No. 113, *Sanitary Sewer Service Area for the Town of Pewaukee Sanitary District No. 3, Lake Pewaukee Sanitary District, and Village of Pewaukee, Waukesha County, Wisconsin,* June 1985, amended periodically with last amendment dated 2005	- -
Environmental	Regional	SEWRPC Memorandum Report No. 93, *A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report,* March 1995	- -
		SEWRPC Planning Report No. 42, *A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin,* September 1997	- -
	Waukesha County	Waukesha County Department of Parks & Land Use-Land Resources Division, *Waukesha County Land and Water Resource Management Plan 2006-2010*	2006
		SEWRPC Planning Report No. 12, *A Comprehensive Plan for the Fox River Watershed,* Volume One, *Inventory Findings and Forecasts,* April 1969	- -

Table 10 (continued)

Plan Type	Community	Plan and Date of Publication	Adoption Date by Governing Body[a]
Environmental (continued)	Waukesha County	SEWRPC Community Assistance Planning Report No. 156, *Waukesha County Animal Waste Management Plan,* August 1987	- -
		SEWRPC Community Assistance Planning Report No. 159, *Waukesha County Agricultural Soil Erosion Control Plan,* June 1988	- -
		SEWRPC Memorandum Report No. 145, *Lake and Stream Resources Classification Project for Waukesha County, Wisconsin: 2000, November 2005*	- -
	City of Waukesha	SEWRPC Memorandum Report No. 111, *Waukesha County Greenway Corridor Study, City of Waukesha and Towns of Waukesha and Vernon,* May 1996	- -
Park and Open Space	Regional	SEWRPC Planning Report No. 27, *A Regional Park and Open Space Plan for Southeastern Wisconsin: 2000,* November, 1977	1977
	Waukesha County	SEWRPC Community Assistance Planning Report No. 137, *A Park and Open Space Plan for Waukesha County,* December 1989[f]	- -
	Town of Delafield	Town of Delafield, *Town Parks and Recreation Facilities Five-Year Master Plan 2006-2010*	- -
	Town and Village of Pewaukee	SEWRPC Community Assistance Planning Report No. 42, *A Park and Open Space Plan for the Town and Village of Pewaukee, Waukesha County, Wisconsin,* October 1980	- -

[a]*No record of adoption provided to SEWRPC if no date is listed.*

[b]*The City of Pewaukee adopted the land use plan map in the Waukesha County development plan, with seven modifications, as an update to the land use element of the City of Pewaukee plan adopted in 1982.*

[c]*The plan was not adopted by the Town of Genesee.*

[d]*The plan was not adopted by the City of Waukesha, but this plan was incorporated by reference in the City of Waukesha Stormwater Management Plan.*

[e]*The plan was not adopted by the City of Waukesha.*

[f]*Updated by Chapter XIII of SEWRPC CAPR No. 209, which was amended in March 2004.*

Source: SEWRPC.

At the local government level, each of the local municipalities with the Pebble Creek watershed has an adopted land use plan, except for the Town of Genesee, which utilizes the County development plan for guidance in making land use decisions.

Within this planning umbrella, special-purpose plans provide more detail on specific issues of concern facing the County and local governments. These include stormwater, wastewater, and environmental management plans which are briefly described below.

Stormwater Management Plans

With the adoption of Chapter NR 216, "Storm Water Discharge Permits," of the *Wisconsin Administrative Code*, stormwater planning and management has taken on greater significance as described in the Regulatory Standards section below. This enhanced awareness was further strengthened with the promulgation of Chapter NR 151, "Runoff Management," and related provisions that set forth specific water quality standards for stormwater management that must be met from urban-, nonurban-, and transportation-related land uses.

Both the Cities of Pewaukee and Waukesha have stormwater management plans applicable to lands within the Pebble Creek watershed. The City of Pewaukee stormwater management plan was originally adopted in 1999 and a 2006 update of that plan is nearly complete.[1] The Storm Water Management Plan for the East Branch of Pebble Creek was prepared for Waukesha County and incorporated into the City of Waukesha Storm Water Management Plan by reference. The citywide stormwater management plan was completed in August of 2003. The study area for the East Branch of Pebble Creek plan includes portions of the Cities of Pewaukee and Waukesha within the upper portion of the Upper Pebble Creek subwatershed upstream of Madison Street. These plans form the basis for the City's stormwater discharge permit issued pursuant to Chapter NR 216. An update of citywide pollutant loading calculations was completed in 2007, as required under the conditions of the City's stormwater discharge permit.

The goals for the East Branch of Pebble Creek Storm Water Management Plan include the following:

- Protect the water quality of Pebble Creek and the Fox River, and the local wetlands, and groundwater;
- Protect environmentally sensitive areas, such as wetlands, fish and wildlife habitat, and environmental corridors; and
- Protect public and private property from the potential damages caused by stormwater runoff.

To meet these goals, water quality management recommendations were prioritized into high, medium, and low categories consistent with recommendations as detailed in the Nonpoint Source Control Plan for the Upper Fox River Priority Watershed Project as summarized below. General water quality recommendations also include: enforcement of construction site erosion control ordinances in the Cities of Waukesha and Pewaukee; continued support for the City of Waukesha Hazardous Response Team; and development of an information and education program to promote proper lawn fertilizer and pesticide use, proper disposal of lawn clippings, leaf composting, proper pet waste disposal, and storm sewer stenciling in an effort to prevent dumping of waste down storm sewers.

There are no plans for any of the Pebble Creek watershed communities to develop regional stormwater plans at this time; however, Waukesha County would provide assistance to any community that prepares a regional stormwater management plan.

Sanitary Sewer Service Area Plans

The provision of public sanitary sewer services to appropriate densities of urban development within southeastern Wisconsin is a fundamental principle of the adopted regional water quality management plan. This plan, described below, provides the planning framework within which the need for sanitary sewerage services can be assessed and evaluated. Currently, the eastern portions of the Pebble Creek watershed are encompassed within the sewer service area centered on the City of Waukesha, documented in SEWRPC CAPR No. 100, 2nd Edition. A small portion of the southwestern portion of the drainage area is included within the service area centered on the Village of Wales, documented in the subregional refinement to the regional water quality management plan for northwestern Waukesha County published in 2001. These areas are shown on Map 7 in Chapter II of this report.

Environmental Plans

Regional Water Quality Management Plan

The Southeastern Wisconsin Regional Planning Commission is the designated water quality planning agency for southeastern Wisconsin, pursuant to the terms of Section 208 of the Federal Water Pollution Control Act (P.L. 92-500), also known as the "Clean Water Act." In 1979, the initial regional water quality management plan for southeastern Wisconsin, with a design year of 2000, was formally adopted as SEWRPC Planning Report No. 30 (Table 10). A status report on implementation of that plan was provided in SEWRPC Memorandum Report No. 93 (MR No. 93), published in 1995.

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[1] *Personal communications Mr. Jeffrey L. Weigel, City of Pewaukee.*

Additionally, the regional water quality management plan can be refined through the preparation and adoption of lake and stream management plans, such as this watershed protection plan. In addition, during 1983, a wetland protection and management plan was prepared for the City of Waukesha and environs and published as SEWRPC CAPR No. 77. Recommendations set forth in that plan have been subsumed into the Regional Natural Areas and Critical Species Habitat Protection and Management Plan (PR No. 42) and related local level plans.

Fox River Basin Water Quality Plan
As the State agency tasked with water resources management, the Wisconsin Department of Natural Resources (WDNR) prepares basin-level plans that guide the application of State resources to the major drainage basins across the State. The basin plan for the Fox River basin is set forth in WDNR Publication WT-701-01, *The State of the Southeast Fox River Basin*, published in 2002. This plan identified nine priority issues affecting the basin's water resources, including the need to acquire basic inventory data on the state of the basin, the impacts of land use changes on the water resources of the basin, the impacts of land use changes on the terrestrial resources of the basin, and the need for consideration of groundwater recharge and quality, as well as for the provision of recreational use opportunities. Of particular relevance to the Pebble Creek watershed are recommendations that implement Federal Phase I and Phase II stormwater permitting requirements for moderate- to large-size municipalities, and which promote compliance within municipalities with construction site erosion control ordinance requirements. In addition, recommendations relating to protection and enhancement of trout streams and coldwater fisheries, implementation of 100-foot-wide buffer zones along streamcourses, and protection of high-value habitat within the basin complement actions set forth in this report.

Priority Watershed Plan (Upper Fox River)
Priority watershed plans for several watersheds in Waukesha County, including the Upper Fox River in 1993, were prepared under the WDNR Wisconsin Nonpoint Source Water Pollution Abatement Program. The Upper Fox River priority watershed plan, published as WDNR Publication WR-366-94, identifies resource issues of concern and recommended specific nonpoint source pollutant reduction goals by subwatershed. For the Pebble Creek subwatershed, the plan recommended a 50 percent reduction in loads of then-existing (circa 1990) urban nonpoint source pollution delivered to streams and 90 percent control of pollution from future urban areas. The plan also recommended a 60 percent reduction in pollutants from croplands and a 50 percent reduction in instream generated pollutants. It is important to note that these pollutant reduction goals are based upon total suspended solid loads. State grants for technical assistance and cost-share funds were made available to encourage landowners to install conservation practices for water quality improvement through December 31, 2005, when the project was closed. The most common use of landowner cost-sharing grants in the Pebble Creek watershed were for conservation tillage.

County Land and Water Resource Management Plan
The 1997 revisions to Chapter 92 of the *Wisconsin Statutes* requires each county to develop a multi-year Land and Water Resource Management (LWRM) plan to address both rural and urban nonpoint source pollution problems. Chapter ATCP 50 of the *Wisconsin Administrative Code* contains details of the planning requirements. The Waukesha County LWRM Plan 2006-2010 was approved by the Waukesha County Board and the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) in March of 2006. This is a second generation plan, intended to be an update to the initial LWRM plan, which was adopted by the Waukesha County Board in February 1999. The LWRM plan outlines the conservation program priorities for the Waukesha County Parks and Land Use, Land Resources Division (LRD) for the next five years. The development of the Pebble Creek watershed protection plan was identified as a high-priority activity in that plan.

Park and Open Space Plans
In addition to the foregoing plans that relate specifically to the aquatic resources of Pebble Creek, the park and open space plans focus on the terrestrial resources and provision of public access to these resources. As with land use in general, local-level park and open space planning is conducted within the framework of the Regional Park and Open Space Plan, initially published as SEWRPC PR No. 27 in 1977, with a design year of 2000. This plan was refined in the Waukesha County Park and Open Space Plan, published in 1989 as SEWRPC CAPR No. 137, and again in the 1996 Waukesha County Development Plan (SEWRPC CAPR No. 209), as well as other local-

level land use plans. A 2004 amendment to the Waukesha County Development Plan incorporated a greenway corridor concept with guidelines for trail preservation and buffer zones. The principal park and open space site within the Pebble Creek watershed is the Waukesha County Retzer Nature Center. The City of Waukesha and Towns of Genesee and Waukesha do not have an adopted park and open space plan, but the City of Waukesha Park Recreation and Forestry Department is in the process of developing such a plan. The Town of Delafield has a five-year master plan for the period from 2006-2010. The plan does not specify land to be acquired in the Pebble Creek watershed, however, the Town is looking for parkland in the southeast quadrant of the Town and has recently expressed interest in a property near the headwaters of Brandy Brook. The location of existing parkland in the watershed is shown on Map 5 in Chapter II of this report under the "recreation" land use category.

WATER USE OBJECTIVES AND WATER QUALITY STANDARDS

The water use objectives for the surface waters of the Pebble Creek watershed are set forth in Chapters NR 102, "Water Quality Standards for Wisconsin Surface Waters," and NR 104, "Uses and Designated Standards," of the *Wisconsin Administrative Code*. Under those code chapters, Pebble Creek upstream of CTH D and Brandy Brook are classified to meet the standards for coldwater sport fish and Pebble Creek downstream of CTH D is classified to meet the standards for warmwater sport fish,[2] and be fully compliant with the fishable and swimmable goals set for the waters of the United States by the Federal Clean Water Act. The water use objectives established for the waters of the Pebble Creek watershed are shown on Map 15, and the recommended water quality standards associated with the various water use objectives are set forth in Table 11. The level of pollution control needed to achieve the established water use objectives were initially identified in the regional water quality management plan and was refined under the WDNR nonpoint source priority watershed plan[3] and the Fox River watershed state-of-the-basin report.[4] These plans contained consistent recommendations on the levels of nonpoint source pollution controls needed to achieve water use objectives for the waterbodies within the Pebble Creek watershed.

Upstream of CTH D, the WDNR has reported that Pebble Creek and associated tributaries could potentially support a Class II brook and brown trout fishery.[5] Class II trout streams may contain some natural trout reproduction, but not enough to utilize available food and space. Consequently, stocking is generally required to sustain a desirable sport fishery. Brown trout were first stocked in 1995 and are currently stocked on an annual basis. There is no evidence of natural reproduction of brown trout within Pebble Creek. Although brook trout have never been observed within Pebble Creek, the continued presence of a healthy population of mottled sculpin (a coldwater indicator species) from the 1970s to the present, indicates the potential for the existence of a coldwater community in this system. The streams recreational classification is for partial body contact due to insufficient depth, width, and water volume. As of 1990, Pebble Creek was not meeting this recreational classification due to elevated bacterial concentrations in the water. Water use objective summaries prepared by the WDNR for the priority watershed study indicate that sedimentation, turbidity, excessive nutrient inputs, loss of fish and aquatic insect habitat, streambank erosion, and temperature extremes prevent this system from attaining a

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[2]*Wisconsin Department of Natural Resources, Publication No. PUBL-FH-806-2002,* Wisconsin Trout Streams*, April 2002.*

[3]*Wisconsin Department of Natural Resources, Publication No. PUBL-WR-366-94,* Nonpoint Source Control Plan for the Upper Fox River Priority Watershed Project*, June 1994.*

[4]*Wisconsin Department of Natural Resources, Publication No. PUBL-WT-701-01,* The State of the Southeast Fox River Basin*, February 2002.*

[5]*Wisconsin Department of Natural Resources,* Water Resource Appraisal Report and Stream Classification for the Upper Fox River Priority Watershed, Upper Fox River Basin*, 1990.*

Map 15

CURRENT REGULATORY WATER USE CLASSIFICATIONS FOR SURFACE WATERS WITHIN THE PEBBLE CREEK WATERSHED: 2005

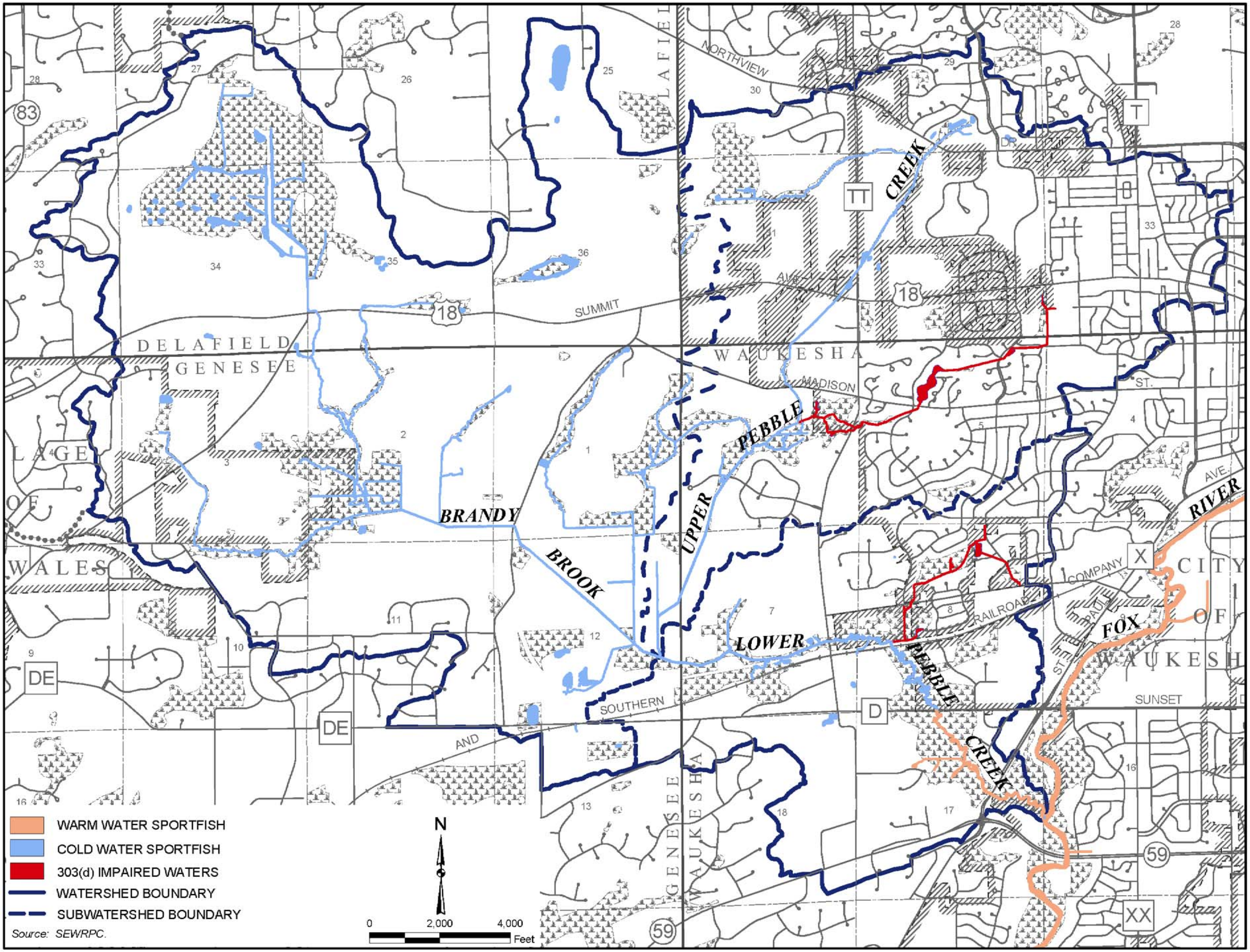

Table 11

APPLICABLE REGULATORY WATER USE OBJECTIVES AND WATER QUALITY STANDARDS, OR CRITERIA, FOR WATERBODIES WITHIN THE PEBBLE CREEK WATERSHED PROTECTION PLAN STUDY AREA

Water Quality Parameter	Combinations of Water Use Objectives Adopted for Planning Purposes[a]						Source
	Coldwater Community	Warmwater Sport Fish and Forage Fish Communities	Limited Forage Fish Community (variance category)	Limited Aquatic Life (variance category)	Special Variance Category A[b]	Special Variance Category B[c]	
Recreational use	Full	Full	Full	Full	Limited	Limited	
Maximum Temperature (^{o}F)[d]	Background	89.0	89.0	- -	89.0[e]	89.0	NR 102.04 (4)[f]
Dissolved Oxygen (mg/l)[d]	6.0 minimum 7.0 minimum during spawning	5.0 minimum	3.0 minimum	1.0 minimum	2.0 minimum	2.0 minimum	NR 102.04 (4) NR 104.02 (3)
pH Range (S.U.)	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0[e]	6.0-9.0[e]	NR 102.04 (4)[g] NR 104.02 (3)
Fecal Coliform (MFFCC)[h]							NR 102.04 (5) NR 104.06 (2)
Mean	200	200	200	200	1,000	1,000	
Maximum	400	400	400	400	2,000	- -	
Ammonia Nitrogen (mg/l)	- -[i]	- -[i]	- -[i]	- -[i]	- -[i]	- -[i]	NR 105 Tables 2c and 4b

[a]*NR 102.04(1) All waters shall meet the following minimum standards at all times and under all flow conditions: substances that will cause objectionable deposits on the shore or in the bed of a body of water, floating or submerged debris, oil, scum, or other material, and material producing color, odor, taste, or unsightliness shall not be present in amounts found to be of public health significance, nor shall substances be present in amounts which are acutely harmful to animal, plant, or aquatic life.*

[b]*As set forth in Chapter NR 104.06(2)(a) of the* Wisconsin Administrative Code.

[c]*As set forth in Chapter NR 104.06(2)(b) of the* Wisconsin Administrative Code.

[d]*Dissolved oxygen and temperature standards apply to continuous streams and the upper layers of stratified lakes and to unstratified lakes; the dissolved oxygen standard does not apply to the hypolimnion of stratified inland lakes. However, trends in the period of anaerobic conditions in the hypolimnion of deep inland lakes should be considered important to the maintenance of their natural water quality.*

[e]*Not specifically addressed within the* Wisconsin Administrative Code. *For planning purposes only, these values are considered to apply.*

[f]*NR 102.04(4) There shall be no temperature changes that may adversely affect aquatic life. Natural daily and seasonal temperature fluctuations shall be maintained. The maximum temperature rise at the edge of the mixing zone above the natural temperature shall not exceed 5ºF for streams. There shall be no significant artificial increases in temperature where natural trout reproduction is to be maintained.*

[g]*The pH shall be within the stated range with no change greater than 0.5 unit outside the estimated natural seasonal maximum and minimum.*

[h]*NR 102.04(5)(a) The membrane filter fecal coliform count may not exceed 200 per 100 ml as a geometric mean based on not less than five samples per month, nor exceed 400 per 100 ml in more than 10 percent of all samples during any month.*

[i]*J.E. McKee and M.W. Wolf,* Water Quality Criteria, 2nd edition, *California State Water Quality Control Board, Sacramento, California, 1963. The standards for ammonia nitrogen are set forth in Table IV-8.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

potential use as a Class II trout stream. These fishery limitations are reported to be due to several factors, including channelization, woody debris snags, cropland runoff, floodplain pasturing, urban runoff, and drain tiles. However, current water quality sampling data indicate that the majority of Pebble Creek upstream of CTH D has the potential to support a Class II brook and brown trout fishery.

Downstream of CTH D, Pebble Creek has been designated by the WDNR as being capable of supporting a warmwater sport fishery.[6] This portion of Pebble Creek contains a high diversity of warmwater fish species, including large game fish such as northern pike, channel catfish, and largemouth bass. The streams recreational classification is for partial body contact due to insufficient depth, width, and water volume. As of 1990, Pebble Creek was not meeting this recreational classification due to elevated bacterial concentrations in the water. Water use objective summaries prepared by the WDNR for the priority watershed study indicate that sedimentation, turbidity, excessive nutrient inputs, loss of fish and aquatic insect habitat, streambank erosion, and temperature extremes limit the warmwater sport fishery in this reach. These fishery limitations are reported to be due to several factors including channelization, woody debris snags, urban runoff, and drain tiles. However, current water quality sampling data indicate that the majority of Pebble Creek downstream of CTH D has the potential to support a high-quality warmwater sport fishery.

Brandy Brook and associated tributaries have been designated by the WDNR as having the potential to support a Class I brook and brown trout fishery.[7] A Class I trout stream is characterized as a high-quality trout water that has sufficient natural reproduction to sustain the native or naturalized populations. Consequently, streams of this category do not require stocking of hatchery raised trout. Although no brook or brown trout have been observed within Brandy Brook, the continued presence of a healthy population of mottled sculpin since the 1970s to present, which is a coldwater indicator species, indicate the potential for the existence of a coldwater community. The streams recreational classification is for partial body contact due to insufficient depth, width, and water volume. As of 1990, Brandy Brook was not meeting this recreational classification due to elevated bacterial concentrations in the water. Water use objective summaries prepared by the WDNR for the priority watershed study and other empirical evidence indicates that loss of habitat for fish and invertebrates, flow fluctuations, sedimentation, pesticides or herbicides, temperature extremes, excessive nutrient inputs, low dissolved oxygen, barnyard runoff, and streambank pasturing prevent this reach from meeting the criteria for a Class I trout stream. These fishery limitations are reported to be due to several factors, including channelization, woody debris snags, cropland runoff, bank debrushing, drain tiles, drainage of wetlands, bacteria, and roadside ditch erosion. However, current water quality sampling data indicate that Brandy Brook has the potential to support a Class I trout fishery.

In addition, two unnamed tributaries located within the eastern portions of the Upper and Lower subwatersheds of Pebble Creek have been proposed for inclusion on the Wisconsin List of Impaired Waters pursuant to the requirements of Section 303(d) of the Federal Clean Water Act. As of June 2006, these intermittent streams have been proposed to be designated as impaired based on degraded habitat and elevated temperatures. These tributaries, shown on Map 15, are consequently identified for application of remedial measures under various programs being implemented by the WDNR with financial assistance from the U.S. Environmental Protection Agency (USEPA).

STATE REGULATORY STANDARDS

Through 1997 Wisconsin Act 27, the State Legislature required the WDNR and DATCP to develop performance standards for controlling nonpoint source pollution from agricultural and nonagricultural land and from transportation facilities.[8] The performance standards are set forth in Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code,* which became effective on October 1, 2002, and was revised in July 2004.

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[6]*Wisconsin Department of Natural Resources,* Water Resource Appraisal Report and Stream Classification for the Upper Fox River Priority Watershed, Upper Fox River Basin*, 1990.*

[7]Ibid.

[8]*The State performance standards are set forth in the Chapter NR 151, "Runoff Management," of the* Wisconsin Administrative Code. *Additional code chapters that are related to the State nonpoint source pollution control program include: Chapter NR 152, "Model Ordinances for Construction Site Erosion Control and Storm Water (Footnote Continued on Next Page)*

Agricultural Performance Standards
Performance standards relate to three areas of agriculture: cropland soil erosion control, manure management, and nutrient management. The agricultural performance standards are:

- Soil erosion rates on all cropland must be maintained at or below "T" (Tolerable Soil Loss).

- Starting in 2005, for high-priority areas, such as impaired or exceptional waters, and 2008 for all other areas, application of manure or other nutrients to croplands must be done in accordance with a nutrient management plan, designed to meet State standards for limiting the entry of nutrients into groundwater or surface water resources.

- Clean water runoff must be diverted away from contacting feedlots, manure storage facilities, and barnyards in water quality management areas (areas within 300 feet of a stream, 1,000 feet from a lake, or areas susceptible to groundwater contamination).

- All new or substantially altered manure storage facilities must meet current engineering design standards to prevent surface or groundwater pollution.

The manure management prohibitions are:

- No direct runoff from animal feedlots to "waters of the State."

- No overflowing manure storage facilities.

- No unconfined manure piles in shoreland areas (areas within 300 feet of a stream, 1,000 feet from lakes).

- No unlimited livestock access to "waters of the State" where the livestock prevent sustaining an adequate vegetative cover.

In general, for land that does not meet the NR 151 standards and that was cropped or enrolled in the U.S. Department of Agriculture Conservation Reserve or Conservation Reserve Enhancement Programs as of October 1, 2002, agricultural performance standards are only required to be met if cost-sharing funds are available. Existing cropland that met the standards as of October 1, 2002, must continue to meet the standards. New cropland must meet the standards, regardless of whether cost-share funds are available.

Chapter NR 243, "Animal Feeding Operations," of the *Wisconsin Administrative Code* sets forth rules for concentrated animal feeding operations and other animal feeding operations for the purpose of controlling the discharge of pollutants to waters of the State. 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

(Footnote Continued from Previous Page)
Management;" Chapter NR 153, "Runoff Management Grant Program;" Chapter NR 154, "Best Management Practices, Technical Standards and Cost-Share Conditions;" Chapter NR 155, "Urban Nonpoint Source Water Pollution Abatement and Storm Water Management Grant Program;" and Chapter ATCP 50, "Soil and Water Resource Management." Those chapters of the Wisconsin Administrative Code *became effective in October 2002. Chapter NR 120, "Priority Watershed and Priority Lake Program," and Chapter NR 243, "Animal Feeding Operations," were repealed and recreated in October 2002.*

chickens each would be considered to have the equivalent of 1,000 animal units. All concentrated animal feeding operations and certain types of other animal feeding operations must obtain Wisconsin Pollutant Discharge Elimination System (WPDES) permits. In general, animal feeding operations are defined as feedlots or facilities, other than pastures, where animals are fed for a total of 45 days in any 12-month period.

Nonagricultural (Urban) Performance Standards

The nonagricultural performance standards set forth in Chapter NR 151 encompass two major types of land management. The first includes standards for areas of new development and redevelopment, and the second includes standards for developed urban areas. The performance standards address the following areas:

- Construction sites for new development and redevelopment,
- Post-construction stormwater runoff for new development and redevelopment,
- Developed urban areas, and
- Nonmunicipal property fertilizing.

Chapter NR 151 requires that municipalities with WPDES stormwater discharge permits, as required under Chapter NR 216 reduce the amount of total suspended solids in stormwater runoff from areas of existing development that is in place as of October 2004 to the maximum extent practicable, according to the following standards:

- By March 10, 2008, the NR 151 standards call for a 20 percent reduction, and
- By October 1, 2013, the standards call for a 40 percent reduction.

Also, permitted municipalities must implement 1) public information and education programs relative to specific aspects of nonpoint source pollution control; 2) municipal programs for collection and management of leaf and grass clippings; and 3) site-specific programs for application of lawn and garden fertilizers on municipally controlled properties with over five acres of pervious surface. Under the requirements of Chapter NR 151, by March 10, 2008, incorporated municipalities with average population densities of 1,000 people or more per square mile that are not required to obtain municipal stormwater discharge permits must implement those same three programs.

In addition, regardless of whether a municipality is required to have a stormwater discharge permit under Chapter NR 216, Chapter NR 151 requires that all construction sites that have one acre or more of land disturbance must achieve an 80 percent reduction in the sediment load generated by the site. With certain limited exceptions, those sites required to have construction erosion control permits must also have post-development stormwater management practices to reduce the total suspended solids load from the site by 80 percent for new development, 40 percent for redevelopment, and 40 percent for infill development occurring prior to October 1, 2012. After October 1, 2012, infill development will be required to achieve an 80 percent reduction. If it can be demonstrated that the solids reduction standard cannot be met for a specific site, total suspended solids must be controlled to the maximum extent practicable.

Section NR 151.12 of the *Wisconsin Administrative Code* requires infiltration of post-development runoff from areas developed on or after October 1, 2004, subject to specific exclusions and exemptions as set forth in Sections 151.12(5)(c)5 and 151.12(5)(c)6, respectively. In residential areas, either 90 percent of the annual predevelopment infiltration volume or 25 percent of the post-development runoff volume from a two-year recurrence interval, 24-hour storm, is required to be infiltrated. However, no more than 1 percent of the area of the project site is required to be used as effective infiltration area. In commercial, industrial and institutional areas, 60 percent of the annual predevelopment infiltration volume or 10 percent of the post-development runoff volume from a two-year recurrence interval, 24-hour storm, is required to be infiltrated. In this case, no more than 2 percent of the project site is required to be used as effective infiltration area.

Transportation Facility Performance Standards
Transportation facility performance standards that are set forth in Chapter NR 151 and in Chapter TRANS 401, "Construction Site Erosion Control and Storm Water Management Procedures for Department Actions," of the *Wisconsin Administrative Code* cover the following areas:

- Construction sites,
- Post-construction phase, and
- Developed urban areas.

The standards of TRANS 401 are applicable to Wisconsin Department of Transportation projects.

Municipal Stormwater Discharge Permits
Chapter NR 216 contains stormwater permitting requirements for communities that address stormwater discharges from municipal separate storm sewer systems. Under Phase I of the permitting program, permits were obtained by eight communities in the Upper Fox River watershed, including the Cities of Pewaukee and Waukesha and the Towns of Delafield and Waukesha within the Pebble Creek watershed. Waukesha County is subject to permitting requirements under Phase II of the rule implementation. Additional communities in the Pebble Creek watershed that will be required to obtain stormwater discharge permits under Phase II of the permitting program include the Village of Wales and the Town of Genesee. All Phase II communities in the Pebble Creek watershed submitted their "Notice of Intent to Apply" during the summer of 2006.

The 1987 amendments to the Federal Clean Water Act established a Federal program for permitting stormwater discharges. The State of Wisconsin obtained certification from the USEPA which enabled the State to administer the stormwater discharge permitting program as an extension of the existing WPDES program. Section 283.33 of the *Statutes*, which provides authority for the issuance of stormwater discharge permits by the State, was enacted in 1993. The administrative rules for the State stormwater discharge permit program are set forth in Chapter NR 216 of the *Administrative Code*, which took effect on November 1, 1994, and was most recently repealed and replaced effective August 1, 2004.

In general, the following entities are required to obtain discharge permits under Chapter NR 216:

1. An owner or operator of a municipal separate storm sewer system serving an incorporated area with a population of 100,000 or more.

2. An owner or operator of a municipal separate storm sewer system notified by WDNR prior to August 1, 2004, that they must obtain a permit.

3. An owner or operator of a municipal separate storm sewer system located within an urbanized area as defined by the U.S. Bureau of the Census.

4. An owner or operator of a municipal separate storm sewer system serving a population of 10,000 or more in a municipality with a population density of 1,000 persons or more per square mile as determined by the U.S. Bureau of the Census.

5. Industries identified in Section NR 216.21.[9]

6. Construction sites, except those associated with agricultural land uses, those for commercial buildings regulated by Chapters Comm 50 through 64 of the *Wisconsin Administrative Code*,[10,11] and Wisconsin Department of Transportation projects which are subject to the liaison cooperative agreement between the WDNR and the Wisconsin Department of Transportation.

The NR 216 municipal permitting system has led to intergovernmental cooperation among a number of local communities. The LRD has executed intergovernmental agreements with the Towns of Delafield and Waukesha to help them satisfy a permit condition of enforcing the nonpoint performance standards for new construction sites. The agreements would allow the Towns to meet this requirement through the LRD's enforcement of the Waukesha County Storm Water Management and Erosion Control Ordinance. In addition, the eight communities in the Upper Fox River watershed stormwater discharge permit group have contracted with the LRD to meet the information and education requirements under their discharge permits. For more details on this requirement see the Community Information and Education Programs section below.

Buffer Standards

Riparian buffers help to slow the velocity of water, allowing the settling of suspended soil particles, infiltration of runoff and soluble pollutants, adsorption of pollutants on soil and plant surfaces, and uptake of soluble pollutants by plants. When the administrative rules concerning the redesign of the State nonpoint pollution control program were being developed in 2000 and 2001, there was disagreement about what role vegetative buffers should have in the performance standards. In order for the rest of the administrative rules to move forward, the WDNR agreed to remove the buffer language from the draft rules and revisit the issue at a later date. The Wisconsin Buffer Initiative, led by the University of Wisconsin, was assigned the duty to conduct additional research on the topic and make recommendations for implementation.[12] When the WDNR adopts a buffer standard for NR 151, the Waukesha County Department of Parks and Land Use plans to incorporate it into local program efforts and revise annual work plans as necessary. Until that time, the Natural Resources Conservation Service (NRCS) technical standards will be applied through voluntary programs. At present, voluntary programs, such as the Conservation Reserve Enhancement Program (CREP), set minimum buffer widths based on program goals and technical standards. However, there has been no participation in this program in the Pebble Creek watershed.

There are no communities in the Pebble Creek watershed that require or provide incentives for vegetated shoreland buffers within the shoreland zone or adjacent to wetlands. Primary environmental corridors (PEC), secondary environmental corridors (SEC), and isolated natural resource areas defined by SEWRPC in the aforementioned natural areas and critical species habitat plan are preserved in an ordinance required by Waukesha County. Within the City of Pewaukee only low-density development is allowed within upland PEC, equivalent to

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[9]*Depending on the type of industry, a statewide general permit or an individual permit may be issued. A holder of a general or an individual permit must prepare and implement a stormwater pollution prevention plan. The requirements for such a plan are set forth in Section NR 216.27.*

[10]*Comm 50.115 describes procedures to be followed regarding filing a notice of intent for coverage under a WPDES General Permit for stormwater discharges associated with construction activities.*

[11]*Construction of one- and two-family dwellings is generally regulated by the Wisconsin Department of Commerce. Comm 21.125 sets forth erosion control procedures for construction of one- and two-family dwellings. Owners of properties on which such dwellings are to be constructed would only have to apply for a permit under Chapter NR 216 if the land-disturbing activities associated with the development involved the disturbance of one or more acres.*

[12]*One of the research sites is located on the Koepke farm in the Town of Oconomowoc.*

one home per five acres. The Town of Delafield zoning code limits density on those lands designated as C-1 on the Town zoning map. The C-1 lands typically follow PEC boundaries on parcels greater than five acres. The Towns of Waukesha and Genesee do not require the preservation of PEC, SEC, or isolated natural resource areas by ordinance or offer incentives, but the Town of Genesee encourages the preservation of these lands.

It is important to note that nonagricultural performance standards set forth in section NR 151.12 (post-construction performance standard for new development and redevelopment) also generally requires impervious area setbacks of 50 feet from streams, lakes, and wetlands. This setback distance is increased to 75 feet to protect Chapter NR 102-designated Outstanding or Exceptional Resource Waters or Chapter NR 103-designated wetlands of special natural resource interest. Reduced setbacks from less susceptible wetlands and drainage channels of not less than 10 feet may be allowed.

COUNTY AND LOCAL GOVERNMENT LAND USE REGULATIONS

The comprehensive zoning ordinance represents one of the most important and significant tools available to local units of government in directing the proper use of lands within their area of jurisdiction. Local zoning regulations include general, or comprehensive, zoning regulations and special-purpose regulations governing floodland and shoreland areas. General zoning and special-purpose zoning regulations may be adopted as a single ordinance or as separate ordinances; they may or may not be contained in the same document. Any analysis of locally proposed land uses must take into consideration the provisions of both general and special-purpose zoning. As already noted, the watershed includes portions of the Cities of Pewaukee and Waukesha; the Village of Wales; and the Towns of Delafield, Genesee, and Waukesha. The ordinances administered by these units of government are summarized in Table 12 and described in more detail below.

General Zoning

Cities in Wisconsin are granted comprehensive, or general, zoning powers under Section 62.23 of the *Wisconsin Statutes*. The same powers are granted to villages under Section 61.35, *Wisconsin Statutes*. Counties are granted general zoning powers within their unincorporated areas under Section 59.69 of the *Statutes*. However, a county zoning ordinance becomes effective only in those towns that ratify the county ordinance. Towns that have not adopted a county zoning ordinance may adopt village powers, and subsequently utilize the city and village zoning authority conferred in Section 62.23, subject, however, to county board approval where a general-purpose county zoning ordinance exists. Alternatively, a town may adopt a zoning ordinance under Section 60.61 of the *Wisconsin Statutes* where a general-purpose county zoning ordinance has not been adopted, but only after the county board fails to adopt a county ordinance at the petition of the governing body of the town concerned. General zoning is in effect in all communities in Waukesha County.

Zoning is a tool used to regulate the use of land in Waukesha County in a manner that serves to promote the general welfare of its citizens, the quality of the environment and the conservation of its resources. Zoning also implements a land use plan. Zoning is the delineation of areas or zones into specific districts which provides uniform regulations and requirements that govern the use, placement, spacing, and size of land and buildings. The Planning and Zoning Division of the Waukesha County Department of Parks and Land Use administers the zoning maps and the zoning ordinance for portions of the unincorporated areas of Waukesha County. The Basic Zoning Code was adopted in 1959 and last updated in May of 2005. Within the watershed that code applies only to the Town of Genesee. The code is designed to provide standards for land development to provide for adequate sanitation, drainage, safety, convenience of access, the preservation and promotion of the environment, property values, and general attractiveness. The Towns of Delafield and Waukesha each have their own zoning code pursuant to Section 60.61 of the *Wisconsin Statutes*.

Floodland Zoning

Section 87.30 of the *Wisconsin Statutes* requires that cities, villages, and counties, with respect to their unincorporated areas, adopt floodland zoning to preserve the floodwater conveyance and storage capacity of floodplain areas and to prevent the location of new flood-damage-prone development in flood hazard areas. The minimum standards which such ordinances must meet are set forth in Chapter NR 116, "Wisconsin's Floodplain

Table 12

LAND USE REGULATIONS WITHIN THE PEBBLE CREEK WATERSHED
RELATED TO ENVIRONMENTAL AND NATURAL RESOURCE ISSUES: JULY 2006

	Type of Ordinance[a]					
Community	General Zoning	Floodland Zoning	Shoreland or Shoreland Wetland Zoning	Subdivision Control	Construction Site Erosion Control	Stormwater Management
Waukesha County	05/2005	05/2005	03/2005	1970 (shoreland only)	03/2005	03/2005
City of Pewaukee.........	06/2006	06/2006	06/2006	06/2006	County 03/2005	County 03/2005
City of Waukesha	12/2001	12/2001	12/2001	1981	06/2005	06/2005
Village of Wales...........	1994	06/2001	06/2001	1994	04/2001	04/2001
Town of Genesee	County 05/2005	County 05/2005	County 03/2005	1992	County 03/2005	County 03/2005
Town of Waukesha......	05/2003	05/2001	County 03/2005	2001	1980	County 03/2005
Town of Delafield.........	2005	County 05/2005	County 03/2005	1995	County 03/2005	County 03/2005

[a]*The dates in this table reflect the most recent revision of each ordinance.*

Source: SEWRPC.

Management Program," of the *Wisconsin Administrative Code*. The required regulations govern filling and development within a regulatory floodplain, which is defined as the area subject to inundation by the 100-year recurrence interval flood event, the event which has a 1 percent probability of occurring in any given year. Under Chapter NR 116, local floodland zoning regulations must prohibit nearly all forms of development within the floodway, which is that portion of the floodplain required to convey the 100-year recurrence peak flood flow. Local regulations must also restrict filling and development within the flood fringe, which is that portion of the floodplain located outside the floodway that would be covered by floodwater during the 100-year recurrence flood. Permitting the filling and development of the flood fringe area, however, reduces the floodwater storage capacity of the natural floodplain, and may, thereby, increase downstream flood flows and stages.

The Waukesha County Shoreland/Floodland Protection Ordinance recognizes existing uses and structures and regulates them in accordance with sound floodplain management practices while protecting the overall water quality of stream systems. This ordinance is intended to 1) regulate and diminish the proliferation of nonconforming structures and uses in floodplain areas; 2) to regulate reconstruction, remodeling, conversion and repair of such nonconforming structures with the overall intent of lessening the public responsibilities attendant to the continued and expanded development of land and structures which are inherently incompatible with natural floodplains; and 3) to lessen the potential danger to life, safety, health, and welfare of persons whose lands are subject to the hazards of floods. Floodland zoning is in place for all the towns in Waukesha County. Towns may enact floodland zoning regulations which may be more restrictive than those in the County Shoreland and Floodland Protection Zoning Ordinance. The Cities of Waukesha and Pewaukee, the Village of Wales, and the Town of Waukesha have all adopted their own floodland zoning ordinance. The remainder of the communities follow the Waukesha County Shoreland/Floodland Protection Ordinance (Table 12).

Shoreland Regulation

Shoreland zoning regulations play an important role in protecting water resources. Under Section 59.692 of the *Wisconsin Statutes*, within their unincorporated areas, counties in Wisconsin are required to adopt zoning regulations within statutorily defined shoreland areas, which are defined as those lands within 1,000 feet of a navigable lake, pond, or flowage; 300 feet of a navigable stream; or to the landward side of the floodplain, whichever distance is greater.[13] Minimum standards for county shoreland zoning ordinances are set forth in Chapter NR 115, "Wisconsin's Shoreland Management Program," of the *Wisconsin Administrative Code*. Chapter NR 115 sets forth minimum requirements regarding lot sizes and building setbacks; restrictions on cutting of trees and shrubbery; and restrictions on filling, grading, lagooning, dredging, ditching, and excavating that must be incorporated into county shoreland zoning regulations. Because these are minimum requirements, counties may enact more restrictive ordinance provisions as are appropriate. In addition, Chapter NR 115 requires that counties place all wetlands five acres or larger and within the statutory shoreland zoning jurisdiction area into a wetland conservancy zoning district to ensure their preservation after completion of appropriate wetland inventories by the WDNR.

In 1982, the State Legislature extended shoreland-wetland zoning requirements to cities and villages in Wisconsin. Under Sections 62.231 and 61.351, respectively, of the *Wisconsin Statutes*, cities and villages in Wisconsin are required to place wetlands five acres or larger and located in statutory shorelands into a shoreland-wetland conservancy zoning district to ensure their preservation. Minimum standards for city and village shoreland-wetland zoning ordinances are set forth in Chapter NR 117, "Wisconsin's City And Village Shoreland-Wetland Protection Program," of the *Wisconsin Administrative Code*. The criteria concerning permitted uses, functional values and uses, and State review and oversight are, for the most part, the same as for county shoreland-wetland zoning, although cities and villages may be more restrictive than State requirements with regard to the uses they allow in shoreland-wetlands. However, the rules regarding minimum lots sizes, building setbacks, and cutting of trees and shrubbery established in Chapter NR 115 for counties do not apply to cities and villages, except for newly annexed areas.

The basis for identification of wetlands to be protected under Chapters NR 115 and NR 117 is the Wisconsin Wetlands Inventory. Mandated by the State Legislature in 1978, that inventory resulted in the preparation of wetland maps covering each U.S. Public Land Survey township in the State. The inventory was completed for counties in southeastern Wisconsin in 1982 with the wetlands being delineated by the Regional Planning Commission on its 1980, one-inch-equals-2,000-feet-scale aerial photography. The Commission staff, working in conjunction with the WDNR, is in the process of updating that wetland inventory.

County shoreland zoning ordinances are in effect in all unincorporated areas of Waukesha County. All of the incorporated municipalities within the Pebble Creek watershed have adopted shoreland-wetland zoning ordinances.

Shoreland Zoning Regulations in Annexed Lands

According to Section 59.692(7)(a) of the *Wisconsin Statutes*, county shoreland zoning regulations remain in effect in areas which are annexed by a city or village after May 7, 1982, or for a town which incorporates as a city or village after April 30, 1994, unless the ordinance requirements of the annexing or incorporating city or village are at least as stringent as those of the county. The only exception to this condition is if, after annexation, the annexing municipality requests the county to amend the county ordinance to delete or modify provisions that establish specified land uses or requirements associated with those uses. In such a situation, stipulations regarding land uses or requirements may be amended by the county.

Regulatory Programs for Wetlands

The determination of permissible, or potentially permissible, activities in wetlands within the Pebble Creek watershed may involve shoreland-wetland regulations as administered by the counties, cities, and villages, all under the oversight of the WDNR, pursuant to authorities set forth in Chapter 30 of the *Wisconsin Statutes*. Wetland water quality standards are set forth in Chapter NR 103, "Wetland Water Quality Standards," of the *Wisconsin Administrative Code*. The procedures and criteria for the application, processing, and review of State

[13]*Definitive determination of navigability and location of the ordinary high water mark on a case-by-case basis is the responsibility of the Wisconsin Department of Natural Resources.*

water quality certifications are set forth in Chapter NR 299, "Water Quality Certification." Chapter NR 103 applies to the discharge of dredged or fill materials to wetlands, among other provisions. These regulations are administered by the WDNR and in some cases through delegated authority from the U.S. Army Corps of Engineers (USCOE) pursuant to Section 404 of the Federal Clean Water Act. As a result of the January 9, 2001, ruling by the U.S. Supreme Court in the matter of Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers, No. 99-1178 ("SWANCC") certain isolated, nonnavigable, intrastate wetlands/waters are not under USCOE regulatory jurisdiction. However, such wetlands may be regulated under complementary State regulations. In addition to the State standards noted above, the U.S. Department of Agriculture (USDA) implements policies and programs regarding wetland protection and preservation that benefit farmers and the environment.

The minimum developable lot size for parcels that include wetland is regulated by the various jurisdictions that have general zoning authority within the watershed in Waukesha County. For development adjacent to statutory wetlands, Waukesha County ordinance specifies a minimum setback. The City of Waukesha, and Towns of Genesee, Delafield, and Waukesha also follow the county standards. The City of Pewaukee Zoning Ordinance provides for a fractional use of wetlands for the green space requirements. All residential developments must be at least outside the wetlands with a minimum 25-foot building setback. The Village of Wales has no specified setback from statutory wetlands, except for those areas annexed after May 7, 1982. In those instances the county setback would apply. There is currently no maximum area of impervious surface allowed for development adjacent to statutory wetlands. However, the Town of Genesee requires a 50 percent minimum upland lot size adjacent to the wetlands before development is allowed.

Subdivision Regulations

Chapter 236 of the *Wisconsin Statutes* requires the preparation of a subdivision plat whenever five or more lots of 1.5 acres or less in area are created either at one time or by successive divisions within a period of five years. The *Statutes* set forth requirements for surveying lots and streets, for plat review and approval by State and local agencies, and for recording approved plats. Section 236.45 of the *Statutes* allows any city, village, town, or county that has established a planning agency to adopt a land division ordinance, provided the local ordinance is at least as restrictive as the State platting requirements. Local land division ordinances may include the review of other land divisions not defined as "subdivisions" under Chapter 236, such as when fewer than five lots are created or when lots larger than 1.5 acres are created.

In accordance with Chapter 236 of the *Wisconsin Statutes*, the subdivision regulatory powers of counties are confined to its unincorporated areas. City and village subdivision control ordinances may be applied to extraterritorial areas, as well as to their incorporated areas.[14] Counties have approval authority in the unincorporated areas and objecting authority in the incorporated areas. It is possible for both a county and a town to have concurrent jurisdiction over land divisions in unincorporated areas, or for a city or village to have concurrent jurisdiction with a town and county in the city or village extraterritorial plat approval area. In the case of overlapping jurisdiction, the most restrictive requirements apply. Each of the incorporated communities within the Pebble Creek watershed has adopted its own subdivision ordinance. The subdivision control ordinances adopted and administered by Waukesha County apply only to the unincorporated statutory shoreland areas of the County. However, it should be noted that the Waukesha County Storm Water Management and Erosion Control Ordinance also contains certain cross-compliance provisions that directly affect the subdivision plat review and approval process in all unincorporated areas, as described further below. It is important to note that the entire watershed is covered by extraterritorial review from a city or village.

[14]*Under Section 236.02 of the* Wisconsin Statutes*, the extraterritorial plat approval jurisdiction is the area within three miles of the corporate limits of a first-, second-, or third-class city and within 1.5 miles of a fourth-class city or a village. Within the Pebble Creek watershed, the Cities of Pewaukee and Waukesha are cities of the third-class. Consequently, extraterritorial zoning applies within three miles of each of the Cities of Pewaukee and Waukesha and within 1.5 miles within the Village of Wales within the Pebble Creek watershed.*

The minimum number of lots and lot sizes that triggers the application of subdivision ordinances varies greatly among the communities of the Pebble Creek watershed. In Waukesha County, the minimum number of lots within a subdivision is set at six or more lots of any size in a five-year period. Lot size in Waukesha County is determined by the zoning district. In the City of Waukesha there is no minimum number of lots per subdivision and the minimum lot size is 8,000 square feet. Minimum lot sizes in the City of Pewaukee are dictated by their Zoning Ordinance. The City of Pewaukee has six single-family zoning districts, two duplex zoning districts, and three multi-family zoning districts. Land is generally not rezoned until a development proposal is approved. The current single-family market for most new developments in the City of Pewaukee is approximately 0.5-acre lot sizes (20,000 square feet). There are no minimum lot number requirements.

The Town of Genesee has no minimum number of lots within a subdivision; however, any land division that results in the creation of more than five lots within a five-year period requires that the development follow the formal subdivision platting process. In the Town of Genesee, the minimum lot size is 40,000 square feet and the minimum average width is 150 feet. The Town of Waukesha has a five lot minimum per subdivision. Lot sizes vary with the zoning district, with the smallest allowable residential or business lot size being 20,000 square feet. The Town of Delafield requires a subdivision plat for any land division that creates two or more parcels, five acres in area or less; two or more parcels of five acres or less in area over a five-year period; or three residential lots of any size over a five-year period. The minimum lot size in the Town of Delafield's R-L and R-3 zoning district is 20,000 square feet. The Village of Wales requires a subdivision plat for any land division that creates five lots or more of five acres each or less over a five-year period. Lot sizes vary by zoning district with the minimum lot size being 30,000 square feet.

In order to promote open space, Waukesha County and the City and Town of Waukesha have supported, promoted, and offered incentives for planned unit developments (PUDs), conservation subdivisions, or similar types of development. Planned unit developments are allowed under the City of Pewaukee Zoning Ordinance, but there are no direct incentives. The City of Pewaukee zoning ordinance requires a minimum of 40 percent green space for new multi-family, industrial, institutional, commercial, or office park developments. The Town of Waukesha has density incentives based on open space percentage. At this time, the Town of Genesee allows planned unit developments, but does not promote them. The Town of Delafield zoning code and land use plan promotes the development of PUDs and requires a minimum of 40 percent open space (green space) in addition to lots which are limited to approximately 25 percent hard surface coverage (75 percent green space depending on the zoning). The Village of Wales also allows PUDs and the recently adopted land use plan for the village encourages them.

Construction Site Erosion Control and Stormwater Management Ordinances
Stormwater management and erosion control ordinances help minimize water pollution, flooding, and other negative impacts of urbanization on downstream water resources (lakes, streams, wetlands, and groundwater) and property owners, both during and after construction activities. These ordinances are an important tool for accomplishing watershed protection goals because they apply to the whole watershed, not just a certain distance from the water resource.

The *Wisconsin Statutes* grant authority to counties (Section 59.693), cities (Section 62.234), villages (Section 61.653), and towns (Section 60.627) in Wisconsin to adopt ordinances for the prevention of erosion from construction sites and the management of stormwater runoff, which generally apply to new development from lands within their jurisdictions. A county ordinance would apply to all unincorporated areas and newly annexed lands, unless the annexing city or village enforces an ordinance at least as restrictive as the county ordinance. Towns may adopt village powers pursuant to Section 60.10 of the *Wisconsin Statutes* and subsequently utilize the authority conferred on villages to adopt their own erosion control and stormwater management ordinances. Pursuant to Section 60.627 of the *Wisconsin Statutes*, Town construction site erosion control and stormwater management zoning requirements adopted under this section supersede county ordinances.

Many communities in Waukesha County first adopted a construction site erosion control ordinance in the early 1990s, including Waukesha County in 1992, as a condition of State grants available through the Upper Fox River

Priority Watershed Project. In the mid-1990s Waukesha County, through the Storm Water Advisory Committee, helped develop a State model ordinance for post-construction stormwater management, which was later merged into a single ordinance for erosion control and stormwater management. The County adopted the merged ordinance in 1998 and many local communities followed. All communities in the Pebble Creek watershed have adopted an erosion control ordinance. The Village of Wales is in the initial stages of updating their stormwater management ordinance to be consistent with Waukesha County's.

Starting in August 2004, the LRD worked with the Waukesha County Storm Water Advisory Committee over the period of seven months to rewrite the county ordinance to reflect the new performance standards and address a number of other implementation issues identified by the LRD. In March of 2005, the Waukesha County Board adopted Chapter 14, Article VIII, "Storm Water Management and Erosion Control Ordinance of the Waukesha County Code."[15] Enforcement of this ordinance currently represents the largest workload for the LRD, resulting in an average of 100 permits per year. It should be noted that local erosion control ordinances do not apply to single-family home construction as these are regulated under Chapter Comm 21 of the *Wisconsin Administrative Code*. Chapter Comm 21 supersedes all local ordinances. In June 2006, the LRD applied for status as an "authorized local program" by the WDNR under the provisions of NR 216.415 for regulating stormwater discharges from new construction sites within the jurisdiction of the County ordinance. This would streamline the regulatory framework that land developers, contractors, and the County must work within to secure the necessary permits before beginning development or road projects.

Under the County ordinance, there are a series of triggers that require a Storm Water Permit from the LRD. "Land disturbing activities" of a certain size require the preparation of an erosion control plan, aimed to reduce soil erosion and sedimentation during the construction and landscaping phases of a development. "Land development activities" generally result in the addition of impervious surfaces to the land (i.e., rooftops and pavement of at least one-half acre in size), which requires the preparation of a stormwater management plan to control post-construction stormwater runoff. Either one requires a Storm Water Permit. The ordinance establishes a series of technical design standards aimed to maintain predevelopment runoff patterns, peak flows, infiltration, water quality and the general hydrology of the site. While these standards may vary slightly between communities, the general intent and resulting best management practices on the landscape are usually similar.

Because stormwater management planning has a large effect on onsite planning and land divisions, several provisions have been incorporated into the County ordinance to better coordinate stormwater planning with these other planning processes. One requires a "Preliminary Review Letter" from the LRD before certain zoning decisions or preliminary plat approval can be completed by the Planning and Zoning Division. Another requires a "Certification of Compliance" with the ordinance from the LRD before a Plat or Certified Survey Map can be approved for recording with the County Register of Deeds. These provisions have proved invaluable in avoiding conflicts between regulatory review processes and in promoting environmentally sound site planning for new developments.

Erosion Control for One- and Two-Family Dwelling Construction

Since the early 1990s, the Wisconsin Uniform Dwelling Code, set forth in Chapter Comm 21 of the *Wisconsin Administrative Code*, has included erosion control requirements for one- and two-family homes that apply statewide. In the Town of Genesee the Town building inspector performs erosion control inspections for new one- and two-family residences, and the Town engineer inspects new subdivisions. In the Town of Waukesha, the Town engineer inspects stormwater management measures and facilities, and the Town building inspector performs erosion control and construction site inspections. Within the Town of Delafield erosion control is inspected by the Waukesha County Department of Parks and Land Use and Town engineer. The Town engineer also performs onsite construction erosion control inspection.

[15] *A copy of the ordinance is available on the LRD's web page at www.waukeshacounty.gov/landconservation.*

The City of Pewaukee last revised its construction site erosion control and post-construction stormwater management ordinance in March of 2005. In the City of Pewaukee the City engineer is responsible for construction site erosion control for all parcels of one acre or larger. The director of building services is responsible for sites smaller than one acre (primarily residential). The inspections are not currently based on run-off events; however, if a one- to two-family site is within a larger development project, such as a subdivision development, then the engineering department will conduct an inspection of the development following a rainfall event. The City of Pewaukee engineering staff is delegated to administer the inspection program. The City of Waukesha routinely inspects construction sites and enforces ordinance requirements for those sites that fall under its jurisdiction. The enforcement of erosion control requirements for one- and two-family home construction is the responsibility of the local building inspectors under the Uniform Dwelling Code. The Village of Wales, like many other communities contracts with a local inspection firm for building inspection services including erosion control.

Building Regulations

Waukesha County has incorporated several standards into their stormwater ordinance that are aimed to prevent basement wetness and flooding in newly developed areas, even if they are outside of zoned floodplains. For buildings designed for human occupation, these standards address flooding from surface water and wetness caused by groundwater seepage. For surface water, the standards use the peak water surface elevation produced by a 100-year, 24-hour design storm as a benchmark, requiring a 50-foot horizontal setback and a minimum two-foot vertical separation from this elevation to the ground surface at the lowest exposed portion of the building. For groundwater, the standards generally do not allow these buildings on hydric soils and require a minimum one-foot vertical separation between seasonal high groundwater table and the proposed basement floor surface. These standards apply to all the unincorporated areas of the County. Similar standards exist in the City of Waukesha with a slightly smaller setback requirement. Within the City of Pewaukee, all buildings must be separated from surface water and groundwater separation is accomplished on a case-by-case basis. The Towns of Genesee, Delafield, and Waukesha follow the County requirement. The Village of Wales zoning code specifies that the lowest building floor level must be at least one foot above the anticipated highest seasonal groundwater level. It also requires a 50-foot setback from a building to a watercourse or drainage channel and requires a vertical separation distance of at least three feet from the ordinary high water line. Requiring buildings to meet these standards helps protect the large investments of local homebuyers, while avoiding potential nuisance drainage issues and costly publicly funded solutions in the future. These restrictions have also become more important in recent years as the living spaces of homes are often extended to a finished lower level.

Stormwater Facility Operation and Maintenance

As stormwater facilities become more complex, they will require more attention by the end users. This is especially true for infiltration practices. Establishing an ongoing operation and maintenance program is key to successful stormwater management. Waukesha County has developed a stormwater facility database that serves as a repository of design, construction, and maintenance information for stormwater best management practices under County jurisdiction. This database is being populated with new projects as they are permitted under the County ordinance. In addition, a process has been developed to populate the database with historical information about previously permitted projects. This database is also accessible to municipal engineers around the County and will serve as a source of information for the continued maintenance of stormwater facilities into the future. The City of Waukesha is in the process of developing a similar database of new and existing stormwater facility locations by subwatershed.

Stormwater management maintenance agreements are now required through all local stormwater ordinances. These agreements include a detailed maintenance plan for each stormwater management practice and describe the owner's obligations for implementation. The agreements usually authorize the local community to enforce the maintenance provisions, using their special assessment powers if needed to ensure the work is done. Detailed as-built documentation is often recorded as an exhibit in the agreement to serve as a reference for future maintenance work. Documentation of inspections and maintenance activities are usually required to be submitted to the local community before a permit is closed and a financial assurance is released.

Beginning with developments that have been finalized in 2006 in the City of Pewaukee there is a requirement, under their revised Stormwater Management Ordinance, for a maintenance agreement between the City of Pewaukee and the developer/homeowner's association. The City of Pewaukee will also, pursuant to NR 216, seek to enter into stormwater maintenance agreements with all privately owned retention/detention ponds that were constructed prior to 2006 (approximately 60 ponds).

Most communities spot check stormwater facilities at the time of initial construction to establish conformance with permit requirements. However, the long-term maintenance of stormwater management practices is often the responsibility of private landowners. Consequently, many communities do not have proactive inspection programs, but may react to citizen complaints. The City of Waukesha was the only community in the watershed that reported doing inspections on a routine basis. Waukesha County has started to include a limited inspection service for existing stormwater practices through intergovernmental agreements with towns. Pursuant to Chapters NR 151 and NR 216 of the *Wisconsin Administrative Code*, the WDNR may require a landowner to maintain stormwater management practices.

Transportation and Infrastructure and Related Elements

Over the next 10 years several major infrastructure, projects are scheduled in the Pebble Creek watershed. New road construction and road widening can have significant environmental and socioeconomic impacts on the watershed. In Waukesha County, discussions are continuing to take place concerning a proposed highway bypass on the west side of the City of Waukesha (see Map 16). Although the final alignment for this project has not been determined, the Advisory Committee expressed significant concerns regarding the possible loss in rural character for the watershed area impacted by the project in terms of added traffic congestion and noise, as well as increased impervious surfaces and possible disturbance to wetlands due to filling. Other projects may include an expansion of CTH TT from USH 18 to Northview Road to four lanes. Design work for this project is scheduled to be completed in 2008 and construction is anticipated to occur in 2010 or 2011. A segment of CTH X from Harris Highland Drive South to STH 59, which is being upgraded to four lanes by the City of Waukesha, is scheduled for construction in 2008. The City of Waukesha plans to replace the Madison Street Bridge over Pebble Creek and to widen the road at that location. Other road reconstruction is planned for Northview Road. The City of Pewaukee intends to extend public sanitary sewers and reconstruct streets in the Arrowhead Trails subdivision, a portion of which lies within the Pebble Creek watershed. At this time, the Towns of Genesee and Delafield cannot predict any major infrastructure changes in the next 10 years.

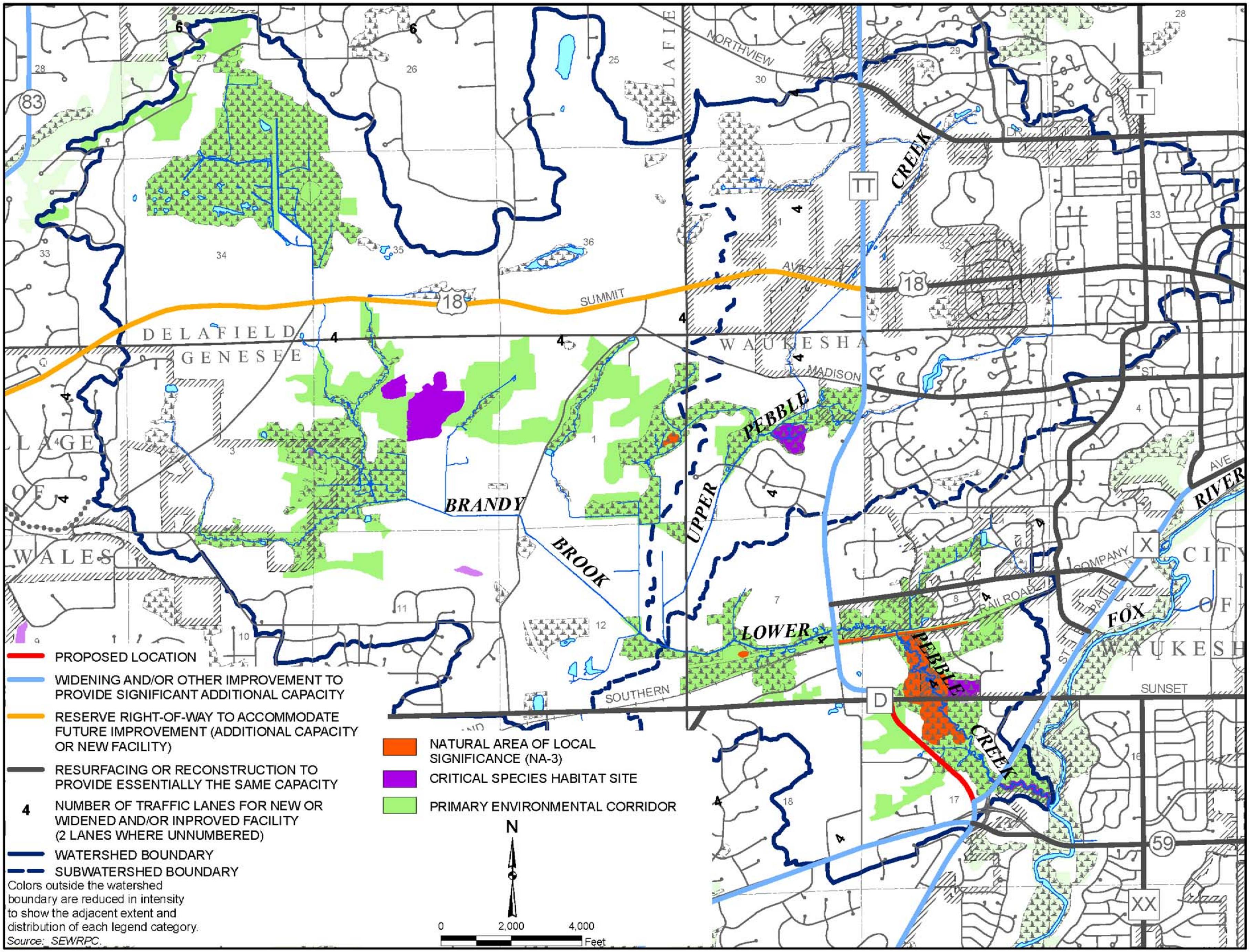
Many communities have longitudinal slope restrictions for roads. Waukesha County has a standard maximum of 8 percent for major roads, and 12 percent for minor roads. The City of Waukesha requires a three horizontal on one vertical slope for grading and generally sets the maximum for slope for roads at 10 percent. A 10 percent longitudinal slope is the maximum allowed by ordinance in the City of Pewaukee, and 6 percent or less is the target maximum. Roads in the Town of Genesee are limited to a maximum slope of 10 percent. The Towns of Delafield and Waukesha and the Village of Wales have allowable roadway slopes ranging from 6 to 10 percent, with the Town of Delafield and the Village of Wales allowing a maximum of 10 percent only on minor roads, and 6 percent on major or collector streets.

To reduce the amount of impervious surface, increase filtration and infiltration, and promote low impact development through alternatives to "curb and gutter" stormwater management practices, the Waukesha County Storm Water Management and Erosion Control Ordinance includes, among its guiding principles, the following:

- Minimize soil compaction and maintain predevelopment groundwater recharge areas; and
- Minimize impervious surfaces and have them drain to vegetated areas for pollutant filtering and infiltration; emphasizing vegetated swales, warm season and wetland plantings, and low-flow velocities for stormwater conveyance, treatment and infiltration, especially for transportation related projects.

Map 16

ARTERIAL STREET AND HIGHWAY SYSTEM PLAN ELEMENT WITHIN THE PEBBLE CREEK WATERSHED: 2035



Communities throughout the Pebble Creek watershed promote and encourage, where practicable, the use of alternative stormwater practices (e.g., grassed swales, infiltration ponds, "rain gardens," and other measures). The existing ordinances promote these practices in principal; however, there presently are no incentives for installing such practices.

Road width and/or sidewalk construction standards designed for the purpose of reducing impervious surfaces are also considered during preliminary development planning. For road construction projects, Waukesha County follows *Wisconsin Statutes* and the Wisconsin Department of Transportation Facilities Development Manual. Design road widths are often related to the source of funding for a particular road construction project.

The City of Waukesha adheres to Subdivision Code 23.06 (4), which provides for street widths to be reduced by the Common Council, and Code 23.07(2)(e), which calls for sidewalk widths to be specified by the City of Waukesha Board of Public Works. The City of Pewaukee does not require sidewalks. They require developers to adhere to their current construction standards, but are willing to consider alternatives that may reduce the impervious areas.

Road width and/or sidewalk construction standards are regulated by the Town of Waukesha Land Division Ordinance. Variance from these standards is based on approval of the Town Board. In the Town of Delafield current road cross-sections provides a 24-foot pavement with grass shoulders and roadside ditches.

An effective street sweeping program can be an important component of an overall stormwater management strategy to reduce nonpoint source pollution through removal of debris and sediment from gutters and roadsides. The Waukesha County Highway Operations Division vacuum sweeps in excess of 1,000 lane-miles of road per year. A concerted effort is made in the early spring to remove debris that accumulates over the winter months. Additional County resources are expended annually to augment street sweeping with the hiring of a private contractor to help with the spring cleanup. The roads that are swept include the urban road segments with curb and gutter. None of the County-maintained road segments in the Pebble Creek watershed are currently in this classification. The City of Waukesha's accelerated street sweeping program includes the use of a high-efficiency, air-regenerative sweeper. Arterials and streets in industrial and commercial areas are swept weekly. Residential streets are swept as the schedule allows. The street sweeping program is suspended during citywide brush and leaf collections, except as needed for those operations. The City of Pewaukee uses standard vacuum sweeping equipment in urban areas, and open brooms in rural areas. They generally sweep the streets about two times per year. The Town of Genesee and the Village of Wales have contracted for street sweeping on a yearly basis. The Town of Waukesha provides street sweeping in the springtime and as needed. The Town of Delafield contracts with a sweeping service which uses an Athey Mobile Street Sweeper, with a mechanical broom. Streets that have limited amounts of curb and gutter are swept twice per year.

