COMMUNITY ASSISTANCE
PLANNING REPORT NO. 309

MUKWONAGO RIVER WATERSHED PROTECTION PLAN

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Special acknowledgement is due to Dr. Thomas M. Slawski, SEWRPC Principal Planner and senior author; Dr. Jeffrey A. Thornton CLM PH, SEWRPC Principal Planner; Mr. Aaron W. Owens and Ms. Sara Wilder Teske, SEWRPC Research Analysts; Mr. Edward J. Schmidt, SEWRPC GIS Planning Specialist; and, Mr. Michael A. Borst, SEWRPC Research Aide, for their contributions to the conduct of this study and the preparation of this report.

Special recognition is due Jacki Lewis, a resident of the Jericho Creek subwatershed, for her detailed review of the draft report.

Special thanks to the following property owners allowing access to the Mukwonago River system: Thomas A. Day, Fred Gier, Chris Hinz, Andy and Barb Holtz, Jean Holtz, Jacki Lewis, Harold (Whitey) Mehlberg, Pamela Meyer, Patricia Morton, Irene Roberts, John and Lynn Schreiber, Duane and Susan Thornton, and Diane Zak.

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Prepared by the

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The preparation of this publication was financed in part through grants from the Wisconsin Department of Natural Resources River Protection Planning Grant Program.

June 2010

$20.00

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INTRODUCTION

PURPOSE OF THE PLAN

Research shows that the health of a lake or stream is usually a direct reflection of the use and management of the land within its watershed and the Mukwonago River system is in very good health (see Figure 1). The River, its tributaries, and associated wetlands are a unique cold and warmwater resource within a biologically diverse watershed located in southeastern Wisconsin (Map 1). The largest portion of the Mukwonago River watershed is situated in southwestern Waukesha County and northeastern Walworth County, with a small fraction within the extreme southeastern portion of Jefferson County. The purpose of this plan is to provide a framework to enable communities in the area to work together with a common goal—*to protect and improve the water resources of the Mukwonago River through the use and management of its watershed*.

This watershed protection plan focuses on what can be done to *prevent* future water pollution or resource degradation from occurring and to continue to *protect* the existing high-quality resources from human impacts. This plan complements other existing programs and ongoing management actions in the Mukwonago River watershed and represents the continuing commitments of government agencies, municipalities, and citizens to diligent land use planning and natural resource protection. This plan presents recommendations for appropriate and feasible watershed management measures for enhancing and preserving the water quality of the Mukwonago River and for providing the public with opportunities for safe and enjoyable recreation within the Mukwonago River watershed.

The Mukwonago River Watershed Protection Plan is designed to assist municipalities in developing strategies that will benefit the natural assets of the Mukwonago River 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 the Mukwonago River and the residents of the watershed. This protection plan should serve as a practical guide for the management of water quality within the Mukwonago River watershed and for the management of the land surfaces that drain directly and indirectly to the streams and lakes in the watershed.

BACKGROUND

The Mukwonago River and its major tributaries are a unique water resource located in the Villages of Eagle, East Troy, Mukwonago, and North Prairie; and, the Towns of Eagle, East Troy, Genesee, LaGrange, Mukwonago, Ottawa, Palmyra, Troy, and Vernon, all located within Jefferson, Walworth and Waukesha Counties (Map 2). The Mukwonago River system, including seven major Lakes (i.e., greater than 75 acres in size), seven minor lakes and numerous tributaries, supports a variety of fishes, mussels, and other aquatic organisms, including nearly 80 State-

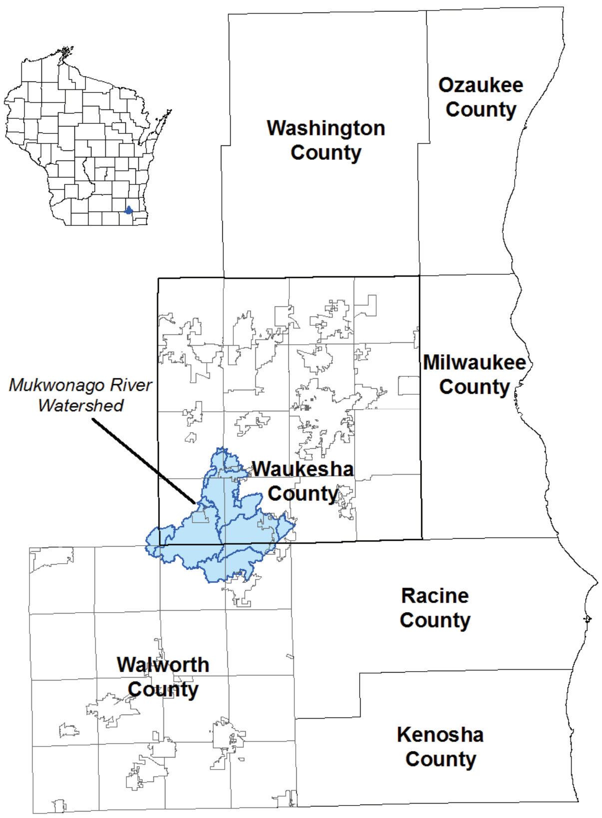
Figure 1

EXAMPLE OF TYPICAL LAKE AND STREAM CONDITIONS IN THE MUKWONAGO RIVER WATERSHED: 2008

Source: SEWRPC.

Map 1

LOCATION OF THE MUKWONAGO RIVER WATERSHED STUDY AREA



Source: SEWRPC.

listed threatened and endangered species and species of special concern. The system is sustained by groundwater recharge, seepage from wetlands and moraines, and precipitation runoff from about a 74-square-mile watershed. The Mukwonago River discharges into the Fox River [Illinois] in the Village of Mukwonago.

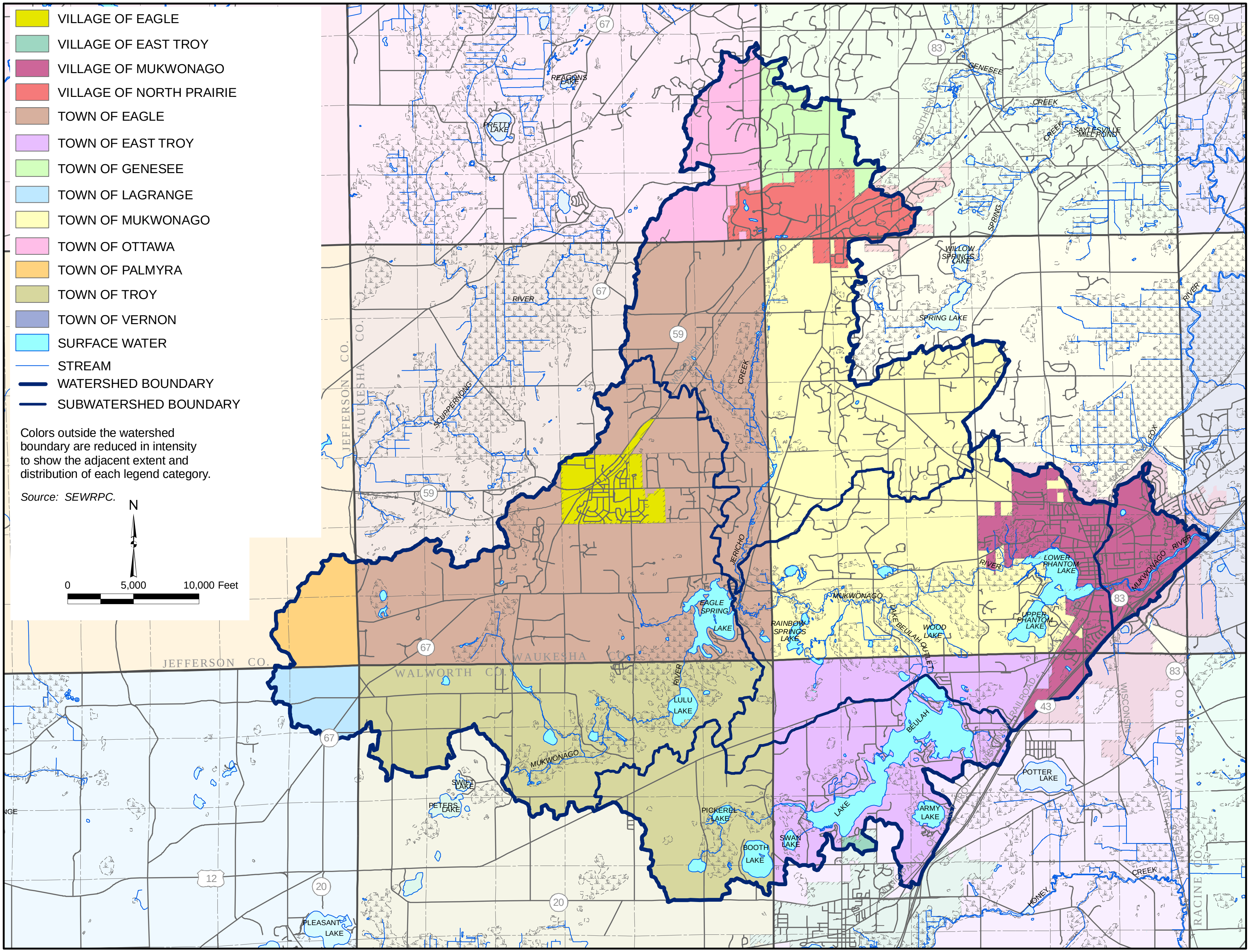
The Mukwonago River watershed has been divided into five subwatersheds for this plan to assist in assessing land use, water quality, biological community, and instream habitat conditions. Map 3 also shows the extent of the approximately 19 miles of stream and five major Lakes including Beulah, Eagle Spring, Lulu, Lower Phantom, and Upper Phantom Lakes that were assessed within this report. The Eagle Spring, Phantom, and Mukwonago subwatersheds are directly tributary to the mainstem of the Mukwonago River. Jericho Creek and Beulah outlet are two major tributaries that flow into the Mukwonago River. Jericho Creek flows from north to south and discharges into the Mukwonago River just downstream of Eagle Spring Lake. The Beulah outlet is the outlet stream from Lake Beulah which continues northward to its confluence with the Mukwonago River. In addition to these five subwatersheds, there are several distinct internally drained areas identified as shown on Map 3. Although these areas do not contribute to surface water runoff (i.e., do not have a discrete outlet) they are particularly important in terms of the land use, water quality, and groundwater.

The Mukwonago River has unique recreational values. The majority of the stream and adjacent riparian corridors exhibit a rural character, which provides recreational opportunities within and adjacent to the River system. Utilized for fishing, hunting, boating, water skiing, wading, canoeing, wildlife watching, and scenic viewing, it provides ecological and recreational benefits for adjacent landowners and other users. Public recreational access opportunities are provided through boating access sites on the major lakes and public parks and other facilities adjacent to the lakes and river system.

The Mukwonago River system also has unique aesthetic and ecological values and is one of the most diverse aquatic ecosystems within the Southeastern Wisconsin Region (See Figures 2 and 3). The River system includes both Lulu Lake which is designated as an Outstanding Resource Water (ORW) under Chapter NR 102, “Water Quality Standards for Wisconsin Surface Waters,” of the *Wisconsin Administrative Code*, and the Mukwonago River downstream of Eagle Spring Lake to its confluence with Upper Phantom Lake, which is designated as an Exceptional Resource Water (ERW) under Chapter NR 102. The Mukwonago River has also been designated as a potential Class II brown trout fishery extending from Phantom Lake upstream to Eagle Spring Lake, and as a Class I brown trout fishery upstream from Lulu Lake. Jericho Creek has been designated as a Class III brown trout fishery for its entire length. Despite these classifications related only to brown trout, brook trout have been stocked in both the Mukwonago River and Jericho Creek and have become an important element of the overall fishery since 2002. Recent introductions of nonnative species such as Eurasian Water Milfoil, zebra mussels, purple loosestrife, and phragmites threaten the biological integrity of this system.

Map 2

CIVIL DIVISIONS WITHIN THE MUKWONAGO RIVER WATERSHED: 2008



Map 3

SURFACE WATER RESOURCES WITHIN THE MUKWONAGO RIVER WATERSHED: 2005

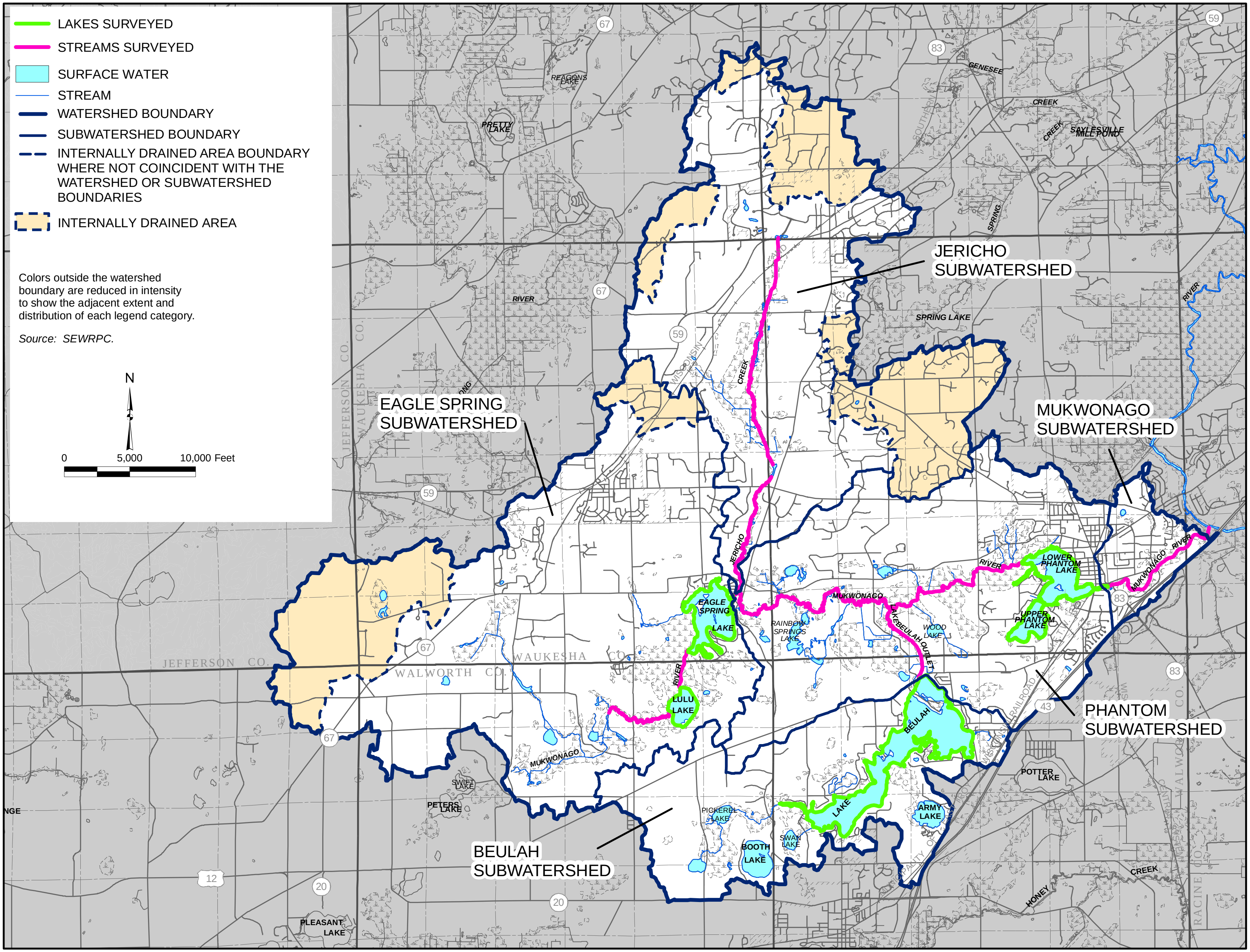


Figure 2

LONGEAR SUNFISH

Wisconsin Status: Threatened

Source: SEWRPC.

"The Mukwonago River has a rich aquatic biota, and is one of the highest quality streams remaining in southern Wisconsin. Much of its watershed remains natural or only lightly developed, water quality is good, and riparian and in-stream habitats are diverse and largely intact. The stretch of river immediately below Phantom Lake in the Village of Mukwonago has the highest fish species richness of any comparably sized stretch of stream in the State of Wisconsin and includes several State threatened and endangered fish and mussel species and numerous gamefish and panfish species. In this stretch, the river is readily accessible and easily waded and has clear water and an attractive setting, and as a result sport fishing and fish watching are popular pastimes."

John Lyons, Research Scientist, WDNR.

Figure 3

MUSSELS IN THE MUKWONAGO RIVER FILTERING WATER

Source: SEWRPC.

"The Mukwonago River contains the most diverse assemblage of mussels in Southeast Wisconsin and is one of three river systems in the State of Wisconsin that exhibit such mussel diversity. It contains the best remaining population of the state endangered Rainbow mussel in the state, with only a couple of other rivers in the southeast Region that contain remnant populations of the Rainbow. It also is one of the last strongholds for other mussel species that are only found sporadically throughout the Region. Since the critical link in the mussel life cycle is its fish host, the diversity of the fish population in the Mukwonago goes hand in hand with the diversity of the mussel population. Without the appropriate host fish, mussels cannot complete their life cycle and survive, so the greater the diversity of fish available, the greater the chance that the different mussel species can find their suitable host species."

Lisie Kitchel, Conservation Biologist, WDNR.

The Mukwonago River watershed is threatened by increasing urbanization. The attributes that make the Mukwonago River and its watershed so unique within the Southeastern Wisconsin Region are the same attributes that attract new residents, businesses, and supporting infrastructure to the watershed. Increasing urban development in recent years has lead to conversion of agricultural and open lands to residential lands with increased impervious area and volumes of stormwater runoff, increased demands for groundwater, and increased demands on the recreational opportunities throughout the river system. These increased demands could affect the hydrological and ecological integrity of this outstanding and exceptional resource water system. These recent concerns, combined with the need to protect and preserve the ecology and water quality of Eagle Spring Lake and Upper and Lower Phantom Lakes, led to the development of comprehensive lake management plans that set forth priority actions to protect and preserve the ecology and water quality of these waterbodies.[1] While these plans have led to the implementation of actions by the lake management districts and municipalities that have addressed the immediate concerns relating to the lakes themselves, ongoing concern over the state of the River linking the lakes has remained. These concerns led to the formation of an informal watershed coalition (referred to as the "Watershed Team") as a means of focusing attention on the entire hydrologic system.

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[1]*SEWRPC Community Assistance Planning Report No. 226,* A Lake Management Plan for Eagle Spring Lake, Waukesha County, Wisconsin, *October 1997; SEWRPC Community Assistance Planning Report No. 230,* A Lake Management Plan For The Phantom Lakes, Waukesha County, Wisconsin, *Volume One,* Inventory Findings, *and Volume Two,* Alternatives and Recommended Plan, *January 2006.*

PLANNING PROCESS

The Phantom Lakes and Eagle Spring Lake Management Districts have received Wisconsin Department of Natural Resources (WDNR) grant funding through the Chapter NR 195 River Planning and Management Grant Program to complete a Protection Plan for the Mukwonago River Watershed in cooperation with The Nature Conservancy (TNC), Friends of the Mukwonago River, the Lake Beulah Management District, Waukesha County, and Southeastern Wisconsin Regional Planning Commission (SEWRPC). Those organizations form the "Watershed Team."

SEWRPC prepared this plan on behalf of the Watershed Team in cooperation with representatives from the *ad hoc* Mukwonago River Watershed Protection Advisory Group, (hereinafter the "Advisory Group;" see Appendix A). The Advisory Group was comprised of self nominated individuals representing a range of stake holders with interests in the Mukwonago River watershed who volunteered their time to review portions of the plan. The Advisory Group represents the diversity of interests and perspectives that affect the watershed, including farmers, developers, residents, and environmental groups; County and local governments; the Southeastern Wisconsin Fox River Commission; and, lake and property owners associations, among others. During 2009, participants in the Advisory Group either attended one or more of the several meetings or provided electronic mail correspondence to define issues, develop goals, and establish recommendations that would help manage local community growth while protecting the natural resources in the Mukwonago River watershed. It is important to note that the Advisory Group 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 establishing a sound framework within which to implement the recommendations.

The Watershed Team and Advisory Group developed the following general goals for the plan:

- Protect and improve wildlife, land, surface water , and groundwater resources

- Minimize impacts of land development by controlling agriculture and urban runoff pollution and flooding

- Build partnerships and inform public to promote protection and use of natural resources

This plan elaborates on each of these planning goals by outlining more specific objectives and action items recommended to accomplish the goals. These objectives and management measures also benefited from discussions with the Watershed Team and Advisory Group throughout the planning process.

This plan represents one component in the implementation of the Waukesha County and Walworth County Land and Water Resource Management Plans' goals of protecting and improving the natural resources within each of these counties by applying a watershed protection planning approach.[2]

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[2]*Waukesha County Department of Parks and Land Use-Land Resources Division,* Waukesha County Land and Water Resources Management Plan: 2006-2010*, March 2006; Waukesha County, A* Comprehensive Development Plan for Waukesha County*, February 2009; SEWRPC Community Assistance Planning Report No. 288,* A Multi-Jurisdictional Comprehensive Plan for Walworth County: 2035, *November 2009; and, Walworth County Land Conservation Committee,* Walworth County Land and Water Resource Management Plan-Plan Amendment, *February 2004.*

PLAN FORMAT AND ORGANIZATION

This document incorporates land, groundwater, and stream management data and analyses compiled from the following sources: the WDNR Priority Watershed Project and State of the Basin Reports;[3] University of Wisconsin-Madison theses and reports; various technical reports completed by engineering and scientific consulting firms; and, County and local government Comprehensive Management Plans. In addition, this plan incorporates water quality, physical habitat, and biological data, and land use information collected by the WDNR, Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP), U.S. Geological Survey (USGS), Wisconsin Geological and Natural History Survey (WGNHS), Walworth County Land Use and Resource Management Department, 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, and population demographics. Chapter III briefly describes State and local plans, regulations, and programs that are related to this watershed protection plan. Chapter IV summarizes the physical conditions of the stream system, existing surface water quality, and habitat and biological conditions in the Mukwonago River watershed. Chapters V and VI include the goals, objectives, alternative and recommended plan elements, and implementation steps to address the identified issues and concerns of the watershed. These chapters contain recommendations regarding outreach and education, methods of program performance review, and plan implementation.

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

Chapter II

NATURAL AND CONSTRUCTED FEATURES OF THE WATERSHED

INTRODUCTION

Information on the natural and constructed features of the study area is essential to sound planning for water quality, stormwater, 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 and lakes are susceptible to water quality degradation due to human activities within the watershed which can interfere with desired water uses, and which are often difficult and costly to correct. Accordingly, the land uses and population levels in the watershed are important considerations in stream and lake water quality 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 Mukwonago River 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, rivers, and streams.

Civil Divisions

Superimposed on the watershed boundary is a pattern of local political boundaries. As shown on Map 1 in Chapter I of this report, the watershed lies in southwestern Waukesha County, north central Walworth County, and southeastern Jefferson County. A total of three counties and 13 civil divisions lie partially within the Mukwonago River 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 Mukwonago River watershed include portions of the Villages of Eagle, East Troy, Mukwonago, and North Prairie, and the Towns of Eagle, East Troy, Genesee, LaGrange, Mukwonago, Ottawa, Palmyra, Troy, and Vernon. The area and proportion of the watershed within the jurisdiction of each civil division is set forth in Table 1.

Table 1

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

Civil Division	Area (acres)	Percent of Total
Jefferson		
Town of Palmyra	948.3	2.0
Walworth		
Village of East Troy	65.0	0.1
Town of East Troy	5,664.2	11.9
Town of LaGrange	694.6	1.5
Town of Troy	8,330.6	17.6
Subtotal	14,754.3	31.1
Waukesha		
Village of Eagle	882.3	1.9
Village of Mukwonago	2,967.4	6.3
Village of North Prairie	1,446.1	3.0
Town of Eagle	12,464.6	26.3
Town of Genesee	1,107.6	2.3
Town of Mukwonago	11,258.2	23.7
Town of Ottawa	1,606.6	3.4
Town of Vernon	16.3	<0.1
Subtotal	31,749.0	66.9
Total	47,451.7	100.0

Source: SEWRPC.

Historical Urban Growth

The types, intensity, and spatial distribution of land uses within the Mukwonago River 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.

Historical urban growth within the Mukwonago River watershed is summarized on Map 4 and in Figure 4. Since 1970, much, though not all, of the urban growth in the watershed has occurred in the northern one-third of the watershed. Figure 4 also shows that the percentage of urban development nearly doubled from about 6 percent in 1975 to nearly 12 percent in 1980, with the majority of that development occurring within the Jericho Creek and Lower Mukwonago River subwatersheds. Since 1980, the Jericho Creek and Lower Mukwonago River subwatersheds, combined, account for more than 90 percent of all the urban development within the entire Mukwonago River watershed. As shown on Map 4, the majority of the urban development has primarily occurred within and around the Villages of Mukwonago and North Prairie and the Town of Eagle.

A comparison of the proportion of the year 2000 urban versus rural land use among subwatersheds is shown in Figure 5 as a percentage of the entire Mukwonago River watershed. The watershed is predominantly in rural uses (approximately 76 percent), but 24 percent of the watershed has been developed for urban purposes (see Land Use section below for more details). In general, except for the Mukwonago subwatershed, each subwatershed is also predominantly rural. As shown in Figure 4 the Mukwonago subwatershed contains the highest percent urban development (nearly 50 percent) of any other subwatershed. However, the Mukwonago subwatershed is the smallest, and only accounts for about 1 percent of the total urban development within the entire Mukwonago River watershed, as shown in Figures 4 and 5. This illustrates the potential importance of local versus watershed scale differences in land use as they relate to amounts of impervious surfaces and resultant urban stormwater runoff (see Runoff from Urban Development and Impervious Surfaces section below).

Map 4

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

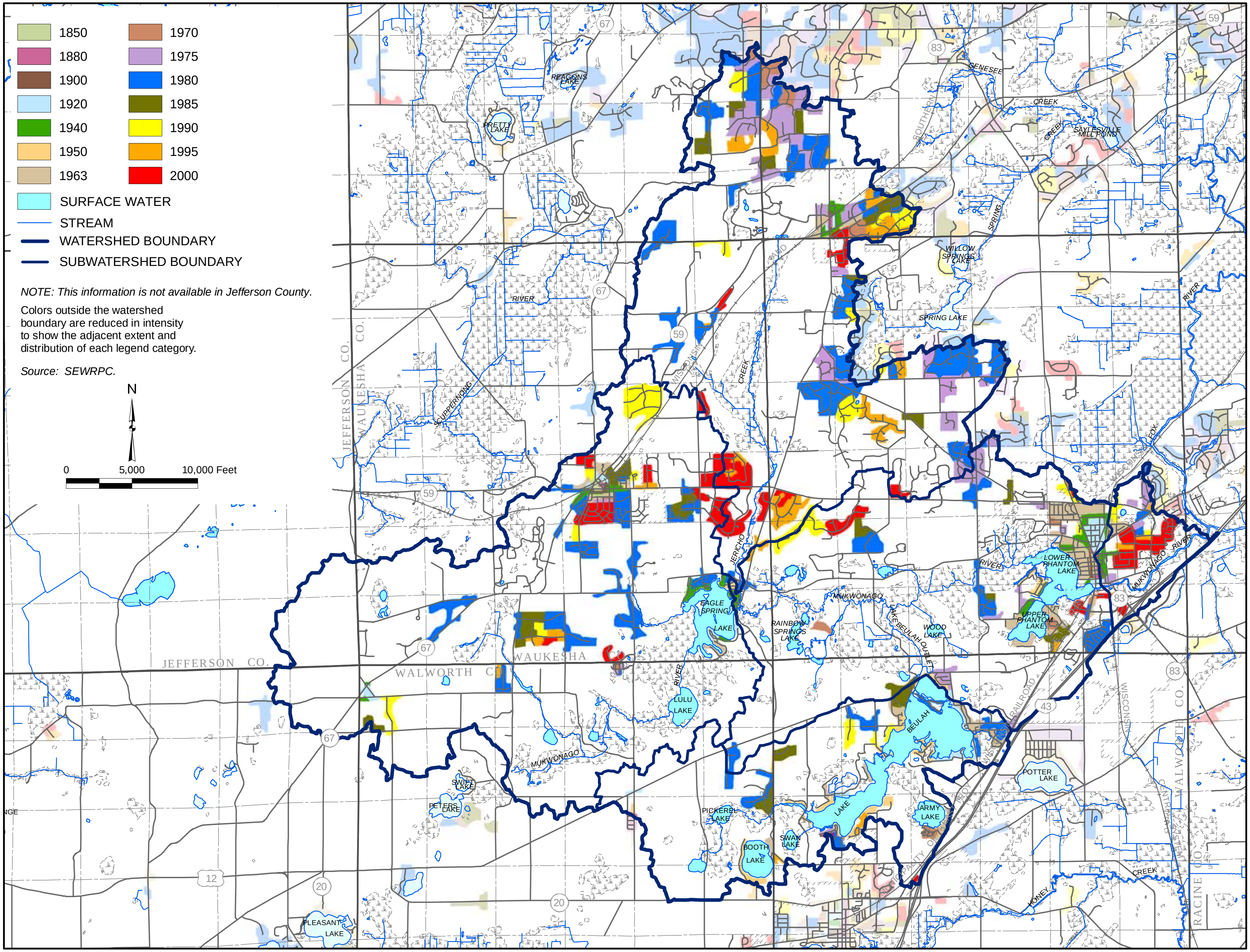
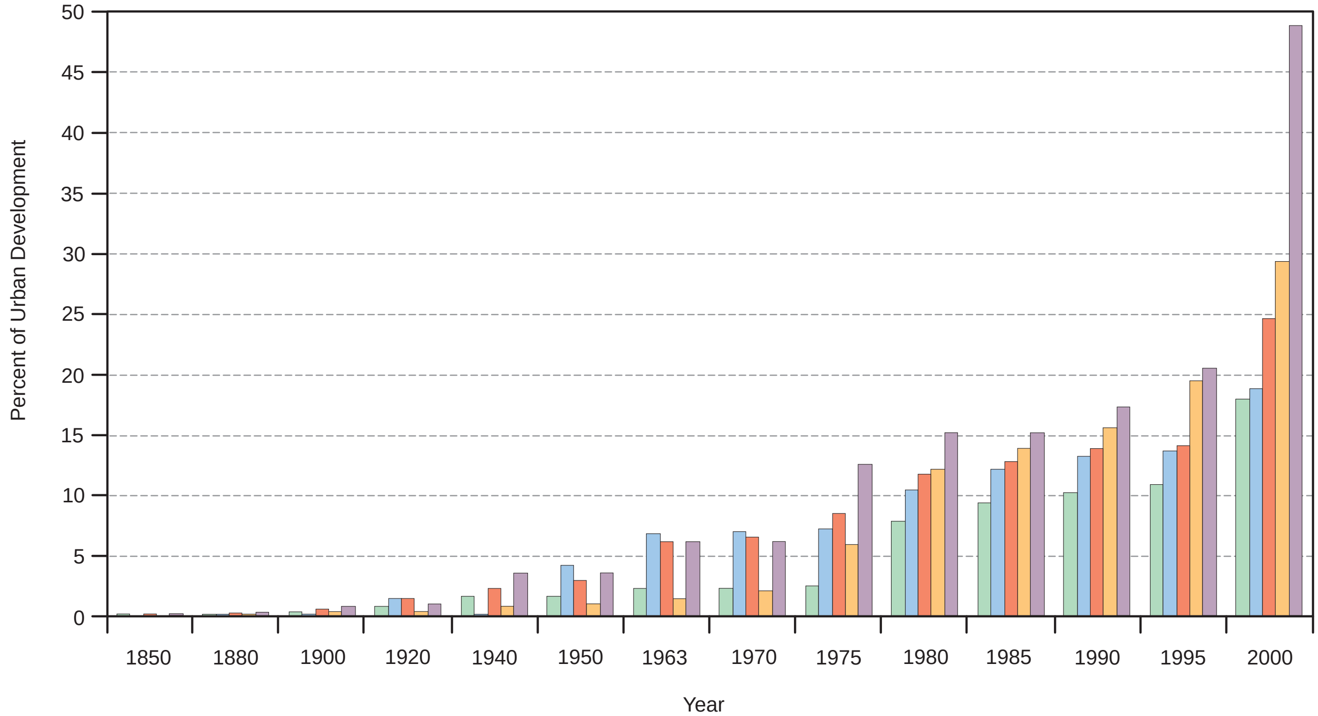


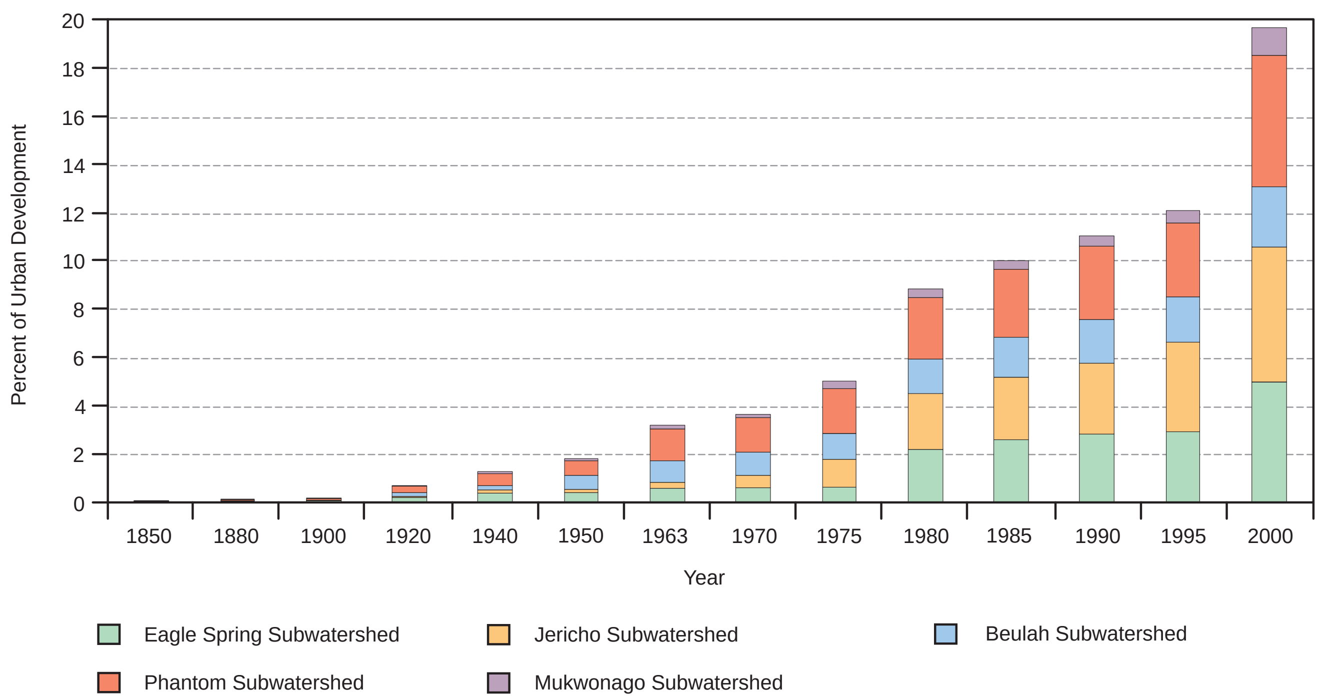
Figure 4

HISTORICAL URBAN GROWTH AMONG SUBWATERSHEDS WITHIN THE MUKWONAGO RIVER WATERSHED: 1850-2000

CUMULATIVE EXTENT OF URBAN DEVELOPMENT IN EACH SUBWATERSHED



CUMULATIVE EXTENT OF URBAN DEVELOPMENT WITHIN THE ENTIRE MUKWONAGO RIVER WATERSHED

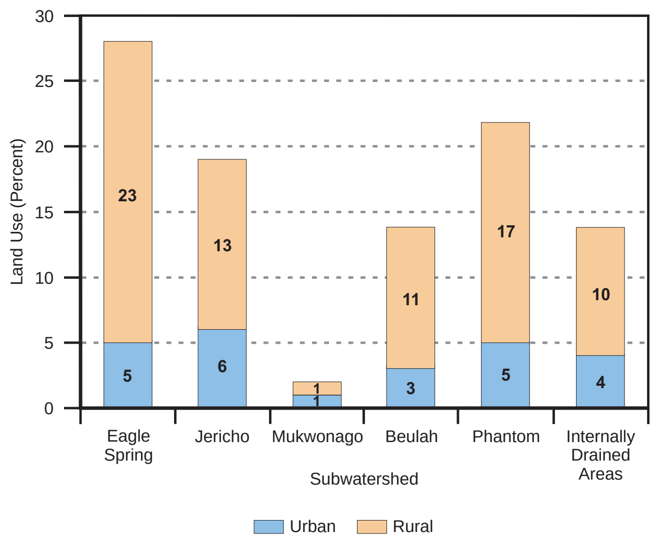


NOTE: Urban development within internally drained areas is not included in these graphs.

Source: SEWRPC.

Figure 5

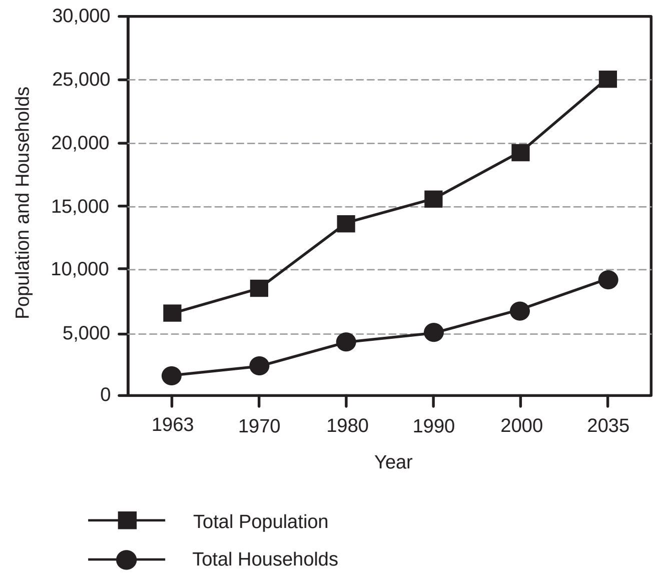
PERCENT URBAN VERSUS RURAL LAND USE AMONG SUBWATERSHEDS WITHIN THE MUKWONAGO RIVER WATERSHED: 2000



Source: SEWRPC.

Figure 6

TOTAL POPULATION AND NUMBER OF HOUSEHOLDS IN THE MUKWONAGO RIVER WATERSHED: 1963-2035



Source: SEWRPC.

Figure 5 also shows that the Jericho subwatershed contains the highest percentage of urban development in the entire Mukwonago River watershed. Since 1990, urban development has significantly increased within the Jericho subwatershed and has primarily occurred within and adjacent to the downstream portions of Jericho Creek in the Town of Eagle (see Map 4). Urban development has also occurred in the headwater portions of Jericho Creek primarily within the Village of North Prairie. The Eagle Spring and Phantom subwatersheds each account for about 5 percent of the urban development within the entire watershed as shown in Figure 5. The Towns of Eagle and Mukwonago account for the majority of the urban development within the Eagle Spring and Phantom subwatersheds, respectively. The Village of Mukwonago comprises the entire area of the Mukwonago subwatershed where the rate of development since 1975 has been higher than in any of the other subwatersheds as shown in Figure 4. The Beulah subwatershed contains the lowest proportion of urban land compared to the other subwatersheds. This subwatershed lies mostly within Walworth County where agricultural preservation is a high priority (see Smart Growth Plan section below). Finally, Figure 5 shows that the internally drained areas that were shown on Map 3 in Chapter I of this report, comprise 14 percent of the Mukwonago River watershed. These areas are generally rural in character and primarily located within Waukesha County (see Internally Drained Areas section below).

Population and Households

The Mukwonago River watershed generally experienced stable growth in population and numbers of households from 1963 to 2000, as shown in Figure 6. Over time, population and numbers of households in the Waukesha County portion of the watershed have grown at about the same rate as population and numbers of households on a countywide basis. The resident population was approximately 6,528 persons in 1963. Since then, the population in the Mukwonago River watershed has steadily increased, with the greatest percentage of increase occurring between 1970 and 1980. As of 2000, there were approximately 19,260 individuals residing in the watershed. The number of resident households also has continued to increase, although at a slower rate than that of the population. As of 2000, there were about 6,757 households in the watershed. Based upon the adopted regional land use plan, the population in the Mukwonago River watershed is projected to increase through the year 2035 by about 30 percent, while the numbers of resident households in the watershed are projected to increase by about 36 percent.

Existing and Planned Land Use
This section characterizes existing land use conditions as of the year 2000, and examines changes anticipated to occur through 2035. Table 2 sets forth land use data for the entire Mukwonago River watershed under existing year 2000 and planned year 2035 conditions. The data in Table 2 and shown on Map 5 indicate that, although a portion of this watershed is urbanized, about 76 percent of the land area of the basin is still in rural and other open space land uses. Only about 24 percent of the watershed area was in urban uses as of the year 2000.

Urban Land Use
As indicated in Table 2, in 2000, urban land uses—which include residential, commercial, industrial, governmental, transportation, communication, utilities, and recreational lands—encompassed approximately 24 percent of the total watershed area. Residential land uses comprised the largest urban land use, covering about 7,020 acres, or about 15 percent of the total watershed. While urban development exists throughout much of the Mukwonago River watershed, it is especially concentrated in and around the Villages of Mukwonago, Eagle and North Prairie.

Under planned 2035 land use conditions, about 18,550 acres, or 39 percent of the watershed, are anticipated to be in urban land uses. Residential development is anticipated to comprise the majority of the increase in urban land use. Map 6 shows the recommended land uses for the watershed, including an increase of about 5,000 acres in residential lands. Much of this growth in residential lands is recommended to be at low densities.[1] Future urban development is recommended to be accommodated within the areas identified on Map 6 as residential, commercial, industrial, and governmental.

Sanitary sewer service areas include existing and planned sewage treatment facilities, as shown on Map 7. These sewer service areas have been delineated through a local sewer service area planning process. As part of this process, the community concerned, assisted by SEWRPC, determines a precise sewer service area boundary consistent with local land use plans and development objectives. Sewer service area plans include detailed maps of environmentally significant areas within the sewer service area. Following adoption of the plan by the designated management agency for the sewage treatment plant, local sewer service area plans are considered for adoption by SEWRPC as a formal amendment to the regional water quality management plan. The Commission then forwards the plans to the WDNR for approval. It should be noted that, despite its proximity to the Mukwonago River, the Village of Mukwonago sewage treatment plant discharges to the Fox River.

Certain lands, associated with the Mukwonago County Park, the Rainbow Springs Resort, and the Eagle Spring Lake Management District as shown on Map 7, have been anticipated to be tributary to the Village of Mukwonago sewage treatment facility and were the subject of previous sewer service area refinements.[2] The provision of capacity in the Rainbow Springs-Mukwonago portion of the recommended Eagle Spring-Mukwonago Intercommunity Trunk Sewer is noted in the regional plan as one option for providing for a connection from the Eagle Spring Lake area to the Village of Mukwonago sewerage system. As of late 1995, the Eagle Spring Lake Management District Commissioners were unwilling to commit the necessary funds to that specific proposal, and the development project that was proposed to construct the Rainbow Springs-Mukwonago portion of the trunk

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[1]*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).*

[2]*SEWRPC Community Assistance Planning Report No. 191,* Sanitary Sewer Service Area for the Village of Mukwonago, *November 1990; pursuant to the provision of Section 33.235 of the* Wisconsin Statutes, *the Eagle Spring Sanitary District was converted to a public inland lake protection and rehabilitation district with sanitary district powers.*

Table 2

LAND USE IN THE MUKWONAGO RIVER WATERSHED: 2000-2035[a,b]

Category[c]	2000		2035		Change: 2000-2035	
	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent
Urban						
High-Density Residential	72	<1	0	0	- -	- -
Medium-Density Residential	915	2	1,728	4	813	89
Low-Density Residential	3,674	8	5,900	12	2,226	61
Suburban-Density Residential	2,359	5	3,771	8	1,412	60
Commercial	120	<1	524	1	404	337
Industrial	103	<1	499	1	396	384
Governmental and Institutional	237	<1	499	1	262	111
Transportation, Communication and Utilities	1,768	4	2,762	6	994	1
Transportation Highway and Rail-Related	958	2	1,144	2	186	<1
Extractive	19	<1	213	<1	194	1,021
Recreational	1,230	3	2,052	4	822	67
Subtotal	11,455	24	19,092	40	7,637	67
Rural						
Agricultural and Open Lands	21,608	46	14,015	30	-7593	-35
Wetlands	4,525	10	4,518	10	-7	<1
Woodlands	7,755	16	7,718	16	-37	<1
Water	2,109	4	2,109	4	0	0
Subtotal	35,997	76	28,360	60	-7,637	-21
Total	47,452	100	47,452	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 to increase the transportation, communication, and utilities category, the result of the use of narrower estimated right-of-ways in prior inventories. The treatment of streets and highways generally diminishes the area of adjacent land uses traversed by those streets and highways in the 2000 land use inventory relative to prior inventories.*

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

Source: SEWRPC.

sewer was abandoned in 1997.[3] Consequently, the best means for providing public sanitary sewer service to Eagle Spring Lake and connecting to the Village of Mukwonago treatment facility will have to be evaluated in subsequent facilities planning when there is local interest in providing such service. In 2008, the WDNR purchased the Rainbow Springs Resort property which subsequently has been dedicated as the Mukwonago River Unit of the Kettle Moraine State Forest. Because of the anticipated change in land use on this property, it is unlikely that these lands will be connected to the Village of Mukwonago sanitary sewer service area.

Rural Land Use

As shown in Table 2, in 2000, rural lands—consisting of woodlands, wetlands, surface water, agricultural crop-lands and other open lands—comprised about 76 percent of the total land area of the Mukwonago River

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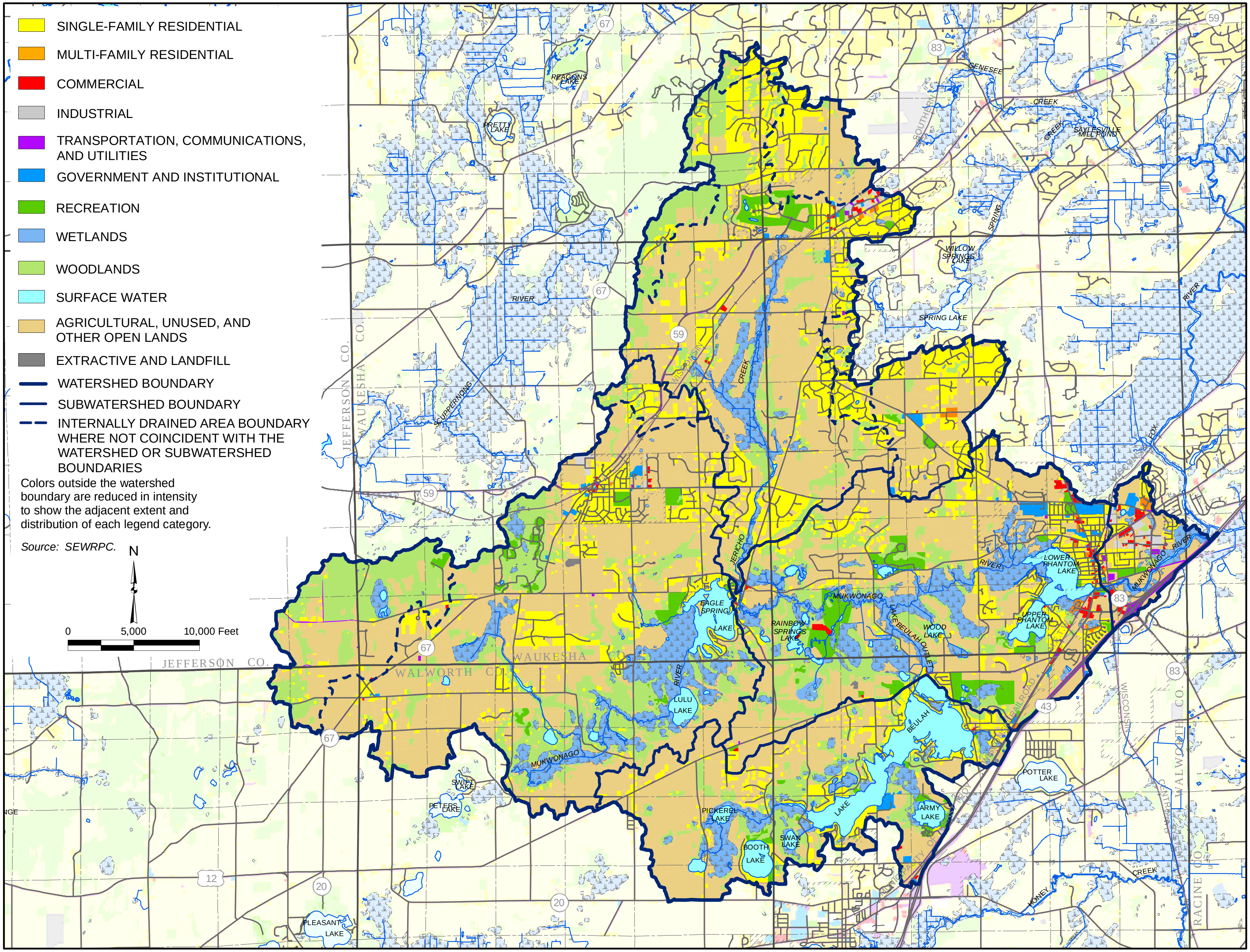
[3]*SEWRPC Community Assistance Planning Report No. 226,* A Lake Management Plan for Eagle Spring Lake, Waukesha County, Wisconsin, *October 1997.*

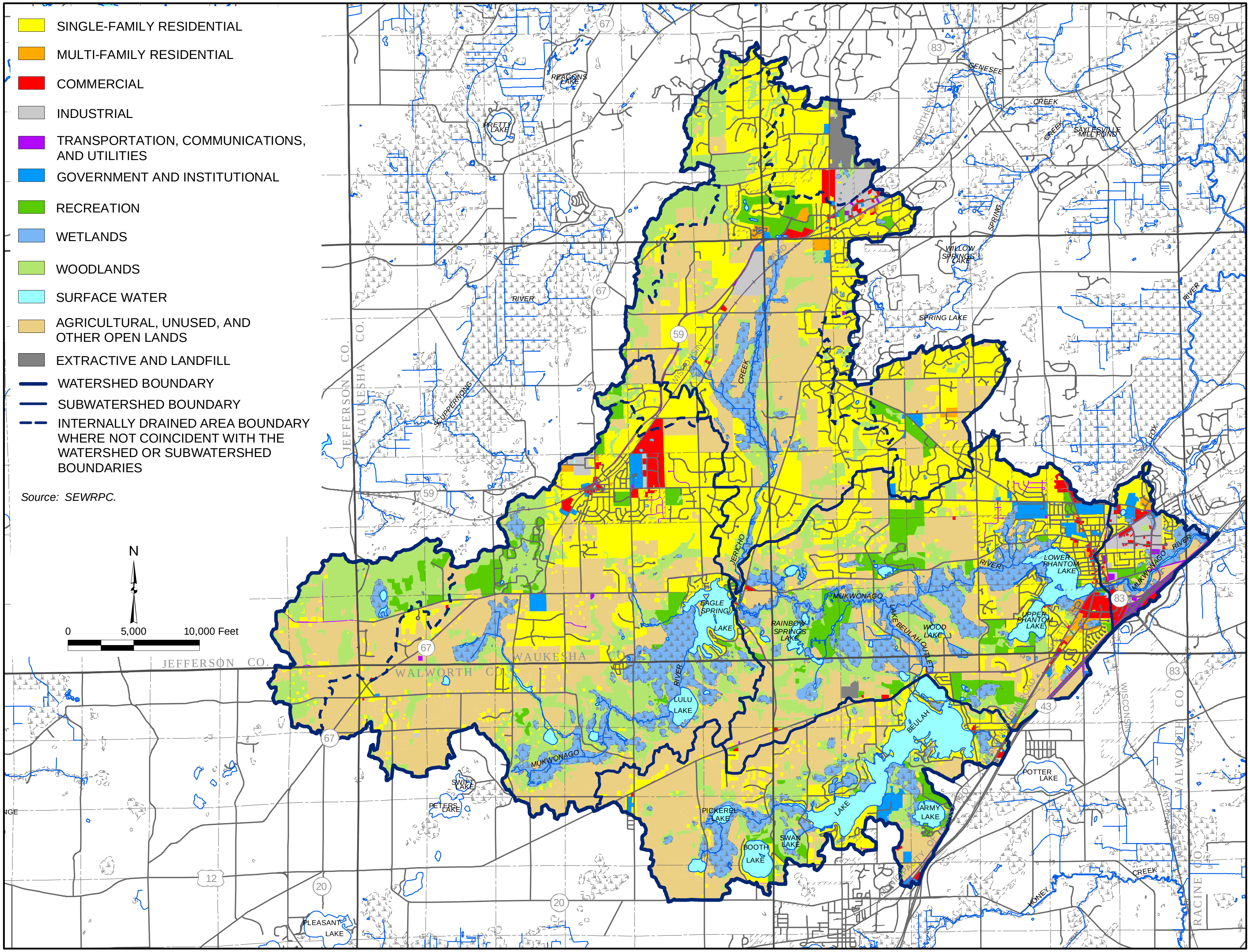
Map 5

EXISTING LAND USE WITHIN THE MUKWONAGO RIVER WATERSHED: 2000



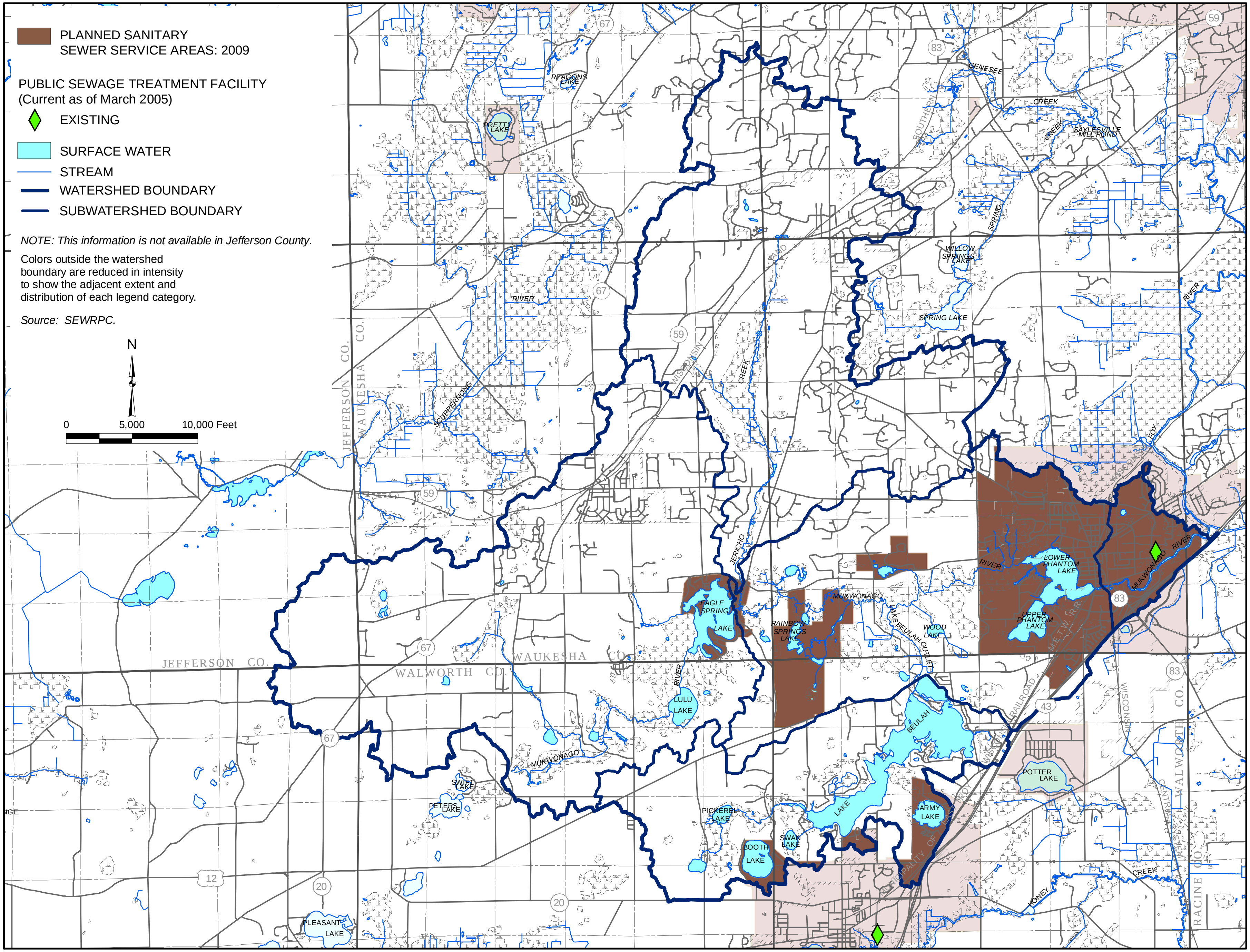
Map 6

PLANNED LAND USE WITHIN THE MUKWONAGO RIVER WATERSHED: 2035



Map 7

ADOPTED SANITARY SEWER SERVICE AREAS WITHIN THE MUKWONAGO RIVER WATERSHED: 2009



watershed. Agricultural and other open land uses were the largest rural land use in the watershed, encompassing about 46 percent of the total land area. Agricultural land use is divided between active cropland and other open lands, which includes farm buildings, pastures, grasslands that have not succeeded to wetland or woodland communities, and lands adjacent to cropland, such as treelines and hedgerows. Surface water, wetlands, and woodlands comprised about 30 percent of the land area in the watershed.

Historically, agricultural land was the most dominant land use and comprised about 56 percent of the total watershed area in 1970. Comparing this area of land with the year 2000 data, there has been a loss of nearly 11,500 acres. This agricultural land has been largely converted into urban land uses. This land conversion is the most significant documented shift in land use over time, altering how the landscape is used, with resultant consequences for water quality, water quantity, and wildlife. Based upon historical 1941 aerial photographs of the watershed, agricultural land use comprised an even larger amount of the watershed and dominated the landscape to an even greater extent than was recorded during 1970 (see Figures 7, 8, and 9). However, comparison of the 1941 aerial photographs to the year 2005 aerial photographs shows that much of the agricultural land has reverted back to woodland and wetland throughout large areas of the watershed. This reversion is especially evident along the riverine corridors, as shown in Figures 7, 8, and 9 (see also Riparian Management Practices section below). This has served to de-fragment and expand the environmental corridors, contributing to the high quality and extent of the natural areas that are currently present, and substantiating the ability of the landscape to shift from a “disturbed” condition to a more “natural” condition.

Between 2000 and 2035, rural land uses in the watershed are anticipated to continue to decrease by approximately 20 percent, as indicated in Table 2. The majority of this loss is anticipated to be from the conversion of agricultural croplands and other open lands to urban lands for residential, commercial, and industrial uses. Woodlands also are anticipated to experience a loss of about 34 acres during this period due to planned development as suggested by the current zoning ordinances within the watershed (see Table 2). Wetlands and woodlands are primarily located adjacent to the Mukwonago River. These lands are considered to be largely Class I and II wildlife habitat areas. In addition, the majority of this wildlife habitat is located within the primary and secondary environmental corridors located adjacent to the river system. Other significant portions of wildlife habitat are located within isolated natural resource areas located throughout the basin.

Relationship of Map 6, the Regional Plan, and Smart Growth Plans

The map showing planned year 2035 land use for the watershed (Map 6) was developed based upon the year 2035 regional land use plan, adopted by the Regional Planning Commission in 2006, and the recently completed comprehensive plans—often referred to as “smart growth” plans—for Walworth and Waukesha County. The regional land use plan is a systems-level plan that indicates a generalized pattern of recommended land uses throughout Southeastern Wisconsin through the year 2035; it is intended to be refined in county and local planning efforts, such as the county comprehensive, or smart growth, planning efforts. The Walworth and Waukesha County comprehensive plans were prepared within the framework of the regional land use plan, providing a more detailed delineation of individual planned land uses. Within the Mukwonago River watershed, these county comprehensive plans are consistent with the basic concepts of the regional plan and are viewed as refinements of the regional plan. Table 3 sets forth a comparison of the characteristics of various land use categories as defined under the county comprehensive plans and/or the 2035 SEWRPC regional land use plan. Map 6 generally reflects the patterns of planned land use for the watershed as presented in the county comprehensive plans, with the county planned land use categories placed into a common set of categories as appropriate.

It should be noted that, as a practical matter, the regional land use plan map shows only primary environmental corridors. While not shown on the regional plan map itself, secondary environmental corridors and isolated natural resource areas are also recommended for preservation, whenever possible, under the regional land use plan. Consistent with the recommendation of the regional land use plan, the Walworth and Waukesha County comprehensive plans (as well as Map 6) reflect secondary environmental corridors and isolated natural resource areas, as well as primary environmental corridors.

Figure 7

COMPARISON OF LAND USE NEAR JERICHO CREEK IN 1941 VERSUS 2005

Source: SEWRPC.

Figure 8

COMPARISON OF LAND USE NEAR THE MUKWONAGO RIVER DOWNSTREAM OF EAGLE SPRING LAKE IN 1941 VERSUS 2005

Source: SEWRPC.

Figure 9

COMPARISON OF LAND USE NEAR PHANTOM LAKES AND THE MUKWONAGO RIVER IN 1941 VERSUS 2005

Source: SEWRPC.

Table 3

COMPARISON OF PLANNED YEAR 2035 RESIDENTIAL, RURAL RESIDENTIAL, AND AGRICULTURAL LAND USE CATEGORIES AMONG THE WALWORTH COUNTY AND WAUKESHA COUNTY COMPREHENSIVE DEVELOPMENT PLANS AND THE SEWRPC REGIONAL LAND USE PLAN[a]

	Data Inventory Source					
Land Use Categories	Defined-Waukesha County Comprehensive Plan 2035	Defined-Walworth County Comprehensive Plan 2035	Defined-SEWRPC 2035	Waukesha (acres/ dwelling unit)	Walworth (acres/ dwelling unit)	SEWRPC (acres/ dwelling unit)
High-Density Residential[b]	Less than 6,000 square feet of area per dwelling unit	None	At least seven dwelling units per net residential acre	<0.14	None	<0.15
Medium-Density Residential[b]	6,000-19,999 square feet of area per dwelling unit	6,200-18,999 square feet of area per dwelling unit	2.3-6.9 dwelling units per net residential acre	0.14-0.46	0.14-0.44	0.16-0.44
Low-Density Residential[b]	20,000 square feet to 1.4 acres of area per dwelling unit	19,000 square feet to 1.4 acres of area per dwelling unit	0.7-2.2 dwelling units per net residential acre	0.46-1.4	0.44-1.4	0.45-1.43
Suburban-Density I Residential	1.5 to 2.9 acres of area per dwelling unit	None	None	1.5-2.9	None	None
Suburban-Density II Residential	3.0 to 4.9 acres of area per dwelling unit	None	None	3.0-4.9	None	None
Suburban-Density Residential[b]	None	1.5 to 4.9 acres of area per dwelling unit	0.2-0.6 dwelling units per net residential acre	None	1.5-4.9	1.44-5.0
Rural-Density Residential	5.0 to 34.9 acres of area per dwelling unit or equivalent density	At least five acres per dwelling	Not more than 0.2 dwelling unit per acre[c]	5.0-34.9	≥5.0	≥5.0
Prime Agricultural	35 acres of area per dwelling unit or greater	Minimum parcel size 35 acres	None	≥35	≥35	None
Other Agricultural, Rural Residential, Open Land	None	Five to 34 acres per dwelling	None	None	5-34	None
Other Agricultural, Rural Residential, Open Land	None	Five to 19 acres per dwelling	None	None	5-19	None
Other Agricultural, Rural Residential, Open Land	None	20 to 34 acres per dwelling	None	None	20-34	None

[a]*The following reports were the Waukesha County Department of Park and Land Use,* A Comprehensive Development Plan for Waukesha County, Waukesha County, Wisconsin, *February 2009; SEWRPC Community Assistance Planning Report No. 288,* A Multi-Jurisdictional Comprehensive Plan for Walworth County: 2035, *November 2009; and SEWRPC Planning Report No. 48,* A Regional Land Use Plan for Southeastern Wisconsin: 2035, *June 2006.*

[b]*For purposes of the Walworth County Comprehensive Plan the high-, medium-, low-, and suburban-density residential categories were combined as a single category called "urban density residential land" defined as less than 5.0 acres per dwelling. The land use plans for the individual towns divide the overall urban density lands into three or more density ranges.*

[c]*This includes prime agricultural land, other agricultural land, and rural density residential.*

Source: SEWRPC.

It should also be noted that certain areas in the watershed are identified on the regional land use plan map as "Rural Area" (with a recommended development density of at least five acres per dwelling unit), but shown as "Suburban II Residential Density" under the Waukesha County comprehensive plan (with a recommended development density of 3.0 to 4.9 acres per dwelling unit).[4] Prior analyses have shown that development as recommended in the County comprehensive plan would result in an overall density of five acres per dwelling, when adjacent open space is taken into account, resulting in the conclusion that the regional plan and county plan are consistent in this respect.

With respect to development design considerations, the Walworth County and Waukesha County comprehensive plans both accommodate the use of conservation subdivision designs for residential development, as recommended in the regional land use plan. Conservation subdivisions permit the clustering of housing units on smaller lots than allowed under conventional zoning, holding the surrounding areas in open use, thereby achieving the permitted density for the site overall. The Walworth County comprehensive plan recognizes conservation subdivisions as an alternative to conventional development and recommends a flexible approach to the choice of design options, with decisions on the use of conservation subdivision designs and other design options made on a case-by-case basis, taking into account the topography, existing natural resource features, and other site characteristics. The Waukesha County comprehensive plan recommends that the neighborhood planning process make full use of the many design options that can enhance the living environment and increase efficiency in the provision of urban services and facilities and in travel patterns—including conservation subdivisions as well as mixed-use development, traditional neighborhood development, and transit-oriented development. These county plan recommendations are consistent with the regional land use plan.

CLIMATE

Long-term average annual air temperature and total precipitation values for the Mukwonago River watershed are set forth in Figure 10. These averages were taken from official National Oceanic and Atmospheric Administration (NOAA) records for the weather recording station at Waukesha, Wisconsin. Due to its relative proximity to the project area, the records of this station may be considered typical of the entire watershed.

The mean annual precipitation at Waukesha between 1950 and 2008 was 33.0 inches, and the mean annual temperature was 47.1 degrees Fahrenheit (°F). Figure 10 shows that variability in each parameter is unpredictably high from year to year. This contributes to the fact that a statistically significant linear trend in either the temperature or precipitation data over the period of record could not be found. Figure 10 distinguishes warm versus cold years as well as wet versus dry years, based upon the calculated upper and lower 95 percent confidence intervals[5] for the entire period of record (see the note in Figure 10 for a specific explanation). Based upon the resulting classifications of wet and dry and warm and cold years, it is easy to see that there was a much higher proportion of warmer years post-1980, indicating that the past 28 years have been relatively warmer than the preceding years in the 58-year period of record. For example, 17 of the 28 years between 1980 and 2008, or about 61 percent of the period, were classified as warm compared to seven of the 30 years between 1950 and 1980, or about 23 percent of the period of record. Similarly, there were a higher proportion of wet years, about 46 percent, post-1980 and a higher proportion of dry years, about 43 percent, pre-1980. Therefore, it seems that there has been a shift from dryer and cooler conditions to wetter and warmer conditions over the period of record. These

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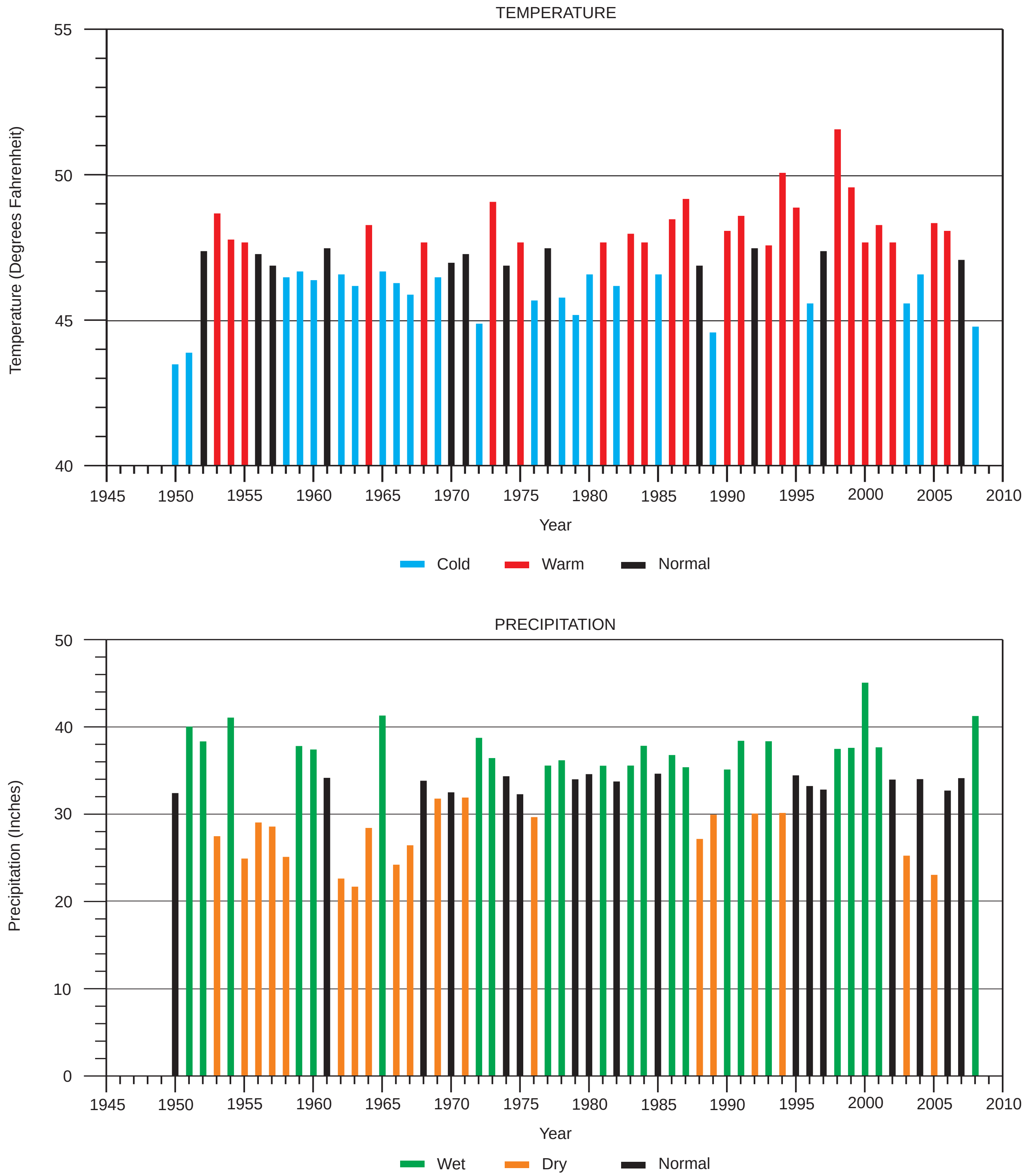
[4]*The Suburban II Residential Areas are shown as single-family residential on Map 6.*

[5]*The upper 95 percent confidence interval consists of the upper 5 percent of all of the values in the entire 58-year set of data for average temperature and total precipitation separately. The lower 95 percent confidence interval consists of the lower 5 percent of the same set of data. In each case, these confidence intervals distinguish extreme high versus low values of annual temperature and precipitation over the entire period of record.*

Figure 10

AVERAGE ANNUAL TEMPERATURE AND PRECIPITATION AT THE NOAA WAUKESHA WEATHER RECORDING STATION: 1950-2008

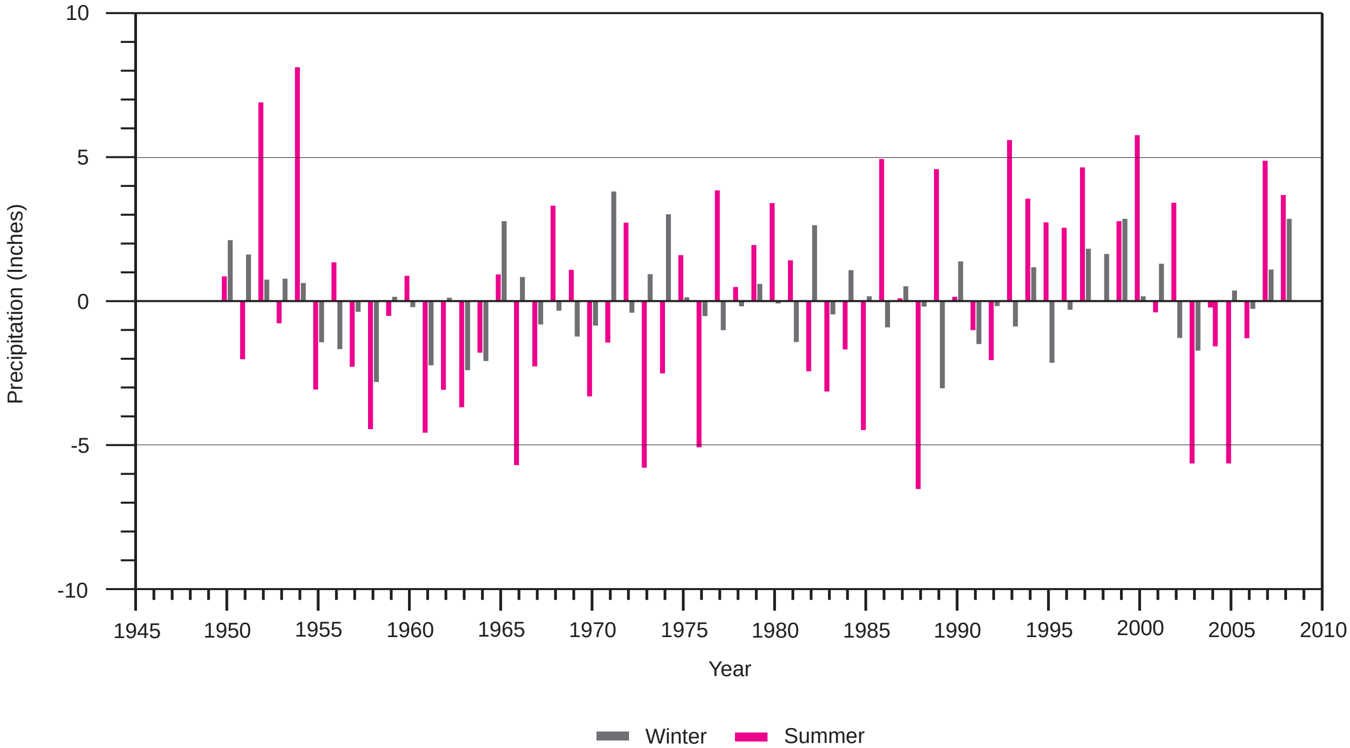


NOTE: Wet versus dry year classifications were determined by the 95 percent upper and lower confidence intervals (CI) of the entire period of record of 1950-2008. Annual average temperatures greater than 47.4 degrees Fahrenheit (i.e. upper 95 percent CI) were classified as 'Warm' and average temperatures less than 46.7 degrees Fahrenheit (i.e. lower 95 percent CI) were classified as 'Cold', and all other years were classified as 'Normal'. Total annual precipitation greater than 34.3 inches (upper 95 percent CI) were classified as 'Wet', and total precipitation less than 31.6 (lower 95 percent CI) were classified as 'Dry', and all other years were classified as 'Normal'.

Source: National Oceanic and Atmospheric Association and SEWRPC.

Figure 11

SUMMER AND WINTER AVERAGE PRECIPITATION DEPARTURES FROM NORMAL AT THE NOAA WAUKESHA WEATHER RECORDING STATION: 1950-2008



NOTE: Summer was defined as the months of June, July, and August and had a mean precipitation of 11.7 inches. Winter was defined as the months of December, January, and February and had a mean precipitation of 4.4 inches.

Source: National Oceanic and Atmospheric Association and SEWRPC.

climatic conditions are drivers of water quality conditions within lake and stream systems and are important considerations in water quality assessments (see Water Quality Conditions section in Chapter IV of this report).[6]

Winter temperature and precipitation trends are potentially important indicators for short- and long-term aquatic health and recreation. Winter temperatures are a major determinant of nonnative aquatic plant growth in lakes and streams in the Midwest. Warmer winters can provide advantages to nonnative species. For example, continued growth of Eurasian water milfoil (*Myriophyllum spicatum*) under the ice or early emergence following spring ice-out contributes to the degradation of the native aquatic plant community, impairment of water uses, and increased management costs and/or user conflicts. Warmer winters also may provide opportunities for colonization by other nonnative plant species, such as Hydrilla (*Hydrilla verticillata)* and fishes, among others (see Nonnative/Invasive Species section in Chapter IV of this report). Warmer winters also may result in decreased winter recreational opportunities, limiting ice fishing and snowmobiling due to unsafe or variable ice conditions. The annual winter precipitation records, set forth in Figure 11, show that winter precipitation between the mid-1950s and mid-1960s was about 1.5 inches less than the long-term winter average of 4.4 inches. Conversely, since the mid-1990s, annual winter precipitation has been about 0.5 inch above the average. The annual winter average temperatures

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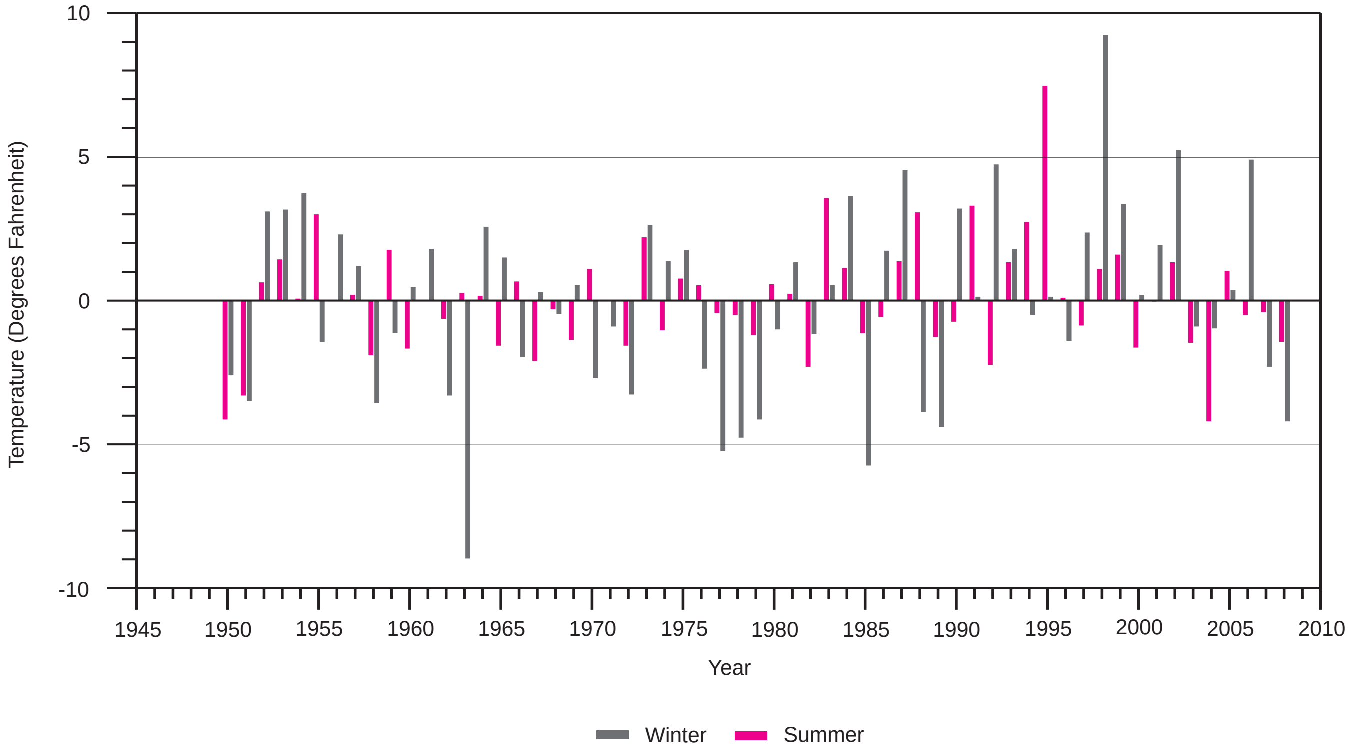
[6]*Wisconsin Academy of Sciences, Arts and Letters (WASAL),Waters of Wisconsin: The Future of Our Aquatic Ecosystems and Resources, Madison, Wisconsin, 2003.*

Figure 12

SUMMER AND WINTER AVERAGE TEMPERATURE DEPARTURES FROM NORMAL AT THE NOAA WAUKESHA WEATHER RECORDING STATION: 1950-2008



NOTE: Summer was defined as the months of June, July, and August and had a mean temperature of 69.8 degrees Fahrenheit. Winter was defined as the months of December, January, and February and had a mean temperature of 22.5 degrees Fahrenheit

Source: National Oceanic and Atmospheric Association and SEWRPC.

shown in Figure 12 suggest that winters were generally colder prior to 1980 and warmer since 1980, with five of warmest winters on record occurring during this latter period. Winter temperatures since 1980 have been greater than 4.0°F above the long-term mean. The recent winter warming is consistent with other observations throughout the State of Wisconsin.[7]

Approximately one-third of the annual precipitation occurs during the winter or early spring when the ground may be frozen. This may result in higher surface runoff rates and/or volumes, especially when air temperatures are high enough for the precipitation to fall as rain or cause rapid snowmelt, or to result in rainfall with associated snowmelt.

More than one-half of the normal yearly precipitation falls during the growing season, between May and September. During this period, runoff volumes 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.

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[7]Ibid.

These climatic indicators can affect water quality. For example, higher 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). Low dissolved oxygen concentrations are a major concern during the summer months. Even short periods of time when dissolved oxygen concentrations fall below 5.0 mg/l can cause significant decreases in the abundance and diversity of the aquatic organisms in streams.

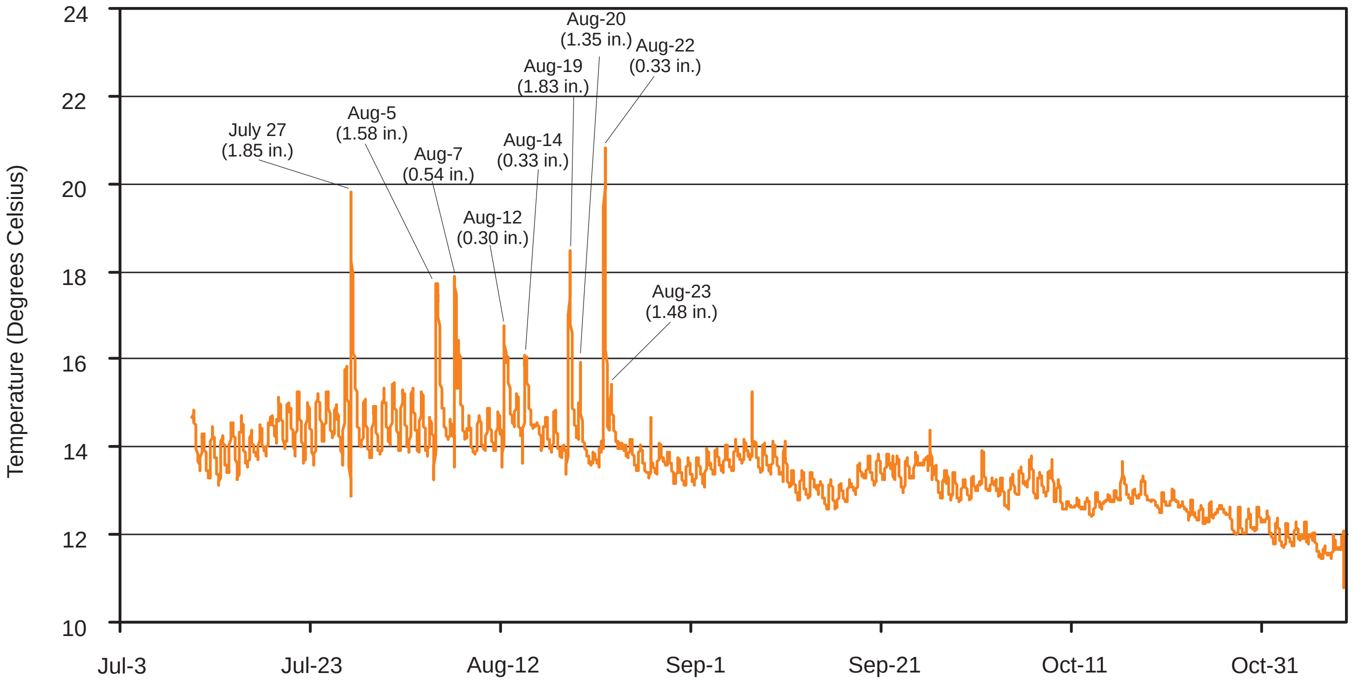
Figures 11 and 12 show the average temperature and total precipitation for the summer months (June, July, and August, combined) to be 69.8°F and 11.7 inches, respectively, over the past 58 years. Similar to the annual trends above, variability in both summer average temperature and total precipitation remains unpredictably high from year to year. The deviation from normal air temperature can range from nearly zero to almost 9 °F and the deviation from normal precipitation can range from zero to eight inches. Fortunately, the Mukwonago River's discharge is supplemented by a high proportion of cold, well-oxygenated groundwater inflow which helps to mitigate critical summer periods that are warmer and/or dryer than normal (see Groundwater section in Chapter IV of this report).