The benefits of regular catch basin cleaning include the removal of course sediment and debris, the reduction of high concentration of pollutants flushed by a storm events, and the prevention of potential clogging of the system. Waukesha County storm sewer catch basins are cleaned out by Highway Operations staff on an as-needed basis. As stated above, no curb and gutter segments that are maintained by Waukesha County are present in the Pebble Creek watershed. In both the City of Waukesha and the City of Pewaukee catch basins and stormceptor units are cleaned on an annual basis. The Town of Waukesha has formerly contracted with the City of Waukesha for maintenance of its catch basins. The catch basins in the Town of Delafield are inspected and cleaned as necessary, once in spring, once in fall, and as needed based on citizen complaints. In the Village of Wales, catch basins are cleaned on an as-needed basis.

The application amounts and ratios of salt and sand mixtures to maintain safe winter road conditions vary among the Pebble Creek watershed communities. Waukesha County primarily uses road salt applied according to State guidelines. This varies from 250 to 600 pounds per lane-mile, and depends on the severity of the weather conditions. Typically, only salt is applied, with magnesium chloride added when the temperature is expected to stay below the optimal temperature for salt to work alone as a deicer. When conditions are especially icy and additional traction is desired, a salt/sand mix is utilized. On an annual basis, Waukesha County uses approximately 34,000 tons of salt on State and County highways. The City of Waukesha varies the amount and mixture with weather conditions. Sand that has been moved to the side of the road by vehicular traffic may collect oil, grease, or other automotive byproducts. If it is collected, this sand residue may have to be disposed of as a hazardous waste; therefore, the City of Pewaukee has chosen to use 100 percent salt. The City of Pewaukee spreads approximately 2,000 tons of salt per year over approximately 84 centerline-miles of streets. The Town of Genesee applies a 50/50 sand/salt mixture. The Town of Waukesha applies a 2:1 ratio of sand to salt, with 1,425 tons applied in 2005. The Town of Delafield uses a sand/salt mixture containing 30 to 40 percent salt. Total annual salt use varies greatly based on the weather, but is in the range of 200 to 300 tons per year. The Town of Delafield is considering moving towards more use of salt for greater efficiency in clearing the roads.

Special Units of Government

Stormwater Utility Districts

Section 66.0827 of the *Wisconsin Statutes* permits towns, villages, and cities of the third and fourth class to establish utility districts for a number of municipal improvement functions, including the provision of sanitary sewer service. Funds for the provision of services within the district which are not paid for through special assessments are provided by levying a tax upon all property within the district. The establishment of utility districts requires a majority vote in towns and a three-fourths vote in cities and villages. Prior to establishing such a district, the local governing bodies are required to hold a formal public hearing. The establishment of stormwater utility districts has become more common in recent years as a mechanism to implement stormwater management practices pursuant to Chapter NR 216 of the *Wisconsin Administrative Code*. Such districts install and maintain stormwater conveyance and management systems typically within subdivisions or other portions of municipalities where such services are required. To date, the City of Pewaukee has the only known utility district established within the Pebble Creek watershed.

Farm Drainage Districts

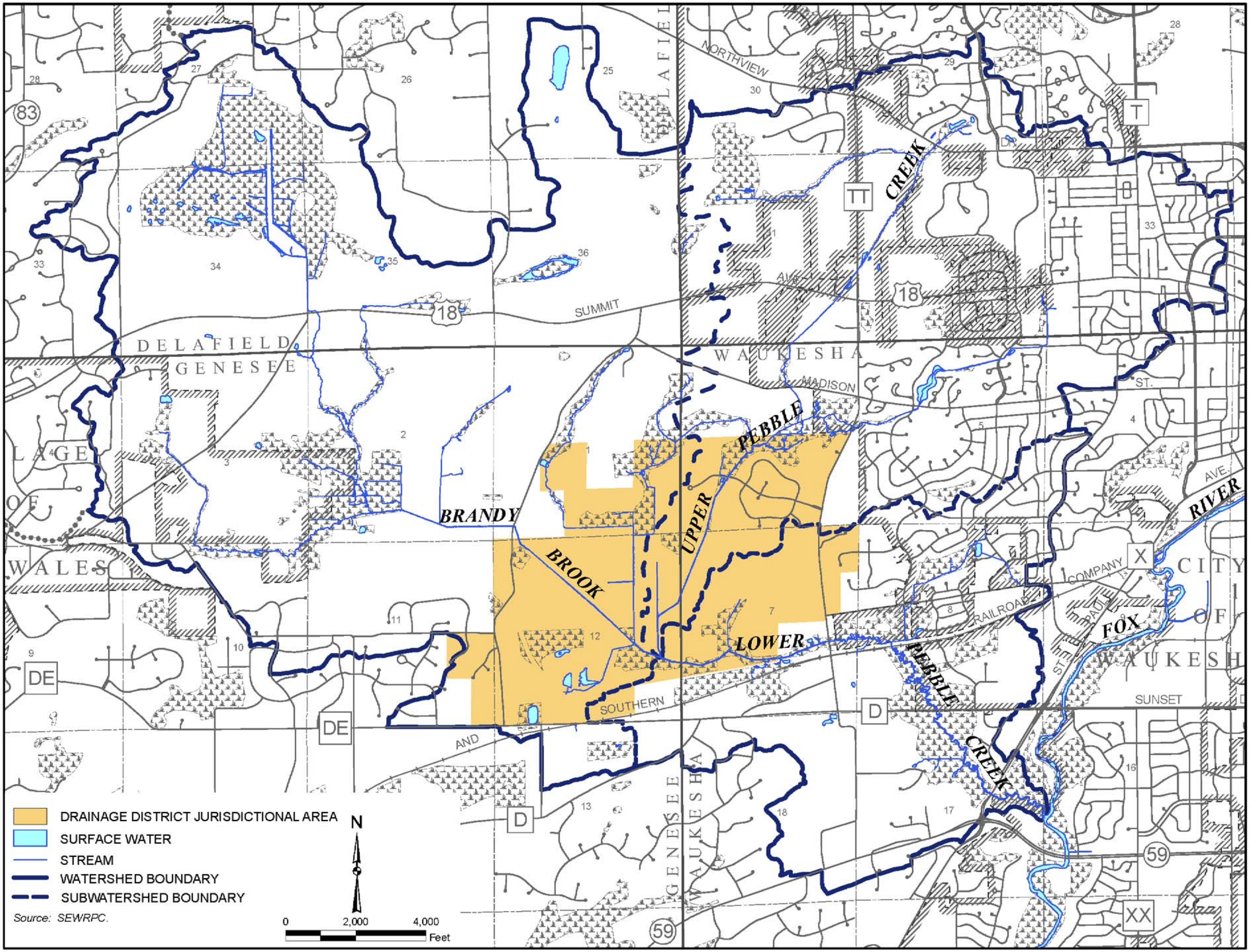
Pursuant to Section 88.11 of the *Wisconsin Statutes*, DATCP promulgated rules regarding farm drainage districts under Chapter ATCP 48 of the *Wisconsin Administrative Code* on July 1, 1995. Those rules were amended effective September 1, 1999. The rules establish procedures for assessing drainage district costs and benefits, inspecting drainage districts, construction and maintenance projects, landowner actions affecting drainage districts, drainage district records, and enforcement and variances. Drainage districts are special-purpose units of government created by petition of the landowners within the proposed district for the purpose of draining land, primarily for agricultural purposes. Lands within a drainage district are drained by means of common drains across individual property boundaries. County drainage boards, established and appointed by the county circuit court, are responsible for operating drainage districts. County drainage boards may levy assessments against landowners in a district to pay for the design, construction, operation and maintenance of district drains, and to pay for other operating expenses. These costs are allocated between landowners based upon a drainage district benefit assessment. The county drainage board may control connections to the district drainage system—the board may prevent municipalities and individuals from discharging to the district drains, or conversely, require such connections and assess the costs thereof to the individual. Once established, the specifications of district drainage systems cannot be changed without the approval of DATCP. County drainage boards and drainage districts operate in perpetuity unless dissolved by the county circuit court upon petition of the landowners within the drainage district.

The Waukesha-Genesee Farm Drainage District No. 1 is the only farm drainage district within the Pebble Creek watershed. The District covers an area of approximately 1,488 acres and is located within the center of the watershed as shown on Map 17.

Pursuant to the requirements of Subchapter IV of Chapter ATCP 48, the Waukesha-Genesee Farm Drainage District No. 1 has quantified the following elements of the drainage district specifications required pursuant to Section ATCP 48.20:

Map 17

DRAINAGE DISTRICT JURISDICTIONAL AREA WITHIN THE PEBBLE CREEK WATERSHED: 2000



- A map which clearly and accurately shows all of the following:
  - The boundaries of the drainage district;
  - The intended alignment and extent of every district drain; and
  - The intended location and width of every district corridor.

- The intended cross-section of every district drain.
  - The intended top and bottom width of the ditch.
  - The intended depth of the ditch.
  - The intended side slope angle of the ditch.
  - Any drainage structures intersected by that vertical section.

- The grade profile of every district drain which shall include all of the following elements:
  - The intended grade elevations of the top and bottom of the ditch;
  - The estimated water surface elevations in the ditch at base flow; and
  - The peak water surface elevations in the ditch in the event of a 10-year, 24-hour storm event.

It is important to note that, in ATCP 48.01, "district drain" is defined as a drain, including a main or lateral drain and all points of inlet to that drain, which is located within a drainage district and is designated as a district drain by either a court order or County drainage board action. A drain is further specified to mean any facility, including a ditch, tile, pipe or other facility, for draining water from land. "Drain" includes structures and facilities, such as dams, culverts, pumps, inlet facilities, dikes, dams, and levees that are ancillary to a drain.

In addition, "district corridor" means the access corridor and buffer strip established and maintained around a district ditch pursuant to Section ATCP 48.24. A county drainage board is required to establish and maintain a district corridor around every district ditch. A district corridor is required to extend for 20 feet from the top of the ditch bank on each side of a district ditch. However, a county drainage board may, by giving specific notice to landowners, establish a wider corridor if necessary to permit vehicle access or to protect water quality in the district ditch. The district corridor is required to be maintained to provide a buffer against land uses which may adversely affect water quality in the district ditch.

These requirements were detailed in several reports by Ayres & Associates, Inc., consultants to the District as of October 2005. The County cost-shared the Flood Study and Grade Profile study that included estimated water surface elevations at base flow and peak water surface elevations expected during a 10-year, 24-hour storm event, pursuant to the requirements of Chapter ATCP 48. These data will be used to update the County floodplain maps for the Pebble Creek watershed (see Chapter IV of this report).

RELATED CONSERVATION PROGRAMS

Federal Programs
The USDA NRCS has several programs directed at agricultural producers to alleviate cropland erosion, and to protect natural resources, as well as provide a financial incentive. The programs available to local producers and landowners are presented in Table 13 and summarized below. There are four programs that help to reduce erosion, protect wildlife habitat, restore wetlands, and improve water quality. All programs involve cost-share assistance from the Federal government, provided the landowner follows the prescribed practices of each program.

Conservation Reserve Program
The Conservation Reserve Program (CRP) and related State CREP are voluntary programs for agricultural landowners that provide annual rental payments and cost-share assistance to establish long-term, resource

Table 13

CHARACTERISTICS OF USDA FINANCIAL ASSISTANCE PROGRAMS

Program	Contract Length	Sign-Up Period	Cost-Share	Rental or Tillage Payments	Practices Suitable for Program	Amount of Land
Conservation Reserve Program (CRP)/Conservation Reserve Enhancement Program (CREP)	10, 15 years or as perpetual easements	Continuous or once a year	50 percent	A specified dollar amount per acre based upon soil type	Permanent pasture, buffer strips, grassed waterways, windbreaks, trees	Small sensitive areas along stream corridors to large tracts of land
Environmental Quality Incentives Program (EQIP)	Five to 10 years	Twice a year	Up to 75 percent	No till practices only, with a 50-acre maximum	Livestock waste management, erosion and sediment control, habitat improvement, groundwater protection	Designed for the whole farm, not just small areas of the farm
Wildlife Habitat Incentives Program (WHIP)	10 years	Continuous	Up to 75 percent	- -	Instream structures for fish habitat, prairie restoration, wildlife travel lanes, wetland scrapes	Site- and species-specific, small to large areas, five-acre minimum
Wetland Reserve Program (WRP)	10 years, or 30 years and permanent easements	Continuous	Up to 100 percent	- -	Wetland restoration	20-acre minimum

Source: U.S. Natural Resources Conservation Service and SEWRPC.

conserving covers on eligible farmland. The CRP goal is to reduce soil erosion, protect the nation's ability to produce food and fiber, reduce sedimentation in streams and lakes, improve water quality, establish wildlife habitat, and enhance forest and wetland resources. It encourages farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover, such as a prairie compatible, noninvasive forage mix, wildlife plantings, trees, filter strips, or riparian buffers. Farmers receive an annual rental payment for the term of the multi-year contract based on the agriculture rental value of the land, and up to 50 percent Federal cost-sharing is provided to establish vegetative cover practices. The program is administered by the Farm Service Agency (FSA), an agency of the USDA with technical assistance provided by NRCS. The NRCS works with landowners to develop their application, and to plan, design, and install the conservation practices on the land. In the Pebble Creek watershed, the County LRD may also provide technical support through the CREP program, although there has been no landowner interest in the program to date. There are multiple projects enrolled in the CRP located throughout the Pebble Creek watershed as shown on Map 18.

Environmental Quality Incentives Program

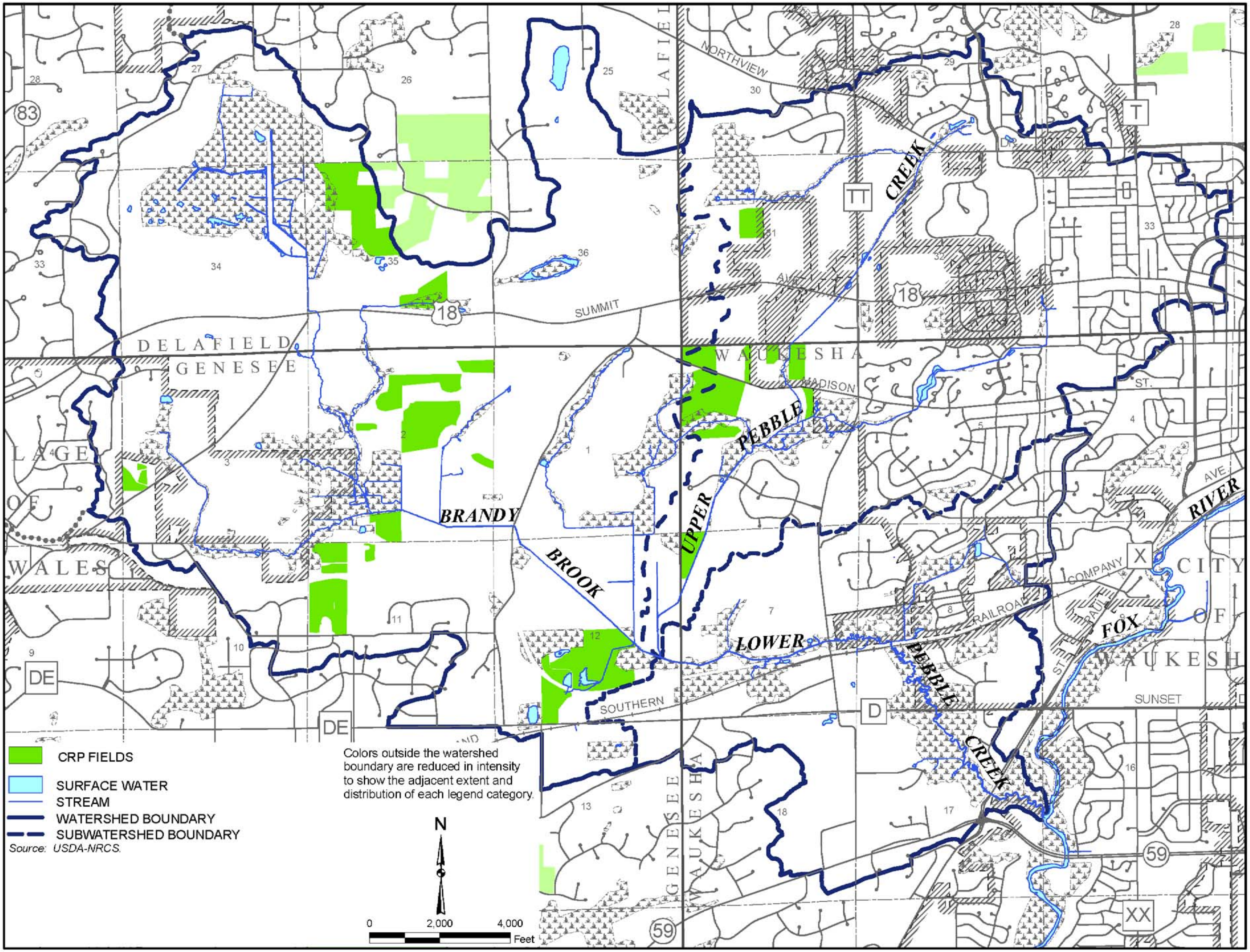
The Environmental Quality Incentives Program (EQIP) is a voluntary conservation program that supports the production of agriculture and environmental quality as compatible goals. Through EQIP, farmers may receive financial and technical help with structural and management conservation practices on agricultural land. EQIP offers contracts for practice implementation for periods ranging from one to 10 years, and it pays up to 50 to 75 percent of the costs of eligible conservation practices. Incentive payments and cost-share payments may also be made to encourage a farmer to adopt land management practices, such as nutrient management, manure management, integrated pest management, or wildlife habitat management.

Wildlife Habitat Incentives Program

The Wildlife Habitat Incentives Program (WHIP) is a voluntary program for people who want to develop or improve wildlife habitat on private lands. It provides both technical assistance and up to 75 percent Federal cost-

Map 18

CONSERVATION RESERVE PROGRAM (CRP) FIELDS WITHIN THE PEBBLE CREEK WATERSHED: 2006



sharing to help establish and improve wildlife habitat. Landowners agree to work with NRCS to prepare and implement a wildlife habitat development plan which describes the landowner's goals for improving wildlife habitat, includes a list of practices and a schedule for installing them, and details the steps necessary to maintain the habitat for the life of the cost-share agreement. The WHIP emphasizes reestablishment of declining species and habitats, including prairie chickens, meadowlarks, sharp-tailed grouse, Karner blue butterfly, smallmouth bass, blue-winged teal, and many other species of grassland birds, reptiles, insects, and small mammals. Some of the opportunities that exist are installing instream structures to provide fish habitat, restore prairie and oak savannahs, and brush management and control of invasive species.

Cost-shared practices include burning, seeding, and brush management of prairies, grasslands, and savannah; instream structures and bank stabilization in streams; and timber stand improvement and brush management on woodlots. Federal or State wildlife agencies or private organizations may provide additional funding or expertise to help complete a project. Contracts normally last a minimum of five years from the date the contract is signed and cost-sharing does not exceed $10,000. Eligible lands must be a minimum of five acres of agricultural or nonagricultural land, woodlots, pasture land, streambanks, and shorelands. Lands currently enrolled in other conservation programs are not eligible to participate in WHIP.

Wetlands Reserve Program

The Wetlands Reserve Program (WRP) is another voluntary program designed to restore and protect wetlands on private property. It is an opportunity for landowners to receive financial incentives to restore wetlands that have been drained for agricultural purposes. Landowners who choose to participate in WRP may sell a conservation easement or enter into a cost-share restoration agreement with USDA to restore and protect wetlands. The landowner voluntarily limits future use of the land, yet retains private ownership. The landowner and NRCS develop a plan for the restoration and maintenance of the wetland. This program offers landowners three options; permanent easements, 30-year easements, and restoration cost-share agreements of a minimum 10-year duration.

State Programs

Farmland Preservation Program

The Department of Agriculture, Trade and Consumer Protection and the Department of Revenue oversee the Farmland Preservation Program (FPP) across the State. This program allows agricultural landowners meeting certain eligibility requirements, to file for tax credits. As a condition to receiving the tax credits, the land for which the credits are to be received must be farmed in accordance with soil and water conservation standards developed by the County and approved by the State of Wisconsin Land and Water Conservation Board. A farm plan for each landowner and farm involved is usually developed by the County or NRCS and ensures that through tillage practices, crop rotations, or other appropriate conservation practices that soil erosion is being effectively reduced to at or below tolerable soil loss rates. Landowners who are found to be in noncompliance with the law must come into compliance with the rules, or become ineligible to participate in the program. There are no lands in the Farmland Preservation Program within the Pebble Creek watershed, because the applicable communities have not adopted Exclusive Agricultural Zoning, which is also required to be eligible for the tax credit.

Targeted Runoff Management Grant Program

To help control polluted runoff from both agricultural and urban sites, Targeted Runoff Management (TRM) grants are directed at high-priority resource problems. Eligibility is limited to local units of government, special purpose districts (i.e., school or stormwater utility districts), tribal commissions, and regional planning agencies. Governmental units granted 70 percent of eligible costs for various (urban or rural) best management practices (BMPs), up to a cap of $150,000. Property purchases (from willing sellers only) granted at 50 percent of WDNR-approved appraised value can be included in the $150,000 grant cap. Rural easements, funded at 75 percent of the WDNR-appraised value, can also be included in the $150,000 grant cap. Units of government hold grant agreement with the WDNR. For rural BMPs (i.e., barnyard relocation, manure storage), units of government (county land conservation departments) hold contracts on behalf of county residents. Funds are disbursed on a reimbursement basis at completion of the project according to the two-year grant contract terms.

Urban Nonpoint Source and Storm Water Planning Program
Urban Nonpoint Source and Storm Water Planning Program (UNPS&SW) grant funds are used to control polluted runoff in urban project areas. Funds are typically awarded for either planning or construction projects. The grant period is two years. Projects funded by these grants are site-specific, serve areas generally smaller in size than a subwatershed, and are targeted to address high-priority problems. An "urban project area" must meet one of these criteria:

- Has a residential population density of at least 1,000 people per square mile;
- Has a commercial or industrial land use;
- Is a portion of a privately owned industrial site not covered by a WPDES permit issued under Chapter NR 216 of the *Wisconsin Administrative Code*;
- Is a municipally owned industrial site (regardless of Chapter NR 216 permit requirements); or
- Governmental units are eligible for a grant even if the governmental unit is covered by a stormwater permit under Chapter NR 216.

Urban Nonpoint Source and Storm Water Planning Program planning grants can be used to pay for a variety of technical assistance activities. Eligible activities, such as stormwater management planning, related information and education activities, ordinance and utility development and enforcement are cost-shared at 70 percent. Eligible UNPS&SW construction grant costs may include such projects as stormwater detention ponds, filtration and infiltration practices, streambank stabilization, and shoreline stabilization. Those eligible costs are cost-shared at 50 percent up to a maximum of $150,000. Additional cost-share reimbursements may be available for project design, land acquisition, and permanent easements costs, with approval by the WDNR regional staff.

An UNPS&SW planning grant was awarded to Waukesha County to cover the costs of the preparation of the Pebble Creek Watershed Protection Plan.

Soil and Water Resource Management Program
The current version of Chapter ATCP 50, "Soil and Water Resource Management Program," of the *Wisconsin Administrative Code* became effective on October 1, 2002, and was most recently revised in October 2004. The administrative rule relates specifically to agricultural programs and it establishes requirements and/or standards for:

- Soil and water conservation on farms;
- County soil and water programs, including land and water resource management plans;
- Grants to counties to support county conservation staff;
- Cost-share grants to landowners for implementation of conservation practices;
- Design certifications by soil and water professionals;
- Local regulations and ordinances; and
- Cost-share practice eligibility and design, construction, and maintenance.

Community Information and Education Programs
The Waukesha County LRD, through an intergovernmental agreement with participating municipalities from the Upper Fox Watershed Community Group, pursuant to Chapter NR 216 requirements, have proposed to undertake

the following activities as part of their stormwater management planning program over a four-year period commencing in 2006. This program will be implemented through an education advisory committee made up of each of the participating communities. For more details on recommended activities see Targeted Informational Programming section in Chapter V of this report.

To date, Waukesha County participates in the WAV (Water Action Volunteer) program and has been monitoring three locations in the Pebble Creek watershed since 2001. In addition, Waukesha County has a trained Project WET (Water Education Training) facilitator on staff and sponsors Project WET training events. The County also makes available storm drain stenciling materials for school and youth organizations to use and assists the Waukesha School District with their fifth grade environmental education curriculum by conducting hands-on water quality monitoring workshops. Within the City of Waukesha, the Waukesha School District has conducted a Fox River Clean-Up program.

In addition to the organizations listed above there is a group known as "The Friends of Retzer Nature Center" in Waukesha County. The Friends of Retzer Nature Center is a 501 (c) (3) organization dedicated to encouraging, perpetuating and promoting the work of conservation and natural resource education through community involvement at the center. The group provides financial support and volunteer assistance to enhance the facility and public programming.

The Waukesha County Environmental Action League (WEAL) helps to protect the natural resources of Waukesha County through local action, public programs, newsletters, and WEAL web site. WEAL provides up-to-date information on environmental issues to the general public; teachers; county, city, and village officials; and State legislators.

The Pewaukee River Partnership and the Fox River Partnership are both active in the City of Pewaukee. There are also informational and educational elements contained in the City of Pewaukee NR 216 Permit.

The Town of Delafield has worked with the Waukesha County Land Conservancy, typically through developers that want to preserve open space as part of their development.

The Town of Delafield encourages conservation easements and partnerships between developers and the Waukesha County Land Conservancy.

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Chapter IV

BACKGROUND AND SUMMARY OF INVENTORY FINDINGS

INTRODUCTION

This chapter presents an inventory and analysis of the surface waters and related features of the Pebble Creek watershed. Included is descriptive information pertaining to the historical trends and current status of habitat (physical, chemical, and biological) quality and ecological integrity within Pebble Creek, bank stability analysis of the main channel of Pebble Creek and Brandy Brook, and potential limitations to water quality and fishery resources.

STREAM CHANNEL CONDITIONS AND STRUCTURES

Stream Reaches

Based upon the analysis of stream water surface elevations, and bridge and culvert crossings, in combination with slope and sinuosity, specific sections of stream, defined as stream reaches, were identified as set forth in Table 14 and shown on Map 19.

Sinuosity

Sinuosity is a measure of channel pattern and is defined as the ratio of channel length between two points on a channel to the straight-line distance between the same two points. Sinuosity or channel pattern can range from straight to a winding pattern, or "meandering." The more a stream meanders within a given distance, the more "sinuous" it is. Channels with sinuosities of 1.5 or greater are considered "meandering." Channelized or sections of streams that have been straightened typically have low sinuosity or a number closer to one. Stream reaches within Pebble Creek have sinuosities that range from 1.05 to 2.23 as shown in Table 14, and include both channelized and nonchannelized segments. Each of these reaches can be further characterized by physical characteristics. Stream channel width, depth, and entrenchment are common measures used to describe hydrological reaches.

Slope

Slope is a ratio of elevation change between two points on a channel to the length of the channel between the same two points. Slope is an indicator of stream energy or power. The lower the slope, the lower the energy, and the slower the water flows. Stream slopes within mountainous stream systems are typically greater than 10 percent. However, most slopes within the Pebble Creek reaches are more indicative of lowland streams and do not exceed 1 percent, except for BB-2, and the unnamed tributaries UT-3 and UT-5, which range from 1.34 to 2.17 percent slope, as shown in Table 14. Elevation profiles for each stream reach are shown on Figure 17.

Table 14

PHYSICAL CHARACTERISTICS AMONG STREAM REACHES WITHIN THE PEBBLE CREEK WATERSHED: PRE-1941, 1941, AND 2005

Stream Reach	Reach Length (miles)			Sinuosity			Minimum Elevation	Maximum Elevation	Slope (percent)
	Pre-1941	1941	2005	Pre-1941	1941	2005			
Lower Pebble Creek									
LP-1	- -	1.35	1.29	- -	1.61	1.60	786	791	0.073
LP-2	- -	1.53	1.54	- -	2.23	2.23	791	798	0.086
LP-3	1.74	1.10	0.96	1.75	1.21	1.05	798	802	0.079
UT-1	- -	0.81	0.69	- -	1.45	1.25	797	821	0.656
Upper Pebble Creek									
UP-1	2.43	2.11	1.80	1.54	1.30	1.12	802	825	0.242
UP-2	- -	1.91	1.83	- -	1.16	1.11	825	878	0.548
UT-2	- -	0.76	0.76	- -	1.26	1.27	822	857	0.868
UT-3	- -	1.11	1.12	- -	1.20	1.21	863	991	2.173
Brandy Brook									
BB-1	2.41	1.86	1.87	1.74	1.08	1.08	802	818	0.162
BB-2	- -	1.75	1.74	- -	1.67	1.65	818	960	1.549
UT-4	- -	0.53	0.54	- -	1.14	1.16	802	817	0.531
UT-5	- -	2.65	2.71	- -	1.16	1.19	818	1,013	1.364

Source: SEWRPC.

One of the most significant changes in gradient occurs at CTH X where a “rock spillway” that was created to protect the bridge abutment footings causes an increase of four feet in channel height (Figure 17). That feature may be limiting the passage of some fish species (see the “Stream Crossings” subsection below). This spillway is impounding water upstream for a distance of more than 3,000 linear feet and it is important to note that, rather than limiting the fishery community, this impounded area contains some of the highest abundance of northern pike in the watershed (see the “Biological Conditions” section below). In contrast, the channelized areas near the confluence of Upper Pebble Creek, Brandy Brook, and Lower Pebble Creek (UP-1, BB-1, LP-3) contain the lowest changes in slope. However, the stream channels in those reaches have been realigned over time, so they are not at their original locations (see the “Channelization and Historic Habitat Loss” subsection below).

Width

Figure 18 and Map 20 show changes in width among stream reaches within Pebble Creek. There is an overall increase in width from the upstream to downstream reaches, which is expected, and there is also considerable variability in width within individual reaches. However, there appear to be two distinct breaks along the continuum of width changes from upstream to downstream, specifically in the channelized reaches LP-3 and BB-1. These two reaches are significantly wider than they would “normally” be prior to channelization, which indicates these reaches were overly widened. Therefore, the changes in width among the reaches are associated with their position and past channelization activities within the watershed, even though past channelization began within the watershed more than 70 years ago.

Depth

Stream depth also demonstrates an overall increase from upstream to downstream as shown in Map 21. The upstream reaches appear to be shallower and the downstream reaches appear to be deeper than other areas within the watershed. This wide range in depth indicates that each of these reaches contains a variety of deep and shallow areas typically referred to as pool and riffle habitats (see the “Habitat” section below).

Streambank Stability and Erosion

The energy of flowing water in a stream is dissipated along the stream length by turbulence, streambank and bed erosion, and sediment resuspension. In general, increased urbanization may be expected to result in increased stream flow rates and volumes, with potential increases in streambank erosion and bottom scour. Streambank

Map 19

STREAM REACHES WITHIN THE PEBBLE CREEK WATERSHED: 2006

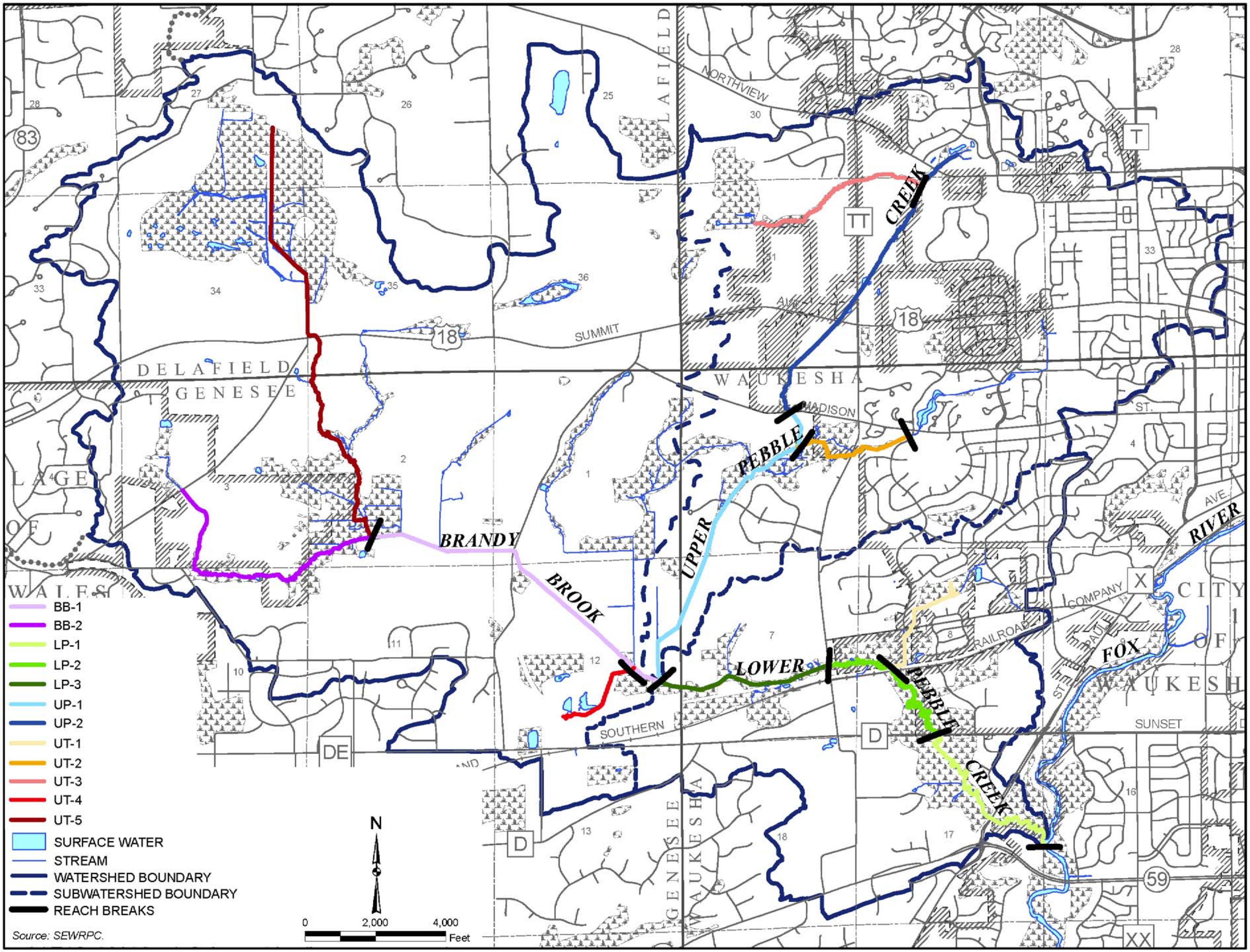
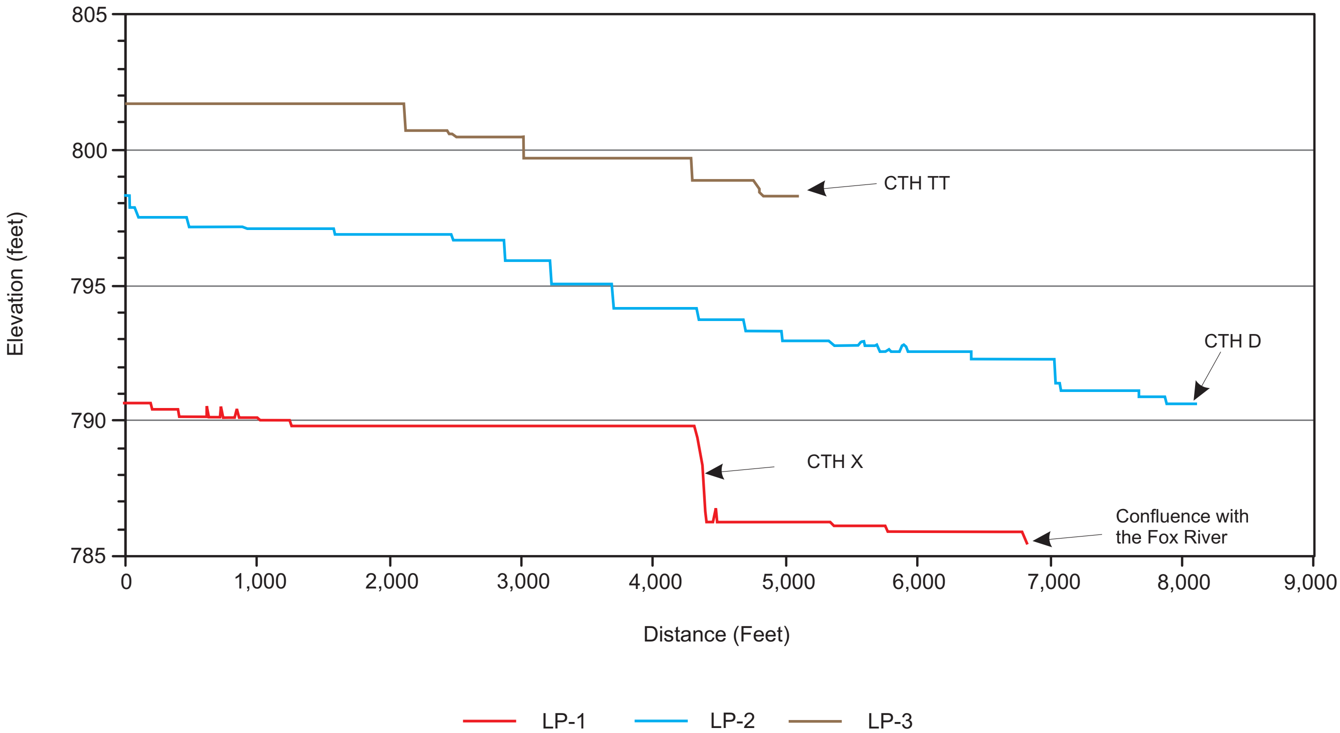


Figure 17

APPROXIMATE NORMAL WATER SURFACE ELEVATION PROFILES BY STREAM REACH IN THE PEBBLE CREEK WATERSHED: 2006



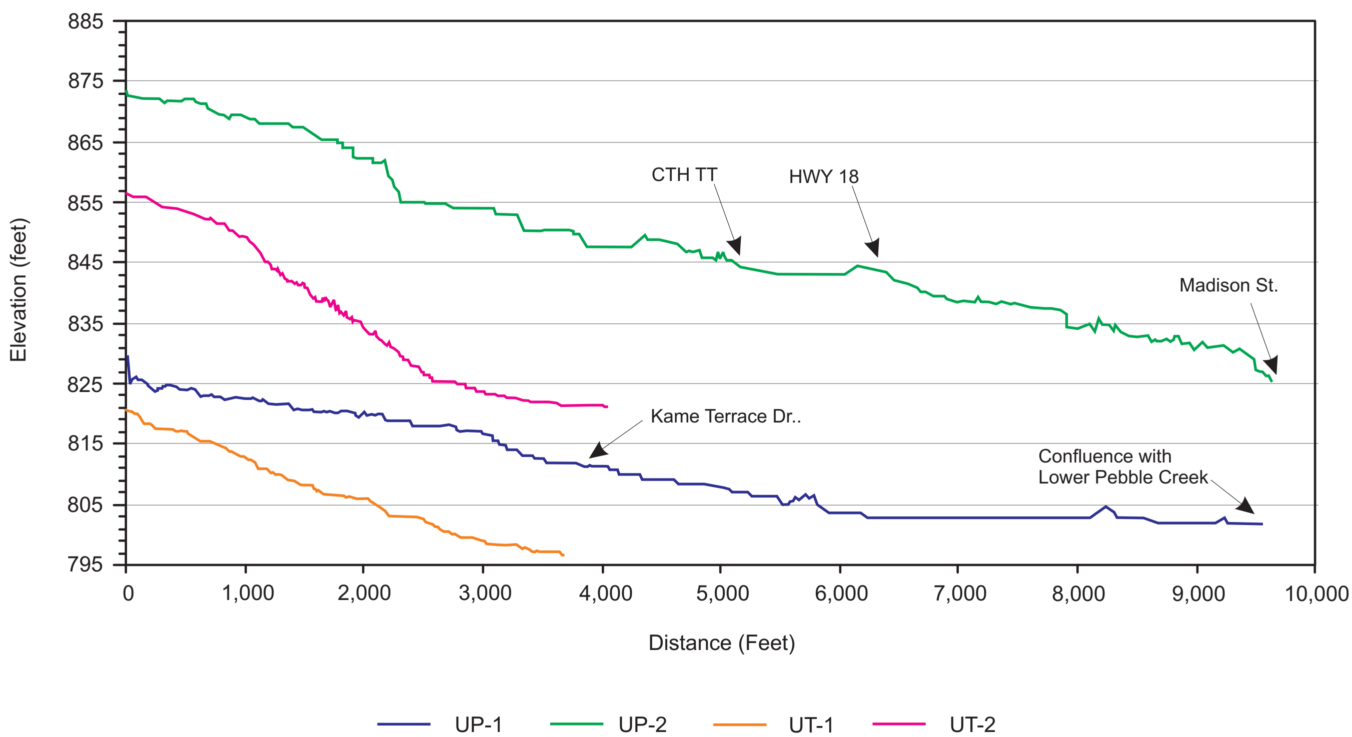
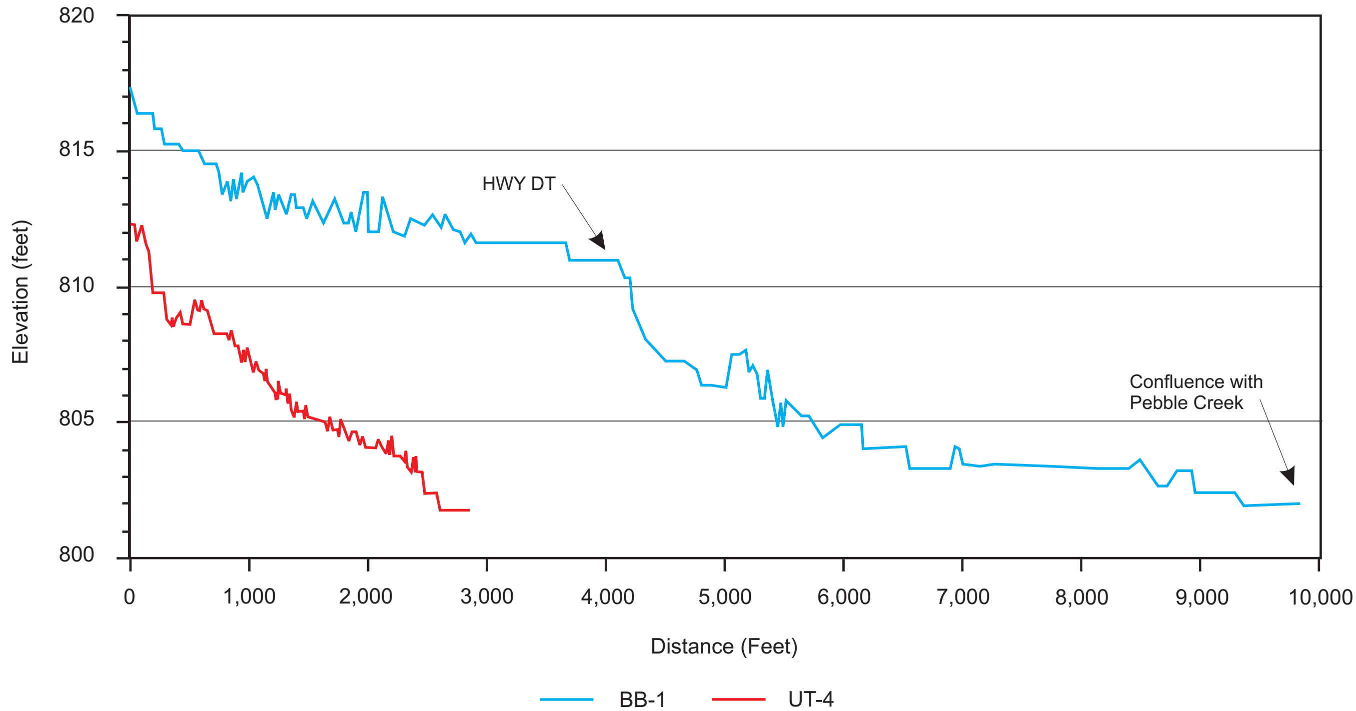
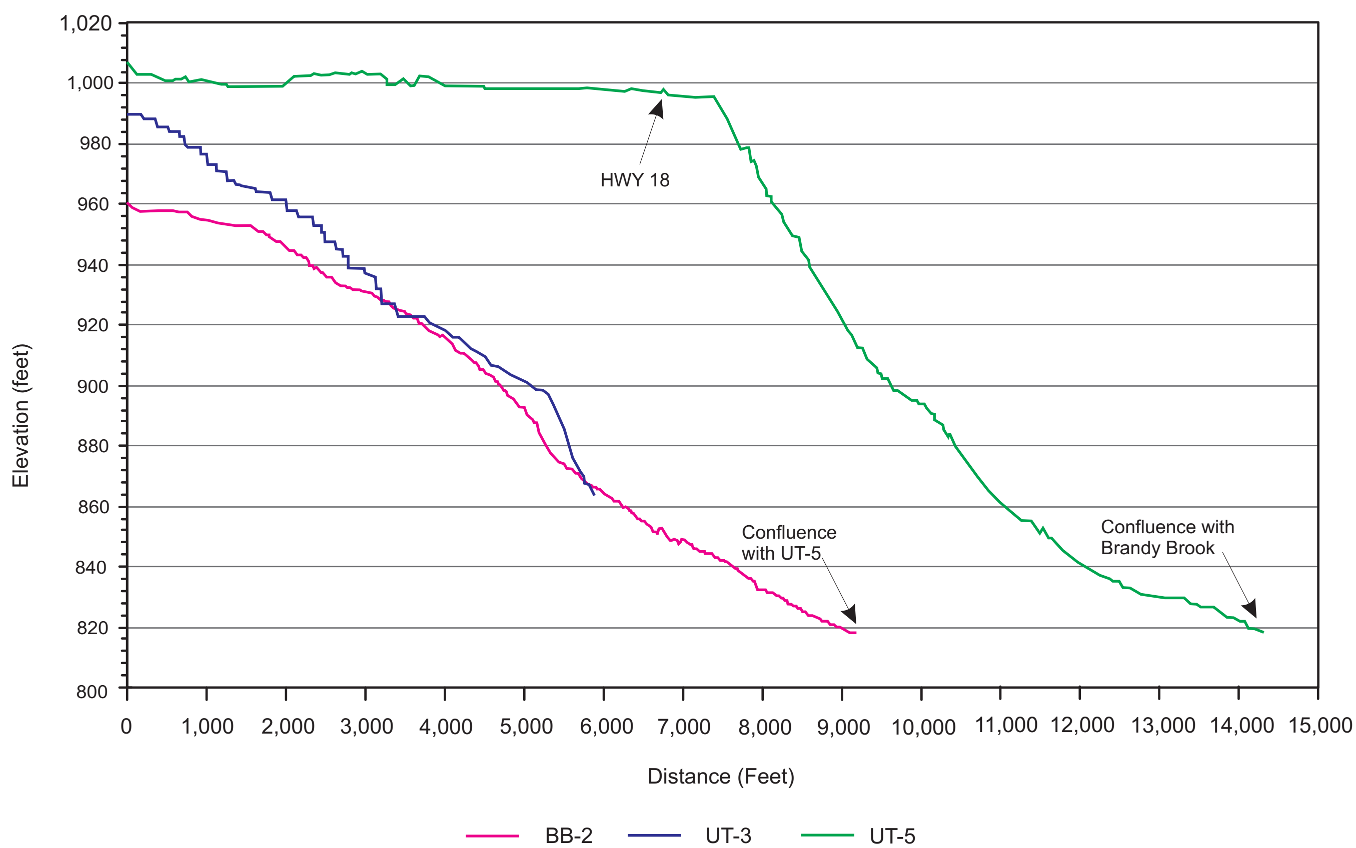


Figure 17 (continued)



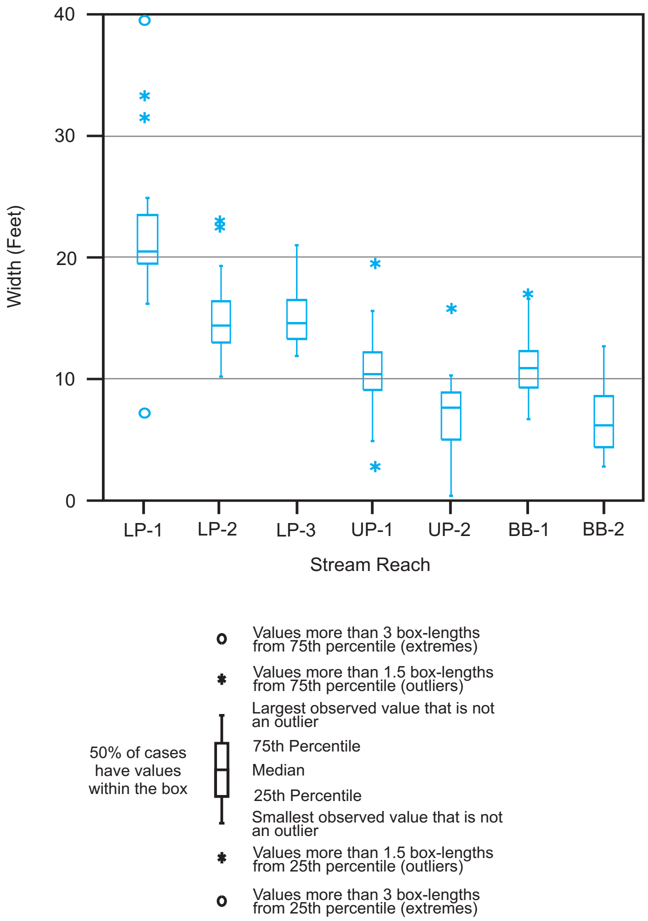


NOTE: Data were obtained from the 2005 Waukesha County digital terrain model. In cases where the water surface elevation appears to increase from upstream to downstream, the plotted elevation may actually represent a localized land surface feature. These plots are intended to provide a general representation of stream slopes.

Source: SEWRPC.

Figure 18

WATER WIDTH AMONG REACHES IN THE PEBBLE CREEK WATERSHED: 2006



Source: SEWRPC.

erosion destroys aquatic habitat, spawning, and feeding areas; contributes to downstream water quality degradation by releasing sediments to the water; and provides material for subsequent sedimentation downstream, which, in turn, covers valuable benthic habitats, impedes navigation, and fills wetlands. These effects may potentially be mitigated by utilization of proper stormwater management and streambank bioengineering practices.

In fall 2004, SEWRPC staff conducted a survey of streambank erosion within Pebble Creek. The stream survey identified streambank erosion problems and quantified the following: locations of active erosion sites, heights of the eroding streambanks, lengths of the erosional scours, slopes of the banks, habitat types, stream widths at the water surface, maximum depths of the water, sediment depths, relative amounts of woody debris, and substrate composition (see Appendix C for definitions). Active eroding streambank sites identified by the survey are shown on Map 22. The field survey indicated that there were more than 58 sites totaling about one mile of streambank where active erosion was found. The average length of these actively eroding sites was about 90 feet and ranged from eight to 265 feet. In an effort to quantify the extent of bank erosion and to determine the potential relationship between bank stability and other physical characteristics of the stream system, the length of bank erosion was standardized into a percent or proportion of total stream length for the streams surveyed in a given subwatershed.[1]

Upper Pebble Creek contained the highest proportion of eroding banks, totaling about 14 percent of the stream length in the entire subwatershed, 7.9 percent of that total being in the low severity category (Figure 19). Not surprisingly, Upper Pebble Creek contains the highest proportion of channelized reaches, in addition to being the most urbanized reach within the watershed. Eroding banks along Lower Pebble Creek totaled about 8.3 percent of the subwatershed, and Brandy Brook was only 4.5 percent.

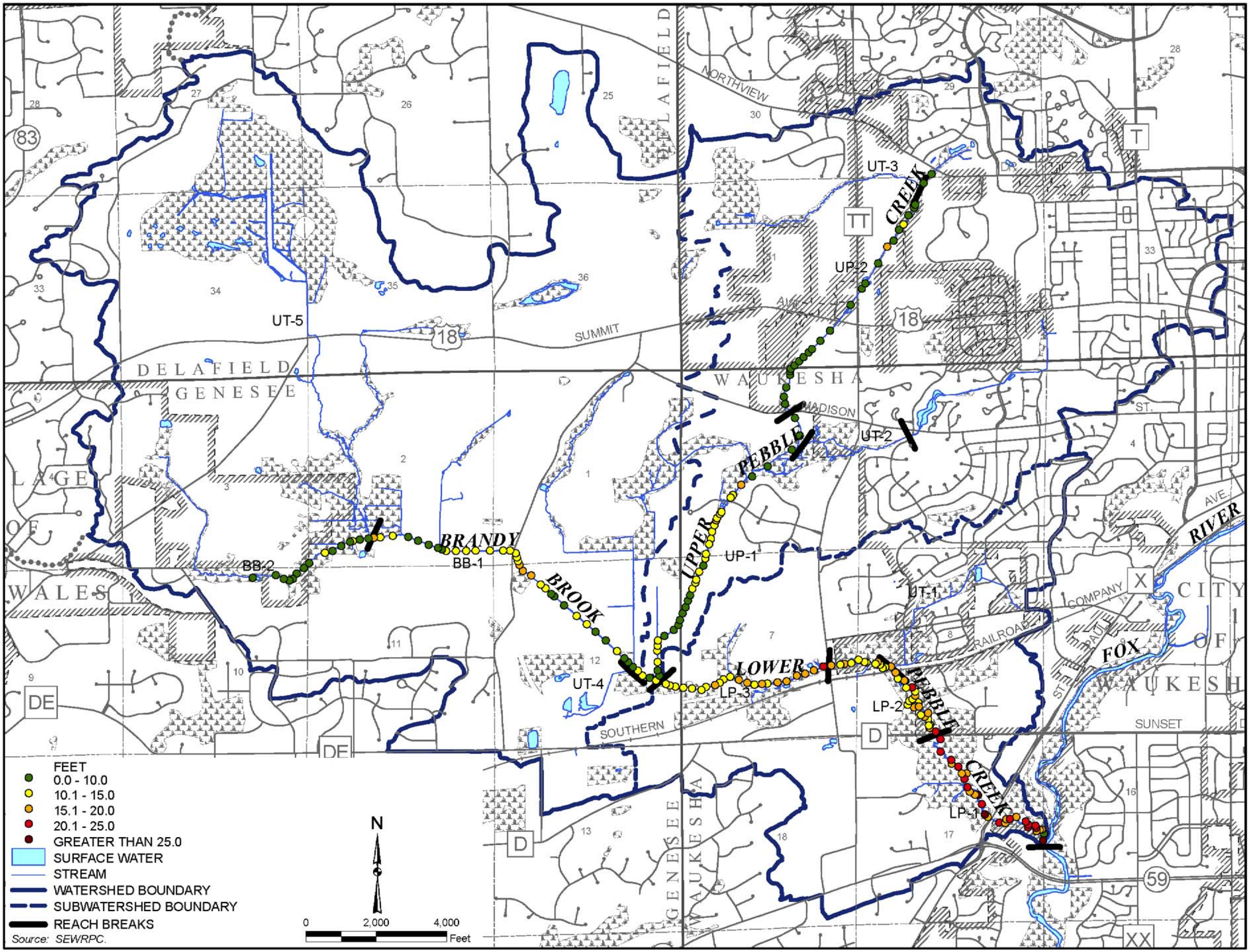
Obstructions and Instream Habitat

The streams of the Pebble Creek watershed contain a large amount of instream cover, characterized by undercut banks, woody debris, and large boulders. Instream large woody debris is an important component of stream ecosystems that provides essential food and habitat for aquatic organisms. Woody debris can affect channel morphology and form pools, retain organic matter, gravel, and sediment, influence invertebrate abundance, and

[1]*The bank length of each site was divided by the entire length of the banks of both sides of the stream within the reach where the particular site was located. For example, low severity erosion along the Lower Pebble Creek reach, which is 20,000 feet in total length, contained eroding banks totaling 820 feet in length that would correspond to a proportional failure of 4.1 percent (820 feet per 20,000 feet). Charles, J. Krebs,* Ecological Methodology*, Harper Collins, University of British Columbia, 1989.*

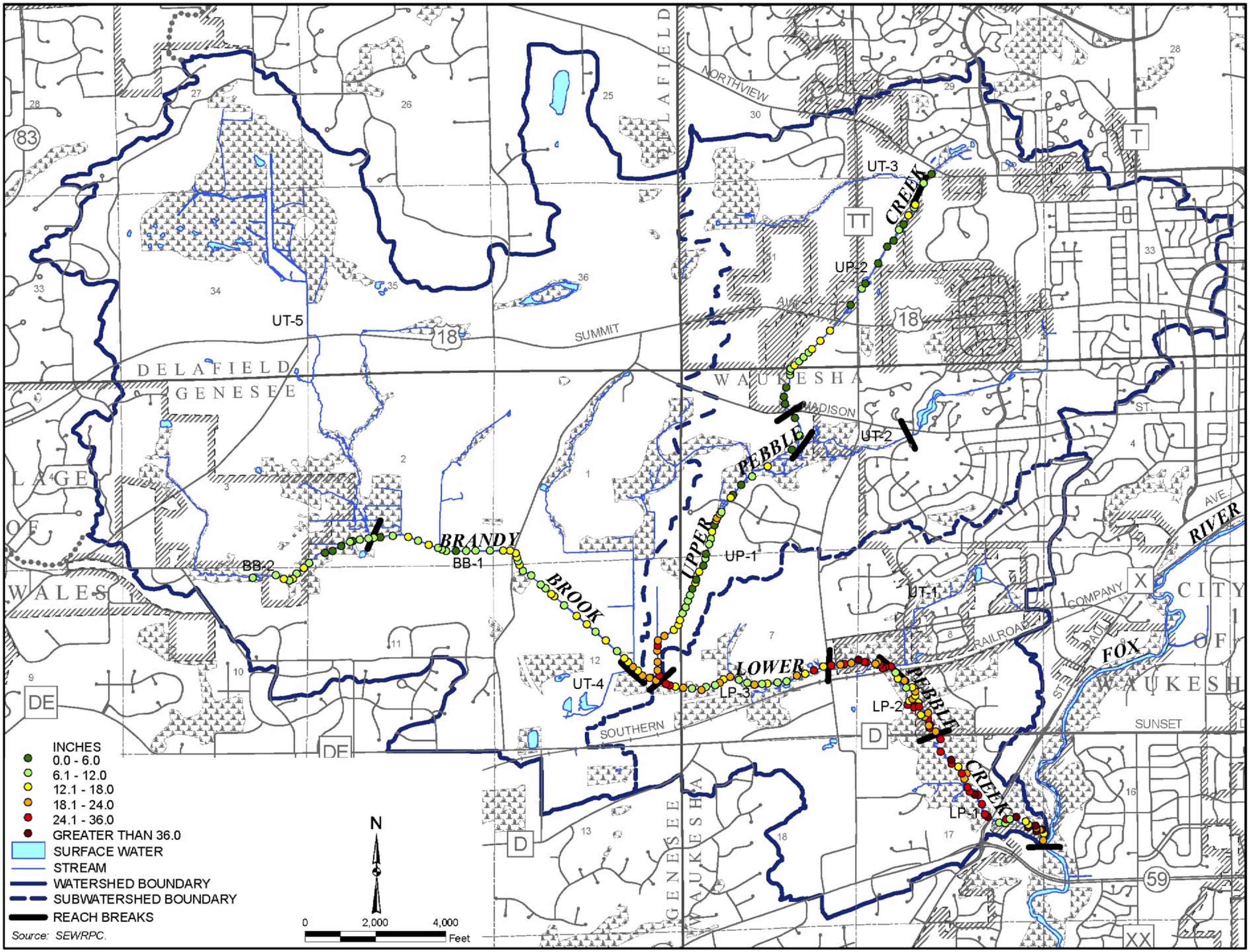
Map 20

NORMAL FLOW STREAM WIDTH WITHIN THE PEBBLE CREEK WATERSHED: 2006



Map 21

NORMAL FLOW WATER DEPTH IN STREAMS WITHIN THE PEBBLE CREEK WATERSHED: 2006



Map 22

EROSION ALONG STREAMS WITHIN THE PEBBLE CREEK WATERSHED: 2006

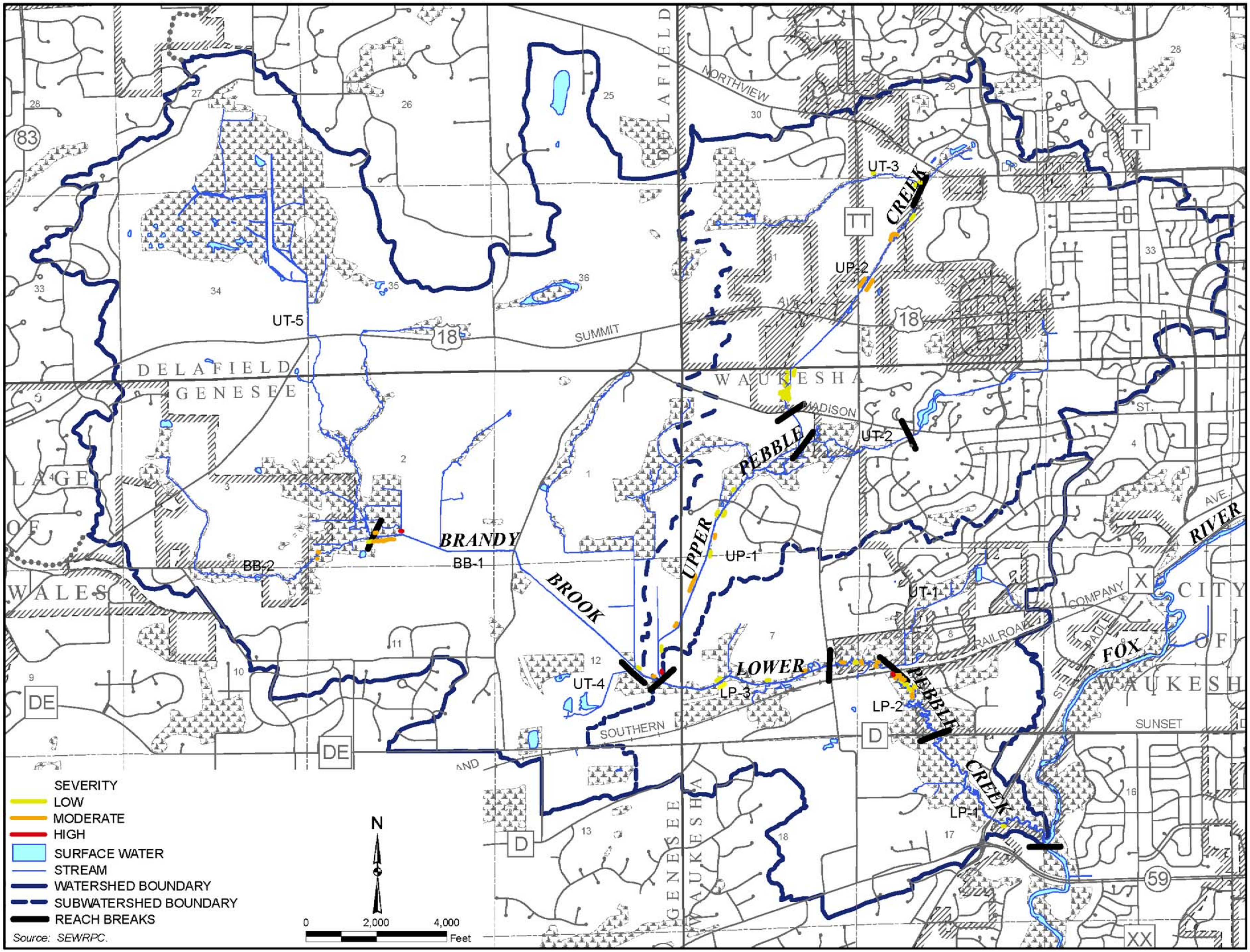
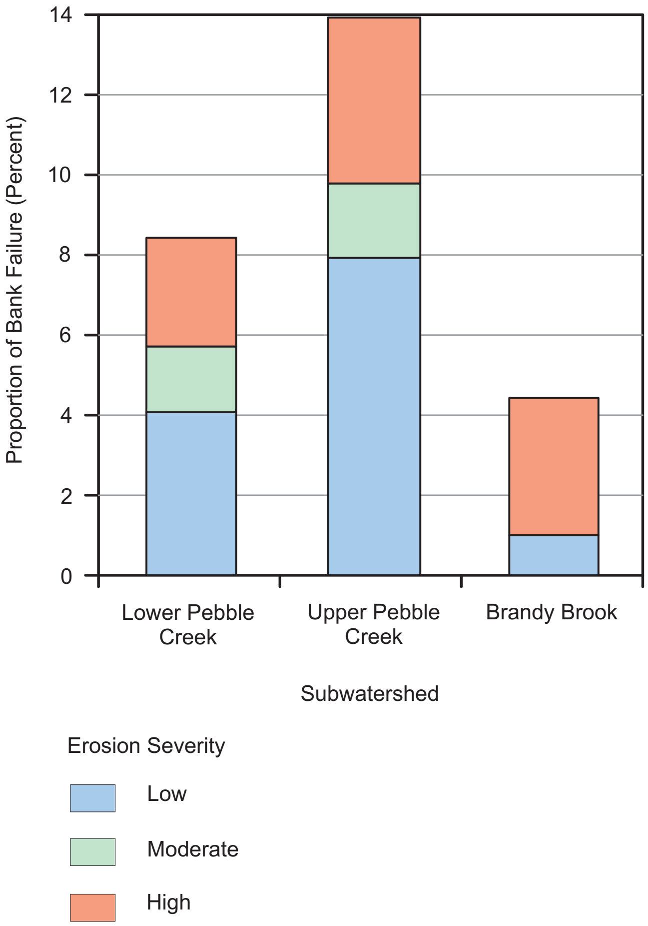


Figure 19

PROPORTION OF ERODED BANKS
IN THE PEBBLE CREEK WATERSHED: 2006



Source: SEWRPC.

provide cover and velocity refuge for fish.[2] The presence and diversity of woody debris within the Pebble Creek system is largely dependent on the amount of riparian forest, but overall woody debris is fairly abundant throughout the stream system. Woody debris had been observed to excessively accumulate in some areas causing debris jams. Debris jams can function like a beaver dam and may cause significant disruption in the stream sediment dynamics, leading to localized flooding and bank stability problems. Debris jams, as well as road culverts, may inhibit fish movement to feeding and spawning areas, thereby decreasing reproduction success. Map 23 shows the locations of beaver dams, woody debris and trash, and stone weirs, all of which have the potential to obstruct fish passage. Table 15 shows these potential obstructions by stream reach and ranks their ability to be removed into three categories based on the severity of blockage and the difficulty and equipment needed to remove these obstructions.

Woody Debris Jams

Pebble Creek contains 31 woody debris jams, as shown on Map 23 and Figure 20. Most of these wood jams occur in areas that are forested and occur due to an accumulation of natural tree down fall as well as man-made trash. The greatest concentration of woody debris jams occurs in stream reaches UP-1 and UP-2. Woody debris and trash accumulate in these more incised stream reaches, and, since the higher channel banks tend to isolate the channel from the floodplain, accumulated debris has nowhere to go. Most of these jams are creating significant blockages that act like dams, holding back water and trapping sediment, and creating areas with active erosion and blow outs.