In like manner to annual average temperature and winter temperature trends summarized above, summer average temperatures seem to have shifted from a cooler condition prior to 1980 to a much warmer condition post-1980, with the warmest recorded summer average temperature being recorded during 1995. Summer precipitation changes over time are similar to the recent annual trends of increased precipitation. These recent summer warming and increased precipitation patterns are consistent with other observations throughout the State of Wisconsin. Nevertheless the high variability in temperature and precipitation data from year to year, and even season to season, 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). In this regard, the Lake Beulah outlet, which is tributary to the Mukwonago River, has been reported by riparian residents to go "dry" periodically during the summer months. SEWRPC staff interpret this statement as suggesting a lack of flow over the dam with no perceptible flow in the outlet. Such conditions are most likely to be due to a combination of low precipitation, pumping of the shallow groundwater aquifers to serve urban development, and high evapotranspiration rates. This loss of discharge through Lake Beulah outlet may have negative consequences for the aquatic organisms living within this tributary to the Mukwonago River. In contrast, high precipitation can lead to increased stormwater runoff and thermal impacts to coldwater streams which has been documented in the headwaters of Jericho Creek (see Figure 13). Hourly water temperature data within Jericho Creek just downstream of State Trunk Highway (STH) 59 indicates significant increases in water temperatures during rainfall events. Figure 13 shows increased heating pulses from about two to more than six degrees for every storm event of more than 0.25 inch of rainfall in a 24-hour period in July and August 2007.

The study year, 2008, was the third wettest year on record, with a total of 40.91 inches of precipitation—the wettest and second wettest years had totals of 44.73 inches of precipitation, in 2000, and 40.96 inches of precipitation, in 1965, respectively. The 2008 study year also was unusual in that the winter was documented to have the third highest recorded level of precipitation since 1950, which was combined with the unusually high levels of precipitation during spring and summer. This unusually wet period led to the highest documented rates of discharge on the Fox River (based upon records from the gauging station located in the City of Waukesha) over the period of record (between 1962 and 2008), as well as increased infiltration into the shallow groundwater aquifers. This combination of circumstances led to a number of flooding related problems occurring throughout the Southeastern Wisconsin Region. In terms of the Mukwonago River watershed, there were concerns over the integrity of the Lower Phantom Lake dam and flooding within the County Bliss Subdivision in the Town of Mukwonago. In contrast, 2008 was one of the coldest years experienced during the 58-year period of record. Both precipitation and average temperature conditions for 2008 are important considerations for water quality assessment with this watershed.

Figure 13

HOURLY WATER TEMPERATURE AT STH 59: JULY THROUGH OCTOBER 2007



NOTE: Rainfall totals are from a station located in Waukesha, Wisconsin.

Source: National Oceanic and Atmospheric Administration and SEWRPC.

GEOLOGY AND PHYSIOGRAPHY

The topographic elevations in the Mukwonago River watershed shown on Map 8 range from approximately 775 feet above National Geodetic Vertical Datum, 1929 adjustment (NGVD 29) near the confluence of Mukwonago River with the Fox River in the southeastern portion of the watershed, to over 1,050 feet above NGVD 29 in the northern portion of the watershed, a variation of about 300 feet. Most of the high points in the watershed are located along the Inter-Lobate Kettle Moraine in the northwestern portion of the watershed, which is one of the major physiographic and topographic features in the watershed as shown on Map 8. The Inter-Lobate Kettle Moraine is part of much larger glacial landform features that were formed more than 10,000 years ago.[8]

Land slopes within the watershed range from less than 1 percent to greater than 20 percent as shown on Map 9. However, significant portions of the Mukwonago River watershed contain slopes exceeding 12 percent, with many such areas being located along the Kettle Moraine. About 13 percent of the total land area of the watershed has slopes of 20 percent or greater. About 7 percent of the total land area has slopes of between 13 and 19 percent. Poorly planned hillside development in these areas can lead to severe construction and post-construction erosion problems, and high maintenance costs associated with public infrastructure. Steeply sloped agricultural lands may make the operation of agricultural equipment difficult or even hazardous, while development or cultivation of steeply sloped lands is likely to result in erosion and sedimentation that negatively impact surface water quality. Approximately 70 percent of the watershed has slopes of less than 6 percent.

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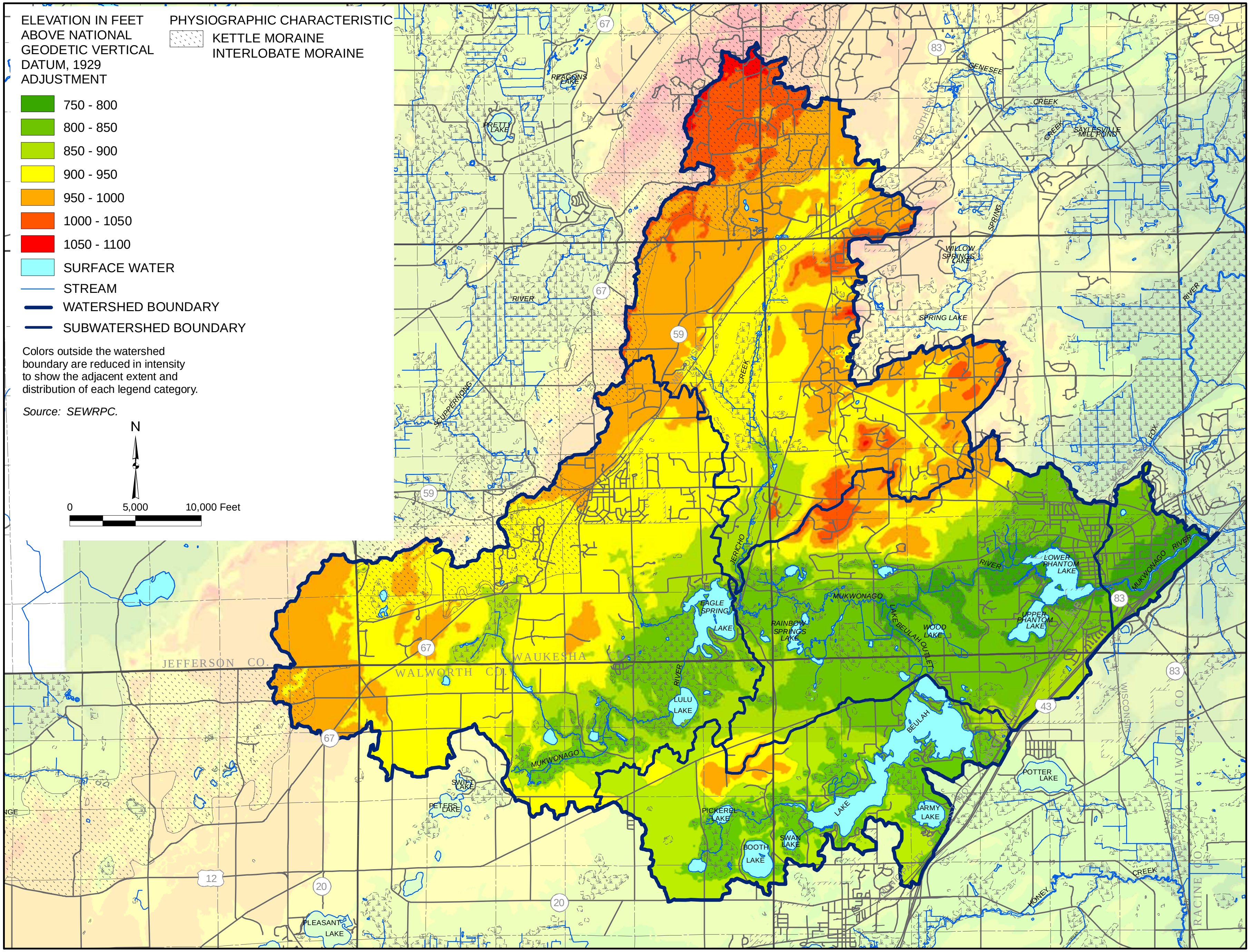
[8]*Waukesha County Department of Parks and Land Use-Land Resources Division,* Waukesha County Land and Water Resources Management Plan: 2006-2010*, March 2006.*

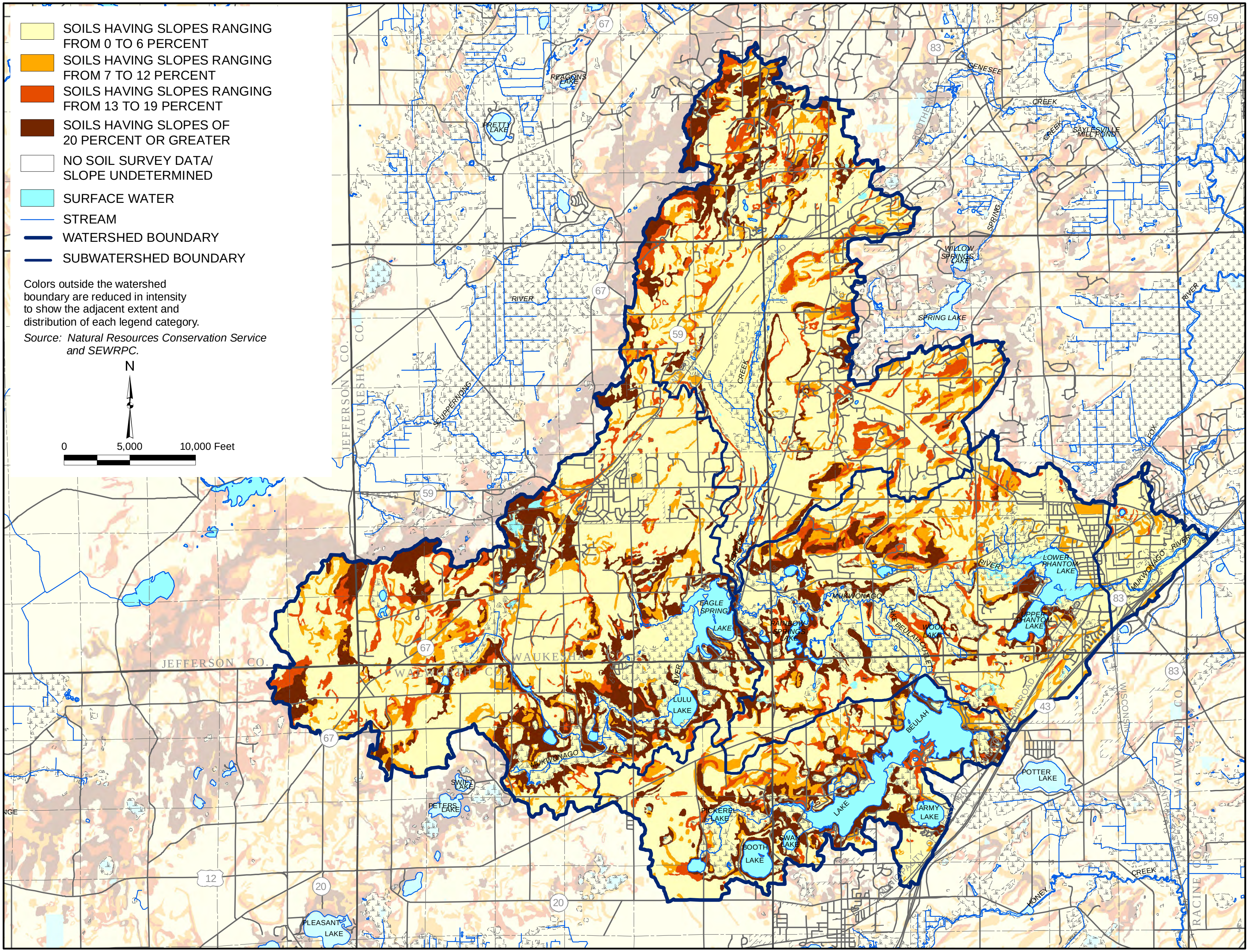
Map 8

TOPOGRAPHIC AND PHYSIOGRAPHIC CHARACTERISTICS WITHIN THE MUKWONAGO RIVER WATERSHED



Map 9

SLOPES WITHIN THE MUKWONAGO RIVER WATERSHED



Bedrock Geology
The bedrock and surface deposits overlying the bedrock directly and indirectly affect the quantity and quality of surface water and groundwater in the Mukwonago River watershed. Water from within the surface sand and gravel deposits supplies the shallow wells and springs that occur within the region.

The Mukwonago River 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 10, there are some areas in the watershed where the bedrock is at the ground surface and visible as bedrock outcrops. For example, a portion of the northern end of Jericho Creek has bedrock at between 0 and 25 feet depth below the ground surface, and was observed to have exposed bedrock in its streambed during the 2008 survey. The northern and western portions of the watershed contain the southern unit of the Inter-Lobate Kettle Moraine, which forms one of the dominant topographic features of the watershed. The Kettle Moraine, which is oriented in a generally northeast-southwest direction across western Washington, Waukesha, and Walworth Counties, is a complex system of kames, or crudely stratified conical hills; kettle holes formed by glacial ice blocks that became separated from the ice mass, creating depressions and small lakes as the meltwater deposited material around the ice blocks; and eskers, long, narrow ridges of drift deposited in abandoned drainageways. The remainder of the watershed is covered by a variety of glacial landforms and features, including various types of moraines, drumlins, kames, outwash plains, and lake basin deposits. The water from within the glacial sand and gravel deposits that characterize this landscape supplies the shallow wells and springs that occur within the watershed.

Fissures in the Niagara dolomite create water storages that are frequently tapped by moderately deep wells for water supply purposes. Underlying the Niagara dolomite is a relatively impervious layer of Maquoketa shale. In some pre-Pleistocene valleys in the western portions of the County, however, the Niagara dolomite is absent and the uppermost bedrock unit is the Maquoketa shale. Beneath the Maquoketa shale are dolomite and sandstone formations that constitute the "deep sandstone aquifer." This aquifer, however, is relatively unimportant in terms of its influence on the surface water resources of the County, since it does not intersect the surface drainage pattern. In the westernmost parts of Waukesha and Walworth Counties where the Maquoketa Formation is not present, including roughly the southern two-thirds of the Mukwonago River watershed, the shallow aquifer system consists of the sand and gravel aquifer, Galena-Platteville aquifer, and upper sandstone aquifer, and its lower boundary is the St. Lawrence semi-confining unit. The general orientation of the aquifers within south-eastern Wisconsin is shown in Figure 14, which is a cross-sectional view of the bedrock and surfacial deposits,[9] while Map 11 shows the generalized water table elevations.

SOILS

The glaciers deposited a wide variety of soil-forming materials and sculpted many different landforms that influence soil type and stream hydrology in the Southeastern Wisconsin region. 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.

There are four distinct types of soils that constitute the soil mantle of the watershed: lacustrine, glacial, alluvial, and peat soils. Both deep and shallow peat soils are commonly located in the poorly drained kettles situated between the ridges of the moraines, while sandy, alluvial soils are found in the valleys of streams and at the base of the drainage lines that indicate the points of convergence between the two glaciers. The U.S. Natural Resources Conservation Service (NRCS), formerly the U.S. Soil Conservation Service, completed a detailed soil survey of

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

Map 10

DEPTH TO BEDROCK WITHIN THE MUKWONAGO RIVER WATERSHED

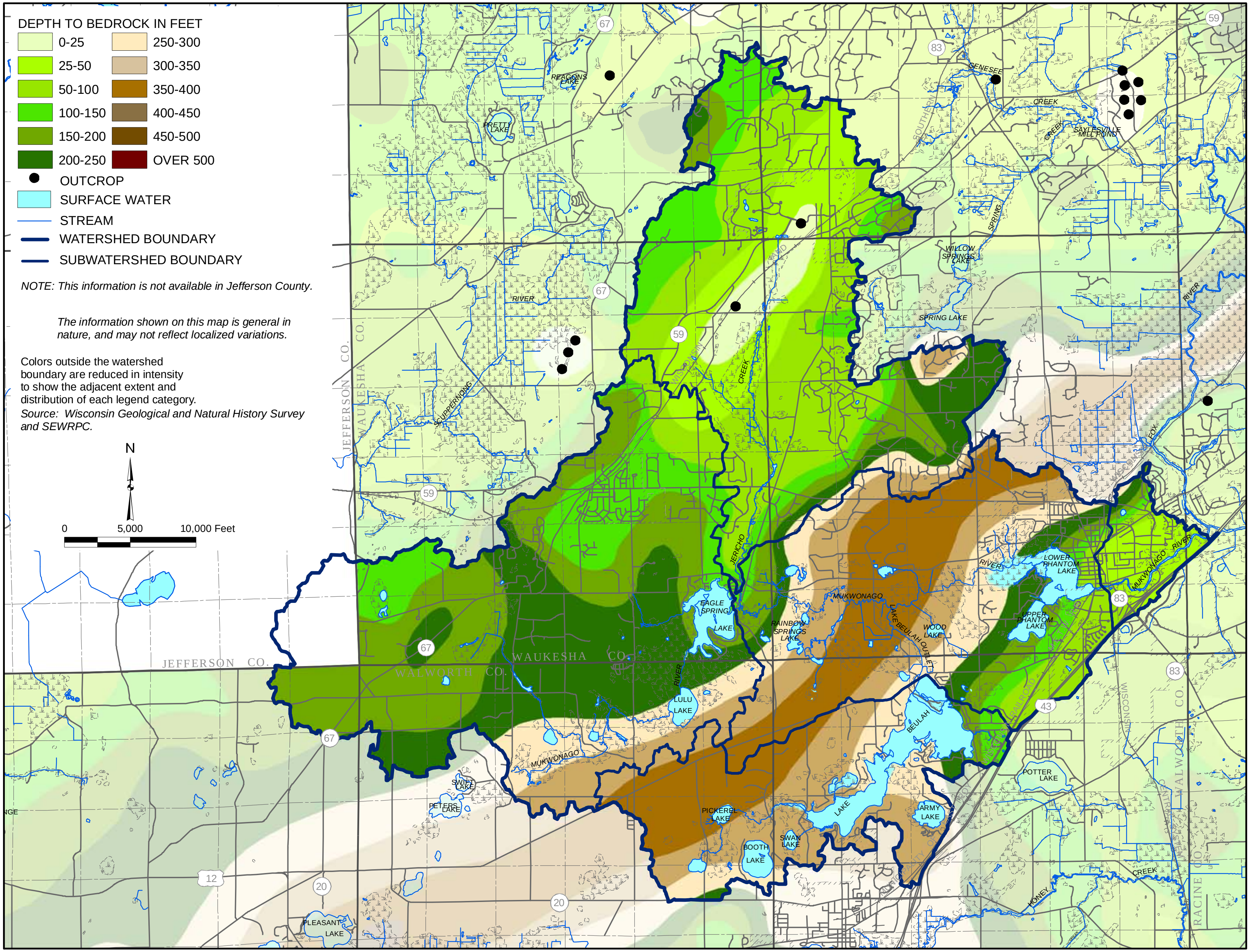
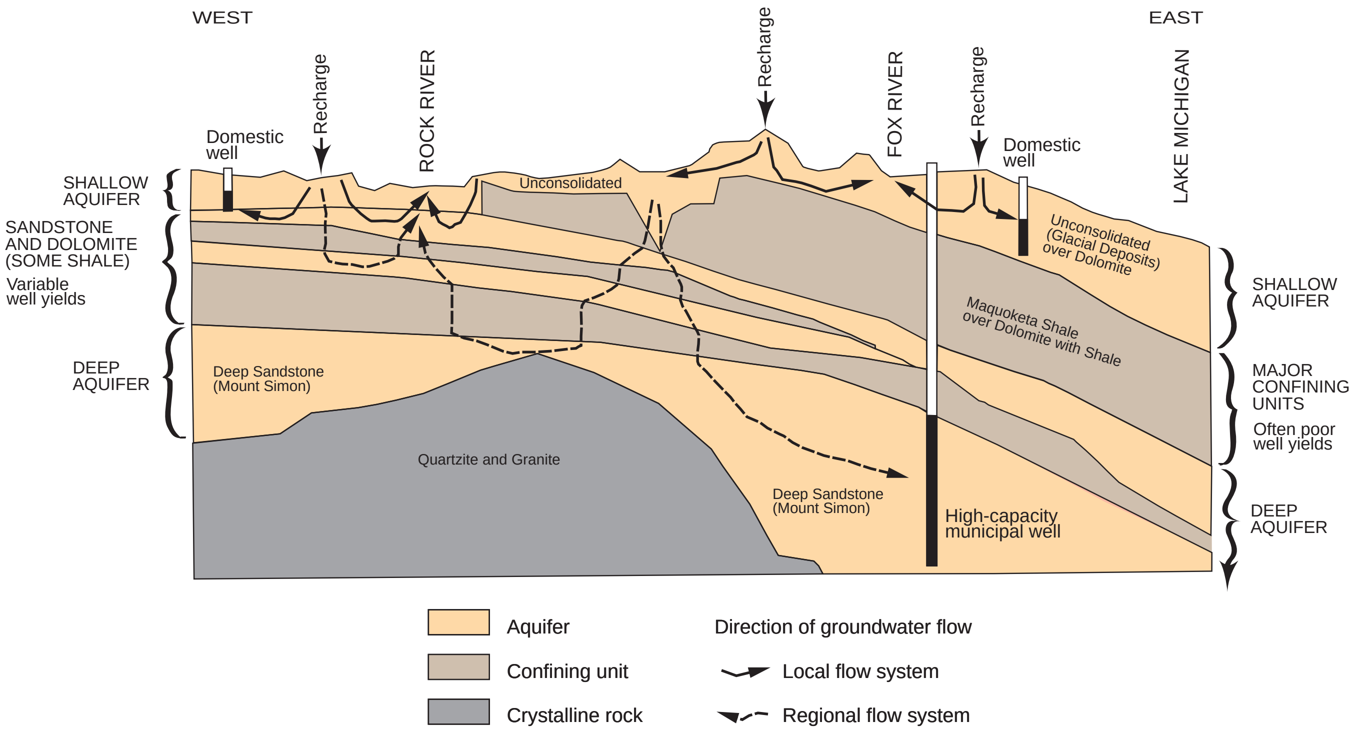


Figure 14

HYDROGEOLOGIC SECTION THROUGH SOUTHEASTERN WISCONSIN



Source: U.S. Geological Survey, University of Wisconsin-Extension, and SEWRPC.

the region in 1971.[10] These soil surveys contained interpretations for planning and engineering applications, as well as for agricultural applications.

The soils in the Mukwonago River watershed range from very poorly drained, organic soils to excessively drained, mineral soils. General grouping of these soils into soil associations is useful for comparing the suitability of relatively large areas of the watershed for various land uses. For this purpose, soil associations—defined as a landscape with a distinctive proportional pattern of soils comprised of one or more major soil types with at least one minor soil type as identified by the NRCS, and named after the major soils—are commonly utilized. Seven such soil associations exist in the Mukwonago River watershed. Their spatial distribution patterns within the watershed are shown on Map 12. The seven soil associations are described as follows:

- Casco-Fox association is comprised of well-drained soils that have a subsoil of clay loam. This association is moderately deep over sand and gravel and can be found on outwash plains and stream terraces.

- Casco-Rodman association is comprised of excessively- to well-drained soils that have a subsoil of clay loam and gravelly sandy loam. This association is shallow over gravel and sand, and is located on the Kettle Moraine.

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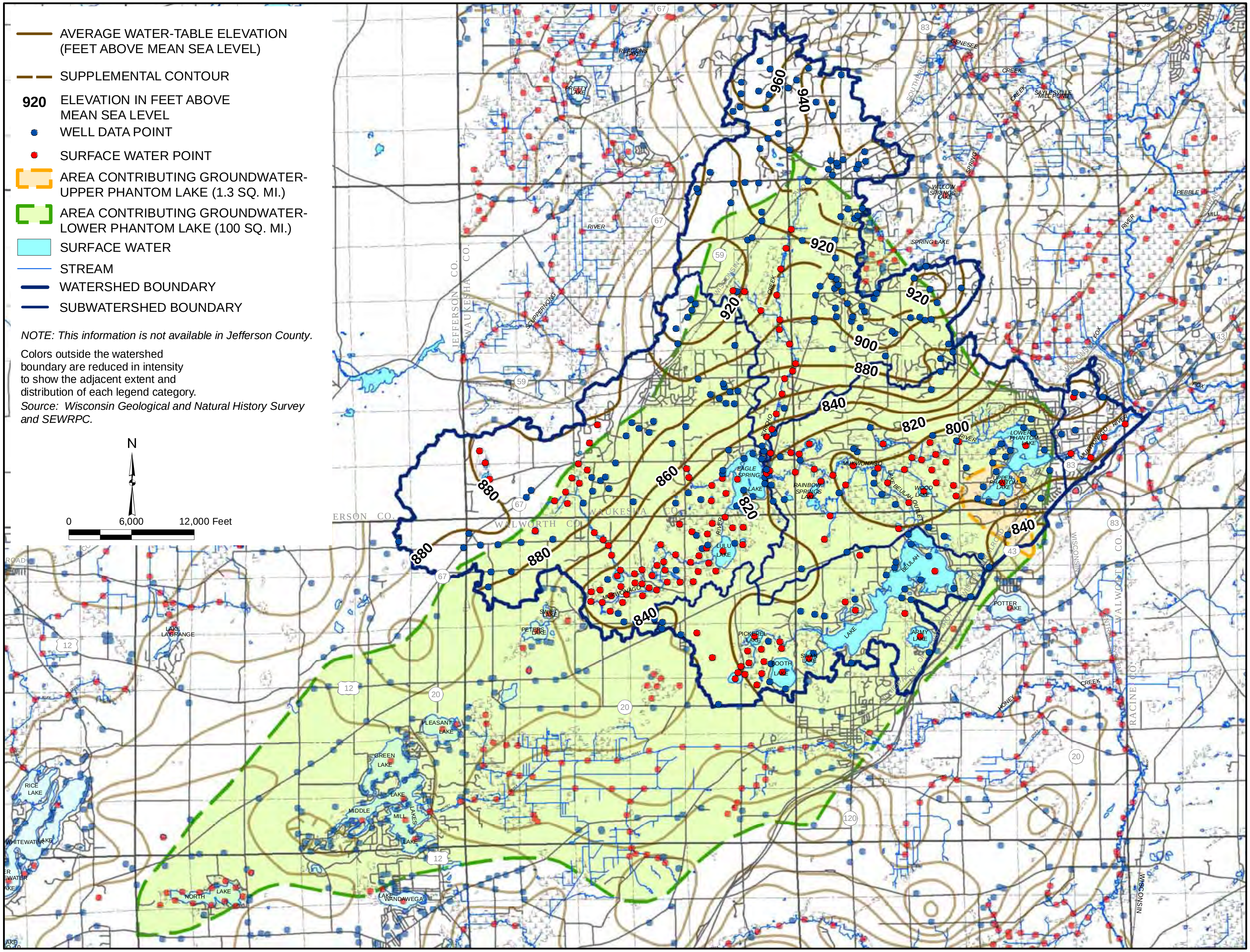
[10]*SEWRPC Planning Report No. 8*, Soils of Southeastern Wisconsin, *June 1966; see also U.S. Department of Agriculture Soil Conservation Service*, Soil Survey of Milwaukee and Waukesha Counties, Wisconsin, *July 1971; U.S. Department of Agriculture Soil Conservation Service*, Soil Survey of Walworth County, Wisconsin, *1971*.

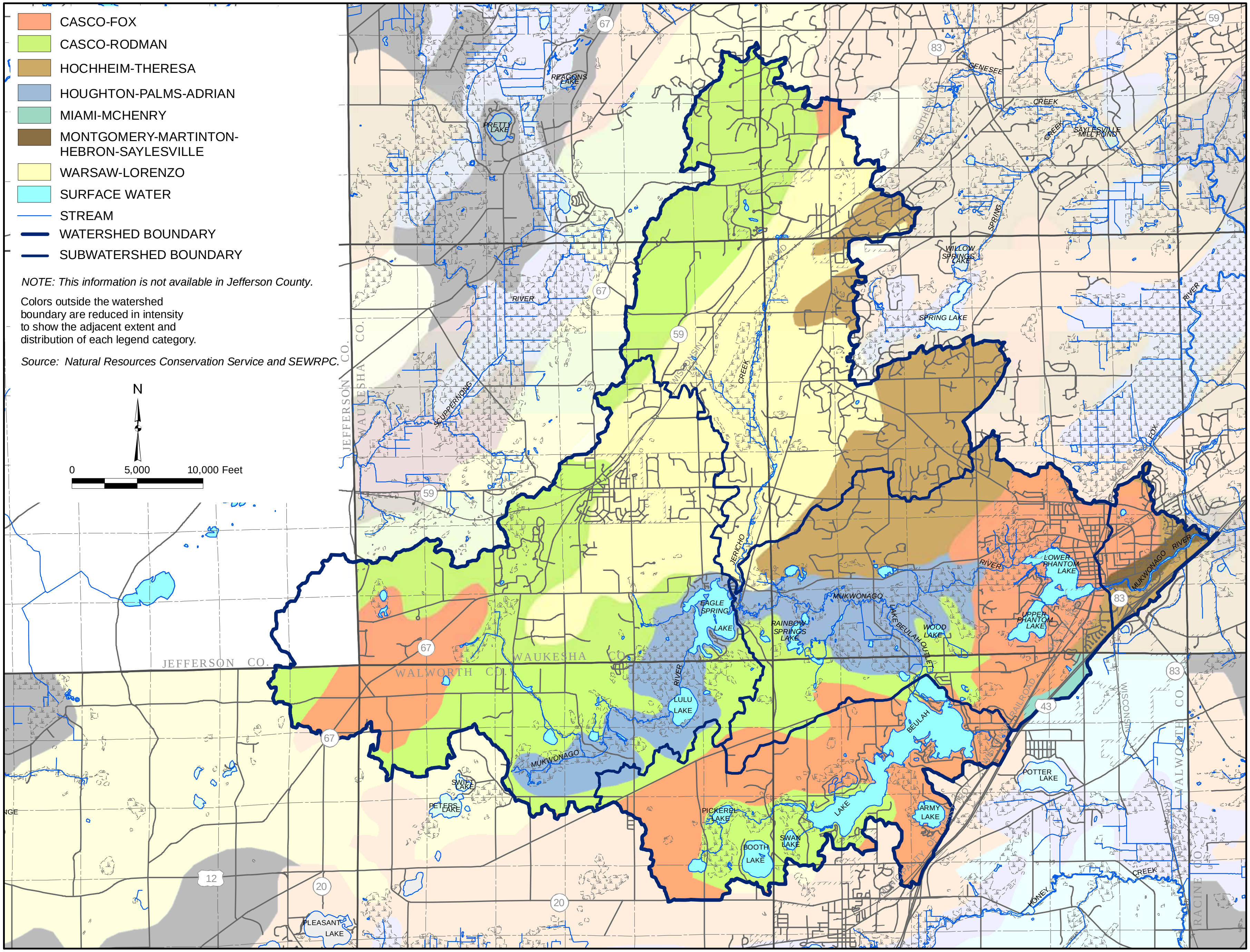
Map 11

GROUNDWATERSHED BOUNDARIES BASED ON WELL ELEVATIONS WITHIN THE MUKWONAGO RIVER WATERSHED



Map 12

SOIL ASSOCIATIONS WITHIN THE MUKWONAGO RIVER WATERSHED



- Hochheim-Theresa association is comprised of well-drained soils that have a subsoil of clay loam and silty clay loam that was formed in thin loess and loam glacial till, on ground moraines.

- Houghton-Palms-Adrian association is comprised of very poorly-drained organic soils located in depressions and bottom lands.

- Miami-McHenry association is comprised of well-drained soils that have a subsoil of clay loam and silty clay loam. This association was formed in loess and the underlying sandy loam to loam glacial till is located on uplands.

- Montgomery-Martinton-Hebron-Saylesville association is comprised of poorly-drained to well-drained soils that have a subsoil of clay to clay loam that was formed in the silty clay or silty clay loam sediments of old lakebeds.

- Warsaw-Lorenzo association is comprised of well-drained soils that have a subsoil of clay loam that is moderately deep over sand and gravel, and located in outwash plains and on river terraces.

Using the regional soil survey, an assessment was made of the hydrologic characteristics of the soils within the watershed. Soils were classified into four main hydrologic groups; well-drained soils, moderately-drained soils, poorly-drained soils, and very poorly-drained soils. Due to the glacial activity within this region, the Mukwonago River watershed is made up of more than 75 percent moderately-drained soils. This results in high to very high permeability with concomitant high to very high groundwater recharge potential.[11]

Agricultural Classifications
As shown on Map 13, lands with soils suitable for agricultural uses made up 15,010 acres, or 32 percent of the watershed area, during 2000. The category of agricultural land that meets the Federal NRCS definition of "prime" agricultural soils includes those lands that would meet the prime classification if artificially drained or protected from flooding. These lands include approximately 6,230 acres, or 13 percent of the watershed. A second category includes agricultural land that does not meet the Federal definition of prime agricultural soils, but is classified by the State as being "soils of statewide importance." These lands include 1,767 acres, or 4 percent of the watershed land area.[12] The third category, shown on Map 13, includes other agricultural lands that do not meet either the State or Federal definitions, and primarily includes fields with slopes greater than 12 percent. This category contains the largest amount of land classified as agricultural lands, comprising 7,013 acres, or 15 percent of the watershed.

WATER RESOURCES

The Mukwonago River watershed contains an area of about 74 square miles (about 47,450 acres). It is one of several subwatersheds that comprise the Upper Fox River watershed and it represents about 8 percent of the land area of that basin. Despite its relatively small size compared to the Fox River watershed, the problems or threats facing the water resources of the Mukwonago River watershed are similar to those facing the Fox River; namely, potential excessive nutrient input, runoff from croplands and urban lands, introductions of pesticides and

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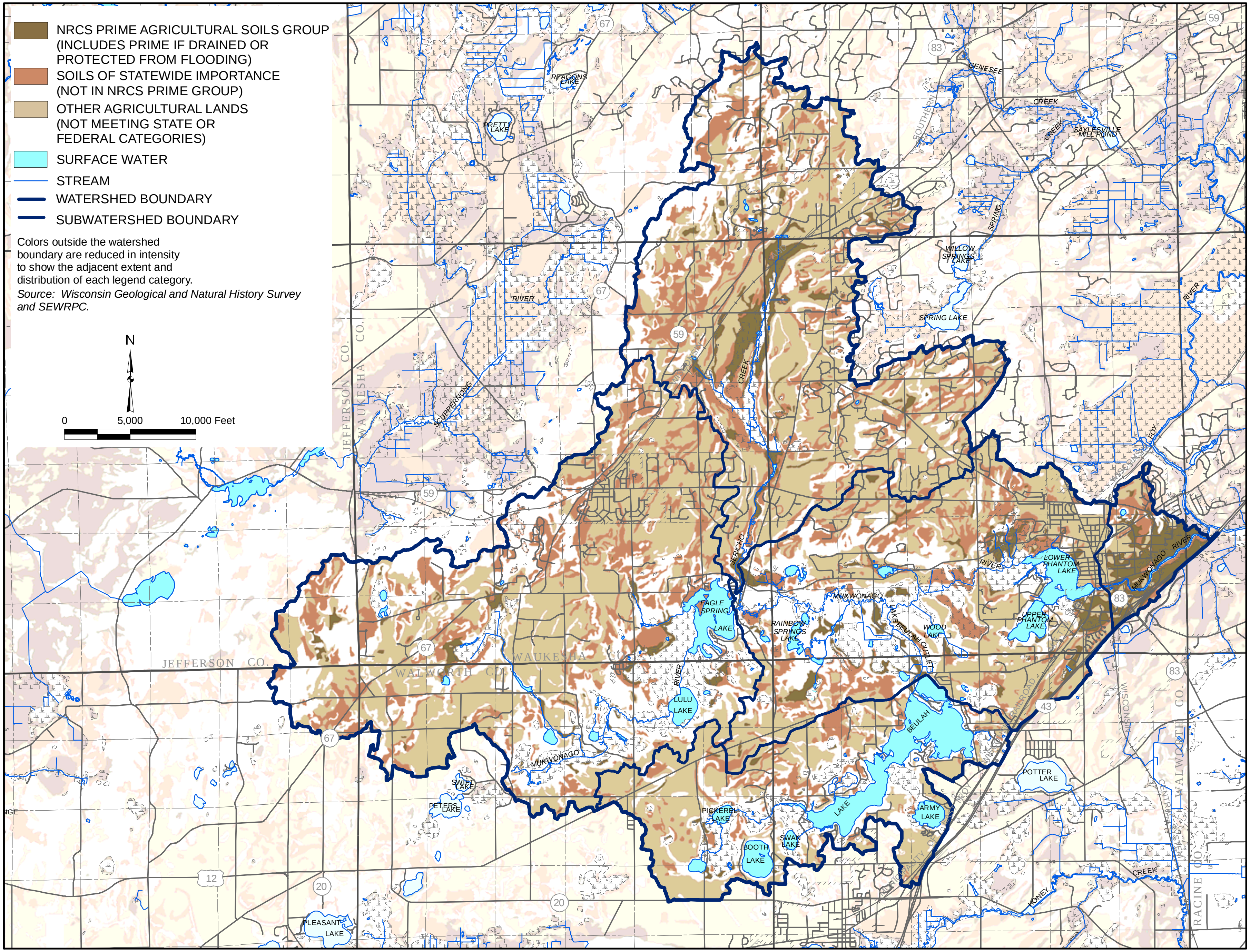
[11]*SEWRPC Technical Report No. 47*, Groundwater Recharge in Southeastern Wisconsin Estimated by a GIS-Based Water Balance Model, *July 2008.*

[12]*In the Mukwonago River watershed, the agricultural lands placed in the second category do not meet the Federal definition primarily because of steep slopes (6 to 12 percent) and poor drainage (water table at zero to three foot depth). However, with the application of soil conservation or drainage practices, these soils have proven to be very productive in Wisconsin.*

Map 13

FEDERAL AND STATE SOIL CLASSIFICATIONS FOR AGRICULTURAL USES WITHIN THE MUKWONAGO RIVER WATERSHED



herbicides, filling of wetlands, extreme fluctuations of stream flow or low flow, temperature extremes, low dissolved oxygen, loss of fish and macroinvertebrate habitat, and barriers to fish and aquatic organism migration.[13]

Surface Water Resources

The Mukwonago River is approximately 17 miles in length, extending from its headwaters in the Town of Eagle to its confluence with the Fox River in the Town of Vernon and Village of Mukwonago (see Map 3 in Chapter I of this report). The Mukwonago River watershed contains a large number of intermittent and perennial tributaries, the longest being Jericho Creek at about six miles in length, as well as a variety of seeps and springs. [14] The mainstem of the Mukwonago River provides a wealth of opportunity for recreational wading, swimming, canoeing, kayaking, hunting, fishing, and bird watching, as well as scientific study among other uses.

The Mukwonago River watershed also contains 14 lakes as listed in Table 4, including seven major lakes with surface areas greater than 75 acres; namely, Lulu Lake, Eagle Spring Lake, Lake Beulah, Upper Phantom Lake, Lower Phantom Lake, Army Lake, and Booth Lake. These lakes located throughout the Mukwonago River watershed provide a variety of boating-related recreation. This mixture of high quality lake and stream systems has provided the unique framework from which development has taken place within the Mukwonago River watershed.

Runoff from Urban Development and Impervious Surfaces

As indicated above, urban land use in the Mukwonago River 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 even flourish in urban settings with appropriate measures to control the impacts of urbanization. The main factors leading to the degradation of urban waterbodies include: the creation of large areas of connected impervious surfaces, the lack of adequate stormwater management facilities to control the quantity and quality of runoff, the proximity of development to waterbodies, loss of natural areas, and inadequate construction site 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 generally have significantly more impervious area than residential land uses, while smaller residential lots generally have more impervious surface than larger residential lots. Table 5 lists the approximate amounts of impervious surface created by residential, industrial, and commercial development. Although commercial and industrial developments generally have a larger percentage of impervious surface, residential developments, where lawns are the single largest use of the land area, 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), reducing their ability to infiltrate water. In many instances, considerable soil compaction occurs during grading of the home sites, significantly reducing the perviousness of lawns. Compared to turf grass, native grasses, forbs, and sedges have significantly deeper root systems, which loosen the soil and create flow channels that increase infiltration capacity. Also, owing to excessive application of fertilizers and pesticides, urban lawns typically produce higher

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

[14]*See Wisconsin Conservation Department,* 1958 Spring Area Survey: Waukesha County, sine datum*.*

Table 4

LAKES AND PONDS OF THE MUKWONAGO RIVER WATERSHED

Name	County	Area (acres)	Maximum Depth (feet)	Mean Depth (feet)	Lake Type	Public Access
Army Lake	Walworth	78	17	8	Spring lake	Walk-in trail
Booth Lake	Walworth	113	24	12	Seepage lake	Boat ramp
Browns Lake	Waukesha	13	15	5	Spring lake	- -
Eagle Spring Lake	Waukesha	279[a]	8	4	Drainage lake	Boat ramp
Hogan Lake	Waukesha	8	3	- -	Seepage lake	- -
Lake Beulah	Walworth	834	58	17	Drainage lake	Boat ramp
Lower Phantom Lake	Waukesha	433	12	4	Seepage lake	Boat ramp, barrier free pier
Lulu Lake	Walworth	95[a]	40	24	Drainage lake	Navigable water[b]
Pickerel Lake	Walworth	30	31	14	Spring lake	Navigable water[b]
Rainbow Springs Lake	Waukesha	25	16	4	Seepage lake	- -
Roxy Pond (Mukwonago Park)	Waukesha	17	3	2	Spring lake	Walk-in trail
Swan Lake	Walworth	27	7	3	Spring lake	- -
Upper Phantom Lake	Waukesha	107	29	11	Seepage lake	Navigable water[b]
Wood Lake	Waukesha	20	22	14	Spring lake	- -

[a]*The use of high-resolution orthophotography (by SEWRPC staff in 2007) resulted in a refinement of the lake surface areas for Eagle Spring Lake and Lulu Lake from the Wisconsin Conservation Department (now WDNR) original reports in 1969.*

[b]*Navigable access is provided by the presence of an inlet or outlet stream which furnishes adequate boat access to a lake. A small stream not large enough to float a boat does not provide effective navigable access.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

unit loads of nutrients and pesticide than do croplands.[15] When new commercial or residential developments are built near a stream, the area of driveways, rooftops, sidewalks, and lawns increases; the area of native plant growths 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 changing stream hydrology (i.e., increasing stormwater runoff volumes and peak flows and altering the baseflow regime). These changes are exacerbated by altering the seasonal thermal regimes in these flowing water systems and changing other characteristics of the streams, such as channel morphology, water quality/quantity, and biological diversity.