Beaver Activity

Beavers can cut trees and alter environments to a greater extent than any other mammal except humans. Their ability to increase landscape heterogeneity by felling trees and constructing impoundments and canals goes beyond their immediate needs for food and shelter (see Figure 21). They can dramatically alter nutrient cycles and food webs in aquatic and terrestrial ecosystems by modifying hydrology and selectively removing riparian trees.[3] The activities of beaver in streams provide an outstanding example of a natural alteration to ecosystem structure and dynamics. Beaver activity may result in differing degrees of alterations that: 1) modify channel geomorphology and hydrology, 2) increase retention of sediment and organic matter, 3) create and maintain

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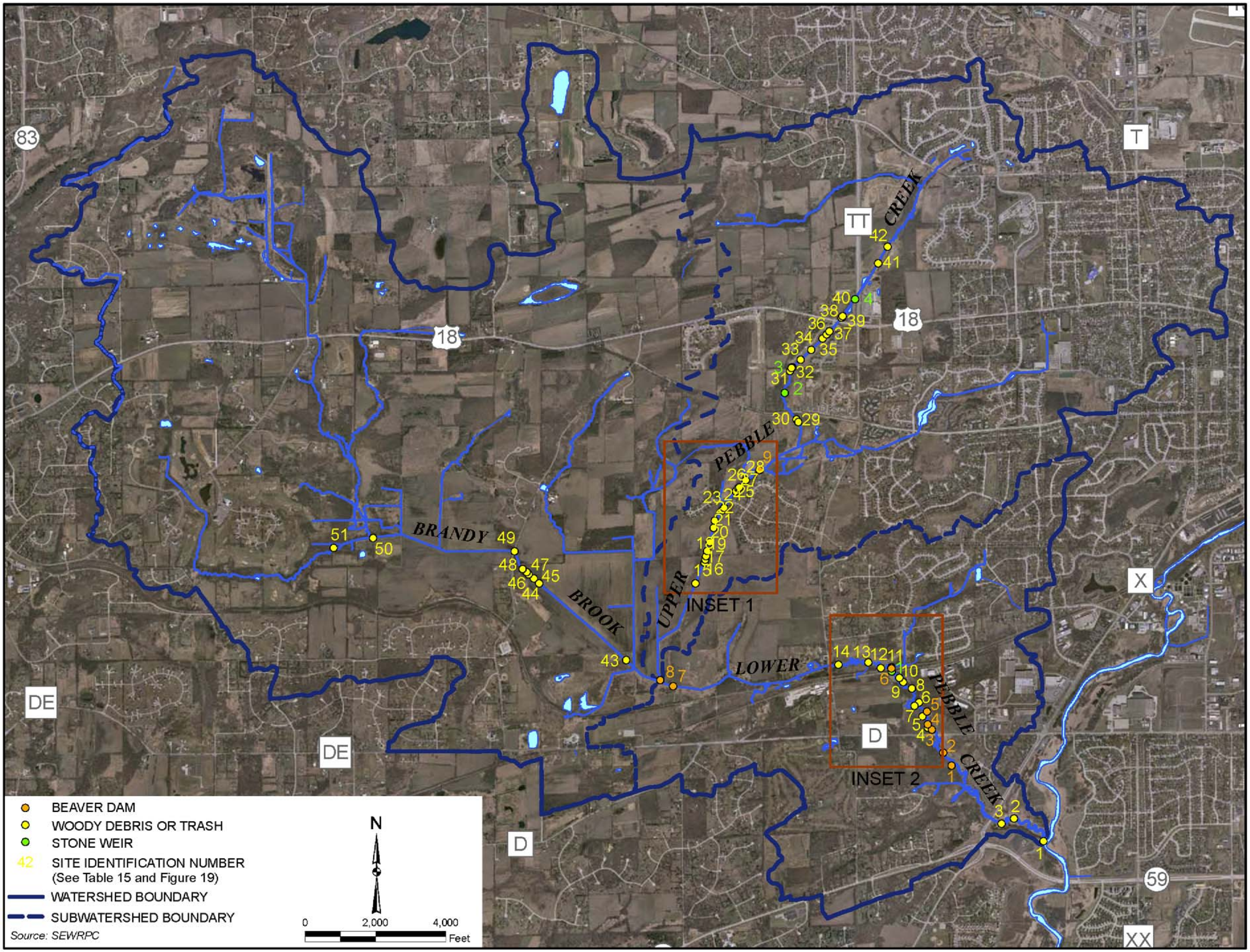
[2]*B. Mossop and M.J. Bradford, Importance of large woody debris for juvenile Chinook salmon habitat in small boreal forest streams in the upper Yukon River basin, Canada,* Canadian Journal of Forestry Resources*, Vol. 35, 2004, pp. 1955-1966.*

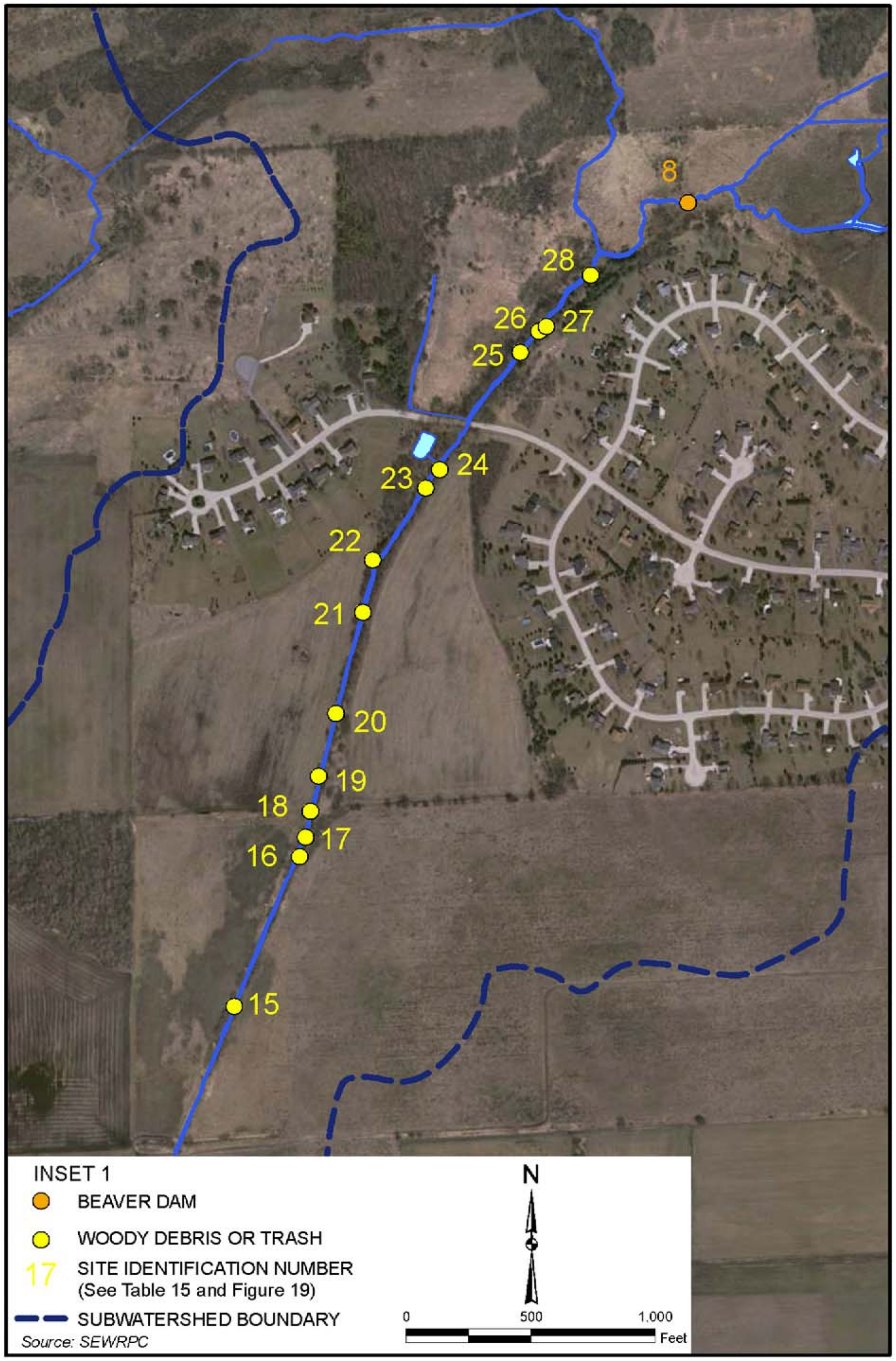
[3]*A.M. Ray, et al, Macrophyte succession in Minnesota Beaver Ponds,* Canadian Journal of Botany*, Vol. 79, 2001, pp. 487-499.*

Map 23

OBSTRUCTIONS, WOODY DEBRIS, AND TRASH IN THE STREAMS OF THE PEBBLE CREEK WATERSHED: 2006



INSETS TO Map 23



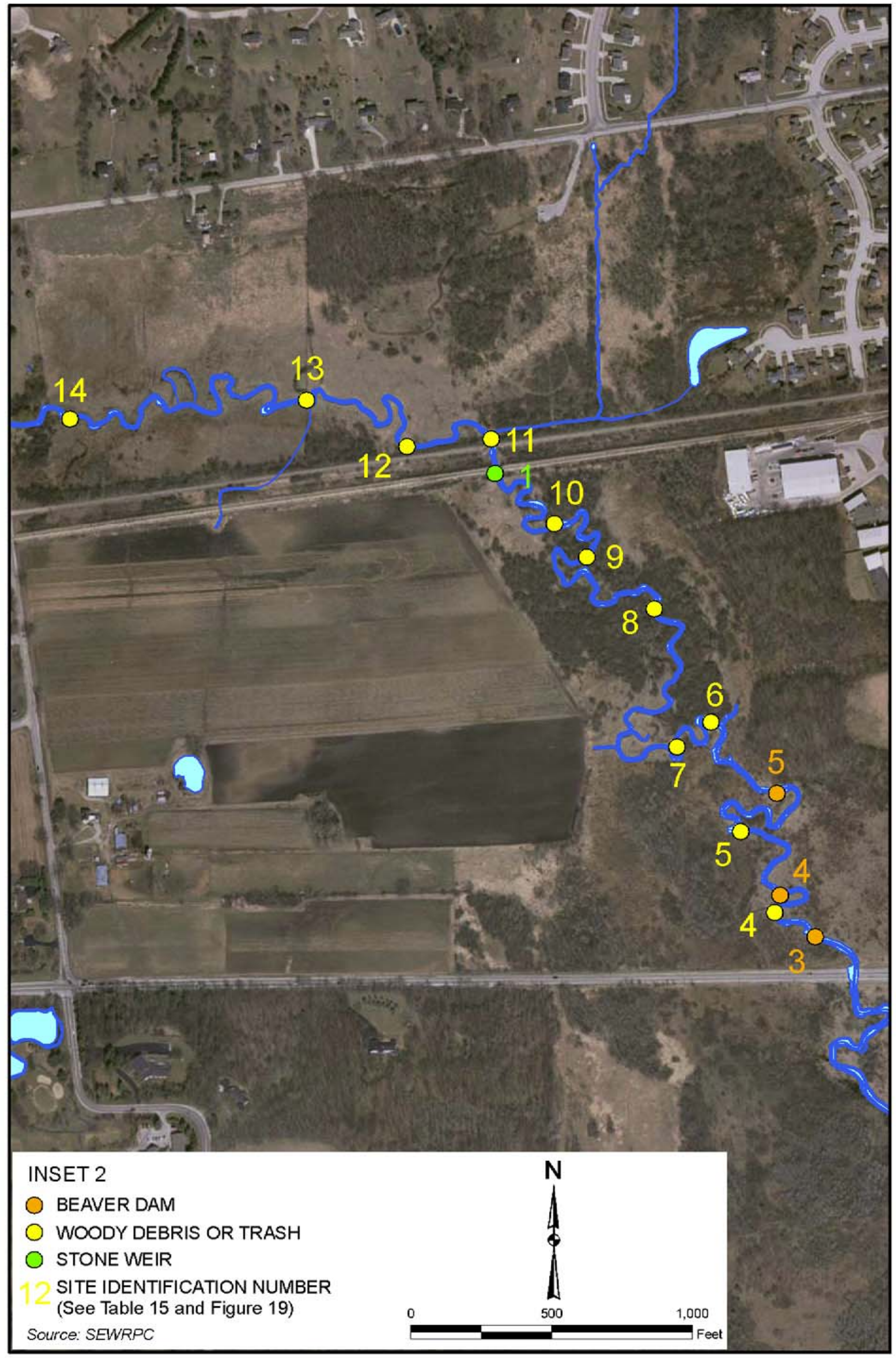


Table 15

COMPARISON OF POTENTIAL OBSTRUCTIONS TO FISHERIES PASSAGE AMONG TRASH, DEBRIS, AND BEAVER DAM LOCATIONS WITHIN THE PEBBLE CREEK WATERSHED: 2006

Stream Reach	River Mile	Structure Number on Map 23 and Figure 20	Description	Material	Clean-Up Effort[a]
LP-1	0.02	1	Trash	Truck tire	Low
	0.31	2	Trash	Bucket	Low
	0.41	3	Trash	Plywood sheet	Low
	1.04	1	Beaver dam	Wood, sticks, mud, and sediment	High
	1.14	2	Beaver Dam	Wood, sticks, mud, and sediment	High
LP-2	1.35	3	Beaver Dam	Sticks, mud, and sediment	Moderate
	1.38	4	Woody debris and various trash	Wood, sticks, sediment, bucket	Moderate
	1.39	4	Beaver Dam	Sticks, mud, and sediment	Moderate
	1.52	5	Woody debris	Sticks and sediment	Moderate
	1.64	5	Beaver Dam	Sticks, mud, and sediment	Moderate
	1.73	6	Woody debris and various trash	Downed trees, sticks, sediment, and bucket	Moderate
	1.78	7	Woody debris	Downed tree, sticks, sediment	Low
	1.94	8	Trash	Tire rim	Low
	2.09	9	Woody debris	Wood, timbers, sediment	Moderate
	2.17	10	Woody debris and various trash	Downed trees, boards, tire	High
	2.28	1	Stone weir	Rocks	Moderate
	2.32	6	Beaver dam	Sticks, mud, sediment	High
	2.32	11	Trash	Lawn mower	Low
	2.38	12	Woody debris and various trash	Wood, sticks, sediment, trash	Moderate
	2.52	13	Woody debris and various trash	Wood, timbers, sediment, barbed wire	High
	2.76	14	Woody debris	Wood timbers, sticks, sediment	High
LP-3	3.17	7	Beaver Dam	Sticks, mud, and sediment	High
UP-1	3.26	8	Beaver Dam	Sticks, mud, and sediment	High
	3.86	15	Woody debris and various trash	Downed trees, sticks, sediment	High
	3.98	16	Woody debris and various trash	Wood, timbers, boards, sediment	High
	4.00	17	Woody debris and various trash	Wood, timbers, boards, sediment, washing machine tub	High
	4.02	18	Woody debris and various trash	Wood, timbers, boards, sediment	High
	4.05	19	Woody debris and various trash	Wood, timbers, boards, sediment	High
	4.10	20	Woody debris	Wood, timbers, sediment	High
	4.18	21	Woody debris and various trash	Wood, timbers, pallets, sediment	High
	4.21	22	Woody debris and various trash	Wood, timbers, boards, sediment	High
	4.28	23	Woody debris	Wood, timbers, boards	Moderate
	4.30	24	Woody debris and various trash	Wood, sticks, pallets, metal, sediment	Moderate
	4.40	25	Woody debris	Wood, sticks, sediment	Moderate
	4.41	26	Woody debris and various trash	Wood, timbers, sediment, pallets, boards	High
	4.44	27	Trash	Cinder blocks, rock	Moderate
	4.49	28	Woody debris and various trash	Wood, timbers, concrete, sediment	High
	4.61	9	Beaver Dam	Sticks, mud, and sediment	High

Table 15 (continued)

Stream Reach	River Mile	Structure Number on Map 23 and Figure 20	Description	Material	Clean-Up Effort[a]
UP-1 (continued)	4.99	29	Trash	Wood wagon	Low
	5.00	30	Trash	Metal box	Low
UP-2	5.20	2	Stone weir	Rock dam	High
	5.32	31	Trash	Wood plank	Low
	5.34	32	Woody debris and various trash	Woody debris, metal fence	Moderate
	5.36	3	Stone weir	Stone, sticks, sediment	Moderate
	5.40	33	Woody debris and various trash	Wood plank, sticks, sediment	Moderate
	5.48	34	Woody debris and various trash	Wood planks, sticks, styrofoam	High
	5.57	35	Woody debris and various trash	Wood planks, sticks, sediment	High
	5.60	36	Woody debris and various trash	Wood planks, sticks, sediment	Low
	5.62	37	Trash	Wood plank	Low
	5.72	38	Woody debris	Wood, sticks, sediment	High
	5.73	39	Woody debris and various trash	Wood, trees, tire, metal fence, plastic, sediment	High
	5.74	40	Woody debris	Wood, trees, sediment	Moderate
	5.85	4	Stone weir	Stone	Moderate
	6.16	41	Trash	Concrete, cinder block, sticks, sediment, culvert	High
	6.18	42	Trash	Concrete, cinder block, sticks, sediment, metal culvert	High
BB-1	0.22	43	Woody debris	Wood, sticks, sediment	High
	0.84	44	Woody debris and various trash	Wood, timbers, sticks, boards, sediment	High
	0.88	45	Trash	Tire	Low
	0.91	46	Trash	Tire and metal	Low
	0.93	47	Woody debris	Wood, sticks, boards, sediment	High
	0.95	48	Trash	Car seat	Low
	1.07	49	Trash	Tire and metal	Low
	1.86	50	Woody debris	Wood, sticks, sediment	High
BB-2	2.09	51	Woody debris	Wood, sticks, sediment	High

[a]Low clean-up potential indicates a small amount of trash, typically less than two pickup truck loads. Moderate is a large amount of trash or bulk items in a small area. Trash may have been dumped over a long period of time, but could be cleaned up in a few days, possibly with a backhoe. High indicates a large amount of trash or debris scattered over a large area, requiring heavy equipment.

Source: SEWRPC.

wetlands, 4) modify nutrient cycling and decomposition dynamics by wetting soils, altering the hydrologic regime, and creating anaerobic zones in soils and sediments, 5) modify the riparian zone, including the species composition and growth form of plants, 6) influence the character of water and materials transported downstream, and 7) modify instream aquatic habitat, which ultimately influences community composition (e.g. fish and macroinvertebrates) and diversity.[4]

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[4]*R.J. Naiman, J.M. Melillo, J.E. Hobbie, Ecosystem alteration of boreal forest streams by Beaver (Castor canadensis),* Ecology*, Vol. 67, 1986, pp.1254-1269.*

Figure 20

OBSTRUCTIONS, WOODY DEBRIS, AND TRASH LOCATION PHOTOS IN THE PEBBLE CREEK WATERSHED: 2004-2006

1- BEAVER DAM (RM 1.04)

2- BEAVER DAM (RM 1.14)

3- BEAVER DAM (RM 1.35)

4- BEAVER DAM (RM 1.39)

5- BEAVER DAM (RM 1.64)

6- BEAVER DAM (RM 2.31)

7- BEAVER DAM (RM 3.17)

8- BEAVER DAM (RM 3.26)

9- BEAVER DAM (RM 4.61)

1- TRASH- TIRE (RM 0.02)

2- TRASH- BUCKET (RM 0.31)

3- TRASH- PLYWOOD (RM 0.41)

Figure 20 (continued)

4- WOODY DEBRIS AND VARIOUS TRASH (RM 1.38)

5- WOODY DEBRIS (RM 1.52)

6- WOODY DEBRIS AND VARIOUS TRASH (RM 1.73)

7- WOODY DEBRIS (RM 1.78)

8- TRASH- TIRE (RM 1.94)

9- WOODY DEBRIS (RM 2.09)

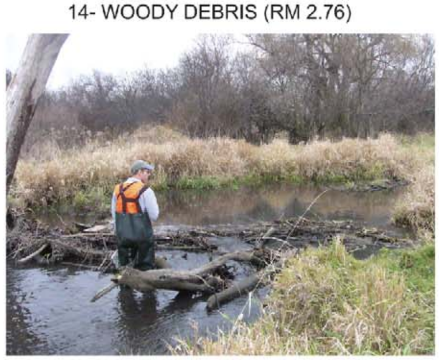
10- WOODY DEBRIS AND VARIOUS TRASH (RM 2.17)

11- TRASH- LAWN MOWER (RM 2.32)

12- WOODY DEBRIS AND VARIOUS TRASH (RM 2.38)

13- WOODY DEBRIS AND VARIOUS TRASH (RM 2.52)

14- WOODY DEBRIS (RM 2.76)



15- WOODY DEBRIS AND VARIOUS TRASH (RM 3.86)

Figure 20 (continued)

16- WOODY DEBRIS AND VARIOUS TRASH (RM 3.98)

17- WOODY DEBRIS AND VARIOUS TRASH (RM 4.00)

18- WOODY DEBRIS AND VARIOUS TRASH (RM 4.02)

19- WOODY DEBRIS AND VARIOUS TRASH (RM 4.05)

20- WOODY DEBRIS (RM 4.10)

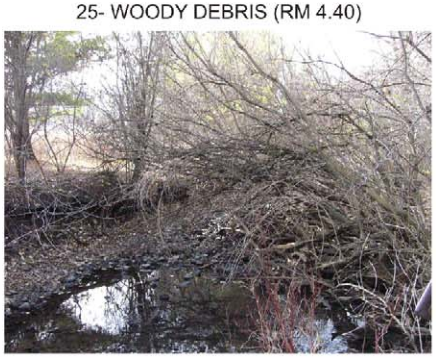
21- WOODY DEBRIS AND VARIOUS TRASH (RM 4.18)

22- WOODY DEBRIS AND VARIOUS TRASH (RM 4.21)

23- WOODY DEBRIS (RM 4.28)

24- WOODY DEBRIS AND VARIOUS TRASH (RM 4.30)

25- WOODY DEBRIS (RM 4.40)



26- WOODY DEBRIS AND VARIOUS TRASH (RM 4.40)

27- TRASH (RM 4.44)

Figure 20 (continued)

28- WOODY DEBRIS AND VARIOUS TRASH (RM 4.49)

29- TRASH- WOOD WAGON (RM 4.99)

30- TRASH- METAL (RM 5.00)

31- TRASH - WOOD PLANK (RM 5.32)

32- WOODY DEBRIS (RM 5.34)

33- WOODY DEBRIS (RM 5.40)

34- WOODY DEBRIS AND VARIOUS TRASH (RM 5.48)

35- WOODY DEBRIS AND VARIOUS TRASH (RM 5.57)

36- WOODY DEBRIS AND VARIOUS TRASH (RM 5.60)

37- TRASH- WOOD PLANK

38- WOODY DEBRIS AND VARIOUS TRASH (RM 5.72)

39- WOODY DEBRIS (RM 5.73)

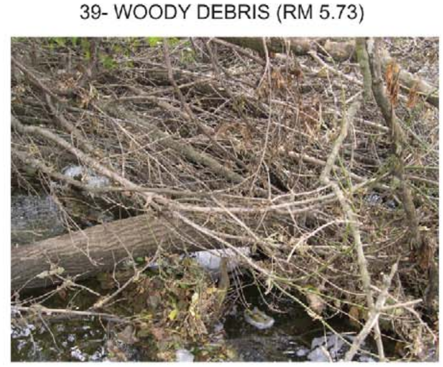


Figure 20 (continued)

40- WOODY DEBRIS (RM 5.74)

41- TRASH- OLD CONCRETE BRIDGE (RM 6.16)

42- TRASH- OLD CONCRETE BRIDGE (RM 6.18)

43- WOODY DEBRIS (RM 0.22)

44- WOODY DEBRIS AND VARIOUS TRASH (RM 0.84)

45- TRASH - TIRE (RM 0.88)

46- TRASH- TIRE AND METAL (0.91)

47- WOODY DEBRIS (RM 0.93)

48- TRASH- CAR SEAT (RM 0.95)

49- TRASH- TIRE AND METAL (RM 1.07)

50- WOODY DEBRIS (RM 1.86)

51- WOODY DEBRIS (RM 2.09)

Figure 20 (continued)

Source: SEWRPC.

Beaver dams consist of tree trunks, branches, twigs, earth, mud, and sometimes stones. Beavers require their shelter (lodge or burrow) to have access points which are under water, and dams are constructed where necessary to achieve this, with building activity being timed according to necessary adjustments in water level.[5] They create dams as a protection against predators and to provide easy access to food during winter. The sound of moving water and current stimulates beavers to build, often engineering large and complex structures to create impoundments in which they will live. Beavers generally prefer habitat where soft soil and sediments are present because this allows them to burrow and tunnel and provides better substrate to bury dam building materials. Lodges are built upstream of the dam, on an island, streambank, or other high area, using sticks and mud and they may contain at least one underwater entrance to make entry nearly impossible for other animals. In addition to providing protection against predators, a lodge also creates a favorable microclimate; air temperature within an occupied beaver lodge remains above freezing even when the outside temperature falls as low as -40 degrees Celsius (ºC).[6] Deeper pools upstream of the dam allows for easy access to winter food supply even when ice has formed over the top of the water surface.

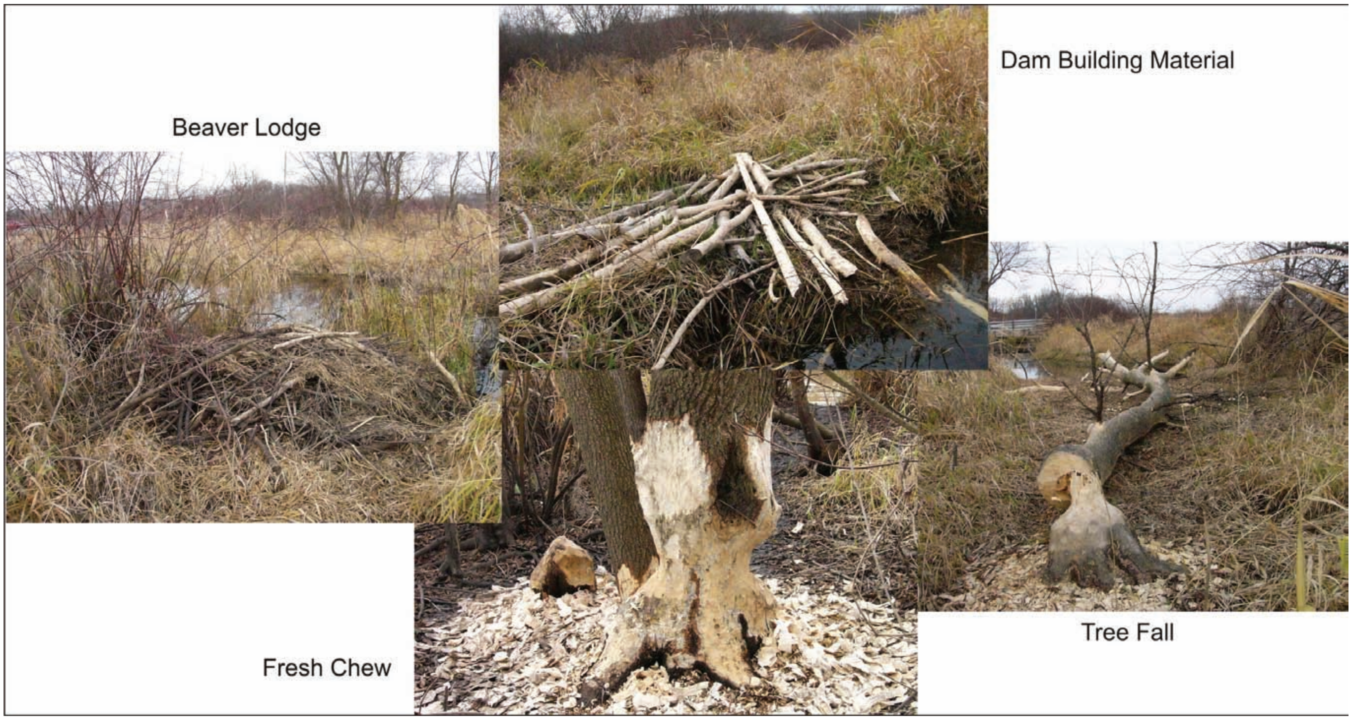
Beaver dams are not permanent structures and without constant maintenance, the dams will be breached and blowouts will then occur. In addition, dams are frequently abandoned when beavers move onto new areas

[5]*A.M. Gurnell, The Hydrogeomorphological effects of beaver dam-building activity,* Progress in Physical Geography*, Vol. 22, 1998, pp. 167-189.*

[6]*A.Kurta,* Mammals of the Great Lakes Region*, University of Michigan Press, 1995.*

Figure 21

BEAVER ACTIVITY WITHIN THE PEBBLE CREEK WATERSHED: 2006



Source: SEWRPC.

depending on food and habitat availability. There is no set time frame within which beavers inhabit areas and maintain dams. It has been documented that dams can be maintained over long periods of time, or used only seasonally. It is likely that, under normal conditions, beaver dams are obstructions for most fish species in terms of upstream passage, but this has not been documented. Most fish species can go downstream without problems; however, it is unknown how passable beaver dams are under high flow conditions.

Beaver dams have been shown to enhance fisheries over watershedwide scales. When beaver impound streams by building dams, they substantially alter stream hydraulics in ways that benefit many fish species.[7] Early research suggested that beaver dams might be detrimental to fish, such as hindering fish passage, and it has been demonstrated that beaver dams seasonally restrict movement of fishes.[8] Until recently, it was common for fish managers to remove beaver dams. However, more than 80 North American fishes have been documented in beaver ponds, including 48 species that commonly use these habitats, and the beaver ponds' overall benefit to numerous fishes has been well documented, causing managers to rethink the practice of removing beaver dams.[9]

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[7] *J.W. Snodgrass, and G.K. Meffe, Influence of beavers on stream fish assemblages: effects of pond age and watershed position,* Ecology *Vol. 79, 1998, pp. 926-942.*

[8] *I.J. Schlosser, Dispersal, boundary processes, and trophic-level interactions in streams adjacent to beaver ponds, Ecology, Vol. 76, 1995, pp. 908-925.*

[9] *M.M. Pollock, et al, The importance of beaver ponds to coho salmon production in the Stillaguamish River Basin, Washington, USA,* North American Journal of Fisheries Management*, Vol. 24, 2004, pp. 749-760.*

Beaver ponds usually have slow current velocities and deep pools, and, therefore, contain extensive cover and a highly productive environment for both vegetation and aquatic invertebrates, conditions which provide fish with foraging opportunities not found in unimpounded stream habitat. Slower water means less energy expenditure for foraging than what is necessary in higher velocity streams. Therefore, sections of streams impounded by beaver dams are often more productive than unimpounded reaches in terms of both number and size of fish. During the winter, juvenile salmonids[10] residing in streams impounded by beaver dams utilize such habitats at a higher density, are consistently larger, and have a greater overwinter survival rate than juveniles that use stream reaches without beaver dams. These areas also serve as important rearing areas in the summer, where higher densities and larger sizes of juvenile salmonids can be found upstream of beaver dams. Research in the northwest shows that salmonid populations could more than double if beaver populations and the slow-water habitats they create are allowed to expand. Therefore, any watershed restoration plan that excludes beaver as a restoration tool will have limited success in restoring salmonid populations.[11]

Pebble Creek contains approximately nine beaver dams as listed in Table 15. Seven beaver dams were located within Lower Pebble Creek, and two were located in Upper Pebble Creek. There were no beaver dams observed in Brandy Brook. Sizable impoundments were observed at Structure Nos. 1, 2, 6, 7, 8, and 9; some of them having a head of about 18 to 24 inches (see Map 23 and Figure 20). Smaller, below water level dams were observed at Structure Nos. 3, 4, and 5. It is possible that these smaller structures serve as a secondary dam for a nearby beaver colony, or that they are the remains of previously abandoned structures. It is important to note that there were two dams that were removed from LP-3 and one was removed from UP-1 about two weeks before the 2004 survey. Structure No. 7 was likely being rebuilt following the removal of one of the dams on LP-3, and No. 8 is in the same location of the previous dam inside a culvert.

Based on the information on warmwater and coldwater systems as described above, it is probable that beaver dams are contributing to the maintenance of the abundance and diversity of the fishery in Pebble Creek.

Stream Crossings

In addition to the woody debris jams and beaver dams, there were a number of other potential physical and hydrological migratory barriers to fisheries movements particularly at culverts and bridges, as shown in Table 16, Map 24, and Figure 22. Upper Pebble Creek contains the greatest number of culverts and the longest culverts compared to the other streams, which is likely contributing to the decreased abundance and diversity of the fishery community in this stream. Lower Pebble Creek does not contain any culverts, because all the road crossings are spanned by bridges. One Bridge at CTH X (Structure No. 1) contains a rock spillway (see Figure 17), is potentially limiting fish passage for some species, based upon limited depths and high velocities, especially during low flow conditions. Problem culverts within Pebble Creek had a wide variety of issues associated with them. Structure No. 14 is perched on a concrete sill with an approximately 12-inch drop, has low flow depth when distributed among all three pipes, and is very long. An excessive woody debris accumulation was also observed at the inlet of one of the culverts comprising Structure No. 14. Structure No. 15 is blocked by a stone weir just downstream in addition to being approximately 280 feet in length. Structures No. 16 and 17 have undersized pipes and are almost completely buried in rubble from the bridges that previously existed.

Because of the relatively high number of culverts within Pebble Creek, their combined impact on stream fish communities could potentially be significant.[12] Culverts tend to have a destabilizing influence on stream morphology that can create selective barriers to fish migration because swimming abilities vary substantially

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[10]*Salmonids found in the Pebble Creek system include brown trout.*

[11]*M.M. Pollock, et al,* op. cit.

[12]*Thomas M. Slawski and Timothy J. Ehlinger, "Fish Habitat Improvement in Box Culverts: Management in the Dark?"* North American Journal of Fisheries Management*, Vol. 18, 1998, pp. 676-685.*

Table 16

COMPARISON OF POTENTIAL OBSTRUCTIONS TO FISHERIES PASSAGE AMONG BRIDGE AND CULVERT LOCATIONS WITHIN THE PEBBLE CREEK WATERSHED: 2006

Structure Number on Map 24 and Figure 22	Description	Road Crossing	River Mile	Subwatershed	Condition	Potential Fisheries Passage Obstructions	
						Potential Restoration Candidate	Cause (extent) of Blockage
1	Concrete span bridge with riprap streambank	CTH X	0.48	Lower Pebble Creek	OK	No	Partial blockage—rock spillway
2	Wood arch bridge	Private–illegal wood bridge	1.06	Lower Pebble Creek	OK	No	None
3	Concrete span bridge	CTH D (Sunset Drive)	1.31	Lower Pebble Creek	OK	No	None
4	Concrete/steel span bridge	Wisconsin and Southern Railroad	2.29	Lower Pebble Creek	Three-foot scour hole downstream	Fish barrier removal	Total blockage—stone weir with one to 1.5 foot drop
5	Concrete span bridge	Glacial Drumlin Bike Trail	2.31	Lower Pebble Creek	OK	No	None
6	Concrete span bridge	CTH TT	2.83	Lower Pebble Creek	OK	No	None
7	Concrete/steel span bridge	Private drive	2.97	Lower Pebble Creek	OK	No	None
8	One 90-inch-diameter, 24-foot-long, smooth steel culvert	Private drive	3.26	Upper Pebble Creek	OK	No (fish barrier removal)	None (Beaver dam inside culvert)
9	One 67-inch-diameter concrete pipe culvert	Private drive	3.74	Upper Pebble Creek	OK	No	None
10	Two approximately nine-foot-wide, 78-inch-high, 28-foot-long elliptical corrugated metal culverts	Kame Terrace Drive	4.34	Upper Pebble Creek	OK	Fish barrier removal	Partial sand, gravel, cobble, and debris blockage
11	Concrete span bridge	Madison Street	5.06	Upper Pebble Creek	OK	No	None
12	One four-foot-diameter, 22-foot-long circular corrugated metal culvert	Bike Trail	5.53	Upper Pebble Creek	OK	No	None
13	Concrete span bridge	New road (condo development)	5.68	Upper Pebble Creek	OK	No	None
14	Three 4.5-foot-wide, three-foot-high elliptical corrugated metal culverts	USH 18	5.70	Upper Pebble Creek	OK	No	None
15	One 64-inch-wide, 47-inch-high; one 91-inch-wide, 72-inch-high; and one 62-inch-wide,77-inch-high concrete culverts, each 280-foot long	CTH TT	5.86	Upper Pebble Creek	OK	Fish barrier removal	Partial sediment blockage
16	Old bridge material, concrete culvert	Private drive	6.16	Upper Pebble Creek	Broken down bridge	Fish barrier removal	Total blockage—broken down concrete and rubble through entire channel
17	Old bridge material, one corrugated metal culvert and concrete rubble	Private drive	6.18	Upper Pebble Creek	Broken down bridge	Fish barrier removal	Total blockage—broken down concrete, rubble and old culvert through entire channel
18	Bedrock crossing	Private drive	6.41	Upper Pebble Creek	OK	No	None

Table 16 (continued)

Structure Number on Map 24 and Figure 22	Description	Road Crossing	River Mile	Subwatershed	Condition	Potential Fisheries Passage Obstructions	
						Potential Restoration Candidate	Cause (extent) of Blockage
19	One 36-inch-diameter, and one 30-inch-diameter, corrugated metal pipes, each 48-feet long	Northview Road	6.68	Upper Pebble Creek	OK	No	None
20	Wood bridge	Foot bridge	0.28	Brandy Brook	OK	No	None
21	One 10-foot-wide, 25-foot-long concrete bottomless box	CTH DT	1.07	Brandy Brook	OK	No	None
22	One 81-inch-wide, 60-inch-high, 24-foot-long, elliptical corrugated metal culvert	ATV bridge	1.72	Brandy Brook	2.5 foot scour hole downstream	Fish barrier removal	Partial—drop too high
23	Wood arch	ATV bridge	1.95	Brandy Brook	Rotting	No	None
24	Concrete/wood span bridge	Golf cart bridge	2.55	Brandy Brook	OK	No	None

Source: SEWRPC.

among species and size-classes of fish affecting their ability to traverse the altered hydrological regime within the culverts.[13] Fish of all ages require freedom of movement to fulfill needs for feeding, growth, and spawning. Such needs generally cannot be found in only one particular area of a stream system. These movements may be upstream or downstream and occur over an extended period of time, especially in regard to feeding. In addition, before winter freeze-up, fish tend to move downstream to deeper pools for overwintering. Fry and juvenile fish also require access up and down the stream system while seeking rearing habitat for feeding and protection from predators. The recognition that fish populations are often adversely affected by culverts has resulted in numerous designs and guidelines that have been developed to allow for better fish passage and to help ensure a healthy sustainable fisheries community.[14]

HABITAT

Channelization and Historic Habitat Loss

Straightening meandering stream channels or "channelization" was once a widely used and accepted technique in agricultural management. The National Resources Conservation Service (NRCS) (formerly Soil Conservation Service) cost shared such activities up to the early 1970s within southeastern Wisconsin.[15] The objectives of channelization were to reduce floods by conveying stormwater runoff more rapidly, to facilitate drainage of low-lying agricultural land, and to allow more efficient farming in rectangular fields. Through channelization, farmers attempted to protect their crops by increasing the velocity of water moving downstream and the rate at which water drained away from their land. However, channelization rarely succeeds in increasing the speed of water moving downstream for two main reasons; 1) waterways throughout the Southeastern Wisconsin Region often have low slopes (i.e. slopes less than one percent), and 2) the effective slope within a reach that is channelized is

[13]*Stream Enhancement Research Committee, "Stream Enhancement Guide", Province of British of Columbia and the British Columbia Ministry of Environment. Vancouver, 1980.*

[14]*B.G. Dane, "A Review and Resolution of Fish Passage Problems at Culvert Sites in British Columbia", Canada Fisheries and Marine Sciences Technical Report 810, 1978. Chris Katopodis, "Introduction to Fishway Design", Freshwater Institute Central and Arctic Region Department of Fisheries and Oceans, January, 1992.*

[15]*Personal Communication, Gene Nimmer, NRCS engineer.*

Map 24

STREAM CROSSINGS WITHIN THE PEBBLE CREEK WATERSHED: 2006

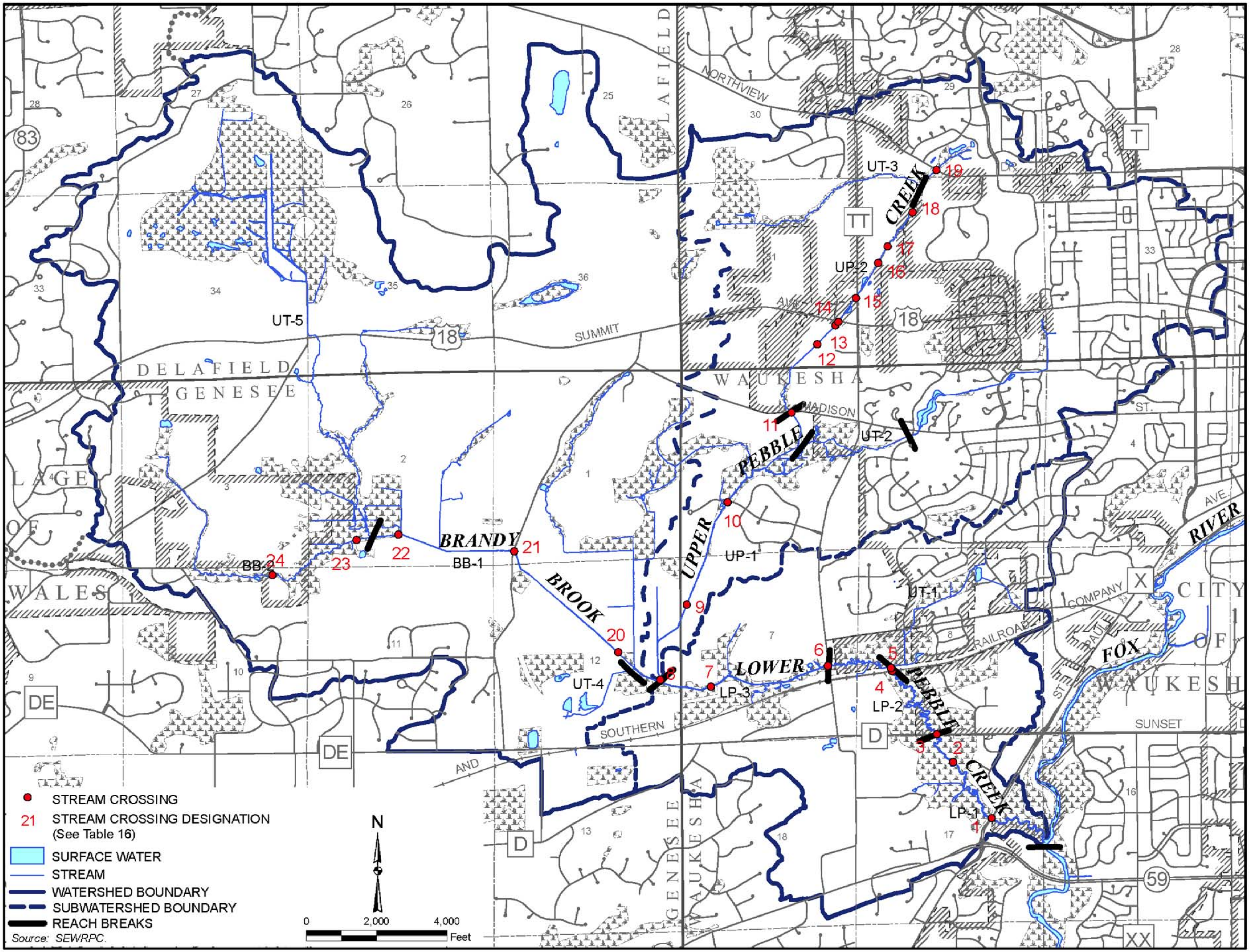

Figure 22

STREAM CROSSING LOCATION PHOTOS IN THE PEBBLE CREEK WATERSHED: 2006

1- CTH X (RM 0.48)

2- PRIVATE BRIDGE AT RM 1.06

3- CTH D/SUNSET DRIVE (RM 1.31)

4- WISCONSIN AND SOUTHERN RAILROAD (RM 2.29)

5- GLACIAL DRUMLIN TRAIL (RM 2.31)

6- CTH TT (RM 2.83)

7- PRIVATE DRIVE (RM 2.97)

8- PRIVATE DRIVE (RM 3.26)

9- PRIVATE DRIVE (RM 3.74)

10- KAME TERRACE DRIVE (RM 4.34)

11- MADISON STREET (RM 5.06)

12- BIKE TRAIL (RM 5.53)

Figure 22 (continued)

13- NEW ROAD (RM 5.68)

14-USH 18 (RM 5.70)

15- CTH TT (RM 5.86)

16- PRIVATE DRIVE (RM 6.16)

17- PRIVATE DRIVE (RM 6.18)

18- PRIVATE DRIVE (RM 6.41)

19- NORTHVIEW ROAD (RM 6.68)

20- FOOT BRIDGE (RM 0.28)

21- HWY DT (RM 1.07)

22- PRIVATE DRIVE (RM 1.72)

23- PRIVATE DRIVE (RM 1.95)

24- GOLF CART PATH (RM 2.55)

Source: SEWRPC.

generally not changed, because slope within the channelized section is limited by the streambed elevation of flatter, downstream reaches. These two factors combined with the fact that channelized reaches are often dredged too deep and too wide, produce areas that are characterized by slow moving, stagnant waterways. Many channelized reaches become long straight pools or areas of sediment deposition. Because the velocities within these reaches are too low to carry suspended materials, sediment particles settle out and accumulate. This is why many channelized reaches contain uniformly deep flocculent organic sediments. Channelization can also lead to instream hydraulic changes that can decrease or interfere with surface water contact to overbank areas during floods. This may result in reduced filtering of nonpoint source pollutants by riparian area vegetation and soils as well as increased erosion of the banks. Channelization can lead to increased water temperature, due to the loss of riparian vegetation, and it can alter instream sedimentation rates and paths of sediment erosion, transport, and deposition. Therefore, channelization activities, as traditionally accomplished without mitigating features, generally lead to a diminished suitability of instream and riparian habitat for fish and wildlife.

Over 2.1 stream-miles have been lost in the main reaches of Pebble Creek due to channel straightening, representing an approximately 15 percent loss in stream-mileage (see Table 14 and Map 25). The actual distance of stream channel lost could be significantly greater, but because of a lack of aerial photography data prior to 1941, it is unknown where the original stream channel was located on UP-2 and BB-1 upstream of CTH DT. In addition to the loss of stream length, channel straightening causes a major decrease in the number of pool and riffle structures within the stream system. Pool-riffle sequences are often found in meandering streams, where pools occur at meander bends and riffles at crossover stretches.[16] Based on these characteristics, an estimate of the number of pools and riffles was calculated using the 1941[17] and prior stream lines drawn from the aerial photos (see Map 25). Reaches LP-1 and LP-2, and BB-2 showed relatively little change over time. Any difference in these reaches is related to the natural meandering of the stream system. Substantial differences were noted among the other reaches; most notably, LP-3, UP-1 and BB-1, which would be expected given the historic channelization of these reaches. Prior to 1941, LP-3 contained approximately 35 pool and riffle structures, UP-1 contained approximately 44 structures, and BB-1 contained at least 30 structures (see Table 17 for current composition for comparison). This indicates that there was a loss of three to four times the amount of pool and riffle habitats in each reach due to channelization. It should also be noted that the reach of BB-1 upstream of CTH DT could not be included in this analysis because channelization occurred well before 1941, so the actual number of pools and riffles in BB-1 could be higher.

Instream Habitat Quantity and Diversity
The amount, quality, and diversity of available instream fisheries and macroinvertebrate habitat generally range from poor to very good within Pebble Creek, as can be inferred from examination of the data presented in Table 17. The reaches with the highest amount of channelization (UP-1, UP-2, BB-1, and LP-3) contained the lowest number of pool and riffle habitats compared to the rest of the watershed. These channelized reaches also exhibited uniform water width and depth compared to the nonchannelized reaches in the watershed, (see Maps 20 and 21, respectively). These factors indicate that these areas contain the poorest quality and lowest diversity of habitat types compared to other areas of the watershed. The proportion of the number of pool to riffle habitats is highest in the LP-1, LP-2, and BB-2 reaches compared to the rest of the watershed, which further supports the conclusion that these areas contain the highest diversity of habitat types compared to the rest of the watershed

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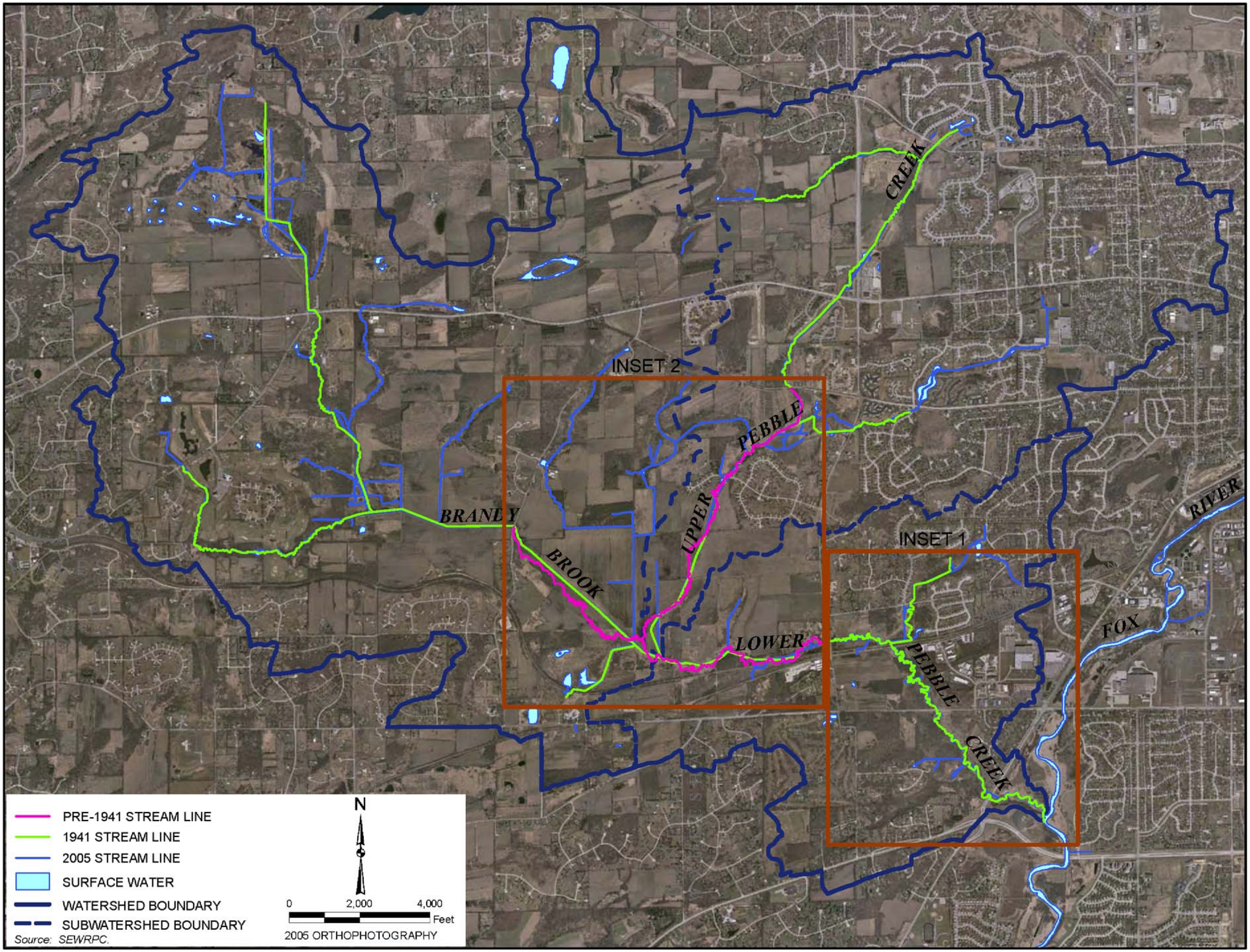
[16]*N.D. Gordon, et al,* Stream Hydrology*, John Wiley and Sons, April 1993, pp. 318.*

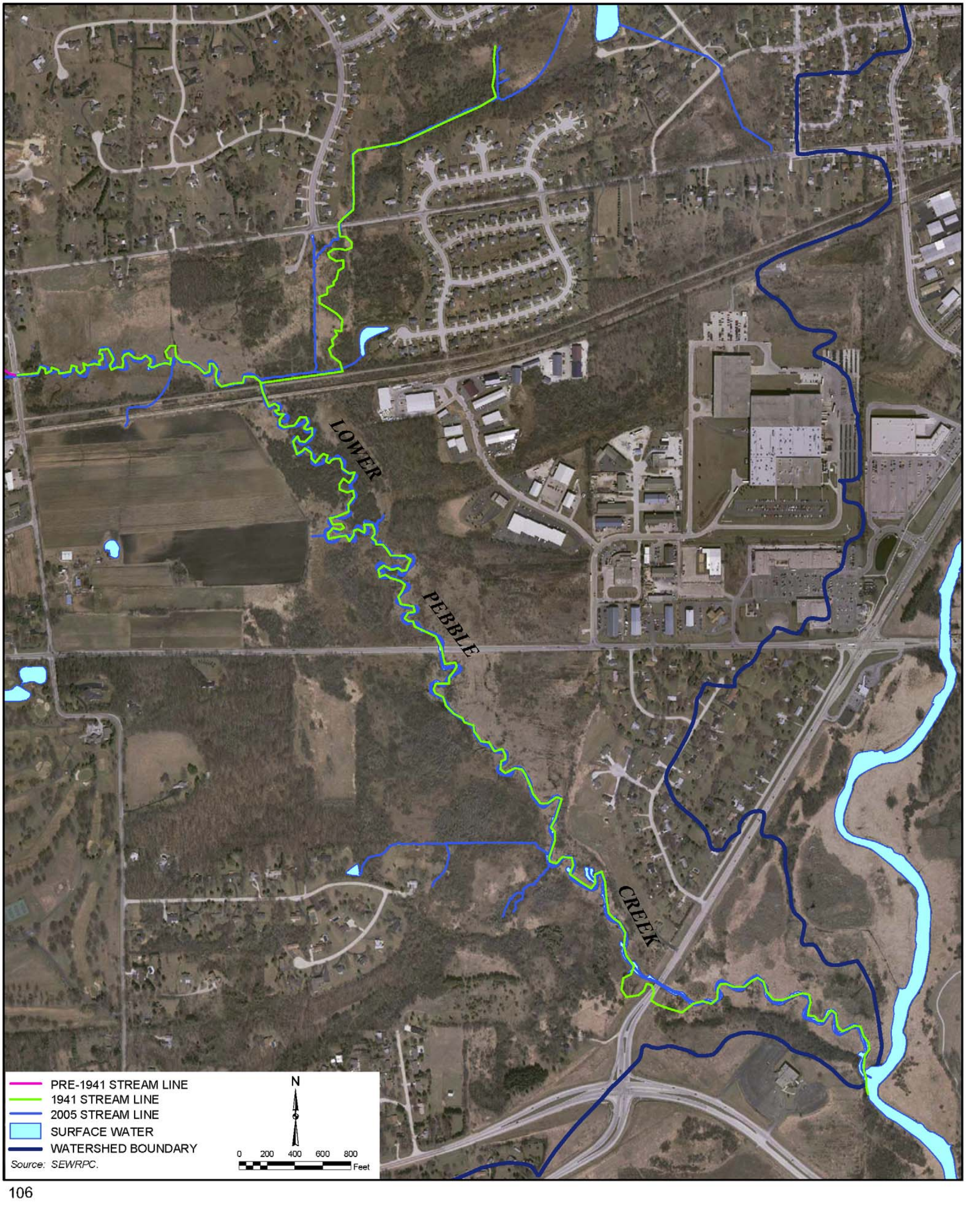
[17]*Aerial photography was provided by the National Archives & Records Administration Photography and was flown by the USDA at a one inch equals 1,667 feet black and white negative scale. Aerial photography film negatives were scanned on a photogrammetric scanner at a 15-micron scanning rate. To georeference the digital images, Ayres Associates selected a minimum five control points for each image based on the year 2000 digital orthophotography for Waukesha County as a control source data. Commonly used features included roads, fence lines, structures, utility features, and a number of other manmade and natural features. Once control data were selected for each image, they were georeferenced using a projective method using image software.*

Map 25

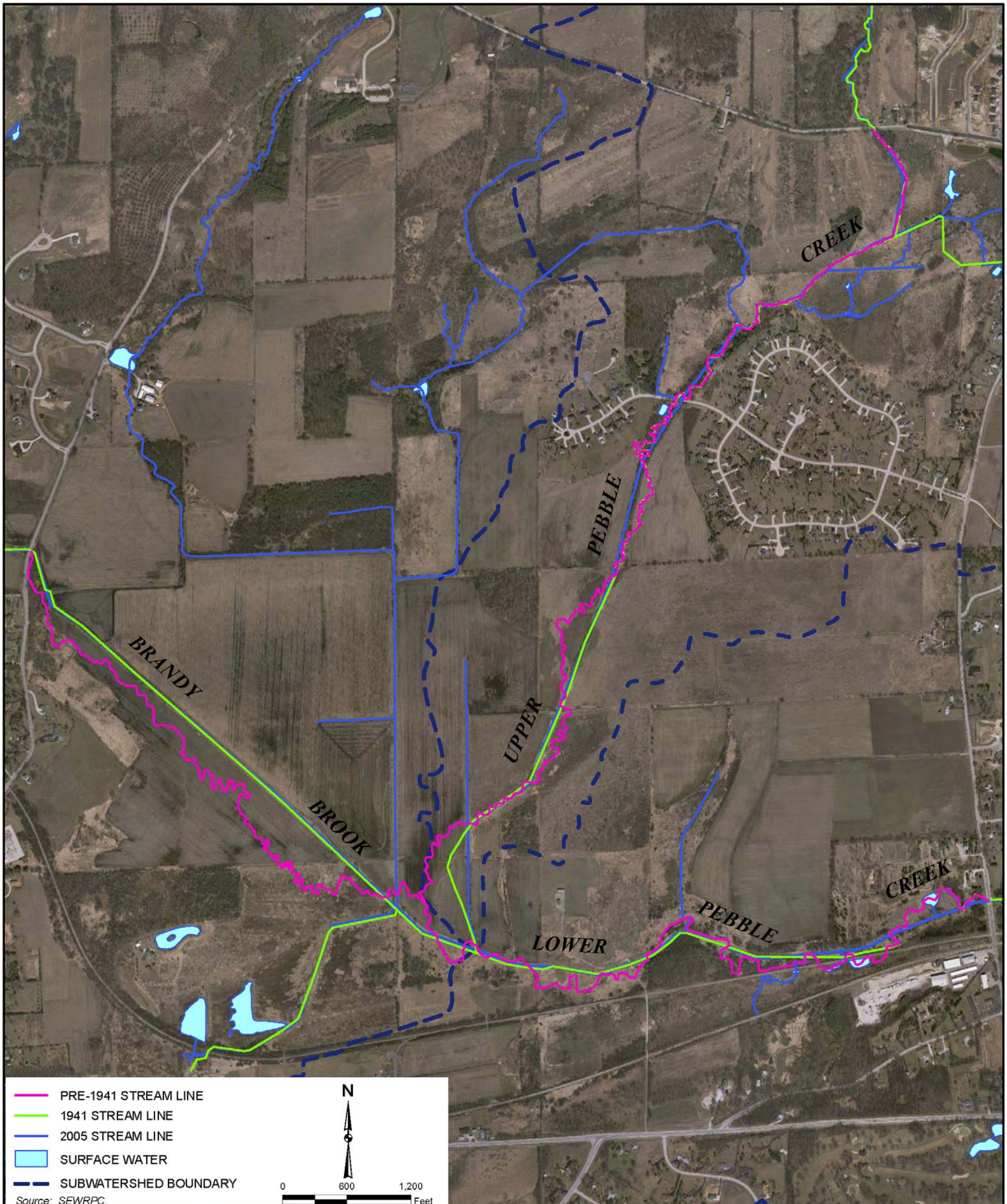
STREAM ALIGNMENTS WITHIN THE PEBBLE CREEK WATERSHED: PRE-1941, 1941, AND 2005



INSET 1 TO Map 25



INSET 2 TO Map 25



Source: SEWRPC.

Table 17

PHYSICAL HABITAT CHARACTERISTICS AMONG STREAM REACHES WITHIN THE PEBBLE CREEK WATERSHED: 2004

Parameters	River Reach[a]						
	Lower Pebble Creek			Upper Pebble Creek		Brandy Brook	
	LP-1	LP-2	LP-3	UP-1	UP-2	BB-1	BB-2
Habitat							
Composition							
Number of Pools per mile	25	45	10	13	9	10	33
Number of Riffles per mile	19	45	13	16	12	14	34
Pool/Riffle Ratio	1.3	1.0	0.8	0.8	0.7	0.7	1.0
Width							
Average Pool Width (feet)	19.9 (13)	13.8 (11)	13.2 (8)	11.2 (10)	9.8 (5)	10.8 (9)	4.5 (6)
Standard Deviation	1.9	2.1	1.2	2.7	3.4	2.8	1.3
Average Riffle Width (feet)	19.6 (6)	15.7 (10)	16.2 (10)	11.2 (14)	5.2 (12)	12.1 (17)	8.6 (7)
Standard Deviation	6.5	3.4	2.4	3.3	3.4	2.4	3.2
Average Run Width (feet)	24.7 (11)	14.9 (14)	15.5 (4)	9.0 (11)	7.5 (11)	9.9 (12)	5.8 (2)
Standard Deviation	7.0	3.0	2.0	2.4	2.2	2.0	2.1
Depth							
Average Pool Depth (feet)	2.1 (65)	1.9 (55)	1.6 (40)	1.1 (50)	0.6 (25)	1.1 (45)	0.8 (24)
Standard Deviation	0.8	0.7	0.6	0.4	0.4	0.5	0.4
Average Riffle Depth (feet)	0.8 (30)	1.2 (50)	0.7 (50)	0.4 (68)	0.2 (57)	0.6 (85)	0.4 (33)
Standard Deviation	0.3	0.6	0.2	0.3	0.2	0.3	0.2
Average Run Depth (feet)	1.5 (55)	1.4 (70)	1.1 (20)	1.3 (55)	0.8 (52)	0.9 (60)	0.7 (8)
Standard Deviation	0.7	0.5	0.4	0.4	0.2	0.3	0.1
Substrate							
Sediment Depth							
Average Depth (feet)	5.5 (30)	5.4 (35)	8.3 (22)	3.2 (35)	0.1 (28)	1.3 (38)	0.4 (15)
Maximum Depth (feet)	14.0 (30)	12.1 (35)	17.6 (22)	5.8 (35)	0.6 (28)	4.4 (38)	0.5 (15)
Composition							
Silt (percent)	38.4	41.3	44.0	29.3	14.5	34.2	2.5
Clay (percent)	26.0	17.5	26.0	15.9	19.4	17.1	2.5
Sand (percent)	12.3	8.8	18.0	24.4	21.0	31.6	22.5
Gravel (percent)	15.1	21.3	6.0	17.1	9.7	5.3	25.0
Cobble (percent)	5.5	6.3	4.0	11.0	14.5	7.9	25.0
Boulder (percent)	2.7	5.0	2.0	2.4	19.4	3.9	22.5
Bedrock (percent)	0.0	0.0	0.0	0.0	1.6	0.0	0.0
Cover							
Undercut Banks							
Deep (percent >1.0 feet)	1.7	1.5	0.0	0.0	1.9	0.0	0.0
Moderate (percent >0.5 and ≤1.0 feet)	8.3	16.2	0.0	2.9	5.6	3.9	3.3
Shallow (percent <0.5 feet)	0.0	10.3	0.0	25.7	38.9	15.8	40.0
None (percent)	90.0	72.1	100.0	71.4	53.7	80.3	56.7
Woody Debris							
High Abundance (percent)	0.0	5.7	0.0	0.0	0.0	7.9	6.7
Moderate Abundance (percent)	3.3	8.5	0.0	5.7	0.0	10.5	13.3
Low abundance (percent)	63.3	60.0	86.4	57.1	53.6	57.9	40.0
None (percent)	33.3	25.8	13.6	37.2	46.4	23.7	40.0
Woody Debris Jams (total number)	0	9	0	13	8	4	1
Trash (total number)	3	7	0	13	10	5	0
Beaver Dams (total number)	2	4	1	2	0	0	0
Stone Weir (total number)	0	1	0	0	1	0	0

[a]*The numbers in parentheses indicates sample size.*

Source: SEWRPC.

(Table 17). Taken as a whole, these comparisons indicate that the watershed continues to be impacted in terms of loss in habitat quantity and quality by the historic channelization that began about 70 years ago.

As indicated in the "Stream Reaches" subsection above, width and depth generally increase from headwater areas to the confluence with the Fox River. Therefore, the average width and depth of pool, riffle, and run habitats also change from headwater areas to the confluence with the Fox River (see Maps 20 and 21 and Figure 23). These changes indicate that, although nominally the same types of habitat areas, the pools, riffles and runs in the upper portions of the watershed effectively form smaller habitat areas than the corresponding habitat areas in the lower reaches of the watershed. These differences can affect and determine the biological community type, abundance, and distribution present within these distinct hydrologic reaches, which, in effect, can result in significant differences in species composition within each of the distinct hydrologic reaches. The upstream reaches contain a lower abundance and diversity of fishes compared to the downstream reaches, because these reaches contain less water volume. For example, pool depths in the upstream reaches are not adequate for adult northern pike or largemouth, but are adequate for a variety of small-bodied forage fish species. However, it is also important to note that these upstream areas are vital for the sustained quality and productivity of the entire fishery within Pebble Creek.

Substrate diversity was generally high throughout Pebble Creek as shown in Table 17. However, the headwater UP-2, and BB-2 reaches demonstrate a much higher proportion of larger substrates (sand, gravel, cobble, and boulder) which is consistent with the higher slopes in these reaches, suggesting that these areas generally contain higher water velocities than other reaches in the watershed. Gravel and cobble substrates offers excellent habitat for macroinvertebrates as well as cover and spawning habitat for fishes. These substrates were also observed in high-quality riffle habitats within the LP-1 and LP-2 reaches. The highest proportion of sand substrates were found in all reaches within Upper Pebble Creek and Brandy Brook, but only in reach LP-3 within Lower Pebble Creek. In addition, reach LP-3 also contained the deepest amount of silt substrate compared with other reaches within the stream as shown in Figure 24 and Map 26, which indicates that there is an average of approximately 0.75 foot of silt over this entire reach. These results indicate that both sand and silt seem to be settling out in reach LP-3 creating a loose flocculent mixture, as shown in Figure 25. This deposition is unique to this portion of the watershed and it indicates that this reach has been historically over-deepened, allowing this material to settle out. As shown in Figure 24 sediment depths in reach LP-3 nearly match water depth in most cases, which is not the case elsewhere in the watershed. Lower Pebble Creek reaches also contained a high proportion of silt substrate with an average of about 0.5 foot in depth. However, these reaches also had a good variety of other substrates and habitat types, such as gravel in riffle habitats. It is also important to note that the majority of the deepest sediments in the lower reaches were generally associated with sections of stream located upstream from obstructions such as woody debris jams and beaver dams.

Pebble Creek generally contained a high amount of in-stream cover for fish and macroinvertebrates in terms of undercut banks, woody debris, and macrophytes as shown in Figure 26, as well as large boulders (Table 17). Although undercut banks are related to streambank stability issues (see the "Streambank Stability and Erosion" subsection above), these are also areas of overhead protection for fishes. Results indicate that most of the watershed is composed of undercut banks that are less than 0.5 foot in depth. The deepest undercut banks are located within the downstream reaches of the watershed. Woody debris is also a significant habitat component within this river system most likely due to the extensive woody riparian buffers that exist throughout most of the watershed.

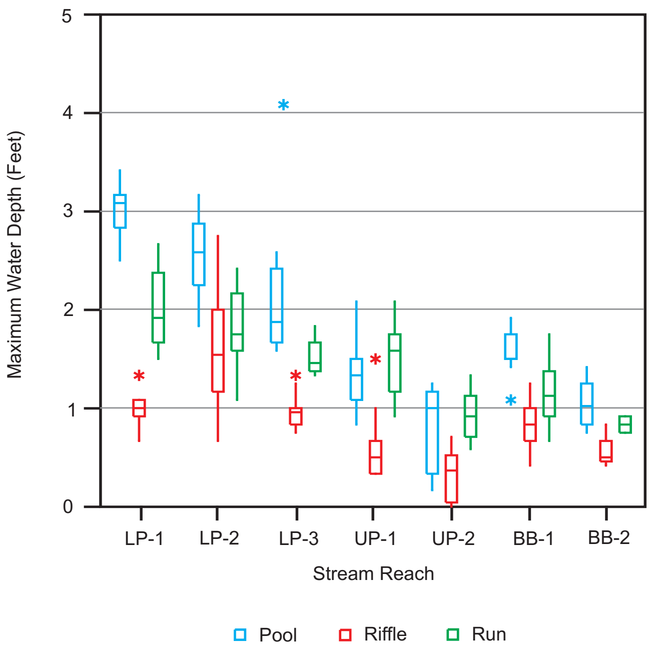
EXISTING STORMWATER MANAGEMENT SYSTEMS

The Pebble Creek watershed contains a variety of stormwater management systems including stormwater discharge points as well as stormwater best management practices (BMPs) as shown on Map 27. A total of 64 BMPs have been implemented throughout the watershed in the form of wet detention basins, grass swales, bioretention devices, sediment traps, infiltration basins, constructed wetlands, compensatory flood storage, in-ground water quality devices, and rain gardens. These data were compiled from field inventories and information obtained from local communities.

Stormwater BMPs are an important part of maintaining good water quality within the Pebble Creek watershed. Not all BMPs in the Pebble Creek watershed were built or installed based on current technical standards because of the time period in which they were constructed. New BMPs in the Pebble Creek watershed are subject to

Figure 23

MAXIMUM WATER DEPTH AMONG HABITAT TYPE AND REACHES IN THE PEBBLE CREEK WATERSHED: 2006

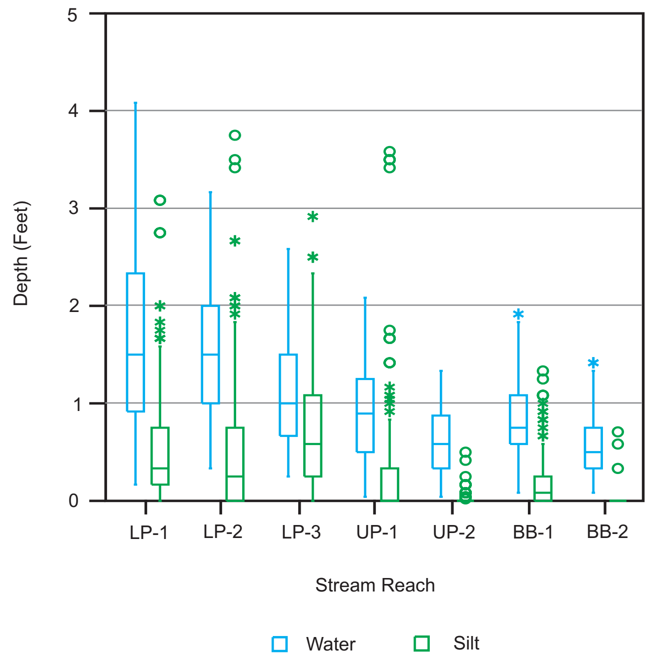


NOTE: See Figure 18 for description of symbols.

Source: SEWRPC.

Figure 24

WATER AND SILT DEPTHS AMONG REACHES IN THE PEBBLE CREEK WATERSHED: 2006



NOTE: See Figure 18 for description of symbols.

Source: SEWRPC.

current technical standards for stormwater management that include design criteria that are also intended to protect water quality. Older stormwater BMPs could have increased functionality if modifications are made to bring them up to the current standards. Modification of existing stormwater BMPs will be addressed in the following chapter.