When urban development increases, the ratio of impervious surface area to water surface area increases proportionately to the decrease in the amount of pervious surface area. For this reason alone, many researchers throughout the United States, including researchers at the WDNR, report that the amount of connected impervious surface is the best indicator of the level of urbanization in a watershed.[16] 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

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

[16]*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.*

Table 5

APPROXIMATE PERCENTAGE OF CONNECTED IMPERVIOUS SURFACES CREATED BY URBAN DEVELOPMENT

Type of Urban Development	Impervious Surface (percent)
Suburban-Density Residential	10-15
Low-Density Residential	20-25
Medium-Density Residential	25-30
High-Density Residential	30-50
Governmental and Institutional	40-75
Industrial	70-80
Commercial	85-95

Source: Natural Resource Conservation Service and SEWRPC.

oxygen and increased pollutant levels) of a stream, leading to a decline in the biological integrity of the stream. For example, each 1 percent increase in watershed imperviousness can lead to an increase in water temperature of nearly 2.5°F.[17] While this temperature increase may appear to be small in magnitude, this small increase can have significant impacts on fish, such as trout and other biological communities that have a low tolerance to temperature fluctuations or very specific thermal ranges within which they flourish.

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 surface rather than infiltrating into the groundwater system. A parking lot or driveway produces much more runoff than an undisturbed prairie or agricultural hay field. Furthermore, runoff traveling over the surface of a parking lot or driveway will pick up heavy metals, bacteria, pathogens, and other pollutants which otherwise might be removed as the stormwater is filtered through vegetation or infiltrated into the surface aquifer. Runoff traveling over such 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. In addition, the location of the impervious surfaces determines the degree of direct impact they will have on a stream. There is a greater impact from impervious surfaces located close to a stream—due to the fact that less time and distance exists wherein the polluted runoff can be naturally treated before entering into the stream. A study of 47 watersheds in Southeastern Wisconsin indicated 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.[18]

Because urban lands located adjacent to a stream have a greater impact on the biological community, an assumption might be made that riparian buffer strips located along the streambank could absorb some of the negative runoff effects attributed to urbanization. While riparian buffers do have a mitigating effect, streambank buffers may not be the complete answer to urban stormwater impacts within the watershed since most urban stormwater is delivered directly to the stream via storm sewers or engineered channels and enters the stream without passing through the buffer zone. 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. In this regard, it is important to note that stormwater and erosion control treatment practices vary in their function, which in turn influences their level of effectiveness. Their location on the landscape, as well as their construction and maintenance, greatly influences their level of pollutant removal.

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[17]*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.*

[18]*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.*

Researchers, evaluating 134 sites on 103 streams throughout the State of Wisconsin, have found that the amount of urban land use upstream of their sample sites had a negative relationship with the biotic integrity scores at the sites.[19] There appeared to be a threshold of about 10 percent directly connected impervious cover in the areas tributary to the streams, beyond which Index of Biotic Integrity (IBI) scores declined dramatically.[20] 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. The researchers 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 that no trout were observed in coldwater streams in watersheds with greater than 11 percent imperviousness (see Figure 15).[21]

Wang and others studied 47 small streams in 43 watersheds in southeastern Wisconsin to retrospectively analyze fisheries and land use data acquired between 1970 and 1990.[22] 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.[23] As these areas urbanized even further, the fish communities changed little since they were already considered to be degraded. In contrast, stream sites that had little urbanization (characterized by connected imperviousness) in 1970, but which were urbanizing by 1990, showed decreases in the quality of the fish community. This study further supported the finding that major differences occurred in the fisheries at the 10 percent connected impervious cover threshold, with poorer fisheries quality generally being reported for stream sites above this threshold. In addition, other studies in different eco-regions and using various techniques have supported these findings, suggesting that, as watersheds become highly urban, aquatic diversity becomes degraded.[24] In addition to increases in the amount of impervious land cover that are associated with urbanization, urban development has often been accompanied by the alteration or loss of wetlands; disturbance or reduction in the size 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.

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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]*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.*

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

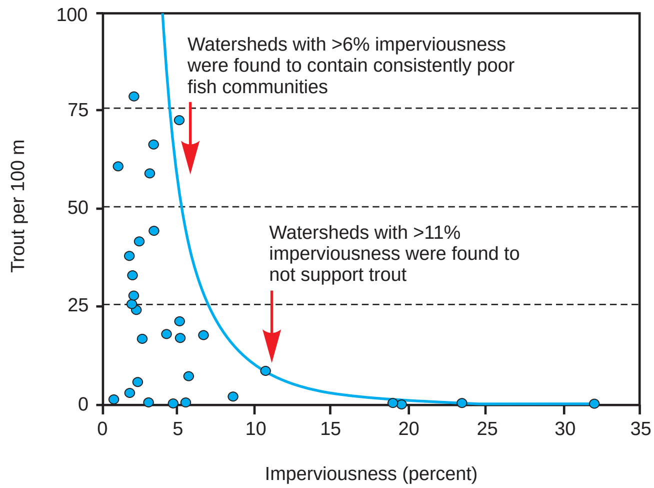
[22]*L. Wang, J. Lyons, P. Kanehl, R. Bannerman, and E. Emmons, "Watershed Urbanization and Changes In Fish Communities In Southeastern Wisconsin Streams,"* Journal of the American Water Resources Association, *Volume 36, No. 5, 2000.*

[23]*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.*

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

Figure 15

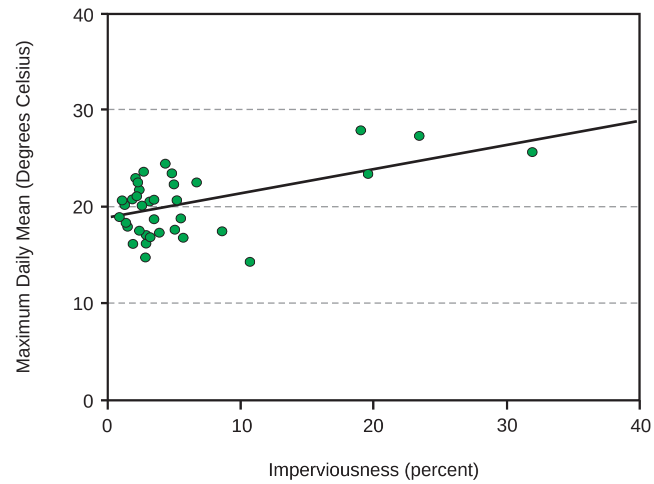
TROUT ABUNDANCE PER 100 METERS OF LINEAR STREAM DISTANCE AND PERCENT IMPERVIOUS SURFACES AMONG COLDWATER STREAM WATERSHEDS WITHIN WISCONSIN



Source: Wisconsin Department of Natural Resources.

Figure 16

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



Source: Wisconsin Department of Natural Resources.

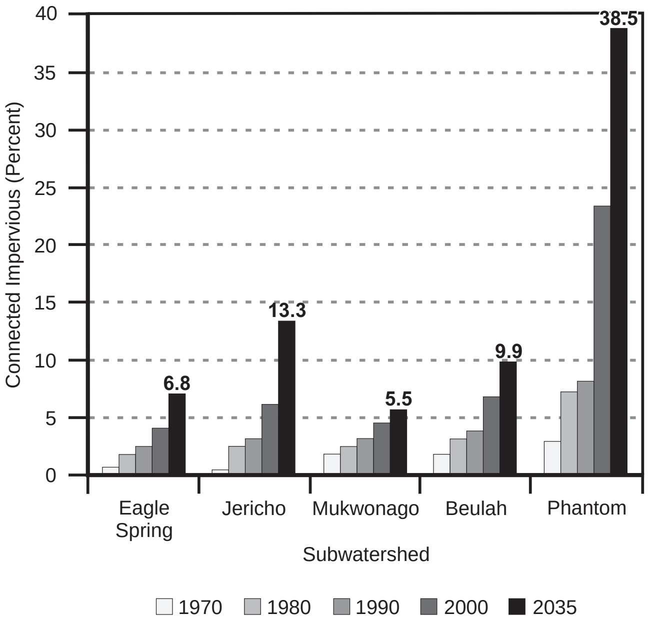
A further important concern related to urban development is thermal pollution. Thermal pollution results when stormwater flows over heated surfaces, such as roads, rooftops, and parking lots, before entering a stream (see Figure 13). The main consequence of thermal pollution is oxygen depletion, because warm water cannot hold as much oxygen as cold water. As these oxygen-deficit events increase, the aquatic organisms living in the stream become more stressed, leading to decreased growth and reproduction, migration out of the system, and, in extreme cases, death of the aquatic organisms. Rainfall events that occur during the warmer summer months are more stressful to fish and other water dwelling organisms than rainfall at other times of the year, due to runoff being heated as it flows over sun-warmed impervious surfaces. When coupled with the chronic affects of reduced infiltration on baseflows to streams, these events can lead to significantly elevated temperatures in the flowing water systems. There is a direct relation between a coldwater stream's maximum daily water temperatures and the percentage of impervious surface (i.e., urban development) in the watershed (see Figure 16). Coldwater fish, such as brown trout, survive best in water temperatures less than 20°C. Temperatures a few degrees below the lethal limit of 25°C can still cause significant stress, eventually leading to illness, infection, and death.[25]

As noted above, the amount of imperviousness in a watershed that is directly connected to the stormwater drainage system can be used as a surrogate for evaluating the combined impacts of urbanization in the absence of mitigation. The Mukwonago River watershed had about 4 percent urban land use in 1970, which approximately corresponds to 1 percent directly connected imperviousness in the watershed. As of 2000, it had about 20 percent urban land overall, corresponding to about 6 percent directly connected imperviousness. That level of imperviousness is just below the threshold level of 6 to 11 percent at which negative biological impacts could be expected to occur in coldwater streams (see Figures 15 and 16). Figure 17 shows that the Eagle Spring, Jericho, Beulah, and Phantom subwatersheds were also below the threshold level of 6 to 11 percent in the year 2000.

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

Figure 17

ESTIMATED HISTORICAL AND PLANNED PERCENT CONNECTED IMPERVIOUS SURFACE AMONG SUBWATERSHEDS WITHIN THE MUKWONAGO RIVER WATERSHED: 1970-2035



Source: SEWRPC.

In contrast, the Mukwonago subwatershed greatly exceeded this threshold, having approximately 25 percent connected impervious surface in the year 2000. This amount of development has often been associated with significant degradation of aquatic resources. However, it is important to note that the Mukwonago subwatershed is at the downstream end of the entire Mukwonago River watershed. Ninety-eight percent of the water flowing into and through this reach is derived from the upstream watershed that has much lower levels of development. Consequently, the reach of stream within the Mukwonago subwatershed retains a quality or condition better than would be predicted based on the amount of connected impervious surface from that subwatershed alone. Nevertheless, local stormwater management practices affecting runoff volume and quality are key to mitigating the consequences of development.

Given the pattern of increased development in the Mukwonago River watershed based upon the 2035 planned land use from the Waukesha and Walworth County comprehensive plans, the Mukwonago and the Jericho subwatersheds are expected to exceed 38 and 13 percent connected impervious surface by 2035 as shown in Figure 17. This would suggest that the Mukwonago subwatershed has exceeded the threshold of being able to support a high quality warmwater fish community and that the Jericho subwatershed may exceed the threshold of being able to support a coldwater trout community. Although urban density development has proceeded at accelerated rates in the Mukwonago and Jericho subwatersheds compared to the other subwatersheds, development is expected to continue to occur in all the subwatersheds, collectively increasing the risks of degradation of water quality and the fishery. It is important to note that these levels of development have likely been largely mitigated by the preservation of substantial riparian buffers throughout the entire Mukwonago River watershed (see Riparian Management Practices section below).

Runoff from Agricultural Development

In addition to the urban impacts discussed above, researchers in Wisconsin have found that the amount of agricultural land use upstream of sample sites had a negative relationship with biotic integrity scores. There appeared to be a threshold of about 50 percent agricultural land use, above which IBI scores declined dramatically.[26] A separate study looking at the effects of multi-scale environmental characteristics on the biota in agricultural streams in eastern Wisconsin demonstrated a strong negative correlation between fisheries IBI scores and increased proportions of agricultural land, ranging from 0 to 80 percent of the land surface within the studied

[26]*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.*

watersheds, which indicates that, as the percentage of agricultural land increased, the resultant fishery community decreased in abundance and diversity.[27]

About 56 percent of the Mukwonago River watershed was in agricultural land use in 1970. As of 2000, agricultural land comprised about 46 percent of the land surface area within the watershed. Agricultural land use has dominated the Mukwonago River watershed overall, but the Lower Mukwonago River subwatershed has been dominated by urban development. The Mukwonago River watershed is near the threshold of 50 percent agricultural land use, at which level declines in fishery abundance and diversity may be expected to begin to occur. It is noteworthy, however, that much of the agricultural land appears to be fallow. In addition, this is the portion of the watershed in which the TNC and WDNR have been acquiring conservancy lands, which are being returned to a lesser disturbed state through prairie restoration, nonnative species control programs, and improved land management practices that minimize human impacts on the stream system.

Riparian Management Practices

The studies of the effects of agricultural land use on biotic integrity scores indicated a positive relationship between the fisheries IBI and increased agricultural riparian buffer vegetation width. This implies that, by analogy, the impacts of increased urban land use may also be mitigated by an increased width of riparian buffer, which, in turn, will act 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 the type(s) of land use within the watershed, the presence of riparian corridors, and the degree of fragmentation of vegetation were the most important variables influencing fish and macroinvertebrate abundance and diversity.[28] In addition, upland best management practices (BMPs)—such as barnyard runoff controls, manure storage, contour plowing, and reduced tillage, when combined with riparian BMPs—such as streambank fencing, streambank sloping, and limited streambank riprapping, significantly improved overall stream habitat quality, bank stability, instream cover for fishes, and fish abundance and diversity.[29] Improvements were most pronounced at sites with riparian BMPs. At sites with limited upland BMPs installed, there were few improvements in water temperature or in the quality of fish community.

Around lakes, where development generally has a more urban character, stormwater management and runoff controls—such as the application of stormwater infiltration practices, onsite detention/retention of stormwater, adoption of good shorescaping measures, and shoreland management practices—offer similar benefits.[30] Wetlands adjacent to lakes and streams help enhance water quality conditions, while preserving desirable open space characteristics for residents to participate in a wide range of resource-oriented recreational activities. Protection of shoreland wetlands also helps to avoid the creation of new environmental and developmental problems as urbanization proceeds within the watershed. In parallel with such protection and preservation, the use of natural and native vegetation as shoreline protection is required pursuant to Chapter NR 328 of the *Wisconsin Administrative Code* as best practice along lake shorelines where such measures are feasible. Recent studies of the

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[27]*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.*

[28]*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.*

[29]*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.*

[30]*See University of Wisconsin-Extension, Publication No. GWQ045,* Storm Water Basins: Using Natural Landscaping for Water Quality and Esthetics, *2005.*

potential impact of riparian landscaping activities on nutrient loadings to lakes 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.[31] 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 this end, the State of Wisconsin has promulgated guidance for turf nutrient management targeted at residential lands, parks, and high use areas, such as golf courses and parks.[32]

In addition to the protection of water quality, riparian buffers simultaneously protect wildlife including both aquatic and terrestrial habitats. Buffer zones adjacent to waterbodies such as lakes, rivers, and wetlands minimize the impacts of human activities on the landscape and contribute to recreation, aesthetics, and quality of life (see Riparian Buffer Booklet in Appendix B). Riparian buffers are unique ecosystems that are exceptionally rich in biodiversity since they function as core habitat and travel corridors for many wildlife species including birds, fishes, amphibians, insects, reptiles, and plants. Fishery quality observed throughout the Mukwonago River watershed ranges from fair to excellent. This difference in quality can be attributed to a number of factors including: position within the watershed and changes in instream channel features including discharge, groundwater inputs, substrates, and gradient; land use changes and limited measures to mitigate the adverse effects of land uses,[33] and extent of riparian buffers protecting lakes and streams (see Chapter IV of this report).

Internally Drained Areas

The watershed and subwatershed boundaries were delineated by SEWRPC staff using two-foot interval elevation contours generated from the 2005 Waukesha County digital terrain model (DTM). This evaluation resulted in the identification of a number of internally drained areas, and the refinement of the outer boundary of the entire Mukwonago River watershed which was originally developed on the basis of United States Geological Survey (USGS) 10-feet contour interval mapping. Of the total watershed, approximately 6,130 acres were determined to be internally drained or about 13 percent of the Mukwonago River watershed, as shown on Map 3 in Chapter I of this report. These depressional areas are characterized by elevation differences of at least 20 feet and lack a surface outlet. Water from these areas either evaporates or is infiltrated into the groundwater system. Consequently, in the absence of an extraordinary rainfall event that results in more than 20 feet of accumulated volume in these areas, these internally-drained areas will not contribute direct runoff to the surface drainage system. Nevertheless, these areas are likely to be vitally important as recharge areas sustaining the maintenance of base flow in the river system as a consequence of groundwater discharge. In general, approximately 50 to 100 percent of the land in each of these internally drained areas is identified as having high to very-high groundwater recharge potential, which indicates these areas have a great potential to infiltrate water (see Groundwater Resources section below). It is important to note that there are additional smaller internally drained areas of various sizes throughout the Mukwonago River watershed that have not been delineated.

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[31]*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.*

[32]*Wisconsin Department of Natural Resources, Technical Standard No. 1100,* Turf Nutrient Management, *2006; 2009 Wisconsin Act 9 created Section 94.643 of the* Wisconsin Statutes *which placed restrictions on the use and sale of fertilizer containing phosphorus as well as on the use and sale of other turf fertilizers, codifying in part the recommended land management measures set forth in Technical Standard No. 1100.*

[33]*The standards and requirements of Chapter NR 151 "Runoff Management," and Chapter NR 216, "Storm Water Discharge Permits," of the* Wisconsin Administrative Code *are intended to mitigate the impacts of existing and new urban development and agricultural activities on surface water resources through control of peak flows in the channel-forming range, promotion of increased baseflow through infiltration of stormwater runoff, and reduction in sediment loads to streams and lakes. The implementation of those rules is intended to mitigate, or improve, water quality and instream/inlake habitat conditions.*

The eight internally drained areas, shown on Map 3 in Chapter I of this report, range from about 200 acres to more than 2,400 acres in area. Many of these areas have been or are being developed for urban density residential uses. Urban density residential development within internally drained areas ranges from about 10 percent to 80 percent of the total area. Because such areas lack a surface water outlet, these areas can be subject to periodic inundation, especially during periods of greater than normal precipitation. Such inundation is a risk to be considered in evaluating future development proposals in these areas. The County Bliss subdivision is located within the internally drained area with the highest percentage of urban development, and the lack of an adequate surface water drainage system contributed to the flooding problems observed within the subdivision during 2008.

Groundwater Resources

Groundwater not only sustains lake levels and wetlands and provides the perennial base flow of the streams, but it 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. Walworth and Waukesha Counties are dependent on groundwater for their 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 each County 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.

SEWRPC initiated a regional water supply study for the Southeastern Wisconsin Region that includes consideration of groundwater.[34] The preparation of this regional water supply plan represents the third, and final, element of the SEWRPC regional water supply management program. The first two elements, comprising the development of basic groundwater inventories and the development of a groundwater simulation model for the Southeastern Wisconsin Region, were completed over the past several years.[35] These elements involved an interagency partnership between SEWRPC and the USGS, the Wisconsin Geological and Natural History Survey, the University of Wisconsin-Milwaukee, the WDNR, and many of the water supply utilities serving the Region.

As part of the water supply planning effort, a technical report on groundwater recharge for the Southeastern Wisconsin Region was prepared.[36] One of the reasons for conducting the water supply study is to better

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

[35]*See SEWRPC Technical Report No. 37,* Groundwater Resources of Southeastern Wisconsin, *June 2002; see also, SEWRPC Technical Report No. 47,* Groundwater Recharge in Southeastern Wisconsin Estimated by a GIS-Based Water-Balance Model, *July 2008.*

[36]*SEWRPC Technical Report No. 47,* Groundwater Recharge in Southeastern Wisconsin Estimated by a GIS-Based Water-Balance Model, *July 2008.*

understand and protect recharge areas that contribute most to baseflow of the lakes, streams, springs, and wetlands of the Region, which is important to the goals of sustainable groundwater use and a healthy natural environment.

Map 14 shows the groundwater recharge potential for the Mukwonago River watershed as derived from a soil-water balance recharge model developed for the Southeastern Wisconsin Region.[37] Groundwater recharge potential was divided into four main categories defined as: low, moderate, high, and very high. Any areas that were not defined were placed into a fifth category as undefined. Most of the Mukwonago River watershed can be considered to have high to very high groundwater recharge potential (about 31,900 acres, or more than 67 percent of the entire watershed area), as shown on Map 14. As shown on Map 11, the groundwatershed is larger than the surface watershed. In particular, a large proportion of the groundwatershed lies within Walworth County south of the Mukwonago River watershed boundary as shown on Map 11. This demonstrates a complex interconnectedness of both the surface water and groundwater quality and quantity between Walworth and Waukesha Counties that will be addressed further to the extent practical in the Groundwater section in Chapter IV of this report.

Vulnerability to Contamination

Groundwater quality conditions can be impacted by such sources of pollution on the surface as infiltration of stormwater runoff, landfill leachate, agricultural fertilizer and pesticide runoff, 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. Map 15 shows that approximately 40 percent of the watershed contains groundwater levels within 0 to 25 feet of the ground surface, which means there is moderate to high potential for contamination in the shallow glacial drift and Niagara aquifers.[38] 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. Potential sources of contamination include runoff pollution, septic system discharges, and chemical spills or leaks.

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 (USEPA) 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 extending from the Illinois-Wisconsin border through Kenosha, Racine, and Waukesha Counties and 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 Town of Mukwonago and Villages of Eagle and Mukwonago, have reported exceedances of the current radium standard and are working with the WDNR to resolve this issue.

Nitrate Concentrations

In contrast to the naturally occurring radium in the substrata, nitrate is generally introduced into the groundwater system as a result of human land management practices, especially those associated with intensive agricultural

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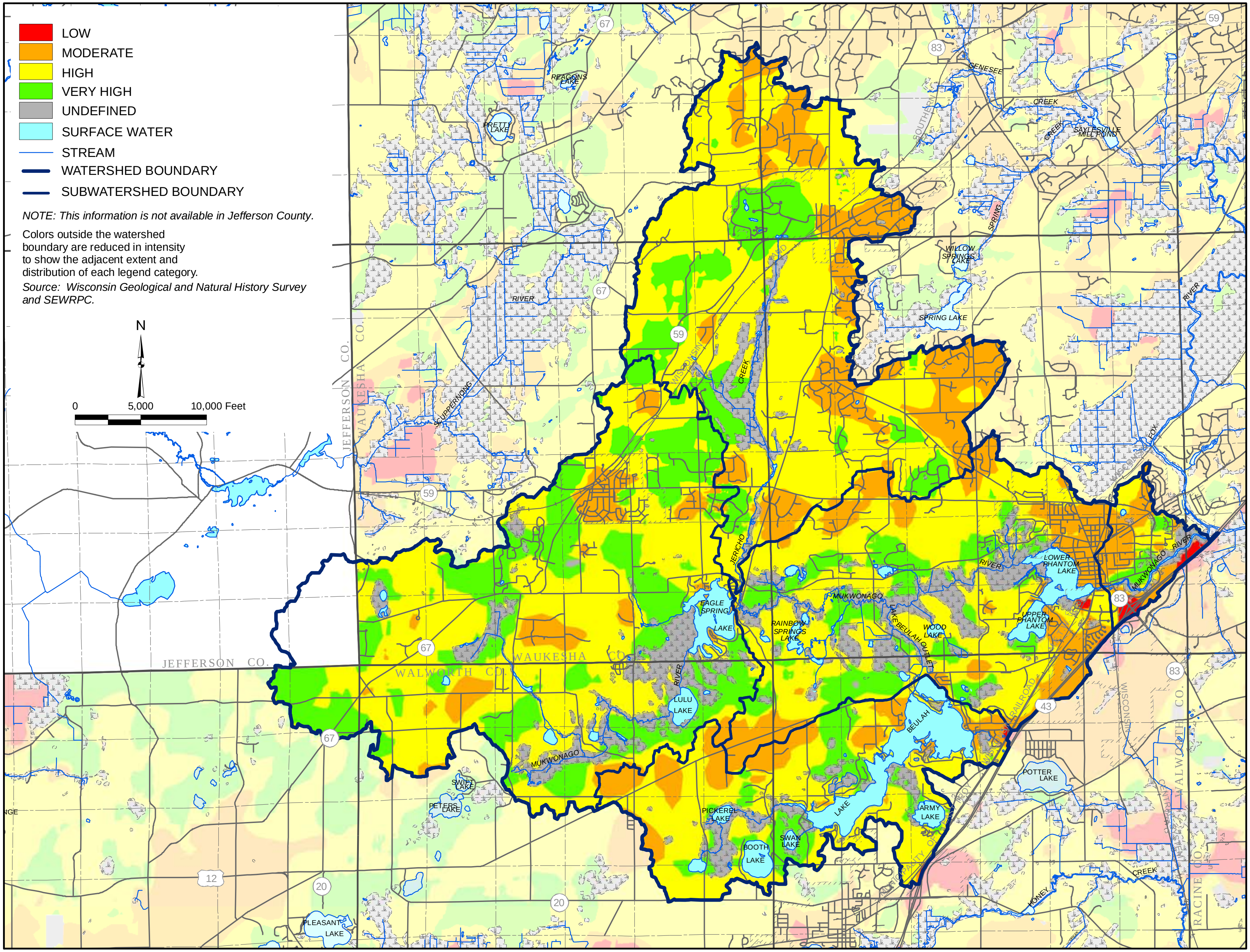
[37]*SEWRPC Memorandum Report No. 167,* Simulation of Shallow Groundwater Flow in the Vicinity of the Village of Eagle, Waukesha County, Wisconsin*, 2004.*

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

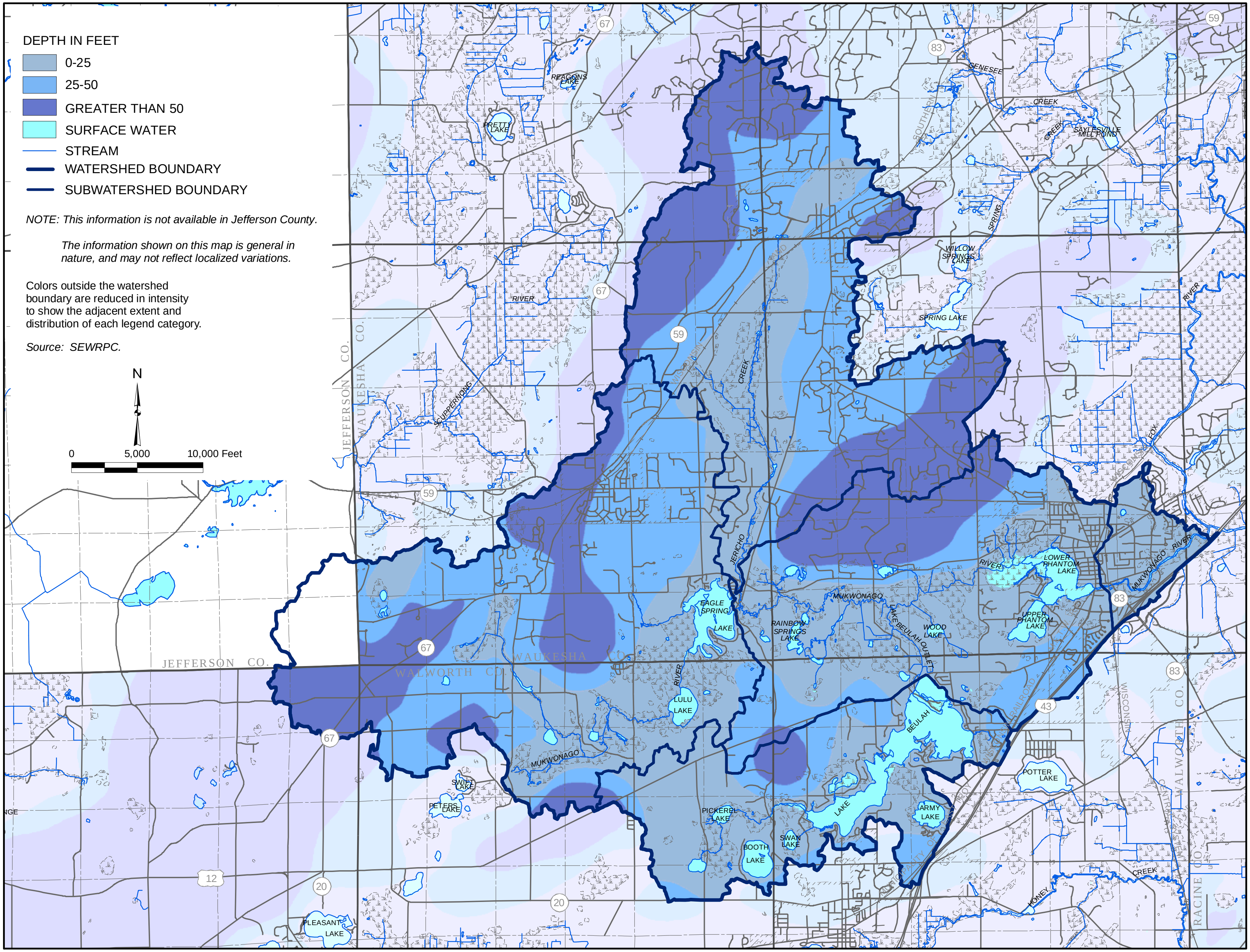
Map 14

ESTIMATES OF GROUNDWATER RECHARGE POTENTIAL WITHIN THE MUKWONAGO RIVER WATERSHED



Map 15

DEPTH TO SEASONAL HIGH GROUNDWATER LEVELS WITHIN THE MUKWONAGO RIVER WATERSHED: 2002



and pastoral production systems. While nitrate contamination generally is not widespread within the Southeastern Wisconsin Region, some areas of concern have been identified. One of these areas is adjacent to Booth Lake in the Mukwonago River watershed. In this case, a potential source of the contamination has been alleged to be intensive farming operations located to the south and upgradient of the Lake.[39] Ongoing monitoring of nitrate concentrations in the area groundwater was recommended as part of the lake protection program for this waterbody.

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 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 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.[40] Primary environmental corridors encompassed about 14,550 acres, or about 30 percent of the Mukwonago River watershed, in 2000. These primary environmental corridors represent a composite of the best remaining elements of the natural resource base, and contain almost all of the best remaining woodlands, wetlands, and wildlife habitat areas in the watershed. Primary environmental corridors in the watershed are shown on Map 16.

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 135 acres, or less than 1 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 Mukwonago River watershed are shown on Map 16.

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

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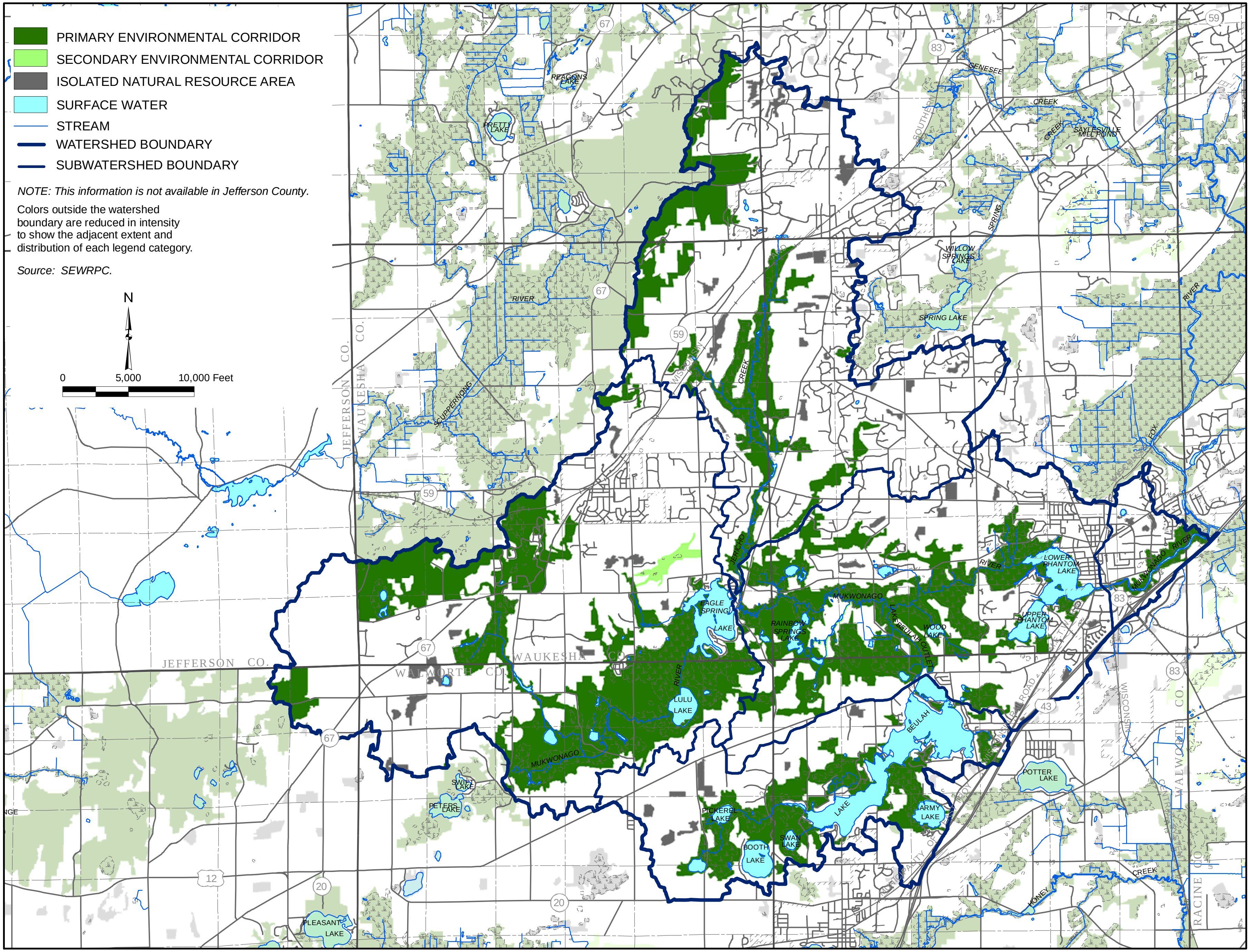
[39] *SEWRPC Memorandum Report No. 144,* An Aquatic Plant and Recreational Use Management Plan for Booth Lake, Walworth County, Wisconsin, *September 2003, page 19.*

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

Map 16

ENVIRONMENTAL CORRIDORS WITHIN THE MUKWONAGO RIVER WATERSHED: 2005



least five acres in size, are referred to as isolated natural resource areas. Widely scattered throughout the watershed, isolated natural resource areas included about 875 acres or about 2 percent of the total study area in 2000. Isolated natural resource areas in the watershed are shown on Map 16.

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 seven-county Southeastern Wisconsin Region in SEWRPC Planning Report No. 42, "*A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*," published in September 1997. This plan 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. Waukesha and Walworth Counties use this document to guide land use decisions.

The identified natural areas were classified into the following three categories:

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 was based upon consideration of several factors, including 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 frequency of occurrence within the Region of the plant and animal communities present; the occurrence of unique natural features within the area; the size of the area; and the educational value. It is important to note that although agricultural lands were 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.

The natural areas and critical species habitats identified in the Mukwonago River watershed are shown on Map 17 and inventoried in Tables 6 and 7. Critical species are defined as those species of plants and animals that are considered to be endangered, threatened, or of special concern. Such species known to occur in the watershed are listed in Table 8.

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 aesthetic value of an area.

Map 17

KNOWN NATURAL AREAS AND CRITICAL SPECIES HABITAT SITES WITHIN THE MUKWONAGO RIVER WATERSHED: 2005

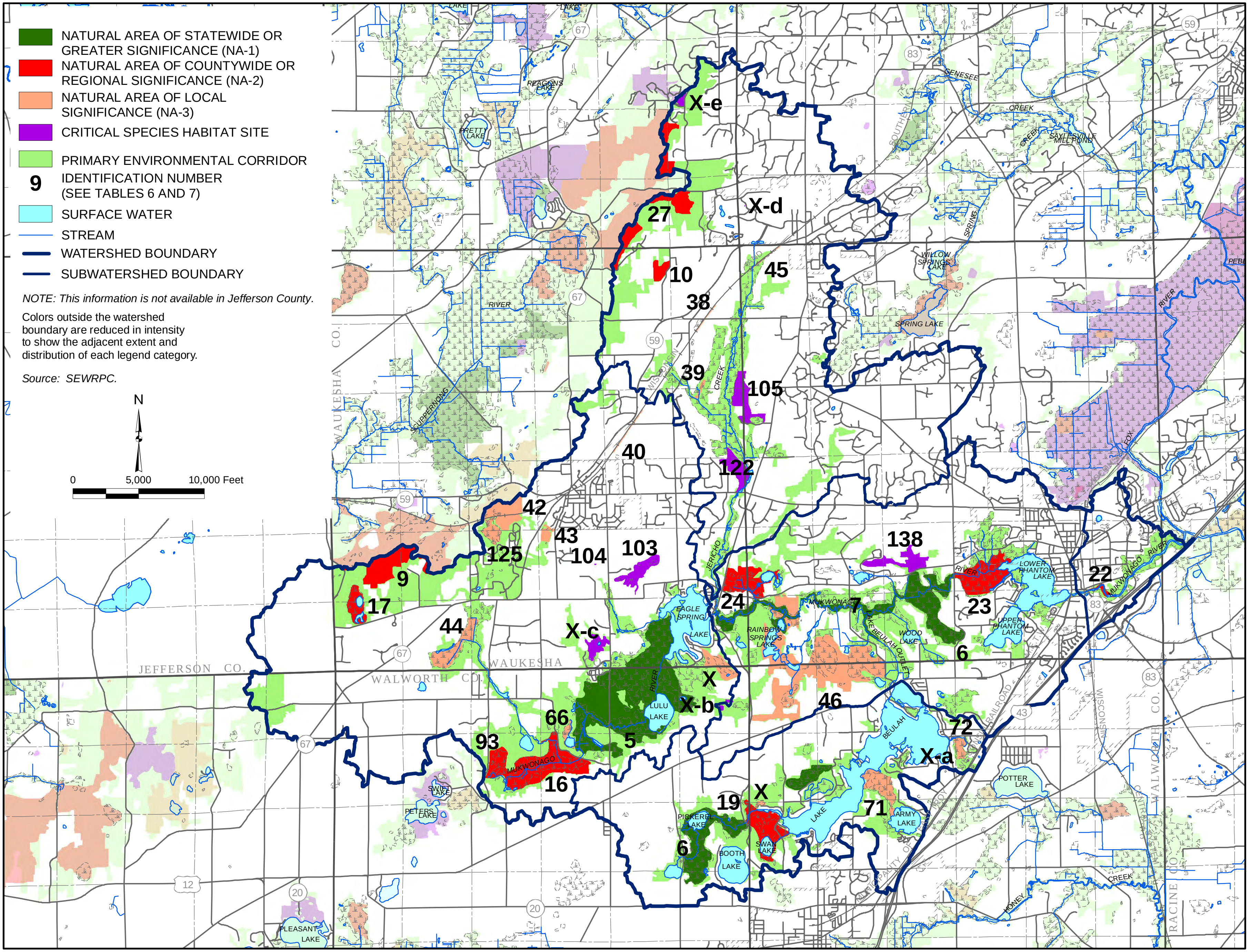


Table 6

NATURAL AREAS IN THE MUKWONAGO RIVER WATERSHED

Number on Map 17	Name	Type of Area	Ownership	Location	Acres Owned	Acres Proposed to Be Acquired	Total Acres	Proposed Acquisition Agency
5	Lulu Lake and Eagle Spring Lake Wetland Complex and Adjacent Uplands	NA-1	Wisconsin Department of Natural Resources, The Nature Conservancy, and other private	Towns of Eagle and Troy	742	329	1,071	Wisconsin Department of Natural Resources and The Nature Conservancy
6	Pickerel Lake Fen State Natural Area	NA-1	The Nature Conservancy and other private	Town of Troy	86	187	273	The Nature Conservancy
6	Mukwonago Fen, Sedge Meadow, and Tamarack Relict	NA-1	Private and Wisconsin Department of Natural Resources	Town of Mukwonago	38	204	242	Wisconsin Department of Natural Resources
7	Upper Mukwonago River	NA-1	Wisconsin Department of Natural Resources and private	Towns of Eagle and Mukwonago	215	- -	215	Wisconsin Department of Natural Resources
7	Beulah Bog State Natural Area	NA-1	Wisconsin Department of Natural Resources and private	Town of East Troy	58	14	72	Wisconsin Department of Natural Resources
9	Eagle Oak Opening, Dry Woods, and Dry Prairie	NA-2	Wisconsin Department of Natural Resources	Town of Eagle	152 (314[a])	- -	466	Wisconsin Department of Natural Resources
10	Ulrickson Road Cedar Glade	NA-2	Wisconsin Department of Natural Resources	Town of Eagle	32	- -	32	Wisconsin Department of Natural Resources
16	Upper Mukwonago River Wetland Complex	NA-2	The Nature Conservancy and other private	Town of Troy	85	253	338	The Nature Conservancy
17	Fur Farm Pond	NA-2	Wisconsin Department of Natural Resources	Town of Eagle	69	- -	69	Wisconsin Department of Natural Resources
19	Swan Lake Wetland Complex	NA-2	Girl Scouts of Milwaukee Area, Inc., and other private	Towns of East Troy and Troy	26	141	167	The Nature Conservancy
22	Lower Mukwonago River	NA-2	Village of Mukwonago, Wisconsin Department of Transportation, and private	Town of Mukwonago and Village of Mukwonago	15	8	23	Village of Mukwonago
23	Phantom Lake Wetlands	NA-2	Private	Town of Mukwonago and Village of Mukwonago	170	20	190	Village of Mukwonago
24	Brown Lake Wetlands, Woods, and Prairies	NA-2	Private	Town of Mukwonago	0	148	148	Waukesha County

Table 6 (continued)

Number on Map 17	Name	Type of Area	Ownership	Location	Acres Owned	Acres Proposed to Be Acquired	Total Acres	Proposed Acquisition Agency
27	Ottawa Oak Woods and Dry Prairies	NA-2	Wisconsin Department of Natural Resources and private	Towns of Eagle and Ottawa	186 (810[a])	- -	996	Wisconsin Department of Natural Resources
38	Road X Railroad Prairie	NA-3	Private	Town of Eagle	0	4	4	Private conservancy
39	Jericho Creek Fen	NA-3	Private	Town of Eagle	0	8	8	Private conservancy
40	Mailman Road Railroad Prairie	NA-3	Private	Town of Eagle	0	9	9	Private conservancy
42	STH 59 Oak Woods and Prairies	NA-3	Wisconsin Department of Natural Resources, Wisconsin Department of Transportation, and private	Town of Eagle	209	9	218	Wisconsin Department of Natural Resources
43	Eagle Centre Oak Opening	NA-3	Waukesha Land Conservancy	Town of Eagle and Village of Eagle	20	0	20	Waukesha Land Conservancy
44	Malek Wetland	NA-3	The Nature Conservancy and private	Town of Eagle	48	48	96	The Nature Conservancy
45	North Prairie Railroad Prairie	NA-3	Private	Town of Mukwonago	0	7	7	Private conservancy
46	Rainbow Springs Woods Wetlands, and Prairies	NA-3	Wisconsin Department of Natural Resources and private	Towns of Mukwonago and East Troy	468	215	683	Wisconsin Department of Natural Resources
66	Crooked Creek Sedge Meadow	NA-3	The Nature Conservancy	Town of Troy	27	- -	27	The Nature Conservancy
71	Army Lake Lowlands	NA-3	Private	Town of East Troy	9	83	92	Private conservancy
72	East Troy Tamaracks	NA-3	Wisconsin Department of Natural Resources	Town of East Troy	26	- -	26	Wisconsin Department of Natural Resources
125	Old World Wisconsin Marsh	NA-3	State of Wisconsin and Private	Town of Eagle	33	5	38	Wisconsin Department of Natural Resources
X	Eagle Spring Lake Bog, Oak Woods, and Prairie	NA-3	Wisconsin Department of Natural Resources	Towns of Eagle and Troy	66	0	66	Wisconsin Department of Natural Resources
X	East Troy Bog	NA-3	Private	Town of East Troy	0	6	6	Lake Beulah Management District

[a]*This area is located outside of the Mukwonago River watershed boundary.*

Source: SEWRPC.

Table 7

CRITICAL SPECIES HABITAT SITES LOCATED OUTSIDE OF NATURAL AREAS IN THE MUKWONAGO RIVER WATERSHED

Number on Map 17	Site Description	Acres	Classification	Status
93	Doyles Lake Little Prairies	<0.1 (1[a])	Plant	Threatened
103	Eagle Dump Oak Opening	72.0	Plant	Threatened
104	Domon Prairie Remnant	0.4	Plant	Threatened
105	Holtz Oak Opening	88.0	Plant	Threatened
122	Jericho Creek Oak Woods	69.3	Plant	Threatened
138	Mukwonago Park Oak Opening	83.0	Mammal	Special concern
X-a	Anderson Bog	0.6	Plant	Special concern
X-b	Horn Dry Prairies	5.0	Plant	Threatened
X-c	Nature Road Oak Woodland and Dry Prairie	43.0	Plant	Threatened
X-d	North Prairie Dry Prairie-West	0.1	Plant	Threatened
X-e	PEL 1134 Oak Opening and Woods	11(130[a])	Plant	Threatened

[a]*This area is located outside of the Mukwonago River watershed boundary.*

Source: SEWRPC.

Wetlands can 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 sanitary 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 18, wetlands are scattered throughout the Mukwonago River watershed and total approximately 4,526 acres, or about 10 percent of the watershed area.

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 7,753 acres, or about 16 percent of the watershed area, as shown on Map 18.

Wildlife Habitat

Wildlife in the Mukwonago River 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 habitat areas and wildlife residing in those areas provide opportunities for recreational, educational, and scientific activities, and constitute an aesthetic asset to the watershed. Habitat areas capable of supporting and sustaining these animals were inventoried in 1985 as part of the regional classification of the natural areas and critical species for southeast Wisconsin.[41] This inventory was updated in 2005 by SEWRPC staff as part of the natural areas and critical species habitat protection and management planning effort. The five major criteria used to determine the value of these wildlife habitat areas are listed below:

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[41]Ibid.

Table 8

ENDANGERED AND THREATENED SPECIES AND SPECIES OF SPECIAL CONCERN IN THE MUKWONAGO RIVER WATERSHED: 2009

Common Name	Scientific Name	Status under the U.S. Endangered Species Act	Wisconsin Status
Crustacea			
Elktoe	*Alasmidonta marginata*	Not listed	Special concern
Ellipse	*Venustaconcha ellipsiformis*	Not listed	Threatened
Rainbow Shell	*Villosa iris*	Not listed	Endangered
Round Pigtoe	*Pleurobema sintoxia*	Not listed	Special concern
Slippershell Mussel	*Alasmidonta viridis*	Not listed	Threatened
Other Insects			
Columbine Dusky Wing	*Erynnis lucilius*	Not listed	Special concern
Newman's Brocade	*Meropleon ambifuscum*	Not listed	Special concern
Red-tailed Prairie Leafhopper	*Aflexia rubranura*	Not listed	Endangered
Dion Skipper	*Euphyes dion*	Not listed	Special concern
Double Striped Bluet	*Enallagma basidens*	Not listed	Special concern
Fragile Forktail	*Ischnura posita*	Not listed	Special concern
Lilypad Forktail	*Ischnura kellicotti*	Not listed	Special concern
Mulberry Wing	*Poanes massasoit*	Not listed	Special concern
Silphium Borer Moth	*Papaipema silphii*	Not listed	Endangered
Swamp Metalmark	*Calephelis muticum*	Not listed	Endangered
Fish			
Banded Killifish	*Fundulus diaphanus*	Not listed	Special concern
Greater Redhorse	*Moxostoma valenviennesi*	Not listed	Threatened
Lake Chubsucker	*Erimyzon sucetta*	Not listed	Special concern
Lake Herring	*Coregonus artedi*	Not listed	Special concern
Least Darter	*Etheostoma microperca*	Not listed	Special concern
Longear Sunfish	*Lepomis megalotis*	Not listed	Threatened
Pugnose Shiner	*Notropis anogenus*	Not listed	Threatened
Slender Madtom	*Noturus exilis*	Not listed	Endangered
Starhead Topminnow	*Fundulus dispar*	Not listed	Endangered
Reptiles and Amphibians			
Butler's Garter Snake	*Thamnophis butleri*	Not listed	Threatened
Blanchard's Cricket Frog	*Acris crepitans blanchardi*	Not listed	Endangered
Blanding's Turtle	*Emydoidea blandingii*	Not listed	Threatened
Bullfrog	*Rana catesbeiana*	Not listed	Special concern
Western Ribbon Snake	*Thamnophis proximus*	Not listed	Endangered
Birds			
Acadian Flycatcher	*Empidonax virescens*	Not listed	Threatened
Barn Owl	*Tyto alba*	Not listed	Endangered
Black Tern	*Chlidonias niger*	Not listed	Special concern
Cerulean Warbler	*Dendroica cerulea*	Not listed	Threatened
Hooded Warbler	*Wilsonia citrine*	Not listed	Threatened
Kentucky Warbler	*Oporornis formosus*	Not listed	Threatened
Northern Harrier	*Circus cyaneus*	Not listed	Special concern
Worm-Eating Warbler	*Helmitheros vermivorus*	Not listed	Endangered
Mammals			
Franklin's Ground Squirrel	*Spermophilus franklinii*	Not listed	Special concern
Plants			
Adder's Tongue	*Ophioglossum pusillum*	Not listed	Special concern
Autumn Coral-Root	*Corallorhiza odontorhiza*	Not listed	Special concern
Beaked Spikerush	*Eleocharis rostellata*	Not listed	Threatened
Capitate Spikerush	*Eleocharis olivacea*	Not listed	Special concern
Christmas Fern	*Polystichum acrostichoides*	Not listed	Special concern
Common Bog Arrow-Grass	*Triglochin maritima*	Not listed	Special concern
Crawe Sedge	*Carex crawei*	Not listed	Special concern
Crossleaf Milkwort	*Polygala cruciata*	Not listed	Special concern
Cuckooflower	*Cardamine pratensis*	Not listed	Special concern
Downy Willow-Herb	*Epilobium strictum*	Not listed	Special concern
Farwell's Water Milfoil	*Myriophyllum farwellii*	Not listed	Special concern
Few-Flower Spikerush	*Eleocharis quinqueflora*	Not listed	Special concern
Forked Aster	*Aster furcatus*	Not listed	Threatened
Kitten Tails	*Besseya bullii*	Not listed	Threatened
Leafy White Orchis	*Platanthera dilatata*	Not listed	Special concern

Table 8 (continued)

Common Name	Scientific Name	Status under the U.S. Endangered Species Act	Wisconsin Status
Plants (continued)			
Lesser Fringed Gentian	*Gentianopsis procera*	Not listed	Special concern
Low Nutrush	*Scleria verticillata*	Not listed	Special concern
Many-Headed Sedge	*Carex sychnocephala*	Not listed	Special concern
Marsh Blazing Star	*Liatris spicata*	Not listed	Special concern
Ohio Goldenrod	*Solidago ohioensis*	Not listed	Special concern
Pale Green Orchid	*Platanthera flava var. herbiola*	Not listed	Threatened
Prairie Indian Plantain	*Cacalia tuberosa*	Not listed	Threatened
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
Showy Lady's-Slipper	*Cypripedium reginae*	Not listed	Special concern
Slender Bog Arrow-Grass	*Triglochin palustris*	Not listed	Special concern
Small Skullcap	*Scutellaria parvula var. parvula*	Not listed	Endangered
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
Swamp Agrimony	*Agrimonia parviflora*	Not listed	Special concern
Swamp Rose Mallow	*Hibiscus moscheutos ssp. Moscheutos*	Not listed	Special concern
Swamp Pink	*Arethusa bulbosa*	Not listed	Special concern
Sycamore	*Platanus occidentalis*	Not listed	Special concern
Torrey Sedge	*Carex torreyi*	Not listed	Special concern
Tufted Club-Rush	*Scirpus cespitosus*	Not listed	Threatened
Twinleaf	*Jeffersonia diphylla*	Not listed	Special concern
Whip Nutrush	*Scleria triglomerata*	Not listed	Special concern

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

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 the required levels for nesting, travel routes, concealment, and protection from weather are met for each of the major species.

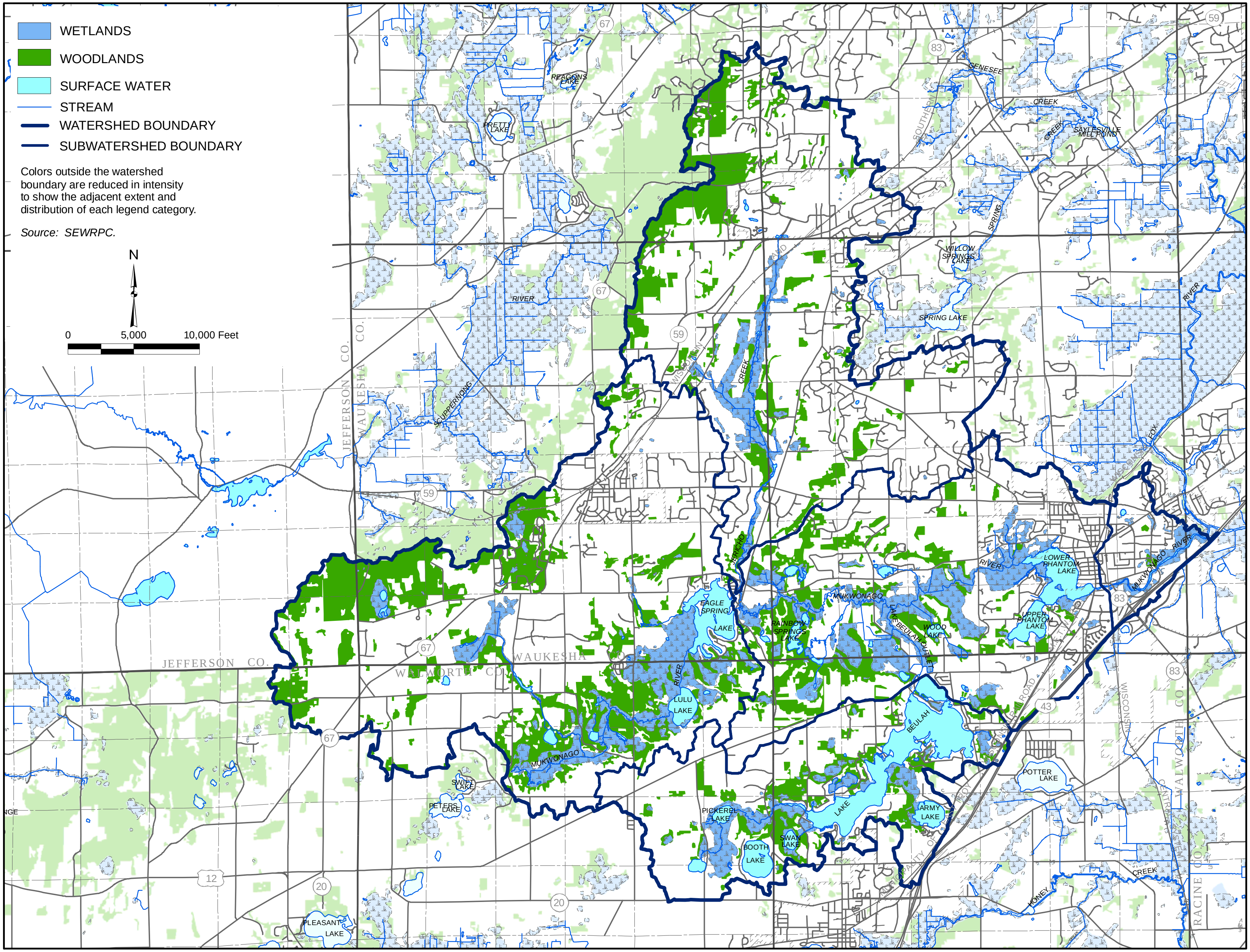
4. Location with Respect to Other Wildlife Habitats: It is very desirable that a wildlife habitat maintain proximity to other wildlife habitats.

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 Mukwonago River 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

Map 18

WETLANDS AND WOODLANDS WITHIN THE MUKWONAGO RIVER WATERSHED: 2000

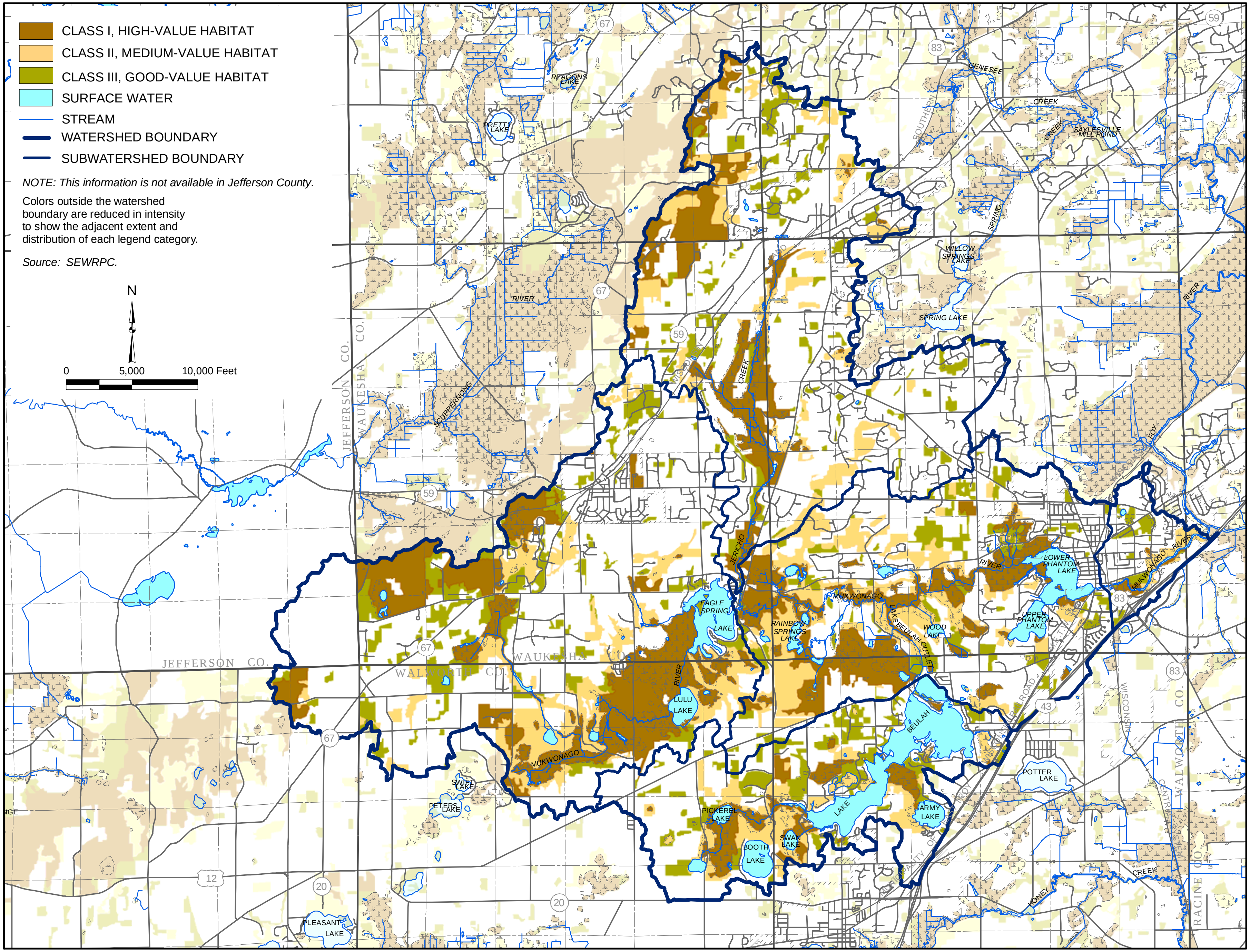


wildlife habitat. These areas may be important if located in proximity to medium- or high-value habitat areas, especially if they provide corridors linking wildlife habitat areas of higher value or if they provide the only available range in an area.

As illustrated on Map 19, the 2005 inventory identified about 18,050 acres of wildlife habitat, covering approximately 38 percent of the land area of the watershed. Approximately 7,692 acres, or about 16 percent of the watershed area, were classified as Class I habitat; 5,867 acres, or 12 percent of the watershed area, were classified as Class II habitat; and 4,489 acres or, 9 percent of the watershed area, were classified as Class III wildlife habitat.

Map 19

WILDLIFE HABITAT WITHIN THE MUKWONAGO RIVER WATERSHED: 2005



Chapter III

RELATED PLANS, REGULATIONS, AND PROGRAMS

RELATIONSHIP TO OTHER PLANS

The Mukwonago River 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 the land and water resources within the Mukwonago River watershed can occur. This planning effort contributes to the environmentally sound management of these valuable resources in a coordinated manner compatible 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 watershed with those of the towns, villages, and counties within the watershed, and which focus on the immediacy and importance of natural resources at the community level. The plans that were collated and reviewed for input into this current planning program were generally most relevant to actions being or potentially being undertaken by Walworth and Waukesha Counties. 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 considered. These plans and reports, which are described below, are listed in Table 9 and provide the basis for developing an integrated scheme for the sustainable management of the natural resources of the Mukwonago River 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 changing populations—size, composition, and distribution—and in the attendant urban development, occurring within the Region. These areawide problems and issues include, among others: stormwater management 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 (PR) No. 48, provides an adopted framework for coordinating and guiding growth and development within the multijurisdictional urbanizing Region (see Table 9). A summary of the existing and planned land use conditions within the Mukwonago River watershed is set forth in Chapter II of this report.

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.

Table 9

LIST OF MANAGEMENT PLANS RELEVANT TO THE MUKWONAGO RIVER WATERSHED

Plan Type	Community	Plan and Date of Publication
Land Use	Regional	SEWRPC Planning Report No. 48, *A Regional Land Use Plan for Southeastern Wisconsin: 2035*, June 2006
	Walworth County	SEWRPC Community Assistance Planning Report No. 252, *A Land Use Plan for Walworth County, Wisconsin: 2020,* April 2001
	Waukesha County	SEWRPC Community Assistance Planning Report No. 209*, A Development Plan for Waukesha County, Wisconsin*, August 1996
	Town of Genesee	SEWRPC Community Assistance Planning Report No. 22, *Alternative and Recommended Land Use Plans for the Town of Genesee–2000,* February 1978
Stormwater and Drainage	Village of Mukwonago	Village of Mukwonago Stormwater Plan
Lake Planning	Army Lake	Wisconsin Department of Natural Resources Lake Use Report No. FX-41, *Army Lake, Walworth County, Wisconsin,* 1969
	Booth Lake	Wisconsin Department of Natural Resources Lake Use Report No. FX-31, *Booth Lake, Walworth County, Wisconsin,* 1969
		SEWRPC Memorandum Report No. 144, *An Aquatic Plant and Recreational Use Management Plan for Booth Lake, Walworth County, Wisconsin,* September 2003
	Eagle Spring Lake	Wisconsin Department of Natural Resources Lake Use Report No. FX-19, *Eagle Spring Lake, Waukesha County, Wisconsin,* 1969
		SEWRPC Community Assistance Planning Report No. 226, *A Lake Management Plan for Eagle Spring Lake, Waukesha County, Wisconsin,* October 1997
		Eagle Spring Lake Management District, *Mukwonago River Watershed Nutrient Study,* August 2004-October 2007, and *Baseline/Runoff Sampling*, April 2008
		Hey and Associates, Inc., *Wetland Vegetation Survey at Eagle Spring Lake,* January 2004
		Hey and Associates, Inc., *Eagle Spring Lake Water Quality Summary and Management Report,* January 2005
		Todd Shoemaker, *Evaluation of the Hydrology and Hydraulics of Eagle Spring Lake, Eagle, Wisconsin,* Master of Science Thesis, Department of Civil and Environmental Engineering, University of Wisconsin-Madison, May 2002
	Lake Beulah	Wisconsin Department of Natural Resources Lake Use Report No. FX-7, *Lake Beulah, Walworth County, Wisconsin,* 1969
		Earth Tech Report, *Lake Beulah Study*, November 1999
		Lynn Carlson, Glenn Kreinbrink, and Phil Davis, *An Aquatic Plant Management Plan for Lake Beulah*, June 1996
		Lynn Carlson, Glenn Kreinbrink, and Phil Davis, *An Aquatic Plant Management Plan for Lake Beulah*, April 2000
	Lulu Lake	Wisconsin Department of Natural Resources Lake Use Report No. FX-39, *Lulu Lake, Walworth County, Wisconsin,* 1969
	Phantom Lakes	Wisconsin Department of Natural Resources Lake Use Report No. FX-14, *Lower Phantom Lake, Waukesha County, Wisconsin,* 1969
		Wisconsin Department of Natural Resources Lake Use Report No. FX-33, *Upper Phantom Lake, Waukesha County, Wisconsin,* 1969
		SEWRPC Community Assistance Planning Report No. 230, *A Lake Management Plan for Phantom Lakes, Waukesha County, Wisconsin,* January 2006
		SEWRPC Memorandum Report No. 81, A*quatic Plant Management Plan for Phantom Lakes, Waukesha County, Wisconsin*, July 1993
Sanitary Sewer	Village of East Troy	SEWRPC Community Assistance Planning Report No. 112, Third Edition, *Sanitary Sewer Service Area for the Village of East Troy and Environs,* December 2000
	Village of Mukwonago	SEWRPC Community Assistance Planning Report No 191, *Sanitary Sewer Service Area for the Village of Mukwonago, Waukesha County, Wisconsin,* November 1990

Table 9 (continued)

Plan Type	Community	Plan and Date of Publication
Environmental	Regional	SEWRPC Planning Report No. 30, *A Regional Water Quality Management Plan for Southeastern Wisconsin—2000*, September 1978
		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
		SEWRPC Planning Report No. 8, *The Soils of Southeastern Wisconsin,* June 1966
		SEWRPC Technical Report No. 47, *Groundwater Recharge in Southeastern Wisconsin Estimated by a GIS-Based Water Balance Model,* July 2008
		SEWRPC Memorandum Report No. 188, *Troy Bedrock Valley Aquifer Model, Waukesha and Walworth Counties, Wisconsin,* November 2009
	Walworth County	Walworth County Land Conservation Committee, *Walworth County Land and Water Resource Management Plan*, February 2004
		SEWRPC Community Assistance Planning Report No. 75, *A Solid Waste Management Plan for Walworth County, Wisconsin*, December 1994
	Waukesha County	Waukesha County Department of Parks & Land Use-Land Resources Division, *Waukesha County Land and Water Resource Management Plan 2006-2010*
		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
	Watershed	Hilary Erin Gittings, *Hydrogeologic Controls on Springs in the Mukwonago River Watershed, SE Wisconsin*, Master of Science Thesis, University of Wisconsin-Madison, 2005
		Karin Marie Hollister, *Hydrologic Modeling of the Upper Mukwonago River: An Investigation of the Effects of Urban Development and Evaluation of Mitigation Schemes, Southeastern Wisconsin*, Master of Science Thesis, University of Wisconsin-Madison, May 2006
		SEWRPC Planning Report No. 12, *A Comprehensive Plan for the Fox River Watershed,* Volume One, *Inventory Findings and Forecasts,* April 1969
Park and Open Space	Regional	SEWRPC Planning Report No. 27, *A Regional Park and Open Space Plan for Southeastern Wisconsin: 2000,* November 1977
	Walworth County	SEWRPC Community Assistance Planning Report No. 135, 2nd Edition, *A Park and Open Space Plan for Walworth County,* September 2000
	Waukesha County	SEWRPC Community Assistance Planning Report No. 137, *A Park and Open Space Plan for Waukesha County,* December 1989
	Town of Eagle	SEWRPC Community Assistance Planning Report No. 27, *A Park and Open Space Plan for the Town of Eagle, Waukesha County, Wisconsin,* April 1979
	Town of Ottawa	SEWRPC Community Assistance Planning Report No. 258, *A Park and Open Space Plan for the Town of Ottawa, Waukesha County, Wisconsin,* November 2001
	Town of Vernon	SEWRPC Community Assistance Planning Report No. 122, *A Park and Open Space Plan for the Town of Vernon, Waukesha County, Wisconsin,* March 1985

Source: SEWRPC.

Smart Growth Plans

In 1999 the Wisconsin Legislature enacted a new comprehensive planning law, set forth in Section 66.1001 of the *Wisconsin Statutes*. The new requirements supplement earlier provisions in the *Statutes* for the preparation of county development plans (Section 59.69(3) of the *Statutes*) and local master plans (Section 62.23 of the *Statutes*). The new requirements, which are often referred to as the "Smart Growth" law, provide a new framework for the development, adoption, and implementation of comprehensive plans in Wisconsin. The law includes a "consistency" requirement, whereby zoning, subdivision, and official mapping ordinances adopted and enforced by counties, cities, villages, and towns must be consistent with the comprehensive plan adopted by the county or local unit of government. Under the comprehensive planning law (Section 66.1001(3) of the *Statutes*), the consistency requirement took effect on January 1, 2010. Walworth County and Waukesha County, in cooperation with the cities, towns, and villages in the counties, recently completed comprehensive land use plans in November and February 2009, respectively.[1] Together these plans provide an overall framework and point of departure for county and local planning efforts and are considered a refinement of the SEWRPC regional land use plan.

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 performance standards for stormwater management that must be met from urban-, nonurban-, and transportation-related land uses.

Sanitary Sewer Service Area Plans

The provision of public sanitary sewer service to appropriate densities of urban development within the Southeastern Wisconsin Region is a fundamental principle of the adopted regional water quality management plan. The regional water quality management 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 Mukwonago River watershed are encompassed within a sewer service area centered on the Village of Mukwonago, documented in SEWRPC Community Assistance Planning Report (CAPR) No. 191. Certain lands associated with the Mukwonago County Park, Rainbow Springs Resort, and the Eagle Spring Lake Management District also are anticipated to be tributary to the Village of Mukwonago sewage treatment facility. These areas are shown on Map 7 in Chapter II of this report.

Environmental Management Plans

Regional Water Quality Management Plan

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) is the designated water quality planning agency for southeastern Wisconsin, pursuant to 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 PR No. 30 (see Table 9). A status report on implementation of that plan was provided in SEWRPC Memorandum Report (MR) No. 93, published in 1995.

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.

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

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[1]*SEWRPC Community Assistance and Planning Report No. 288,* A Multi-Jurisdictional Comprehensive Plan for Walworth County: 2035, *November 2009; and Waukesha County Department of Park and Land Use*, A Comprehensive Development Plan for Waukesha County, Waukesha County, Wisconsin, *February 2009.*

across the State. The basin plan for the Fox River basin is set forth in WDNR Publication No. 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 Mukwonago River 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 recommended in this watershed protection plan.

County Land and Water Resource Management Plan

The 1997 revisions to Chapter 92 of the *Wisconsin Statutes* required 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 Walworth County 2010 LWRM Plan was adopted by the Walworth County Board of Supervisors and was approved by the Wisconsin Land and Water Conservation Board in April of 2010. The plan, which will be implemented between 2010 and 2020, incorporates land use and natural resource data and goals from the adopted County comprehensive plan, recognizes the Wisconsin Working Lands Initiative,[2] sets forth strategies to achieve compliance with the agricultural and non-agricultural nonpoint source pollution abatement standards of NR151 of the *Wisconsin Administrative Code*, and addresses efforts to promote the biodiversity and sustainability of the County's natural resources.

Park and Open Space Plans

The park and open space plans focus on the terrestrial resources and provision of public access to these resources. As with land use planning in general, county- and 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, the Walworth County Park and Open Space Plan, published in 2000, as SEWRPC CAPR No. 135, and in the 1996 Waukesha County Development Plan (SEWRPC CAPR No. 209). 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 Mukwonago River watershed is the Waukesha County Mukwonago Park. 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.

Lake Management Plans

The Wisconsin Legislature has identified seven areas related to the development and protection of water resources and their attendant watersheds, as the basis for evaluating the sensitivity of lakes and streams to human influences. Section 281.69(5)(b) of the *Wisconsin Statutes* defines these characteristics in terms of the size, depth, and shape of the waterbody; the size of the watershed; the quality of the water; the potential for recreational use; the potential for land development; the potential for nonpoint source pollution; and, the type and size of the fish

[2]*See* www.datcp.state.wi.us/workinglands/index.jsp.

and wildlife populations in and around the waterbody. These attributes allow lakes and streams to be categorized into groups of varying sensitivities to human influences. Various types of lake management plans have been prepared for a number of the lakes within the Mukwonago River basin. These include comprehensive lake management plans for Eagle Spring and Upper and Lower Phantom Lakes; an aquatic plant management and recreational use plan for Booth Lake; and aquatic plant management plans for the Phantom Lakes and Lake Beulah, as shown in Table 9. Comprehensive lake management plans address both current and forecast water quality concerns facing lakes, while aquatic plant management plans focus more closely on issues of current concern. These plans address issues of concern to the individual lakes and lake communities, in the context of their drainage basins, but with a primary focus on the individual waterbodies. As such, these plans form an important contribution to this overall planning effort.

WATER USE OBJECTIVES AND WATER QUALITY STANDARDS

The water use objectives for the surface waters of the Mukwonago River watershed are set forth in Chapters NR 102, "Water Quality Standards for Wisconsin Surface Waters," NR 104, "Uses and Designated Standards," and NR 207, "Water Quality Antidegredation" of the *Wisconsin Administrative Code*. Under these chapters, the Mukwonago River and Jericho Creek are classified as meeting the standards for coldwater sport fish,[3] and being fully compliant with the fishable and swimmable water use goals set for the waters of the United States in the Federal Clean Water Act. The water use objectives established for the waters of the Mukwonago River watershed are shown on Map 20, and the recommended water quality standards associated with the various water use objectives are set forth in Table 10. The levels of pollution control needed to achieve the established water use objectives were initially identified in the SEWRPC Fox River watershed study and the regional water quality management plan,[4] and were refined in the Fox River watershed state-of-the-basin report.[5] These plans contained consistent recommendations on the levels of nonpoint source pollution controls needed to achieve water use objectives for the waterbodies within the Mukwonago River watershed.

The Mukwonago River is a Chapter NR 102-designated Exceptional Resource Water (ERW) downstream of Eagle Spring Lake to its confluence with Upper Phantom Lake and the watershed includes Lulu Lake, which is a Chapter NR 102-designated Outstanding Resource Water (ORW).

The Mukwonago River upstream of the Lulu Lake and associated tributaries has been designated by the WDNR as having the potential to support a Class I brown trout fishery.[6] 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. However, it should be noted that no brook or brown trout have been observed upstream of Lulu Lake.

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

[4]*SEWRPC Planning Report No. 12*, A Comprehensive Plan for the Fox River Watershed, *Volume One,* Inventory Findings and Forecasts, *April 1969, and Volume Two,* Alternative Plans and Recommended Plan, *February 1970, as amended; and SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume One,* Inventory Findings, *September 1978, Volume Two,* Alternative Plans, *February 1979, and Volume Three,* Recommended Plan, *June 1979, as amended; SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995.*

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

[6]Ibid.

Map 20

CURRENT REGULATORY WATER USE CLASSIFICATIONS FOR SURFACE WATERS WITHIN THE MUKWONAGO RIVER WATERSHED

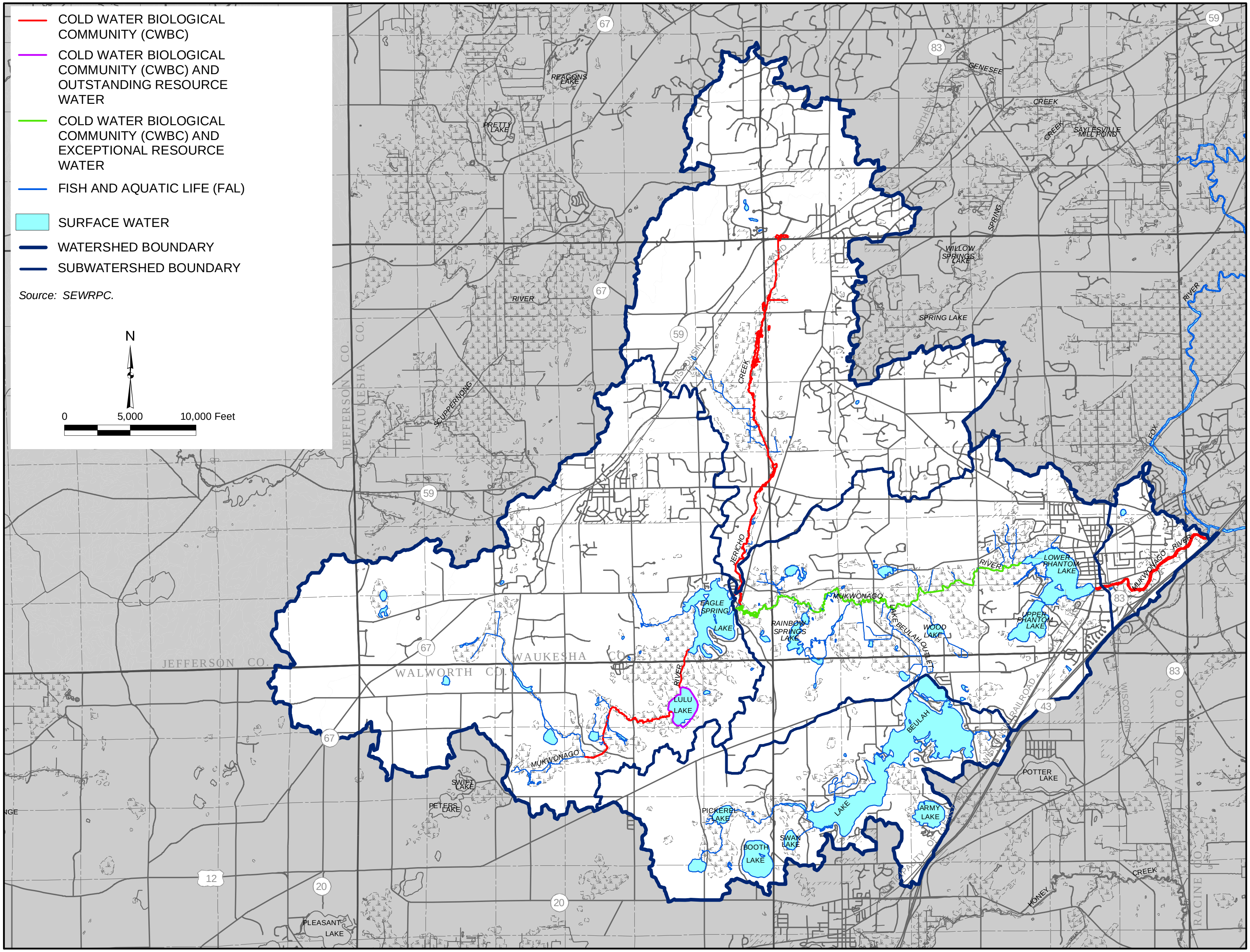

Table 10

APPLICABLE REGULATORY WATER USE OBJECTIVES AND WATER QUALITY CRITERIA FOR WATERBODIES WITHIN THE MUKWONAGO RIVER 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	
Recreational use	Full	Full	- -
Maximum Temperature (^{o}F)[d]	Background	89.0	NR 102.04 (4)[c]
Dissolved Oxygen (mg/l)[b]	6.0 minimum 7.0 minimum during spawning	5.0 minimum	NR 102.04 (4) NR 104.02 (3)
pH Range (S.U.)	6.0-9.0	6.0-9.0	NR 102.04 (4)[d] NR 104.02 (3)
Fecal Coliform (MFFCC)[e]	- -	- -	NR 102.04 (5) NR 104.06 (2)
Mean	200	200	- -
Maximum	400	400	- -

[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]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.

[c]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.

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

[e]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.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Between Eagle Spring Lake and Lower Phantom Lake, the Mukwonago River has been designated as a potential Class II brown trout fishery. 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 1988 and were stocked on an annual basis until 2007. However, there was no evidence of natural reproduction of brown trout within the Mukwonago River. Despite being designated as a Class II brown trout stream, brook trout have been stocked in the Mukwonago River and have become an important element of the overall fishery since 2002.

Jericho Creek has been designated as a Class III brown trout fishery for its entire length. A Class III designation requires annual stocking of trout to provide trout fishing, and has marginal trout habitat with no natural reproduction, and generally no carryover from one year to the next. Brook and brown trout have been stocked almost annually in Jericho Creek since 2001.

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.[7] 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.[8]

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

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[7]*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 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.*

[8]*As of the date of publication of this report, the WDNR was in the process of promulgating revisions to the agricultual and non-agricultural standards of Chapter NR 151.*

poultry operations with more than 1,000 animal units. Animal units are calculated for each different type and size class of livestock and poultry. For example, facilities with 1,000 beef cattle, 700 milking cows, or 200,000 chickens each would be considered to have the equivalent of 1,000 animal units. 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 development. The first includes standards for areas of new development and redevelopment, and the second includes standards for existing 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.[9]

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 have implemented 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.[10] 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.

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[9]*The revisions to NR 151 that were being promulgated, but had not been adopted, as of the date of this report establish a procedure to extend the compliance period for up to 10 years if a permittee can adequately document an inability to meet the standard.*

[10]*The NR 151 revisions that are being promulgated substitute a maximum discharge of five tons per acre per year for the 80 percent construction erosion control standard for sites of one acre or more and add prescriptive standards for construction sites of less than one acre.*

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.[11]

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

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.[12]

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[11]*The revisions to NR 151 that were being promulgated, but had not been adopted, as of the date of this report eliminate the option to infiltrate 25 percent of post-development runoff from a two-year, 24-hour storm and substitute 90 percent, 75 percent, and 60 percent infiltration volume standards based on low, moderate, and high imperviousness definitions, respectively.*

[12]*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.*

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*,[13],[14] and Wisconsin Department of Transportation projects which are subject to the liaison cooperative agreement between the WDNR and the Wisconsin Department of Transportation.

The Village of Mukwonago was issued a MS4 municipal stormwater discharge permit on January 1, 2007. The Village's permit sets forth a goal of reducing "to the maximum extent practicable" the volume of total suspended solids flowing into the stream with runoff. The goal is to reduce the volume of these pollutants going into the stream by 20 percent by the end of 2008 and 40 percent by 2013. The Village assembled a stormwater committee consisting of Village staff and elected officials, local citizens and business leaders, staff from the WDNR, and members of the Friends of the Mukwonago River. In addition, the Village was awarded a WDNR grant to help determine how to best reach the goals of the stormwater discharge permit. In-depth background information on the Village's stormwater system, projected rainfall, and projected future growth were collected in order to help guide decision-making on the most cost-effective ways to address stormwater runoff issues. To mitigate future damage to the river from stormwater runoff, the committee is working on a revision to the Village's stormwater ordinance.

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 for redesign of the State nonpoint source 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. 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.

There are no communities in the Mukwonago River 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 regional natural areas and critical species habitat plan are preserved in Walworth and Waukesha County ordinances.

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 require impervious area setbacks of 50 feet from streams, lakes, and wetlands. This setback distance is increased to 75 feet to protect

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[13]*Chapter 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.*

[14]*Construction of one- and two-family dwellings is generally regulated by the Wisconsin Department of Commerce. Chapter 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.*

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 Villages of Eagle, East Troy, Mukwonago, and North Prairie; and the Towns of Eagle, East Troy, Genesee, LaGrange, Mukwonago, Ottawa, Palmyra, Troy, and Vernon. The ordinances administered by these units of government are summarized in Table 11 and described in more detail below.

General Zoning

Villages in Wisconsin are granted comprehensive, or general, zoning powers under Section 61.35 of the *Wisconsin Statutes*. Counties are granted general zoning powers within their unincorporated areas under Section 59.69 of the *Wisconsin 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 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 within the Mukwonago River watershed.