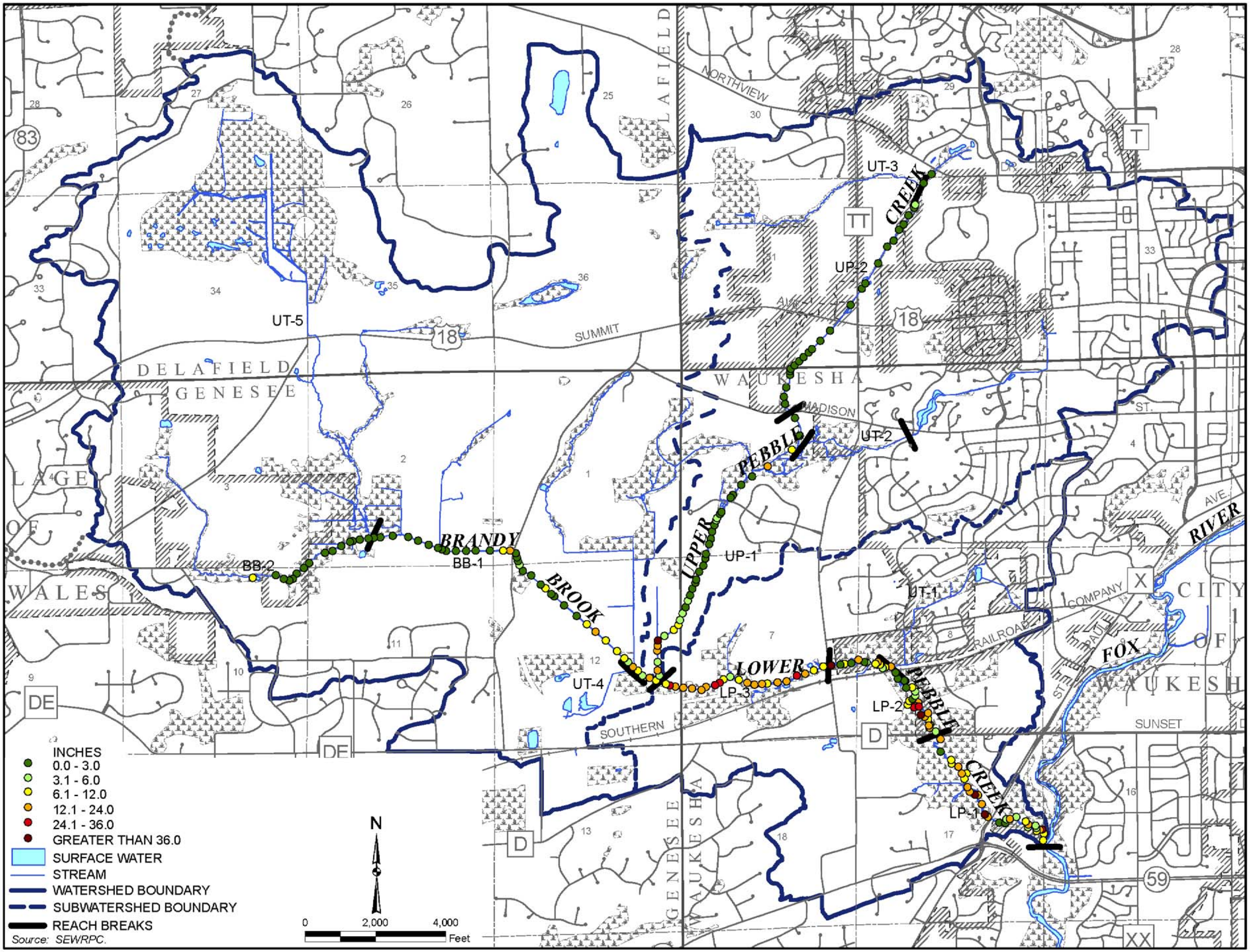
WATER QUALITY CONDITIONS

As described in Chapter II of this report, the Pebble Creek watershed contains three major subwatersheds, designated as Brandy Brook and Upper and Lower Pebble Creek. The mainstem of Pebble Creek is 6.5 miles in length, ending at the confluence with the Fox River. Pebble Creek contains a large number of intermittent and perennial tributaries totaling more than 20 miles, the longest being Brandy Brook at about 4.8 miles in length (Map 3). As described in Chapter III of this report, Pebble Creek upstream of CTH D and Brandy Brook are assigned coldwater sport fish and partial water recreation use objectives. Downstream of CTH D, Pebble Creek is assigned a warmwater sport fish use objective. Water quality conditions are the determining factor when assigning fishery community status, and important management decisions are based on that status. Table 11 in Chapter III of this report illustrates the applicable regulatory water use objectives and water quality standards, or criteria, for waterbodies within the Pebble Creek Watershed Protection Plan study area.

Water quality monitoring within Pebble Creek was performed by a number of organizations from 1990 to present, including the Wisconsin Department of Natural Resources (WDNR); Water Action Volunteers (WAV); Midwest Engineering Services, Inc. under contract to Harmony Homes, Inc.; and SEWRPC. A total of 20 sample sites were monitored for bacteria, pH, total suspended solids, dissolved oxygen, and water temperature to characterize

Map 26

SILT DEPTH IN STREAMS WITHIN THE PEBBLE CREEK WATERSHED: 2006



Source: SEWRPC.

Figure 25

EXAMPLE OF TYPICAL LOOSE SUBSTRATE IN REACH LP-3 OF THE PEBBLE CREEK WATERSHED: 2004

Source: SEWRPC.

Figure 26

EXAMPLE OF TYPICAL MACROPHYTES IN THE PEBBLE CREEK WATERSHED: 2004

Source: SEWRPC.

water quality conditions (Map 28). The WDNR collected water quality data from twelve different locations within Pebble Creek in 1990, 1999, 2004, and 2005. WAV collected water quality grab samples from three locations approximately once a month from 2002 to 2006. The WAV monitoring program is still in effect in Pebble Creek. Harmony Homes, Inc. collected water quality grab samples from 2002 through 2005, approximately every two weeks from April through November at five locations, within Upper Pebble Creek (see Maps 28 and 29) to monitor stream water quality during construction activities in the Rolling Ridge Subdivision which is located near the intersection of Northview Road and Merrill Hills Road (CTH TT). Table 18 shows the site location, collection date, and sampling organization for data used to characterize water quality conditions in Pebble Creek.

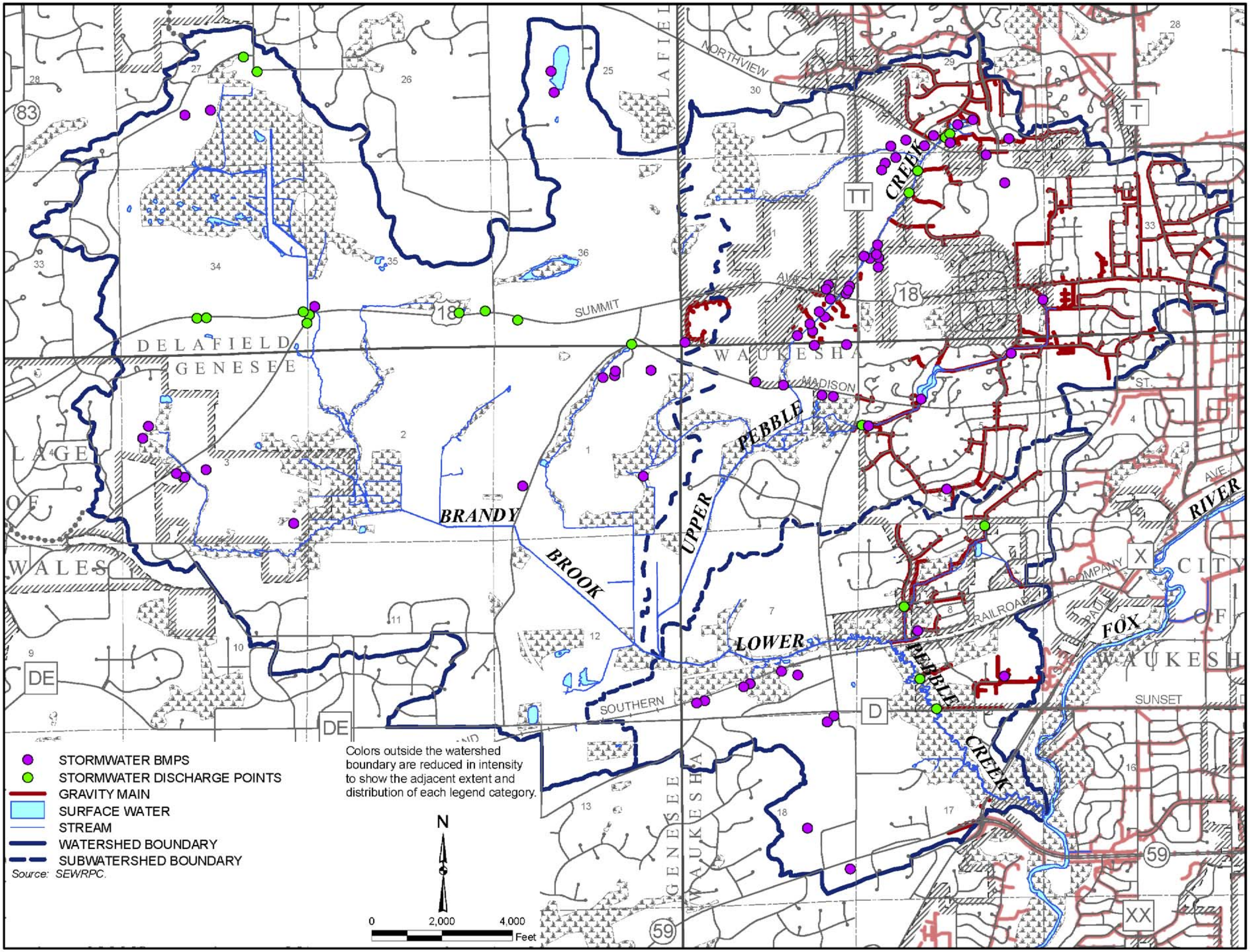
Bacteria

Five surface bacteriological water samples were collected by the WDNR from Pebble Creek at CTH X from August 27, 1990, through September 19, 1990. Fecal streptococcus values ranged from 320 to 2,330 cells per 100 milliliters. The maximum fecal coliform value recorded was 2,900 cells per 100 milliliters, the minimum was 260 cells per 100 milliliters, and the fecal coliform geometric mean was equal to 613 cells per 100 millimeters. All of these samples exceeded the existing WDNR regulatory standards which call for a geometric mean that does not exceed 200 cells per 100 milliliters and three of the five samples exceeded the single-sample maximum standard of 400 cells per 100 milliliters. There have not been any additional bacteriological samples taken since 1990. It is important to note that bacterial concentrations in urban stormwater runoff are often elevated and can frequently exceed the bacteria concentration standard.[18]

[18]*Alissa K. Salmore, Erika J. Hollis, and Sandra L. McClellan, "Delineation of a Chemical and Biological Signature for Stormwater Pollution in an Urban River,"* Journal of Water and Health*, Volume 4, No. 2, pages 27-262, 2006.*

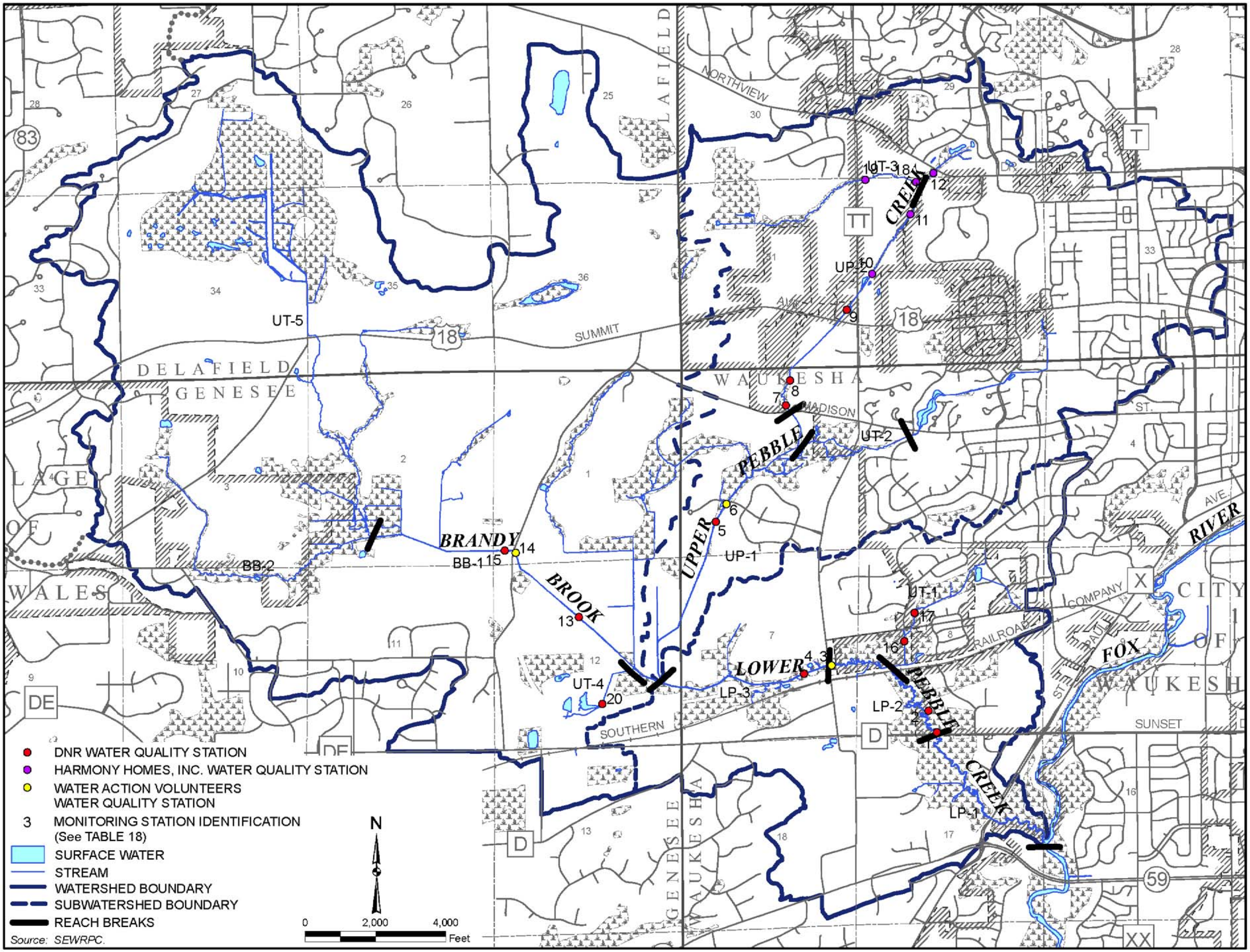
Map 27

STORMWATER BEST MANAGEMENT PRACTICES (BMPS) AND DISCHARGE POINTS WITHIN THE PEBBLE CREEK WATERSHED: 2004



Map 28

WATER QUALITY MONITORING STATIONS WITHIN THE PEBBLE CREEK WATERSHED: 1990-2005



Source: SEWRPC.

Map 29

TEMPERATURE MONITORING STATIONS WITHIN THE PEBBLE CREEK WATERSHED: 2002-2005

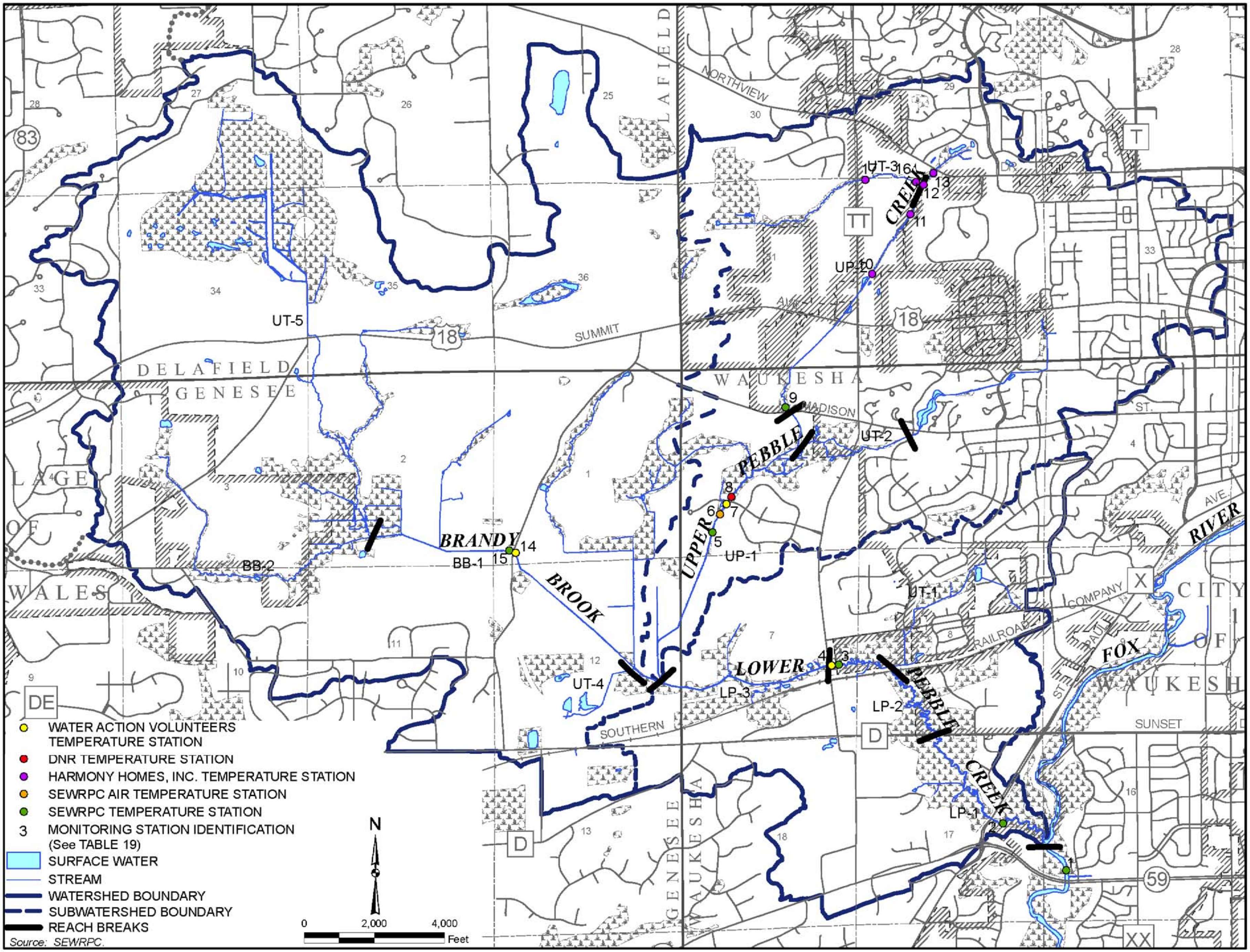


Table 18

INVENTORY DATA FOR WATER QUALITY SAMPLING SITES IN THE PEBBLE CREEK WATERSHED: 1990-2006

Site Number on Map 28	Sampling Agency	Location	River Mile	Subwatershed	Period of Record
1	WDNR	CTH D (Sunset Drive)	1.31	Lower Pebble Creek	06/2005
2	WDNR	Upstream CTH D	1.63	Lower Pebble Creek	08/1990
3	Water Action Volunteers	CTH TT	2.83	Lower Pebble Creek	09/2002-02/2006[a]
4	WDNR	Upstream CTH TT	2.98	Lower Pebble Creek	09/1990
5	WDNR	Downstream Kame Terrace	4.20	Upper Pebble Creek	08/2004
6	Water Action Volunteers	Kame Terrace	4.34	Upper Pebble Creek	09/2002-02/2006[a]
7	WDNR	Madison Street	5.06	Upper Pebble Creek	06/1999
8	WDNR	Upstream Madison Street	5.28	Upper Pebble Creek	08/1990
9	WDNR	Between USH 18 and CTH TT	5.77	Upper Pebble Creek	08/1990
10	Harmony Homes, Inc.[b]	Upstream CTH TT	5.99	Upper Pebble Creek	05/2002-07/2004[c]
11	Harmony Homes, Inc.[b]	Between CTH TT and Northview Road	6.43	Upper Pebble Creek	05/2002-07/2004[c]
12	Harmony Homes, Inc.[b]	Downstream Northview Road	6.56	Upper Pebble Creek	05/2002-07/2004[c]
13	WDNR	Between confluence with Pebble Creek and CTH DT	0.56	Brandy Brook	08/1990
14	Water Action Volunteers	CTH DT	1.07	Brandy Brook	09/2002-02/2006[a]
15	WDNR	CTH DT	1.11	Brandy Brook	06/1999
16	WDNR	Downstream MacArthur Road	0.20	Lower Pebble Creek	11/1990
17	WDNR	Upstream MacArthur Road	0.39	Lower Pebble Creek	10/1990
18	Harmony Homes, Inc.[b]	Upstream confluence with Pebble Creek	0.05	Upper Pebble Creek	05/2002-07/2004[c]
19	Harmony Homes, Inc.[b]	Upstream confluence with Pebble Creek	0.30	Upper Pebble Creek	06/2002, 05/2003, 04/2004-06/2004[c]
20	WDNR	CTH DT	0.29	Brandy Brook	10/1990

[a]*Water Action Volunteers collects grab samples approximately once per month.*

[b]*Data sampling was done by Midwest Engineering, contracted out by Harmony Homes, Inc.*

[c]*Midwest Engineering took grab samples approximately every two weeks from April through November.*

Source: SEWRPC.

Dissolved Oxygen

The minimum dissolved oxygen standards for both coldwater (trout) and warmwater streams, as set forth in Chapter NR 102 of the *Wisconsin Administrative Code*, are 6.0 and 5.0 milligrams per liter, respectively. Minimum dissolved oxygen standards for coldwater streams are also designated to not be lower than 7.0 milligrams per liter during the spawning season for trout species. Dissolved oxygen concentrations have a clear relationship with water temperature. Cold water can hold more dissolved oxygen than warmer water. As water becomes warmer it can hold less dissolved oxygen. If the water becomes too warm, dissolved oxygen levels may be suboptimal (i.e., less than 5.0 milligrams per liter) for many species of fishes and other aquatic organisms. Because the warmest water temperatures are in the summer, this is the most important time of the year for determining physiological limitations based on dissolved oxygen concentrations for aquatic organisms.

WDNR collected eight dissolved oxygen samples from various stations throughout Pebble Creek between August 14, 1990, and September 30, 1990, which indicated that concentrations met coldwater community standards. The minimum concentration recorded among the samples was 7.2 milligrams per liter.

More recent data from 1999 through 2006 showed that dissolved oxygen concentrations varied greatly among sample locations (see Figure 27) with some extremely high concentrations (greater than 15 milligrams per liter) recorded during the winter months, which is normal, due to very cold water temperatures. In general, dissolved oxygen concentrations throughout Pebble Creek met both coldwater and warmwater community standards, with the exception of Upper Pebble Creek, which consistently failed to meet both the coldwater and warmwater standards in the summer and fall months particularly in 2002 and 2003, but only failed to meet coldwater standards in 2004 and 2005. It is important to note that most of the samples within Upper Pebble Creek that recorded dissolved oxygen concentrations of less than 5.0 milligrams per liter were located upstream of Madison Street. Within Upper Pebble Creek, from 1999 through 2006, only one sample taken at Kame Terrace was below 5.0 milligrams per liter and two samples were below 7.0 milligrams per liter. Brandy Brook contained the highest dissolved oxygen concentrations, averaging 11.2 milligrams per liter, and no samples were shown to go below coldwater standards. Dissolved oxygen concentrations within Lower Pebble Creek were not below 7.0 milligrams per liter at CTH TT, which is above the applicable coldwater standard of 6.0 milligrams per liter. The dissolved oxygen concentration of the only sample taken at CTH D in June 2005 was 5.0 milligrams per liter.

These results indicate that dissolved oxygen concentrations may have declined since 1990, but the data from 1990 were somewhat limited and did not include samples from the entire summer. The recent data on dissolved oxygen concentrations indicate that Brandy Brook meets the coldwater community standards. Dissolved oxygen concentrations within Lower Pebble Creek indicate that it meets coldwater standards at CTH TT (where brown trout are stocked) and warmwater standards at CTH D. Upper Pebble Creek consistently goes below coldwater and warmwater standards upstream of Madison Street, which is limiting to aquatic organisms. The area downstream of Madison Street within Upper Pebble Creek generally meets both warmwater and coldwater standards. However, these standards are not being met periodically, which indicates that this subwatershed is potentially limiting for aquatic organisms and more degraded than all other areas of Pebble Creek, which is consistent with the biological data for streams in Upper Pebble Creek (see the "Biological Conditions" section below).

pH

As set forth in Chapter NR 102 of the *Wisconsin Administrative Code*, pH should be within the range of 6.0 to 9.0, with no change greater than 0.5 units outside the estimated natural seasonal maximum and minimum. This range is the standard for all types of freshwater fish communities. In general, monitored locations within the Pebble Creek watershed recorded pH levels that were within the acceptable range (Figure 28). These ranges in water quality conditions for Pebble Creek are well within the recommended ambient water quality criteria for streams and rivers as set forth for the larger ecoregional area as defined by the U.S. Environmental Protection Agency.[19]

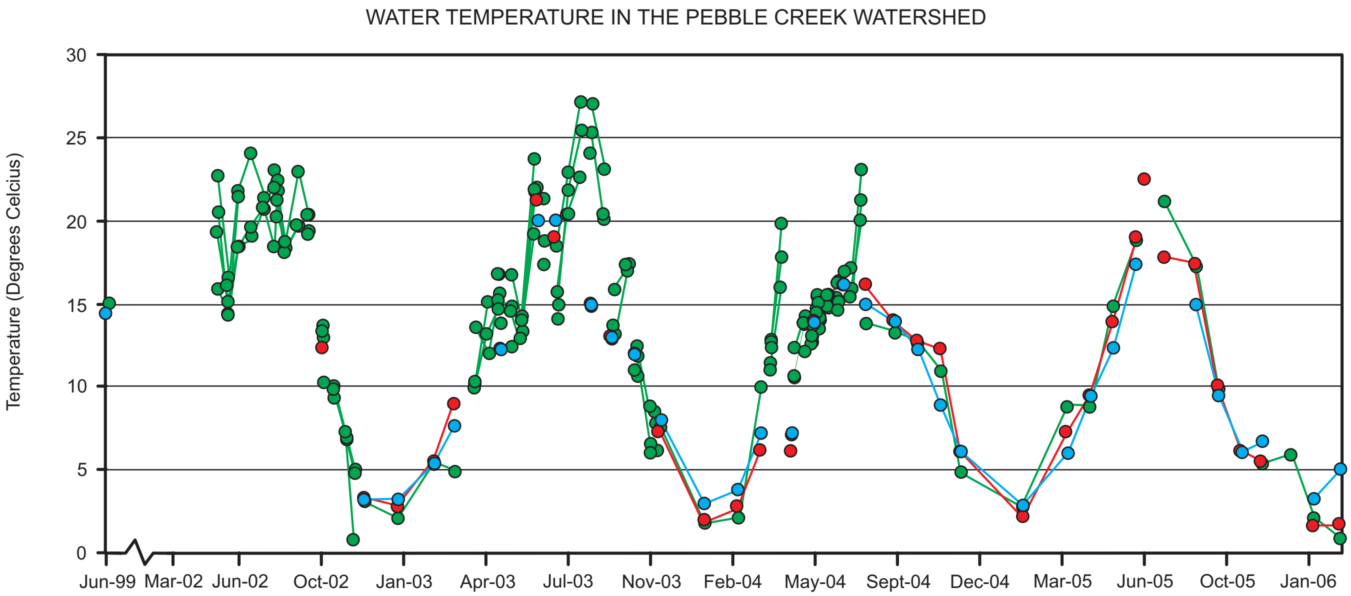
Total Suspended Solids

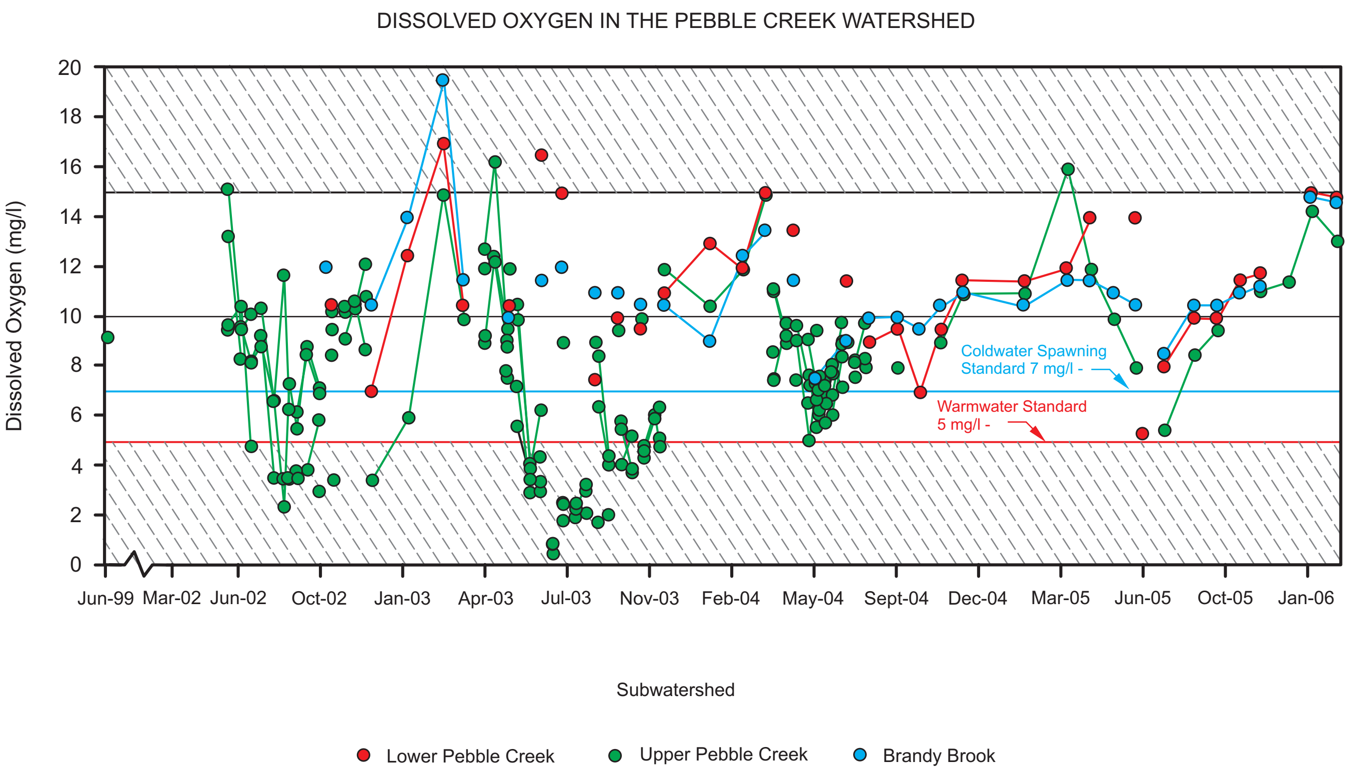
Total suspended solids (TSS) concentrations indicate the amount of solids suspended in the water, whether mineral (e.g., soil particles) or organic (e.g., algae). TSS concentrations are reported in units of milligrams of suspended solids per liter of water. High concentrations of particulate matter can cause increased sedimentation and siltation in a stream, which in turn can harm important habitat areas for fish and other aquatic life. Other pollutants, notably metals and bacteria, may attach to particles. Land use is probably the greatest factor influencing TSS concentrations in the Pebble Creek watershed. As urban development or certain agricultural activities occur in the watershed, there is an increase in disturbed area, a decrease in vegetation, and increase in the rate of runoff (see the "Effects of Urbanization and Agriculture on Instream Biological Communities" section in Chapter II of this report). These all cause increases in erosion of sediment and nutrients, which in turn promotes increased algal growth. TSS concentrations were only measured in the upstream reach of Upper Pebble Creek as

[19]*U.S. Environmental Protection Agency,* Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion VII*, EPA 822-B-00-018, December 2000.*

Figure 27

WATER TEMPERATURE AND DISSOLVED OXYGEN AT SITES IN THE PEBBLE CREEK WATERSHED: 1999-2006



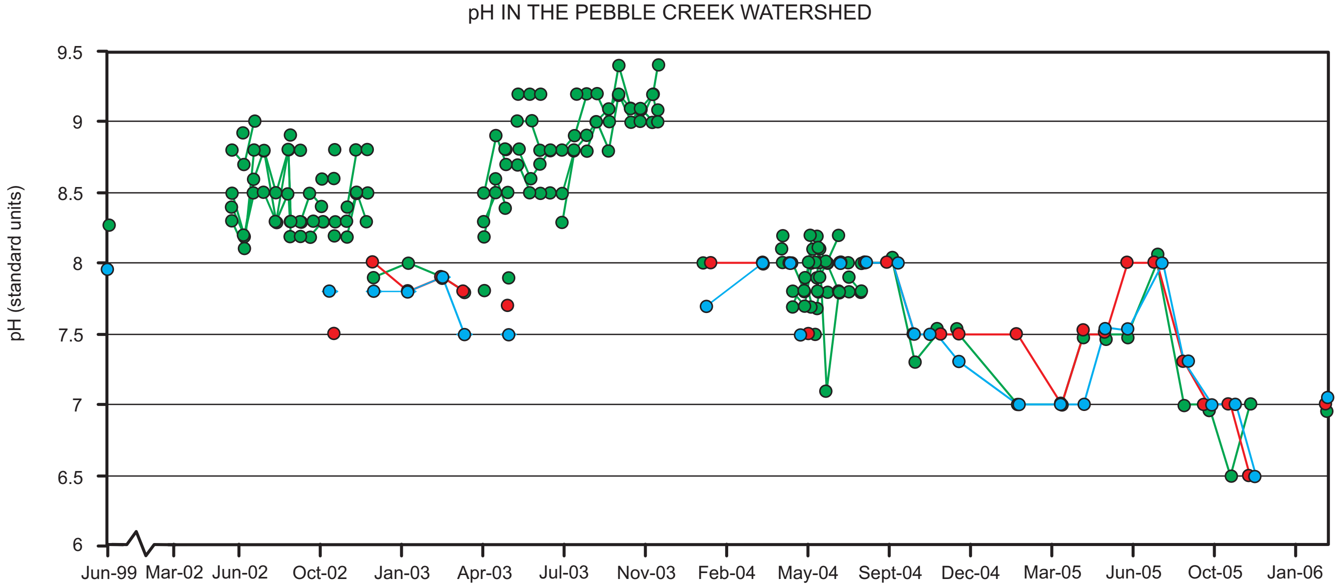


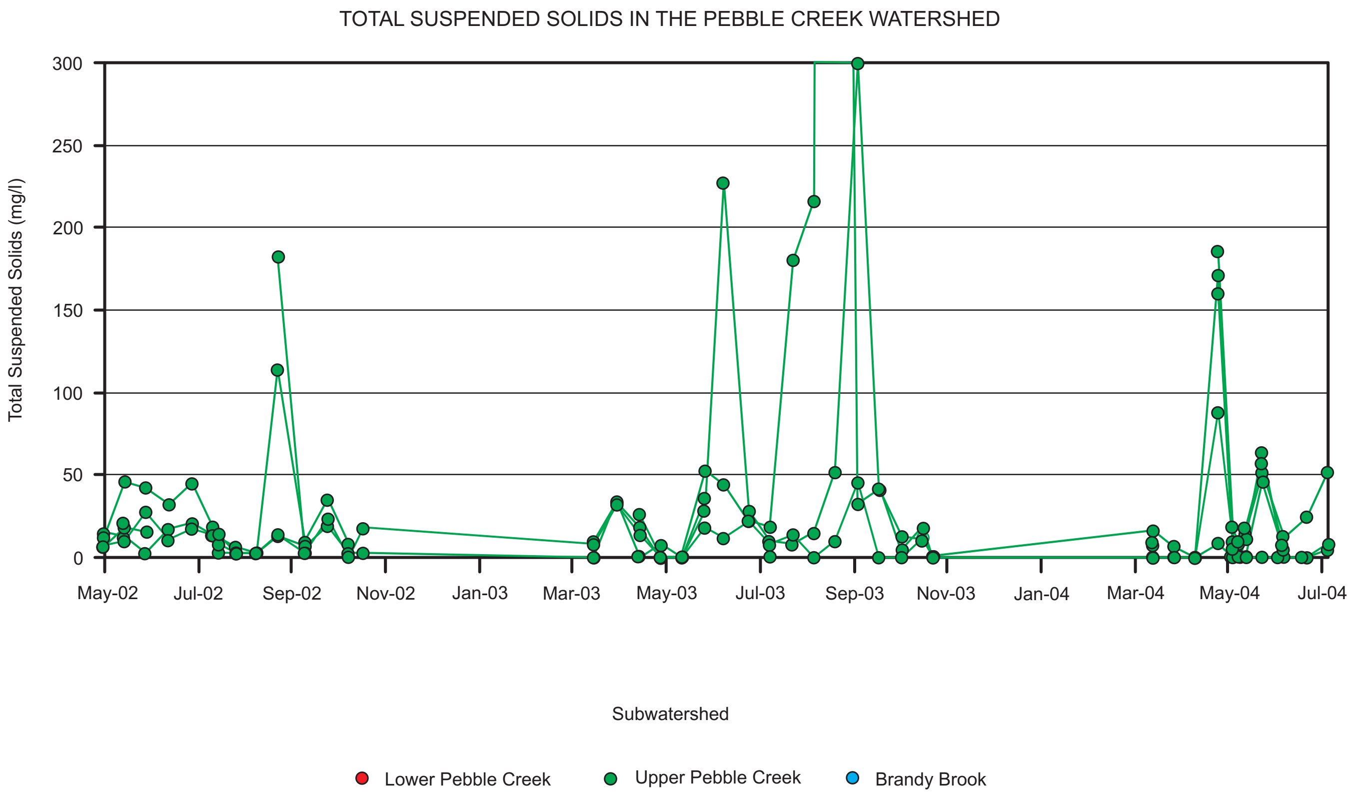
NOTE: The temperature and dissolved oxygen data were collected as discrete grab samples and analyzed in the field.

Source: Harmony Homes, Inc., Water Action Volunteers, Wisconsin Department of Natural Resources, and SEWRPC.

Figure 28

pH AND TOTAL SUSPENDED SOLIDS IN THE PEBBLE CREEK WATERSHED: 1999-2006





NOTE: There is one sample in September 2003, with a TSS measurement at 1,330 mg/l which is off the graph.

Source: Harmony Homes, Inc., Water Action Volunteers, Wisconsin Department of Natural Resources, and SEWRPC.

part of the new development by Harmony Homes, Inc. Rolling Ridge development. All monitored locations recorded TSS levels that were less than 50 milligrams per liter (Figure 28), with the exception of a few very high TSS concentrations recorded between May 2002 and July 2004. There was one unusually high measurement of 1,330 milligrams per liter recorded on September 12, 2003. TSS concentrations are known to vary for physical and/or biological reasons. Heavy rain events can cause erosion and higher TSS concentrations. Not as profound in riverine systems are seasonal variations in algae growth. Warm temperatures, prolonged daylight, and release of nutrients from decomposition may cause algae blooms that increase TSS concentrations. However, no algae blooms have been recorded within the Pebble Creek watershed, therefore, the TSS concentrations increases within this watershed are more likely due to physical rather than biological causes.

Water Temperature

Water temperature data were collected among several sites by the organizations listed above, with one extra site sampled by both the WDNR and Harmony Homes, Inc., as shown on Map 29. To better define temperature regimes within Pebble Creek, in the summer of 2004 SEWRPC deployed continuous monitoring devices at four locations and one additional site to monitor air temperatures (Map 29). These devices were programmed to read water temperature in hourly increments nearly continuously from August 2004 through November 2005. Table 19 and Map 29 show the site locations, collection dates, and sampling organizations for temperature data used to characterize trends in Pebble Creek.

The maximum water temperature standard for both coldwater and warmwater streams, as set forth in Chapter NR 102 of the *Wisconsin Administrative Code*, is 89.0ºF (31.7ºC). However, it is important to note that this standard has limited biological relevance for coldwater or warmwater streams other than almost no aquatic organisms could survive in water that remained at or near 30ºC for even small periods of time. For example, coldwater streams in Wisconsin are distinguished as having maximum daily mean water temperatures of less than 22ºC, where as, warmwater habitats have a maximum daily mean water temperatures in excess of 24ºC.[20] In particular, salmonids, such as brook trout, survive best in water temperatures of 20.0ºC or less and have been shown to prefer temperatures in the wild from 13.9 to 15.6ºC. Optimum feeding temperature for salmonids is about 19ºC, whereas, for both brook and brown trout species, the recommended temperature for optimum growth is 20ºC and the recommended temperature for spawning is 12.8ºC.[21] The lethal limit for brook trout is 25.0ºC and for brown trout it is 25.6ºC. However, temperatures well below the lethal limit can cause significant stress that can lead to illness, infection, and ultimately death.

Pebble Creek contains a variety of both warmwater (maximum daily mean temperature greater than 24ºC) and coldwater (maximum daily mean temperature less than 22ºC) stream reaches.[22] The majority of the reaches in Pebble Creek, based upon summer (June through August) daily maximum water temperatures, can be considered warmwater fisheries; however, as shown in Figure 29, this classification largely depends upon the air temperature and groundwater discharge. For example in 2004 maximum summer air temperatures did not exceed 30ºC and every portion of the stream could be classified as coldwater, as shown in Figure 29. In contrast, in 2005, the air temperature was significantly warmer than 2004 with approximately 25 percent of the summer daily maximum air temperature exceeding 30ºC. This increase in air temperature caused the entire stream network to increase in temperature to well within the warmwater classification for each reach except for Brandy Brook, which remained within the coldwater limits. Brandy Brook seems to contain enough groundwater discharge to mitigate the effects

[20]*See John Lyons, Lizhu Wang and Timothy D. Simonson, "Development and Validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin,"* North American Journal of Fisheries Management*, Volume 16, No. 2, pages 241-256, May 1996,*

[21]*G.S. Becker, Fishes of Wisconsin, University of Wisconsin Press, 1983.*

[22]*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 19

INVENTORY DATA FOR TEMPERATURE SAMPLING SITES IN THE PEBBLE CREEK WATERSHED: 2002-2006

Site Number on Map 29	Sampling Agency	Location	River Mile	Subwatershed	Period of Record
1	SEWRPC	STH 59 and Fox River Parkway	- -[a]	Fox River	04/2005-06/2005
2	SEWRPC	CTH X	0.48	Lower Pebble Creek	08/2004-01/2005, 04/2005 -11/2005
3	SEWRPC	CTH TT	2.83	Lower Pebble Creek	08/2004-01/2005, 04/2005 -11/2005
4	Water Action Volunteers	CTH TT	2.83	Lower Pebble Creek	09/2002-02/2006[b]
5	SEWRPC	Kame Terrace	4.29	Upper Pebble Creek	06/2004-10/2004, 04/2005 -11/2005
6	SEWRPC–air temperature	Kame Terrace	4.32	Upper Pebble Creek	08/2004-01/2005, 04/2005 -11/2005
7	Water Action Volunteers	Kame Terrace	4.34	Upper Pebble Creek	09/2002-02/2006[b]
8	WDNR	Kame Terrace	4.34	Upper Pebble Creek	06/2004-10/2004
9	SEWRPC	Madison Street	5.06	Upper Pebble Creek	08/2004-09/2004
10	Harmony Homes, Inc.[c]	Upstream CTH TT	5.99	Upper Pebble Creek	05/2002-07/2004, 10/2004-04/2005
11	Harmony Homes, Inc.[c]	Between CTH TT and Northview Road	6.43	Upper Pebble Creek	05/2002-07/2004, 10/2004-04/2005
12	Harmony Homes, Inc.[c]	Downstream Northview Road	6.56	Upper Pebble Creek	10/2004-04/2005
13	Harmony Homes, Inc.[c]	Downstream Northview Road	6.4	Upper Pebble Creek	05/2002-07/2004, 10/2004-04/2005
14	Water Action Volunteers	CTH DT	1.07	Brandy Brook	09/2002-02/2006[b]
15	SEWRPC	CTH DT	1.07	Brandy Brook	08/2004-01/2005, 04/2005 -11/2005
16	Harmony Homes, Inc.[c]	Upstream Confluence with Pebble Creek	0.05	Upper Pebble Creek	06/2002, 05/2003, 04/2004-06/2004
17	Harmony Homes, Inc.[c]	Upstream Confluence with Pebble Creek	0.30	Upper Pebble Creek	05/2002-07/2004

[a]*This site was located on the Fox River approximately 0.2 mi. downstream of the confluence with Pebble Creek.*

[b]*Water Action Volunteers samples were taken approximately once per month.*

[c]*Data sampling was done by Midwest Engineering, contracted out by Harmony Homes, Inc.*

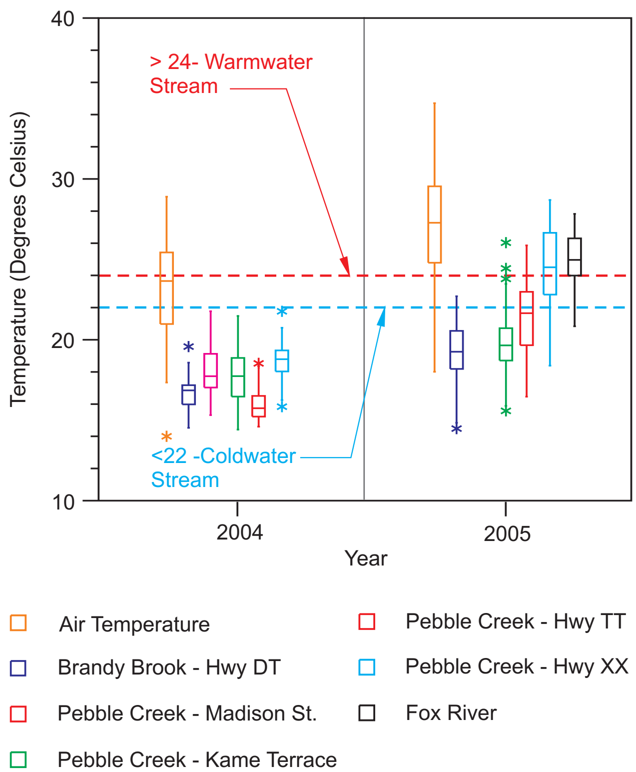
Source: SEWRPC.

of the higher air temperatures that keeps the water temperatures colder than anywhere else in the system, which is also consistent with the sustained high abundance of mottled sculpin (a coldwater indicator species) in this reach from the 1970s to present (see the “Biological Conditions” section below). This is also consistent with the greater amount of groundwater seepage areas observed in Brandy Brook, as shown on Map 30. These coldwater 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. However, as previously mentioned, brook trout were never recorded in this reach. In contrast, a few mottled sculpin were found within the UP-1 reach of Upper Pebble Creek in 1999, but none have been recorded in the UP-2 reach from 1999 to 2005 (see the “Fisheries” subsection below).

It is also important to note that the relative magnitude of increasing temperatures between 2004 versus 2005 changed among sites within Pebble Creek, as shown in Figure 29. Average daily maximum air temperatures

Figure 29

MAXIMUM DAILY SUMMER TEMPERATURES AMONG SITES WITHIN THE PEBBLE CREEK WATERSHED: 2004-2005



NOTES: In 2004, all sites, except Kame Terrace, recorded only the month of August; including air temperature.

The temperature data were collected *in-situ* using programmable data loggers at one-hour intervals that recorded simultaneously at all sites in the study area.

See Figure 18 for description of symbols.

Source: Wisconsin Department of Natural Resources and SEWRPC.

increased from 23 degrees in 2004 to 27ºC in 2005. In addition, for the single warmest day of the summer, there was a six degree increase in air temperature in 2005 compared to 2004. In response to this increase in air temperature, the Brandy Brook site and the Kame Terrace site demonstrated increases in average daily maximum water temperature of 2.4 and 2.0ºC, respectively. In contrast, the average daily maximum water temperature at the sites at CTH TT and CTH X increased nearly 6.0ºC, which indicates that the relative response to the increase in air temperatures was significantly greater in these downstream sites compared to the upstream sites.

Comparison of the hottest maximum daily water temperature in 2004 versus 2005 indicates that the Brandy Brook site increased 3.0 degrees, the Kame Terrace increased 4.6 degrees, the CTH TT site increased 7.3 degrees, and the CTH X increased 6.9ºC. As previously mentioned, there was only a 6.0ºC increase in the maximum air temperature between 2004 and 2005, but the downstream sites at CTH TT and CTH X demonstrated increased water temperatures beyond the maximum difference in air temperature. This indicates that the downstream sites are the most sensitive and Brandy Brook is the least sensitive to increases in air temperatures, and it also indicates that there are additional temperature inputs to Pebble Creek at, or upstream from, the sites at CTH TT and CTH X. The response to an increase in temperature at the Kame Terrace site was much more dramatic than the Brandy Brook site. Although the average daily maximum temperature increase at the Kame Terrace site was similar to the Brandy Brook site, the relative difference on the single hottest day was nearly twice that of the Brandy Brook site. This seems to indicate that, while there is a substantial amount of groundwater discharge within the Upper Pebble Creek subwatershed, there is not as much groundwater input compared to Brandy Brook and, therefore, Upper Pebble Creek is more susceptible to increases in air temperature.

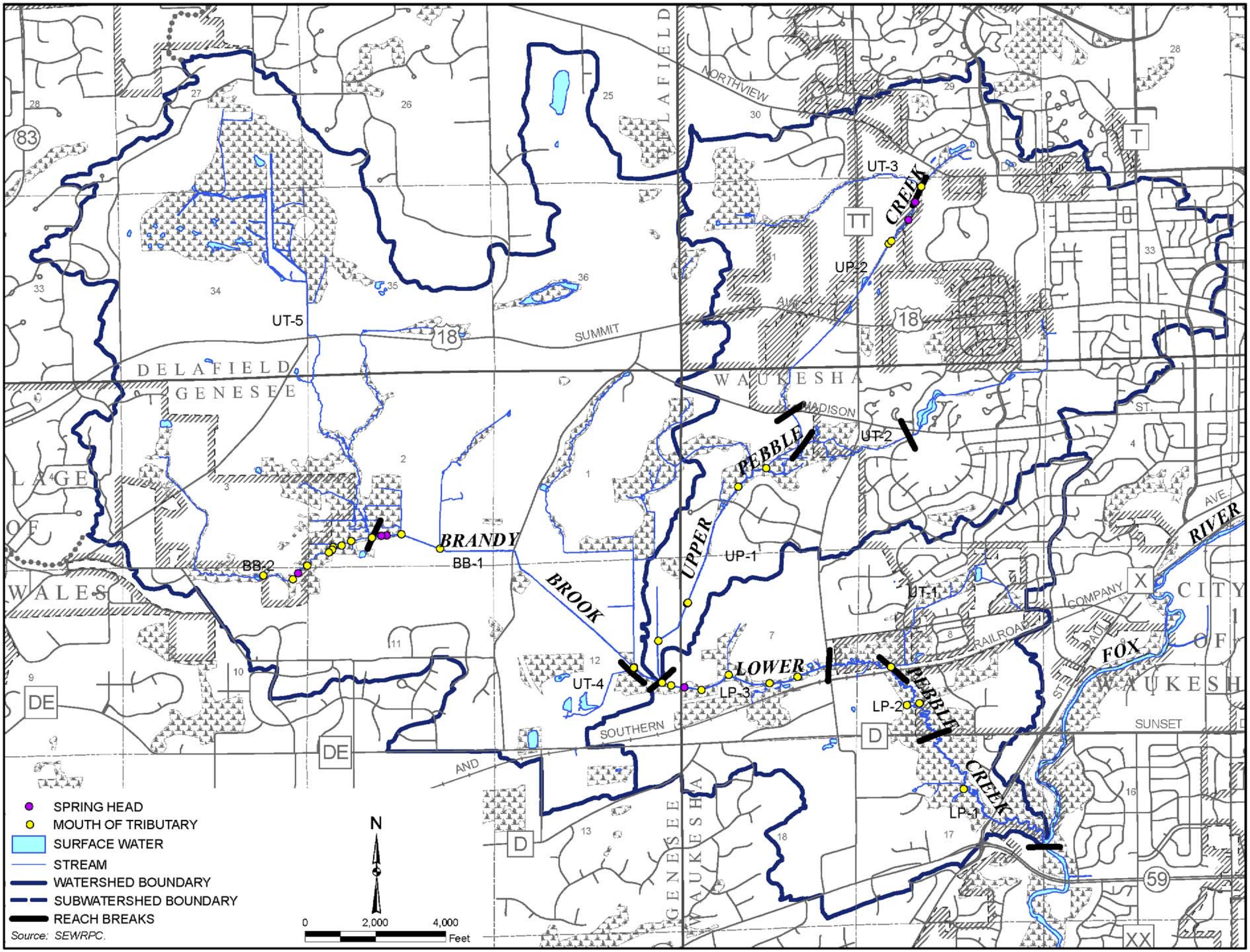
In summary, seasonal water temperature data collected during the summers of 2004 through 2005 indicated that Pebble Creek would not be likely to support a sustainable salmonid fishery except possibly within the Brandy Brook subwatershed. Figure 29 shows that every site within Pebble Creek generally exceeded 20.0ºC, and all sites except for the Brandy Brook site were shown to reach the lethal limit for salmonids of 25ºC on several occasions.[23]

As previously mentioned, there are no brook trout within Pebble Creek and there are no records that there have ever been brook trout within this watershed. Brown trout are stocked at CTH TT annually, but this species has not

[23]*G.S. Becker,* Fishes of Wisconsin*, University of Wisconsin Press, 1983.*

Map 30

HYDROLOGIC FEATURES DISCHARGING TO PEBBLE CREEK AND BRANDY BROOK: 2005



been able to successfully reproduce within this watershed. It is possible that the temperatures greater than 20.0 and 25.0 degrees within this system are causing suboptimal growth and/or stress that can lead to decreased energy reserves to actually reproduce. Temperature may also be inappropriate to induce spawning and/or for egg development after they are deposited into the stream channel. This would have to be determined by additional assessments of brown trout population abundance and growth, integrated with more temperature monitoring, before such relationships could be definitively established.

Other Considerations

Water quality degradation is related to a number of factors that include land use (see the sections entitled "Urban Development and Impervious Surfaces," and "Effects of Urbanization and Agriculture on Instream Biological Communities" in Chapter II of this report); extent, nature, and continuity of buffers (see the "Riparian Corridor Conditions" section below); and, volume and quality of stormwater runoff, all of which contribute to the varied nature and sources of contaminants entering the stream. For example, stormwater runoff is likely to be a major source of chloride,[24] concentrations of which have been shown to be increasing in every lake sampled throughout the Southeastern Wisconsin Region.[25]

Stream crossings act as direct conduits for nonpoint source pollution, especially in terms of the road runoff. Stream crossings also bisect riparian corridors fragmenting the continuity of the corridor, which has also been shown to be associated with decreased water quality and biological diversity within watersheds. The number of stream crossings within a watershed has been determined to be directly associated with increased water quality degradation. There are more stream crossings within Upper Pebble Creek than in the other streams within Pebble Creek (see Map 24). Consequently, the water quality impacts of roadways on the stream as a result of direct inflow from road crossings and stormwater inflows from riparian areas can be inferred, and Upper Pebble Creek is assumed to be the most impacted compared to other streams within this system.

To compare the effects of land use differences among the three subwatersheds, nonpoint source pollution loads have been estimated based upon a unit area load-based model developed for use within the Southeastern Wisconsin Region. Pollutant loads to waterbodies are generated by various natural processes and human activities that take place in the tributary area. These loads are transported directly onto the surface of a stream or lake through the atmosphere, across the land surface, and by way of inflowing tributaries, including stormwater drains and agricultural drain tiles. Pollutants transported by the atmosphere can be deposited as dry fallout and direct precipitation. Pollutants transported across the land surface enter a waterbody as direct runoff and, indirectly, as groundwater inflows, including drainage from onsite wastewater treatment systems. Pollutants are transported by stream aquatic systems as surface flows from tributary streams, stormwater drains, and agricultural drain tiles, among other conveyance systems. Pollutants transported across the land surface directly tributary to the waterways, in the absence of identifiable or point source discharges from industries or wastewater treatment facilities comprise the principal route by which contaminants enter a waterbody.[26] Currently, there are no significant point source discharges of pollutants to Pebble Creek. For this reason, the discussion that follows is based upon nonpoint source pollutant loadings to the Creek.

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[24]*U.S. Environmental Protection Agency, What You Should Know About Safe Winter Roads and the Environment, EPA 901-F-05-020, September 2005.*

[25]*SEWRPC Technical Report No. 39,* Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds*, November 2007.*

[26]*Sven-Olof Ryding and Walter Rast,* The Control of Eutrophication of Lakes and Reservoirs*, Unesco Man and the Biosphere Series, Volume 1, Parthenon Press, Carnforth, 1989; Jeffrey A. Thornton, Walter Rast, Marjorie M. Holland, Geza Jolankai, and Sven-Olof Ryding,* The Assessment and Control of Nonpoint Source Pollution of Aquatic Ecosystems*, Unesco Man and the Biosphere Series, Volume 23, Parthenon Press, Carnforth, 1999.*

Sediment, phosphorus, and selected urban-source heavy metals loads have been estimated for each of the three subbasins within the Pebble Creek system. The loads are estimated for the purpose of comparing potential loads among the subwatersheds and they do not reflect the effects of any existing or future controls on nonpoint source pollution. Thus, this information is useful 1) in establishing the potential effects of planned land use changes on loads of given pollutants and 2) in targeting controls under planned land use conditions, but it is not an indication of the actual loads expected to be delivered to streams, since load reductions from existing and future controls are not reflected. These loads are presented in Tables 20, 21, and 22, and are generated based upon the land uses within each of the three subwatersheds. In actuality, the total contaminant load from the Lower Pebble Creek subwatershed, in the absence of controls, would be the sum of the various loads set forth in each of the three tables, as both Upper Pebble Creek and Brandy Brook drain into the Lower Pebble Creek subwatershed. However, for the purposes of this discussion, each subwatershed is analyzed separately in order to better understand the relative importance of the various land uses on water quality.

Phosphorus Loadings

Phosphorus has been identified as the factor generally limiting aquatic plant growth in lakes and stream in Wisconsin. Thus, excessive levels of phosphorus are likely to result in conditions that interfere with the desired uses of these waters. In all three cases, as agricultural lands are converted to urban land uses, phosphorus loads are expected to decline. Current year 2005 and forecast year 2035 loads, in the absence of controls, are presented. In the Brandy Brook subwatershed, total phosphorus loads are expected to decrease from about 2,735 pounds of phosphorus per year to about 2,200 pounds per year; in the Upper Pebble Creek subwatershed, total phosphorus loads are expected to decrease from about 1,450 pounds of phosphorus per year to about 1,230 pounds per year; and in the Lower Pebble Creek subwatershed, total phosphorus loads are expected to decrease from about 735 pound of phosphorus per year to about 580 pounds per year. Because of the likely implementation of additional controls on phosphorus generated by rural and urban lands and by construction sites, it would be expected that the actual loads delivered to the streams of the study area would be lower than those cited above.

While these forecast loads suggest a slight diminution of the phosphorus load as agricultural lands within the area are converted to residential and other urban land uses, urban residential lands will contribute an increasing percentage of the total phosphorus load. In the Brandy Brook subwatershed, urban residential lands are estimated to have contributed about 6 percent of the total phosphorus load under 2005 land use conditions. This load is expected to increase to about 15 percent of the load under year 2035 conditions. In the Upper Pebble Creek subwatershed, urban residential lands are estimated to contribute about 30 percent of the phosphorus load under year 2005 conditions, increasing to nearly 50 percent of the phosphorus load under year 2035 land use conditions. Likewise, in the Lower Pebble Creek subwatershed, the estimated total phosphorus load from urban residential lands is expected to increase from about 20 percent under year 2005 land use conditions to about 35 percent of the load under forecast year 2035 land use conditions. This situation may be exacerbated by the increasing use of agrochemicals in urban lawn and garden care applications. For example, urban residential lands fertilized with a phosphorus-based fertilizer can contribute up to two-times more dissolved phosphorus to a lake than lawns fertilized with a phosphorus-free fertilizer or not fertilized at all.[27]

Sediment Loadings

The estimated sediment loads from the watershed, in the absence of controls, under existing year 2005 and forecast year 2035 land use conditions also are shown in Tables 20, 21, and 22. A total annual sediment load of about 650 tons was estimated to be produced within the Brandy Brook subwatershed under year 2005 land use conditions; this load is forecast to decrease to about 485 tons of sediment under year 2035 land use conditions. In the Upper Pebble Creek subwatershed, the total annual sediment load of about 320 tons, estimated under year 2005 land use conditions, is forecast to decrease to about 245 tons of sediment under year 2035 conditions. In the Lower Pebble Creek subwatershed, a total annual sediment load of about 165 tons was estimated under year 2005

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[27] *U.S. Geological Survey Water-Resources Investigations Report No. 02-4130,* Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from Lakeshore Lawns, Lauderdale Lakes, Wisconsin*, July 2002.*

Table 20

ESTIMATED NONPOINT SOURCE POLLUTANT LOADS IN THE BRANDY BROOK SUBWATERSHED: 2005 AND 2035

Land Use	2005						2035					
	Area (acres)	Sediment (pounds)	Phosphorus (pounds)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)	Area (acres)	Sediment (pounds)	Phosphorus (pounds)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)
Residential	896	20,612	181.9	0.8	14.0	0.0	1,663	37,661	337.2	1.3	25.1	0.0
Commercial	7	5,488	8.4	1.5	10.4	0.1	7	5,488	8.4	1.5	10.4	0.1
Industrial	8	6,016	9.4	1.8	11.9	0.1	8	6,016	9.4	1.8	11.9	0.1
Communications, Transportation, and Utilities	279	29,585	30.7	64.3	230.5	2.6	423	46,530	46.5	101.5	363.8	4.2
Governmental	6	3,066	8.1	0.4	4.8	0.0	10	5,110	13.5	0.7	8.0	0.0
Recreational	280	6,720	75.6	- -	- -	- -	269	6,456	72.6	- -	- -	- -
Open Lands	331	3,144	36.4	- -	- -	- -	240	2,280	26.4	- -	- -	- -
Water	26	4,888	3.4	- -	- -	- -	26	4,888	3.4	- -	- -	- -
Wetlands	840	3,108	33.6	- -	- -	- -	834	3,086	33.4	- -	- -	- -
Woodlands	463	1,713	18.5	- -	- -	- -	463	1,713	18.5	- -	- -	- -
Agricultural	2,709	1,219,050	2,329.7	- -	- -	- -	1,902	855,900	1,635.7	- -	- -	- -
Total	5,845	1,303,390	2,735.7	68.8	271.6	2.8	5,845	975,128	2,205.0	106.8	419.2	4.4

Source: SEWRPC.

Table 21

ESTIMATED NONPOINT SOURCE POLLUTANT LOADS IN THE UPPER PEBBLE CREEK SUBWATERSHED: 2005 AND 2035

Land Use	2005						2035					
	Area (acres)	Sediment (pounds)	Phosphorus (pounds)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)	Area (acres)	Sediment (pounds)	Phosphorus (pounds)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)
Residential	1,428	132,016	437.6	34.6	241.9	1.3	1,957	174,308	583.1	44.3	310.5	1.6
Commercial	29	22,736	34.8	6.4	43.2	0.3	46	36,064	55.2	10.1	68.5	0.4
Industrial	0	0	0.0	0.0	0.0	0.0	0	0	0.0	0.0	0.0	0.0
Communications, Transportation, and Utilities	507	54,765	55.8	119.3	427.4	5.0	567	62,370	62.4	136.1	487.6	5.7
Governmental	132	67,452	178.2	9.2	105.6	0.0	195	99,645	263.3	13.7	156.0	0.0
Recreational	53	1,272	14.3	- -	- -	- -	174	4,176	46.9	- -	- -	- -
Open Lands	240	2,280	26.4	- -	- -	- -	17	161	1.9	- -	- -	- -
Water	8	1,504	1.0	- -	- -	- -	8	1,504	1.0	- -	- -	- -
Wetlands	214	792	8.6	- -	- -	- -	214	792	8.6	- -	- -	- -
Woodlands	140	518	5.6	- -	- -	- -	140	518	5.6	- -	- -	- -
Agricultural	805	362,250	692.3	- -	- -	- -	238	107,100	204.7	- -	- -	- -
Total	3,556	645,585	1,454.6	169.5	818.2	6.6	3,556	486,638	1,232.7	204.1	1,022.6	7.7

Source: SEWRPC.

Table 22

ESTIMATED NONPOINT SOURCE POLLUTANT LOADS IN THE LOWER PEBBLE CREEK SUBWATERSHED: 2005 AND 2035

Land Use	2005						2035					
	Area (acres)	Sediment (pounds)	Phosphorus (pounds)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)	Area (acres)	Sediment (pounds)	Phosphorus (pounds)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)
Residential	634	29,429	141.6	4.2	33.9	0.0	894	36,512	195.4	4.7	39.7	0.0
Commercial	23	18,032	27.6	5.1	34.3	0.2	26	20,384	31.2	5.7	38.7	0.3
Industrial	76	57,152	88.9	16.7	113.2	0.8	83	62,416	97.1	18.3	123.7	0.8
Communications, Transportation, and Utilities	215	21,740	23.6	47.0	168.6	1.9	277	30,470	30.5	66.5	238.2	2.8
Governmental	7	3,577	9.5	0.5	5.6	0.0	26	13,286	35.1	1.8	20.8	0.0
Recreational	178	4,272	48.0	- -	- -	- -	223	5,352	60.2	- -	- -	- -
Open Lands	116	1,102	12.8	- -	- -	- -	37	352	4.1	- -	- -	- -
Water	6	1,128	0.8	- -	- -	- -	6	1,128	0.8	- -	- -	- -
Wetlands	358	1,325	14.3	- -	- -	- -	341	1,261	13.6	- -	- -	- -
Woodlands	89	329	3.6	- -	- -	- -	89	329	3.6	- -	- -	- -
Agricultural	424	190,800	364.6	- -	- -	- -	124	55,800	106.6	- -	- -	- -
Total	2,126	328,886	735.3	73.5	355.6	2.9	2,126	227,290	578.2	97.0	461.1	3.9

Source: SEWRPC.

land use conditions, which load is forecast to decrease to about 115 tons of sediment under year 2035 land use conditions. Of the likely annual sediment loads, it is estimated that agricultural lands currently contribute more than one-half of the sediment load from each of the subbasins, with agricultural lands contributing almost 95 percent of the sediment load from the Brandy Brook subwatershed under year 2005 land use conditions. Under forecast year 2035 conditions, it is estimated that, in the absence of further controls, agricultural lands would generate about 90 percent of the sediment load from the Brandy Brook subwatershed, but that such lands will generate only about one-quarter of the sediment load in both the Upper and Lower Pebble Creek subwatersheds as agricultural lands are converted to urban uses. Because of the likely implementation of additional controls on sediment generated by rural and urban lands and by construction sites, it would be expected that the actual loads delivered to the streams of the study area would be lower than those cited above.

Urban Heavy Metals Loadings

Urbanization brings with it increased use of metals and other materials that contribute to the pollution of aquatic systems.[28] Tables 20, 21, and 22 set forth the estimated loadings of copper, zinc, and cadmium likely to be generated by urban development in the Pebble Creek watershed, in the absence of controls, under both existing year 2005 and forecast year 2035 land use conditions,. It should be noted that the majority of these metals become associated with sediment particles,[29] and are likely to be encapsulated into the bottom sediments of the stream system. Under year 2005 land use conditions, about 70 pounds of copper and 3 pounds of cadmium are estimated to be generated annually by urban lands in the Brandy Brook subwatershed and similar loads are estimated for the Lower Pebble Creek subwatershed. Also under year 2005 conditions, about 270 and 360 pounds of zinc are estimated to be generated annually by urban lands in the Brandy Brook and Lower Pebble Creek subwatersheds, respectively. About 170 pounds of copper, 7 pounds of cadmium, and 820 pounds of zinc are estimated to be generated in the Upper Pebble Creek subwatershed under year 2005 land use conditions. Under year 2035 land use conditions, the copper, cadmium, and zinc loads generated in the Brandy Brook subwatershed are expected to increase to about 107, 4, and 420 pounds, respectively; the copper, cadmium, and zinc loads generated in the Lower Pebble Creek subwatershed are expected to increase to about 100, 4, and 460 pounds, respectively; and the copper, cadmium, and zinc loads generated in the Upper Pebble Creek subwatershed are expected to increase to about 200, 8, and 1,020 pounds, respectively. In each case, these increases are related to the increase in urban lands expected within the subwatersheds under year 2035 land use conditions. Because of the likely implementation of additional controls on heavy metals generated by urban lands, it would be expected that the actual loads delivered to the streams of the study area would be lower than those cited above.

However without significant mitigation, the ongoing urbanization of the Pebble Creek watershed is likely to contribute to further water quality degradation, limiting fisheries opportunities and reducing aesthetic enjoyment. The shift in land use from agricultural uses to urban residential uses introduces new contaminants such as heavy metals, which can further modify the aquatic habitat in the absence of mitigation (see the “Riparian Corridor Conditions” section below; also see Chapter III, which sets forth current requirements for stormwater management in Wisconsin).

RIPARIAN CORRIDOR CONDITIONS

The provision of buffer strips along waterways represents an important intervention that addresses anthropogenic sources of contaminants, with even relatively small buffer strips providing a degree of environmental benefit, as suggested in Table 23 and Figure 30.[30] The Wisconsin Buffer Initiative (WBI) further developed two key

[28] *Jeffrey A. Thornton, et al.,* op. cit.

[29] *Werner Stumm and James J. Morgan,* op. cit.

[30] *Data were drawn from 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.*

Table 23

EFFECT OF BUFFER WIDTH ON CONTAMINANT REMOVAL

Buffer Width Categories (feet)	Contaminant Removal (percent)[a]				
	Sediment	Total Suspended Sediment	Nitrogen	Phosphorus	Nitrate-Nitrogen
1.5 to 25					
Mean	75	66	55	48	27
Range	37-91	31-87	0-95	2-99	0-68
Number of Studies	7	4	7	10	5
25 to 50					
Mean	78	65	48	49	23
Range	- -	27-95	7-96	6-99	4-46
Number of Studies	1	6	10	10	4
50 to 75					
Mean	51	- -	79	49	60
Range	45-90	- -	62-97	0-99	- -
Number of Studies	5	- -	2	2	1
Greater than 75					
Mean	89	73	80	75	62
Range	55-99	23-97	31-99	29-99	- -
Number of Studies	6	9	8	7	1

[a]*The percent contaminant reductions in this table are limited to surface runoff concentrations.*

Source: University of Rhode Island Sea Grant Program.

concepts that are relevant to this plan: 1) riparian buffers are very effective in protecting water resources, and 2) riparian buffers need to be a part of a larger conservation system to be most effective.[31] However, it is important to note that the WBI limited its assessment and recommendations solely to the protection of water quality, and did not consider the additional values and benefits of riparian buffers such as flood control, prevention of channel erosion, provision of fish and wildlife habitat, enhancement of environmental corridors, and water temperature moderation, among others. Research clearly shows that riparian buffers can have many potential benefits;[32] however, the nature of the benefits and the extent to which the benefits are achieved is very site-specific. Consequently, the ranges in buffer width for each of the buffer functions shown in Figure 30 are large. For example, Figure 30 shows that, based upon a number of studies of sediment removal, buffer widths ranged from about 25 to nearly 200 feet to achieve removal efficiencies of between 33 and 92 percent, depending upon local site differences. Figure 30 also shows that for any particular buffer width, for example 75 feet, the buffer can provide multiple benefits, ranging from water temperature moderation to enhancement of wildlife species diversity, as well as other benefits not shown in the figure, such as bank stabilization, which is an important concept in utilizing buffers for habitat protection.

Riparian buffer strips provide both physical protection of streamcourses, as a result of their function in intercepting sediment and other contaminants mobilized from the land surface as a result of natural and anthropogenic activities, and biological benefit, as a result of the habitat available within the shoreland and littoral

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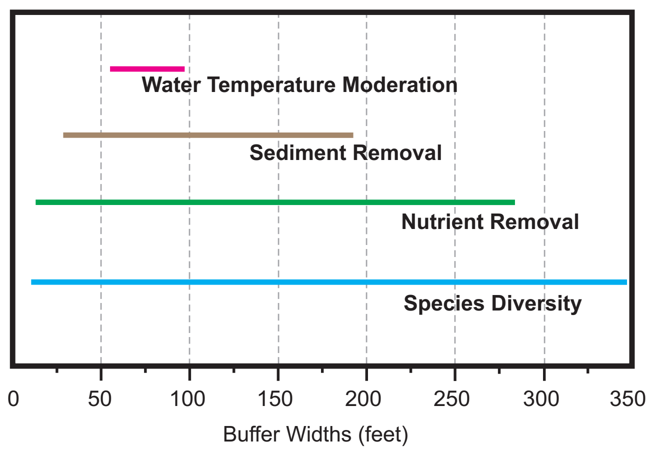
[31]*University of Wisconsin-Madison, College of Agricultural and Life Sciences,* The Wisconsin Buffer Initiative*, December 2005.*

[32]*See A. Desbonnet, P. Pogue, V. Lee, and N. Wolff,* op. cit.

Figure 30

RANGE OF BUFFER WIDTHS FOR PROVIDING SPECIFIC BUFFER FUNCTIONS



NOTE: Site-specific evaluations are required to determine the need for buffers and specific buffer characteristics.

Source: Adapted from A. J. Castelle and others, "Wetland and Stream Buffer Size Requirements-A Review," Journal of Environmental Quality*, Vol. 23.*

areas associated with the stream.[33] These characteristics are discussed more fully below, with particular reference to the Pebble Creek watershed.

Physical Characteristics

Maps 31, 32, and 33 show the current status of riparian buffers along Pebble Creek and its major tributary streams. Buffers are characterized into the following width categories: 0 to 10 feet, 10 to 25 feet, 25 to 50 feet, 50 to 75 feet, and greater than 75 feet. Buffers greater than 75 feet in width were the most common category, accounting for about 56 percent of the bank lengths in Upper Pebble Creek, 63 percent in Brandy Brook, and 85 percent in the Lower Pebble Creek subwatershed (Figure 31). This indicates that the majority of Pebble Creek, or about 65 percent, is currently meeting a minimum 75-foot buffer width. Among the categories less than 75 feet in width, the 0 to 10 feet, 10 to 25 feet, 25 to 50 feet, and 50 to 75 feet width categories comprise 10.3, 11.2, 9.2, and 2.9 percent, respectively, of the bank lengths inventoried in Pebble Creek. All of the buffers in the categories less than 50 feet in width are generally found within both Upper Pebble Creek and Brandy Brook, which indicates that these streams contain the greatest opportunities for increased buffer protection. These opportunities in Upper Pebble Creek, however, are limited by the presence in this stream of enclosed conduits, which comprise approximately one mile of the Pebble Creek stream system.

As previously discussed in Chapter III of this report, the Waukesha-Genesee Farm Drainage District No. 1 is required, pursuant to Chapter ATCP 48 of the *Wisconsin Administrative Code*, to establish and maintain a minimum 20-foot-wide riparian buffer corridor around every district drain to protect water quality from land use impacts. In addition, wider corridors must be established to permit vehicle access and to further protect water quality where appropriate. The extent and distribution of riparian corridors within the Drainage District boundary indicate that nearly 30 percent of the stream network within this boundary is comprised of lands with buffers of less than 25 feet in width, as shown on Map 34. The length of buffers in that category approximates the amount of riparian buffers that do not meet the 20 feet minimum corridor requirement defined in section ATCP 48.24. Figure 32 is an example of a limited buffer of less than 10 feet in width that includes an access road between the stream and the farm field. Approximately 20 percent of the riparian buffers within the Drainage District contain buffers of less than 10 feet in width. While the majority of the riparian buffers are meeting the requirements of the 20-foot-wide minimum buffer width, the lands within the Drainage District present opportunities for buffer enhancement.

Biological Characteristics

While there are a number of high-quality wetland, upland, and woodland areas—in terms of size, habitat, and species diversity—distributed throughout Pebble Creek, the majority of the riparian areas adjacent to the mainstem and tributaries of Pebble Creek contain a high proportion of exotic invasive species. Within open

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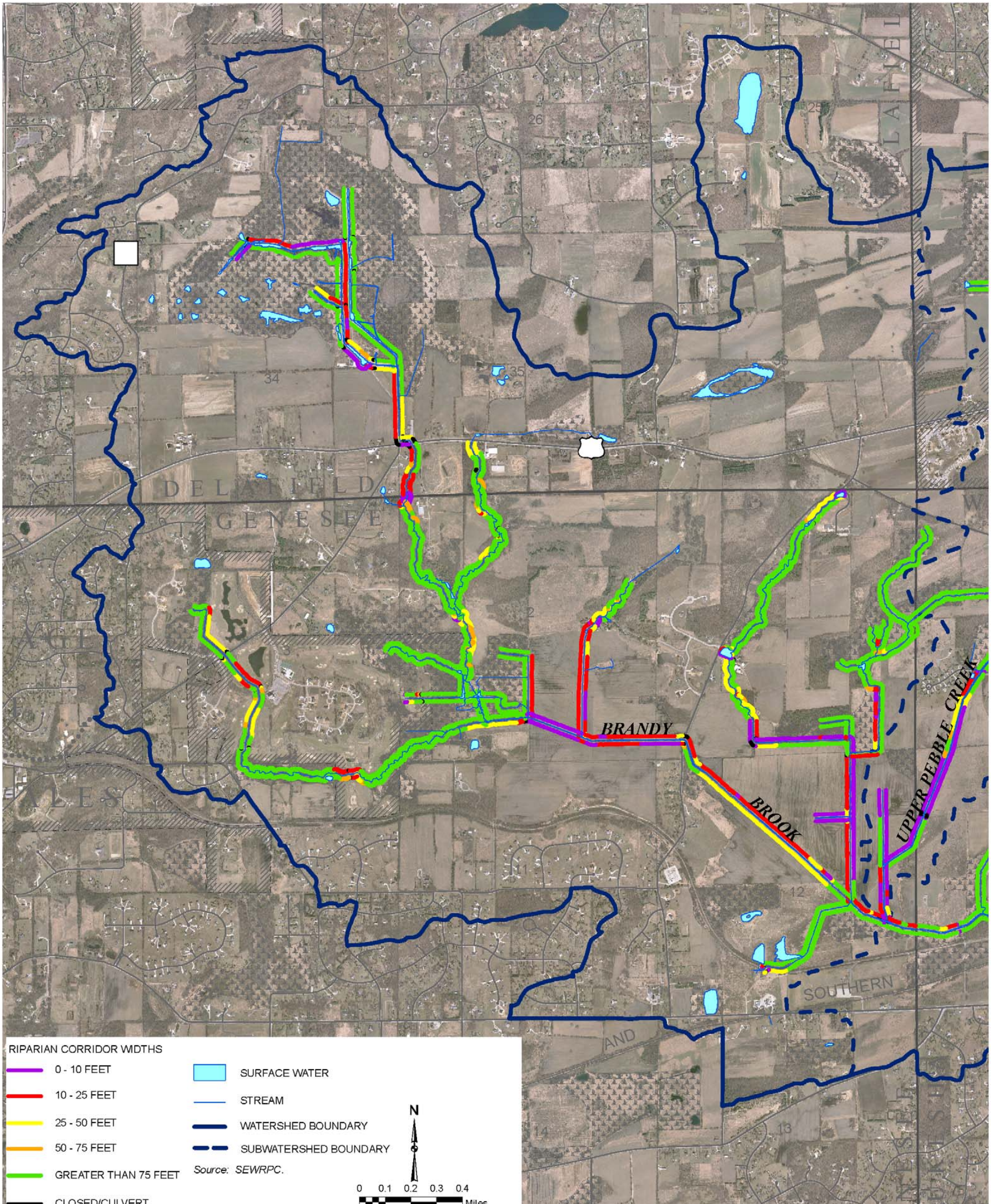
[33]*See, for example, Brian M. Weigel, Edward E. Emmons, Jana S. Stewart, and Roger Bannerman, " Buffer Width and Continuity for Preserving Stream Health in Agricultural Landscapes,"* Wisconsin Department of Natural Resources Research and Management Findings*, Issue 56, December 2005.*

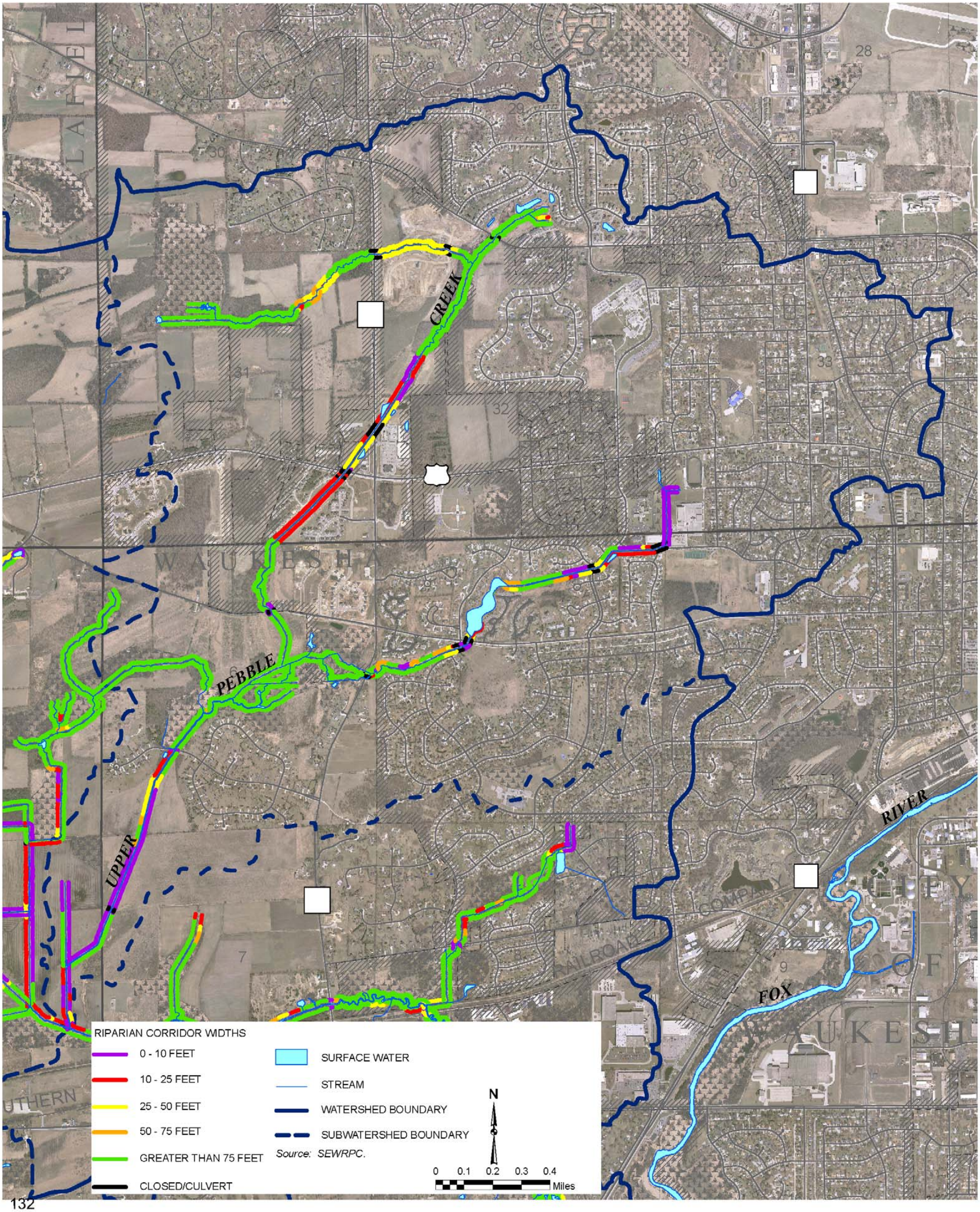
Map 31

RIPARIAN CORRIDORS WITHIN THE BRANDY BROOK SUBWATERSHED: 2005



Map 32

RIPARIAN CORRIDORS WITHIN THE UPPER PEBBLE CREEK SUBWATERSHED: 2005



Map 33

RIPARIAN CORRIDORS WITHIN THE LOWER PEBBLE CREEK SUBWATERSHED: 2005

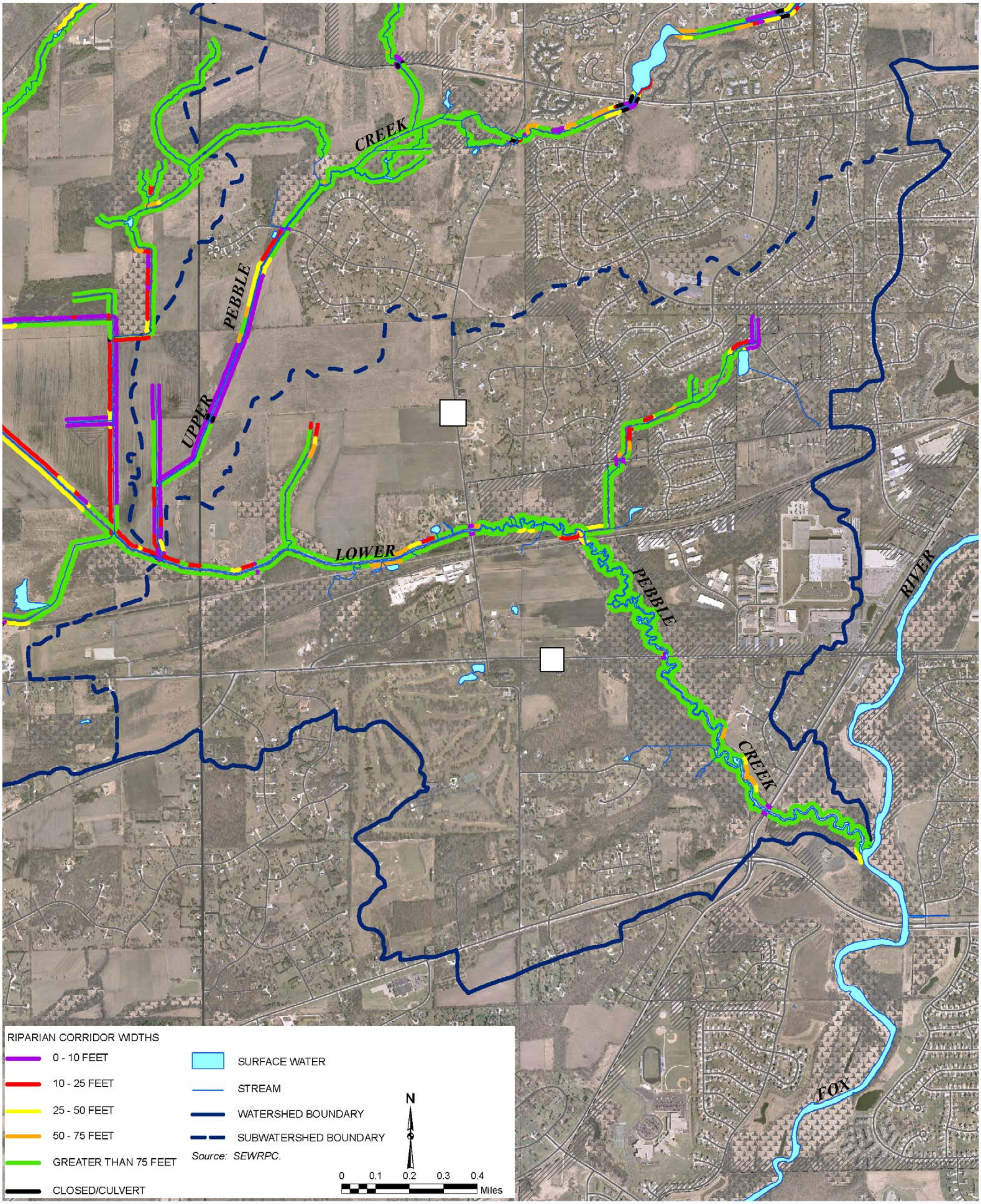
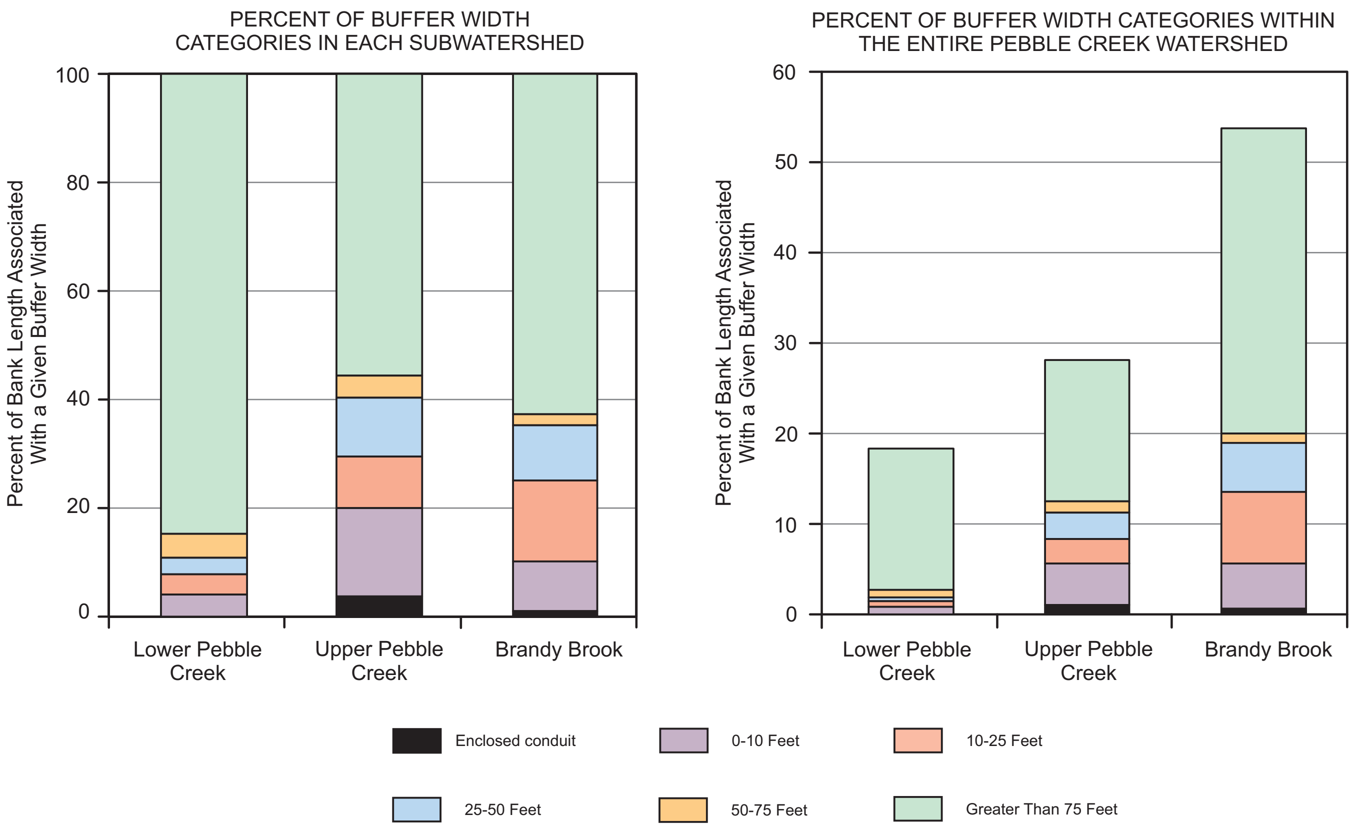


Figure 31

RIPARIAN CORRIDOR BUFFER WIDTHS IN STREAMS WITHIN THE PEBBLE CREEK WATERSHED: 2005



Source: SEWRPC.

canopy areas along the streams and tributaries, reed canary grass was observed to dominate the riparian vegetation, as shown in Figure 33. Purple loosestrife was generally found only within the lower stream reaches of the watershed, and flowering rush was found near the CTH X road crossing. Within the wooded areas along the streams and tributaries, both garlic mustard and European buckthorn were noted to be abundant. Consequently, management measures are required to restore the ecological integrity of the riparian corridor. Nevertheless, although this vegetation is invasive, it still provides some bank stability, shading, and, in some cases, instream cover for fish and macroinvertebrates. Thus, restoration measures should be implemented in such a manner as to preserve these functions while replacing nonnative vegetation with appropriate native species.

Environmental Corridors

As discussed in Chapter II of this report, there are both primary and secondary environmental corridors distributed throughout the Pebble Creek watershed. These corridors have been established as a valuable conservation tool that provides connectivity among landscapes to improve the viability of wildlife populations within the habitats comprising the corridors.[34] The Pebble Creek watershed has three main clusters of Primary Environmental Corridor (PEC) lands, four segments of Secondary Environmental Corridor (SEC), and a variety of isolated natural resources areas distributed throughout the watershed, as shown in Map 35. The SEC segments designated SEC1, SEC2, and SEC4 provide critical links for wildlife between the three main larger and higher quality PEC

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[34]*Paul Beier and Reed F. Noss, "Do Habitat Corridors Provide Connectivity?,"* Conservation Biology*, Vol. 12, No. 6, December 1998.*

Map 34

DRAINAGE DISTRICT JURISDICTIONAL AREA WITHIN THE PEBBLE CREEK WATERSHED: 2000

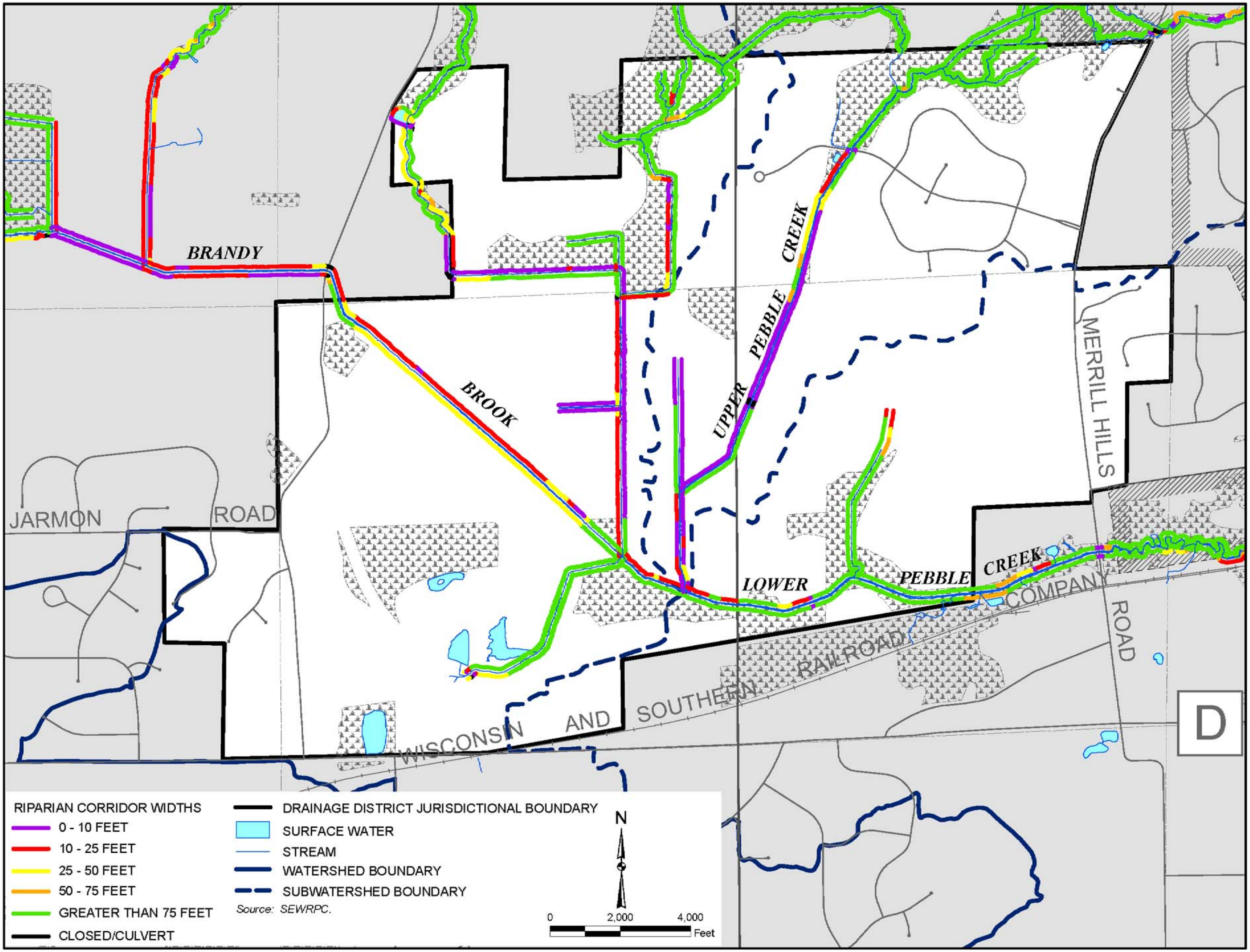

Figure 32

EXAMPLE OF RIPARIAN BUFFER WIDTH WITHIN THE WAUKESHA-GENESEE FARM DRAINAGE DISTRICT NO. 1: 2004

Source: SEWRPC.

clusters designated PEC1, PEC2, and PEC3. However, as shown on Maps 31, 32, 33 and 35, the SEC are dominated by riparian buffers of less than 75 feet in width, with such buffers ranging from about 73 to 96 percent of the streambank length within SEC1, SEC2, and SEC4. Those sections of narrower buffer represent key areas with the greatest opportunities for enhancement of both aquatic and terrestrial ecosystems within the Pebble Creek watershed. Analysis of the extent and distribution of the riparian corridors within each of the PEC clusters indicates that about 10 to 30 percent of the stream networks among these clusters are comprised of buffers of less than 75 feet in width, as shown in Maps 31, 32, 33 and 35. These areas also provide opportunities for enhancement. Connecting the multiple isolated natural resource areas throughout the Pebble Creek watershed to the larger PEC and SEC areas is an opportunity to enhance the corridor system and wildlife areas within this basin.

It is important to note that there are a few isolated patches of recreational land distributed throughout the Pebble Creek watershed as shown on Map 35, including both the Retzer Nature Center and Glacial Drumlin Trail. The Retzer Nature Center is located within a portion of PEC2 and the Glacial Drumlin Trail is located within PEC3. Therefore, there is an opportunity to enhance recreational and ecological values within the watershed by connecting the Nature Center and the Trail along the riverine corridors between them. This also means that the Waukesha-Genesee Farm Drainage District No. 1 forms a critical link between the environmental corridor networks as shown on Maps 34 and 35.

BIOLOGICAL CONDITIONS

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 important determinants of the overall quality of the environment in the Pebble Creek watershed.

Fisheries

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 (Figure 34). Intolerant species (species that are particularly sensitive to water pollution and habitat degradation) are also common in high-quality warmwater systems.[35] Tolerant fish species (species that are capable of persisting under a wide range of degraded conditions) are 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

[35]*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.*

Figure 33

EXOTIC INVASIVE RIPARIAN VEGETATION IN THE PEBBLE CREEK WATERSHED: 2004

Source: SEWRPC.

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.

Review of the fishery data collected in Pebble Creek between 1973 and 2004-2005 indicates an apparent gain of 26 species since 1973 as shown in Table 24. Two species, the bigmouth shiner and rosyface shiner, which is a species intolerant to pollution, have not been observed in this watershed since 1973.[36] Most notable were gains in species intolerant to pollution such as the rock bass, spottail shiner, blacknose shiner, mimic shiner, and weed shiner, the latter being a species of special concern in the State of Wisconsin. The longear sunfish is a designated

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[36]*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; Wisconsin Department of Natural Resources, Publication No. PUBL-WR-366-94,* Nonpoint Source Control Plan for the Upper Fox River Priority Watershed Project*, June 1994; and Wisconsin Department of Natural Resources,* Water Resource Appraisal Report and Stream Classification for the Upper Fox River Priority Watershed*, Upper Fox River Basin, 1990.*

Map 35

ENVIRONMENTAL CORRIDORS AND RIPARIAN CORRIDORS WITHIN THE PEBBLE CREEK WATERSHED: 2000

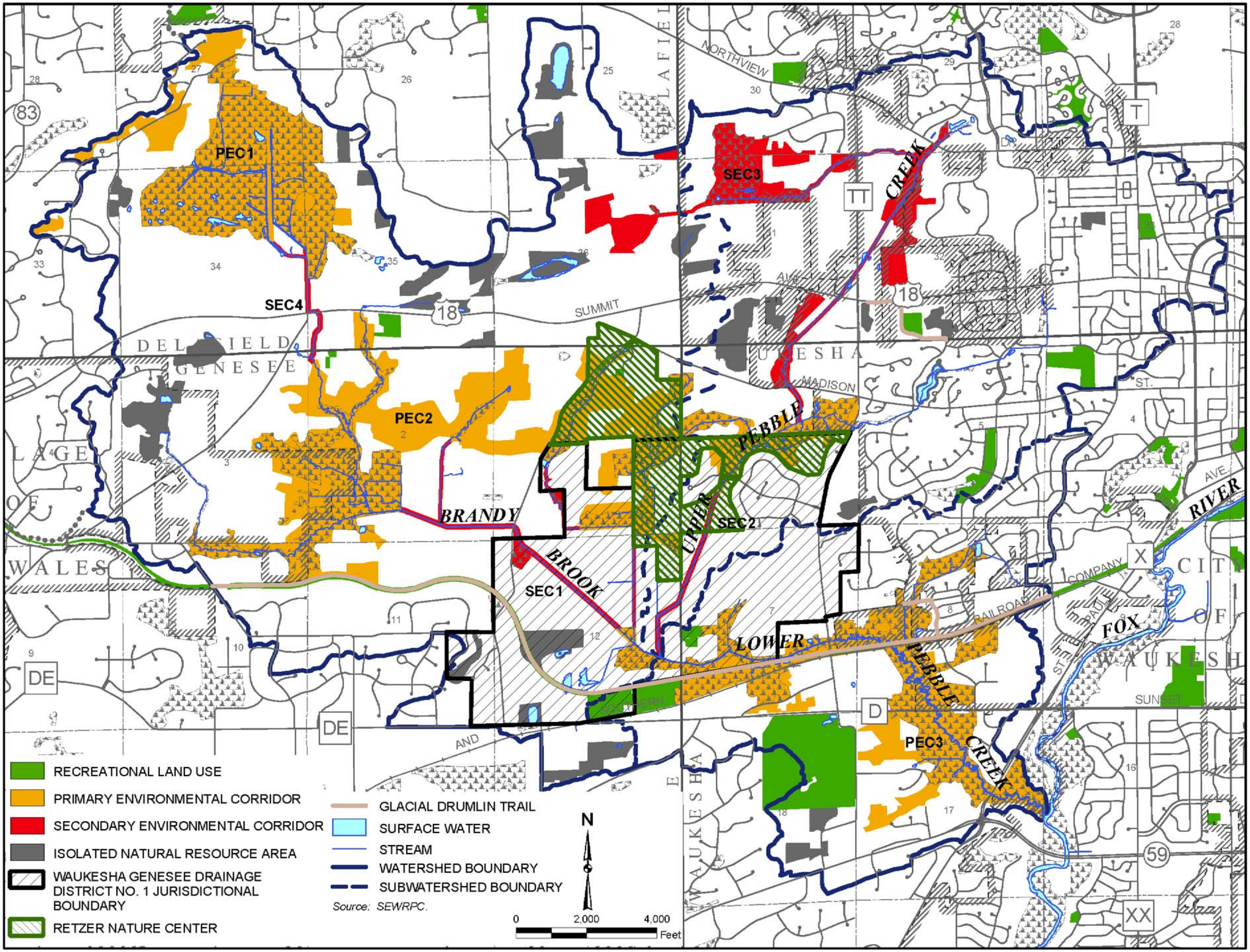

Figure 34

NATIVE FISH SPECIES WITHIN THE PEBBLE CREEK WATERSHED: 2004-2005

Source: SEWRPC.

threatened species in the State of the Wisconsin and was also found within both Pebble Creek and the Fox River, where it had never been recorded previously (see Figure 13 in Chapter II of this report). The only other known longear sunfish population to exist within the Fox River basin (within the State of Wisconsin) is in the Mukwonago River subwatershed, which is approximately nine miles downstream of the Pebble Creek watershed. Twelve additional species that have never been recorded within Pebble Creek include the blackstripe topminnow, bowfin, brook silverside, golden shiner, longnose dace, sand shiner, and spotfin shiner as well as panfish and gamefish species including black crappie, orangespotted sunfish, black bullhead, grass pickerel, and brown trout. Approximately 1,800-3,600 brown trout fingerlings ranging from three to six inches in length were stocked annually into Pebble Creek at the CTH TT Bridge from 2001 to 2005. Pebble Creek was considered a good candidate for stocking the coldwater brown trout, based upon the presence of the mottled sculpin, a coldwater indicator species.[37] Adult brown trout were observed in Pebble Creek, but there is no evidence that this species is successfully reproducing in this system. The tolerant common carp species, which is considered a potential threatening invader, was also observed for the first time in 2004-2005, but this exotic species was not a dominant component of the fishery.

The gain of more than two dozen species during the period from 1973 through 2004-2005 appears to be due, in large part, to an increased sampling effort as opposed to any significant increase in water quality or fishery abundance and diversity changes. The increased sampling program was conducted by the SEWRPC and Waukesha County staffs and Dr. Michael Pauers of the University of Wisconsin-Milwaukee to collect data for the

[37]*Personal communications with Sue Beyler, Fisheries Biologist, WDNR.*

Table 24

FISH SPECIES COMPOSITION IN THE PEBBLE CREEK WATERSHED: 1973-2005

Species According to Their Relative Tolerance to Temperature	Year					
	1973	1978	1990	1995	1999	2004-2005
Primary Coldwater						
Brown Trout[a]	- -	- -	- -	- -	- -	X
Mottled Sculpin[b]	- -	X	X	X	X	X
Secondary Coolwater						
Blacknose Dace[c]	X	X	X	X	- -	X
Brook Stickleback[c]	X	X	X	X	X	X
Central Mudminnow[c]	X	X	X	- -	X	X
Fathead Minnow	X	X	- -	X	X	X
Johnny Darter	X	X	X	X	X	X
Northern Pike	- -	- -	X	X	- -	X
Rock Bass[b]	- -	- -	- -	- -	- -	X
Spottail Shiner[b]	- -	- -	- -	- -	- -	X
White Sucker[c]	X	X	X	X	X	X
Warmwater						
Bigmouth Shiner	X	- -	- -	- -	- -	- -
Black Bullhead[c]	- -	- -	- -	- -	- -	X
Black Crappie	- -	- -	- -	- -	- -	X
Blacknose Shiner[b]	- -	- -	- -	X	- -	X
Blackside Darter	- -	- -	- -	- -	X	- -
Blackstripe Topminnow	- -	- -	- -	- -	- -	X
Bluegill	- -	- -	X	X	X	X
Bluntnose Minnow[c]	X	- -	X	X	- -	X
Bowfin	- -	- -	- -	- -	- -	X
Brook Silverside	- -	- -	- -	- -	- -	X
Common Carp[c]	- -	- -	- -	- -	- -	X
Central Stoneroller	- -	X	X	- -	X	X
Channel Catfish	- -	- -	- -	X	- -	X
Common Shiner	X	X	X	X	X	X
Creek Chub[c]	X	X	X	X	X	X
Golden Shiner[c]	- -	- -	- -	- -	- -	X
Grass Pickerel	- -	- -	- -	- -	- -	X
Green Sunfish[c]	- -	- -	- -	X	X	X
Hornyhead Chub	X	- -	X	X	- -	- -
Largemouth Bass	- -	- -	X	X	- -	X
Largescale Stoneroller	- -	- -	- -	X	- -	- -
Longear Sunfish[d]	- -	- -	- -	- -	- -	X
Longnose Dace	- -	- -	- -	- -	- -	X
Mimic Shiner[b]	- -	- -	- -	- -	- -	X
Orangespotted Sunfish	- -	- -	- -	- -	- -	X
Pumpkinseed	- -	X	X	X	- -	X
Rosyface Shiner[b]	X	- -	- -	- -	- -	- -
Sand Shiner	- -	- -	- -	- -	- -	X
Spotfin Shiner	- -	- -	- -	- -	- -	X
Smallmouth Bass	- -	- -	X	- -	- -	- -
Weed Shiner[b,e]	- -	- -	- -	- -	- -	X
Total Number of Species	12	11	16	19	12	36
Total Number of Samples	1	1	9	2	2	20

[a]*This species is stocked by Wisconsin Department of Natural Resources fisheries management staff.*

[b]*This species is classified as intolerant to pollution.*

[c]*This species is classified as tolerant of pollution.*

[d]*Designated threatened species.*

[e]*Designated species of special concern.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Pebble Creek watershed protection plan. For example, the 2004-2005 time period contained about two to 20 times the number of recorded total samples compared to all of the other time periods. In addition, most of the new species occurrences were found in the lower reaches of Pebble Creek (see stream reach LP-1 and LP-2 in Table 25 and Map 36), which had previously never been sampled. These lowest reaches are in close proximity and contain a good connection with the Fox River, and also contain the most diverse habitat areas (see the "Stream Channel Conditions and Structures" section above) within the Pebble Creek watershed.

Table 25 also shows that the farthest downstream reach of Pebble Creek, LP-1, shares a high proportion of the same species, approximately 80 percent, as the Fox River samples based upon the 2004-2005 surveys downstream and upstream of the confluence of Pebble Creek with the Fox River (see Map 36). Although the surveys summarized in Table 24 only used seines within these areas, which limits the ability to catch large adult gamefish species, Pebble Creek was found to contain a fish community as diverse as the Fox River at the sampling locations. This result is also consistent with results of electrofishing surveys conducted in the early 1990s by WDNR staff as part of the Water Resource Appraisal and Stream Classification for the Upper Fox River Priority Watershed, which indicated that samples from the mainstem of Pebble Creek contained, on average, a similar fishery quality as in the Upper Fox River watershed. However, two significant fish species that include the banded killifish, which is a species of special concern in the State of Wisconsin, and the starhead topminnow, which is an endangered species in the State of Wisconsin, were found within the Fox River watershed and not within Pebble Creek. Both of these species are new records within this portion of the Upper Fox River watershed and, given their proximity to the confluence with Pebble Creek, it is very likely that one or both of these species may utilize areas within the lower reach of Pebble Creek.

Pebble Creek contains a variety of both warmwater (maximum daily mean temperature greater than 24ºC) and coldwater (maximum daily mean temperature less than 22ºC) stream reaches (see the "Water Temperature" subsection above).[38] 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 is 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 Index of Biotic Integrity (IBI) was developed to assess the health of coldwater streams.[39] 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 (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. However, since there are no brook trout within the Pebble Creek watershed, only the warmwater IBI was used to assess the fishery among warmwater and coldwater reaches in the analyses of the fisheries abundance and distribution within the Pebble Creek watershed that are presented below.

IBI results are consistent with the species abundances shown in Table 25, which indicate that the quality of the fishery of the Pebble Creek watershed ranges from very poor (IBI score 0-20) in reaches with a low number of species to good community IBI rating score of 50 to 64 in reaches with a higher number of species. Mean IBI scores from sites within the lower reaches of Pebble Creek (LP-1, LP-2, and LP-3) were the highest quality scores

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[38]*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.*

[39]*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 25

FISH SPECIES COMPOSITION BY PHYSIOLOGICAL TOLERANCE AND REACH IN THE PEBBLE CREEK WATERSHED: 1999-2005

Species According to Their Relative Tolerance to Temperature	Stream Reach (see Map 19)						
	BB-1	UP-2	UP-1	LP-3	LP-2	LP-1	Fox River
Primary Coldwater							
Brown Trout[a]	- -	- -	- -	X	- -	- -	- -
Mottled Sculpin[b]	X	- -	X	X	X	X	- -
Secondary Coolwater							
Blacknose Dace[c]	- -	- -	- -	X	- -	- -	- -
Brook Stickleback[c]	X	X	X	X	X	X	X
Central Mudminnow[c]	X	X	X	X	X	X	- -
Emerald Shiner	- -	- -	- -	- -	- -	- -	X
Johnny Darter	X	- -	X	X	X	X	X
Longnose Dace	- -	- -	X	- -	- -	- -	- -
Northern Pike	- -	- -	- -	- -	X	X	X[d]
Rock Bass[b]	- -	- -	- -	- -	X	X	X
Spottail Shiner[b]	- -	- -	- -	- -	- -	X	X
White Sucker[c]	X	- -	X	X	X	X	X
Warmwater							
Banded Killifish[e]	- -	- -	- -	- -	- -	- -	X
Black Bullhead[c]	- -	- -	- -	- -	X	- -	X[d]
Black Crappie	- -	- -	- -	- -	- -	X	X
Blacknose Shiner[b]	- -	- -	- -	- -	- -	X	- -
Blackside Darter	X	- -	- -	- -	- -	- -	- -
Blackstripe Topminnow	- -	- -	- -	X	- -	X	X
Bluegill	X	- -	X	X	X	X	X
Bluntnose Minnow[c]	- -	- -	- -	X	X	X	X
Bowfin	- -	- -	- -	- -	- -	X	X[d]
Brook Silverside	- -	- -	- -	X	- -	X	X
Common Carp[c]	- -	- -	- -	- -	- -	X	X
Central Stoneroller	X	- -	- -	- -	X	- -	- -
Channel Catfish	- -	- -	- -	- -	- -	X	X[d]
Common Shiner	X	X	X	X	X	X	X
Creek Chub[c]	X	X	X	X	X	- -	- -
Golden Shiner[c]	X	- -	- -	X	X	X	X
Grass Pickerel	- -	- -	- -	- -	X	- -	X
Green Sunfish[c]	X	- -	X	X	X	X	X
Largemouth Bass	- -	- -	X	X	X	X	X
Longear Sunfish[f]	- -	- -	- -	X	- -	X	X
Mimic Shiner[b]	- -	- -	- -	- -	- -	X	- -
Orangespotted Sunfish	- -	- -	- -	- -	- -	X	X
Pumpkinseed	X	- -	- -	X	- -	X	X
Sand Shiner	- -	- -	- -	X	X	X	X
Spotfin Shiner	- -	- -	- -	X	X	X	X
Starhead Topminnow[e]	- -	- -	- -	- -	- -	- -	X
Tadpole Madtom	- -	- -	- -	- -	- -	- -	X
Weed Shiner[b,e]	- -	- -	- -	- -	- -	X	- -
Total Number of Species	14	5	11	21	20	29	29
Total Number of Samples	6	1	4	4	2	5	3

[a]*This species is stocked by Wisconsin Department of Natural Resources fisheries management staff.*

[b]*This species is classified as intolerant to pollution.*

[c]*This species is classified as tolerant of pollution.*

[d]*These gamefish species were not present in these surveys due to gear limitations, but these species are known to exist in this portion of the Fox River based upon WDNR 1995 surveys and were therefore included in the species total.*

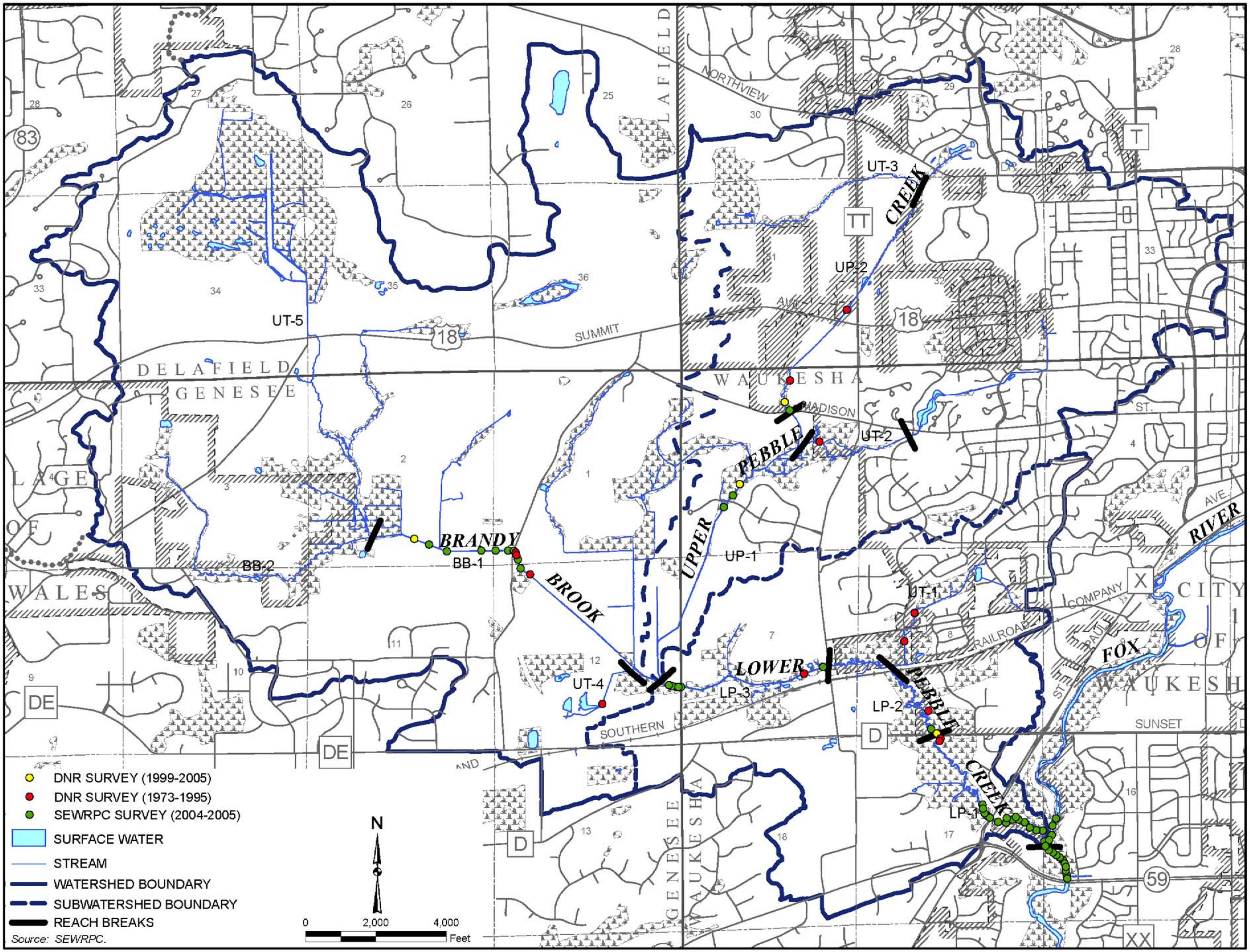
[e]*Designated species of special concern.*

[f]*Designated threatened species.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 36

FISHERIES SAMPLE LOCATIONS WITHIN THE PEBBLE CREEK WATERSHED: 1973-2005



(good) and the rest of the watershed in the upstream reaches and headwater tributaries contained very poor to fair scores. In addition to having the highest and most diverse fishery community, gamefish and panfish species dominate the lower reaches of Pebble Creek, in particular northern pike dominate within reaches LP-1 and LP-2 and brown trout are present within LP-3. These lower reaches also contained a better distribution of size classes of younger and older fish species such as largemouth bass and grass pickerel as well as a higher abundance and diversity of forage fishes (Figure 35). Mottled sculpin and other forage fishes dominate within Brandy Brook reach BB-1. The reaches UP-1 and UP-2 of Upper Pebble Creek contain the least diverse and lowest abundance of fishes compared to the entire watershed. In many cases, there were not high enough numbers of fishes caught to calculate an IBI. Upper Pebble Creek also contains the poorest water quality and habitat, lowest diversity and abundance of food (macroinvertebrates) base, the highest number of road crossings, the highest proportion of channelized stream length, the highest proportion of enclosed channels, the highest number of debris jams and trash in the channel, and the highest proportion of impacted riparian buffers in comparison to Brandy Brook and Lower Pebble Creek.

Although the fish IBI is useful for assessing environmental quality and biotic integrity in streams, it is most effective when used in combination with additional data on physical habitat, water quality, macroinvertebrates, and other biota when evaluating a site.[40] Hence, supplemental data for macroinvertebrates surveys conducted by the WDNR and WAV are summarized below.

Macroinvertebrates

The Hilsenhoff Biotic Index[41] (HBI) and the Water Action Volunteer (WAV) Biotic Index[42] were used to classify the macroinvertebrate and environmental quality in this stream system using survey data from various sampling locations in Pebble Creek.

Macroinvertebrate surveys conducted by the WDNR from 1980 through 1999 and by WAV from 2002 through 2006 show that biotic index scores generally range from fair to very good throughout Pebble Creek, as shown on Map 37. Similar to the fisheries community summary above, the quality of the macroinvertebrate community within Pebble Creek is on average much better than the adjacent main stem of the Fox River, which has some sites of fairly poor quality (see Map 37). These data also show that the streams of Brandy Brook and Lower Pebble Creek contain higher quality macroinvertebrate communities than do those of Upper Pebble Creek.

Since the WAV monitoring protocol established three stations that have been sampled consistently for five years, the data collected at those stations are potentially useful in distinguishing qualitative differences among sites within Pebble Creek. However, it is important to note that the WAV biotic index is a quality measurement of the macroinvertebrate community and this index has not been calibrated against a set of reference streams, which makes it impossible to interpret the magnitude of difference in water quality or stream health that a difference in the index reflects. Overall, the results of the WAV biotic index indicate that all three sites showed a fair value. The results of these WAV data generally support the conclusions drawn from the WDNR HBI data above, which indicate that the streams of Brandy Brook and Lower Pebble Creek showed a higher proportion of macroinvertebrate groups sensitive to pollution and a lower proportion of groups tolerant to pollution than did those of Upper Pebble Creek for all samples combined over all years from 2002 through 2006 (see Figure 36). Therefore, all supporting data generally indicate that macroinvertebrate diversity and abundances are indicative of fair to very good water quality throughout Pebble Creek, with the exception of Upper Pebble Creek.

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[40]*John Lyons,* General Technical Report NC-149, op. cit.

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

[42]*Water Action Volunteer Biotic Index Monitoring(http://clean-water.uwex.edu/wav/monitoring/biotic/index.htm)*

Figure 35

NATIVE FORAGE AND JUVENILE GAMEFISH SPECIES WITHIN THE PEBBLE CREEK WATERSHED: 2004-2005

Source: SEWRPC.

Other Wildlife

Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of this study, a list of species observed during the field visits made for this project includes: whitetail deer, beavers, raccoons, opossums, squirrels, chipmunks, rabbits, green frogs, Butler's garter snakes, Blanding's turtles, sandhill cranes, great blue herons, crows, redwinged blackbirds, chickadees, cardinals, robins, woodpeckers, swallows, blue jays, doves, ducks, turkeys, red-tailed hawks (see Figure 37), various warblers, and sparrows.

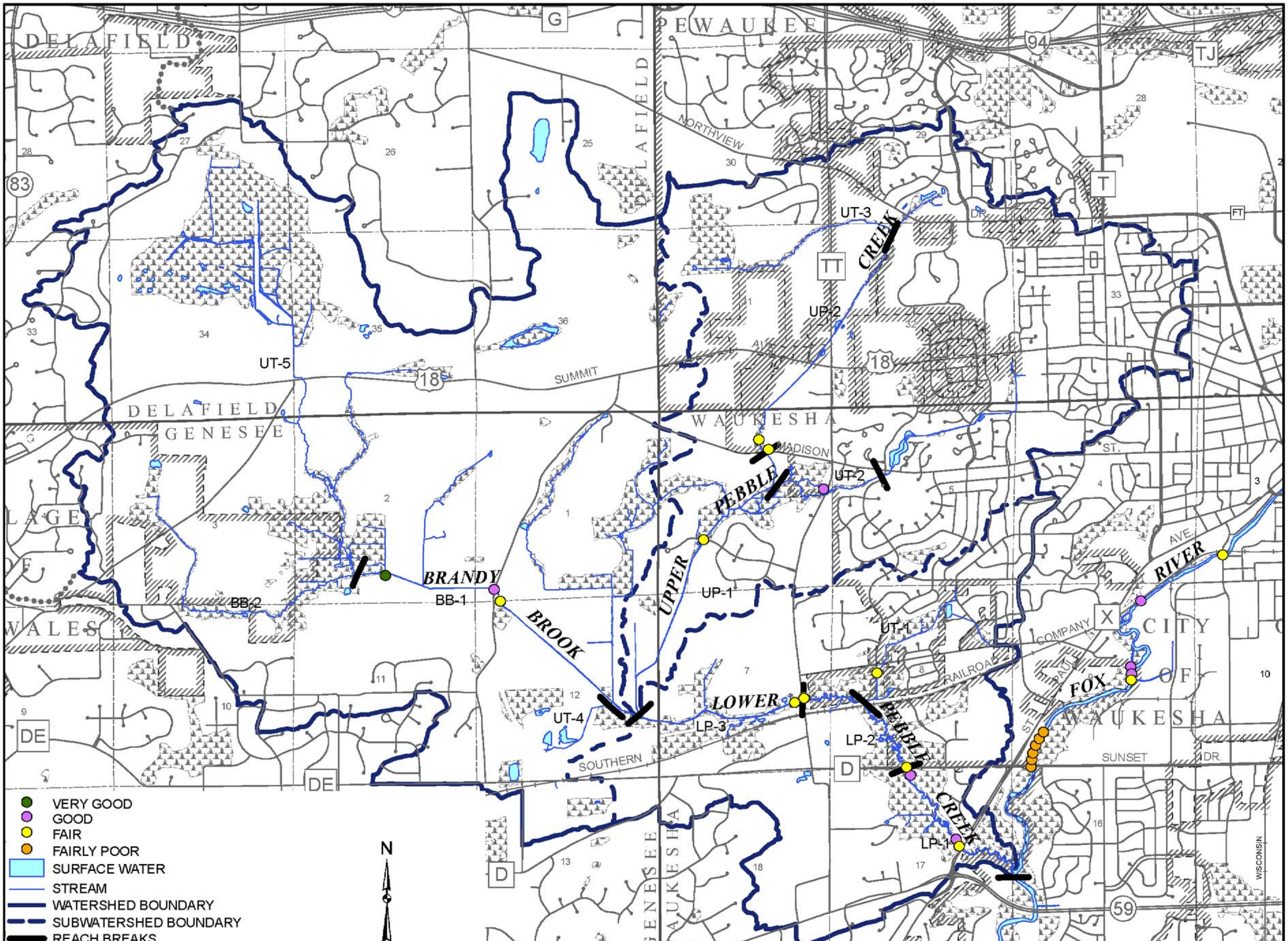
There is a game farm licensed by the WDNR in the middle of the Pebble Creek watershed near the confluence of Brandy Brook and Upper Pebble Creek (Figure 38). In addition, there is an enclosed deer farm located in the upper portion of the Brandy Brook subwatershed, as shown in Figure 39.

Exotic Invasive Species

As previously mentioned in the "Fisheries" subsection above, common carp, an exotic invasive species, has been found within the lower reaches of Pebble Creek. The only other aquatic exotic invasive species known to exist is the rusty crayfish, which was found within all portions of Pebble Creek. In terms of vegetation species, garlic mustard, buckthorn, reed canary grass, purple loosestrife, and flowering rush were found among the nonnative plants on the riparian streambanks throughout the watershed (see "Riparian Corridor Conditions" section above.)

Map 37

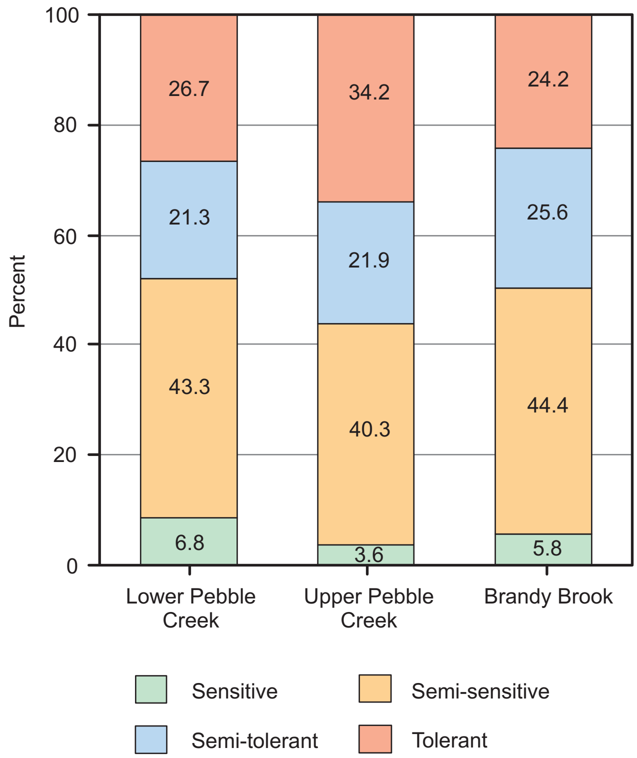
MACROINVERTEBRATE SAMPLE LOCATIONS AND CONDITIONS WITHIN THE PEBBLE CREEK WATERSHED: 1980-2006



Source: Water Action Volunteers, Wisconsin Department of Natural Resources and SEWRPC.

Figure 36

PROPORTION OF MACROINVERTEBRATES BY WATER ACTION VOLUNTEER TOLERANCE CLASSIFICATION IN THE PEBBLE CREEK WATERSHED: 2002-2006



Source: Water Action Volunteers and SEWRPC.

Figure 37

RED-TAILED HAWK EATING RABBIT IN THE PEBBLE CREEK WATERSHED: 2004

Source: SEWRPC.

Figure 38

SIGN FROM A LICENSED GAME FARM WITHIN THE PEBBLE CREEK WATERSHED: 2004

Source: SEWRPC.

Figure 39

DEER FROM A GAME FARM WITHIN THE PEBBLE CREEK WATERSHED: 2004

Source: SEWRPC.

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Chapter V

WATERSHED GOALS, OBJECTIVES, AND RECOMMENDED ACTIONS

INTRODUCTION

There are a number of issues of concern that impact the water quality and recreational use of Pebble Creek. These issues were identified in Chapters II through IV and include issues of concern related to the existing and predicted developmental changes in land use in the Pebble Creek watershed and their associated potential effects on hydrology, water quality, habitat quality, bank stability, and fisheries.

As noted in Chapter I of this report, this protection plan was prepared as part of a coordinated planning effort in cooperation with representatives from the Pebble Creek Watershed Protection Advisory Committee (see Appendix A). The advisory committee was assembled by the Waukesha County Department of Parks and Land Use, Land Resources Division (LRD) and represents the diversity of interests and perspectives that affect the watershed, including farmers, developers, and environmental groups; the LRD; the Towns of Delafield, Genesee, and Waukesha; the Village of Wales; the Cities of Pewaukee and Waukesha; the Wisconsin Department of Natural Resources (WDNR); and the U.S. Natural Resources Conservation Service (NRCS). The selection of the recommended plan elements followed an extensive review by the Advisory Committee of the technical feasibility, economic viability, environmental impacts, potential public acceptance, and practicality of the various alternative water quality management plans considered.

The recommended plan calls for the implementation of a comprehensive set of specific actions devised to ensure the enhancement and/or preservation of the surface water quality of the streams in the Pebble Creek watershed, and the preservation of the quality of the groundwater which affects the baseflow of those streams. A primary consideration in the selection of the components of the recommended plan was the degree to which those measures, functioning together as a watershed-based system, would be expected to achieve the agreed-upon water use objectives.

In this chapter, recommended management measures address the four major goals identified by the Pebble Creek Watershed Advisory Committee, which include the following:

- Protect and improve surface water and groundwater quality and aquatic life throughout the watershed.
- Control urban runoff pollution and flooding.
- Encourage the continuation of agricultural uses and control pollution from agricultural runoff.
- Educate the public about conservation issues and watershed protection.

Recommended management objectives and recommended actions to address these goals are described below. The recommendations set forth herein focus on those measures which are applicable to all of the stakeholders and agencies with jurisdiction within the Pebble Creek watershed. Units of government within the Pebble Creek watershed are specifically encouraged to adopt these recommendations and implement this protection plan through local policies, practices, programs, and ordinances where deemed appropriate.

PROTECT AND IMPROVE SURFACE WATER AND GROUNDWATER QUALITY AND AQUATIC LIFE THROUGHOUT THE WATERSHED

The most fundamental and basic element of this water quality protection plan is the land use element. The future distribution of urban and rural land uses will largely determine the character, magnitude, and distribution of nonpoint sources of pollution and ultimately, the quality of surface waters in the Pebble Creek watershed. Consequently, the selection of a land use plan for the study area is the first and most basic step in synthesizing the water quality plan. The process for developing the planned land use data that form the land use element of the plan is described in Chapter II of this report.

Land Management Measures

One of the most important tasks undertaken by the Commission as part of its regional planning effort is 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.[1] 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

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[1] *The process of delineating environmental corridors and isolated natural resource areas as areas encompassing concentrations of natural resource base features such as wetlands, woodlands, and wildlife habitat areas, along with the resulting configuration of environmental corridors and isolated natural resource areas, is described in Chapter II of SEWRPC Planning Report No. 48,* A Regional Land Use Plan for Southeastern Wisconsin: 2035, *June 2006.*

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 significant, 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 Pebble Creek watershed thus becomes apparent.

Objective
Preserve and protect environmentally sensitive areas such as designated natural areas, wetlands, fish and wildlife habitat, riparian buffers, and primary and secondary environmental corridors.

Recommended Actions

- Observe and implement the guidelines set forth in regional, county, local land use plans, and the Waukesha County land and water resource management plan, to protect environmentally sensitive lands as recommended in the regional natural areas and critical species habitat protection and management plan;[2]

- Integrate the Pebble Creek Watershed Protection Plan recommendations into regional and local level development plans including a refined comprehensive watershed management plan for the Fox River basin;[3]

- Limit development within environmental corridors and isolated natural resource areas as identified by SEWRPC and shown in Maps 11 through 13 in Chapter II of this report;

- Promote defragmentation by connecting environmental corridor and isolated natural resource areas with other larger corridors and natural areas where and when possible as recommended in the regional natural areas and critical species habitat protection and management plan as shown on Map 35 in Chapter IV of this report. Encourage expansion and connection of natural areas by means of the environmental corridor network, as shown in Maps 11 through 13;

- Maintain or establish natural vegetation in urban and rural areas, preferably using native species, within the riparian corridors along perennial, intermittent and ephemeral waterways in accordance with WDNR and NRCS technical standards for filter strips. Encourage voluntary perpetual conservation easements as needed to implement this plan. Maps 31, 32, and 33 in Chapter IV of this report show the existing buffers along perennial and intermittent streams;

- To the extent possible, eradicate and control the spread of purple loosestrife and other nonnative invasive species. Consider partnerships between communities, schools, volunteer groups and/or service organizations, and participation in the WDNR purple loosestrife beetle rearing program;

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

[3]*The Fox River watershed study is documented in SEWRPC Planning Report No. 12,* A Comprehensive Plan for the Fox River Watershed*; Volume One,* Inventory Findings and Forecasts; *Volume Two,* Alternative Plans and Recommended Plan*, February 1970. See also WDNR, Publication No. PUBL-WT-701-02,* The State of the Southeast Fox River Basin*, February 2002.*

- Upon the discontinuation of farming practices, when funding can be obtained, restore undeveloped wetlands that were previously converted to agricultural uses. Such restoration would only be accomplished in cases where the landowner chooses to participate in restoration, either through donation of land, granting easements, or selling land for restoration. Map 38 shows the location of 778 acres of prior converted wetlands that are potentially restorable. Future development is not suitable for any of these areas due to high groundwater and flooding potential and thus, should be strictly prohibited through land use regulations (see Encourage The Continuation Of Agricultural Uses And Control Pollution From Agricultural Runoff section below);

- Preserve and/or restore natural vegetation and topography along perennial, intermittent and ephemeral waterways by seeking voluntary, perpetual conservation easements on targeted lands. Targeted lands are recommended to be designated as open space areas. Lands recommended to be included within such targeted easements lie within 75 feet of each streambank or within the floodplain, whichever is greater;

- Update and implement zoning standards to ensure preservation of targeted lands including:

  — Protect and enhance wetlands through ordinance enforcement, appropriate zoning, development of setbacks and runoff management measures by requiring minimum 75-foot wetland setbacks for all proposed impervious surfaces or site grading. *(Note: To minimize basement wetness and flooding, it is also recommended to enforce minimum vertical surface water and seasonal high groundwater separation requirements, consistent with Waukesha County Storm Water Ordinance standards.)*;

  — Protect and enhance riparian wildlife habitat and improve stream water quality by requiring minimum 75-foot vegetated protective area buffers along all perennial, intermittent and ephemeral waterways.

Groundwater Protection Measures

Under the regional water supply planning process, groundwater sustainability analyses were made for six selected demonstration areas, each selected to represent a range of hydrogeologic conditions. The areas were analyzed to provide guidance on the number of individual household wells which could be sustained without significant impacts on the shallow groundwater aquifer system with the intent that the analysis results could be applied to the evaluation of similar developments throughout the Region. It is recommended that the groundwater sustainability guidance set forth in SEWRPC Planning Report No. 52 be considered by municipalities in this watershed in evaluating the sustainability of proposed developments and in conducting local land use planning.[4]

The groundwater contamination potential of shallow aquifers in the Southeastern Wisconsin Region was mapped under the SEWRPC regional groundwater program. As shown on Map 33 in Chapter VII of SEWRPC Technical Report No. 37, the groundwater contamination potential in the Pebble Creek watershed is considered to be moderate to high.[5] Consequently, it is recommended that the groundwater contamination potential of the shallow aquifers also be considered in locating new development and/or redeveloping sites within the watershed.

Groundwater protection measures are an integral part of the County Land and Water Resources Management Plan, which recognizes the need to protect groundwater recharge areas and minimize the impacts of stormwater borne contaminants on groundwater, under goal 3 of the plan.

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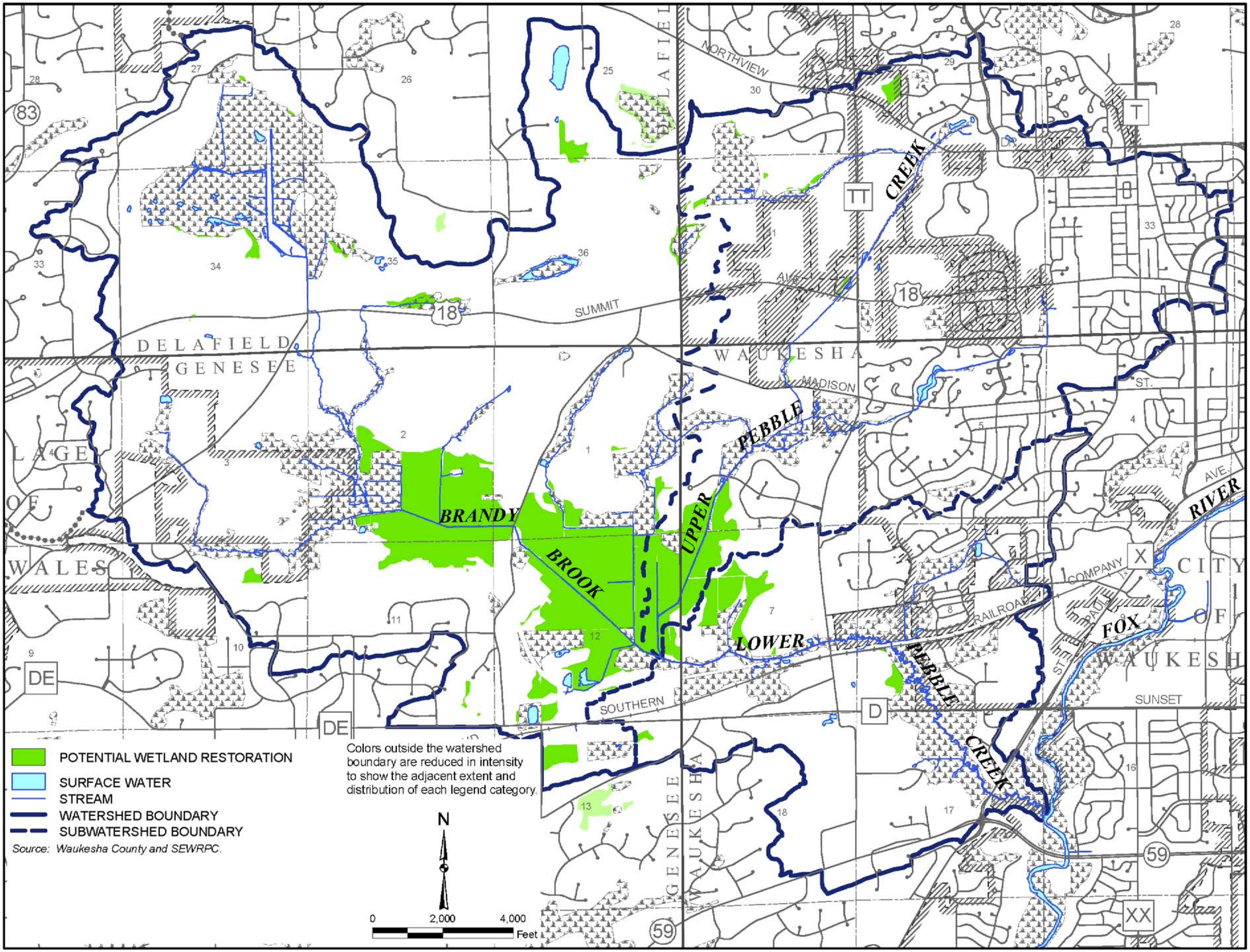
[4]*SEWRPC Planning Report No. 52,* A Regional Water Supply Plan for Southeastern Wisconsin*, in preparation.*

[5]*SEWRPC Technical Report No. 37,* Groundwater Resources of Southeastern Wisconsin*, June 2002.*

Map 38

POTENTIAL WETLAND RESTORATION SITES WITHIN THE PEBBLE CREEK WATERSHED: 2005



Objective
Preserve groundwater recharge areas in accordance with the regional water supply plan, and prevent groundwater contamination from stormwater infiltration practices.