Zoning is a tool used to regulate the use of land in Walworth and Waukesha Counties in a manner that serves to promote the general welfare of its citizens, the quality of the environment, and the conservation of its resources, as well as implement 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, and the Land Use and Resource Management Division of Walworth County administers the zoning maps and zoning ordinance for portions of the unincorporated areas of Walworth 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 Towns of East Troy, Genesee, LaGrange, Ottawa, Troy, Palmyra, and Vernon. 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 Eagle and Mukwonago 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 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 Management Program,” of the *Wisconsin Administrative Code*. The required regulations govern filling and development within a regulatory floodplain, which is defined as the area which has a 1 percent annual probability of being inundated. The 1-percent-annual-probability (100-year recurrence interval) floodplains within the Mukwonago River watershed are shown on Map 21. Under Chapter NR 116, local floodland zoning regulations must prohibit nearly

Table 11

LAND USE REGULATIONS WITHIN THE MUKWONAGO RIVER WATERSHED BY CIVIL DIVISION

Community	Type of Ordinance				
	General Zoning	Floodland Zoning	Shoreland or Shoreland-Wetland Zoning	Subdivision Control	Construction Site Erosion Control and Stormwater Management
Waukesha County	Adopted	Adopted	Adopted and Wisconsin Department of Natural Resources approved	Floodland and shoreland only	Adopted
Town of Eagle	Adopted	County	County	Adopted	Adopted
Town of Genesee	County	County	County	Adopted	County
Town of Mukwonago	Adopted	County	County	Adopted	County
Town of Ottawa	County	County	County	Adopted	County
Town of Vernon	County	County	County	Adopted	County
Village of Eagle	Adopted	None[a]	Not required	Adopted	Adopted
Village of Mukwonago	Adopted	Adopted	Adopted	Adopted	Adopted
Village of North Prairie	Adopted	None[b]	Not required	Adopted	County
Walworth County	Adopted	Adopted	Adopted and Wisconsin Department of Natural Resources approved	Adopted	Adopted
Town of East Troy	County	County	County	Adopted	Adopted
Town of LaGrange	County	County	County	Adopted	Adopted
Town of Troy	County	County	County	Adopted	County
Village of East Troy	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Mukwonago	Adopted	Adopted	Adopted	Adopted	Adopted
Jefferson County	Adopted	Adopted	Adopted	Adopted	None
Town of Palmyra	County	County	County	County	None

[a]Flood hazard areas have been identified or mapped on year 2008 FEMA digital flood insurance maps.

[b]No flood hazard areas have been identified or mapped.

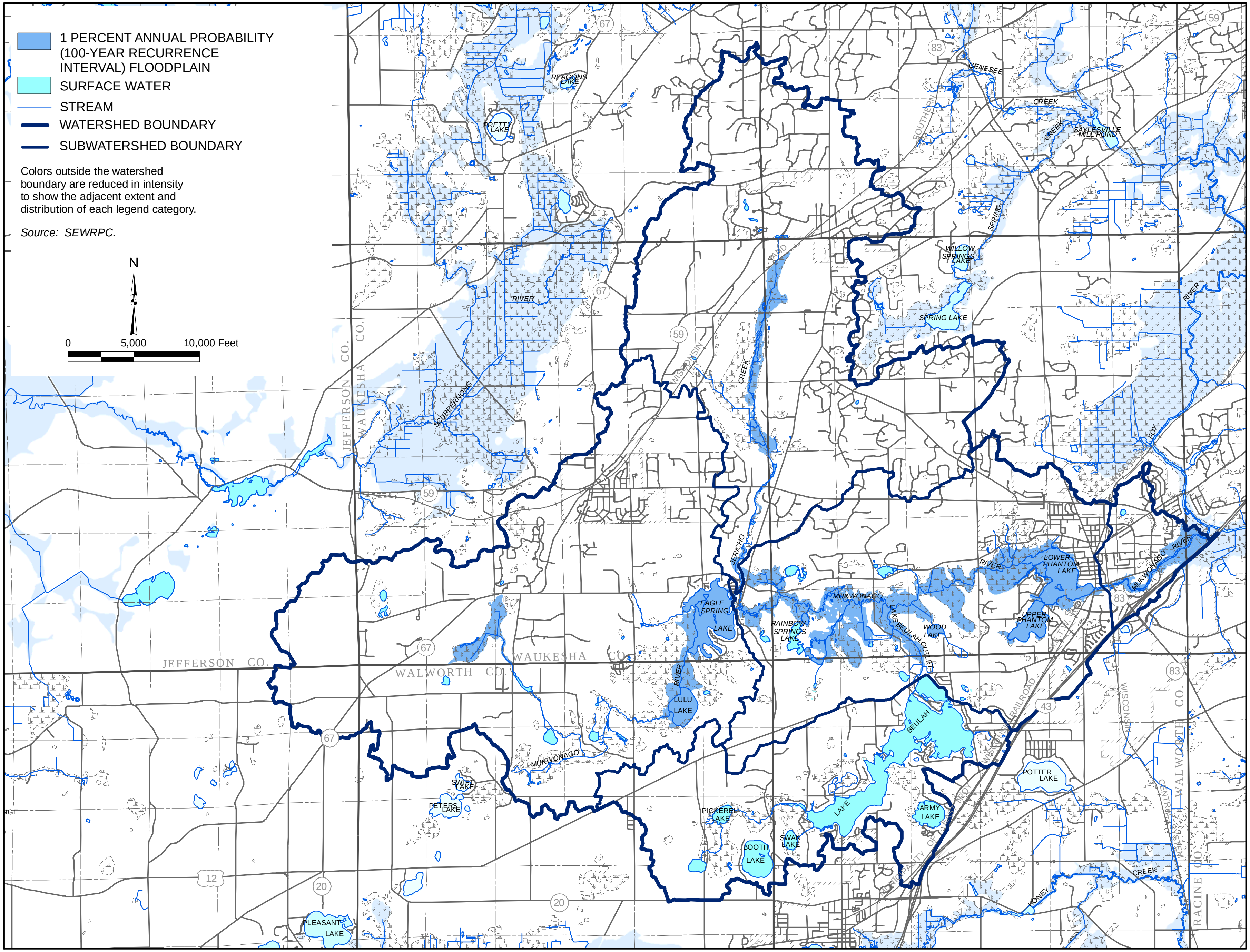
Source: Waukesha County, Walworth County, Jefferson County, Town of Palmyra, and SEWRPC.

all forms of development within the floodway, which is that portion of the floodplain required to convey the 1-percent-annual-probability 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 1-percent-annual-probability 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 and Walworth County ordinances related to shoreland and floodland protection recognize existing uses and structures and regulates them in accordance with sound floodplain management practices while protecting the overall water quality of stream systems. This ordinances are intended to: 1) regulate and diminish the proliferation of nonconforming structures and uses in floodplain areas; 2) 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

Map 21

FLOODPLAINS WITHIN THE MUKWONAGO RIVER WATERSHED



incompatible with natural floodplains; and, 3) 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 Walworth and Waukesha County (see Table 11). The Villages of East Troy and Mukwonago have adopted their own floodland ordinances. The Village of Eagle had flood hazard areas identified and mapped on year 2008 FEMA digital flood insurance rate maps, but has not adopted a floodland ordinance at this time. The Village of North Prairie has no flood hazard areas and, therefore, does not require an ordinance.

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.[15]

Minimum standards for county shoreland zoning ordinances are set forth in Chapter NR 115, "Wisconsin's Shoreland Management Program," of the *Wisconsin Administrative Code*.[16] 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. 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 villages, except for newly annexed areas. Minimum standards for 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 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 SEWRPC on its 1980, one-inch-equals-2,000-feet-scale aerial photography. SEWRPC staff, working in conjunction with the WDNR, recently completed updating that wetland inventory based on interpretation of 2005 color digital orthophotography and field verification of selected wetland boundaries.

County shoreland zoning ordinances are in effect in all unincorporated areas of Walworth and Waukesha Counties. All of the incorporated municipalities within the Mukwonago River watershed have adopted shoreland-wetland zoning ordinances except for the Villages of Eagle and North Prairie where shoreland-wetland zoning is not required.

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

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[15]*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.*

[16]*As of June 2009, a refined Chapter NR 115 of the* Wisconsin Administrative Code *was approved by the Wisconsin Natural Resources Board. These refinements, in part, provided for limitation of impervious surface areas in the shoreland zone.*

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 Mukwonago River watershed may involve shoreland-wetland regulations as administered by the counties 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 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 sizes for parcels that include wetlands are regulated by the various jurisdictions that have general zoning authority within the watershed in Waukesha County. For development adjacent to statutory wetlands, Waukesha and Walworth County ordinances specifies a minimum setback. There is currently no specified limit on the maximum area of impervious surface for development adjacent to statutory wetlands.

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 *Wisconsin 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 *Wisconsin 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 unincorporated areas. Village subdivision control ordinances may be applied to extraterritorial areas, as well as to their incorporated areas.[17] 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 village to have concurrent jurisdiction with a town and county in the village extraterritorial plat approval area. In the case of overlapping jurisdiction, the most restrictive requirements apply. Each community within the Mukwonago River watershed has adopted its own

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[17]*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 Mukwonago River watershed, the Villages of Eagle, East Troy, Mukwonago, and North Prairie are fourth-class villages. Consequently, extraterritorial zoning applies within 1.5 miles of each of the Villages within the Mukwonago River watershed.*

subdivision ordinance, except for the Town of Palmyra, which has adopted those subdivision control ordinances adopted and administered by Jefferson County. The subdivision control ordinances adopted and administered by Waukesha County apply only to the unincorporated statutory shoreland areas of the County. However, 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.

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), 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.[18] 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.

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.

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."[19] Enforcement of this ordinance currently represents the largest workload for the LRD. 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 streamlines 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

[18]*The Village of Mukwonago's "Chapter 34, Division 4: Stormwater Management and Erosion Control Ordinance," effective January 6, 2009, is based on the WDNR model ordinance.*

[19]*A copy of the ordinance is available on the LRD's web page at:* http://www.waukeshacounty.gov/uploadedFiles/Media/PDF/Parks_and_Land_Use/Land_Conservation/Stormwater/Index_Docs/Final%202005%20Storm%20Water%20Ordinance%20-%20Waukesha%20Co%20Web%20Version.pdf.

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 significant 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.

The Walworth County stormwater management ordinances apply to residential lands of five acres or more in areal extent, residential lands of between three and five acres where there is at least 1.5 acres of impervious surface, nonresidential lands of two acres, where there is at least one acre of impervious surface, or other lands on which development activities may result in stormwater runoff likely to harm public property or safety. The stormwater management ordinances establish performance standards to manage both rate and volume of stormwater flows from regulated sites, and water quality.

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. Specific construction site and erosion control requirements for unincorporated areas of Walworth County have been promulgated under Chapter 26, Environment, of the *County Code of Ordinances*. In Waukesha County, similar provisions are set forth in Chapter 14, Parks and Land Use, of the *County Code of Ordinances*.

Building Regulations

Waukesha County has incorporated several standards into their stormwater ordinance that are intended 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 the seasonal high groundwater table and the proposed basement floor surface. These standards apply to all the unincorporated areas of the County. 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 critical 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.

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.

Most communities 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. 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.

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. 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 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, there are no known utility districts established in the Mukwonago River watershed, however, one has been considered as part of the plan to address stormwater management and high groundwater levels related to the Country Bliss subdivision in the Town of Mukwonago.

Public Inland Lake Protection and Rehabilitation Districts

In order to maintain, protect, and improve the water quality of a lake and manage its watershed in an environmentally-sound manner, the Wisconsin Legislature has authorized the creation of Public Inland Lake Protection and Rehabilitation Districts under Subchapter IV of Chapter 33 of the *Wisconsin Statutes*.[20] Similar to town sanitary districts, lake districts can be established by orders or resolutions adopted by a town, village, or county in response to the petition of the landowners within the boundary of the proposed district. Lake management districts are governmental bodies, and as such, have strictly defined boundaries. Lake districts have limited powers outside of their lake management functions.

In the Mukwonago River watershed, there are four public inland lake management districts:

- Booth Lake Management District,
- Eagle Spring Lake Management District,
- Lake Beulah Management District, and
- Phantom Lakes Management District.

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[20]*University of Wisconsin-Extension Publication No. G3818*, People of the Lakes: A Guide for Wisconsin Lake Organizations: Lake Associations and Lake Districts, *11th Edition, 2006.*

All of these organizations depend on the cooperation of general purpose units of government to address many of the jurisdictional issues that affect the use of the lakes.

Southeastern Wisconsin Fox River Commission
Within the lower portions of the River in the Town and Village of Mukwonago, the Southeastern Wisconsin Fox River Commission, organized under Subchapter VI of Chapter 33, *Wisconsin Statutes*, has implemented a program of streambank stabilization under its mandate to coordinate the activities of its member local governments. This Commission, created by the Wisconsin Legislature in 1997, is charged with developing and implementing plans, projects and programs to improve water quality and enhance the economic and environmental values of surface and ground waters within its jurisdiction, which includes and extends from the City of Waukesha in Waukesha County to the Village of Waterford in Racine County. The Commission provides a forum for local governments and citizens and citizen groups to coordinate activities in the basin.

Nonprofit Conservation Organizations
In addition to governmental organizations, voluntary community organizations often participate in resource management projects. While they lack governmental authority, and both membership and payment of dues are voluntary, many of these nonprofit conservation organizations (NCOs) are influential in sustaining public interest in resource management issues and provide an important mechanism for public informational programming and involvement in communities. Many NCOs are incorporated under Chapter 181 of the *Wisconsin Statutes* and many are registered charitable organizations under Section 501(c)(3) of the Federal Internal Revenue Code. Several such organizations exist in the Mukwonago River watershed. In addition, incorporated lake associations, meeting specific criteria established by the WDNR, may be eligible for cost-share grant funds under the lake management and lake protection grant programs described below.

The Lake Beulah Protective and Improvement Association supports lake-focused informational programming and conducts civic involvement activities focused on Lake Beulah. The Friends of the Mukwonago River and The Nature Conservancy (TNC) provide more broadly based programming throughout the Basin. The TNC is a major landowner in the upper portions of the watershed, maintaining and rehabilitating several tracts of former agricultural land for conservation purposes—the TNC owns 1,274 acres within the watershed and has helped to protect an additional 360 acres through partnerships with individual landowners and partner organizations. These organizations depend on the cooperation of the general and special purpose units of government to address many of the jurisdictional issues that affect the use of the lakes, and perform an important advocacy role in the basin. In addition, these organizations perform a vital role in community-based educational and informational programming, as discussed below.

RELATED CONSERVATION PROGRAMS

Coordination with Federal, State, regional, and local agencies is paramount to the protection of the land and water resources of the Mukwonago River watershed. The conservation programs mentioned below are vital to the successful implementation of this plan. The positive integration of programs and funding sources administered by the counties and their cooperating agencies do the most toward accomplishing these goals.

Federal Programs
The U.S. Department of Agriculture Natural Resources Conservation Service (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 12 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.

Table 12

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.

Conservation Reserve Program

The Conservation Reserve Program (CRP) and related State Conservation Reserve Enhancement Program (CREP) are voluntary programs for agricultural landowners that provide annual rental payments and cost-share assistance to establish long-term, resource 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 USDA Farm Service Agency (FSA), with technical assistance provided by the NRCS. The NRCS works with landowners to develop their application, and to plan, design, and install the conservation practices on the land.

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-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 DATCP and the Wisconsin Department of Revenue oversee the Farmland Preservation Program (FPP) across the State. This program allows agricultural landowners who meet certain eligibility requirements to file for tax credits. As a condition of 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 counties 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.

Targeted Runoff Management Grant Program

To help control polluted runoff from both agricultural and urban sites, Targeted Runoff Management (TRM) grants awarded under Chapter NR 151 of the *Wisconsin Administrative Code* 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 can be granted up to 70 percent of eligible project 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 amount. Rural easements, funded at 75 percent of the WDNR-appraised value, can also be included in the $150,000 grant cap. Projects are executed by units of government under grant agreements with the WDNR. For rural BMPs (i.e., barnyard relocation, manure storage, etc.), units of government (e.g., county land conservation departments) execute the projects under contracts held on behalf of county residents. Funds are disbursed on a reimbursement basis, payable upon completion of the project, at the conclusion of the two-year grant period.

Urban Nonpoint Source and Storm Water Planning Program

Urban Nonpoint Source and Storm Water Planning Program (UNPS&SW) grant funds awarded under Chapter NR 155 of the *Wisconsin Administrative Code* are used to control polluted runoff in urban project areas. Funds are awarded for either planning or construction projects. The grant period is two years. Projects funded through this grant program are site-specific, serve areas generally smaller in size than a subwatershed, and are targeted at identified high-priority problems. An "urban project area" must meet one of these criteria:

- An area with a residential population density of at least 1,000 people per square mile;
- Lands in either commercial or industrial use;
- A portion of a privately owned industrial site not covered by a WPDES permit issued under Chapter NR 216 of the *Wisconsin Administrative Code*; or,
- A municipally owned industrial site (regardless of Chapter NR 216 permit requirements).

UNPS&SW planning grants can be used to pay for a variety of technical assistance activities. Eligible planning and technical assistance activities, such as stormwater management planning, related information and education activities, and ordinance and utility development and enforcement, are cost-shared at 70 percent. Eligible UNPS&SW construction grant costs may include the costs of such projects as stormwater detention ponds, filtration and infiltration practices, streambank stabilization, and shoreline stabilization. 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 the approval of WDNR regional staff.

Soil and Water Resource Management Program

The current Chapter ATCP 50, "Soil and Water Resource Management Program," became effective on October 1, 2002, and was most recently revised in October 2004. The administrative rule relates specifically to agricultural management 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.

Lake Management Planning and Protection Grant Programs

Lake management planning projects may be eligible for a 75 percent cost-share grant, up to $10,000 State-share under the Chapter NR 190 Lake Management Planning Grant Program, with implementation projects being eligible for a 50 percent cost-share grant under the Chapter NR 191 Lake Protection Grant Program. Lake management planning projects are further divided into small-scale projects of up to $3,500 and larger-scale projects of up to $10,000 State-share. The former are designed primarily to support lake water quality monitoring projects, although other planning activities are also eligible for funding.

Chapter NR 191 lake protection activities related to land acquisition and implementation of remedial measures identified in a WDNR-approved lake management plan may receive up to $200,000 in State cost-share funding, while ordinance development projects and diagnostic feasibility studies may be cost shared up to $100,000. These grants are available to local units of government, public inland lake protection and rehabilitation districts, lake sanitary districts, and qualified lake associations. In addition, counties are eligible to apply for funding to develop and implement local land and water management programs that are targeted to specific classes of lakes in response to various development and recreational use pressures. Grant awards may fund up to 75 percent of eligible project costs, not to exceed $50,000.

Additional funding for specific land acquisition activities may be available through the Knowles-Nelson Stewardship Program, created by the Wisconsin Legislature in 1989 and authorized under Chapters NR 50/51 of the *Wisconsin Administrative Code*, to preserve valuable natural areas and wildlife habitat, protect water quality and fisheries, and expand opportunities for outdoor recreation. Similarly, the Recreational Boating Facilities Grant program, authorized under Chapter NR 7 of the *Wisconsin Administrative Code*, can provide additional funds for public recreational boating access, access site improvements, Eurasian water milfoil control, and establishment and/or marking of navigational channels, among other activities.

River Planning and Protection Grant Program

In a like manner to the lake grant programs, the Chapter NR 195 River Planning and Protection Grant program supports efforts of local governments to develop and implement river (and stream) management practices designed to minimize or mitigate human impacts on flowing water systems. Grant awards are made on a 75 percent cost-share basis to eligible units of government in amounts up to $10,000 for planning projects and $50,000 for management projects. Property acquisition, implementation of best management practices, and educational and informational programming are eligible projects under this program.

Aquatic Invasive Species Grant Program

The Chapter NR 198 Aquatic Invasive Species Control Grant awards may not exceed 75 percent of the project cost. Maximum grant awards depend upon the type of project being executed, with education, prevention and planning projects being limited to a maximum award of $150,000. Watercraft inspection program projects, conducted within this grant category, are limited to a State share of $4,000 annually for each public boat launch facility, with the total project cost-share amount being less than or equal to the 75 percent State share. Early detection and response projects, conducted under this grant program, are limited to a maximum award of $20,000, and established population control projects to a maximum State share amount of $200,000. Education, prevention and planning projects can be funded as small-scale projects of up to $50,000 State cost-share or larger-scale projects of greater than $50,000 State cost-share.

Community Information and Education Programs

Community involvement and educational outreach is a key element of preserving the ecologically significant areas within the Mukwonago River watershed. There are several active organizations within the watershed including: the lake management districts, land conservancy organizations, and citizen monitoring groups.

Monitoring and Evaluation Programs

Monitoring and evaluation program efforts are important to ensure program effectiveness and accountability in the expenditure of public funds. Measuring progress for nonpoint pollution control programs has been identified as a serious challenge in several State legislative audits since the late 1980s. Past program efforts have focused on tracking best management practices installed to control nonpoint pollution and associated expenditures involved. Actually measuring changes in water quality is the best way to track progress, but can be expensive. In addition, because of the high number of variables involved in monitoring water quality, it is often difficult to interpret the data. One solution to this problem is to encourage volunteer citizen monitoring.

Citizen Stream Monitors
For several years, groups like the Water Action Volunteers (WAV) have held training sessions to teach interested citizens how to monitor streams for temperature, turbidity, dissolved oxygen, stream flow, and how to conduct biotic index and habitat assessments. The data collected is entered into an internet accessible database that will be useful for monitoring future trends in stream condition. There is one WAV monitoring location in the Mukwonago River watershed, located at CTH LO on Jericho Creek which has been monitored on and off since 2003.

Citizen Lake Monitoring Network
Wisconsin's Self-Help Lake Monitoring Program began in 1986 as one component of the WDNR Lake Management Program. The program is now included within the Citizen Lake Monitoring Network (CLMN) administered by the University of Wisconsin-Extension (UWEX) Lakes Partnership team. The CLMN is a data collection program implemented on approximately 1,000 of Wisconsin's 15,000 lakes which serves as a citizen education program about lakes in general. Each volunteer learns about his or her own lake(s) by collecting water quality data. These data are focused on Secchi disc transparency measurements, although the expanded program includes data collection necessary to support determination of Trophic State Indices (TSI values)—the expanded program includes the collection of water samples for total phosphorus and chlorophyll-*a* analysis, which is conducted by the State Laboratory of Hygiene (SLOH), as well as collection of temperature and dissolved oxygen concentration profiles. The data from both the basic and expanded programs are summarized in a detailed report provided to the volunteers at the end of each sampling season.

The Program was designed around a set of objectives designed to teach citizen volunteers about lake water quality sampling techniques along with some concepts of basic limnology, and to increase their understanding of their study lakes. Data are collected over time and analyzed for normal and seasonal variations and long-term trends, and are intended to help lake organizations and communities in making sound lake management decisions. Lakes included in the Self-Help monitoring program within the Mukwonago River watershed include: Eagle Spring Lake, Upper and Lower Phantom Lakes, Lake Beulah, and Booth Lake.

Informational and Educational Programs
Various citizen-based organizations take an active interest in the Mukwonago River basin. These groups address a number of concerns facing the basin and its communities, both natural and human, through both informational programming and management activities. Activities focus on both the terrestrial and aquatic resources of the basin.

With respect to the terrestrial resources of the Mukwonago River basin, the TNC has an active science and land management program, hosting work parties to control terrestrial nonnative species and "burn" workshops to promote effective management of prairie grasslands. Similarly, the Kettle Moraine Land Trust currently is working to preserve rare, threatened, and endangered species in and around Beulah Bog through partnerships with landowners and other interested stakeholders. The Waukesha County Environmental Action League (WEAL) helps to protect the natural resources of Waukesha County through local advocacy, public informational programs, newsletters, and the 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.

With respect to the aquatic resources of the Mukwonago River basin, the Friends of the Mukwonago River promote the protection of the Mukwonago River and its associated watershed ecosystems through education, advocacy, and the promotion of sound land use planning and implementation throughout the watershed. Supporting these efforts is the Mukwonago River Initiative, an active team of citizens and professionals from Walworth and Waukesha Counties, local government, and civic organizations created as a subcommittee of the Fox River Partnership. The Fox River Partnership was formed as an outreach program within the WDNR Mukwonago River Geographic Management Unit (GMU). The Initiative sponsors activities to preserve and protect the Mukwonago River through land protection, advocacy, public education, and resource monitoring.

Finally, the lake organizations collectively support a range of educational and informational programming activities in addition to executing their more active lake management functions. For example, the Eagle Spring Lake Management District currently is offering a $1,000 reward for each of two tagged carp as a way to increase awareness of this damaging invasive species. The District asks anyone who catches a carp to not return it to the water, but instead to dispose of it at the public recreational boating access site, and record the number of carp so disposed for the District's records. All of the lake districts and lake associations include informational programming in their annual and periodic meetings.

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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 Mukwonago River watershed. Included is qualitative and quantitative information pertaining to 1) the historical trends and current status of habitat (physical, chemical, and biological) quality and ecological integrity within the Mukwonago River and its tributaries and the lakes in the watershed; 2) physical conditions of the Mukwonago River, Jericho Creek, and the Lake Beulah outlet; and 3) potential limitations to water quality and fishery resources.

STREAM CHANNEL CONDITIONS AND STRUCTURES

Stream System Characteristics

Water from rainfall and snowmelt flows into streams by one of two pathways: 1) either directly flowing overland as surface water runoff or 2) infiltrating into the soil surface, recharging the groundwater, and eventually reaching streams as baseflow. Ephemeral, or intermittent, streams generally flow only during the wet season or during large rainfall events. Perennial streams that flow year-round are primarily sustained by groundwater during dry periods. The surface water drainage systems within the Mukwonago River watershed are shown on Map 22, as well as the reaches, which were established based on a number of considerations in the system that include gradient, sinuosity, dams, bridge and culvert crossings, and physical instream characteristics. The six reaches for this watershed include Mukwonago-1 through 3, Jericho-1 and 2, and Beulah (see Table 13). These reaches form the basis for the summary statistics and recommendations in this report.

Viewed from above, the network of water channels that form a river system typically displays a branch-like pattern as shown in Figure 18. A stream channel that flows into a larger channel is called a tributary of that channel. The entire area drained by a single river system is termed a drainage basin, or watershed. Stream size increases in the downstream direction as more and more tributary segments enter the main channel. A classification system based on the position of a stream within the network of tributaries, called stream order, was developed by Robert E. Horton and later modified by Arthur Strahler. In general, the lower stream order numbers correspond to the smallest headwater tributaries and are shown as the Order 1 or first-order streams in Figure 18. Second-order streams (Order 2) are those that have only first-order streams as tributaries, and so on (see Figure 18). As water travels from headwater streams toward the mouth of larger rivers, streams gradually increase their width and depth and the amount of water they discharge also increases. It is important to note that over 80 percent of the total length of Earth’s rivers and streams are headwater streams (first- and second-order), which is also generally characteristic of the Mukwonago River watershed.

Map 22

STREAM REACHES WITHIN THE MUKWONAGO RIVER WATERSHED: 2009

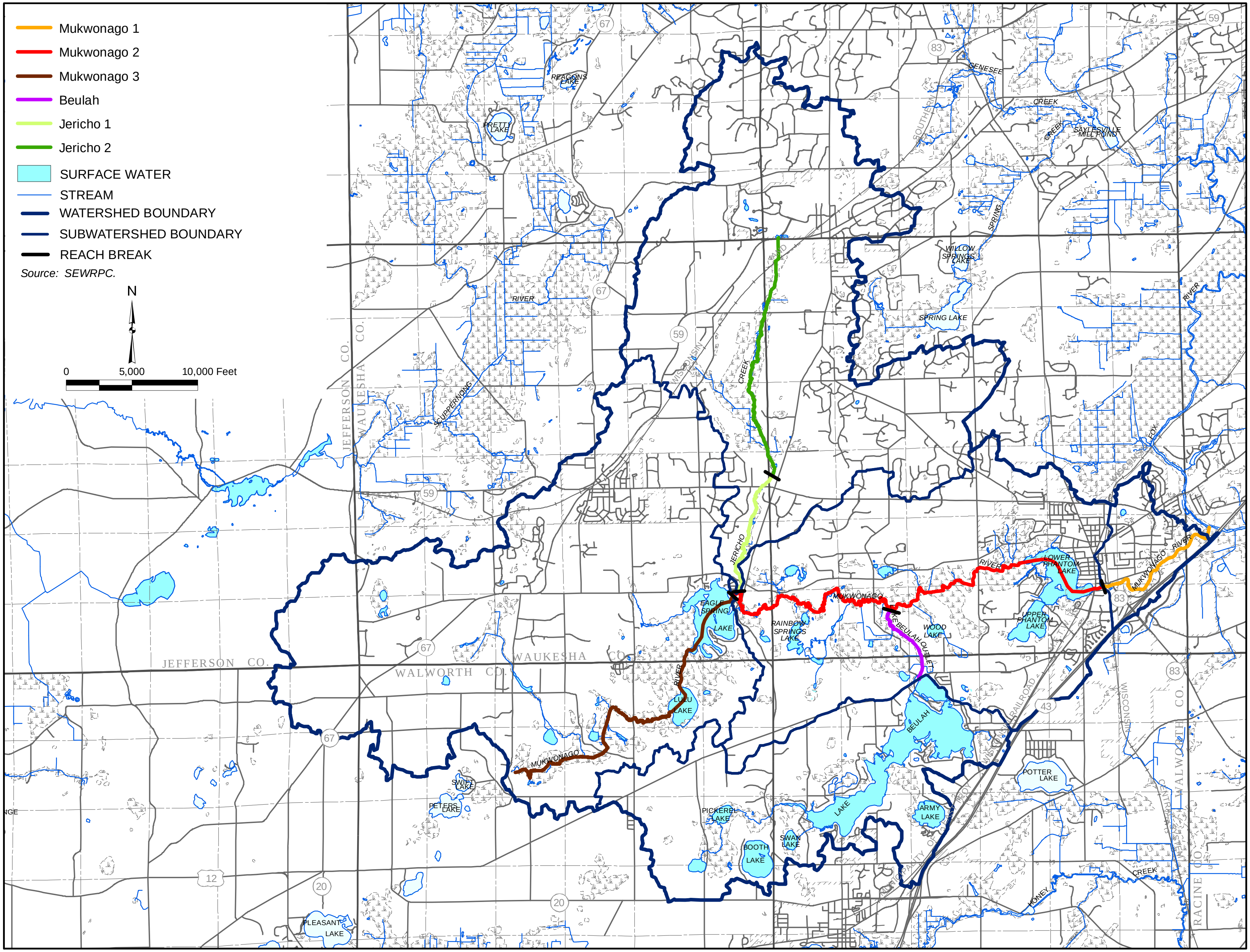

Table 13

PHYSICAL CHARACTERISTICS OF STREAM REACHES WITHIN THE MUKWONAGO RIVER WATERSHED: 1941 AND 2005[a]

Stream Reach	Reach Length (miles)[b] 1941	Reach Length (miles)[b] 2005	Sinuosity 1941	Sinuosity 2005	Minimum Elevation (feet above NGVD29)	Maximum Elevation (feet above NGVD29)	Slope (percent)
Lower Mukwonago							
Mukwonago 1..........	2.25	2.25	1.3	1.3	776.6	782.0	0.045
Phantom							
Mukwonago 2..........	8.55	7.17	2.0	1.7	789.9	812.2	0.045
Eagle Spring							
Mukwonago 3..........	- -[c]	3.72	- -[c]	1.5	820.8	848.5	0.141
Jericho							
Jericho 1.................	2.53	2.33	1.4	1.3	812.2	885.6	0.596
Jericho 2.................	4.10	4.17 (3.58)[d]	1.4	1.2	885.6	931.4	0.208 (0.242)[d]
Beulah							
Beulah 1.................	1.54	1.37	1.4	1.3	792.4	797.0	0.063

[a]*See Map 18 for stream reach locations.*

[b]*Length of lakes was not used in the calculation of river miles.*

[c]*Historical river miles cannot be calculated because there are no orthorectified 1941 aerial photographs available for Walworth County.*

[d]*Number in parentheses indicates the original distance of the stream reach prior to lengthening at the headwaters, but this increase did not significantly affect the sinuosity.*

Source: SEWRPC.

To better understand stream systems and what shapes their conditions, it is important to understand the effects of both spatial and temporal scales. Streams can be theoretically subdivided into a continuum of habitat sensitivity to disturbance and recovery time as shown in Figure 19.[1] Microhabitats, such as a handful-sized patch of gravel, are most susceptible to disturbance and river systems and watersheds are least susceptible. Furthermore, events that affect smaller-scale habitat characteristics may not affect larger-scale system characteristics, whereas large disturbances can directly influence smaller-scale features of streams. For example, on a small spatial scale, deposition at one habitat site may be accompanied by scouring at another site nearby, but the reach or segment containing the habitat sites does not appear to change significantly. In contrast, a large-scale disturbance, such as a debris flood, is initiated at the segment level and reflected in all lower levels of the hierarchy (reach, habitat, microhabitat). Similarly, on a temporal scale, siltation of microhabitats may disturb the biotic community over the short term. However, if the disturbance is of limited scope and intensity, the system may recover quickly to pre-disturbance levels.[2]

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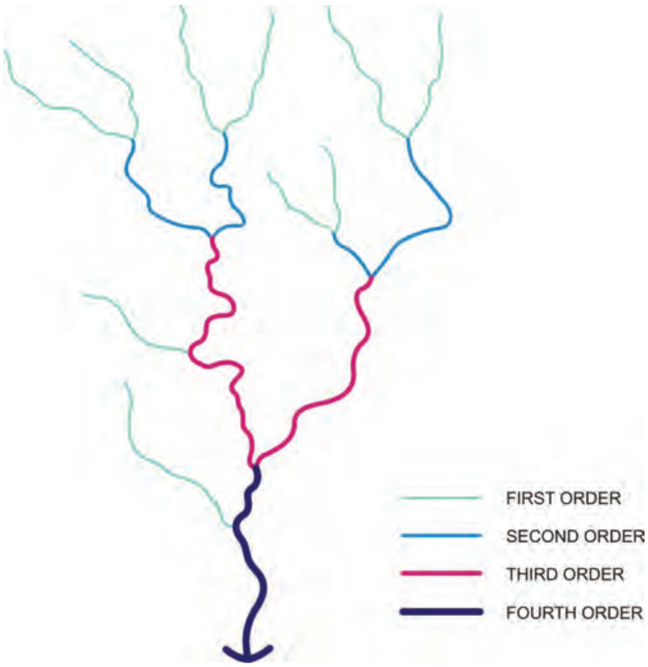
[1]*C.A. Frissell, et al., "A Hierarchical Framework for Stream Classification: Viewing Streams in a Watershed Context,"* Journal of Environmental Management, *Volume 10, pages 199-214, 1986.*

[2]*G.J. Niemi, et al., "An Overview of Case Studies on Recovery of Aquatic Systems From Disturbance,"* Journal of Environmental Management, *Volume 14, pages 571-587, 1990.*

Figure 18

TYPICAL STREAM NETWORK PATTERNS BASED ON HORTON'S CLASSIFICATION SYSTEM



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

The most important fundamental aspects of stream systems are 1) that the entire fluvial system is a continuously integrated series of physical gradients in which the downstream areas are longitudinally linked and dependent upon the upstream areas; and 2) that streams are intimately connected to their adjacent terrestrial setting, that is, the land-stream interaction is crucial to the functioning of stream ecosystem processes and this connectivity does not diminish in importance with stream size. In this regard, land uses have a significant impact on stream channel conditions and associated biological responses.[3] For example, a recent study on the impact of pesticides on streams found that only one pesticide metabolite was quantified in the samples collected from the Mukwonago River between April and September 2008.[4] The metolachlor ESA was observed at very low concentrations,[5] but it was concluded that these concentrations within the Mukwonago River were a result of groundwater discharge. This illustrates how applications of pesticides on agricultural lands can infiltrate into the groundwater and ultimately be discharged into the River system. It is also very likely that these compounds would be found in water from private wells using water from the shallow groundwater aquifer.[6]

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

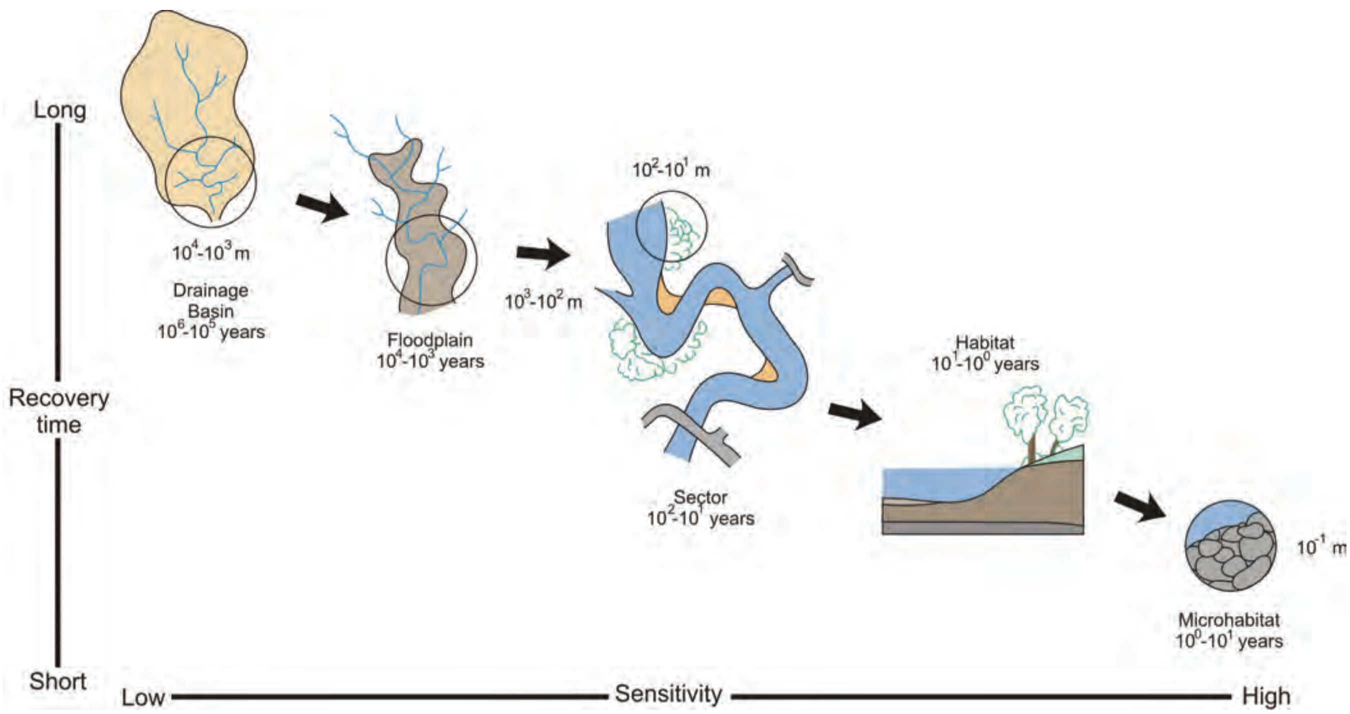
[4]*DATCP,Wisconsin Department of Agriculture, Trade and Consumer Protection,* Surface Water Sampling Project: Impact of Pesticides on Streams in Smaller Wisconsin Watersheds, *July 2009.*

[5]*Metolachlor Ethane Sulfonic Acid (ESA) is a breakdown product of Metolachlor, which is a pre-emergent herbicide that is used to control certain broadleaf weeds and grasses in corn, soybean, and other crops. Metolachlor is not considered to be toxic to mammals, birds, and insects; moderately toxic to warm and coldwater fishes; and toxic to some aquatic plants. However, the toxicity of the degradate Metolachlor ESA is unknown. Source for this information from Linda Rivard,* Environmental Fate of Metolachlor, *Environmental Monitoring Branch, Department of Pesticide Regulation, Sacramento, California, April 2003.*

[6]*DATCP,Wisconsin Department of Agriculture, Trade and Consumer Protection,* Agricultural Chemicals in Wisconsin Groundwater, *Agricultural Resource Management Division Publication 180, 2008.*

Figure 19

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



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

The major lakes within the Mukwonago River watershed and their associated dams interrupt the continuity of physical, chemical, and biological aspects of the river system.[7] In other words, dams are often viewed as an interruption within the context of the normal continuum of characteristics from upstream to downstream within a natural stream system.[8] For example, significant warming of surface waters and subsequent downstream reaches occurs within the three major lakes of the Mukwonago River system (see Temperature section below). However, it is important to note that the deeper areas of these lakes also offer vast thermal refuges (i.e., cooler water temperatures) which have diverse high quality habitats and spawning areas. In addition, these lakes serve as the focal point of recreation within the Mukwonago River watershed.

Urban Development, Imperviousness, and Hydrology

As noted previously in Chapter II of this report, urbanization increases impervious surface, which can lead to an increase in "flashiness" (or the rate at which flow responds to a precipitation event as shown in Figure 20). In the absence of mitigating measures, urbanization impacts the watershed, not only by altering the ratio between

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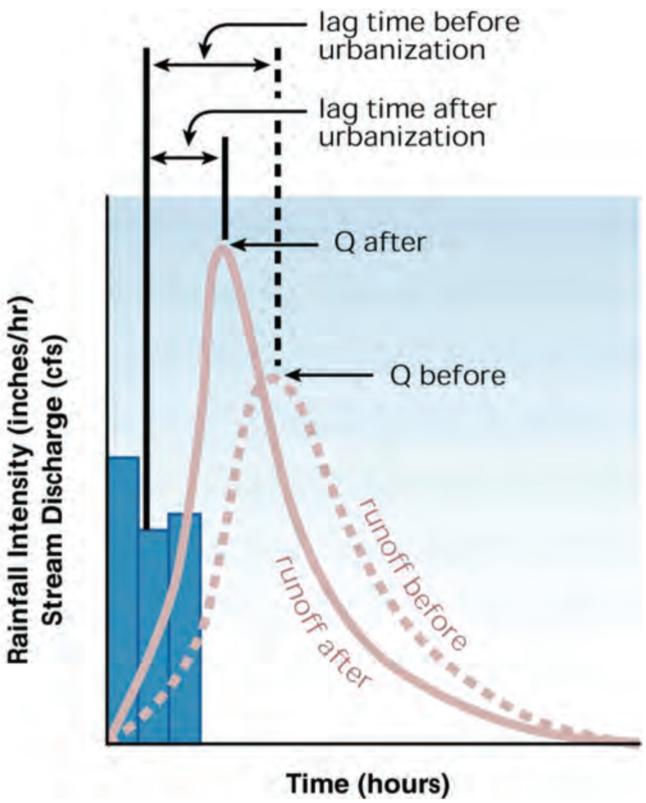
[7]*J.V. Ward, and J.A. Stanford. "The serial discontinuity concept of lotic ecosystems," In Dynamics of Lotic Ecosystems (T.D. Fontaine and S.M. Bartell, editors), Ann Arbor Science Publishers, Ann Arbor, MI, pages 29-42, 1983.*

[8]*R.L. Vannote, G.W. Minshall, K.W. Cummings, J.R. Sedell, and C.E. Cushing, "The River Continuum Concept,"* Canadian Journal of Fisheries and Aquatic Sciences, *Volume 37, pages 130-137, 1980.*

Figure 20

A COMPARISON OF HYDROGRAPHS BEFORE AND AFTER URBANIZATION



Source: *Federal Interagency Stream Restoration Working Group (FISRWG),* Stream Corridor Restoration: Principles, Processes, and Practices, *October 1998.*

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 (see Figure 20), 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, streambed and streambank stability, water quality/quantity, which, in turn, affect habitat availability and quality and biological diversity. More specifically, recent research has shown that average flow magnitude, high flow magnitude, high flow event frequency, high flow duration, and rate of change of stream cross-sectional area were the hydrological variables most consistently associated with changes in algal, invertebrate, and fish communities.[9] As detailed in Chapter II of this report, the overall levels of urban development in the watershed have been relatively low, but there are localized areas of more intensive urban development. The amounts of urban development within the watershed are at high enough levels to potentially be negatively affecting water quality and water quantity and they are projected to increase. Therefore, the hydrology of this urbanizing stream system within this watershed is a major determinant of stream dynamics and is a vital component of habitat for fishes and other organisms (see Figure 21).