Recommended Actions

- Update local and County land use regulations to require conservation development practices providing for the clustering of any new development within the watershed area to minimize nonpoint pollution impacts on, and potential losses of, groundwater recharge and discharge;

- Maintain infiltration and recharge as close to existing rates as practicable by incorporating runoff management recommendations for infiltration and low-impact design standards in accordance with the Regional Water Supply Plan that is currently being completed;[6]

- Consider groundwater impacts during the installation of sewer and water lines and other buried utilities, which could intercept groundwater flows. Adequate soil profile investigations during the design phase and the development of groundwater remediation plans are recommended as needed;

- Consider impacts on the groundwater flows and potential property damage when locating buildings with basements over shallow soils over bedrock or groundwater, as shown in Map 9 in Chapter II of this report. Local ordinance enforcement of a one-foot vertical separation from groundwater is recommended, consistent with the procedures recently adopted by Waukesha County. These procedures set up specific screening criteria and soil investigation standards.

It is recommended that the design of stormwater management facilities that directly or indirectly involve infiltration of stormwater consider the potential impacts on groundwater quality. Those effects should be considered in the design of infiltration facilities such as infiltration trenches, infiltration basins, bioretention facilities, rain gardens, and grassed swales and in the design of stormwater detention basins, especially in areas with a shallow depth to groundwater. The WDNR has developed post-construction stormwater management technical standards for site evaluation for stormwater infiltration, infiltration basins, bioretention facilities, and wet detention basins.[7] Those standards include provisions intended to protect groundwater quality, and it is recommended that the standards be applied in the design of stormwater management facilities.

Chlorides that are applied for snow and ice control on roads are persistent constituents that are often dissolved in stormwater runoff. Stormwater infiltration practices do not treat and remove chlorides dissolved in runoff. Thus, special safeguards must be applied to avoid adverse effects of chlorides on groundwater quality. The State technical standards recognize the inability of infiltration devices to remove chlorides from stormwater runoff and they suggest reducing, or eliminating the application of chlorides in the area tributary to an infiltration device. The recommendation in the nonpoint source pollution section of this chapter regarding implementing programs to reduce the use of road salt would have a positive effect on groundwater quality as well as surface water quality.

Fisheries and Wildlife Enhancement
The maintenance and rehabilitation of the warmwater and coldwater sport fishery, key natural resources in the Pebble Creek watershed, are important components of this protection plan. As described in Chapter III of this report, Pebble Creek upstream of CTH D and Brandy Brook are generally capable of supporting coldwater sport fish and partial water recreation use objectives. Downstream of CTH D, Pebble Creek is generally capable of supporting warmwater sport fish and partial water recreation use objectives. Based upon this analysis and review of historic and recent fisheries reconnaissance in Chapter IV of this report, fishery conditions in the Pebble Creek watershed range from very-poor to good.

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[6]*SEWRPC Planning Report No. 52,* op. cit.

[7]*The technical standards can be found at http://www.dnr.state.wi.us/org/water/wm/nps/stormwater/techstds.htm*

The watershed ecosystem is a continuum including the stream, the wildlife, all the other natural resources, and most importantly, the local citizens who reside there. In order to sustain the ecology of the watershed, action should not solely focus on the fishery. Other key natural resource features located throughout the greater Pebble Creek watershed study area will need to be maintained and/or enhanced if the study area is to sustain a viable fishery. As recommended above, actions to preserve and enhance the interconnection between the watershed's ecosystems should focus on the restoration and management of declining habitats found not only within the stream, but also within the watershed as a whole.

There are a number of issues that affect the quality of the fisheries resource that should be addressed to ensure the continued maintenance and future production of the fishery. These issues are related to existing and forecast changes in land use and the associated effects of those changes on stream hydrology, water quality, aquatic habitat quality, and streambank stability. This subsection sets forth the recommended fisheries management plan, which was developed to complement and to be consistent with the other plan recommendations regarding land use, nonpoint source pollution control, runoff management, and environmental monitoring. Specifically, these recommendations follow actions recommended by WDNR for habitat improvement of stream systems.[8] These include the following: 1) enhancement of streambank stability, 2) limitation of instream sediment deposition, 3) implementation of techniques to moderate the effects of channelization, and 4) restoration of instream and riparian habitat.[9] Implementation of these actions will improve water quality, including water clarity and temperature regime, and the improvement of the quality/quantity of food resources and habitat for fish and other aquatic species.

The following recommendations were formulated as an outgrowth of the assessment of fish and aquatic life resources set forth in Chapters III and IV of this report. These recommendations are made to supplement or reinforce related recommendations set forth below to control urban and rural nonpoint sources of pollution, to establish riparian buffers, and to restore and rehabilitate stream channels where feasible. Implementation of the recommendations would help to protect and reestablish a high quality native warmwater and/or coldwater fishery where appropriate.

Objective
Protect stream reaches to support quality fisheries, habitat, or water quality.

Recommended Actions

- Protect remaining natural stream channels, including small tributaries and shoreland wetlands that provide habitat for the continued survival, growth, and reproduction of a sustainable fishery and wildlife throughout the study area.

- Restore wetlands, woodlands, and grasslands adjacent to stream channels and establish buffers with a minimum of width of 75 feet to reduce pollutant loads entering streams and protect water quality.

- Restore, enhance, and/or rehabilitate stream channels to provide increased quality and quantity of available fisheries habitat—through improvement of water quality, fish passage, shelter/cover, food production, and spawning opportunities—using management measures that include, but not limited to[10]:

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[8]*Wisconsin Department of Natural Resources,* A Review of Fisheries Habitat Improvement Projects in Warmwater Streams, with Recommendations for Wisconsin*, Technical Bulletin No. 169, 1990.*

[9]Ibid.

[10]*It is important to note that one or more of the following recommended actions listed below may require permits from the WDNR prior to implementation (see Roles and Responsibility section in Chapter VI of this report).*

— Remove all trash identified within the Pebble Creek system as shown on Map 23 in Chapter IV of this report (see Table 15 in Chapter IV of this report and Figure 19, also in Chapter IV of this report).

— Remove the stone weirs Structure Nos. 1-4 that are potentially impeding fish movement within the Pebble Creek system as shown on Map 23 (see Table 15 and Figure 19).

— Remove and/or modify woody debris jams causing streambank instability, reducing habitat quality, and potentially impeding fish movement as shown on Map 23. In particular, high priority should be given to Structure Nos. 10, 13-22, 26, 28, 34, 35, 38-42, 50, and 51 (see Table 15 and Figure 19).

— Remove trash and debris at Points 41 and 42 on Map 23 (Structure Nos. 16 through 18 in Table 15) and restoration of the stream in this reach of Upper Pebble Creek County staff has confirmed that Harmony Homes, Inc., which is the developer for the Rolling Ridge subdivision, is responsible for implementing these actions as a requirement of the rezoning of this area in 1999-2000. It is recommended that the developer complete the restoration of this stream reach as soon as practicable before transferring ownership of the development to the subdivision landowners.

— Remove beaver dam Structure No. 8 (see Table 15 and Figure 19) from the inside of the culvert which causes detrimental flooding of upstream lands

— Stabilize actively eroding streambanks as identified and prioritized in Map 24 in Chapter IV of this report by regrading and/or revegetating the banks using bioengineering techniques where appropriate (see Appendix D) and as part of the design and implementation ensure that the stream is reconnected to its floodplain. In this latter regard, priority should be given to reaches LP-3, UP-1, UP-2, and BB-1.

— Consider physically restructuring and/or relocating portions of the existing channels to reflect the original meandering flow path, and re-establish a direct connection to its floodplain to reduce the frequency of flooding on adjacent farmland while improving runoff filtering, wildlife habitat, and bank stabilization (see Figure 40, for example). This recommendation is particularly applicable to the channelized reaches of streams where the naturally meandering character has been eliminated as shown on Map 25 in Chapter IV of this report (reaches LP-3, UP-1, UP-2, and BB-2). Specific design standards should approximate the undisturbed reaches (reaches BB-2, LP-1, and LP-2) and be subject to further site-specific engineering and hydro-ecological design.

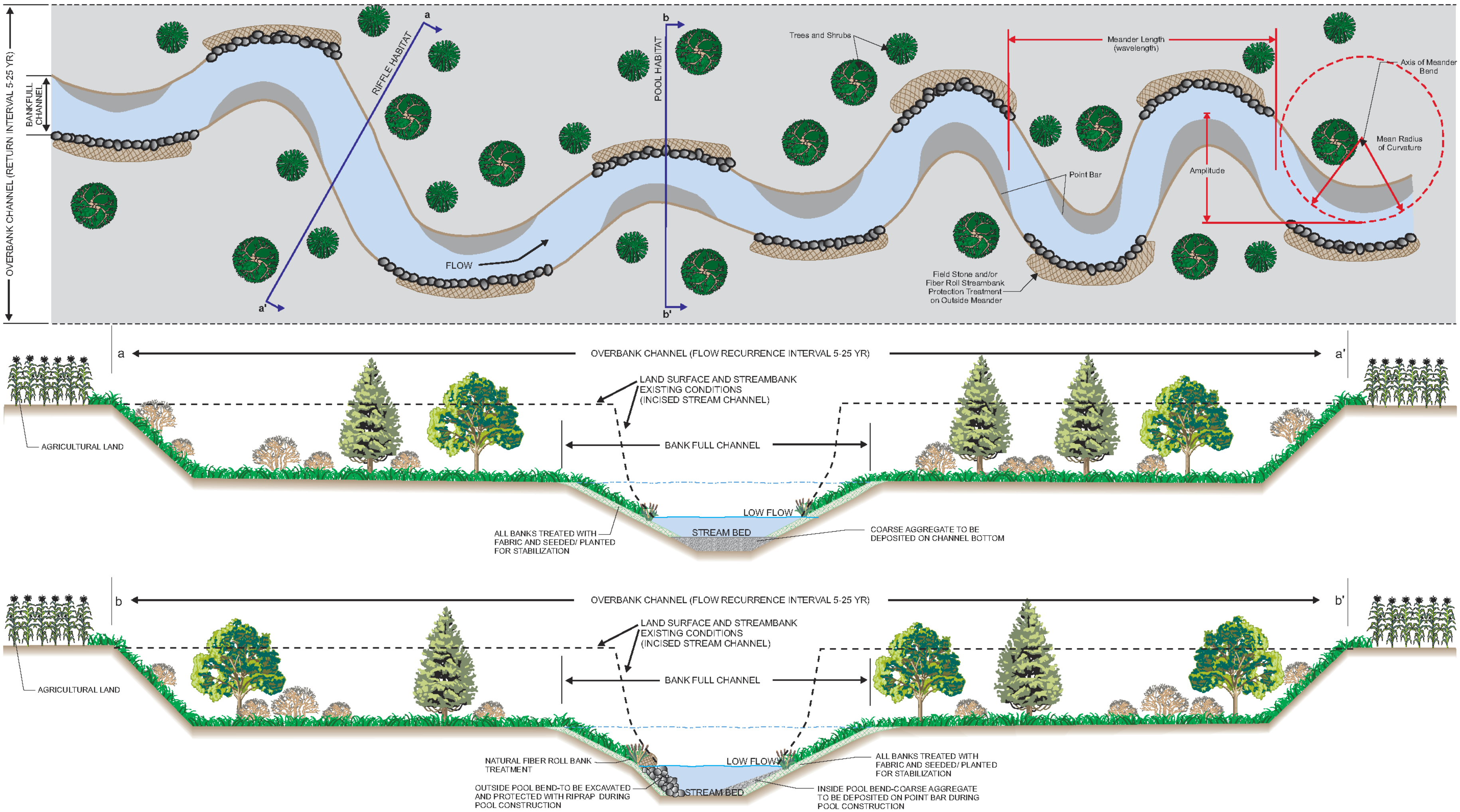
- Minimize the number of stream crossings and other obstructions to limit fragmentation of stream reaches (see Appendix E).

— Should the proposed CTH TT/STH 59 bypass be constructed as indicated on Map 16 in Chapter III of this report, from the fisheries perspective, it is important that stream crossings be accomplished using a single-span bridge, if practicable. From the floodplain perspective the road alignment should be designed such that floodwater storage within the Pebble Creek floodplain be maintained to the degree practicable.

— It is recommended that the alignment of the proposed bypass be designed to minimize the number of stream crossings.

Figure 40

SCHEMATIC OF STREAM MEANDER AND CROSS-SECTIONAL PROFILES FOR REFERENCE POOL AND RIFFLE FEATURES



NOTES: Modifications to the channel must be accomplished in a manner that preserves the hydraulic capacity of the channel and meets the requirements of applicable floodplain zoning ordinances.

Streambank treatments are for demonstration purposes only. Actual treatments will depend upon localized site conditions as part of a geomorphology and engineering design.

Drawing is not to scale.

Source: Waukesha County Land Resources Division; A. Brookes, Channelized Rivers: Perspectives for Environmental Management, 1990, John Wiley & Sons, Ltd.; A. Ward, et.al., "Two-Stage Channel Design Procedures," American Society of Agricultural and Biological Engineers, 21-24, March 2004; and SEWRPC.

- It is recommended that the bypass be located so as to avoid impacting the highest quality reaches with the highest quality fisheries and habitat of the Pebble Creek system, namely reaches LP-1 and LP-2 on Map 19 in Chapter IV of this report.

- It is recommended that the proposed bypass be located so as to minimize impacting the primary environmental corridor adjacent to Pebble Creek to avoid impacting natural areas or critical species habitats, and cause no net loss of wetlands within the Pebble Creek watershed.

- To minimize development and development impacts on Pebble Creek, it is recommended that access to the bypass be restricted between CTH D and CTH X.

• As opportunities arise when roadways crossing streams are replaced or reconstructed, remove or retrofit obstructions such as culverts, dams, and drop structures that limit the maintenance of healthy fish and macroinvertebrate populations.

• Modify and/or remove and replace culvert and bridge installations with moderate to high potential for causing hydrological and/or physical obstructions to fish passage.

- High priority should be given to stream-crossing location numbers 16 and 17 shown on Map 24 in Chapter IV of this report (see Table 16 in Chapter IV of this report and Figure 21, also in Chapter IV of this report);

- The bridge crossing at CTH X, crossing number 1 on Map 24, contains a rock spillway that is potentially limiting fish passage (see Table 16 and Figures 16 and 21), and it is recommended that the new bridge crossing be designed and constructed to ensure improved fish passage at this location (see Appendix E for fish passage design recommendations). The current plans indicate that the bridge at CTH X, which crosses Pebble Creek, will be replaced and the road will be widened to four lanes at that location as part of roadway improvement project of CTH X from Harris Highland Drive South to STH 59. This project is scheduled for construction in 2008.

• Coordinate activities with efforts to reduce erosion throughout the entire watershed and particularly during onsite construction activities on new development sites.

• Maintain and/or enhance existing linkages between terrestrial and aquatic biological communities, including fish, amphibians, and other wildlife.

• Maintain baseflows and minimize fluctuations of instream water temperatures through preservation of groundwater recharge areas, establishment and maintenance of adequate riparian buffers, and implementation of sound urban stormwater BMPs.

• Monitor fish and macroinvertebrate populations in order to evaluate the effectiveness of the water quality management program.

CONTROL URBAN RUNOFF POLLUTION AND FLOODING

All human activities upon the land surface result in some degree of mobilization of contaminants and modification of surface runoff patterns that can affect lakes and streams, their quality, and biotic condition. Many human activities can be mitigated to a large extent by the implementation of sound planning, provision of sanitary sewer services, appropriate nonpoint source pollution abatement measures, and the actions of an informed public. In the first instance, sound land use development and management in the tributary watershed, and protection of environmentally sensitive lands, are the fundamental building blocks for protecting stream water quality and habitat and preserving human use opportunities that will support a broadly based recreational and residential community. Where appropriate densities of dwellings and other urban land uses exist, provision of sanitary sewer service, along with provision of secondary or tertiary wastewater treatment, can mitigate the delivery of contaminants to receiving waters, and has proven effective in reducing levels of enrichment of waterways. In addition, specific nonpoint source pollution control and abatement measures should be integrated into land use regulations and promoted by a far-reaching informational and educational program within the drainage area tributary to individual streams. Each of these measures is elaborated further below.

Land Use Management and Zoning

As noted above, a basic element of any water quality management effort is the promotion of sound land use development and management in the watershed. The type and location of future urban and rural land uses in the Pebble Creek watershed will determine, to a large degree, the character, magnitude, and distribution of nonpoint sources of pollution; the practicality of, as well as the need for, stormwater management; and, to some degree, the water quality of the streams of the watershed.

Existing 2000 and planned year 2035 land use patterns and existing zoning regulations in the Pebble Creek watershed have been described in Chapter II. If the recommendations set forth in the adopted regional and County land use plans are followed, under year 2035 conditions, urban residential development within the watershed would approximately double during this time period. Much of this residential development is likely to occur on agricultural lands. Nearly all of the planned new urban development is located beyond the riparian zone. Within those areas, it is envisioned that there will be some infilling of existing platted lots and some backlot development, as well as the redevelopment and reconstruction of existing residential properties. Recent surveillance indicates that this type of development is currently occurring. Accordingly, given the potential impact of riparian development and redevelopment throughout the watershed, future development proposals should be evaluated for potential impacts on Pebble Creek, as such proposals are advanced.

Recent studies of the potential impact of riparian landscaping activities on the nutrient loadings to waterbodies in southeastern Wisconsin have suggested that urban residential lands can contribute up to twice the mass of phosphorus to a lake when subjected to an active program of urban lawn care than similar lands managed in a more natural fashion.[11] The application of agrochemicals to such lands, in excess of the plant requirements, therefore, results in enhanced nutrient loading directly to the adjacent waterbodies. To address these concerns, a number of communities in southeastern Wisconsin are debating the enactment of, or have adopted, fertilizer management ordinances in addition to the public informational programming discussed below. Some communities, such as the Big Cedar Lake Protection and Rehabilitation District, also have purchased bulk lots of phosphorus-free lawn and garden fertilizers for resale to riparian landowners. Given the increasing importance of urban land uses within the Pebble Creek watershed, consideration of a comprehensive program to regulate urban nutrient and pest management practices appears to be warranted.

The adopted regional and local land use and water quality management plans set forth management measures directed at urban and rural nonpoint sources within the Pebble Creek watershed.[12] These measures were subsequently refined in the priority watershed plan for Upper Fox River.[13] Sediment and total phosphorus load reduction goals for the Pebble Creek watershed, established during this latter planning process, indicated up to 90 percent reductions in urban sediment loading and up to 65 percent reductions in urban phosphorus loading. The adopted County Land and Water Resources Management Plan specifically noted these requirements under goal I, control of urban runoff pollution and flooding.

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[11] *U.S. Geological Survey Water-Resources Investigations Report No. 02-4130,* Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from Lakeshore Lawns, Lauderdale Lakes, Wisconsin*, July 2002.*

[12] *See Table 10 for a list of applicable plans.*

[13] *Wisconsin Department of Natural Resources, Publication No. PUBL-WR-255-90,* Nonpoint Source Control Plan for the Upper Fox River Priority Watershed Project*, June 1994.*

With respect to stormwater management, as noted in Chapter III, all of the municipalities have adopted stormwater management ordinances. The City of Waukesha and Village of Wales have adopted their own stormwater management ordinances, while the other municipalities have adopted the Waukesha County stormwater ordinance as indicated in Table 12 in Chapter III of this report. These ordinances reflect current best practices regarding the determination of stormwater flows and increased runoff volumes, mitigation of flooding potential, and the control of contaminants from land use activities. Periodic review of these ordinances and their provisions to ensure their currency with the state-of-the-art should be undertaken on a regular basis to facilitate control of urban-source contaminants that would likely be delivered to Pebble Creek and to minimize the impacts of urban runoff on the natural resources of the Pebble Creek watershed. This would be consistent with the recommendations set forth under goal II of the County Land and Water Resources Management Plan.

Objective
Develop policies and install practices that reduce urban nonpoint source water pollution and help achieve the recommended water use objectives and supporting water quality standards for surface waters.

Recommended Actions

- Given the increasing importance of urban land uses within the Pebble Creek watershed, periodically review applicable land use plans and regulatory requirements to ensure conformity with best land management practices.

    — Update local zoning ordinances to require minimum 75-foot vegetated buffers within shoreland zones or adjacent to wetlands, consistent with the recommended setback requirements noted in the Land Management Measures section above.

- Evaluate existing stormwater management BMPs for potential modifications to improve water quality and water quantity functionality. A preliminary identification of BMPs that are recommended for further analysis for this purpose is shown in Map 39. (Note: As part of the NR 216 permit process, communities must evaluate all municipally owned or operated structural flood control facilities to determine the feasibility of retrofitting such facilities to increase total suspended solids removal from runoff.):

    — Install new stormwater treatment facilities at locations where runoff is currently untreated, or where additional treatment is necessary;

    — Increase infiltration of urban runoff where it can be accomplished and where it can be achieved without degrading groundwater quality; promote post-development groundwater recharge by meeting or exceeding infiltration standards set forth in NR 151, *Wisconsin Administrative Code* and local ordinances;

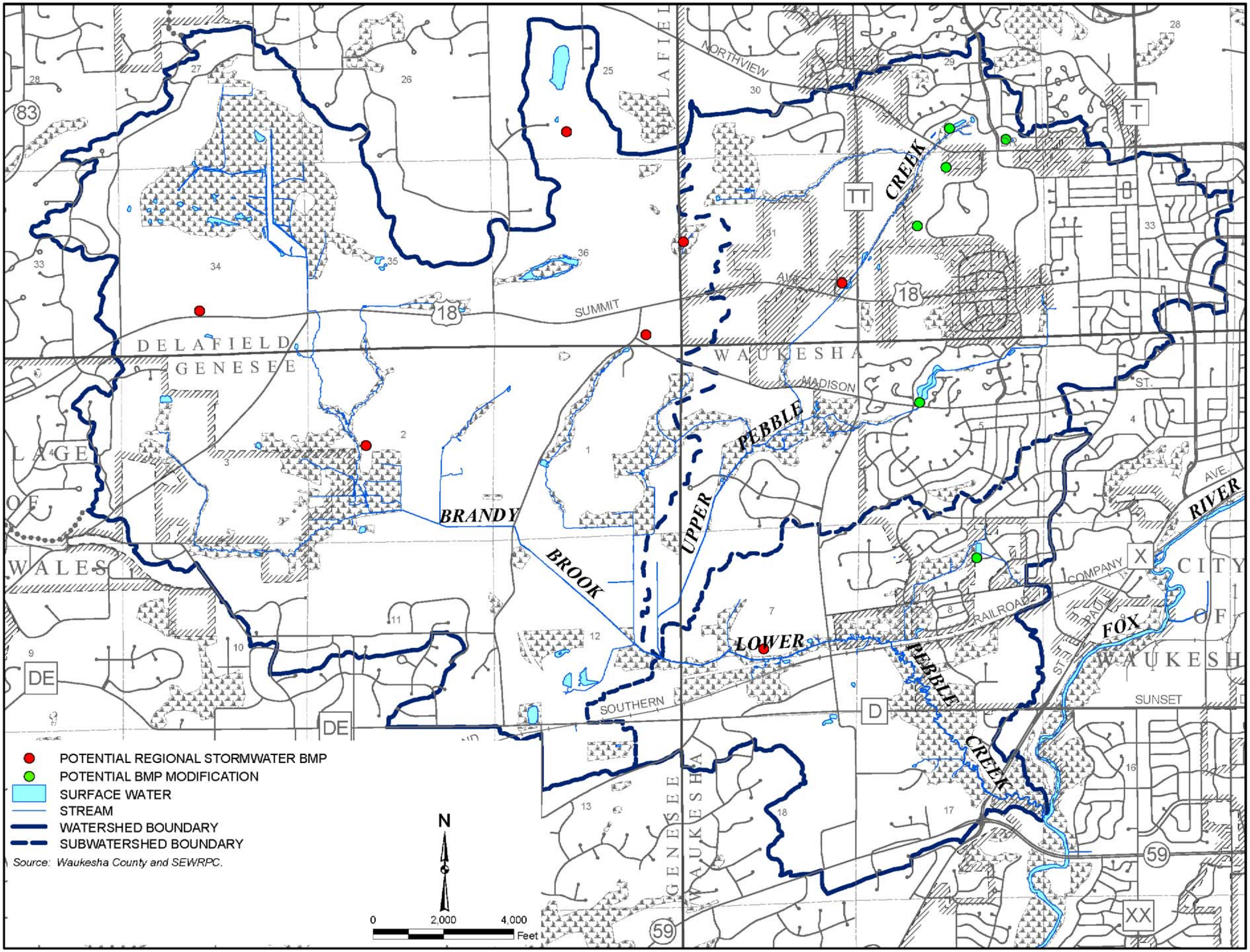
- Use multipurpose stormwater facilities where practicable and advantageous to the achievement of the objectives of this plan. Multipurpose uses include water quality control, water quantity control, active or passive recreation, and aesthetic enhancement.

    — Minimize stormwater pollutant loading, runoff temperature increases, and changes in downstream hydrology that would otherwise result from development and maintain adequate baseflow through establishment and maintenance of riparian buffers, stormwater infiltration practices, and other urban best management practices.

- Review road salt/sand use and consider alternatives such as salting intersections only, using a calcium chloride solution, or modifying the salt:sand ratio wherever practicable to limit the introduction of chlorides to surface and ground waters in the Pebble Creek watershed.

Map 39

POTENTIAL SITES FOR STORMWATER BMP MODIFICATIONS AND REGIONAL STORMWATER BMPS WITHIN THE PEBBLE CREEK WATERSHED: 2005



- Continue development and data population of the Internet-based Waukesha County Storm Water BMP Tracking System and encourage municipalities to request training and access to utilize the system.

- Protect water resources when adding, improving and upgrading urban infrastructure.

  — For planned road construction, as shown in Map 16 in Chapter III of this report, ensure that adequate right-of-way land is purchased for the installation of state-of-the-art erosion control and post-construction stormwater management practices without damaging adjacent sensitive areas.

  — Ensure adequate erosion and sediment control techniques are used when installing sewer systems and other buried utilities, including any proposed sanitary sewer extensions;

  — Ensure that all road, bridge and culvert construction or reconstruction, such as that shown on Map 16, employs good planning and enforcement of erosion control and stormwater management practices.

  — Consider updating municipal design standards for collector streets and associated sidewalks and stormwater management systems to reduce impervious surfaces and increase treatment of runoff through biofiltration and other practices.

- Prepare and periodically review and update, as necessary, local transportation, park and open space, stormwater management and land use plans consistent with the recommendations contained in this plan.

- Coordinate activities for stormwater management throughout the entire watershed. Consider the formation of stormwater utility districts within local jurisdictions and/or the adoption of a Section 66.0301, *Wisconsin Statutes*, intergovernmental stormwater management entity with responsibility for stormwater management throughout the Pebble Creek Watershed. Such entities would have authority to implement, fund and maintain stormwater facilities and BMPs.

- Meet plan goals through enforcement of State and local erosion control and stormwater management standards for new urban development. Consider coordinating enforcement of construction erosion control efforts through intergovernmental agreements, including one- to two-family home construction.

- Work cooperatively with area fueling and automotive service stations to decrease potentially contaminated runoff.

- Implement State turf management standards on all lands including public lands in accordance with requirements of municipal permits under Chapter NR 216 *Wisconsin Administrative Code*.

- Consider adopting local ordinances to limit the use of phosphorus in lawn fertilizers.

- Continue to promote information and education activities intended to draw attention to the water resources in the Pebble Creek watershed. Activities could include such things as: a) storm drain stenciling; b) volunteer water quality stream monitoring; c) information distribution related to proper management of materials that may cause water pollution from sources including automobiles, pet waste, household hazardous waste and household practices; d) promotion of beneficial onsite reuse of leaves and grass clippings and proper use of lawn and garden fertilizers and pesticides; e) promotion of infiltration practices for residential stormwater runoff, such as "rain gardens."

Stormwater and Floodland Management Measures
The recommended stormwater and floodland management plan element for the Pebble Creek watershed includes the improvement of stormwater management facilities, requirements for control of runoff from areas of future development, protection of wetlands, and the prevention of future floodprone development. A basic nonstructural plan element consists of the land use development proposals contained in the land use element of the protection plan. The extent and placement of incremental urban development over the planning period is critical if the intensification of the existing and the creation of new flooding problems in the watershed are to be avoided, since such extent and placement directly affect the hydrologic and hydraulic behavior of the watershed. In this respect, preservation of the primary environmental corridors is of particular importance and affects not only the hydrologic and hydraulic behavior of the stream system but also water quality conditions. Preservation of floodlands in open uses lying outside the environmental corridors is also critical as is encouraging the use of floodland areas for outdoor recreation and related open space activities.

Objective
Preserve floodwater storage areas and mitigate flow increases and storage losses, and control the quantity of runoff from new urban development.

Recommended Actions

- Update County and municipal floodland zoning ordinances based on the results of the floodplain analysis undertaken as part of this planning effort, as presented in Appendix H in Part Two of this report.

- Upon review by the Waukesha County Storm Water Advisory Committee, update local stormwater management ordinances to incorporate recommended unit peak discharge standards generated through this planning effort. Because these standards are based on a watershedwide analysis of peak flows, they should be more effective at minimizing downstream flooding from future development. The recommended standards are presented in Appendix I in Part Two of this report.

- It is recommended that the County stormwater ordinance be updated to require using SEWRPC regional rainfall frequency data along with the 2005 SEWRPC revised design storm temporal rainfall distribution.[14]

- Prepare regional stormwater management plans for areas where future urban development is planned or where detention and/or treatment of existing stormwater runoff could benefit the water resources of the Pebble Creek system. A preliminary location of potential regional stormwater BMPs is shown on Map 39. Further watershed analysis and site design would be required for each of these, as well as for the potential location of other regional BMPs;

- Stormwater management facilities should promote the achievement of recommended water use objectives and supporting water quality standards for Pebble Creek, and should not degrade existing habitat conditions for fish and aquatic life.

- Stormwater management practices should promote the attainment of sediment quality criteria for toxic substances.

- Stormwater management systems shall be designed to minimize disruption to primary and secondary environmental corridors, including the incorporated woodlands, wetlands, and wildlife habitat areas.

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[14]*SEWRPC Technical Report No. 40,* Rainfall Frequency in the Southeastern Wisconsin Region, *April 2000. The 2005 temporal distribution was developed in conjunction with the WDNR and is being applied by WDNR for statewide floodplain management purposes. That distribution and the rainfall frequency data can be accessed at http://www.sewrpc.org/rainfallfrequency/default.shtm.*

- Stormwater management facilities should be designed to protect valuable and sensitive wetlands from the adverse impacts of stormwater runoff.

- Stormwater management facilities shall be designed to control sedimentation in receiving streams and lakes and to prevent the loss of fish and aquatic life habitat through streambank erosion and stream-bed scour.

- To the extent practicable, stormwater drainage facilities should be designed to avoid enclosure of tributary streams identified as having significant and valuable biological and recreational uses.

- Enforce existing and adopt, as appropriate, regulations to reduce risks to life and property in flood-prone areas.

- Develop and maintain up-to-date inventories and maps to identify areas and structures at risk of flooding.

- Establish, as appropriate, open space lands, riparian corridors, and park lands in floodprone areas to protect and preserve fish and wildlife habitat and water quality benefits.

- Provide, maintain, develop, and implement, as appropriate, stormwater and floodland management facilities; modify as necessary to minimize or prevent damage from inundation events up to and including the 100-year recurrence interval flood event.

- Develop and implement floodland management plans to control erosion in stream channels and flood-plain areas.

- Develop stormwater management plans which identify and mitigate, as appropriate, nonpoint pollution sources.

- Implement and develop, as necessary, public education and information programs regarding floodplain development and nonpoint source pollution abatement and funding assistance programs for property owners wishing to floodproof their at risk structures.

In addition to the land use development proposals, the plan recommends that existing and probable future flood problems in the watershed be resolved through a combination of wetland protection and controls on peak rates of runoff from areas of new development. Implementation of this floodland management plan element would result in controlling runoff in the watershed under planned land use conditions (representing full development of the planned urban service areas) during events with recurrence intervals up to and including 100 years. Implementation of the floodland management plan element will not, however, serve to eliminate all local stormwater drainage problems in the watershed. The abatement of those problems should be addressed through the preparation of stormwater management system plans such as the plan which was prepared for the East Branch of Pebble Creek, or through case specific analyses of stormwater problems in some areas of existing development.

ENCOURAGE THE CONTINUATION OF AGRICULTURAL USES AND CONTROL POLLUTION FROM AGRICULTURAL RUNOFF

The County Development Plan and County Land and Water Resources Management Plan promote the protection of the most productive farmland, identified by the U.S. Natural Resources Conservation Service as prime agricultural soils and soils of statewide importance as shown on Map 10 in Chapter II of this report. These plans seek to accommodate incremental rural density residential development without adversely impacting highly productive farmland. The recommended rural nonpoint source control measures for the Pebble Creek watershed are generally consistent with the objectives of the Land and Water Resource Management Plan for Waukesha County in the study area.[15]

This protection plan envisions that some farmland that is located in the vicinity of existing urban service areas will be converted to urban uses as a result of the planned expansion of those urban service areas, as shown on Map 6 in Chapter II of this report. Such expansion should be viewed as a matter of balancing objectives for the preservation of productive farmland with objectives for meeting urban land needs as warranted by increases in population, households, and employment and with objectives for the orderly and efficient provision of urban facilities and services. The plan anticipates the development of lands beyond the planned urban service areas that have been committed to low-density and sub-urban density residential development through subdivision plats and certified surveys. This could be expected to result in the additional loss of high quality farmland.

Agricultural Land Use Planning and Zoning Measures

Encouraging the continuation of agricultural uses of land in the watershed was identified as one of the overall goals of this plan because agriculture is considered good for the water resources. This is because agricultural lands allow rainfall and melting snow to infiltrate the soil surface and recharge the shallow aquifer, thus maintaining stream baseflows and minimizing negative impacts downstream. Preserving agricultural businesses near urban centers also offers educational opportunities for local youth, provides food and other agricultural products for local markets, diversifies the local economy and helps preserve the rural character of a community. Chapter II described in detail the negative impacts that urbanization has historically had on water resources if adequate protective actions are not taken, including increased runoff volumes, peak flows, water pollution, bank destabilization, loss of baseflow and wildlife habitat, stream sedimentation, among others. As described in Chapter IV, the Upper Pebble Creek subwatershed currently demonstrates most of these symptoms.

Objective

Promote the continuation of agricultural uses in designated areas of the watershed.

Recommended Actions

- Consider the use of land use planning and regulatory tools to preserve productive farmland and agricultural businesses while minimizing land use conflicts with urban areas using one or more of the approaches described below:

  — Exclusive Agricultural Zoning. In Wisconsin, exclusive agricultural zoning districts generally limit the division of land into parcel sizes less than 35 acres, and limit land use within the district to agricultural purposes and one residence per 35 acres. Under the State's Farmland Preservation Program, urban counties such as Waukesha are required to prepare a Farmland Preservation Plan and each Town must adopt Exclusive Agricultural Zoning Districts in order for local landowners to be eligible for a State income tax credit. The Wisconsin Department of Agriculture, Trade and Consumer Protection administer the program in cooperation with local zoning authorities. To date, none of the three towns within the Pebble Creek watershed contains exclusive agricultural zoning districts.

  — Land Division Ordinances. As described in Chapter 3 ("Subdivision Regulations"), these ordinances are used to regulate the division of land into smaller parcels, usually for nonagricultural purposes such as residential subdivisions. While *State Statutes* contain minimum requirements that must be followed for land divisions of five lots or greater, local regulations vary widely. In the Pebble Creek watershed, all communities have adopted and administer a land division ordinance, although Waukesha County's only applies to the statutory shoreland zone of 1,000 feet from a lake, 300 feet from navigable streams and within the 100-year floodplain.

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[15] *Waukesha County Department of Parks and Land Use,* Waukesha County Land and Water Resource Management Plan: 2006-2010*, March 2006.*

- Conservation Subdivisions. These types of residential subdivisions usually require permanent protection of at least 30-50 percent of the subdivision as open space, sometimes with protection standards that apply to specific areas such as road setbacks or natural resource features such as steep slopes, wetlands or woodlands. As briefly described in Chapter 3 ("Subdivision Regulations"), several local land division ordinances encourage conservation subdivisions or planned unit developments over conventional subdivisions by allowing additional lots of smaller sizes to be created in nonsensitive areas of the property, sometimes referred to as "bonus lots" or incentives. Conservation subdivisions can provide an open space buffer between agricultural and residential uses and can even allow farming some of the open space lands, making them applicable to transitional zones between rural and urban uses.

- Purchase of Development Rights. PDR is a method of preserving farmland and natural areas in which landowners are compensated for voluntarily limiting future development of their land. Under a PDR program, an entity such as a county, municipality, or land trust, purchases the development rights and records a permanent land preservation easement on the property deed. The land remains in private ownership on the tax rolls, but can only be used for agricultural and open space purposes. PDR program funds can be targeted to large agricultural areas, sometimes called Agricultural Enterprise Areas, to encourage investment in the local agricultural business sector. There is currently no active PDR program in the Pebble Creek watershed or Waukesha County.

- Transfer of Development Rights. TDR is similar to a PDR program except that the development rights are transferred from one property to another rather than purchased, and developers rather than a land trust or local government usually pays the initial costs. A TDR program requires establishing a "sending zone", from which development rights are transferred to preserve farmland tracts, and a "receiving zone", to which the development rights are transferred, generally allowing for a higher density of development to occur than authorized by zoning. There is currently no TDR program established in the Pebble Creek watershed, but the Waukesha County zoning code does allow TDR to occur in their zoning code in certain zoning districts.

- Consider updating local land use plans to include the identification of Agricultural Enterprise Areas,[16] as shown in Map 40.

- Direct future growth outside of the Agricultural Enterprise Areas to minimize land use conflicts with the agricultural sector.

- Consider implementing a PDR and/or TDR program within the Agricultural Enterprise Area.

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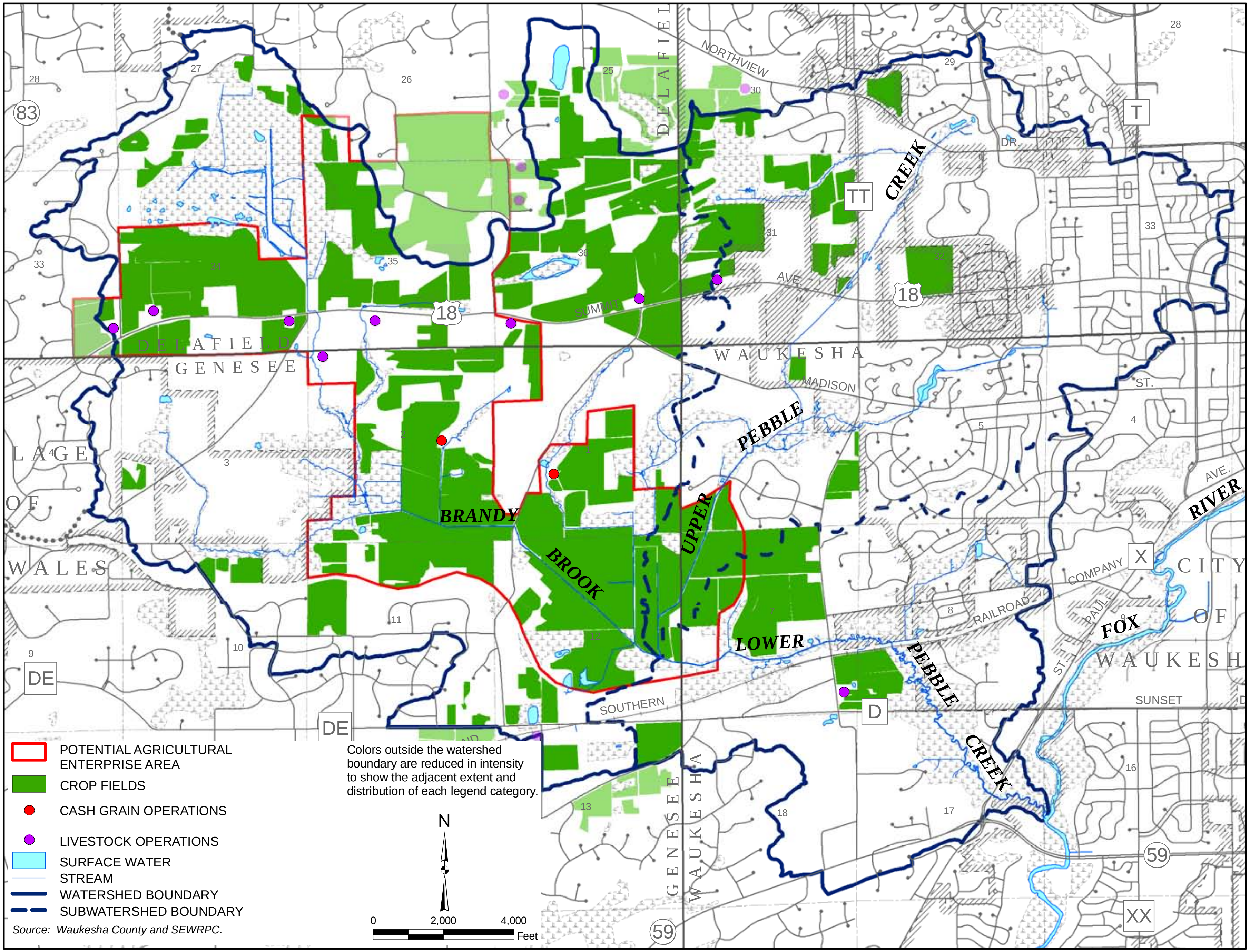
[16]*Wisconsin Department of Trade and Consumer Protection (DATCP),* Working Lands Enterprise Areas Proposal for Committee Approval*, http://www.datcp.state.wi.us/workinglands/meeting_materials.jsp, May 2006. While Wisconsin has historically relied on local exclusive agricultural zoning and State tax income credits to encourage farmland preservation in urbanizing counties, the State is now promoting the use of Agricultural (Working Lands) Enterprise Areas and Purchase of Development Rights programs. This strategy has proven to be effective around the country and relies heavily on land use planning to identify areas to be targeted for protection efforts. At the time of this plan preparation, no State funding was yet available, but Federal funding in the form of matching grants was available through the US Department of Agriculture. Map 40 shows potential Agricultural Enterprise Areas within the Pebble Creek watershed based on current adopted land use plans and the location of existing agricultural operations and productive soils. For purposes of this plan, "Agricultural Enterprise Areas" are defined as large contiguous areas of agricultural lands located outside of planned urban areas.*

Map 40

POTENTIAL AGRICULTURAL ENTERPRISE AREA WITHIN THE PEBBLE CREEK WATERSHED: 2005



- Consider requiring conservation subdivision designs in areas identified for future low-density residential development to create a transition to the open space in the agricultural areas, protect sensitive lands and minimize land use conflicts with agricultural producers.

- Consider adding Agricultural Enterprise Areas as a component of a PDR or TDR program in local land use and land division ordinances.

- Develop boundary agreements among the applicable communities to jointly protect the Agricultural Enterprise Area and to possibly implement a PDR and/or TDR program among communities.

Agricultural Pollution Control Measures

Chapter III of this plan contains a review of the applicable State and local nonpoint pollution control standards that apply to agricultural operations, which are contained in Chapters NR 151 and ATCP 50 *Wisconsin Administrative Code*. Details of how these performance standards will be implemented in Waukesha County are contained in the Waukesha County Land and Water Resource Management Plan (2006-2010). In general, the County strategy relies on creating a GIS-based screening process and tracking system, followed by landowner contacts in targeted watersheds. Pebble Creek was identified as one of the targeted watersheds, but as of the preparation of this plan, fieldwork for this effort is only in the preliminary stages.

One of the State performance standards requires the maintenance of cropland soil erosion rates at or below "T" values.[17] This could be accomplished through a combination of practices, including, but not limited to, expanded conservation tillage, contour farming, crop rotations and grassed waterways. The applicable measures are usually determined by the development of individual farm conservation plans, consistent with the recommendations set forth in the NRCS Technical Guide and Conservation Planning Manual. It should be noted that maintaining erosion rates at "T" values may not adequately protect water quality from sediment delivery and that the State is currently working on administrative rule modifications to address this issue, as described further below.

Chapter IV of this plan characterized existing riparian buffer widths along streams in the study area as shown on Maps 31 through 34 in Chapter IV of this report. Such buffers serve important water quality-related functions, including the removal of nonpoint source pollutants from both surface water and groundwater, reduction of instream water temperatures through shading of the stream channel, and maintenance of streambank stability, among others. In addition, riparian buffers provide habitat for a variety of aquatic and terrestrial wildlife and are an essential component of environmental corridors. The riparian corridor forms the nexus between the surface water and groundwater systems, including areas of groundwater discharge that coincide with the ability of streams to sustain economically important coldwater species and with groundwater recharge areas.

While Waukesha County currently does not have a program for the establishment of riparian buffers, the County Land and Water Resources Management Plan recommends promoting buffers along all the water resources for water quality, wildlife habitat, and groundwater recharge purposes as part of goal 4, control of agricultural runoff pollution. The establishment and maintenance of riparian buffers are important mitigation measures recognized by this program.

The Wisconsin Department of Natural Resources is currently in the process of establishing a minimum State performance standard for buffers to address sediment delivery from cropland at "T" values. In the absence of a standard, a literature review was recently conducted by SEWRPC as part of the update to the Regional Water Quality Management Plan to evaluate the effectiveness of riparian buffers in controlling nonpoint source pollu-

[17] *"T-value" is the tolerable soil loss rate—the maximum level of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely. T values are published for each soil type by the USDA Natural Resource Conservation Service in Chapter 2 of the Field Office Technical Guide. "Excessive" cropland erosion refers to erosion in excess of the tolerable rate, or T-value.*

tion.[18] Based upon this review it was determined that a buffer width of 75 feet represented the most appropriate to utilize for modeling purposes in terms of 1) percent effectiveness for control of nitrogen, phosphorus, and Total Suspended Solids concentrations, 2) practicality, and 3) regulatory considerations (see Appendix F). It is important to note that riparian buffers are only a single component of a comprehensive watershed management strategy, which must also include point source and nonpoint source control of nutrients and sediment loadings, provision of habitat, and management of floodwaters.

Chapters NR 151 and ATCP 50 also contain certain provisions relating to the control of barnyard runoff, manure storage and the application of nutrients on cropland and pastures. Map 40 shows the location of existing livestock and other active farming operations in the watershed. When the Upper Fox River Priority Watershed Plan[19] was prepared in 1994, it was estimated that animal waste management practices could eliminate more than 300 pounds of phosphorus per year in agricultural runoff in the Pebble Creek subwatershed, which accounted for approximately 33 percent of the total pollutant loadings to streams from barnyards in the entire Fox River watershed. Of this amount, more than 200 pounds of phosphorus was estimated to be contributed from barnyards directly connected to rivers, streams, and wetlands. Although these estimates were not updated during this planning effort, there are currently only nine barnyards remaining in the subwatershed, which suggests that loadings from this source are greatly reduced. Additional reductions in barnyard loadings may be anticipated on a case by case basis as a result of the implementation of the State rules as discussed above.

Objective
Promote the use of agricultural nonpoint pollution control practices to meet or exceed State and Federal standards.

Recommended Actions

- Permanent vegetative buffers should be installed along perennial, intermittent, and ephemeral waterways in accordance with WDNR and NRCS technical standards for filter strips where cropland or livestock pastures lie within 75 feet (see Map 34 in Chapter IV of this report);

- Limit the number of stream crossings and configure any such crossings to minimize the fragmentation of stream habitat (see Appendix E);

- Evaluate remaining livestock operation in the watershed, as shown on Map 40 to determine compliance with State standards to control barnyard runoff. Also included with the evaluation process will be a determination of compliance with the State manure management prohibitions. If necessary, prescribe corrective measures and work with the landowner to secure cost-share funding to install required practices;

- Consider agricultural drainage needs in any proposed practices for stream restoration, wetland restoration, nonpoint pollution reduction, or flood control;

- Promote agricultural conservation programs that offer cost sharing to agricultural producers for implementing conservation practices, such as Conservation Reserve and the Environmental Quality Improvement Program and the Soil and Water Resource Management Program;

- Encourage preparation and implementation of farm level nutrient management plans for croplands within the watershed that comply with State standards. Provide educational and technical assistance and secure cost-sharing needed to bring landowners into compliance;

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

[19]*Wisconsin Department of Natural Resources, Publication No. PUBL-WR-255-90,* Nonpoint Source Control Plan for the Upper Fox River Priority Watershed Project*, June 1994.*

- Consider the impacts of urban development on agricultural lands, including preservation of agricultural drainage and erosion and stormwater from urban runoff;

- Control cropland erosion by working with landowners and farm operators to review and update as necessary, conservation plans intended to control cropland erosion rates to levels that meet or exceed the State standards for nonpoint pollution runoff control.

EDUCATE THE PUBLIC ABOUT CONSERVATION ISSUES AND WATERSHED PROTECTION

As part of the overall citizen informational and educational programming to be conducted in the Pebble Creek area, residents and visitors in the watershed should be made aware of the value of the ecologically significant areas in the overall structure and functioning of the ecosystems of the watershed. Specifically, informational programming related to the protection of ecologically valuable areas in the watershed should focus on the need to protect riparian corridors, minimize the spread of nuisance aquatic species such as purple loosestrife, and the value of good urban housekeeping and yard care practices.

Educational and informational brochures and pamphlets, of interest to homeowners, are available from the University of Wisconsin-Extension, the Wisconsin Department of Natural Resources, the Waukesha County Land Resources Division, and many Federal government agencies. These brochures could be provided to homeowners through local media, the Internet, direct distribution, or targeted library/civic center displays. Many of the ideas contained in these publications can be integrated into ongoing, larger-scale activities, such as anti-littering campaigns, recycling drives, and similar pro-environment activities.

Targeted Informational Programming

Promotion of local support for fisheries management and environmentally sensitive and sustainable measures through targeted informational programming and creation of opportunities for public participation in decision-making processes is recommended. Such opportunities for shared decision-making include the creation of citizen advisory committees, completion of memoranda of understanding with lake and river organizations within the Fox River basin, and participation in programs, such as Adopt-a-Waterbody, Project WET, Project WILD, and Project Learning Tree (PLT) programs, and related school-based programming. A sound and vocal base of public support for a fisheries rehabilitation project will benefit all aspects of watershed management. This is consistent with the recommendations set forth under goal 7, monitor water quality/flow of local lakes and streams, of the County Land and Water Resource Management Plan.

Experience suggests that coordinating these individual efforts is a valuable and useful element of an information and education program. Establishment of a stream-focused conservation organization can promote local support for river protection by providing a focal point for private residents, and an umbrella under which businesses and other nonprofit organizations may participate in a meaningful manner in stream protection activities. To this end, and based upon the model provided by the existing Waukesha County Information and Education Program for the Upper Fox Watershed Community Group—which includes the Pebble Creek watershed area, the establishment of a private, nonprofit watershed protection organization or "Pebble Creek Stewardship Initiative"—could provide such a focus for the Pebble Creek community. This organization could play a lead role in coordinating and garnering citizen and community participation in support of the implementation of this watershed protection plan, in stewardship activities, and in enhancing the natural resources within the Pebble Creek Watershed. This organization, as has been done effectively in the case of the Root-Pike Watershed Initiative Network (WIN), also could establish and operate a watershed protection fund that would help finance activities and projects within the watershed, such as demonstration projects, research, and monitoring programs.

Objective

Develop or expand land use and water quality information and education programs as needed to implement plan goals and objectives.

Recommended Actions

- Encourage the creation of, and provide support to, a citizen advocacy group that will promote wise resource management and help implement watershed protection activities through development and distribution of educational materials, displays, and conduct of events.

- Promote watershed protection and the implementation of this plan through educational programs at Retzer Nature Center and local schools, as well as other environmental education efforts by the county and municipalities:

  — Provide local residents, businesses, developers and government officials with a basic understanding about the geography, natural resources and environmental issues of the Pebble Creek Watershed;

  — Inform these same groups about the types of practical actions and behaviors that contribute to the health or destruction of the watershed; and

  — Provide opportunities and incentives to make those behavioral changes and actions that will protect and preserve the watershed, its river and its other natural resources.

- Incorporate additional stream corridor lands into the Waukesha County Park and Open Space Plan to enhance public educational and recreational opportunities in conjunction with the stream restoration recommendations noted in the Fisheries and Wildlife Enhancement section above. Recommended plan revisions are shown on Map 41, including connections to the Retzer Nature Center and planned City of Waukesha parks and trail systems.

- Encourage citizen participation in:

  — Storm drain stenciling (see Waukesha County Nonpoint Information and Education Program Proposal below);

  — Litter and pet waste clean ups and "Clean Sweep" programs;

  — Water quality monitoring through the Water Action Volunteers; and

  — Gardening and natural landscaping programs, including the installation of rain gardens.

- Encourage business owner participation in:

  — Use of grocery bags, posters, and place mats printed with an awareness message;

  — Placement of revolving displays;

  — Employee education on waste minimization and recycling; and

  — Use of natural landscaping and stormwater management in yards and parking areas.

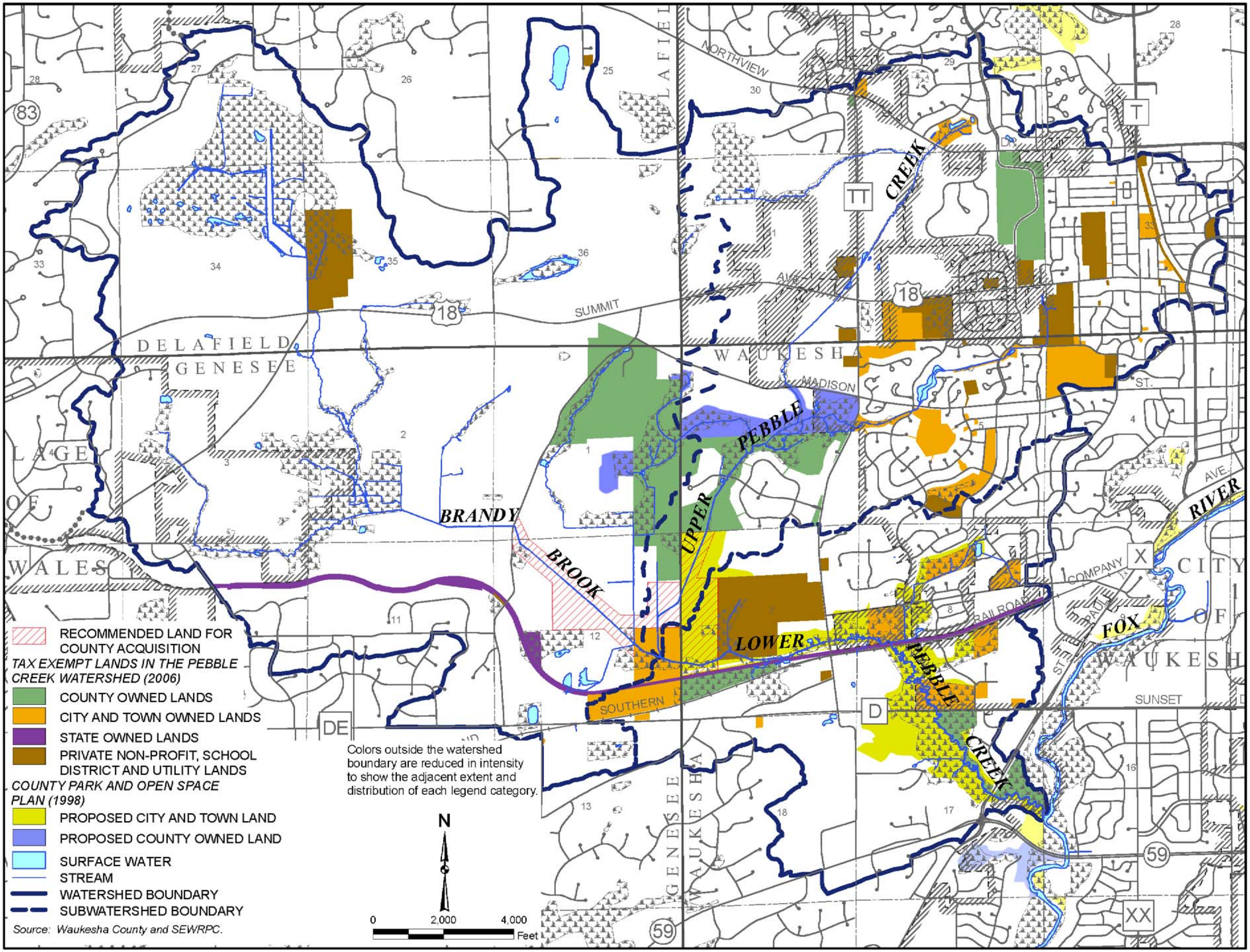
- Encourage participation of builders and developers in:

  — Workshops on special and alternative design considerations necessary for the preservation of the streams in the Pebble Creek watershed (see Waukesha County Nonpoint Information and Education Program Proposal below);

  — Use of erosion control and construction site stormwater management practices;

Map 41

RECOMMENDED REVISIONS TO THE COUNTY PARK AND OPEN SPACE PLAN WITHIN THE PEBBLE CREEK WATERSHED: 2005



— Environmentally friendly building, landscaping and conservation development practices (green building);

— Education of people in the process of building new homes to make positive environmental choices; and

— Green space preservation following the recommendations of this plan.

- Encourage participation of local government in:

— Educational programming through workshops, informational packets, etc.;

— Developing stewardship activities for watershed residents;

— Waste minimization and solid and hazardous waste management;

— Stormwater management and prevention of water pollution;

— Street sweeping and leaf pick up programs;

— Use of alternative salts and deicers, and snow removal;

— Storm sewer and catch basin maintenance; and

— Naturalized highway and road plantings/maintenance.

- It is recommended a comprehensive monitoring and evaluation plan be developed and implemented for the Pebble Creek watershed to assess the degree to which proposed watershed management measures, and alternative strategies meet the adopted goals and objectives (see Chapter VI for more details).

Waukesha County Nonpoint Information and Education Program Proposal
The following activities are being conducted by the Waukesha County Department of Parks and Land Use – Land Resources Division through an intergovernmental agreement with the participating municipalities from the Upper Fox Watershed Community Group. Unless otherwise noted below, the County has taken the lead on these activities and the municipalities provide support services, as needed. The proposed activities are grouped by three general target audiences, as listed below.

Objective
Comply with educational component of Municipal Separate Storm Sewer System (MS4) Permit Requirements under NR 216 of the *Wisconsin Administrative Code*.

Recommended Actions

- Suggestions for contractors, builders, developers, and consultants:

— Conduct periodic workshops to explain erosion control and stormwater management program requirements and permitting procedures. Also use the workshops to promote conservation sub-divisions, green roofs, rain gardens, and other effective Best Management Practices (BMPs). It is anticipated that at least one workshop be conducted annually in the county.

— Offer periodic demonstrations and tours to local sites to show how conservation subdivisions and BMPs such as those noted above can be used to reduce runoff pollution and meet local stormwater regulations. This may be combined with annual workshops or run as a separate event, depending on interest and availability of sites.

- Offer newsletter articles for Metropolitan Builders Association (MBA) and other local newsletters targeted to this audience, focusing on local nonpoint pollution control problems, solutions, ongoing program efforts and success stories. Also use these to advertise local workshops, tours, and demonstrations.

• Suggestions for the general public:

- Provide stencils, paint, and educational door hangers to schools, student groups or adult organizations to paint the message "Dump No Waste – Drains to River/Lake" on local storm drains. This ongoing activity educates the people doing the stenciling and residents living in the neighborhoods being stenciled.

- Offer periodic news releases and articles to local newspapers and articles for municipal newsletters announcing water quality related activities, programs, and services.

- Offer a speaker and equipment to local civic groups and other organizations to discuss local water quality issues and actions local citizens can take.

- Assist communities with preparing displays with handout materials for special events or building lobbies and entryways. Displays will focus on water quality, but be tailored to address seasonally specific issues, such as snow management, lawn fertilizer, fall leaf collection, etc.

- Promote runoff reduction from individual homes and businesses through a local rain garden workshop or demonstration, in cooperation with WDNR and the UWEX.

- Recognize (in local news releases/newsletters, incentives, etc.) local citizens that adopt "water friendly" practices around their home or business or otherwise promote nonpoint pollution control. This activity will depend on having good examples to recognize.

- Create resource lists for rain gardens, rain barrels, housekeeping, porous pavement, leaf mulching, and composting. Offer them as handouts and on the county web page.

- Offer interested citizens the opportunity to monitor a stream site once a month from April to September. Train and equip them to collect temperature, turbidity, biotic index, flow, and dissolved oxygen. This activity educates participants while collecting useful water quality data for monitoring program purposes.

- Promote yard waste composting and onsite mulching of leaves through flyers, web page, videos, etc. Continue offering free yard waste disposal and composting at the county-owned site in Genesee for all communities. Final compost product will be used as a topsoil substitute to reclaim a county-owned gravel pit on the site.

• Suggestions for teachers and students:

- Offer training and curriculum guides for teachers on the use of project WET in the classroom. Project WET is not an entire curriculum, but is supplemental water education that can be used in science, math, art, physical education and other areas. All activities are hands-on and water-related.

- Offer a speaker to local classrooms to discuss local water quality issues, including actions that students and their families can take to reduce nonpoint pollution.

- Help participating schools work through the WDNR's "Green & Healthy Schools" program. Assist school teams with completing the "water" and "school grounds" inventories, making recommendations for controlling runoff and reducing water usage. The County may also provides some grant dollars to help implement the recommendations and move toward State certification.

- Offer local teachers the opportunity to expose students to a one-time field trip for stream monitoring. Students would collect temperature, turbidity, biotic index, flow and dissolved oxygen. This type of monitoring is primarily designed to educate students on water quality issues and the techniques used to measure the impacts of land use on water quality.

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Chapter VI

PLAN IMPLEMENTATION

INTRODUCTION

The actions recommended in this plan largely represent an extension of ongoing actions being carried out by agencies such as the Waukesha County Department of Parks and Land Use; the Cities of Pewaukee and Waukesha; Towns of Delafield, Genesee, and Waukesha; and the Village of Wales in cooperation with neighboring municipalities, and state agencies. The recommended plan introduces few new elements, although many of the plan recommendations represent refinements of current ordinances and programs. With respect to the proposed new initiatives, the water quality, aquatic habitat and fisheries management programs introduce continuing field surveys to permit more efficient management of these resources. Likewise, refining performance standards and periodically reviewing current ordinance requirements and land management plans applicable to lands within the Pebble Creek watershed will contribute to enhanced and long-term protection of this valuable resource.

PLAN ADOPTION

Following completion of this protection plan, a public informational meeting should be held to provide citizens within the watershed the opportunity to review and provide input to the plan as part of the planning process, prior to presentation to and adoption by the County Board. Additional meetings with each community should be conducted, and copies of the approved report provided to advise City, Town, and Village officials of the actions requested of them to protect this vital resource. Digital copies of the plan are also available on the Waukesha County and SEWRPC websites.

POTENTIAL IMPLEMENTATION COSTS AND FUNDING SOURCES

A major cost element in the plan relates to the manner in which development occurs in the basin. Implementation of the recommended plan would entail capital expenditures for implementation of stormwater management and water quality management measures within the watershed and along the lands riparian to the stream and its tributaries. A New Hampshire study on the economic values of surface waters concludes that, even though the initial development costs may be slightly higher than has previously been the case, these costs are generally viewed favorably by landowners and the community in general, since they contribute to preserving the ambience of the area—with commensurate benefit to property values and quality of life.[1]

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[1]*Lisa Shapiro and Heidi Kroll, "A Study of the Economic Values of the Surface Waters of New Hampshire,"* Phase I Report, Preliminary Assessment of the Existing Literature, Data, and Methodological Approaches to *(Footnote Continued on Next Page)*

Typically additional land use recommendations, such as included in this watershed protection plan, have little or no impact on the amount of construction activity within the affected area and have been shown, in one New Jersey case study, to have little effect on the local tax base.[2] There may be additional upfront costs for developers, but they may be able to recoup some of these additional costs by selling lots at a higher price. Studies of the affects of watershed planning on the value of developed land within watershed protection areas have found that land values for developed land can increase by as much as 10 percent, and the value of vacant land by as much as 20 percent, as a result of the protection measures.[3] This Chesapeake Bay study notes, "residents benefited from the knowledge that public actions were taken to protect the environmental amenity in which they had already invested." Other studies focusing strictly on stream corridors indicate that properties located adjacent to a stream buffer can increase in value by more than 30 percent due to the "sense of place" created by water, green space, and forested natural areas.[4] People expressed a greater willingness to pay more to live near these protected natural resources. Taking a proactive stance, and installing stream buffers before pollutants degrade water quality, generally means that less money will need to be spent in the future on potentially costly remedial efforts. When these buffers also contain the entire 100-year floodplain, they are a very cost-effective form of flood damage control, both for communities and individual property owners. Conserving streamside vegetation, especially trees, within these buffers not only cools the stream, but also protects water quality.

Funding for these watershed management measures may be available as cost-share funding through the Chapter NR 50/51 Stewardship Grant Program, the Chapter NR 120 Nonpoint Pollution Abatement Program in the form of Targeted Runoff Management (TRM) and Urban Nonpoint Source grants, the Chapter NR 153/NR 154 Runoff Management Programs, and the Chapter NR 195 River Protection Grant Program. Under Chapter NR 120, additional, limited cost share funding may be available for maintenance of measures implemented within the Pebble Creek watershed under the previously funded Upper Fox River Priority Watershed Program. Appendix G provides additional opportunities under Federal grant programs and private funding sources.

It is recommended that communities consider the formation of stormwater utility districts within local jurisdictions and/or the adoption of an intergovernmental stormwater management entity under Section 66.0301 of the *Wisconsin Statutes.* Such entities would have authority to plan, implement, fund, and maintain stormwater management facilities and best management practices. An intergovernmental arrangement could coordinate and carry out these duties for the entire Pebble Creek watershed.

ROLES AND RESPONSIBILITIES

Role of Waukesha County

The suggested lead agency for implementation of the watershed protection plan is the Waukesha County Department of Parks and Land Use, Land Resources Division (LRD). In general, the LRD should continue to provide a coordinating role for the community, in cooperation with the appropriate local government units and state agencies. In addition, the Waukesha County Department of Parks and Land Use has oversight of shoreland, floodland, and shoreland wetland zoning in the unincorporated areas within the watershed. That department also

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(Footnote Continued from Previous Page)

Estimating the Economic Value of Surface Water*, August 2001;* Phase II Report, Estimates of Select Economic Values of New Hampshire Lakes, Rivers, Streams and Ponds*, June 2003.*

[2]*W.P. Beaton, "The Impact of Regional Land Use Controls on Property Values: the Case of the New Jersey Pinelands,"* Land Economics*, Volume 67 No. 2, pages 172-194, 1991.*

[3]*W.P. Beaton, "The Cost of Government Regulations, Volume 2, A Baseline Study for the Chesapeake Bay Critical Area," Chesapeake Bay Critical Area Commission, Annapolis, MD, 216 pages, 1988.*

[4]*Mark R. Correl, Jane H. Lillydahl, and Larry D. Singell, "The Effects of Greenbelts on Residential Property Values: Some Findings on the Political Economy of Open Space,"* Land Economics*, Volume 54 No. 2, 1978.*

regulates the installation and maintenance of all private onsite sewage treatment systems and stormwater management facilities for new development in the unincorporated areas.

Roles of Municipalities

An integral part of the maintenance and protection of Pebble Creek and its natural resources is sound land management practices within the watershed. While many of these practices can be implemented by individual property owners, community level action is predicated on the adoption and implementation of land use, stormwater management, and park and open space plans supported by appropriate zoning requirements. Many municipalities within the watershed have existing plans and ordinances in place as described in Chapter III. Nevertheless, such plans and ordinances should be reviewed and periodically updated to ensure conformance with current best management practices and technologies. Consequently, it is recommended that local municipalities within the Pebble Creek watershed develop, update, and implement land use, park and open space, and stormwater management plans consistent with the recommendations contained in this plan. Specifically, the review of applicable plans summarized in Chapter III suggests the following recommendations:

- City of Pewaukee:
  - Update and implement a land use plan;
  - Update and implement a stormwater management plan; and
  - Prepare and implement a park and open space plan.
- City of Waukesha:
  - Update and implement a land use plan; and
  - Prepare and implement a park and open space plan.
- Town of Delafield:
  - Prepare and implement a stormwater management plan.
- Town of Genesee:
  - Prepare and implement a land use plan;
  - Prepare and implement a stormwater management plan; and
  - Prepare and implement a park and open space plan.
- Town of Waukesha:
  - Update and implement a land use plan;
  - Prepare and implement a stormwater management plan; and
  - Prepare and implement a park and open space plan.
- Village of Wales:
  - Prepare and implement a stormwater management plan; and
  - Prepare and implement a park and open space plan.

Roles of Wisconsin Department of Natural Resources

The Department of Natural Resources is dedicated to the preservation, protection, effective management, and maintenance of Wisconsin's natural resources. It is responsible for implementing the laws of the state and, where applicable, the laws of the Federal government that protect and enhance the natural resources of our state. It is the one agency charged with full responsibility for coordinating the many disciplines and programs necessary to provide a clean environment and a full range of outdoor recreational opportunities for Wisconsin citizens and visitors. Part of WDNR's overall strategic plan is to work together with the public, organizations, and officials to provide Wisconsin with healthy, sustainable ecosystems. That mission is consistent with WDNR's participation as an active member of the Pebble Creek Watershed Advisory Committee.

WDNR staff serves a variety of functions from legal enforcement (including community and construction site stormwater runoff under NR 216, agricultural performance standards under NR 151, and review of local implementation of shoreland, floodplain and wetland zoning ordinances as summarized in Chapter III of this report) to science-based management of waste, air, land, and water resources. The WDNR also has designated fishery managers whose duties include protecting and managing fish, other aquatic biota, and their habitats. The designated WDNR fishery manager will be a key partner in the assessment of fisheries populations and other components of the aquatic ecosystem of Pebble Creek. Such managers are also responsible for a variety of other services that include: analyzing data, formulating and implementing management plans; assessing aquatic habitat; developing and implementing stream habitat mitigation, improvement, or restoration plans; and reviewing permit applications. It is important to note that one or more of the recommended measures, particularly actions associated with any instream work, summarized in Chapter V of this report may require permits from the WDNR prior to implementation. Therefore, based upon this regulatory responsibility, WDNR is a critical and important partner for the implementation of policies and actions summarized in this plan as well as the monitoring and evaluation of the Pebble Creek watershed to help ensure the sustained protection and improvement of this valuable resource.

MONITORING AND EVALUATION

Generally, water quality and fisheries management practices, such as the Water Action Volunteer monitoring and public awareness campaigns currently being implemented by the Waukesha County LRD, are recommended to continue with refinements as proposed below. Some aspects of these programs lend themselves to citizen involvement through participation with the school monitoring programs, and identification with environmentally sound owner-based land management activities. It is recommended that the Waukesha County LRD, in cooperation with the local municipalities, assume the lead in the promotion of such citizen actions, with a view toward building community commitment and involvement. Assistance is generally available from agencies such as the WDNR, the University of Wisconsin-Extension Service office, and SEWRPC.

Given that it is desirable to be able to consolidate data from various monitoring programs to facilitate evaluation of temporal and spatial variation and trends in water quality, it is recommended that agencies and organizations conducting monitoring adopt common quality assurances and quality control procedures. In addition, it is recommended that, to the extent possible, sampling protocols and analysis protocols be standardized across monitoring programs, including both agency programs such as WDNR baseline monitoring program and citizen-based programs. In order to facilitate the coordination of sampling and the dissemination of water quality data, it is also recommended that current data management systems be maintained and upgraded.

Citizen-based monitoring can act to increase awareness and understanding of local water quality issues and can spur local decisions and action to protect water quality. Currently the UW-Extension's Water Action Volunteers Program is active within the Pebble Creek watershed. Data collected by Level I volunteers in their program are submitted to the Water Action Volunteers Program's database. Data collected by Level II volunteers have been submitted for incorporation into publicly accessible WDNR databases. It is recommended that citizen-based monitoring efforts be continued and supported.

The methods and protocols used by these programs should be reviewed and upgraded to promote integration of the data they generate with data from agency-based programs. Specifically, this should replace the use of the current semi-quantitative WAV Biotic Index field collection methodology with a calibrated methodology such as that utilized by the WDNR stream monitoring protocol. Adoption of this methodology would permit calculation of indices such as the Hilsenhoff Biotic Index (HBI) or Family Biotic Index (FBI),[5] and allow evaluation of water quality changes within the stream system. The current WAV Biotic Index methodology is not capable of distinguishing biological diversity and/or water quality changes among sites. This would also shift the WAV biological monitoring effort to only one sample in the spring and/or fall, which would free up volunteer monitoring time in the summer months for the collection of other water chemistry and physical data. Additional data that could be collected would include continuous temperature data from sampling locations using programmable dataloggers placed and retrieved by the volunteers. In addition, the current baseline program should be expanded to include the collection of turbidity data during storm events.[6] Such collection could utilize the same equipment as the baseline program, but further target water quality during flood flows. In this regard, it would be important to sample from safe locations such as bridges. The opportunity is also available to incorporate physical channel measurements into the baseline program to assess long-term channel conditions such as streambank erosion and substrate composition. These elements lend themselves to increased opportunities for volunteer monitoring and will produce a more useful data set and lead to a more comprehensive understanding of the stream ecosystem.

As this plan is implemented, it will be important for implementing agencies to have access to monitoring data, in order to fine-tune implementation and to evaluate the effectiveness of water pollution control measures. It is further recommended that the findings of monitoring programs be set forth in reports prepared on an annual basis by the agencies and groups responsible for the data collection. In addition, it is recommended that the monitoring data be made available to agencies involved in plan implementation in a form that is readily usable and can be integrated with data from other monitoring programs.

Comprehensive Monitoring and Evaluation Plan

It is recommended that a comprehensive monitoring and evaluation plan for the Pebble Creek watershed be developed and implemented to assess the effectiveness and adequacy of existing and proposed watershed management measures and alternative strategies against adopted goals, objectives, and recommended actions. A comprehensive monitoring and evaluation plan should include:

- Establishment of long-term biological monitoring goals and objectives for the watershed;
- Continued gathering of accurate data for long-term study of stream health;
- Continued coordination of sampling efforts between organizations;
- Communication of monitoring results to stakeholders; and
- Qualitative and quantitative assessment of recommended actions.

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[5]*William L. Hilsenhoff, "An Improved Biotic Index of Organic Stream Pollution,"* Great Lakes Entomologist*, Volume 20, pages 31-39, 1987; and William L. Hilsenhoff, "Rapid Field Assessment of Organic Pollution with Family-Level Biotic Index," University of Wisconsin, Madison, 1988.*

[6]*See for example, Minnesota Pollution Control Agency, Citizen Stream Monitoring Program, http://www.pca.state.mn.us/water/csmp.html*

In addition, it is recommended that an annual assessment of the status of implementation be completed by County staff and communicated to the municipalities comprising the Advisory Committee, and to any citizen group that may be formed pursuant to recommendations set forth herein.

Further, it is recommended that a periodic review of the plan recommendations and the effectiveness of management measures be undertaken on a three- to five-year basis. Such a review should include the following actions:

- Evaluate appropriate, site-specific fish habitat and streambank stability treatment measures in Pebble Creek.

- Promote the modification of existing, and development of new, management measures as necessary and appropriate based upon the monitoring and assessment program findings.

- Convene and support a multi-agency work group, or other entity, responsible for implementing the necessary measures identified in the Pebble Creek Watershed Protection Plan, developing a Comprehensive Monitoring and Evaluation Plan for the Pebble Creek watershed, and refining these plans as necessary and appropriate based upon the outcomes of the foregoing actions.

This review should also include a qualitative and quantitative assessment of progress toward plan implementation using, among others, the following instream, land based, informational, and programmatic indicators.

- Instream measures:
  - Physical
    - Linear feet of eroding streambanks stabilized;
    - Linear feet of streams restored (remeandered, reconnected to floodplain, etc.); and
    - Numbers of obstructions removed including culverts, woody debris jams, and trash.
  - Chemical
    - Utilization of quantitative protocols for water quality monitoring; and
    - Percentage improvement in any quality parameter (i.e. turbidity, nutrients, bacteria, etc.).
  - Biological
    - Numbers and diversity of fisheries and macroinvertebrates within any portion of the stream network;
    - Continued presence of the primary coldwater indicator species such as mottled sculpin and brown trout within the streams; and
    - Utilization of quantitative protocols for water quality monitoring.
- Land based measures:
  - Area or linear feet of riparian corridors adjacent to streams established or expanded;
  - Acres of land within the watershed purchased and preserved for open space and recreation;

- — Numbers of properties on which invasive species are controlled in the watershed (i.e. clearing buckthorn, control of purple loosestrife, etc.);
- — Acres of sensitive lands (environmental corridors, etc.) lost or protected;
- — Acres of wetland or feet of stream restored (native seed plantings, re-creation of natural stream channels, bank regrading, connection with floodplain, etc.);
- — Numbers of stormwater facilities effectively providing both water quantity and water quality benefit (new systems and upgraded older systems);
- — Number of acres of conservation development designs for new development;
- — Consistency with adopted land use plans; and
- — Parcels, sites, or landowners that implement conservation practices to comply with agricultural nonpoint pollution performance standards.

- Informational measures:

  - — Number of people attending seminars and participating in awareness building programs (i.e. curb stenciling, litter pickups, attendance at lectures, etc.);
  - — Formation and active involvement of a "Friends of Pebble Creek" group possibly sponsored through the existing Friends of Retzer Nature Center association;
  - — Numbers of households participating in good housekeeping programs (use of low- or no-phosphorus fertilizers, composting, limited pesticide use)—such a program could be sponsored by a "Friends of Pebble Creek" group; and
  - — Evaluation of effectiveness of informational and education activities.

- Programmatic measures:

  - — Number of volunteers participating in continued monitoring;
  - — Adopting 75-feet wetland setbacks and shoreland buffers in local ordinances;
  - — Requiring conservation development designs for new developments through local ordinances;
  - — Adopting basement/structure separation standards from groundwater, bedrock, and surface water;
  - — Incorporating CTH TT/STH 59 bypass planning, design and construction recommendations;
  - — Adopting ordinance provisions to protect groundwater recharge areas;
  - — Updating floodplain zoning ordinances to incorporate new data;
  - — Updating stormwater ordinances to use SEWRPC rainfall depth/distribution;
  - — Revising stormwater ordinances to use unit peak discharge standards;

- Preparation of regional stormwater management plans for target areas;
- Use of county or local stormwater BMP tracking systems;
- Modified design standards for collector streets, etc., to reduce impervious surfaces;
- Creation of stormwater utility district(s);
- Improved enforcement of erosion control on one- to two-family sites;
- Nutrient management on public lands and regulation of phosphorous fertilizer;
- Use of agricultural conservation program cost-share funds to implement agricultural performance standards;
- Adoption of "Agricultural Enterprise Area", PDR, TDR, exclusive agricultural zoning, boundary agreements or other tools to encourage the continuation of agricultural uses in the watershed; and
- Tracking compliance with agricultural nonpoint performance standards.

CONCLUSION

Pebble Creek is a valuable natural resource in the Southeastern Wisconsin Region. As increases in population, urbanization, income, leisure time, and individual mobility may be expected to result in additional development pressures within the Pebble Creek watershed, adoption and administration of an effective management and protection program for Pebble Creek, based upon the recommendations set forth herein, will provide the water quality protection needed to maintain conditions in the watershed suitable for the maintenance of the natural beauty and ambience of the Creek and its recreational fishery.

APPENDICES

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Appendix A

PEBBLE CREEK WATERSHED PROTECTION PLAN ADVISORY COMMITTEE MEMBERS AND MEETINGS

COMMITTEE MISSION STATEMENT

"To advise Waukesha County and SEWRPC on the preparation of a plan aimed to protect the water resources of the Pebble Creek/Brandy Brook Watershed, and to assist with plan implementation."

MEMBERS OF THE PEBBLE CREEK WATERSHED PROTECTION ADVISORY COMMITTEE

Perry Lindquist (Chair), Waukesha County Land Resources Manager
Jim D'Antuono, Wisconsin Department of Natural Resources (SED)
Tim Barbeau, Town of Delafield Engineer
Steve Crandell, City of Waukesha Planner
Paul Day, City of Waukesha
Rich Eberhardt, Town of Waukesha Engineer
Russ Evans, Citizen/Waukesha Environmental Action League
Jeff Flaws, Village President, Wales
Jeff Herrmann, Town of Genesee Administrator/Planner
Larry Kascht, Retzer Nature Center
Dick Mace, Waukesha County Planning & Zoning Manager
Randy Melody, Harmony Homes/MBA
Maureen McBroom, Wisconsin Department of Natural Resources
Bill Mitchell, Waukesha County Board
Tom/Joan Oberhaus, Local Farmer/Town of Delafield Plan Commission
Steve Styza, Harmony Homes/MBA
Jeff Weigel, City of Pewaukee Public Works Director
Ron Williams, Farmer/Chair, Waukesha County Drainage Board

PROJECT STAFF

Michael G. Hahn, SEWRPC
Thomas M. Slawski, SEWRPC
Daniel R. Treloar, SEWRPC
Joshua A. Murray, SEWRPC
Alan Barrows, Waukesha County LRD
Mark W. Jenks, Waukesha County LRD

MEETINGS OF THE PEBBLE CREEK WATERSHED PROTECTION ADVISORY COMMITTEE

Date	Agency	Description
03-29-06	PCWPP Committee	First meeting of PCWPP Committee
04-26-06	PCWPP Committee	Second meeting of PCWPP Committee
07-18-06	PCWPP Committee	Third meeting of PCWPP Committee
10-04-06	PCWPP Committee	Fourth meeting of PCWPP Committee
12-20-06	PCWPP Committee	Fifth meeting of PCWPP Committee
04-04-07	PCWPP Committee	Sixth meeting of PCWPP Committee
05-09-07	PCWPP Committee	Seventh meeting of PCWPP Committee

Appendix B

LAND USE BY SUBWATERSHED

Table B-1

LAND USE IN THE BRANDY BROOK SUBWATERSHED: 2000-2035[a,b]

Category	2000		2005		2035		Change: 2005-2035	
	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent
Urban								
Suburban-Density, Single-Family Residential	146	2	153	3	156	3	3	2
Low-Density, Single-Family Residential	550	9	705	12	1,440	25	735	104
Medium-Density, Single-Family Residential	17	<1	39	1	67	1	28	72
High-Density, Single-Family Residential	0	0	0	0	0	0	0	0
Commercial	6	<1	7	<1	7	<1	0	0
Industrial	8	<1	8	<1	8	<1	0	0
Governmental and Institutional	11	<1	6	<1	10	<1	4	67
Transportation: Motor Vehicle Related[c]	192	3	268	5	424[d]	7	145	52
Transportation: Rail Related	2	<1	2	<1	- -	- -	- -	- -
Communication, and Utilities	5	<1	9	<1	- -	- -	- -	- -
Recreational	54	1	280	5	269	5	-11	-4
Subtotal	991	17	1,477	25	2,381	41	904	61
Rural								
Agricultural and Related	3,111	53	2,710	46	1,902	33	-808	-30
Water	26	<1	26	<1	26	0	0	0
Wetlands	840	14	839	14	834	14	-5	-1
Woodlands	483	8	462	8	462	8	0	0
Open Lands	394	7	331	6	240	4	-91	-27
Subtotal	4,854	83	4,368	75	3,464	59	-904	-21
Total	5,845	100	5,485	100	5,845	100	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 the increase to 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 projected 2035 land use combines Transportation, Communication, and Utilities into one category.*

Source: SEWRPC.

Table B-2

LAND USE IN THE UPPER PEBBLE CREEK SUBWATERSHED: 2000-2035[a,b]

Category	2000		2005		2035		Change: 2005-2035	
	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent
Urban								
Suburban-Density, Single-Family Residential	0	0	0	0	0	0	0	0
Low-Density, Single-Family Residential	363	10	367	10	521	15	154	42
Medium-Density, Single-Family Residential	764	21	927	26	1,238	35	311	34
High-Density, Single-Family Residential	83	2	134	4	160	5	26	19
Commercial	15	<1	30	1	46	1	16	53
Industrial......................................	2	<1	0	0	0	0	0	0
Governmental and Institutional	132	4	133	4	196	5	63	47
Transportation: Motor Vehicle Related[c]	458	13	496	14	605[d]	16	98	19
Transportation: Rail Related	0	0	0	0	- -	- -	- -	- -
Communication, and Utilities........	10	<1	11	<1	- -	- -	- -	- -
Recreational	53	1	53	1	174	5	121	228
Subtotal	1,880	53	2,151	60	2,940	83	789	37
Rural								
Agricultural and Related	997	28	804	23	238	7	-566	-70
Water...	8	<1	8	<1	8	<1	0	0
Wetlands	221	6	213	6	213	6	0	0
Woodlands	155	4	140	4	140	4	0	0
Open Lands.................................	295	8	240	7	17	0	-223	-93
Subtotal	1,676	47	1,406	40	616	17	-789	-56
Total	3,556	100	3,556	0	3,556	100	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 the increase to 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 projected 2035 land use combines Transportation, Communication, and Utilities into one category.*

Source: SEWRPC.

Table B-3

LAND USE IN THE LOWER PEBBLE CREEK SUBWATERSHED: 2000-2035[a,b]

Category	2000		2005		2035		Change: 2005-2035	
	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent
Urban								
Suburban-Density, Single-Family Residential	0	0	0	0	0	0	0	0
Low-Density, Single-Family Residential	420	20	422	20	634	31	212	51
Medium-Density, Single-Family Residential	212	10	212	10	225	11	13	6
High-Density, Single-Family Residential	0	0	0	0	0	0	0	0
Commercial	11	1	23	1	26	1	3	13
Industrial	59	3	76	4	83	4	7	9
Governmental and Institutional	7	<1	7	<1	26	1	19	271
Transportation: Motor Vehicle Related[c]	223	11	196	9	312[d]	13	97	45
Transportation: Rail Related	17	1	17	1	- -	- -	- -	- -
Communication, and Utilities	2	<1	2	<1	- -	- -	- -	- -
Recreational	178	8	177	8	223	10	46	26
Subtotal	1,129	53	1,132	53	1,529	72	397	35
Rural								
Agricultural and Related	425	20	425	20	125	6	-300	-71
Water	6	<1	6	<1	6	<1	0	0
Wetlands	357	17	357	17	340	16	-17	-5
Woodlands	89	4	89	4	89	4	0	0
Open Lands	120	6	117	6	37	2	-80	-68
Subtotal	997	47	994	47	597	28	-397	-40
Total	2,126	100	2,126	100	2,126	100	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 the increase to 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 projected 2035 land use combines Transportation, Communication, and Utilities into one category.*

Source: SEWRPC.

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Appendix C

PEBBLE CREEK BANK STABILITY SURVEY IN FALL 2004: DESCRIPTION OF FIELD MEASUREMENTS AND STATISTICAL ANALYSIS RESULTS

STREAMBANK CHARACTERISTICS

Bank Height: Height of the bank from the streambed to the top edge of the lateral scour line as shown in Figure C-1.

Undercut Depth: A bank that has had its toe of slope, or base, cut away by the water action creating overhangs in the stream as shown in Figure C-1.

Length of Erosion: Total linear distance of active erosion along the streambank as shown in Figure C-2.

Slope: Ratio of horizontal distance divided by the vertical height of the streambank as shown in Figure C-2.

INSTREAM HABITAT CHARACTERISTICS

Width: The width of the existing water surface measured at a right angle to the direction of flow from shore to shore.

Maximum Depth: The vertical height of the water column from the existing water surface level to the deepest point of the channel bottom.

Habitat Type: An aquatic unit, consisting of an aggregation of habitats having equivalent structure, function, and responses to disturbance. Pool, riffle, and run habitat types were observed in the Pebble Creek watershed.

- A pool is that area of the water column that has slow water velocity and is usually deeper than a riffle or run (Figure C-3). Pools usually form around bends or around large-scale obstructions that laterally constrict the channel or cause a sharp drop in the water surface profile.
- Riffles are portions of the water column where water velocity is fast, stream depths are relatively shallow, and the water surface gradient is relatively steep (Figure C-4).
- A run is that area of the water column that does not form distinguishable pools or riffles, but has a rapid nonturbulent flow. A run is usually too deep to be a riffle and has flow velocities too fast to be a pool.

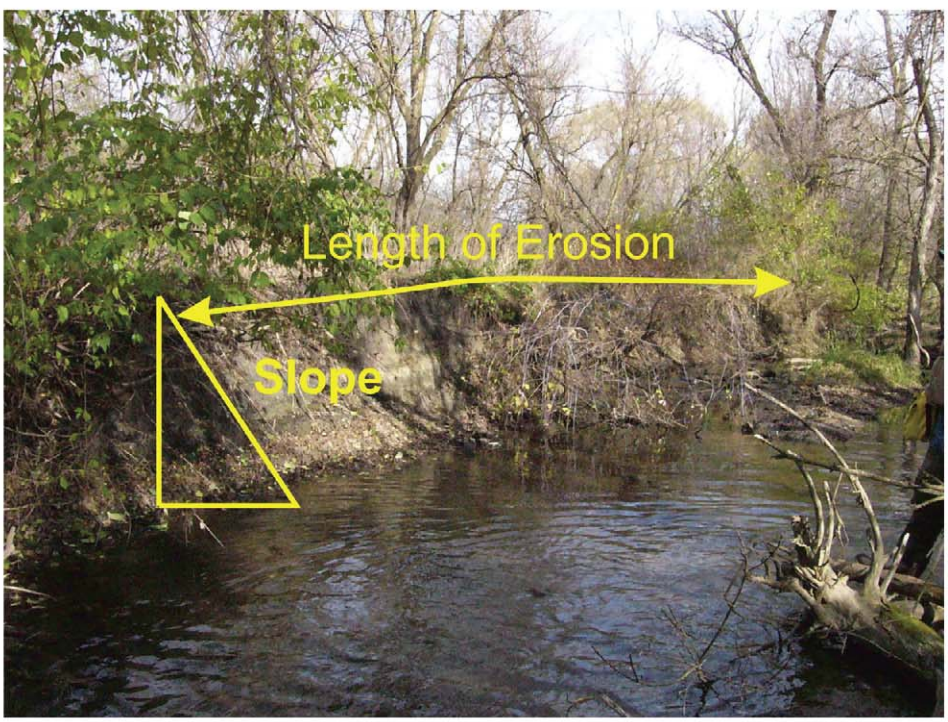
Figure C-1

EXAMPLE OF BANK HEIGHT AND UNDERCUT DEPTH MEASURED
AT AN ACTIVELY ERODING SITE REACH LP-2: FALL 2004

Source: SEWRPC.

Figure C-2

EXAMPLE OF LENGTH OF EROSION AND BANK SLOPE MEASURED
AT AN ACTIVELY ERODING SITE WITHIN THE UP-1 REACH: FALL 2005



Source: SEWRPC.

Figure C-3

POOL HABITAT IN THE FOX RIVER NEAR THE CONFLUENCE WITH PEBBLE CREEK: 2004

Source: SEWRPC.

Figure C-4

TYPICAL RIFFLE HABITAT IN THE PEBBLE CREEK WATERSHED: 2004

Source: SEWRPC.

Substrates: Refers to the materials that make up the streambed. Substrate composition was determined visually by recording the dominant substrate types within the area of the actively eroding streambank site. The following categories of substrate type were used.

- Boulder: Rocks with a maximum length of 10-20 inches.
- Cobble: Rocks with a maximum length of 2.5-10 inches.
- Gravel: Rocks with a maximum length of 0.07-2.5 inches.
- Sand: Inorganic particles smaller than gravel, but coarser than silt with a maximum length of 0.002-0.07 inches.
- Silt: Fine inorganic particles, typically dark brown in color. Feels greasy and muddy in hands. The material is loose and does not retain shape when compacted into a ball and will not support a person's weight when it makes up the stream bottom. Silt particles have a maximum length of less than 0.0001 inches.
- Clay: Very fine, inorganic, dark brown or gray particles. Individual particles are barely or not visible to the unaided eye. The particles feel gummy and sticky and slippery underfoot. Clay particles retain shape when compacted and partially or completely support a person's weight when they comprise the stream bottom. Clay particles have a maximum length of less than 0.0001 inches.

Sediment Depth: The depth of fine sediments (usually sand and silt) that overlay or comprise the streambed. Sediment depth is an indicator of sediment deposition and was measured to the nearest 0.1 foot.

Woody Debris: Large pieces or aggregations of smaller pieces of wood (e.g. logs, large tree branches, root tangles) located in or in contact with the water surface.

Woody Debris Jams: A group of three or more large diameter (greater than 7.8 inches) intermingled logs partially or completely submerged in the channel that substantially alter stream flow and sedimentation patterns.

FISHERIES PASSAGE BARRIERS

Culverts can create hydraulic and physical obstructions within a river system that result in reduced water depths and increased velocities that can limit fisheries passage.

Depth: In order to provide adequate fish passage a depth of at least nine inches at any point in the culvert is generally required.[1]

Velocity: In order to provide adequate fish passage velocities should not exceed three feet per second. In addition, a culvert should be designed so that the average stream bank full width, depth, and slope of the existing stream are maintained.[2]

[1] *SERC Stream Enhancement Research Committee,* Stream Enhancement Guide*, Province of British Columbia and the British Columbia Ministry of the Environment, Vancouver, 1980.*

[2] *Washington Department of Fish and Wildlife, Habitat and Lands Program, Environmental Engineering Division,* Fish Passage at Road Culverts: A Design Manual for Fish Passage at Road Crossings*, Washington, March 3, 1999.*

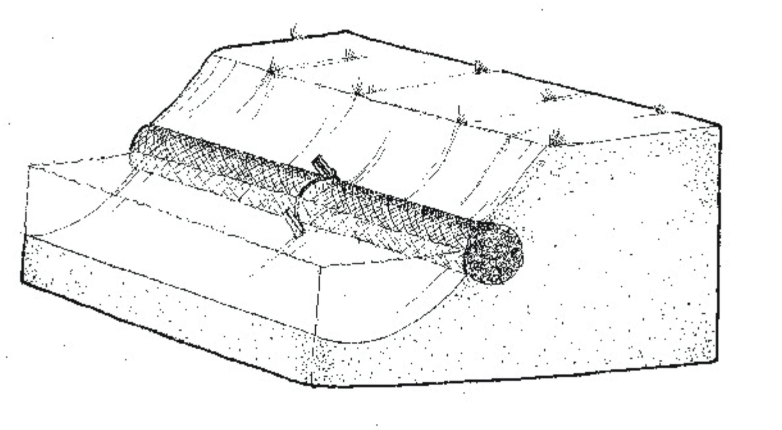
Appendix D

STREAMBANK BIOENGINEERING GUIDE

*Source: Bentrup, G, Hoag, C. The Practical Streambank Bioengineering guide, Wisconsin United States Department of Agriculture,<**http://plant-materials.nrcs.usda.gov/pubs/idpmcpustguid.pdf>**, May 1998.*

Additional References: Eubanks, C.E.Meadows, D. A soil bioengineering guide for Streambank and Lakeshore Stabilization United States Department of Agriculture Forest Service.
*<**http:// http://www.fs.fed.us/publications/soil-bio-guide**/>.*

FIBERSCHINE



Materials:

- fiber rolls or biologs
- 10-12 gauge wire
- wood stakes
- sledgehammer
- 2 person minimum

Description and Use

This technique uses a coconut-fiber roll product to protect the streambank by stabilizing the toe of the slope and by trapping sediment from the sloughing streambank. Cuttings and herbaceous riparian plants are planted into the fiberschine and behind it. By the time the fiberschine decomposes, riparian vegetation will have stabilized the streambank.

How to Install

1. Determine the length of treatment area and acquire the necessary amount of fiberschines from a supplier. Common tradenames for fiberschines include Biologs and Fiber Rolls. Be sure to order enough fiberschine to allow for a 5 foot extension past each end of the treatment area.
A list of suppliers can be obtained from the International Erosion Control Association listed in the Resource section of this guide. Fiberschines can be purchased in various diameters, with the 12 inch diameter being one of the more popular sizes.

2. Place the fiberschine along the toe of the streambank at approximately the low flow line. Submerge the fiberschine so that approximately ½ the fiberschine is below the water line. Place other fiberschines along the bank. Tie the ends of adjacent fiberschines together with strong twine.

3. It is critical to key the ends of the fiberschine into the bank to prevent flows from getting behind it. Both ends should then be protected with something hard such as rock to prevent the ends from being scoured.

4. Secure the fiberschine with 24 to 36 inch long wedge-shaped wooden stakes on both sides of the fiberschine at 5 foot intervals. Cut a 3/4" deep notch in each stake about 5" from the top. Tie twine or wire around each pair of stakes at the notches. Drive the stakes in so that the twine is secured against the top of the fiberschine.
Another option for securing the fiberschines is to use cable and soil anchors. This method will probably secure the fiberschine more firmly into the streambank.

5. Backfill behind the fiberschine by knocking down the top of the streambank onto the fiberschine.

6. Plant herbaceous wetland plants or willows into and behind the fiberschine. Herbaceous plants should be planted approximately 0.5-1 foot on center (see other Technique Sheets).

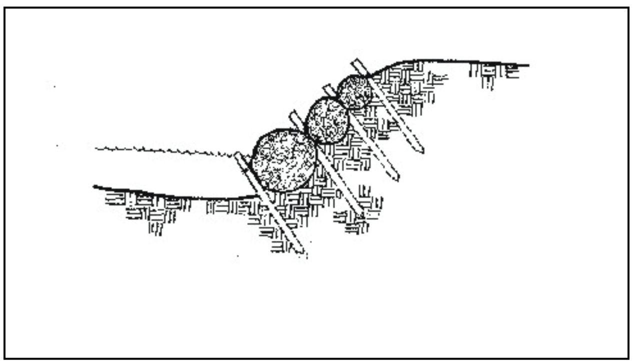
FIBERSCHINE

Inventory & Planning Considerations

1. Installation of the fiberschine can usually be accomplished throughout the year. High water periods should be avoided for safety reasons.

2. The fiberschine should extend upstream and downstream past the eroded area being treated to prevent flows from getting behind the fiberschine. Analysis and calculations may reveal that additional toe protection is necessary[1]. In many cases, rock may be appropriate if placed properly.
Improperly placed rock can result in erosion problems on the opposite streambank as well as downstream.

3. Be sure to key the upstream and downstream end of the fiberschine into the streambank and secure it with some hard materials such as tree trunks or large rocks.



Tiered Fiberschine Construction

4. If this method is used in a highly erodible area and bank shaping is not possible, a tiered fiberschine technique may be necessary. Three fiberschines of different diameters are often used but various numbers and combinations of sizes can be used.

5. Never disturb the site unnecessarily. Remember the goal is to stabilize a site. The less it is disturbed, the easier it will be to restore.

Management

To ensure the highest success for the treated area, determine the land management practices that created the eroded streambanks and modify those land use practices necessary.

If the area is grazed, restrict livestock from treated areas to allow the eroded section of streambank to heal. Exclosure fences are the most efficient means to accomplish this goal. Managers should resist the temptation to put the exclosure fences at the high water line. The exclosure areas should include enough of the riparian zone to allow the stream to shift naturally over time.

If the area is farmed, a riparian buffer strip should be established and maintained. A buffer strip on both sides of the stream should be set aside to allow for natural riparian vegetation and stream function. A wider buffer strip is strongly encouraged and will yield greater benefits.

Check with your local NRCS district conservationist for cost-share programs and volunteers for fencing, planting, and other restoration activities.

Finally, a stream is an interconnected system and landuse practices both upstream and downstream will affect the success of your bioengineering work. Talk with your neighbors and work together to create a healthier riparian and stream system that can benefit everyone.

Monitoring & Maintenance

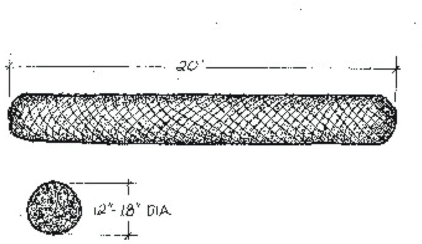
Do not ignore the project after it has been installed. Periodic monitoring of the project will provide valuable insight into the stabilization process and may offer important information for future projects. Periodic maintenance includes checking on the fiberschine to ensure that the posts and wire are holding the fiberschine in place. Additional native plantings may be necessary to accelerate the healing process.

FIBERSCHINE

Fiberschine Installation Procedure

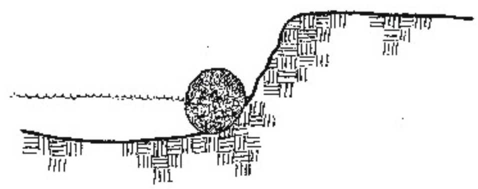
Step One: Acquisition of fiberschines

Acquire the amount of fiberschines needed for the project.



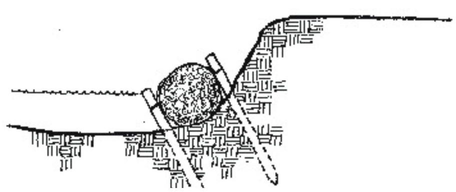
Step Two: Excavate Trench

Place fiberschine at the toe of the streambank at the low water line. Key in the ends of the fiberschine. See "How to Install".



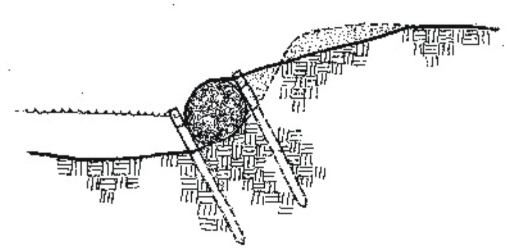
Step Three: Secure fiberschines

Drive notched wooden stakes at 5' intervals on each side of the fiberschine. Tie twine between each pair of notched stakes. Drive stakes in until twine is tight across the top of the fiberschine.



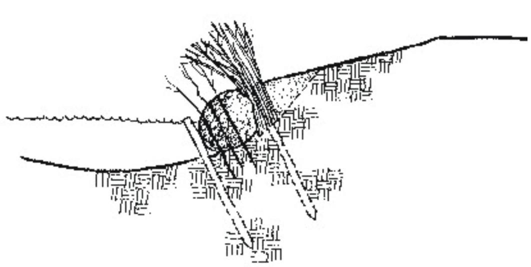
Step Four: Backfill

Backfill behind the fiberschine.



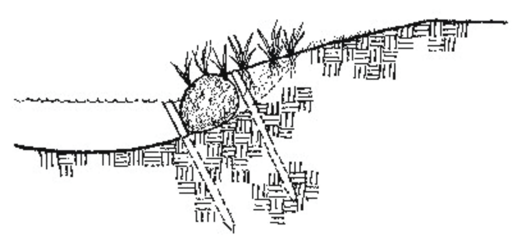
Step Five: Willow Plantings

Willow cuttings should be planted into and behind the fiberschine before backfilling.

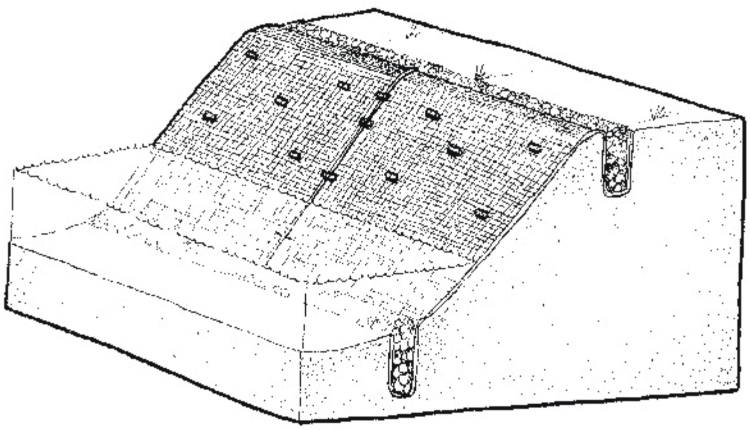


Step Six: Herbaceous Wetland Plantings

Herbaceous wetland plants should be planted into the roll and the soil after backfilling. Make sure the root systems are in saturated soil.



EROSION CONTROL FABRIC



Materials:

- erosion control fabric
- shovel
- sledgehammer
- wedge-shaped wood stakes
- 1 person minimum

Description and Use

Erosion control fabrics are commercially-available products that can be used to prevent erosion on slopes until vegetation establishes and has a chance to stabilize the slope. The fabrics are constructed of a variety of materials from coconut fiber or jute to straw mulch encased in plastic netting. For stream applications, a tightly woven coconut fiber blanket is the most durable option. Woody cuttings and herbaceous plants can be planted into the fabric and seed can be placed underneath the fabric. By the time the blanket decomposes (usually 2 to 5 years depending on local climate), vegetation will have significantly stabilized the streambank.

NOTE: Although this technique can be used by itself in a stream system, it is probably best to use this material with other techniques.

How To Install

Determine the square footage of the treatment area and acquire the necessary amount of fabric from a supplier. Order extra material to allow for overlap. A list of suppliers can be obtained from the International Erosion Control Association.

1. Seed the streambank with native herbaceous seed and rake to ensure good seed-soil contact. Fabrics are most effective on slopes that are no steeper than 2H:1V.

2. Excavate two trenches, one at the toe of the slope and the other at the top of the bank. The trench at the toe should be 12 inches deep and 6 to 8 inches wide. The trench at the top of the bank should be located at least a foot from the edge and should be 12 inches deep and 6 to 8 inches wide.

3. A key trench at the upstream end should be excavated perpendicular to the flow, connecting the ends of the other trenches (See illustrations).

4. The fabric should be placed on the streambank with the ends of the fabric in the trench so that the fabric is touching the three sides of the trench. Use a wedge-shaped wood stake to secure the fabric to the bottom of the trench.

5. Continue to cover the rest of the streambank with the fabric blanket. Install the blankets so the edge overlaps are shingled away from the direction of the current. Overlap the blanket edges approximately 12 inches and secure with wedge-shaped wooden stakes. Secure the blanket to the slope according to manufacturer specifications. Usually, a triangular spacing of 24" on center is suitable for stream applications. The upstream end of the blanket should be keyed into the final trench.

6. Backfill the trenches with excavated soil or small cobble and compact it

EROSION CONTROL FABRIC

Inventory & Planning Considerations

1. An important step with this technique is to ensure the upstream and downstream ends of the erosion control blanket are well keyed into the bank to prevent high flows from pulling the blanket out. Cobble should be placed in the key trenches to prevent the fabric from being pulled out.

2. Another important step is where the fabric overlaps, it should be shingled away from the direction of the current to prevent flows from pulling at the fabric.

3. Never disturb the site unnecessarily. Remember the goal is to stabilize a site. The less it is disturbed, the easier it will be to restore.

Management

To ensure the highest success for the treated area, determine the land management practices that created the eroded streambanks and modify those practices as necessary.

If the area is grazed, restrict livestock from treated areas to allow the eroded section of streambank to heal. Exclosure fences are the most efficient means to accomplish this goal. Managers should resist the temptation to put the exclosure fences at the high water line. The exclosure areas should include enough of the riparian zone to allow the stream to shift naturally over time.

If the area is farmed, a riparian buffer strip should be established and maintained. A buffer strip on both sides of the stream should be set aside to allow for natural riparian vegetation and stream function. A wider buffer strip is strongly encouraged and will yield greater benefits.

Check with your local NRCS district conservationist for cost-share programs and volunteers for fencing, planting, and other restoration activities.

Finally, a stream is an interconnected system and land use practices both upstream and downstream will affect the success of your bioengineering work. Talk with your neighbors and work together to create a healthier riparian and stream system that can benefit everyone.

Monitoring & Maintenance

Do not ignore the project after it has been installed. Periodic monitoring of the project will provide valuable insight into the stabilization process and may offer important information for future projects.

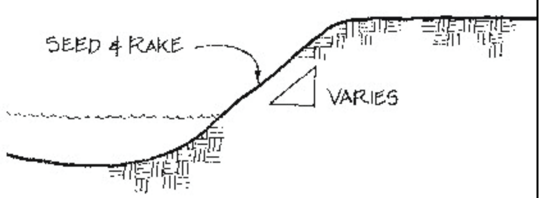
Periodic maintenance includes making sure the staples and key trenches are still securing the fabric blanket to the streambank. The upstream end should be carefully checked to make sure flows are not getting behind the blanket.

EROSION CONTROL FABRIC

Erosion Control Installation Procedure

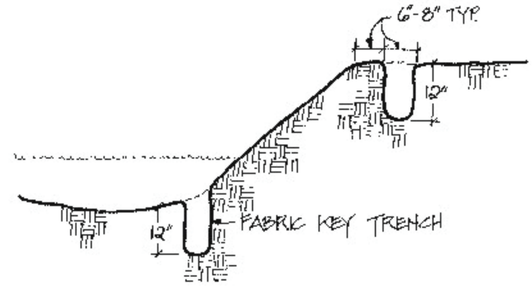
Step One: Seeding

Seed the streambank with native herbaceous seed and rake in to ensure good seed-soil contact. Slope varies-See "How to Install".



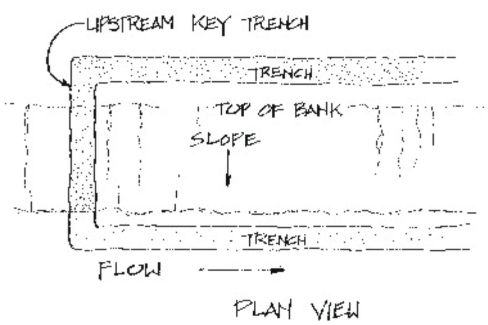
Step Two: Excavate Trench

Excavate two trenches as shown.



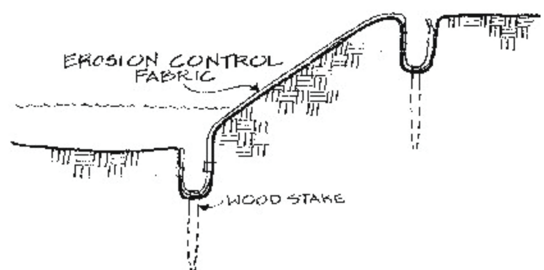
Step Three: Upstream Key Trench

Excavate an upstream key trench perpendicular to flows.



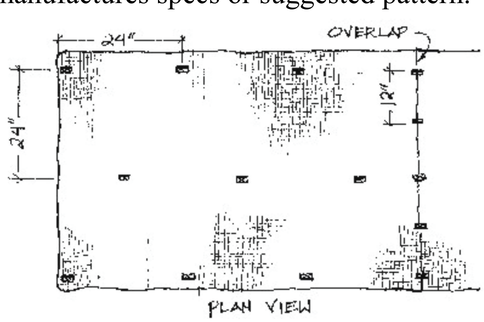
Step Four: Fabric Placement

Place fabric on streambank and in trenches and secure with a wedge-shaped wooden stake..



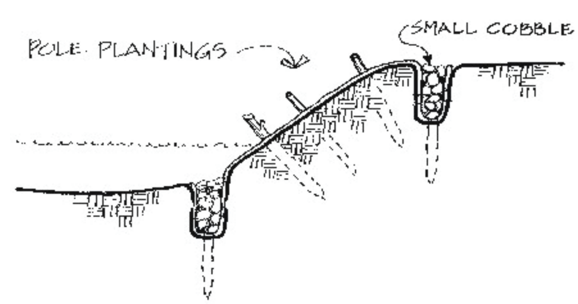
Step Five: Suggested Stake Layout

After laying out the blanket, secure the fabric with wedge-shaped wooden stakes according to manufactures specs or suggested pattern.

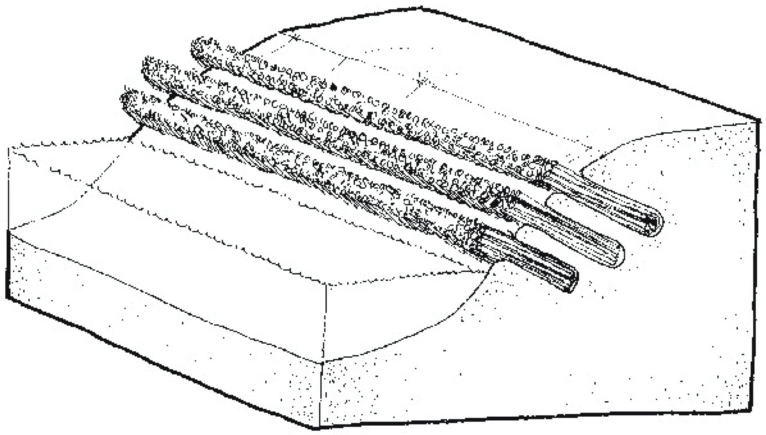


Step Six: Backfill

Backfill all trenches with excavated soil or small cobble and compact it.



BRUSH LAYERING



Materials:

- willow cuttings
- clothesline cord or wire
- chainsaw or loppers (to harvest willow)
- shovel
- 1 person minimum

Description and Use

This technique uses bundles of willow cuttings (Salix spp.) in buried trenches along the slope of an eroding streambank. This willow "terrace" is used to reduce the length of slope of the streambank. The willow cuttings will sprout and take root, thus stabilizing the streambank with a dense matrix of roots. Some toe protection such as a wattle, fiberschine, or rock may be necessary with this technique.

How To Install

1. Harvest willow cuttings from a local, native stand that is in healthy condition taking no more than 2/3 of each plant. Cuttings should be at least a 1/2 inch diameter or larger to ensure an adequate supply of stored energy for rooting, but there should be a good mixture of various sizes. This is to ensure better entrapment of sediment which will promote better root growth.

Ideally, cuttings should be collected during the dormant season to ensure the highest success rate. Cuttings can be collected during the growing season if all the leaves are removed from the stem, although establishment success will be lowered. Spring plantings are more successful than fall plantings.

2. The cuttings may be tied into bundles to facilitate transportation to the project site. The terminal bud should be removed so that stem energy will be re-routed to the lateral buds for more efficient root and stem sprouting.

3. Soak the bundles for 4 to 5 days.

4. Toe protection if needed should be installed prior to excavation. Excavate a horizontal trench into the streambank along the length of the area to be treated. The trench should be located between the annual low and high water levels. The trench should be approximately 2 to 3 feet deep and the back portion must reach the permanent water table. The surface of the trench should be sloped 10 to 20 degrees such that the outside edge is higher than the inside.

5. Cut the twine on the bundles and place the cuttings in the trench. Make sure the basal cut ends reach the back of the trench. Spread the cuttings in the trench until desired thickness is achieved. In general, the thicker and denser the cuttings, the better the technique will work.

6. Slough the bank down on to the cuttings and pack the soil into the cuttings. To remove air pockets around the cuttings, water the soil when backfilling. The cuttings should extend no more than 12 to 18 inches from the bank to prevent them from being ripped out during high flows. Trim off the excess.

7. Create another terrace for cuttings behind the first layer as shown in the illustrations. Repeat the trenching and layering process until the streambank is sufficiently covered with brush layers.

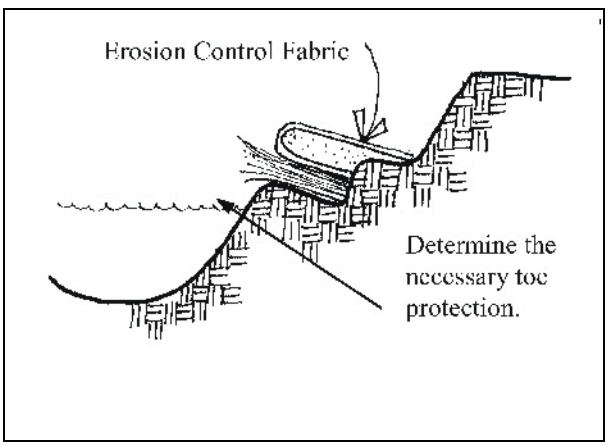
BRUSH LAYERING

Inventory & Planning Considerations

1. Coyote willow (Salix exigua) is a particularly good species for this method because of its' dense rooting system. This technique can also be used with a mixture of redoiser dogwood (Cornus sericea) and willow but to encourage rooting in the dogwood, the stems will need to be manually nicked or cut and treated with rooting hormone.

2. A critical inventory step is to determine the availability of moisture for the cuttings. This technique is best applied to areas with bank seepage to supply enough moisture for the cuttings. In our semi-arid to arid region, the upper portion of the streambank may not have enough permanent moisture to establish the cuttings, and thus, other techniques may be required.

3. Another critical step with this technique is to determine if toe protection is necessary. Analysis and calculations will provide some guidance[1]. In many cases rock will be necessary to provide adequate protection. In addition to toe protection, erosion control fabric can be used to protect the soil.



Brush Layering with Erosion Control Fabric

4. Give careful attention to the upstream and downstream ends of the treatment area to prevent flows from getting behind the layers. Tying into existing features on site such as trees and rocks or the additional placement of brush and rocks are possible solutions.

Management

To ensure the highest success for the treated area, determine the land management practices that created the eroded streambanks and modify those practices as necessary.

If the area is grazed, restrict livestock from treated areas to allow the eroded section of streambank to heal. Exclosure fences are the most efficient means to accomplish this goal. Managers should resist the temptation to put the exclosure fences at the high water line. The exclosure areas should include enough of the riparian zone to allow the stream to shift naturally over time.

If the area is farmed, a riparian buffer strip should be established and maintained. A buffer strip on both sides of the stream should be set aside to allow for natural riparian vegetation and stream function. A wider buffer strip is strongly encouraged and will yield greater benefits.

Check with your local NRCS district conservationist for cost-share programs and volunteers for fencing, planting, and other restoration activities.

Finally, a stream is an interconnected system and land use practices both upstream and downstream will affect the success of your bioengineering work. Talk with your neighbors and work together to create a healthier riparian and stream system that can benefit everyone.

Monitoring & Maintenance

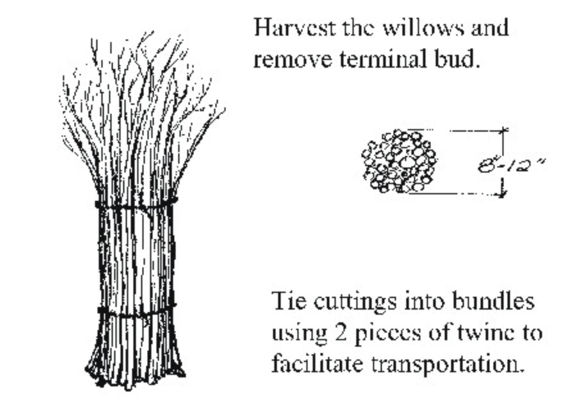
Do not ignore the project after it has been installed. Periodic monitoring of the project will provide valuable insight into the stabilization process and may offer important information for future projects.

Periodic maintenance includes making sure the streambank is not eroding close to the side of the trench. It may be determined that some additional protection is necessary to allow more time for the cuttings to take root and stabilize the streambank.

BRUSH LAYERING

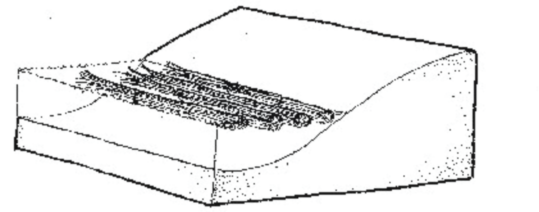
Brush Layering Installation Procedure

Step One: Acquire Willow



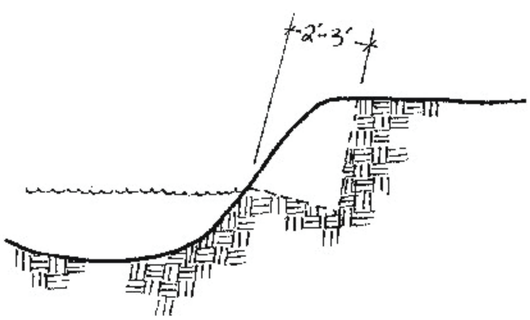
Step Two: Soak Willow Bundles

Soak the bundles for 5 to 7 days before planting. Remove from water before roots emerge.



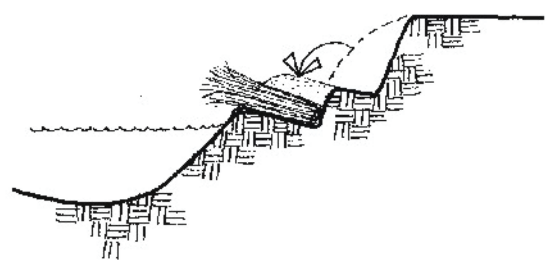
Step Three: Excavate Trench

Install the selected toe protection. Excavate the trench and make sure the trench slopes back..



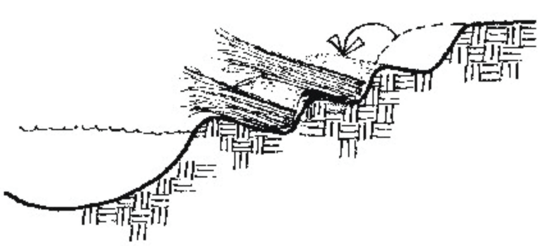
Step Four: Layer Placement

Lay out the cuttings along the trench and slough the bank onto the cuttings. Work the soils into the cuttings.



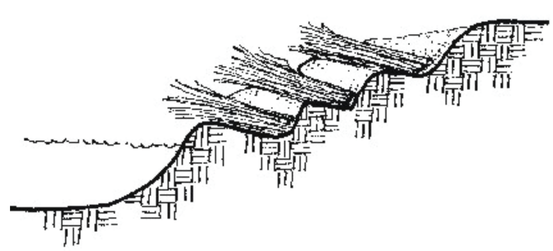
Step Five: 2nd Layer Placement

Create another terrace as shown and place the cuttings. Slough the bank on to the cuttings.

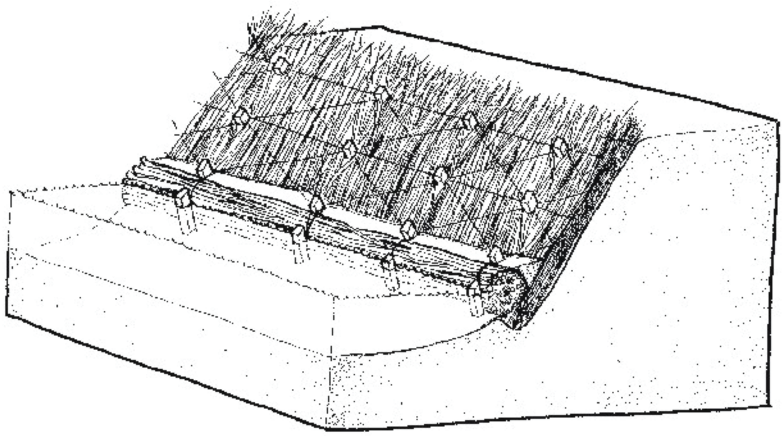


Step Six: 3rd Layer Placement

Repeat the process until the final layer is placed.



BRUSH MATTRESS



Materials:

- willow cuttings
- clothesline cord or wire
- chainsaw or loppers (to harvest willow)
- shovel
- 10-12 gauge wire
- wood stakes
- 2 person minimum

Description and Use

This technique uses a mat of willow cuttings along the slope of an eroding streambank. The cut ends of the willows are placed in a trench at the toe of the slope and are anchored with a wattle (See other techniques). A grid of wire and wooden stakes is used to secure the mat to the slope. The willow cuttings will sprout and take root, thus stabilizing the streambank with a dense matrix of roots.

How To Install

See Willow Wattle/Fascine techniques for information on collecting willow cuttings for the wattle and brush mattress.

1. Prepare the slope of the streambank by clearing away large debris, however, do not remove woody debris from the stream channel because this provides important fish habitat. The brush mattress technique is probably most effective on slopes no steeper than 2H:1V. Excavate a horizontal trench, 8 to 12 inches deep, at the toe of the streambank along the length of the area to be treated.

2. Place willow cuttings in the trench. Make sure the cut ends reach the bottom of the trench. Spread the cuttings along the face of the slope until a thickness of 4 to 6 inches is achieved.

3. Pound in a grid of 24 to 36 inch long wooden stakes into the mattress every 3 to 4 foot centers (See illustrated procedure). Use longer stakes in less cohesive soil. Secure the brush mattress by using 10-12 gauge galvanized annealed wire or clothesline cord tied in horizontal runs and then diagonally between each row of stakes. Tie the wire to the stakes in such a manner that if the wire breaks between two stakes, the integrity of the remaining wiring is maintained.

4. After wiring the mattress, drive the stakes in further to compress the mattress tightly against the streambank.

5. Construct a wattle the length of the area to be treated (refer to Willow Wattle techniques). Make sure the wattle is tightly tied together. Place the wattle in the trench over the cut ends of the brush mattress. Secure the wattle with 18 to 48 inch long wedge-shaped wooden stakes every 5 feet as shown the illustrated sequence. Use longer stakes in less cohesive soil. In some instances, a rock toe may be used instead of a willow wattle to anchor the cut ends of the mattress.

6. Backfill around the wattle and mattress by using material excavated from the trench, making sure to work soil into the branches. Use buckets of water to wash the soil down into the stems. Key the upstream end of the mattress and wattle into the streambank to prevent high flows from getting behind the mattress. It is a good idea to protect this area with some revetment, large rocks, or tree trunks.

BRUSH MATTRESS

Inventory & Planning Considerations

1. Make sure the upstream end of the wattle and mattress is keyed back into the bank to prevent high flows from scouring behind the mattress. Brush revetment, rock barbs, large rocks, and tree trunks can be used in front of this area to protect the mattress.

2. Be sure to pound in the stakes after wiring the mattress in order to compress the mattress tightly against the streambank.

3. Coyote willow (Salix exigua) is a particularly good species for this method because of its' dense rooting system.

4. Rooting hormones and fertilizers do not significantly improved success compared to the cost of the materials.

5. Never disturb the site unnecessarily. Remember the goal is to stabilize a site. The less it is disturbed, the easier it will be to restore.

Saw a 2 x 4 diagonally to produce 2 stakes. The length will vary based on soil conditions. Use longer stakes in less cohesive soil(i.e. sandy soils).

Management

To ensure the highest success for the treated area, determine the land management practices that created the eroded streambanks and modify those practices as necessary.

If the area is grazed, restrict livestock from treated areas to allow the eroded section of streambank to heal. Exclosure fences are the most efficient means to accomplish this goal. Managers should resist the temptation to put the exclosure fences at the high water line. The exclosure area should include enough of the riparian zone to allow the stream to shift naturally over time.

If the area is farmed, a riparian buffer strip should be established and maintained. A buffer strip on both sides of the stream should be set aside to allow for natural riparian vegetation and stream function. A wider buffer strip is strongly encouraged and will yield greater benefits.

Check with your local NRCS district conservationist for cost-share programs and volunteers for fencing, planting, and other restoration activities.

Finally, a stream is an interconnected system. Land use practices both upstream and downstream will affect the success of your bioengineering work. Talk with your neighbors and work together to create a healthier riparian and stream system that can benefit everyone.

Monitoring & Maintenance

It is important to monitor the project after it has been installed. Periodic monitoring of the project will provide valuable insight into the stabilization process and may offer important information for future projects.

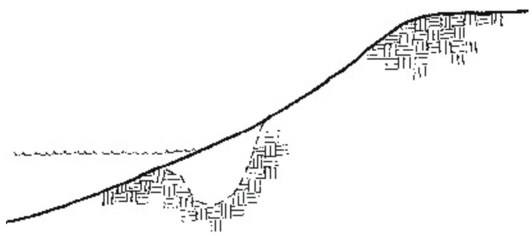
Periodic maintenance includes making sure the stakes and wire are still securing the mattress to the streambank. The upstream end should be carefully checked to make sure flows are not getting behind the mattress.

BRUSH MATTRESS

Brush Mattress Installation Procedure

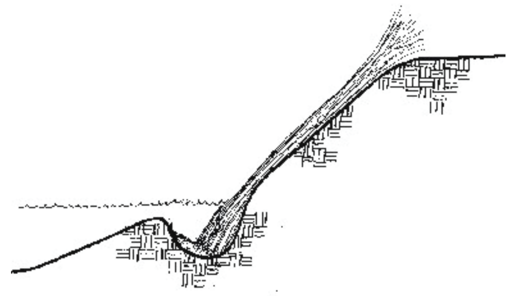
Step One: Excavate Trench

Willow collection, soaking and wattle construction should occur prior to excavation of the trench. See "How to Install".



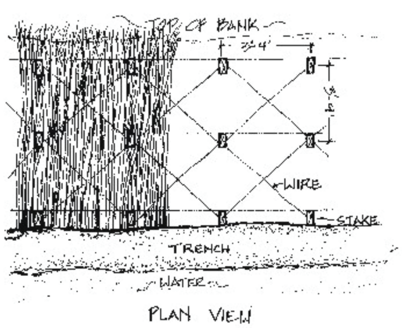
Step Two: Mattress Placement

Place willows in the trench, making sure the cut ends reach the bottom.



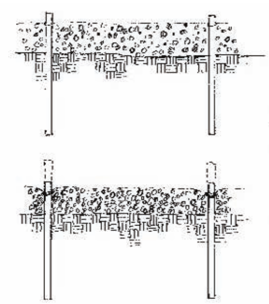
Step Three: Stake Placement and Wiring

Establish a gird of wedge-shaped wooden stakes and wire as shown.



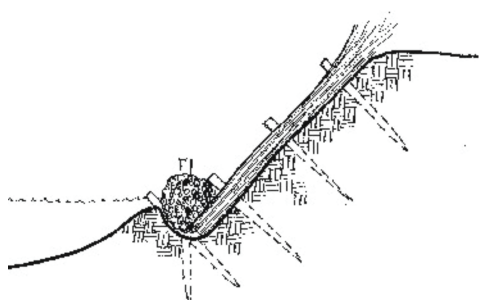
Step Four: Mattress Compression

After wiring the mattress, drive the stakes in further to compress the mattress against the streambank.



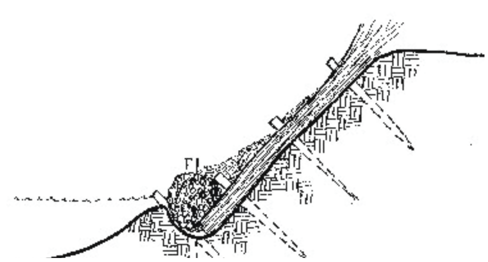
Step Five: Secure Wattle

Place wattle in trench. Secure wattle with 2 wedge-shaped wooden stakes as shown

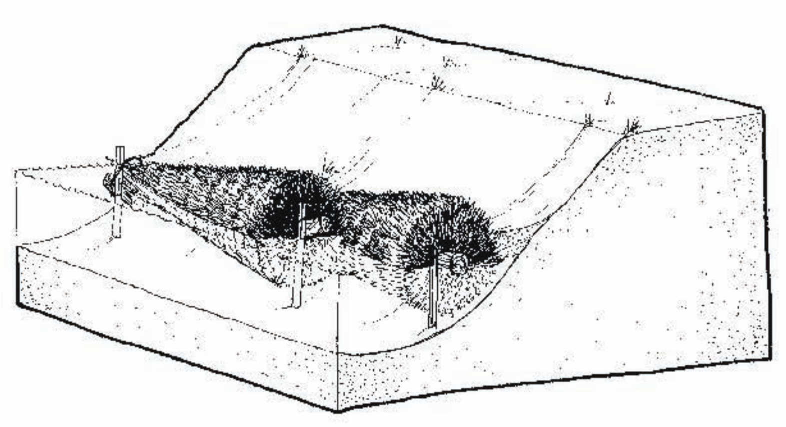


Step Six: Backfill

The mattress and wattle should be partially covered with soil, making sure to work the soil into the voids. Leave parts of the blanket exposed for sprouting.



BRUSH OR TREE REVETMENT



Materials:

- dead/live brush or trees such as junipers or hawthorns
- 10-12 gauge wire
- poly rope
- 7-1/2'metal T-posts
- wire cutters
- post pounder
- chainsaw (for cutting brush)
- 2 person minimum

Description and Use

Brush or trees are secured to the streambanks slow excessive erosion by diverting the current away from the bank edge's. The revetment also traps sediment from the stream and sloughing streambank and provides overhead cover for fish habitat. The revetment material does not need to sprout (most species used will not). Always plant live willows or other quickly sprouting species behind the revetment to provide permanent cover and roots.

How To Install

1. Collect trees or brush and stage at treatment area. Use trees with dense branching such as junipers, because they will collect more sediment. Place the first tree with the stump pointing upstream at the top of the treatment area along the top of the bank. Overlap the next tree trunk into the main branches of the first one. Continue this process until a linear row of brush the length of the treatment area is created.

2. Secure the revetment together by tightly wiring at the overlap sections. Overlap by about 1/3 at each end. Wire main trunks together, leaving branches loose.

3. Pound temporary T-posts along the top of the streambank behind the revetment every 12 to 15 feet. At each post, tie an 8 to 10 foot section of rope to the revetment and wrap it around the post.

4. Pound a permanent T-post at the toe of the slope of the streambank at the upstream end of the treatment area. Lower the upper end of the revetment and secure it to the post in stream with wire.

5. Lever the revetment into the stream, while using the rope at each of the posts to control placement and to secure it temporarily. Continue the process until revetment is placed along the streambank.

6. Pound T-posts on the outside edge (stream side) of the revetment at overlap areas. Secure the revetment to posts with wire. Remove rope and temporary posts on the top of the streambank.

7. Fill in the space between the streambank and revetment with additional branches or wattles to form a dense matrix of brush.

8. (Optional) To enhance recovery of treated area, knock down the sloughing streambank on the revetment to create a more gentle streambank slope. Make sure the revetment has enough brush material to catch the soil. If not, add additional brush before shaping the bank. Willow cuttings or other quickly sprouting species should then be planted on the new slope using techniques such as willow wattles, brush mattress, vertical bundles, or willow pole plantings (see other techniques).

NOTE: Illustrated procedure is shown on page 3. Revetment can be constructed in the water by permanently installing one tree at a time.

BRUSH OR TREE REVETMENT

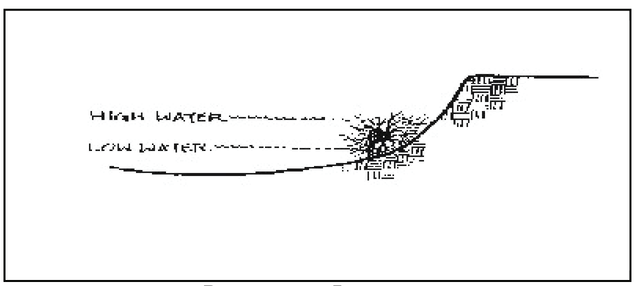
Inventory & Planning Considerations

1. Installation of brush or tree revetment can usually be accomplished throughout the year. For safety reasons, avoid high water periods.

2. Typically, the trunks of the revetment should be placed between the annual low and high water levels.

In areas of extreme fluctuation in water levels, it may be necessary to place a second row of revetment at the high water line in order to prevent scouring behind the revetment during flood events.

3. It is critical that the revetment extend upstream and downstream at least 1 to 3 tree lengths past the eroded area being treated to prevent flows from getting behind the revetment. Key the upstream and downstream ends of the revetment into the bank and reinforced with additional brush or rock. These endpoints are the sections most likely to fail and require substantial protection.



Revetment Location

4. Never disturb the site unnecessarily. Remember that the goal is to stabilize a site. The less it is disturbed, the easier it will be to restore.

Management

To ensure the highest success for the treated areas, determine the land management practices that created the eroded streambanks and modify those land use practices as necessary.

If the area is grazed, restrict livestock from treated areas to allow the eroded section of streambank to heal. Exclosure fences are the most efficient means to accomplish this goal. Managers should resist the temptation to put exclosure fences at the high water line. The exclosure areas should include enough of the riparian zone to allow the stream to shift naturally over time.

If the area is farmed, a riparian buffer strip should be established and maintained. A buffer strip on both sides of the stream should be set aside to allow for natural riparian vegetation and stream function. A wider buffer strip is strongly encouraged and will yield greater benefits for the streambanks and the riparian area as a whole.

Check with your local NRCS district conservationist for cost-share programs, volunteers for fencing, planting, and other restoration activities.

Finally, a stream is an interconnected system. Land use practices both upstream and downstream will affect the success of your bioengineering work. Talk with your neighbors and work together to create a healthier riparian and stream system that will benefit everyone.

Monitoring & Maintenance

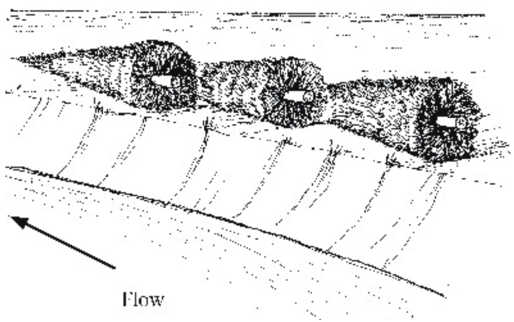
Do not ignore the project after it has been installed. Periodic monitoring of the project will provide valuable insight into the stabilization process and may offer important information for future projects. Periodic maintenance for brush or tree revetment includes checking the revetment to ensure that the posts and wire are holding it in place. If significant erosion is still occurring in sections of the treated area, additional brush should be added to the revetment.

BRUSH OR TREE REVETMENT

Brush or Tree Revetment Installation Procedure – Option A

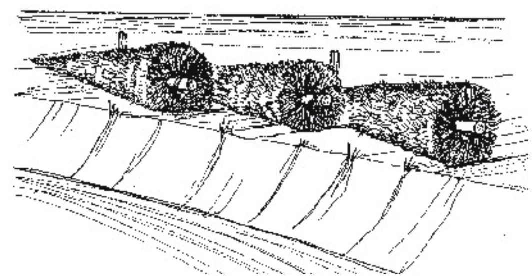
Step One: Harvest & Stage Material

Overlap the trunk of one tree into the main branches of the next tree.



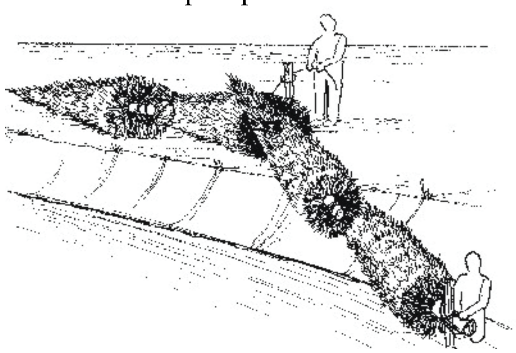
Step Two: Fastening Revetment

Secure the trees together at the main trunks using wire. Place T-posts along the revetment and secure rope from the posts to the revetment



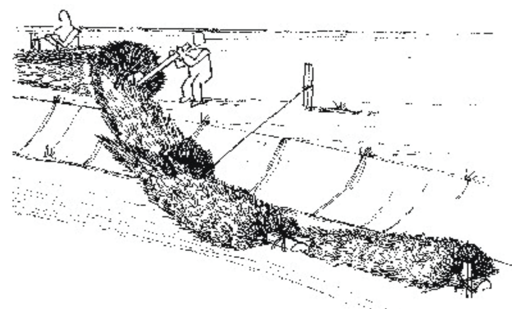
Step Three: Begin Placement

Lower revetment into stream and fasten end of revetment to a T-post placed at toe of bank.



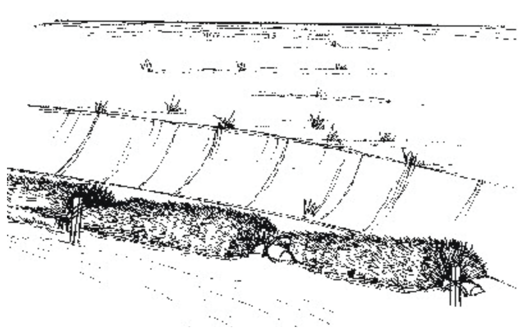
Step Four: Final Placement

Lever the rest of the revetment into the stream, temporarily securing the revetment to the T-posts.



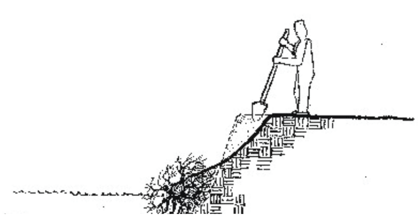
Step Five: Final T-Post Placement

Pound T-posts next to the revetment and secure revetment to posts with wire.



Step Six: Optional Bank Shaping

Streambank can be knocked down on to the revetment. Slope should be seeded with grass and planted with willows.
The slope can also be treated with techniques like brush mattress. See other techniques.