To some degree, impervious surface impacts can be mitigated through implementation of traditional stormwater management practices and emerging green infrastructure technologies such as pervious pavement, green roofs, rain gardens, bioretention, and infiltration facilities. Traditional stormwater management practices seek to manage runoff using a variety of measures, including detention, retention, and conveyance. Emerging technologies, in contrast, differ from traditional stormwater practices in that they seek to better mimic the disposition of precipitation on an undisturbed landscape by retaining and infiltrating stormwater onsite. There are a number of nontraditional, emerging low impact development (LID) technologies that have been implemented throughout the Southeastern Wisconsin Region, including disconnecting downspouts; installing rain barrels, green roofs, and rain gardens; and constructing biofiltration swales in parking lots and along roadways. Experience has shown that these emerging technologies can be effective. For example, recent research has demonstrated that bioretention systems can work in clayey soils with proper sizing, remain effective in the winter, and contribute significantly to groundwater recharge, especially when such facilities utilize native prairie plants.[10]

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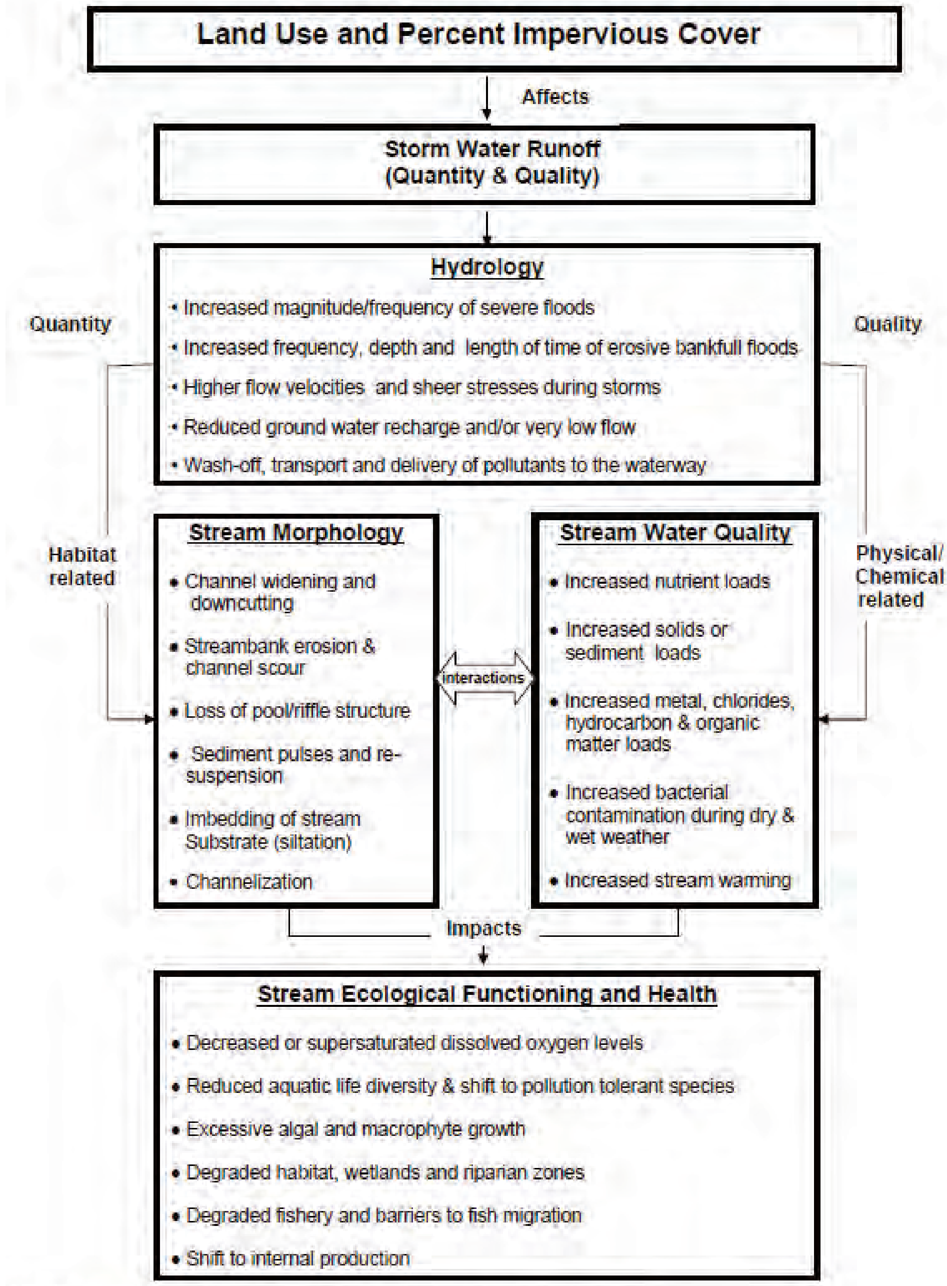
[9]*Personal Communication, Dr. Jeffrey J. Steuer, U.S. Geological Survey.*

[10]*Roger Bannerman, WDNR and partners;* Menasha biofiltration retention research project, *Middleton, WI, 2008; N.J. LeFevre, J.D. Davidson, and G.L. Oberts,* Bioretention of Simulated Snowmelt: Cold Climate Performance and Design Criteria, *Water Environment Research Foundation (WERF), 2008; William R. Selbig and Nicholas Balster*, Evaluation of Turf Grass and Prairie Vegetated Rain Gardens in a Clay and Sand Soil: Madison, Wisconsin, Water Years 2004-2008, *In cooperation with the City of Madison and Wisconsin Department of Natural Resources, U.S. Geological Survey Scientific Investigations Report, in draft.*

Figure 21

SCHEMATIC DIAGRAM DEPICTING THE RELATIONSHIP BETWEEN LAND USE, HYDROLOGY, WATER QUALITY, HABITAT QUALITY, AND ECOLOGICAL HEALTH



Source: Milwaukee Metropolitan Sewerage District and SEWRPC.

Location of impervious surfaces also 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 there is less time and distance for the polluted runoff to be naturally treated before entering 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 streams have a greater impact on the biological community, an 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 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 detention basins, grass swales, and infiltration facilities, 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 can single, stand-alone practices. 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.

An additional artifact of urbanization is the intentional and unintentional accumulation of trash and debris in waterways and associated riparian lands. These accumulations of trash are unsightly and can cause physical and/or chemical (i.e., toxic) damage to aquatic and terrestrial wildlife. Sometimes debris can accumulate to such an extent that it may limit recreation and the passage of aquatic organisms and/or cause streambank erosion. Although there has not been a comprehensive survey of trash and debris conditions within all the lakes, streams, and riparian areas of the Mukwonago River watershed, Southeastern Wisconsin Regional Planning Commission (SEWRPC) staff found that trash and debris were mainly located at or near road crossings within the extent of the rivers assessed as part of this study. Continued efforts to remove trash and debris from waterways and roadways within this watershed by lake management districts or the Friends of the Mukwonago River group or individuals demonstrates that this is an important issue to consider for the continued protection of this watershed.

What is Habitat?

Habitat is comprised of a complicated mixture of biological, physical, chemical, and hydrological variables. Biotic interactions such as predation and competition can affect species abundance and distributions within aquatic systems, however, such interactions are beyond the scope of this report and are not considered further in this document. Abiotic factors such as stream flow, water depth, water volume, temperature, dissolved oxygen concentrations, and substrate diversity are strong determinants of aquatic communities (fishes, invertebrates, and algae). Therefore, biological community quality is a surrogate for habitat quality. For example, high abundance and diversity of fishes is strongly associated with high-quality habitat.

In addition, anything that affects one or more of the abiotic factors that determine biological quality becomes an important (albeit nontraditional) component of habitat quality. For example, as previously noted above, the hydrology of this urbanizing stream system is a major determinant of stream dynamics and also is a vital component of habitat for fishes and other organisms (see Figure 21), so habitat quality is intimately related to land use within this watershed, as well as to land use directly adjacent to the streambank. Consequently, watershed size and associated land use characteristics as well as riparian buffer width are critical elements in defining habitat quality. Channelization, fragmentation due to road crossings, regulation and management of urban and rural nonpoint source pollution, and accumulation of trash and debris are also important aspects of what constitutes "habitat" and habitat quality within the Mukwonago River watershed.

STREAM REACHES

Based on the analysis of physical, chemical, and biological conditions from data obtained for years 1928 through 2009, this section summarizes information by stream reaches for the Mukwonago River watershed as set forth in Tables 13 and 14. This assessment was based upon a total of 306 cross sections located throughout the river

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[11]*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, pages 255-266.*

Table 14

PHYSICAL HABITAT CHARACTERISTICS OF STREAM REACHES WITHIN THE MUKWONAGO RIVER WATERSHED: 2008

Parameters	River Reach[a]					
	Mukwonago	Phantom		Eagle Spring	Jericho Creek	
	Muk-1	Muk-2	Beulah	Muk-3	Jer-1	Jer-2
Transects						
Number of Transects	32	163	24	38	64	96
Transects (number per mile)	14	23	18	19	28	23
Habitat						
Composition						
Number of Pools per mile	2.7	17.4	12.4	18.0	24.0	19.4
Number of Riffles per mile	4.0	3.5	0.7	0.5	12.0	4.1
Pool/Riffle Ratio	0.7	5.0	17.0	36.0	2.0	4.8
Average Width (feet)	96.6	35.5	32.4	28.3	18.5	11.1
Standard Deviation	28.5	13.8	12.3	23.7	6.2	4.5
Depth						
Average Pool Depth (feet)	2.4 (6)	2.8 (75)	2.7 (6)	2.5 (12)	1.3 (21)	1.9 (35)
Standard Deviation	0.4	0.7	0.4	0.4	0.2	0.4
Residual Pool Depth (feet)	0.9 (6)	2.9 (125)	2.8 (17)	2.6 (36)	1.1 (56)	1.2 (80)
Standard Deviation	0.5	1.1	1.2	0.9	0.5	0.4
Average Riffle Depth (feet)	1.9 (9)	1.4 (25)	1.5 (1)	0.85 (1)	0.7 (28)	1.2 (17)
Standard Deviation	0.2	0.3	- -	- -	0.2	0.4
Average Run Depth (feet)	2.2 (17)	2.2 (63)	2.1 (17)	2.2 (25)	1.0 (15)	1.5 (44)
Standard Deviation	0.3	0.6	0.4	0.5	0.25	0.4
Substrate						
Flocculent Sediment Depth						
Average Depth (feet)	0.1	0.3	0.2	1.2	0.1	0.2
Maximum Depth (feet)	0.8	4.8	3.7	5.6	1.0	2.4
Composition[b]						
Peat (percent)	0	9	20	64	1	6
Silt (percent)	5	19	21	13	6	21
Sand (percent)	45	53	45	14	22	28
Gravel (percent)	44	15	8	5	23	21
Cobble (percent)	2	3	6	4	32	16
Boulder (percent)	4	1	0	0	16	3
Bedrock (percent)	0	0	0	0	0	5
Cover						
Undercut Banks						
Deep (percent >1.0 feet)	0	0	0	0	0	0
Moderate (percent >0.5 and ≤1.0 feet)	0	<1	2	0	21	0
Shallow (percent <0.5 feet)	0	<1	0	0	0	5
None (percent)	100	99	98	100	79	95
Amount of Cover						
High Abundance (percent)	3	42	42	16	21	15
Moderate Abundance (percent)	47	36	46	66	45	58
Low Abundance (percent)	38	17	4	18	28	23
None (percent)	12	5	8	0	6	4
Woody Debris						
High Abundance (percent)	0	15	0	0	17	14
Moderate Abundance (percent)	3	27	42	0	41	31
Low Abundance (percent)	38	27	29	3	25	27
None (percent)	59	31	29	97	17	28
Macrophytes						
High Abundance (percent)	0	26	38	21	0	15
Moderate Abundance (percent)	59	44	50	58	6	13
Low Abundance (percent)	38	25	8	13	3	21
None (percent)	3	5	4	8	91	51

Table 14 (continued)

Parameters	River Reach[a]					
	Mukwonago	Phantom		Eagle Spring	Jericho Creek	
	Muk-1	Muk-2	Beulah	Muk-3	Jer-1	Jer-2
Cover (continued)						
Algae						
High Abundance (percent)	0	4	0	0	5	2
Moderate Abundance (percent)	25	33	46	29	20	15
Low Abundance (percent)	69	49	50	66	19	17
None (percent)	6	14	4	5	56	66
Shading						
High Abundance (percent)	0	10	0	0	66	19
Moderate Abundance (percent)	3	15	4	0	17	7
Low Abundance (percent)	28	31	13	0	12	4
None (percent)	69	44	83	100	5	70
Obstructions						
Beaver Dams (total number)	0	0	0	0	0	5
Road Crossings (total number)	5	18	1	4	8	9
Total Obstructions (number per mile)	2.2	2.5	0.7	1.1	3.4	3.4
Qualitative Habitat Environmental Index (QHEI) Rating						
QHEI Score Average	68	68	59	61	69	62
QHEI Score Range (minimum-maximum)	55-76	49-81	51-68	49-69	57-79	47-73
QHEI Quality Range (minimum-maximum)	Good-Excellent	Fair-Excellent	Fair-Good	Fair-Good	Good-Excellent	Fair-Excellent

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

[b]*Based on generalized evaluation of substrate composition at each transect.*

Source: SEWRPC.

system for assessment of physical habitat conditions, 228 fish surveys in streams, 169 fish surveys in lakes, mussel surveys, 182 terrestrial plant surveys, bird surveys to assess the biological community, and several years of water quality data, including deploying more than 40 continuously recording temperature dataloggers throughout the stream system, two streamflow gauging stations, one weather station, and several groundwater level monitoring stations. This information was collected for a variety of purposes by the Wisconsin Department of Natural Resources (WDNR), U.S. Geological Survey (USGS), universities, SEWRPC, public inland lake protection and rehabilitation districts, private sector organizations, and citizens. These samples were collected for a variety of purposes and programs that include baseline monitoring by the WDNR, the USGS National Water Quality Assessment (NAWQA) and individual lake projects, and other research projects. It is important to note that the collection methods used were similar and comparable for purposes of this report. The only samples not used in direct quantitative comparison were fisheries samples collected within lakes versus streams due to differences in sampling gear in these two environments or where sampling gear were unknown. These data were used for species presence or absence information only.

Slope and Sinuosity

The slope, length, and sinuosity of the six reaches within the Mukwonago River system as shown in Table 13 are determined by a combination of geological history (i.e., glaciation) and human intervention (i.e., lake impoundments and channelization). The Phantom Lakes dam and the Eagle Spring Lake dams were used as break points for reaches Mukwonago-1 through 3, the private dam just upstream of CTH NN was used as a break point for reaches Jericho-1 and 2, and the Beulah reach ends at the Lake Beulah dam (see Map 22). These reaches represent the limit of the physical data collected within the Mukwonago River system as part of this study as shown in Map 22 and summarized in Table 14.

Healthy streams naturally meander or migrate across a landscape over time. Sinuosity is a measure of how much a stream meanders and the sinuosities found within the Mukwonago River system are indicative of a healthy moderate to highly meandering stream system (see Table 14). Streams are transport systems for water and sediment and are continually eroding and depositing sediments, which causes the stream to migrate. When the amount of sediment load coming into a stream is equal to what is being transported downstream—and stream widths, depths, and length remain consistent over time—it is common to refer to that stream as being in a state of "dynamic equilibrium." In other words the stream retains its physical dimensions (equilibrium), but those physical features are shifted, or migrate, over time (dynamic). For example, it is not uncommon for a low-gradient stream in Southeastern Wisconsin to migrate more than 1 foot within a single year. Comparison of the 1941 versus 2009 stream alignments as shown on Map 23 shows that this system is a highly meandering river system that moves across the landscape over time. This observation, combined with observations of generally stable streambed and streambanks indicate that the Mukwonago River system seems to be in a state of dynamic equilibrium. The extensive riparian buffer areas allow for the river system to naturally make adjustments. It is also important to note that the extent of meandering increases with the area tributary to the stream reach, so as tributary area increases so does the width of the meander belt (see Appendix B, page 14). This increase in the meander belt can be seen in the series of insets shown on Map 23 with the largest areas found within the downstream portions of the Mukwonago River.

The longitudinal slope of a channel is the ratio of elevation change between two points on the 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, slopes within the Mukwonago River reaches are more indicative of lowland streams found in Southeastern Wisconsin and do not exceed 1 percent, as shown in Table 13. Elevation profiles for each stream reach are shown in Figure 22.

In general, reaches Jericho-1 and Jericho have the greatest slopes in the Mukwonago River watershed compared to the other four reaches (see Figure 22 and Table 13). These higher sloped reaches also contain the greatest proportions of larger substrates including sands, gravels, cobbles, and boulders compared to the other reaches, which are dominated by sand and organic substrates such as silt and peat (see Table 14 and Figures 23 through 28). One exception is the Mukwonago-1 reach, which is dominated by gravel and sand substrates and only contains limited amounts of organic substrates. This can partially be attributed to the effect of the upstream dam at Lower Phantom Lake, which allows for settling of organic sediments out of the water prior to flowing past the dam, that promotes discharge of cleaner waters into the Mukwonago-1 reach than would occur if the dam were not present. These substrate differences also can be largely attributed to the soil associations (see Map 12 in Chapter II of this report) that these reaches flow through. For example, Jericho Creek flows through the Warsaw-Lorenzo soil association, which is a glacial till dominated by large substrates including sand, gravel, cobble, and boulder as can be seen in Table 14 and Figures 27 and 28.[12] The Mukwonago-1 reach flows through the Hochheim-Theresa soil association, which is a glacial till dominated by sands and gravels (see Table 14 and Figure 23). In contrast, the remaining reaches of the Mukwonago River watershed (Mukwonago-2, Mukwonago-3, and Beulah) flow through the Houghton-Palms-Adrian soil association that is comprised of very poorly drained organic soils. Consequently, these reaches are also dominated by organic silt, peat, and sand. Sands are the most dominant component of the soil associations within the watershed, therefore, it is not surprising that sand is also the most dominant substrate within the Mukwonago River system (see Table 14). The distribution and diversity of substrates have important implications for habitat quality and biological communities (see Habitat and Biological Community sections below).

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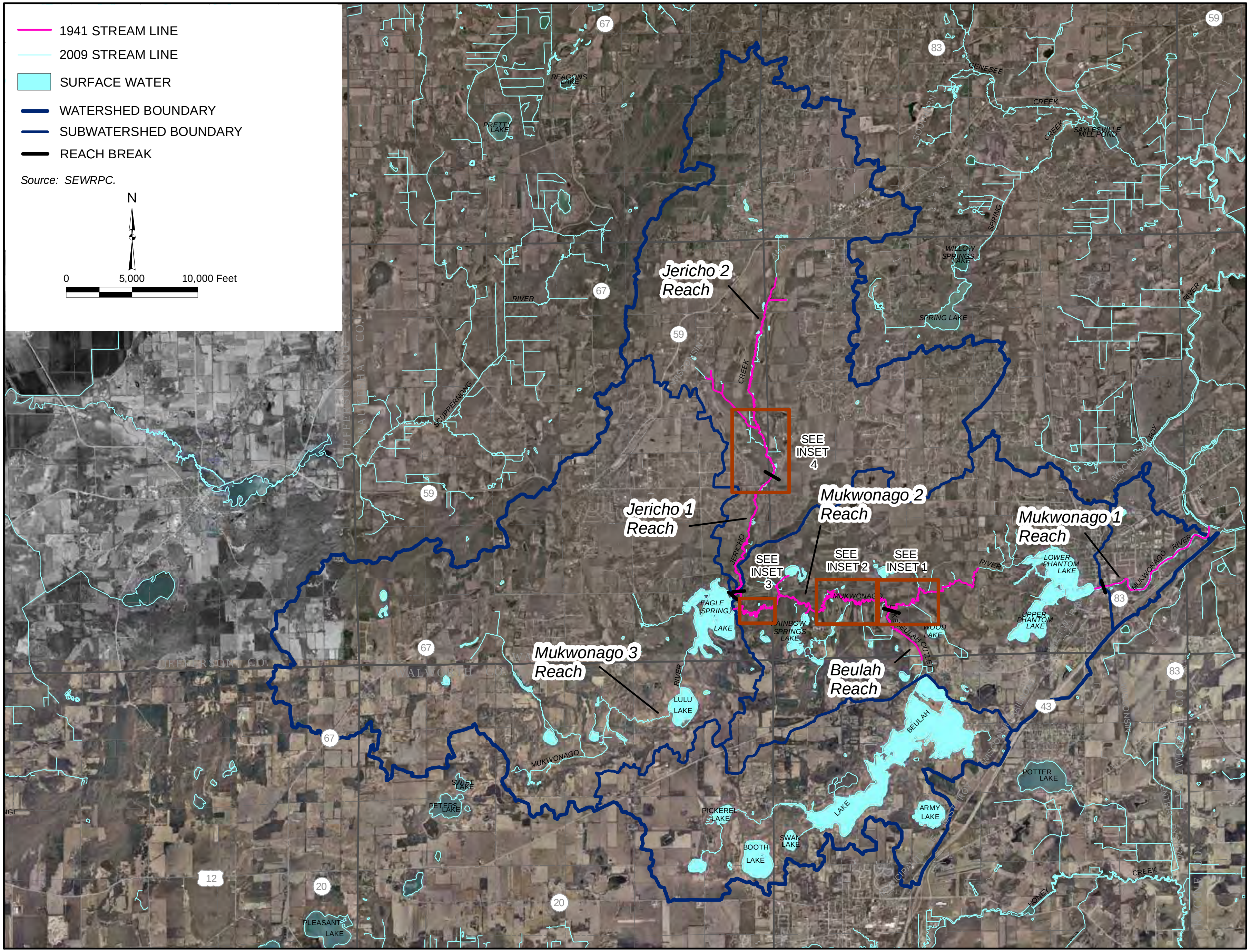
[12]*Glacial till is defined as unstratified (not layered) drift deposited directly by the ice of a melting glacier and consists of a mixture of clays, sands, and gravels, often with large boulders mixed together in any proportion.*

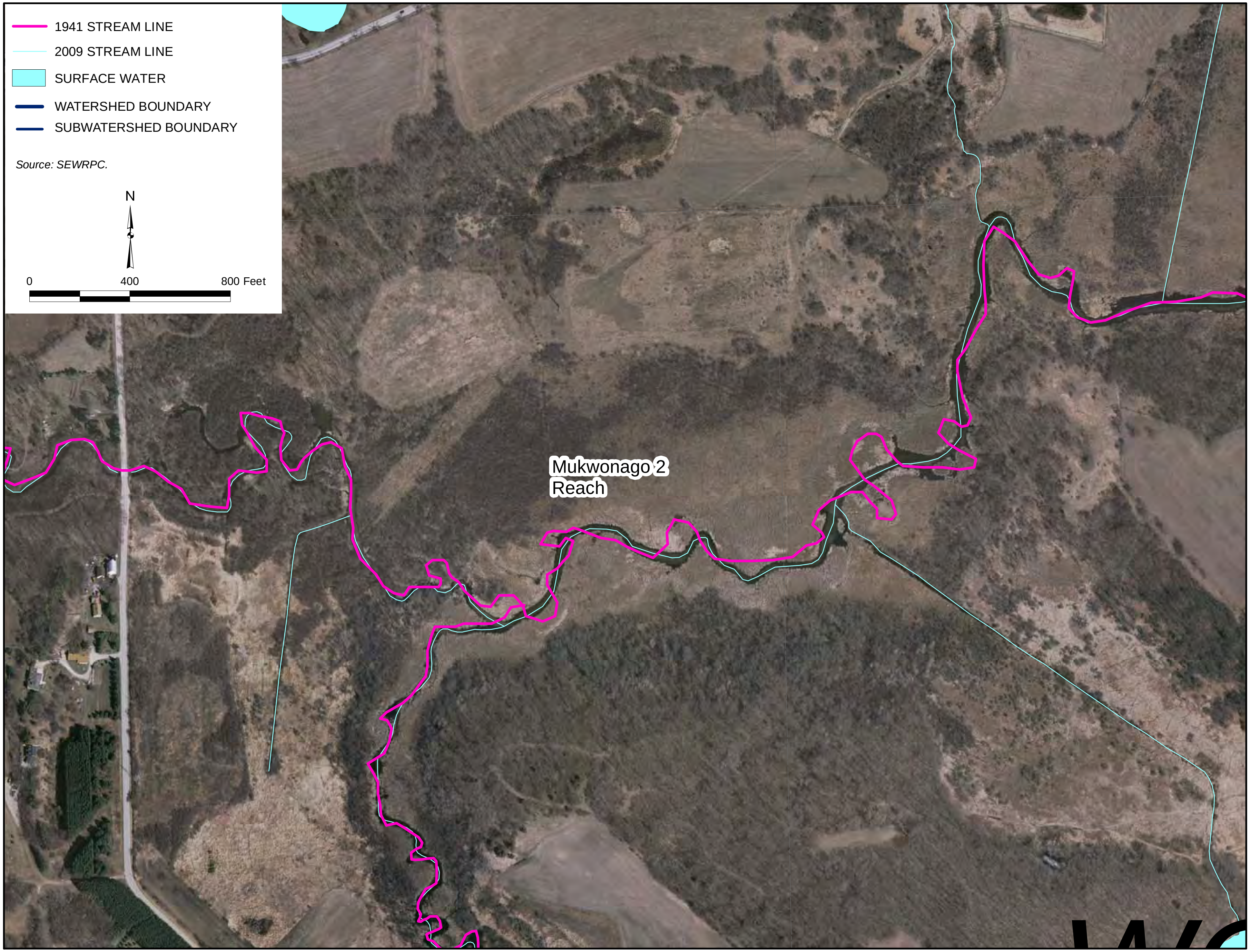
Map 23

STREAM ALIGNMENTS WITHIN THE MUKWONAGO RIVER WATERSHED: 1941 AND 2009



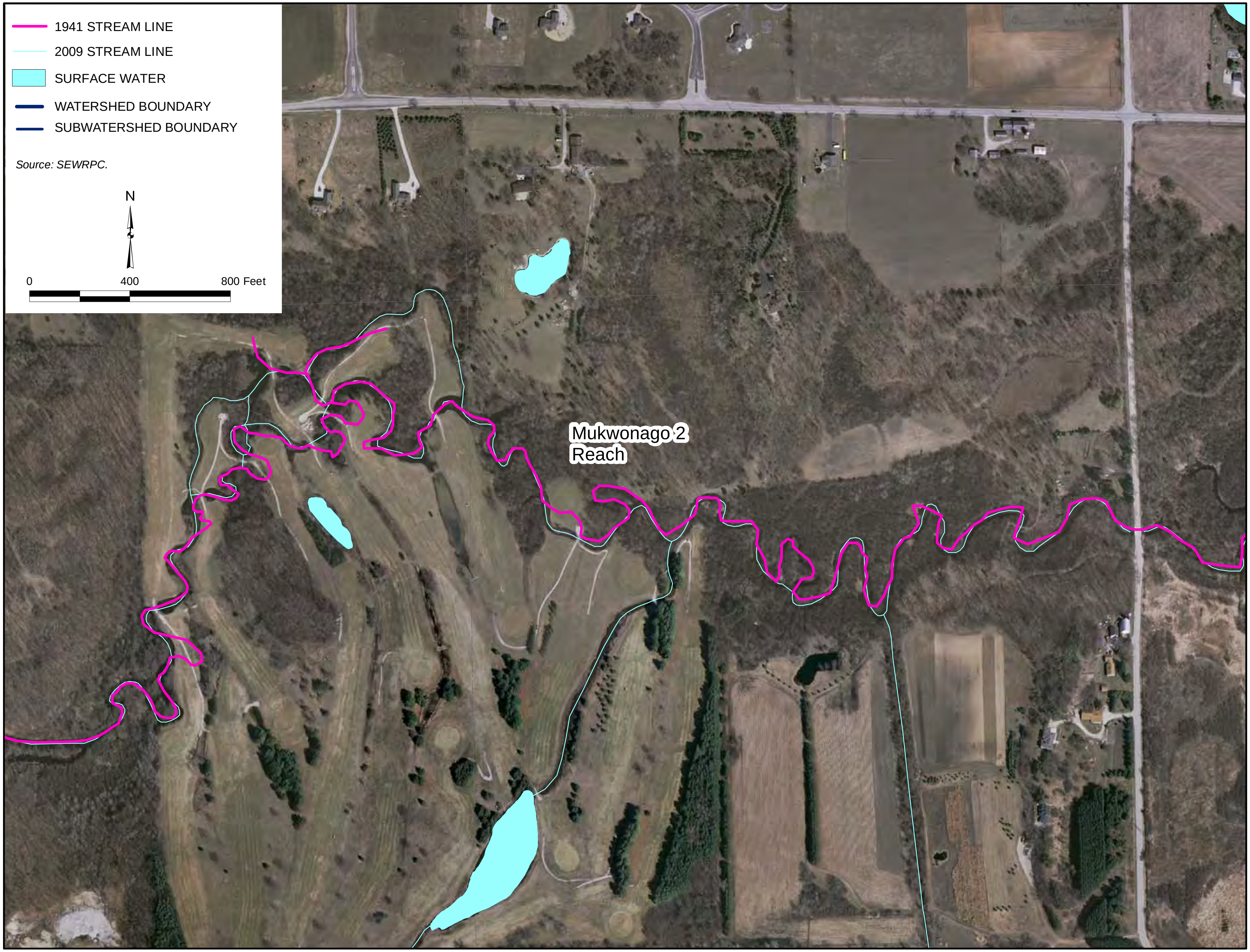
Inset 1 to Map 23

STREAM ALIGNMENTS ALONG THE MUKWONAGO RIVER: 1941 AND 2009



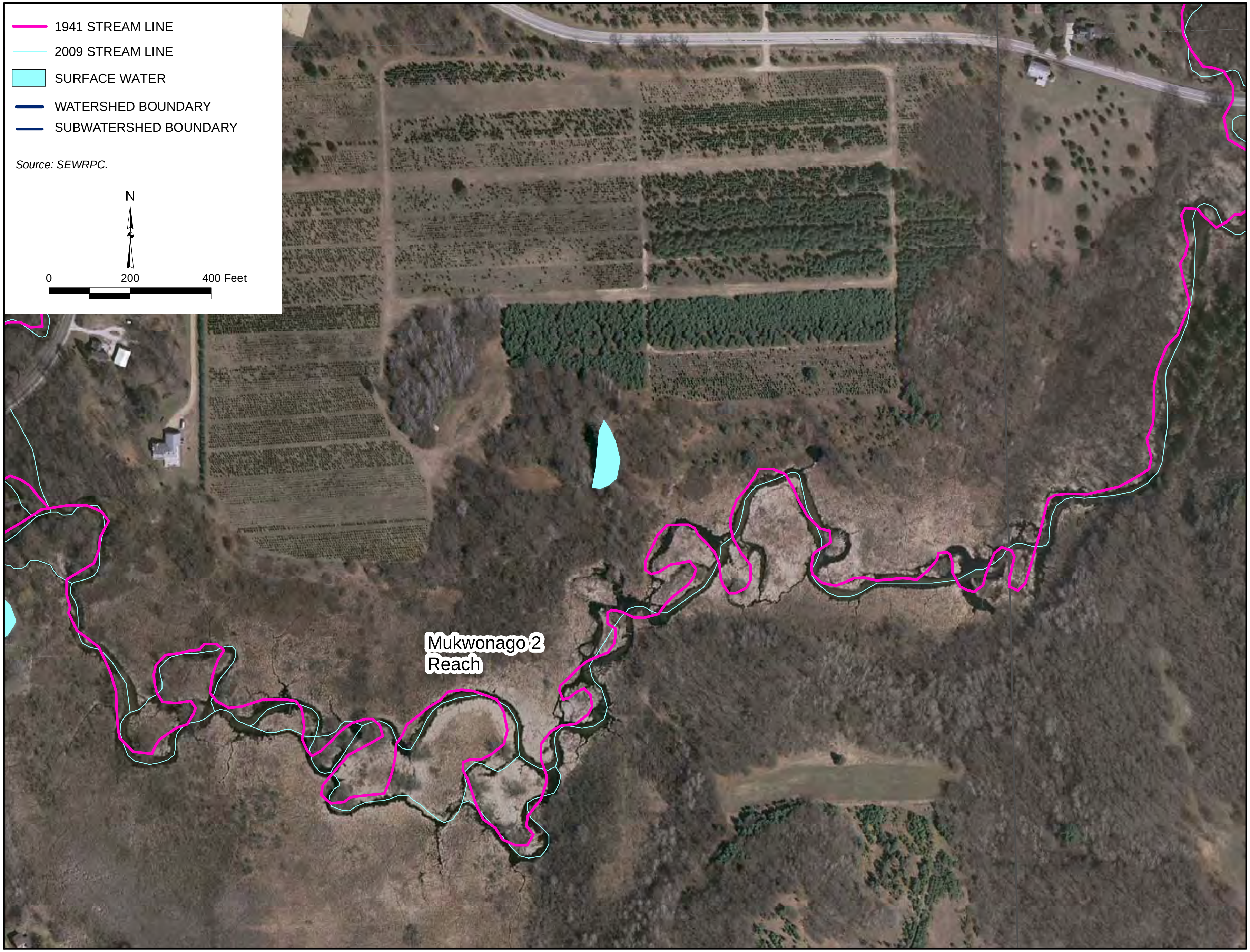
Inset 2 to Map 23

STREAM ALIGNMENTS ALONG THE MUKWONAGO RIVER: 1941 AND 2009



Inset 3 to Map 23

STREAM ALIGNMENTS ALONG THE MUKWONAGO RIVER: 1941 AND 2009



Inset 4 to Map 23

STREAM ALIGNMENTS ALONG JERICHO CREEK: 1941 AND 2009

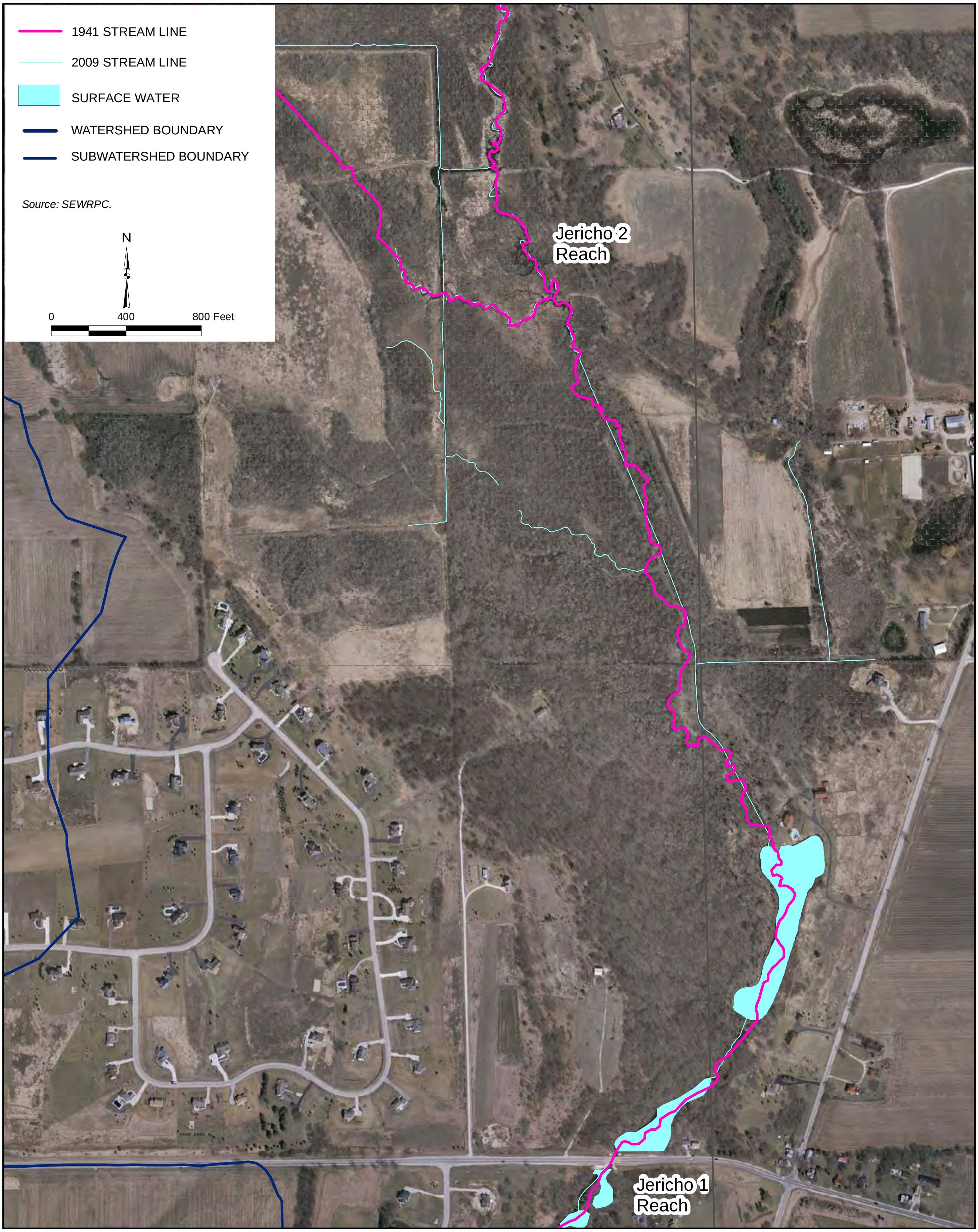
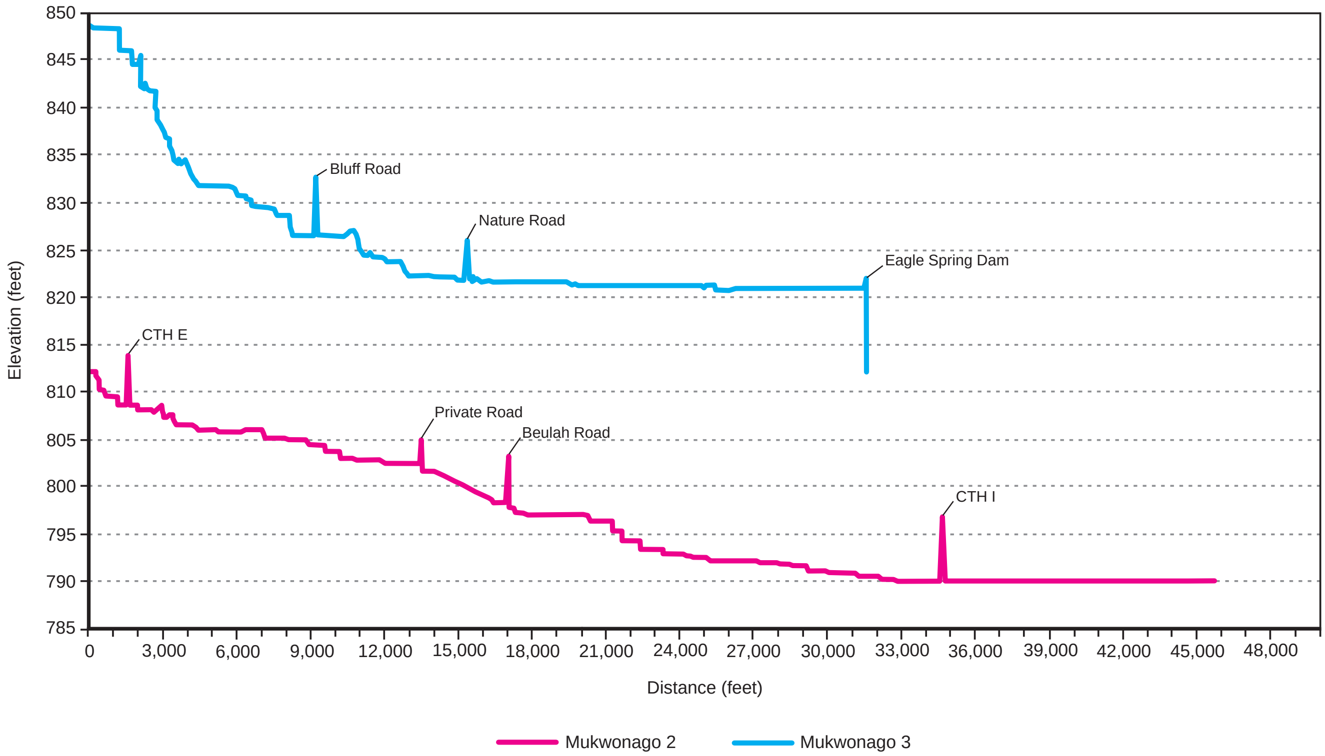


Figure 22

APPROXIMATE NORMAL WATER SURFACE ELEVATION PROFILES BY STREAM REACH IN THE MUKWONAGO RIVER WATERSHED: 2009



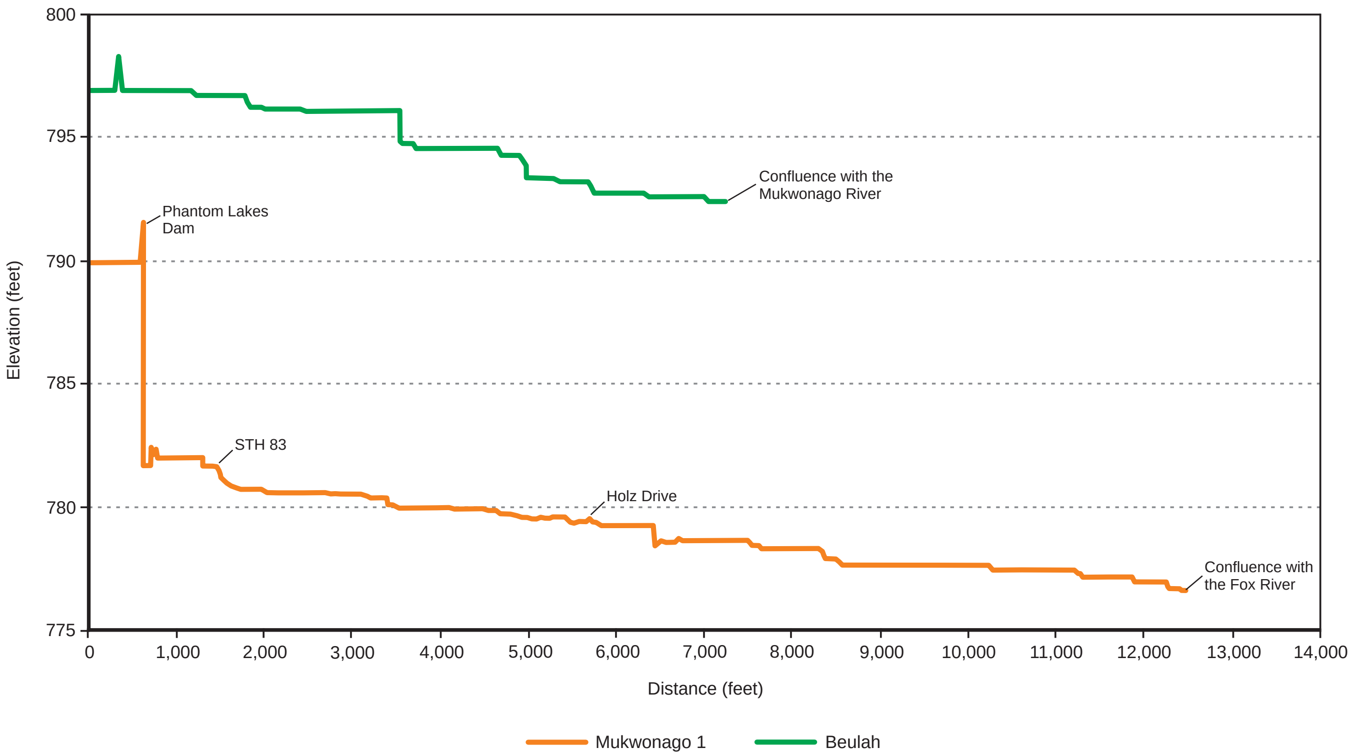
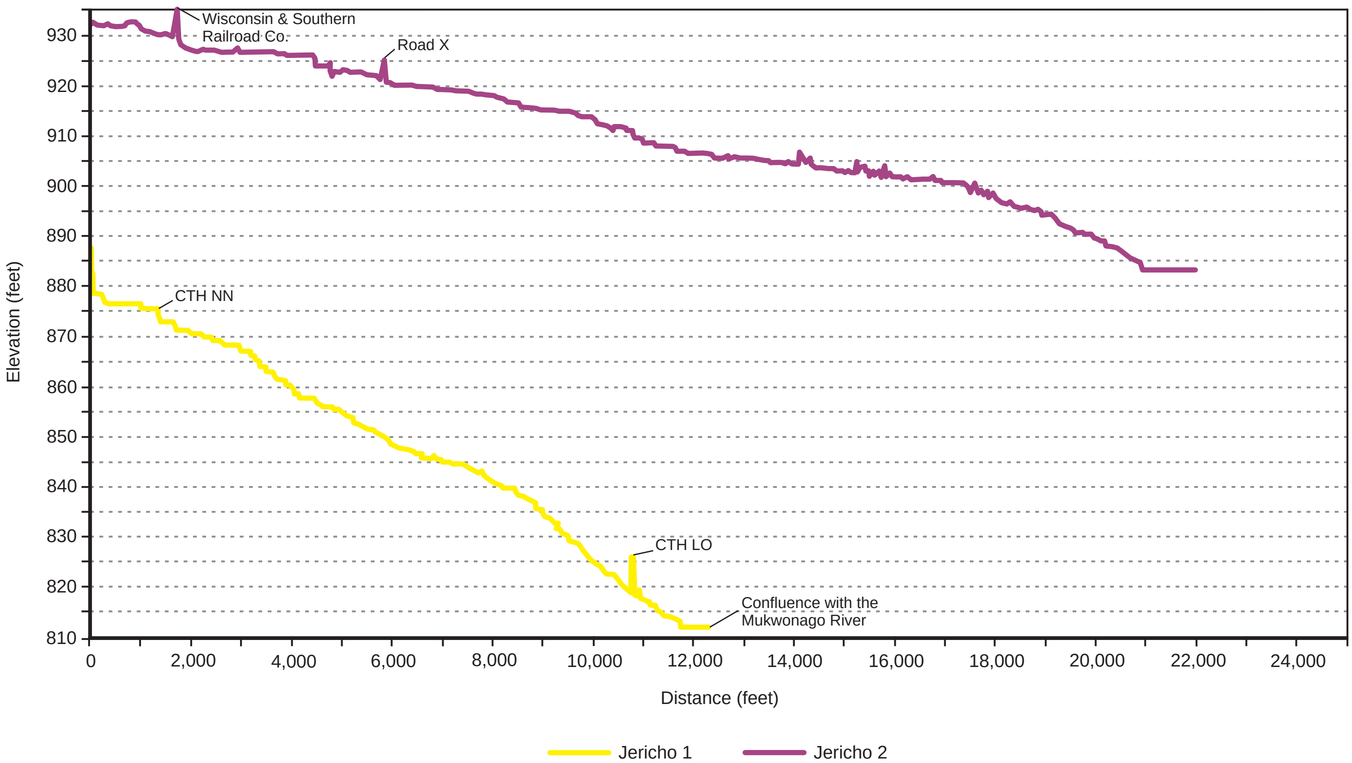


Figure 22 (continued)



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.