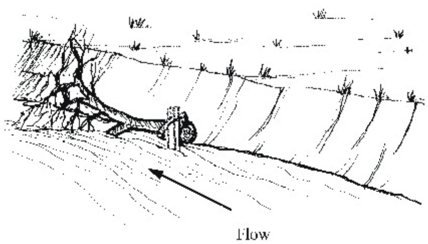


BRUSH OR TREE REVETMENT

Brush or Tree Revetment Installation Procedure – Option B

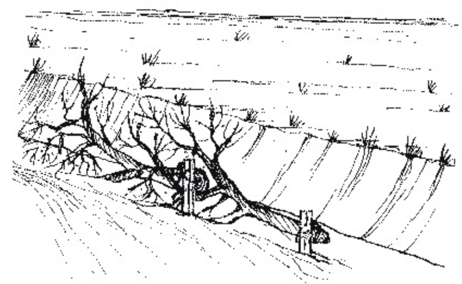
Step One: Placement of First Tree

Pound a T-post at the downstream end and secure the trunk of the first tree to the post using wire.



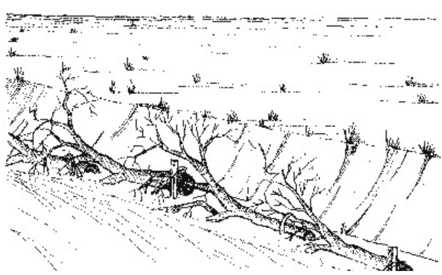
Step Two: Placement of Second Tree

Overlap the second tree onto the first tree so that no large gaps exist. Wire the trunks together.



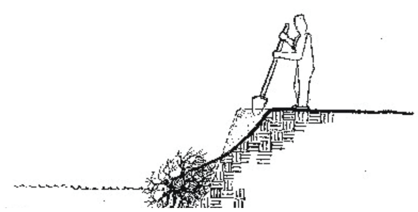
Step Three: Continue Placement

Pound a T-post near the second tree and secure tree to post. Continue placement of trees and posts till area is treated.



Step Four: Optional Bank Shaping

Streambank can be knocked down on to the revetment. Slope should be seeded with grass and planted with willows.
The slope can also be treated with techniques like brush mattress. See other techniques.



How To Install

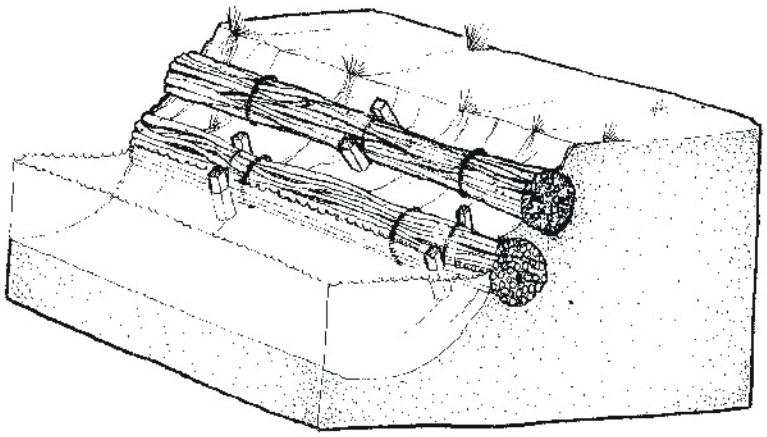
1. Harvest the trees for the revetment and stage near site. Pound a T-post at the downstream end of the site. Secure the first tree to the post with the trunk pointing upstream.

2. Place the second tree so the branches overlap the trunk of the first tree. The goal is to provide for a continuous row of dense branches to protect the streambank. Wire the main trunks together, leaving the branches loose. Pound in another T-post to secure the trunk of the second tree.

3. Continue the process of placing and securing trees until area is treated. Fill in the space between the bank and the revetment with branches to create a dense matrix of brush or willow wattles.

4. (Optional) To enhance recovery of the treated area, knock down the sloughing streambank on to the revetment to create a more gentle streambank slope. Plant willow cuttings on the new slope using techniques such as willow wattles, vertical bundles or willow pole plantings (see other techniques).

WILLOW WATTLES OR FASCINES



Materials:

- willow cuttings
- clothesline cord or wire
- wood stakes
- chainsaw or loppers (to harvest willow)
- shovel
- 1 person minimum

Description and Use

Willow wattles (Salix spp.) or live fascines are cigar or sausage-like bundles of live cuttings tied together and inserted into a shallow trench dug into the streambank. The willow bundles will sprout and take root, thus stabilizing the streambank with a dense matrix of roots. This is a good technique to break up slope length and minimize erosion.

How To Install

1. Harvest willow cuttings from a local stand that is in healthy condition taking no more than 2/3 of each plant. Cuttings should be at least a 1/2 inch diameter or larger to ensure an adequate supply of stored energy for rooting, but there should be a good mixture of various sizes. This is to ensure better entrapment of sediment that will promote better root growth.
Ideally cuttings should be collected during the dormant season to ensure the highest success rate. Cuttings can be collected during the growing season if all the leaves are removed from the stem, although establishment success will be lowered.

2. The cuttings can be tied into bundles to facilitate transportation to the project site. The terminal bud should be removed so that energy will be re-routed to the lateral buds for more efficient root and stem sprouting.

3. Soak the bundles for 5 to 7 days before planting.

4. After soaking, the bundles should be laid out in one, long sausage-shaped bundle with the cut ends placed in alternating directions. The bundle should be tied every 18 inches.

5. Excavate a horizontal trench 2/3 the diameter of the wattle in the streambank at approximately the low flow line.

6. Place the wattle in the trench and stake every 3 to 4 feet with 24 to 42 inch wedge-shaped wooden stakes Stake length will depend on soil conditions. Place stakes on both sides of the wattle and wire across the bundle. Backfill around the wattle by knocking the top of the bank on to the wattle, making sure to work soil into the branches.

Often a second wattle is placed up the bank behind the first wattle. If the streambank consists of saturated soils for most of the growing season, a series of wattles can be established up the streambank. However, in the arid and semi-arid regions, there is normally not enough moisture near the surface to establish several layers of wattles. Pole plantings[2] might be a good option behind the initial wattle since the poles will reach the permanent watertable. It should also be noted that some additional toe protection such as rock may be necessary for this technique.

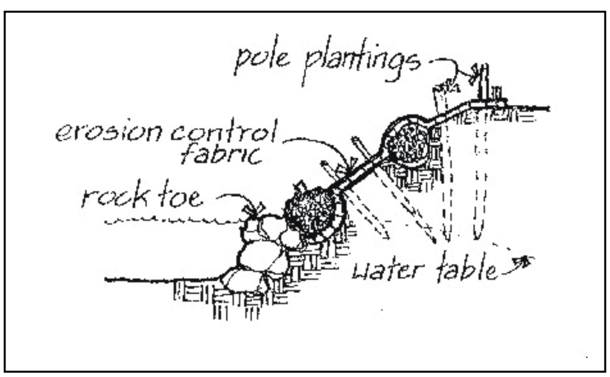
WILLOW WATTLES OR FASCINES

Inventory & Planning Considerations

1. Coyote willow (Salix exigua) is a particularly good species for this method because of its' dense root system. This technique can also be used with a mixture of redoiser dogwood (Cornus spp) and willows. To encourage rooting in the dogwood, the stems need to be manually nicked or cut and treated with rooting hormone.

2. If this method is used in a highly erodible area, some protection should be placed in front of the wattles to prevent scour. Analysis and calculations of forces will provide guidance for suitable toe protection[1]. In some cases, brush revetment or fiberschines may be adequate (see other techniques), while other situations may require rock. If no other protection is used, the wattle should be 12 to 24 inches in diameter.

3. Another variation of this technique is to cover the wattles with erosion control fabric to prevent the soil from being washed away from the wattles.
Secure the fabric under the first wattle. Poles can be planted into the permanent water table between the wattles. The following illustration also shows the use of a rock toe to prevent scour.



Wattles with Fabric and Pole Planting

4. Rooting hormones and fertilizers do not significantly improved success for the cost of the materials.

5. Never disturb the site unnecessarily. Remember that the goal is to stabilize a site. The less it is disturbed, the easier it will be to restore.

Management

To ensure the highest success for the treated area, determine the land management practices that created the eroded streambanks and modify those practices as necessary.

If the area is grazed, restrict livestock from treated areas to allow the eroded section of streambank to heal. Exclosure fences are the most efficient means to accomplish this goal. Managers should resist the temptation to put the exclosure fences at the high water line. The exclosure areas should include enough of the riparian zone to allow the stream to shift naturally over time.

If the area is farmed, a riparian buffer strip should be established and maintained. A buffer strip on both sides of the stream should be set aside to allow for natural riparian vegetation and stream function. A wider buffer strip is strongly encouraged and will yield greater benefits.

Check with your local NRCS district conservationist for cost-share programs and volunteers for fencing, planting, and other restoration activities.

Finally, a stream is an interconnected system and land use practices both upstream and downstream will affect the success of your bioengineering work. Talk with your neighbors and work together to create a healthier riparian and stream system that can benefit everyone.

Monitoring & Maintenance

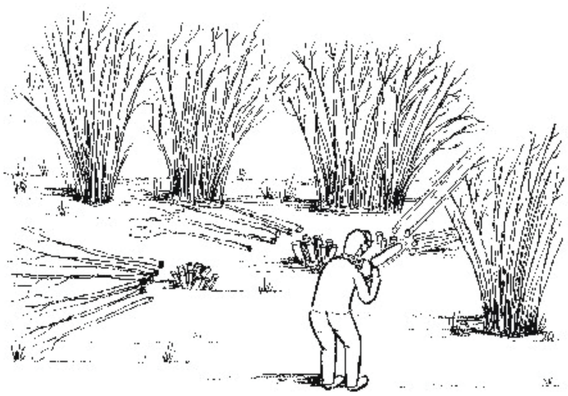
Do not ignore the project after it has been installed. Periodic monitoring of the project will provide valuable insight into the stabilization process and may offer important information for future projects.

Periodic maintenance includes making sure the wattle is secured to the streambank and that some soil cover remains on the wattle. Additional plantings may be necessary to speed up the rate of vegetative establishment and spread.

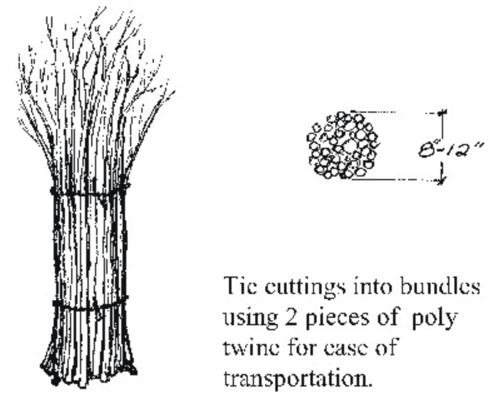
WILLOW WATTLES OR FASCINES

Willow Wattles or Fascines Installation Procedure

Step One: Harvest Willow Cuttings

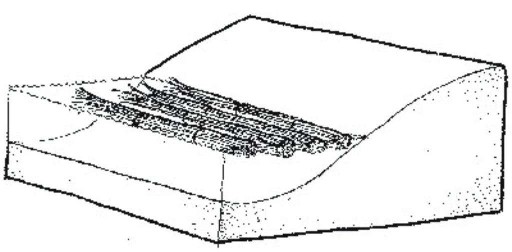


Step Two: Create Wilow Bundles



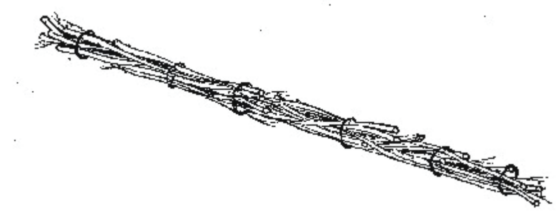
Step Three: Soak Willow Bundles

Soak bundles for 5 to 7 days. Remove them from water before roots emerge.



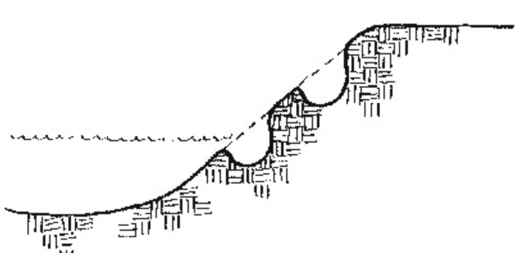
Step Four: Build Wattle

Build one long sausage-shaped bundle with the cut ends alternating directions. The bundle should be tied every 18 inches.



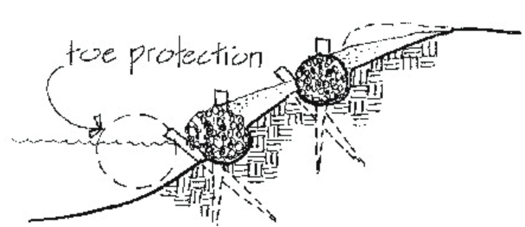
Step Five: Excavate Trench

Excavate a horizontal trench 2/3 the diameter of the wattle along the streambank at approximately the low flow line at the toe of the bank.



Step Six: Place Wattle

Place the wattle in the trench and stake with wedge-shaped stakes. Backfill around the wattle by knocking the top of the bank onto the wattle. Leave some of the branches exposed to sprout.



Appendix E

CRITERIA AND GUIDELINES FOR STREAM CROSSINGS TO ALLOW FISH PASSAGE AND MAINTAIN STREAM STABILITY WITHIN THE PEBBLE CREEK WATERSHED PROTECTION PLAN

TYPES OF CROSSINGS

- The number of stream crossings should be minimized.
- If a crossing is necessary, structures that maintain to the extent possible the existing streambed and bank conditions are more preferable; therefore, bridges spanning streams are more preferable than other structures.
- If a culvert is necessary, open bottom structures are more preferable than a closed bottom structures.
- If a closed bottom culvert is necessary, box culverts, elliptical, or pipe arch culverts are preferable to round pipe culverts, because round pipes generally reduce stream width to a much larger degree than the aforementioned structures, causing long term upstream and downstream passage limitations (see physical considerations below).

BIOLOGICAL CONSIDERATIONS[1]

- Contact the area WDNR fisheries manager prior to design.[2]
- Species of fish present (coldwater, warmwater, threatened, endangered, species of special concern).
- Life stages to potentially be impacted (e.g. egg development within substrates should be avoided).
- Migration timing of affected species/ life stages (e.g. adult spawning times should be avoided).

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[1]*British Colombia Ministry of Forests,* Fish-stream crossing guidebook, *For. Prac. Br., Min. For., http://www.for.gov.bc.ca/tasb/legsregs/fpc/FPCGUIDE/Guidetoc.htm, Victoria, B.C. Forest Practices Code of British Columbia guidebook, 2002.*

[2]*UW-Extension and WDNR,* Fish Friendly Culverts*, 2002.*

PHYSICAL CONSIDERATIONS[3]

It is important to note that in order to achieve the minimum physical criteria outlined below, the culvert(s) will need to be oversized as part of the design to ensure adequate long-term fish passage as well as the ability to pass the designed rainfall event period.

It is understood that it may not be possible to achieve some of the minimum passage criteria below based upon specific on-site conditions or constraints, however, the closer the design and completed culvert can meet these criteria the better the long-term passage and overall sustainability of the fishery will be achieved in this region.

Provide Adequate Depth

- Slope—Culvert should be installed with a slope that matches the riffle slope as measured in the thalweg (see Minnesota DNR guidelines[4])

- Water Depth—Depths should maintain the determined thalweg depth at any point within the culvert during low flow periods (see Minnesota DNR guidelines).

- Installation Below Grade—The culvert should be installed so that the bottom of the structure is buried to a depth equal to 1/6th the bankfull width of the stream (up to two feet) below the natural grade line elevation of the stream bottom (see Minnesota DNR guidelines). The culvert should then be filled to stream grade with natural substrates. The substrates should consist of a variety of gravel ranging from one to four inches in diameter and either mixed with nonuniformly laid riprap or uniformly placed alternate riprap baffles, large enough to be stable during the culvert design discharge, which will ensure stability of substrates during high flow events.

Provide Adequate Width

- Width—Culvert width shall match the bankfull width (minimum) of the existing channel.

- Offsetting Multiple Culverts—The number of culverts used should be minimized. However, if multiple culverts are necessary, it is recommended that the culvert inverts be offset vertically and only one culvert be designed to provide passage during low flow conditions and the additional culverts be used to pass the higher flow events (see Figure E-1). Therefore, the low flow culvert will be the only culvert, in a series of two or more culverts, designed to provide fish passage during low flows and shall meet the physical requirements of passage above.

Provide adequate Resting Areas

- Length—Culverts that exceed more than 75 feet in length need to provide additional resting areas (e.g. installation of baffles or weirs) within the culvert to facilitate passage.[5]

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[3]*Washington Department of Fish and Wildlife, Habitat and Lands Program, Environmental Engineering Division,* Fish Passage Design at Road Culverts: A Design Manual for Fish Passage at Road Crossings*, Washington, March 3, 1999.*

[4]*Minnesota DNR,* Best Practices for Meeting DNR General Public Waters Work Permit GP 2004-0001*, March 2006.*

[5]*Thomas Slawski and Timothy Ehlinger, "Habitat Improvement in Box Culverts: Management in the Dark?,"* North American Journal of Fisheries Management*, Volume 18:676-685, 1998.*

Figure E-1

COMPARISON OF UNDERSIZED AND ADEQUATELY SIZED AND PLACED CULVERTS

Undersized culvert | Properly sized and placed culverts

Source: Minnesota Department of Natural Resources.

Inlet and Outlet Protection

- Align the culvert with the existing stream alignment (e.g. 90 degree bends at the inlet or outlet should be avoided, even though this will increase culvert length, see Minnesota DNR guidelines).
- The low flow culvert should be centered on the thalweg of the channel to ensure adequate depths inside the culvert.
- Provide grade control where there is potential for head-cuts that could degrade the channel.
- It may be necessary to install riprap protection on the outside bank below the outlet to reduce bank erosion during high flow events.

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Appendix F

RIPARIAN BUFFER EFFECTIVENESS ANALYSIS

INTRODUCTION

The scientific literature on the effectiveness of riparian buffers in improving water quality through processing and removing anthropogenic contaminants from surface and ground waters is extensive. Added to this literature is legal practice that has established the principle of shoreline setbacks, especially with respect to both the shoreland management of lakes and flowages and to flood control. Recently, riparian buffers have been employed as an environmental management tool. Despite significant research efforts, there remains no consensus for what constitutes optimal riparian buffer design or proper buffer width to achieve maximum pollutant removal effectiveness, water quality protection, and biological protection. The Wisconsin Buffer Initiative (WBI) further developed two key concepts that are relevant to this plan: 1) riparian buffers are very effective in protecting water resources, and 2) riparian buffers need to be a part of a larger conservation system to be most effective.[1] However, it is important to note that the WBI limited its assessment and recommendations solely to the protection of water quality, and did not consider the additional values and benefits of riparian buffers such as flood control, prevention of channel erosion, provision of fish and wildlife habitat, enhancement of environmental corridors, and water temperature moderation, among others.

This analysis seeks to identify documented scientific information extracted from published literature, which allowed the derivation of the recommended 75-foot-wide riparian buffer width for lakes and streams in the regional water quality management plan update study area, and by extension, the Southeastern Wisconsin Region. This will aid managers and planners in making decisions about establishing, maintaining, or restoring riparian buffers adjacent to all waterbodies. Although, buffer width stands out as one factor influencing the capacity for buffers to remove potential contaminants, numerous other factors described herein play significant roles in the establishment of 75-foot-wide riparian buffers.

More than 65 peer-reviewed scientific publications dating from 1975 through 2005 were examined for data on the effectiveness of riparian buffers for total suspended solids (TSS), nitrogen, and phosphorus removal around streams and lakes. These data form the basis for defining the relationship between buffer width and percent removal efficiencies for those contaminants. When introduced into the natural environment in quantities or

[1]*University of Wisconsin-Madison, College of Agricultural and Life Sciences,* The Wisconsin Buffer Initiative*, December 2005.*

concentrations exceeding the absorption capacity of shoreland buffers, these potential pollutants have the ability to negatively impact waterways and waterbodies, diminishing their utility as recreational and aesthetic resources and reducing their value as essential elements of aquatic ecosystems.

As part of this analysis, three key elements were incorporated into the general 75-foot buffer width recommendation set forth in the regional water quality management plan update. These elements are:

- The value of riparian buffers as vegetated zones adjacent to streams, lakes, and wetlands and their use as a best management practice (BMP) for **controlling contaminants** such as nutrients and TSS entering waterbodies.

- The value of riparian buffers as habitat areas adjacent to streams, lakes, and wetlands and their use as a BMP for **protecting and maintaining species** habitat and diversity, especially among species of economic concern.

- The role of riparian buffers as a **component of comprehensive watershed management plans**, which must also include point source and nonpoint source control of nutrients and TSS loadings.

CONTROL OF CONTAMINANTS

Riparian buffers are one of the most effective best management practices to protect water resources in terms of water quality, riverbank stability, wildlife habitat, and aesthetics. These strips of grass, shrubs, and/or trees along the banks of rivers, streams, and lake shorelines filter polluted runoff and provide a transition zone between the land and water and associated human uses. These buffers work in various ways and with varying degrees of effectiveness. Effectiveness depends upon a number of factors including the nature of the specific contaminant, its environmental reactivity, the mass of contaminant being conveyed across the land surface, and the distance and slope across which the contaminant is being carried. The role of buffers in controlling and managing the transfer of several major contaminants through the land-water ecotone, or interface, is briefly reviewed below.

Sediment Filter
Riparian buffers help catch and filter out sediment and debris from surface runoff. Depending upon the width and complexity of the buffer, generally 50 percent to 100 percent of the sediment particles—as well as the nutrients and other contaminants attached to them—can settle out and be retained within the buffer strip as plants slow sediment-laden runoff waters. These buffers act as physical filters, retaining particulates within the mass of plant materials, roots, and stalks. For this purpose, wider forested buffers are even more effective than narrow grassed buffers.

Nutrient Filter, Transformer, and Sink
Riparian buffers "trap" pollutants that could otherwise wash into surface and ground water. Such buffers act both as a physical filter, retaining contaminants that adhere to sediment particles through the settling processes described above, and as biological filters. The plants that comprise the buffer strips can utilize a portion of the nutrient load being processed through the buffer strip for nutrition and growth. Phosphorus and nitrogen from sources such as fertilizer application and animal waste can become pollutants if more is applied to the land than upland plants can use. These "excess" nutrients can be transported by runoff of rainfall or snowmelt to aquatic systems, such as streams and lakes where the nutrients are then available to support and sustain the growth and reproduction of shoreland and aquatic plants. In large quantities, these plants commonly limit recreational use of the waters and shorelands, and interfere with the aesthetic enjoyment of these areas.

Phosphorus stimulates growth (i.e. it is a growth limiting element) of both terrestrial and aquatic plants in the Southeastern Wisconsin Region, and is largely responsible for the eutrophication of our waterbodies. The affinity of this element to soil particles results in approximately 80 percent or more of the available phosphorus being captured when sediment is filtered out of surface runoff by passing through the buffer.

In the case of nitrogen, another important element for plant growth, the chemical and biological activity in the soil, particularly in the soils of streamside forests, can capture and transform nitrogen and other pollutants into less biologically-available forms. Nitrogen-fixing bacteria are especially useful in capturing "excessive" nitrogen and transforming the elemental nitrogen into biologically available and/or gaseous forms.

It should be noted that, with respect to aquatic systems, the vegetation within the buffers acts as a temporary sink as the nutrients and excess water are taken up by root systems and stored in the biomass of trees during the growing season. A large portion of these nutrients are then re-released into the environment during the autumn as the plants senesce or die; however, nutrients entering the aquatic environment during the fall are less likely to create or contribute to conditions that interfere with human recreational use and aesthetic enjoyment of the downstream water resources.

Stream Flow Regulator
Riparian buffers slow the passage of water across the land surface and allow water to infiltrate into the soil. This recharge contributes to the maintenance of the groundwater supply. Groundwater reaches streams and rivers at a much slower rate, and over longer periods of time, than surface runoff. Thus, increasing recharge helps maintain stream flow during the driest times of the year.

Bed and Bank Stabilizer
Riparian buffer vegetation helps to stabilize streambanks and shorelines and reduce erosion. The roots of the plants hold bank soils together, and the stems protect banks by deflecting the erosive action of waves, ice, boat wakes, and storm runoff. In like manner, riparian buffers also can reduce the amount of streambed scour by absorbing surface water runoff and slowing water velocities. When plant cover is removed, more surface water reaches a stream, causing the water to crest higher during storms or snowmelt, and subjecting the shorelands to higher flow velocities that can scour shorelines and streambeds.

Effectiveness of Shoreland Buffers
The following range of buffer widths can be gleaned from the literature:

- To Stabilize Eroding Banks: On smaller streams, good erosion control may only require covering the banks with shrubs and trees, and a 35-foot-wide managed grass buffer. If there is active bank erosion, or on larger streams, at least a 50-foot width is necessary. Severe bank erosion on larger streams may require engineering actions to stabilize and protect the bank; however, once completed, bank protection can be done with plants. For better stabilization, more of the buffer should be planted in shrubs and trees.

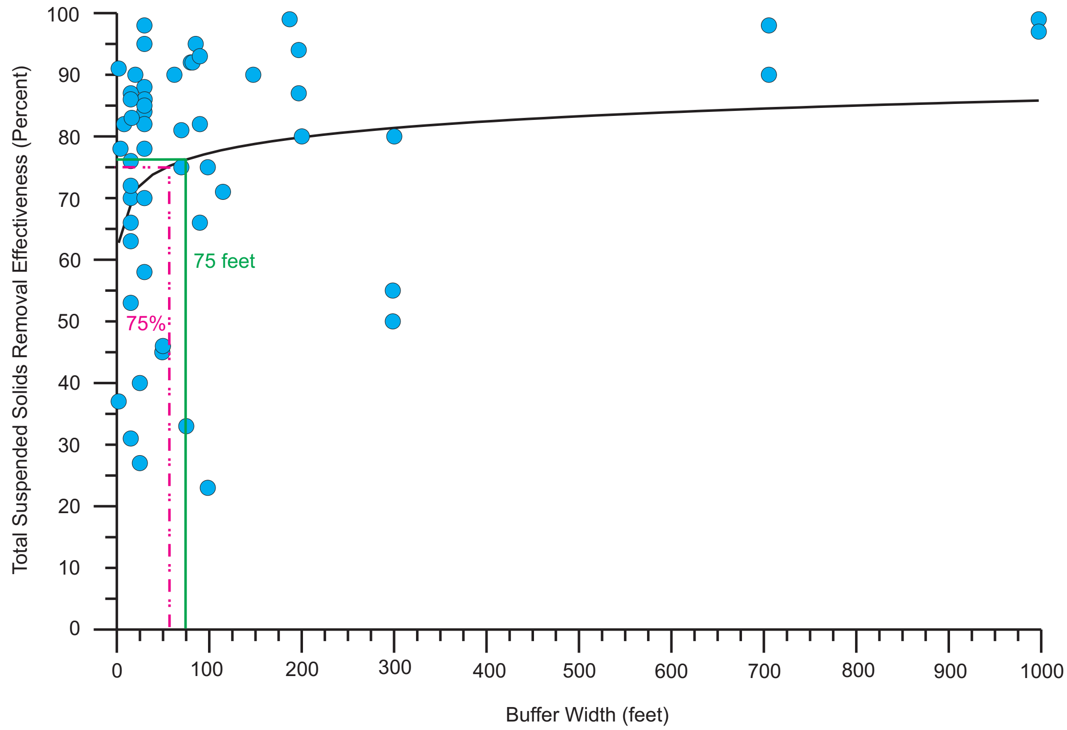
- To Filter Sediment and Attached Contaminants from Runoff: For slopes of less than 15 percent, most sediment settling occurs within a 35-foot-wide buffer of grass. Greater width is needed on steeper slopes, for shrubs and trees, or where sediment loads are particularly high.

- To Filter Dissolved Nutrients and Pesticides from Runoff: A width of up to 100 feet or more may be necessary on steeper slopes and on less permeable soils to allow runoff to soak in sufficiently, and for vegetation and microbes to work on nutrients and pesticides. Most pollutants are removed within 75 feet.

Based upon the literature review, for the purposes of contaminant management, a buffer width of 75 feet represents the most appropriate width for water quality protection. As shown in Figures F-1 through F-4, and consistent with the water quality modeling assumptions applied for the regional water quality management plan update, a 75-foot buffer width provides a high level of effectiveness in reducing TSS loads delivered to the buffer by about 75 percent, delivered total nitrogen loads by about 65 percent, delivered nitrate loads by about 75 percent, and delivered total phosphorus loads by about 70 percent. There are increased benefits of reduction beyond the 75-foot width for each of these parameters. For example, about 90 percent removal effectiveness would be expected for both nitrate and total phosphorus at approximately a 300-foot buffer width. Coincidently,

Figure F-1

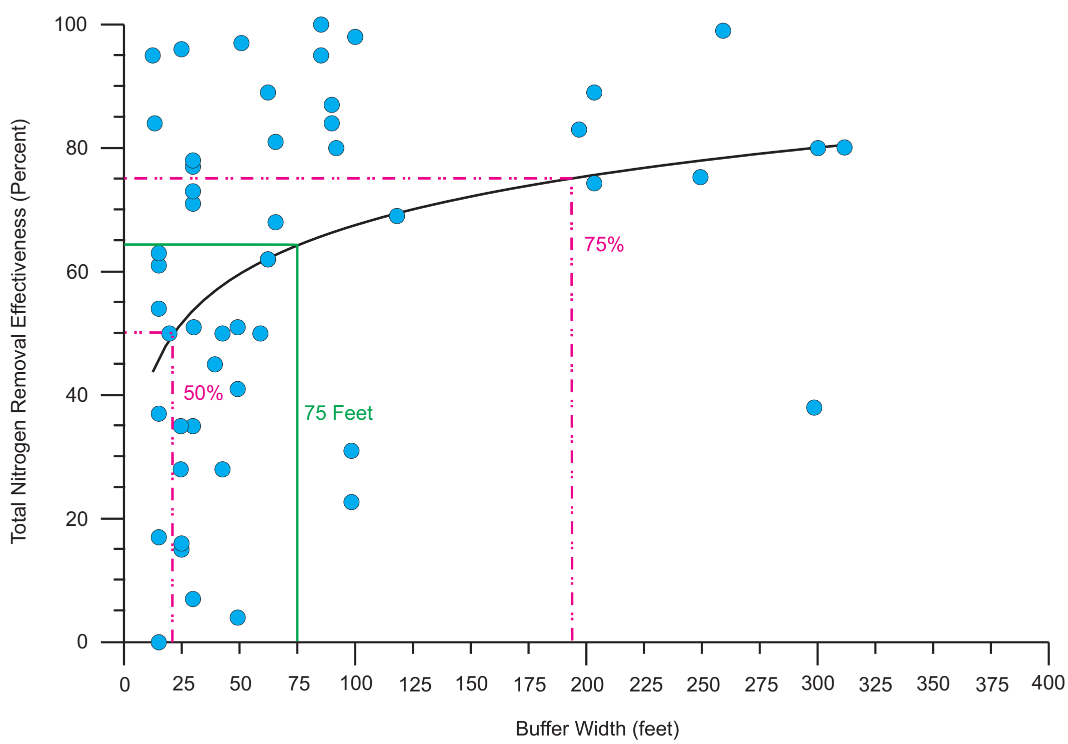
RELATIONSHIP OF TOTAL SUSPENDED SOLIDS REMOVAL EFFECTIVENESS TO RIPARIAN BUFFER WIDTH



Source: SEWRPC.

Figure F-2

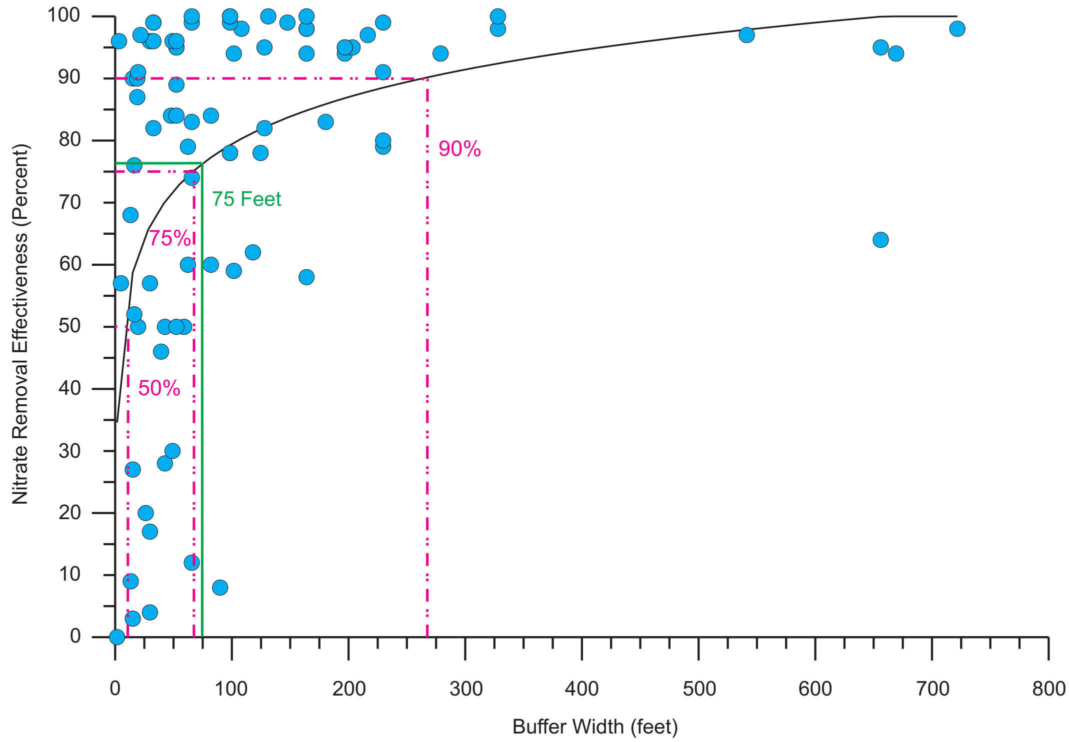
RELATIONSHIP OF TOTAL NITROGEN REMOVAL EFFECTIVENESS TO RIPARIAN BUFFER WIDTH



Source: SEWRPC.

Figure F-3

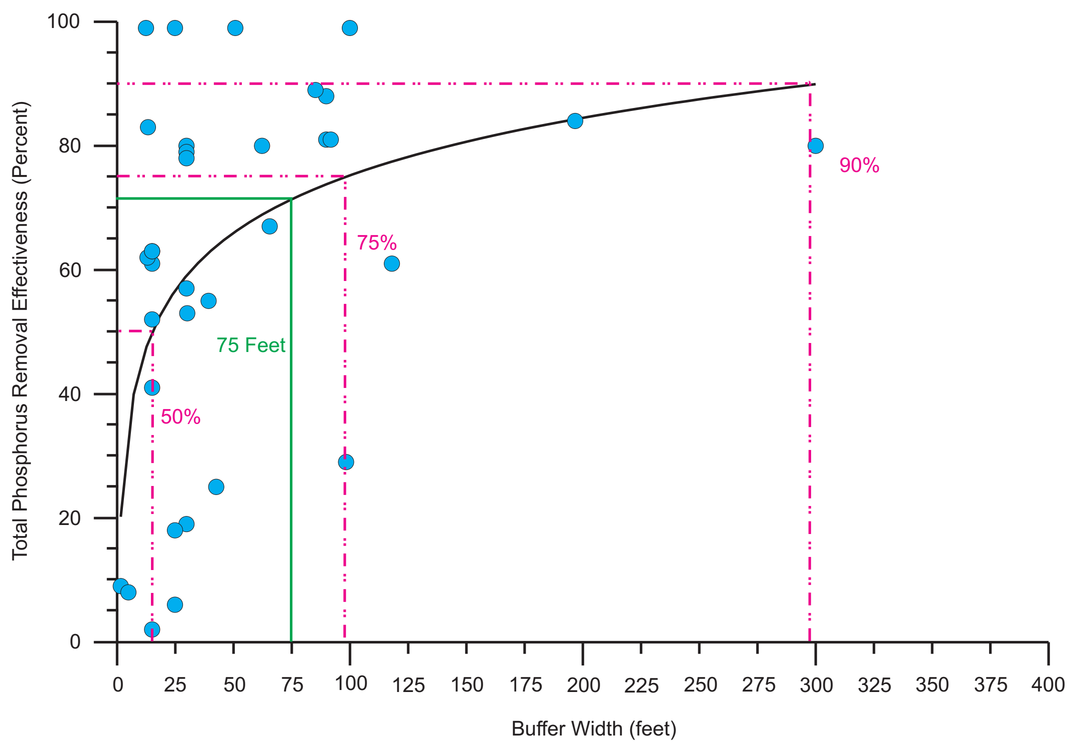
RELATIONSHIP OF NITRATE REMOVAL EFFECTIVENESS TO RIPARIAN BUFFER WIDTH



Source: SEWRPC.

Figure F-4

RELATIONSHIP OF TOTAL PHOSPHORUS REMOVAL EFFECTIVENESS TO RIPARIAN BUFFER WIDTH



Source: SEWRPC.

this 300-foot buffer width is well within the range for added biological community benefits as described below. However, examination of Figures F-1 through F-4 indicates that for a relatively high cost, as indicated by the incremental buffer width beyond 75 feet, a relatively small improvement in water quality would be achieved, as indicated by the incremental increase in pollutant removal effectiveness beyond that for the 75-foot buffer.

It should also be noted that buffer effectiveness is determined by slope, soil permeability, and nature of vegetative cover. Steep slopes and soils of low permeability have less capacity to provide water quality benefits and therefore, require greater buffer widths than less steeply sloped and more permeable soils. Steeply sloped lands promote rapid runoff of water and associated contaminants, while less permeable soils limit infiltration and interflow. Studies show that subsurface flows provide more effective pollutant removal capacity than surface runoff flows.[2] However, the effectiveness and efficiency of all buffers can be limited by the extent of contaminant loading, with even the largest buffers having reduced effectiveness under conditions of extremely high loadings. Thus, a system of riparian buffers along with agricultural nutrient management plans and urban stormwater management plans is recommended under the regional water quality management plan update to provide effective control of nonpoint source pollution.

The nature of vegetated cover within the buffer also will determine in part the magnitude of nutrient removal based upon: the requirements of specific plants primarily for nitrogen and phosphorus necessary for growth; the season, with the majority of removal occurring during the growing season; and the degree of physical filtration, with more densely packed stems typically slowing runoff and retaining a greater percentage of soil bound pollutants. Seasonality in terms of both plant growth cycles and freeze thaw cycles can influence the net effectiveness of pollutant removal, with plants actively taking up or removing nutrients in the spring and summer and releasing those nutrients during the fall when plants senesce, while frozen ground limits the ability of water to infiltrate during the winter months reducing the percentage of uptake of nutrients.[3] Modifying the timing and rate of delivery of contaminants to aquatic systems can significantly modify undesirable biological responses in receiving waters such as lakes and streams.

BIOLOGICAL PROTECTION

Riparian buffers can be complex ecosystems that provide habitat and improve the stream and lake communities that they shelter. Habitat and riparian corridor conditions are strongly influenced by the width and nature of the buffers adjacent to a waterbody and are an important BMP with regard to protecting water from contamination by nonpoint source pollutants, as previously noted. There are many different kinds of buffers. While these buffers may be applied to a variety of situations and may be called by different names, their functions are much the same—the improvement and protection of surface water and groundwater quality; reduction of erosion on croplands, streambanks, and lakeshores; and, provision of protection and cover for insects, fish, birds, amphibians, reptiles, and mammals. The types of riparian buffers include, but are not limited to: streamside or lakeshore plantings of trees, shrubs, and grasses; filter strips or grassed waterways; and undisturbed shoreland vegetation.

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[2]*Paul M. Mayer, Steven K. Reynolds, and Timothy J. Canfield,* Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations*, U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, EPA/600/R-05/118, October 2005.*

[3]*D.M. Robertson, S.J. Field, J.F. Elder, G.L. Goddard, and W.F. James,* Phosphorus Dynamics in Delavan Lake Inlet, Southeastern Wisconsin*,* 1994*, U.S. Geological Survey Water Resources Report 96-4160, 1996; W.F. James, C.S. Smith, J.W Barko, and S.J. Field, "Direct and Indirect Influences on Aquatic Macrophyte Communities on Phosphorus Mobilization from Littoral Sediments of an Inlet Region in Lake Delavan, Wisconsin," U.S. Army Corps of Engineers,* Technical Report W-95-2*, September 1995.*

Wildlife Habitat
The distinctive habitat offered by riparian buffers is home to a multitude of plant and animal species, including those rarely found outside of this band of land influenced by a river or lake. Continuous stretches of riparian buffer serve as wildlife travel corridors. Consequently, streambanks and lakeshores form integral elements of the environmental corridor concept developed and implemented within the Region in accordance with the regional land use and natural areas and critical species habitat protection and management plans.

Aquatic Habitat
Riparian buffers benefit aquatic habitat by improving the quality of nearby waters through shading, filtering, and moderating stream flow. Trees and shrubs provide shade during the summer months, maintaining cooler and more even water temperatures, especially along small streams. Cooler water holds more oxygen and reduces stress on fish and other aquatic creatures. A few degrees difference in temperature can have a major effect on their survival. High value species, such a trout, for example, require cooler water temperatures for survival and reproduction.

The woody debris generated from within the riparian buffer supports the aquatic food web by providing food and cover for fish and their food organisms. By slowing water velocities, providing substrate for insects, among other benefits the woody debris encourages a range of organisms within a system that would be less diversely populated if it did not contain woody debris.

Recreation and Aesthetics
Riparian buffers are especially valuable in providing a green screen along waterways, blocking views of nearby development, and allowing privacy for riverfront landowners. Buffers also provide such recreational opportunities as hiking trails. For many humans, it is these attributes of riparian buffers that are most obvious and most enjoyable.

To Protect Fisheries
Research has shown that a minimum 100-foot buffer width is required to protect the quality and health of the aquatic food web.[4] However, the highest quality fishery communities were associated with the widest riparian buffers that ranged from approximately 650-3,000 feet in width, which indicates that buffer widths greater than 100 feet continue to provide additional protection benefits to the fishery community. Regardless of the type of fishery, the 100-foot minimum is a relevant buffer width standard to protect and maintain a coldwater, coolwater, or warmwater fishery and associated aquatic community. The quality of these communities improves with increases beyond the minimum buffer width. In addition, research also has shown that impacts to the continuity and fragmentation of the riparian corridor buffer width are equally as important in protecting aquatic communities. Similarly, both width and continuity of undisturbed buffer strips were related positively to stream health as indicated by aquatic insect IBI, aquatic insect species richness, fisheries Index of Biotic Integrity (IBI), and trout presence.[5] These researchers found that stream health was generally well protected with riparian buffers that ranged from about 110-130 feet in width, contained less than 13 fragments per kilometer (e.g., number of road crossings or some equivalent per length of buffer), and at least 31 percent of the buffer was comprised of 100 feet or more in width. As shown in Figure F-5, stream health (i.e. aquatic insect IBI) and buffer characteristics were linearly related where stream health improves with buffer width from about 50 to 160 feet in width. Narrow buffers having some fragmentation had modest effects on reducing stresses to stream health, whereas wide buffers

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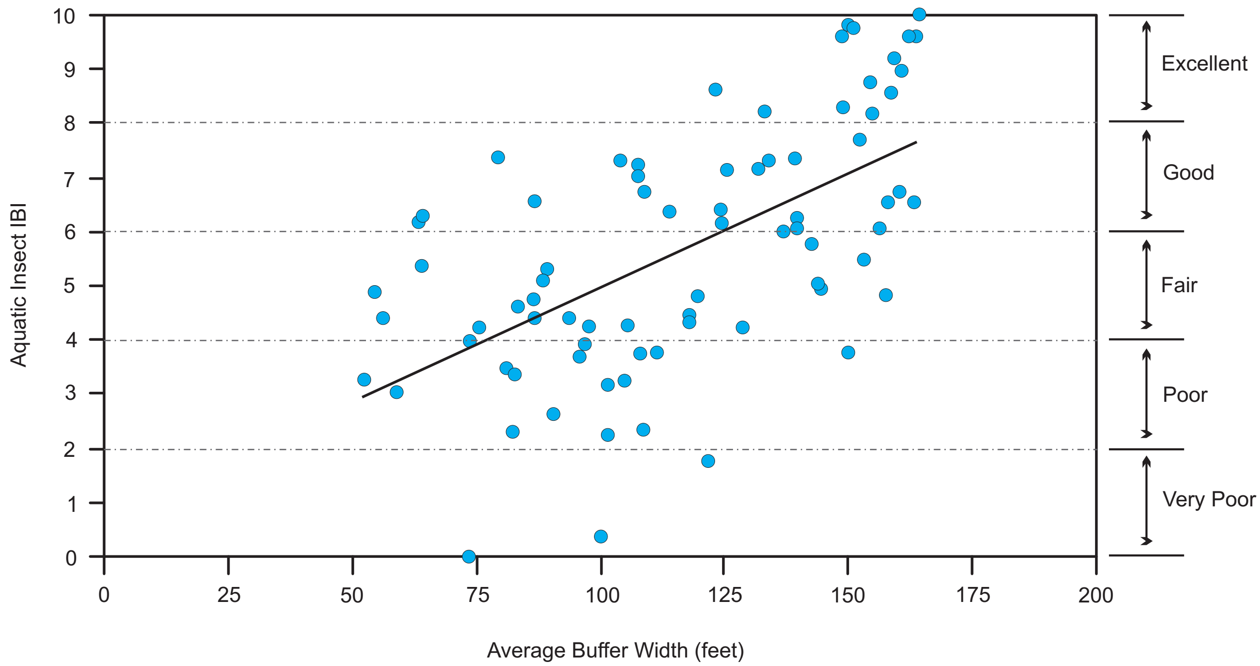
[4]*Jana S. Stewart, Lizhu Wang, John Lyons, Judy A. Horwatich, Roger Bannerman, "Influences of watershed, riparian-corridor, and reach-scale characteristics on aquatic biota in agricultural watersheds,"* Journal of the American Water Resources Association*, Vol. 37, No. 6, 1475-1487, 2001; Wisconsin Department of Natural Resources Bureau of Integrated Science Services,* Buffer Width and Continuity for Preserving Stream Health in Agricultural Landscapes*, Issue Fifty-six, December 2005.*

[5]*Wisconsin Department of Natural Resources Bureau of Integrated Science Services,* Buffer Width and Continuity for Preserving Stream Health in Agricultural Landscapes*, Issue Fifty-six, December 2005.*

Figure F-5

MACROINVERTEBRATE INDEX OF BIOTIC INTEGRITY SCORES AND AVERAGE BUFFER WIDTH



Source: Adapted from B.M. Weigel and others, "Buffer Width and Continuity for Preserving Stream Health in Agricultural Landscapes," Bureau of Integrated Science Services, Wisconsin Department of Natural Resources, Issue 56, 2005.

without fragmentation had substantial effects. Consistent with these findings related to stream health, the regional water quality management plan update includes a recommendation that opportunities to expand riparian buffers beyond the recommended 75-foot width be pursued along high-quality stream systems including those designated as outstanding or exceptional resource waters of the State, trout streams, or other waterways that support and sustain the life cycles of economically important species such as salmon, walleye, and northern pike.

Land use within the watershed also is an important variable influencing fish and macroinvertebrate abundance and diversity, which is why riparian buffers alone cannot address the stresses of excessive nutrient loading, stormwater runoff, or other nonpoint source pollution. For example, researchers found that combined upland (barnyard runoff controls, manure storage, and contour plowing and reduced tillage) and riparian (streambank fencing, streambank sloping, limited streambank riprapping) Best Management Practices (BMPs) treatments significantly improved overall stream habitat quality, bank stability, instream cover for fishes, and fish abundance and diversity.[6] Specifically, improvements were most pronounced at sites with riparian BMPs; however, in sites with limited upland BMPs installed in the watershed there were no improvements in water temperature or the quality of fish community. The regional water quality management plan update recommends buffers as part of an overall system of agricultural controls such as those listed above.

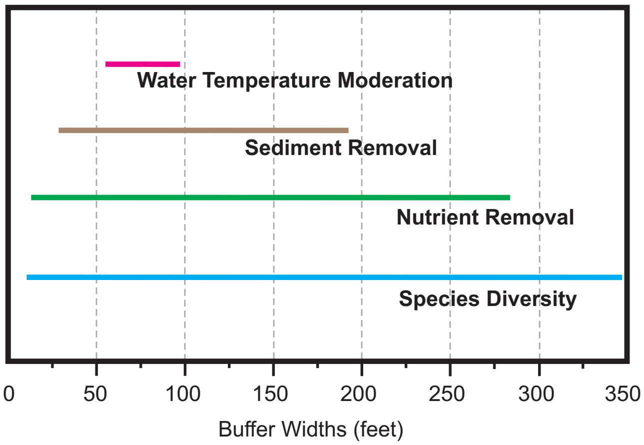
To Protect Wildlife Habitat

Buffer widths for wildlife depend upon the desired species to be protected. As shown in Figure F-6, large streamside forest buffer widths of up to 350 feet are needed for wildlife habitat purposes in contrast to those required for protection of water quality. The larger the buffer zone, the more valuable it is as wildlife habitat.

[6]*Lizhu Wang, John Lyons, and Paul Kanehl, "Effects of watershed best management practices on habitat and fish in Wisconsin streams,"* Journal of the American Water Resources Association*, Vol. 38, No. 3, 663-680, June 2002.*

Figure F-6

RANGE OF BUFFER WIDTHS FOR PROVIDING SPECIFIC BUFFER FUNCTIONS



NOTE: Site-specific evaluations are required to determine the need for buffers and specific buffer characteristics.

Source: Adapted from A.J. Castelle and others, "Wetland and Stream Buffer Size Requirements–A Review," Journal of Environmental Quality*, Vol. 23.*

Larger animals—such as fox, deer, raccoon, and large birds of prey—and interior forest species—especially forest dwelling birds that require deep forest habitat—generally require more room. Additionally, the diversity of various sedges, grasses, forbs, shrubs, and trees may be dependent upon the area available for seed dispersal, germination, and growth. Nevertheless, a narrow width and reduced diversity of vegetation may be acceptable as a travel corridor if connected to larger diverse areas of habitat. Even small patches of trees are better for migrating birds than no buffer or monotypical stands such as lawns or crops. These wildlife buffer concepts underlie the primary environmental corridor specifications of a 200-foot minimum width and two mile length.[7]

SYNTHESIS

Buffers can be used for a variety of purposes from enhancing aquatic species diversity through reducing water temperature entering streams to enhancing terrestrial species diversity through the provision of safe passages with adequate food and shelter. For these reasons, buffer size may vary widely, depending on the specific functions required for a particular buffer or for the protection of a particular species as shown in Figure F-6. Buffers that have widths in the 15- to 35-foot range generally provide limited water quality benefit and minimal protection of aquatic resources under most conditions. Under most circumstances, a minimum buffer width of about 50 to 100 feet is necessary to protect wetlands and streams. In general, minimum buffer widths in the 50- to 65-foot range would be expected to provide for the maintenance of the natural physical and chemical characteristics of aquatic resources. Buffer widths at the upper end of the 50- to 100-foot range seem to be necessary for the maintenance of the biological components of many wetland and stream systems, although it is important to note that site-specific conditions, such as slope, vegetation, and soil characteristics, can greatly influence the need for either wider or narrower buffers. Based upon the literature review, for the purposes of habitat management, a buffer width of 75 feet represents the minimum width necessary for provision of protection of aquatic organisms and habitat. However, a buffer of only 75 feet is not adequate to protect all aquatic and terrestrial plant and animal species.

It is clear that "one size does not fit all" with regard to riparian buffers. Buffer width depends on the purpose which the buffer is meant to serve. There is no single generic buffer which will keep the water clean, stabilize the bank, protect the fish and wildlife, and satisfy human demands. The minimum acceptable width is one that will provide acceptable levels of all of these beneficial uses at an acceptable cost. Consequently, a basic buffer should be about 75 feet from the top of the bank at the water's edge.

In practice, the size and vegetation of the buffer should match the land use and topography of the site.

- Topography: A buffer is more important for water quality in areas that collect runoff and deliver it to streams, and less critical on lands that drain away from the water. Steeper slopes call for a wider riparian buffer to allow more opportunity for the buffer to capture pollutants from faster moving runoff.

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[7] *Paul Beier and Reed F. Noss, "Do Habitat Corridors Provide Connectivity?,"* Conservation Biology, Review*, Vol. 12, No. 6, 1241-1252, December 1998.*

- Hydrology and Soils: The ability of the soil to remove pollutants and nutrients from surface and ground water depends upon the type of soil, its depth, and relation to the water table. On wetter soils, a wider buffer is needed to achieve the same benefit.

- Vegetation: The purposes of the buffer will influence the type of vegetation to plant or encourage. In urban and residential areas, trees and shrubs do a better job at capturing pollutants from parking lots and lawn runoff and providing visual screening and wildlife habitat. Between croplands and waterways, a buffer of shrubs and grasses can provide many of the benefits of a forested buffer without shading crops, although trees can be used on the north side of fields. Trees have several advantages over other plants in improving water quality and offering habitat. Trees are not easily smothered by sediment and have greater root mass to resist erosion. Above ground, they provide better cover for birds and other wildlife using waterways as migratory routes. Trees can especially benefit aquatic habitat on smaller streams. In general, native vegetation is preferable to nonnative plants.

CONCLUDING REMARKS

While it is clear from the literature that wider buffers can provide a greater range of values for aquatic systems, the need to balance human access and use with the environmental benefits to be achieved suggests that a 75-foot-wide riparian buffer provides a minimum width necessary to contribute to good water quality and a healthy aquatic ecosystem. In general, most pollutants are removed within a 75-foot buffer width. While water quality benefits increase somewhat when buffers exceed the 75-foot width, such increases in width are increasingly less cost effective as a smaller portion of the total pollutant load is removed at a significantly higher cost. From an ecological point of view, buffers beyond a 75-foot width provide greater benefits.

These findings form the basis for the Washington County shoreland protection program, for example, and underlie many of the other shoreland ordinances adopted elsewhere in Wisconsin. A 75-foot buffer width is consistent with the required shoreland setbacks set forth in Chapter NR 115 of the *Wisconsin Administrative Code*, and with other recommended setbacks currently included within legal definitions of the shoreland area. Thus, a 75-foot wide buffer appears to be the best and most practical compromise between human use of the landscape and the needs of the environment that sustain such human uses. However, the quality and continuity of these corridors play important roles in their effectiveness, with greater levels of fragmentation by roadways and other structures limiting the effectiveness of those buffers that are put into place.

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Appendix G

POTENTIAL FEDERAL AND PRIVATE FUNDING SOURCES FOR THE PEBBLE CREEK WATERSHED

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Source Type	Funding Source	Program Name	Internet Address	Uses						Eligibility		
				Admin	*Conserv*	*Research*	*Educ*	*Acquisit*	*Tech*	*Non-Profit*	*Town*	*County*
Federal Grants			**www.grants.gov**									
Dept. of Agriculture (USDA)	Cooperative State Research Education and Extension Service	Competitive Grants Program	http://www.csrees.usda.gov/fo/fundview.cfm?fonum=1112			X	X			X	X	X
Dept. of Agriculture (USDA)	Cooperative State Research Education and Extension Service	Land Cover/Land Use Change Research	http://www.csrees.usda.gov/fo/fundview.cfm?fonum=1360			X	X			X	X	X
Dept. of Agriculture (USDA)	Cooperative State Research Education and Extension Service	Managed Ecosystems	http://www.csrees.usda.gov/fo/fundview.cfm?fonum=1104		X	X				X	X	X
Dept. of Agriculture (USDA)	Cooperative State Research Education and Extension Service	Pest Management Alternatives Research	http://www.csrees.usda.gov/fo/fundview.cfm?fonum=1114		X	X	X			X	X	X
Dept. of Agriculture (USDA)	Cooperative State Research Education and Extension Service	Water and Watersheds	http://www.csrees.usda.gov/fo/fundview.cfm?fonum=1135		X	X				X	X	X
Dept. of Agriculture (USDA)	Natural Resources Conservation Service	Conservation Innovation Grants	http://www.nrcs.usda.gov/programs/cig/		X	X			X	X	X	X
Dept. of Agriculture (USDA)	Natural Resources Conservation Service	Cooperative Conservation Partnership Initiative	http://www.nrcs.usda.gov/programs/ccpi/		X				X	X	X	X
Dept. of Agriculture (USDA)	Natural Resources Conservation Service	Wetlands Reserve Program	http://www.nrcs.usda.gov/programs/wrp/		X					X		
Dept. of Agriculture (USDA)	Natural Resources Conservation Service	Wildlife Habitat Incentive Program	http://www.nrcs.usda.gov/programs/whip/		X					X	X	X
Environmental Protection Agency (EPA)	Watershed Academy	Bring Back the Natives Grant Program	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=2	X	X					X	X	X

Source Type	Funding Source	Program Name	Internet Address	Uses						Eligibility		
				Admin	*Conserv*	*Research*	*Educ*	*Acquisit*	*Tech*	*Non-Profit*	*Town*	*County*
Federal Grants			**www.grants.gov**									
Environmental Protection Agency (EPA)	Watershed Academy	Clean Vessel Act Grant Program	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=10								X	
Environmental Protection Agency (EPA)	Watershed Academy	Coastal Program	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=12		X			X		X	X	X
Environmental Protection Agency (EPA)	Watershed Academy	Community- based Restoration Program	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=17		X			X		X	X	X
Environmental Protection Agency (EPA)	Watershed Academy	Emergency Watershed Protection	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=92		X			X		X	X	X
Environmental Protection Agency (EPA)	Watershed Academy	Environmental Education Grant	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=25	X			X			X		
Environmental Protection Agency (EPA)	Watershed Academy	Flood Mitigation Assistance Program	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=31		X			X	X	X	X	X
Environmental Protection Agency (EPA)	Watershed Academy	Land and Water Conservation Fund	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=39					X			X	X
Environmental Protection Agency (EPA)	Watershed Academy	Learn and Serve America	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=40	X			X			X	X	X
Environmental Protection Agency (EPA)	Watershed Academy	Migratory Bird Conservancy	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=85	X	X	X	X	X		X	X	X
Environmental Protection Agency (EPA)	Watershed Academy	National Fish & Wildlife Foundation General Matching Grants	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=81		X		X			X	X	X

Source Type	Funding Source	Program Name	Internet Address	Uses						Eligibility		
				Admin	*Conserv*	*Research*	*Educ*	*Acquisit*	*Tech*	*Non-Profit*	*Town*	*County*
Federal Grants			**www.grants.gov**									
Environmental Protection Agency (EPA)	Watershed Academy	National Sea Grant College Program	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=43			X	X		X	X	X	X
Environmental Protection Agency (EPA)	Watershed Academy	Native Plant Conservation Initiative	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=86		X	X	X			X	X	X
Environmental Protection Agency (EPA)	Watershed Academy	Natural Resources Conservation Service: Conservation on Private Lands	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=87		X					X	X	X
Environmental Protection Agency (EPA)	Watershed Academy	Partners for Fish and Wildlife Program	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=46		X					X	X	X
Environmental Protection Agency (EPA)	Watershed Academy	Targeted Watershed Grant Programs	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=95		X				X	X	X	X
Environmental Protection Agency (EPA)	Watershed Academy	Wetlands Program Development Grants	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=65	X	X	X				X	X	X
Environmental Protection Agency (EPA)	Watershed Academy	Wildlife Habitat Incentives Program	http://cfpub.epa.gov/fedfund/search2.cfm?prog_num=68	X						X		
Department of the Interior (DOI)	U.S. Fish and Wildlife Service	Endangered Species Grants to State, Territories and Private Landowners	http://www.fws.gov/endangered/grants/index.html		X					X		
Department of the Interior (DOI)	U.S. Fish and Wildlife Service	The Neotropical Migratory Bird Conservation Act Grant Program	http://www.fws.gov/birdhabitat/NMBCA/eng_neo.htm	X	X	X	X			X	X	X

Source Type	Funding Source	Program Name	Internet Address	Uses						Eligibility		
				Admin	*Conserv*	*Research*	*Educ*	*Acquisit*	*Tech*	*Non-Profit*	*Town*	*County*
Federal Grants			**www.grants.gov**									
Department of the Interior (DOI)	U.S. Fish and Wildlife Service	North American Wetlands Conservation Act Small Grants	http://www.fws.gov/birdhabitat/NAWCA/USsmallgrants.html		X			X		X	X	X
Department of the Interior (DOI)	U.S. Fish and Wildlife Service	Multi-State Conservation Grants	http://www.iafwa.org/multistate_grants.htm		X	X	X		X	X		
Department of the Interior (DOI)	U.S. Fish and Wildlife Service	Private Stewardship Grants Program	http://www.fws.gov/endangered/grants/private_stewardship/index.html	X	X	X	X			X	X	X
U.S. General Services Administration (GSA)	U.S. General Services Administration (GSA)	Surplus Federal Property is a Good Deal	http://www.gsa.gov/Portal/gsa/ep/contentView.do?contentType=GSA_BASIC&contentId=14360&noc=T						X	X	X	X
National Endowment for the Humanities (NEH)	National Endowment for the Humanities	Implementation Grants for Special Projects	http://www.neh.gov/grants/guidelines/implement-special.html	X			X			X	X	X
National Oceanic and Atmospheric Administration (NOAA)	NOAA / National Fish and Wildlife Foundation / National Association of Counties	Coastal Counties Restoration Initiative	http://www.nfwf.org/programs/ccri.cfm		X		X			X	X	X
National Oceanic and Atmospheric Administration (NOAA)	NOAA /Trout Unlimited * Apply through local TU chapters	Embrace-A-Stream Grant Program	http://www.nmfs.noaa.gov/habitat/restoration/projects_programs/crp/partners/troutunlimited.html	X	X	X	X			X	X	X
National Oceanic and Atmospheric Administration (NOAA)	NOAA Office of Education	Environmental Literacy Grant Program	http://www.oesd.noaa.gov/funding_opps.html				X			X	X	X
National Oceanic and Atmospheric Administration (NOAA)	NOAA /Gulf of Maine Council * For States of: ME, MA, and, NH only	Habitat Restoration Grants Program	http://www.gulfofmaine.org/habitatrestoration/		X					X	X	X

Source Type	Funding Source	Program Name	Internet Address	Uses						Eligibility		
				Admin	*Conserv*	*Research*	*Educ*	*Acquisit*	*Tech*	*Non-Profit*	*Town*	*County*
Federal Grants			**www.grants.gov**									
National Oceanic and Atmospheric Administration (NOAA)	NOAA /The Nature Conservancy	Community-Based Habitat Restoration Grants	http://www.nmfs.gov/habitat/restoration/projects_programs/crp/partners/tnc.html		X	X	X			X	X	X
National Oceanic and Atmospheric Administration (NOAA)	NOAA /American Sportfishing Association /Fish America Foundation	Community-Based Habitat Restoration Projects	http://www.fishamerica.org/faf/grants/index.html		X					X	X	X
National Oceanic and Atmospheric Administration (NOAA)	NOAA /National Marine Fisheries Service	Community-Based Marine Debris Prevention and Removal Projects Grants	http://www.nmfs.noaa.gov/habitat/restoration/projects_programs/crp/partners_funding/callforprojects2.html		X	X	X			X	X	X
National Oceanic and Atmospheric Administration (NOAA)	NOAA /National Marine Fisheries Service	Community-Based Restoration Projects Grants	http://www.nmfs.noaa.gov/habitat/restoration/projects_programs/crp/partners_funding/callforprojects.html		X	X				X	X	X
USA Freedom Corps	Corporation for National & Community Service	Senior Corps, Ameri Corps, Learn & Serve America	http://www.nationalservice.gov/Default.asp	X						X	X	X

Source Type	Funding Source	Program Name	Internet Address	Uses						Eligibility		
				Admin	*Conserv*	*Research*	*Educ*	*Acquisit*	*Tech*	*Non-profit*	*Town*	*County*
Private Grant Sources												
Endowment	The Heinz Endowment	Environment Program	http://www.heinz.org/nav.asp?sec=E&whr=n#		X	X	X			X		
Foundation	American Express Foundation	Cultural History	http://home3.americanexpress.com/corp/gb/cult_her.asp		X		X			X		
Foundation	The Annenberg Foundation	Community and Civic Grants	http://www.annenbergfoundation.org/grants/				X			X		
Foundation	The William and Flora Hewlett Foundation	Community-Based Collaboratives Research Consortium	http://www.cbcrc.org/grants.html			X				X	X	X
Foundation	Fish America Foundation	General Conservation Projects General Research Projects	http://www.fishamerica.org/faf/grants/index.html		X	X			X	X		
Foundation	The Home Depot Foundation	Healthy Community and Wildland Forests	http://homedepotfoundation.org/hfus/enus/programs.html		X		X			X		
Foundation	Mitsubishi International Corporation	MIC Foundation	http://www.micusa.com/corporatecitizenship_micfoundation.shtml				X			X		
Foundation	National Fish and Wildlife Foundation	General Matching Grant Program Special Grant Program	http://www.nfwf.org/programs.cfm		X	X	X	X		X	X	X
Foundation	Project Aware Foundation	Project Aware Foundation Grant Program	http://www.projectaware.org/americas/english/grants.asp	X	X	X	X			X		
Foundation	Surdna Foundation	Environment Program	http://surdna.org/programs/programs_show.htm?doc_id=314245&attrib_id=12037		X					X		

Source Type	Funding Source	Program Name	Internet Address	Uses						Eligibility		
				Admin	*Conserv*	*Research*	*Educ*	*Acquisit*	*Tech*	*Non-profit*	*Town*	*County*
Private Grant Sources												
Foundation	The Moneypaper, Inc.	Temper of the Times Foundation, Inc.	http://www.temperfund.org/	X						X		
Foundation	Toyota	Toyota USA Foundation	http://www.toyota.com/about/community/fundguidelines/index.html		X		X			X		
Foundation	Trout Unlimited	Home Rivers Initiative	http://www.tu.org/site/pp.asp?c=7dJEKTNuFmG&b=356129	X	X	X	X			X		
Fund	American Hiking Society	National Trails Fund	http://www.americanhiking.org/alliance/fund.html	X				X	X	X		
Fund	American Water	Environmental Grant Program	http://www.amwater.com		X		X			X	X	
Fund	Banrock Station Wines	Wetlands Conservation Program	http://www.conservationfund.org/?article=2831		X	X		X		X		
Fund	Bush Gardens -Sea World Adventure Park	Sea World & Bush Gardens Conservation Fund	http://www.swbg-conservationfund.org/default.htm	X	X	X	X			X	X	X
Fund	The Conservation Fund	Kodak American Greenways Awards Program	http://www.conservationfund.org/?article=2106	X	X	X			X	X		
Fund	The Conservation Fund	Land Acquisition	http://www.conservationfund.org/?article=2016					X		X		
Fund	The Conservation Fund	Watershed Action Grants	http://www.conservationfund.org/?article=2829		X	X			X	X		

Source Type	Funding Source	Program Name	Internet Address	Uses						Eligibility		
				Admin	*Conserv*	*Research*	*Educ*	*Acquisit*	*Tech*	*Non-profit*	*Town*	*County*
Private Grant Sources												
Fund	Disney Worldwide Outreach	The Disney Wildlife Conservation Fund	http://disney.go.com/disneyhand/environmentality/dwcf/index.html		X	X	X			X		
Fund	DuPont	Community Outreach	http://www2.dupont.com/Social_Commitment/en_US/outreach/		X		X			X		
Fund	Environmental Systems Research Institute	ESRI Conservation Program	http://www.conservationgis/aaesrigrants.html						X	X		
Fund	Funding Factory	Funding Factory	http://www.fundingfactory.com						X	X		
Fund	L.L. Bean	Charitable Giving Program	http://www.llbean.com/customerService/about LLBean/charitable_giving.html		X				X	X		
Fund	Microsoft	Microsoft Grants	http://www.microsoft.com/industry/publicsector/grants.mspx						X	X		
Fund	The National Urban and Community Forestry Advisory Council	Challenge Cost-Share Grant Program	http://www.treelink.org/nucfac/		X		X			X		
Fund	New England Environmental Finance Center	Directory of Watershed Resources	http://efc.boisestate.edu/index.asp	X	X	X	X	X	X	X	X	X

Source Type	Funding Source	Program Name	Internet Address	Uses						Eligibility		
				Admin	*Conserv*	*Research*	*Educ*	*Acquisit*	*Tech*	*Non-profit*	*Town*	*County*
Private Grant Sources												
Fund	Patagonia	Environmental Grants	http://www.patagonia.com/enviro/enviro_grants.shtml		X					X		
Fund	Pepsico	Pepsico Community Affairs	http://www.pepsico.com/PEP_Citizenship/Contributions/index.cfm	X					X	X		
Fund	REI	REI Gives	http://www.rei.com/aboutrei/gives02.html	X	X		X		X	X		
Fund	Rockefeller Family Fund	The Environment	http://www.rffund.org/environment.cfm	X	X					X		
Fund	International Association of Fish and Wildlife Agencies	Projects and Grants	http://www.iafwa.org/projects_grants.htm		X	X					X	X
Fund	Wal-Mart Good Works	Environment	http://www.walmartfoundation.org/wmstore/goodworks/scripts/index.jsp		X				X	X	X	X
Trust	National Geographic	Conservation Trust	http://nationalgeographic.com/conservation/index.html		X	X	X			X		
Trust	National Tree Trust	Roots Program for Community Action	http://www.nationaltreetrust.org/index.cfm?cid=43000	X	X		X		X	X		
Trust	National Tree Trust	Seeds program for Organizational Support	http://www.nationaltreetrust.org/index.cfm?cid=41000	X					X	X		
Trust	The Pew Charitable Trusts	Advancing Policy Solutions	http://www.pewtrusts.com/ideas/area_index.cfm?area=2		X	X	X			X		

<u>Uses</u> The *Uses* categories, as listed above, may include the following funding opportunities:

Admin – Administrative cost, volunteers or staff salaries, training, and marketing

Conserv – Conservation and restoration of: land, water, air, birds, fish, wildlife, and preservation of cultural history

Research – Research, monitoring, surveys, consultations, and planning

Educ – Environmental education programs, outreach programs, and continuing professional education

Acquisit – Land acquisitions

Tech – Technology (computers, software, GPS, office supplies, etc.)
– Equipment (canoes, outdoor gear, tools, office furniture, etc.)
– Construction (structural assistance and equipment, and building supplies)
– Trails (assistance or funding for the construction trail)