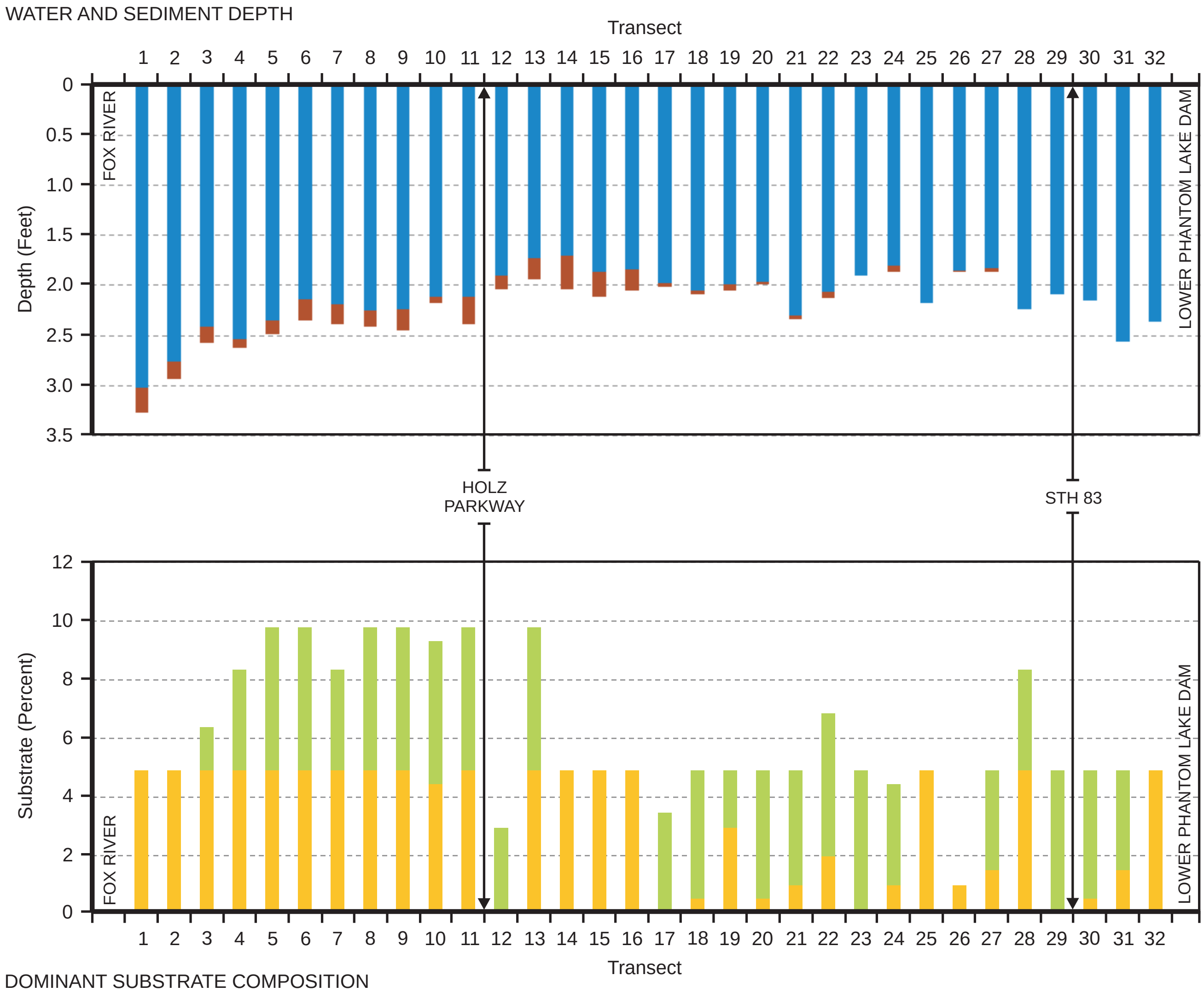
As expected, the most significant changes in stream gradient occur at the Lower Phantom Lake and Eagle Spring Lake dams in reaches Mukwonago-1 and Mukwonago-3 in Figure 22, respectively. The Lake Beulah dam also creates an important gradient change, but this was not shown in the elevation profile for the Beulah reach in Figure 22. Each of these three dam structures creates a backwater effect (about two miles in the case of Lower Phantom Lake and the Eagle Spring-Lulu Lakes and more than three miles in the case of Lake Beulah). These structures maintain the hydrology and physical morphometry of the Lakes as shown in Table 15. Eagle Spring and Lower Phantom Lakes are considered shallow lake systems with a mean water depth equal to or less than four feet, whereas Lulu, Upper Phantom, and Beulah Lakes are considered deep lakes with a mean water depth equal to or greater than 11 feet (see Table 15). Lake surface area and depth affects the residence time for water to move through them, which in turn affects water quality within the lake and the reaches into which the lake discharges (see Water Quality section below). The estimated residence time for Lulu Lake is nearly two months, for Upper Phantom it is about one year, and for Lake Beulah it is more than three years. Residence times for Eagle Spring Lake and Phantom Lakes are 26 days and 15 days, respectively, which indicates that water passes through these lakes fairly quickly compared to the other lakes.

Channelization

Straightening meandering stream channels or "channelization" was once a widely used and accepted technique in agricultural management. The U.S. Department of Agriculture National Resources Conservation Service (NRCS) (formerly Soil Conservation Service) cost shared such activities up to the early 1970s within southeastern

Figure 23

MEAN WATER DEPTH, SEDIMENT DEPTH, AND DOMINANT SUBSTRATE COMPOSITION AMONG TRANSECTS WITHIN THE MUKWONAGO 1 STREAM REACH: 2008



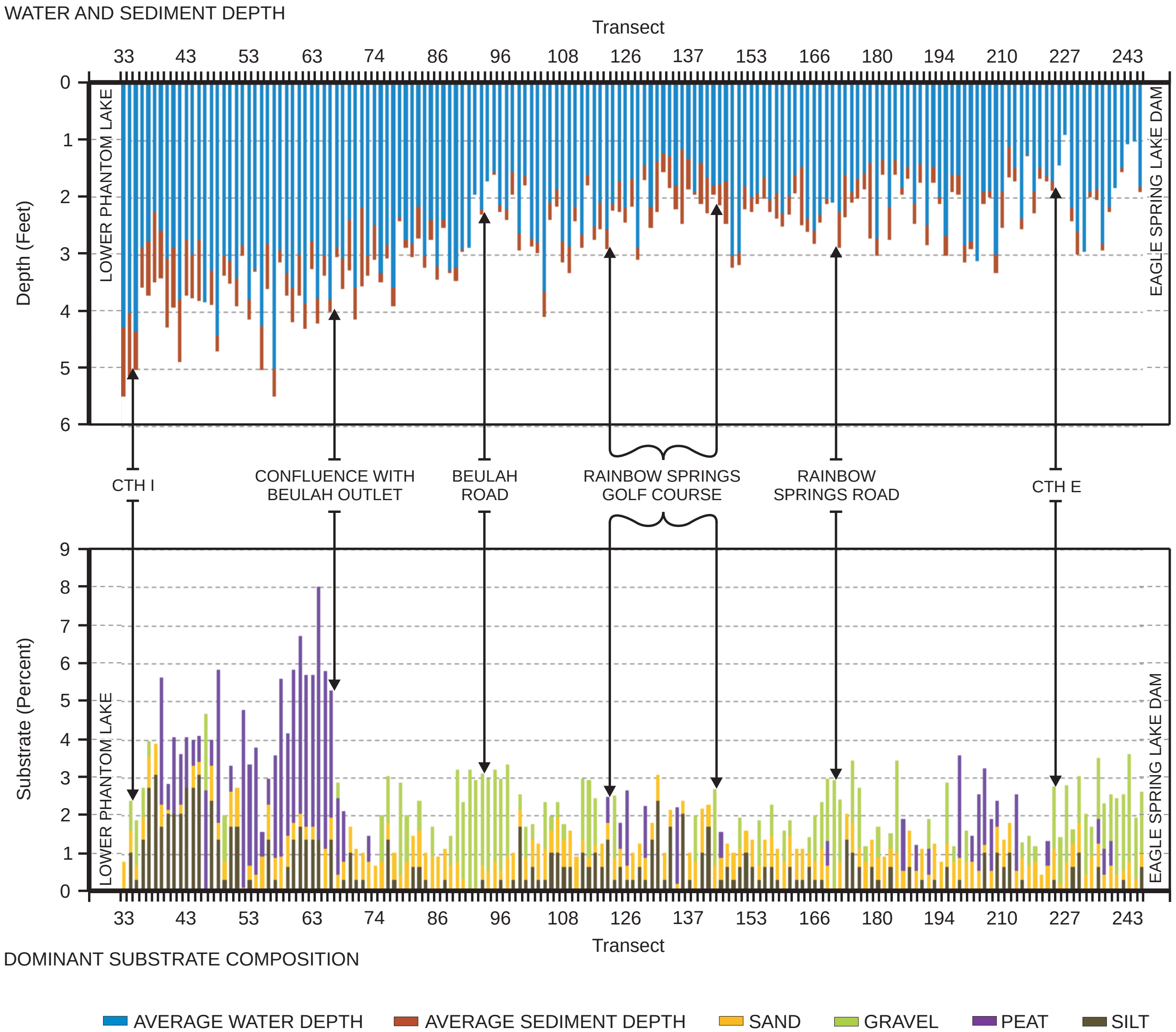
Source: SEWRPC.

Wisconsin.[13] 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 and 2) the effective slope within a reach that is channelized

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

Figure 24

MEAN WATER DEPTH, SEDIMENT DEPTH, AND DOMINANT SUBSTRATE COMPOSITION AMONG TRANSECTS WITHIN THE MUKWONAGO 2 STREAM REACH: 2008

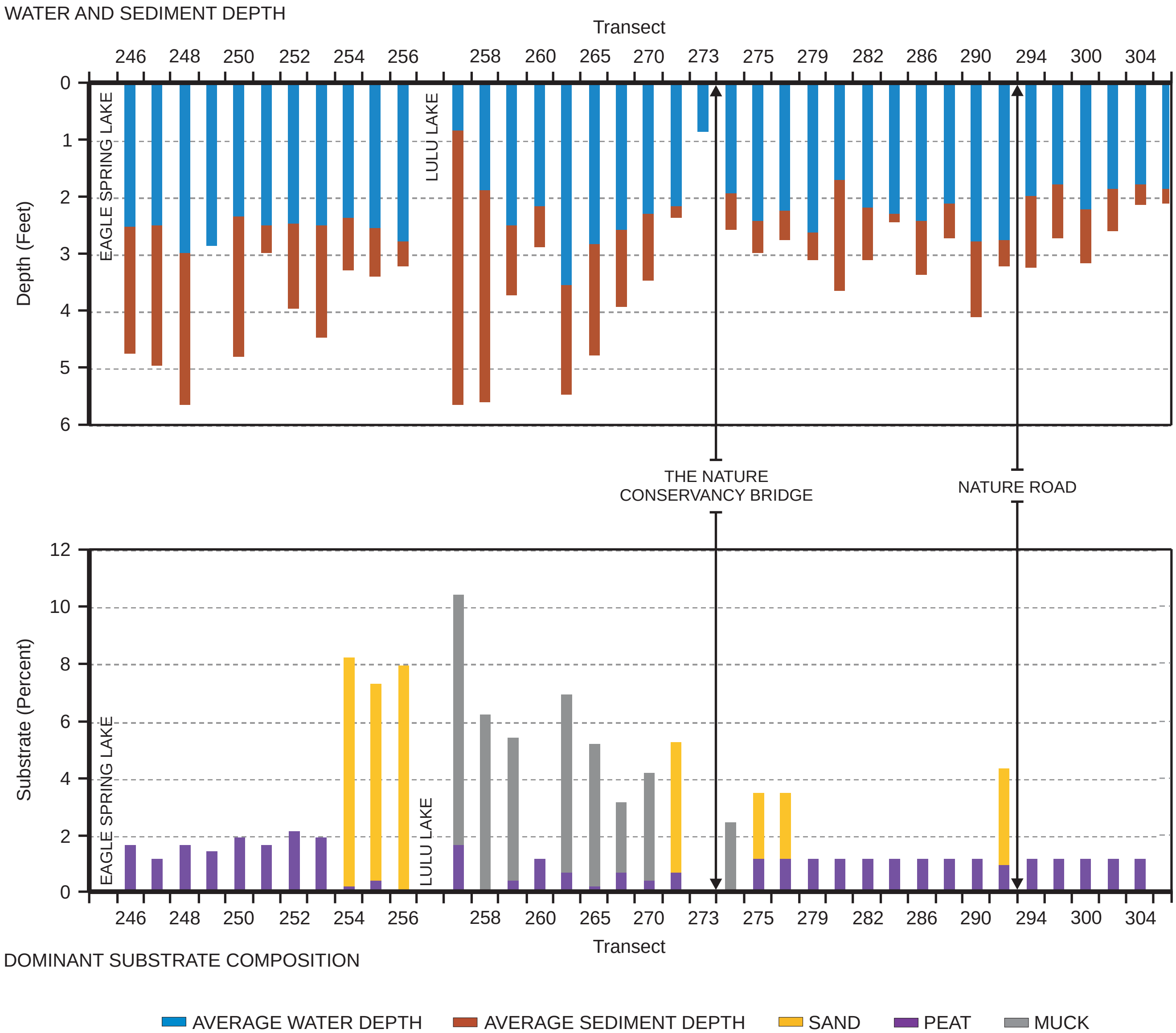


Source: SEWRPC.

is 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 the connection between the channel and 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

Figure 25

MEAN WATER DEPTH, SEDIMENT DEPTH, AND DOMINANT SUBSTRATE COMPOSITION AMONG TRANSECTS WITHIN THE MUKWONAGO 3 STREAM REACH: 2008



Source: SEWRPC.

the loss of riparian vegetation, and it can alter instream sedimentation rates and paths of sediment erosion, transport, and deposition. 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.[14] Therefore, channelization activities, as traditionally accomplished without mitigating features, generally lead to a diminished suitability of instream and riparian habitat for fish and wildlife.

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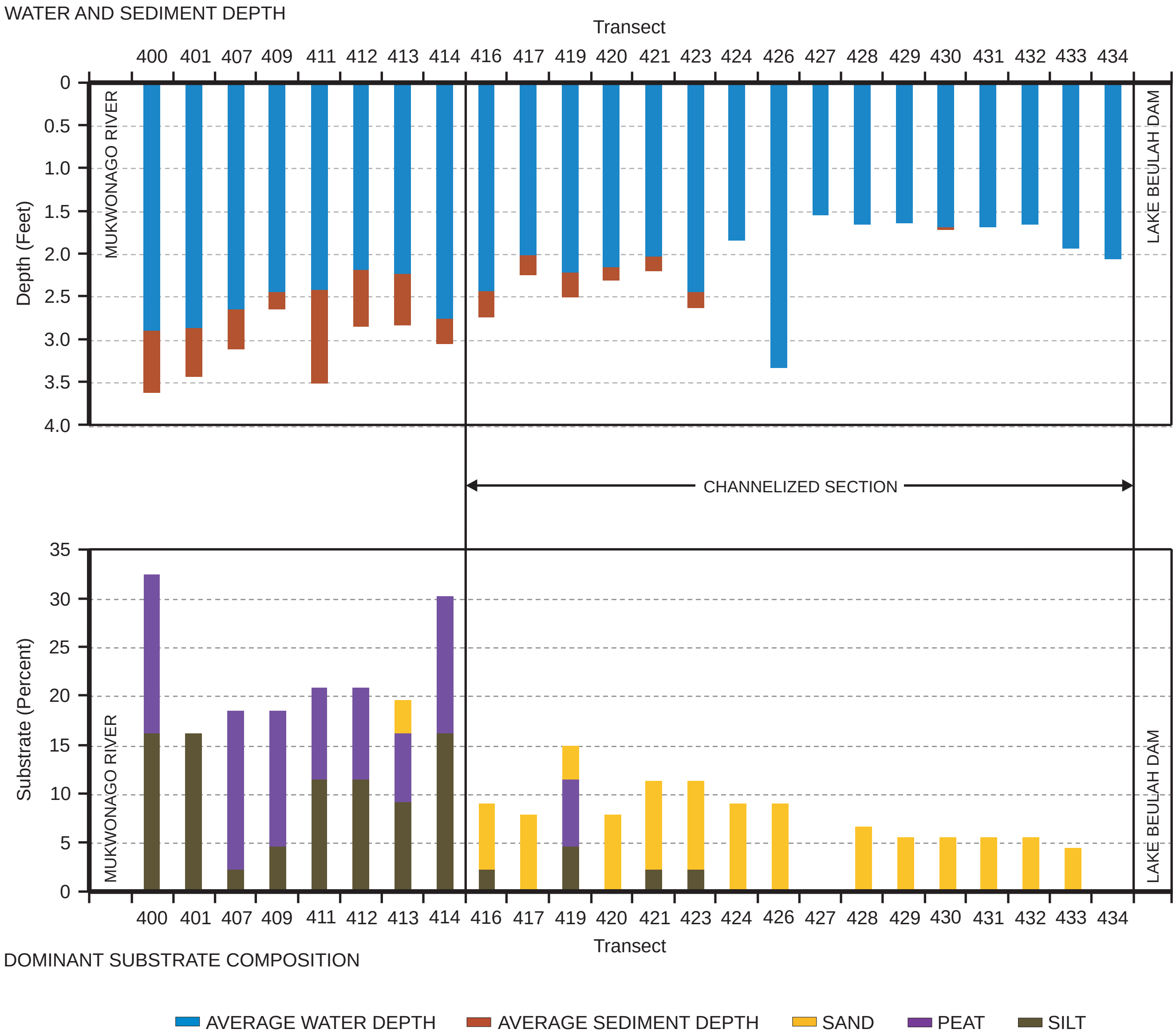
[14]*N.D. Gordon, et al.*, Stream Hydrology, *John Wiley and Sons, April 1993, page 318.*

Figure 26

MEAN WATER DEPTH, SEDIMENT DEPTH, AND DOMINANT SUBSTRATE COMPOSITION AMONG TRANSECTS WITHIN THE BEULAH STREAM REACH: 2008

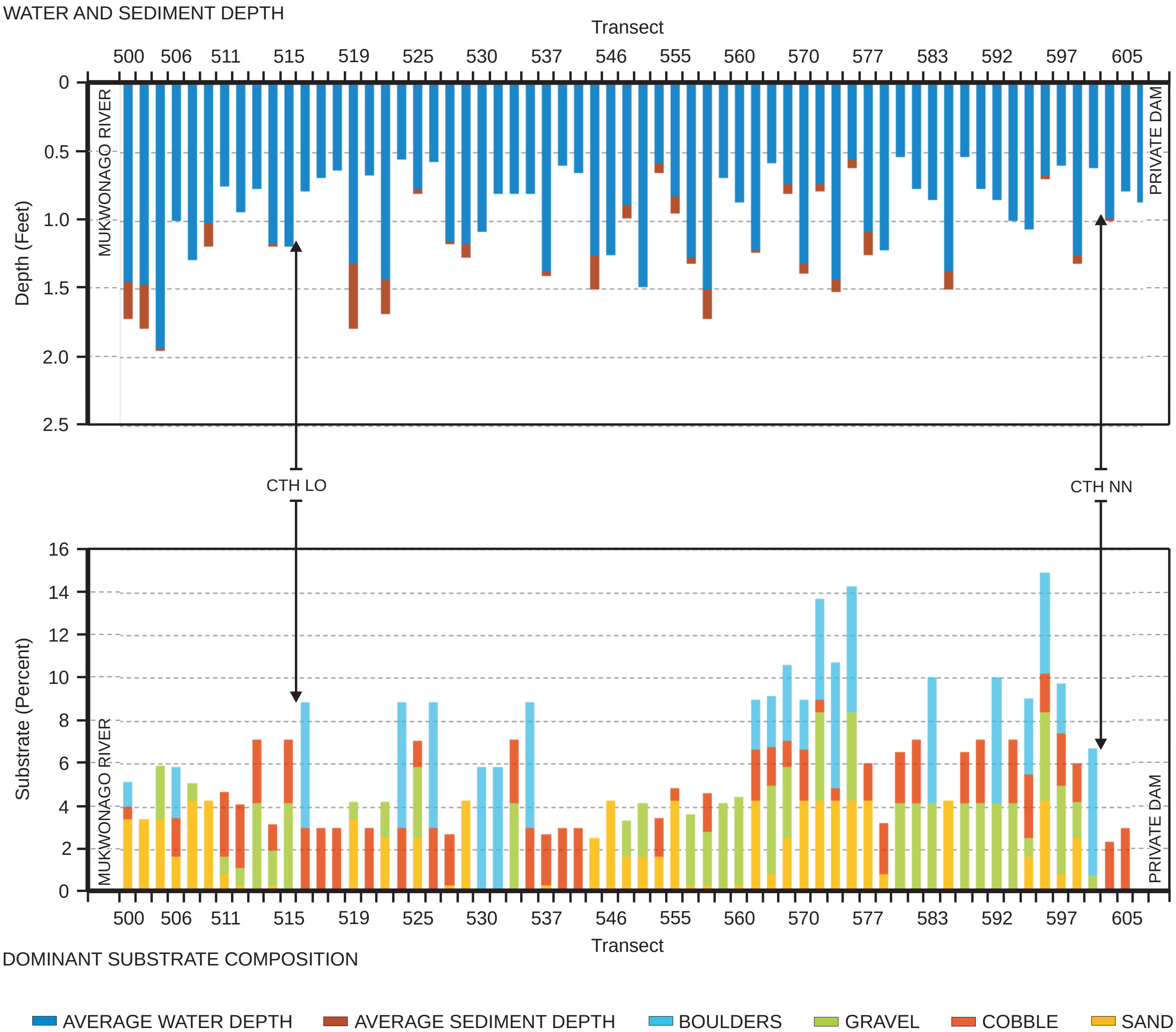


Source: SEWRPC.

A comparison of aerial photographs from 1941 to 2005 indicates that no channelization has occurred on reaches Mukwonago-1, Mukwonago-2, or Mukwonago-3. Table 13 indicates an apparent loss of approximately 1.5 stream-miles compared to year 1941, but as shown on Map 23 this is a result of the highly meandering system within this reach that ultimately cut off several sections of channel. These abandoned sections of channels are called oxbows and help contribute to the habitat complexity within this system, which provide backwater areas for a variety of aquatic and terrestrial wildlife. These oxbows do actually reduce the total length of the river, which in this case was cumulatively about 1.5 miles, but these are a normal component of a naturally functioning healthy river system and they have had little effect on the overall sinuosity of this reach.

Figure 27

MEAN WATER DEPTH, SEDIMENT DEPTH, AND DOMINANT SUBSTRATE COMPOSITION AMONG TRANSECTS WITHIN THE JERICHO 1 STREAM REACH: 2008

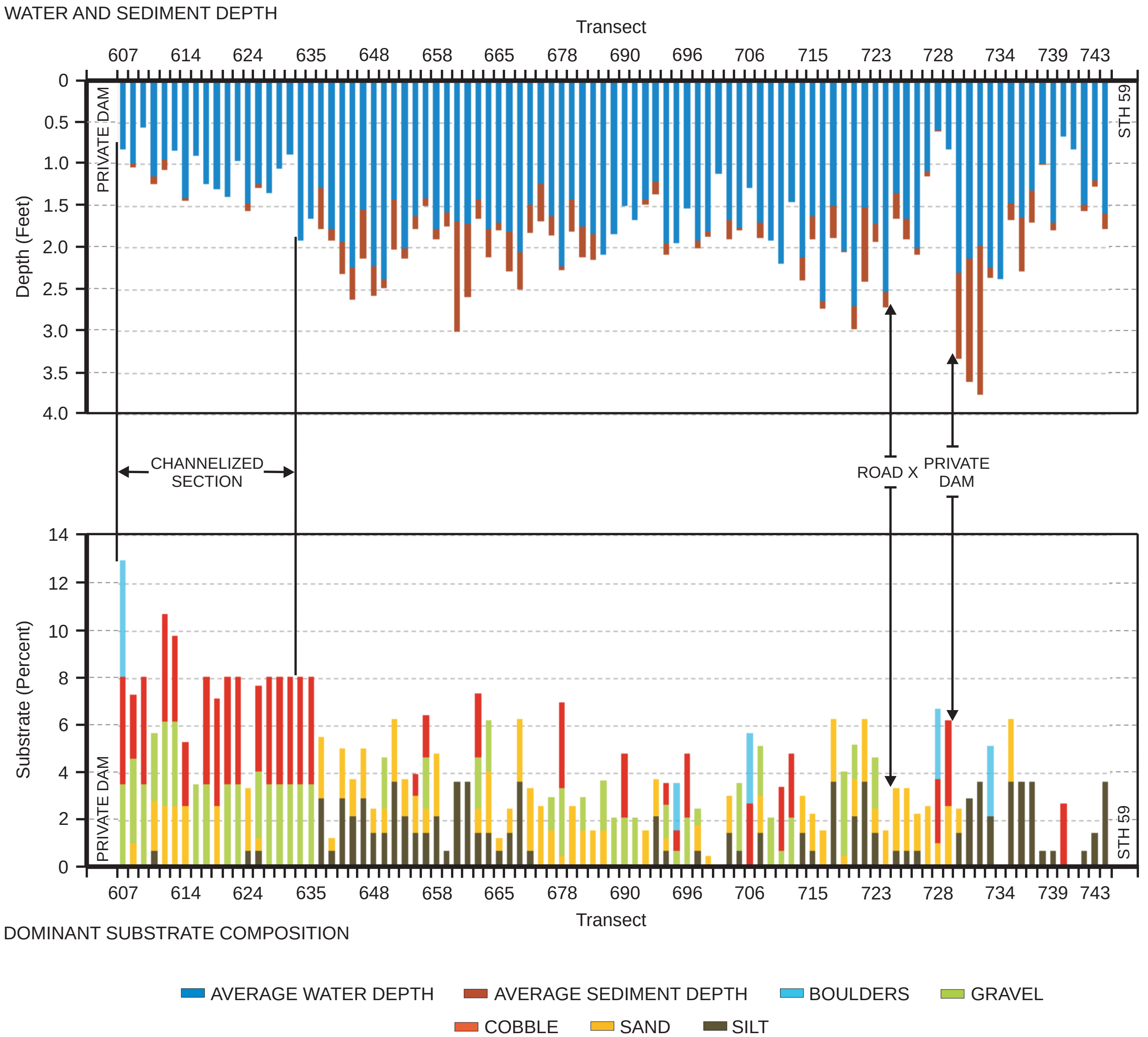


Source: SEWRPC.

Approximately one-half of the upper portion of the Beulah reach was channelized at some time before the 1941 aerial photograph was taken. The effect of this channelization can still be seen in the elevation profile shown in Figure 22 with an abrupt change in elevation occurring at the transition between the natural channel and the beginning of the channelized section. There also is a shift in substrates with higher dominance of sand substrates within the channelized section and dominance of organics within the downstream nonchannelized section of stream (see Figure 26). This channelization has resulted in an approximate loss of nearly 0.2 mile of stream length, which has a limited affect on the overall sinuosity of this reach which changed from 1.4 to 1.3. Since it has probably been more than 70 years since the upper section of the Beulah reach has been channelized, it seems to have largely recovered in terms of instream habitat, bank stability, riparian buffer vegetation, and fishery community.

Figure 28

MEAN WATER DEPTH, SEDIMENT DEPTH, AND DOMINANT SUBSTRATE COMPOSITION AMONG TRANSECTS WITHIN THE JERICHO 2 STREAM REACH: 2008



Source: SEWRPC.

Sometime between 1941 and 1950, Jericho Creek experienced some historical channelization in the area north of CTH NN, which included construction of ponds along the stream alignment that occurred sometime between 1970 and 1980. Any loss in stream length due to this channelization is offset by an increase of stream length between Road X and STH 59, where Jericho Creek was actually lengthened sometime between 1970 and 1980 by extending it upstream to accommodate stormwater runoff from the Village of North Prairie (see Map 23). This upper section of Jericho Creek was historically part of the shallow groundwater aquifer and did not exist as a stream prior to 1980. In fact, creation of the channel in the upper portion of Jericho Creek required construction

Table 15

HYDROLOGY AND MORPHOMETRY OF MAJOR LAKES WITHIN THE MUKWONAGO RIVER WATERSHED: 2009

Parameter	Lulu Lake	Eagle Spring Lake	Lake Beulah	Upper Phantom Lake	Lower Phantom Lake
Surface Area (acres)	95.5	279.2	834.0	107.0	433.0
Percent of Area <3.0 feet deep	10.8 (10.4 acres)	28.0 (78.3 acres)	13.0 (108.4 acres)	8.1 (8.7 acres)	79.00 (342.1 acres)
Percent of Area >6.0 feet deep	78.6 (75.1 acres)	13.3 (37.2 acres)	- -	- -	- -
Percent of area >20.0 feet deep	52.5 (50.2 acres)	0.0	34.0 (283.6 acres)	12.2 (13.1 acres)	0.0
Total Watershed Area (acres)	- -[a]	16,076.1	6,534.0	- -[b]	46,275.0
Total Watershed Area excluding internally drained areas (acres)	- -	13,127.7	6,534.0	- -	39,191.0
Ratio of Watershed Area to Lake Area	- -	57.6	7.8	- -	106.9
Volume (acre-feet)	2,292.0	1,005.1	14,279.0	1,154.0	1,555.0
Residence Time (years)	0.16 (58 days)	0.07 (26 days)	3.34 (1,219 days)	0.98 (358 days)	0.04 (15 days)
Maximum Length of Lake (miles)	0.55	1.18	2.60	0.70	1.70
Maximum Width of Lake (miles)	0.42	0.65	1.30	0.40	0.80
Length of Shoreline (including islands) (miles)	2.07	7.44	15.30	2.00	5.60
Length of Natural Shoreline (including islands) (miles)	2.07	2.11	2.99	0.54	4.81
Mean Depth (feet)	24.0	3.6	17.0	11.0	4.0
Maximum Depth (feet)	40.0	8.0	58.0	29.0	12.0
Ratio of Mean Depth to Maximum Depth	0.60	0.45	0.29	0.38	0.33

[a]*Watershed area was not calculated for Lulu Lake.*

[b]*Watershed area was not calculated for Upper Phantom Lake.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

with the use of dynamite and other heavy equipment through solid bedrock.[15] This section of stream exhibits the coldest temperatures compared to all other sites within Jericho Creek (see Temperature section below). The stream appears to have largely recovered from the channelization that occurred nearly 30 years ago in terms of streamside vegetation, and it is capable of supporting a coldwater fishery. However, instream habitat remains limiting within this section of stream compared to the natural areas downstream.

Channelization of Jericho Creek north of CTH NN (see Inset 4 to Map 23) initially was likely to have negatively impacted the habitat and aquatic communities within that section of stream. However, this reach seems to have largely recovered in terms of instream habitat and presence of fishes and other wildlife and streambank vegetation. This section of stream has a relatively steep slope, but the streambed and streambanks have been protected due to the naturally occurring large substrates within this area. Due to the high slopes, no accumulation of fine sediment has occurred within the channelized section of this stream from upstream transport of sediments, but there are significant amounts of organic sediments that have settled out within the two impoundments on the north side of the CTH NN road crossing.

In conclusion, despite some limited channelization within selected areas of the watershed as described above, the reaches are generally indicative of natural meandering stream systems with sinuosities of 1.3 and greater. In addition, these channelized sections of stream seem to have largely recovered (see Habitat section below).

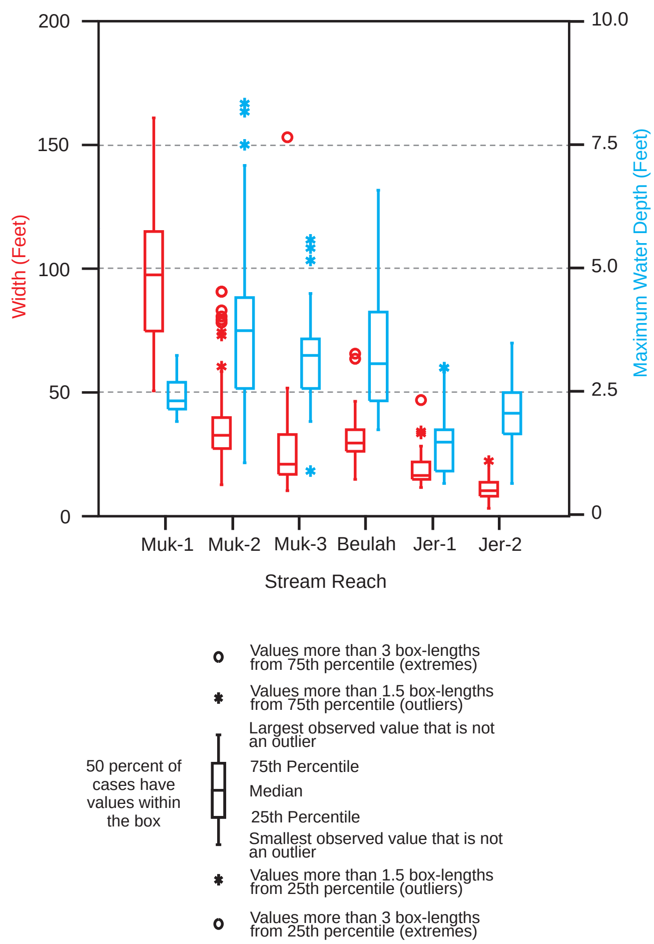
HABITAT CONDITIONS

SEWRPC staff conducted field inventories from May through August 2008 to quantitatively and qualitatively characterize the physical habitat characteristics of the Mukwonago River watershed. Both quantitative and qualitative measures were largely based upon the WDNR Baseline Monitoring protocols for instream fisheries

[15]*Personal Communication, Bob Klusendorf.*

Figure 29

STREAM WIDTH AND MAXIMUM DEPTH AMONG REACHES IN THE MUKWONAGO RIVER WATERSHED: 2008



Source: SEWRPC.

habitat assessment.[16] A total of 417 cross sections surveys were obtained throughout the watershed and the number of transects ranged from 14 to nearly 30 transects per mile, depending on the reach sampled as shown in Table 14 (see Appendix C). An additional 177 maximum water depths were recorded in pool habitats to assess number and quality in order to supplement information between cross sections where the full complement of data was collected. Physical parameters that were measured include water and sediment depth, substrate composition, undercut bank, bank slopes, and channel width. The remaining cover parameters were each qualitatively estimated as none, low, moderate, and high percent abundances based upon categories as defined in the Qualitative Habitat Evaluation Index (QHEI) methodology.[17]

It is important to note that the following sections summarize the physical conditions of the Mukwonago River system in the year 2008, which was an uncharacteristically "wet" year as discussed in Chapter II of this report. As a result higher than normal annual precipitation and stream discharge occurred within the Mukwonago River watershed (see Hydrology and Groundwater section below). The average summer discharge in 2008 was 123.3 cubic feet per second (cfs), which was nearly twice the normal average discharge. Therefore, based upon this increase in discharge, the Mukwonago River system in 2008 more closely represents bankfull conditions than normal summer low flow conditions, which is consistent with observations during the time of the survey.

There is a general increase in stream width and maximum water depth among reaches from upstream to downstream as shown in Figure 29. The Mukwonago River increases in average width from 28 feet in the Mukwonago-3 reach to 36 feet in the Mukwonago-2 reach and to 97 feet in the most downstream Mukwonago-1 reach. Jericho Creek increases from an average width of about 11 feet in reach Jericho-2 to 19 feet in reach Jericho-1. The Beulah reach has an average width of about 32 feet. In terms of maximum water depths, Jericho Creek is the shallowest tributary to the Mukwonago River, ranging from an average of about 1.0 to 1.5 feet in

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[16]*WDNR, Guidelines for Evaluating Habitat of Wadable Streams, Bureau of Fisheries Management and Habitat Protection, Monitoring and Data Assessment Section, Revised June 2000; Timothy Simonson, John Lyons, and Paul Kanehl, "Guidelines for Evaluating Fish Habitat in Wisconsin Streams,"* General Technical Report NC-164, *1995; and Lihzu Wang, "Development and Evaluation of a Habitat Rating System for Low-Gradient Wisconsin Streams,"* North American Journal of Fisheries Management, *Vol. 18, 1998.*

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

maximum water depth. The remaining reaches within the Mukwonago River system all have maximum water depths generally greater than 2.0 to 2.5 feet.

However, there are two notable exceptions to the general trend of increased width and depth from upstream to downstream. The first exception is in the Mukwonago-1 reach, which is unusually shallow and wider than all other reaches on this system. The second exception is in Jericho-2, which is unusually deeper than the downstream Jericho-1 reach. Figure 29 also shows that there is a large amount of variability in the width and depth values both within and between the reaches, which is why there is no significant linear relationship between stream width and water depth on this system. This inconsistency between width and depth is primarily due to a combination of backwater effects created by dams and other channel modifications, selected road crossings, and substrate types.

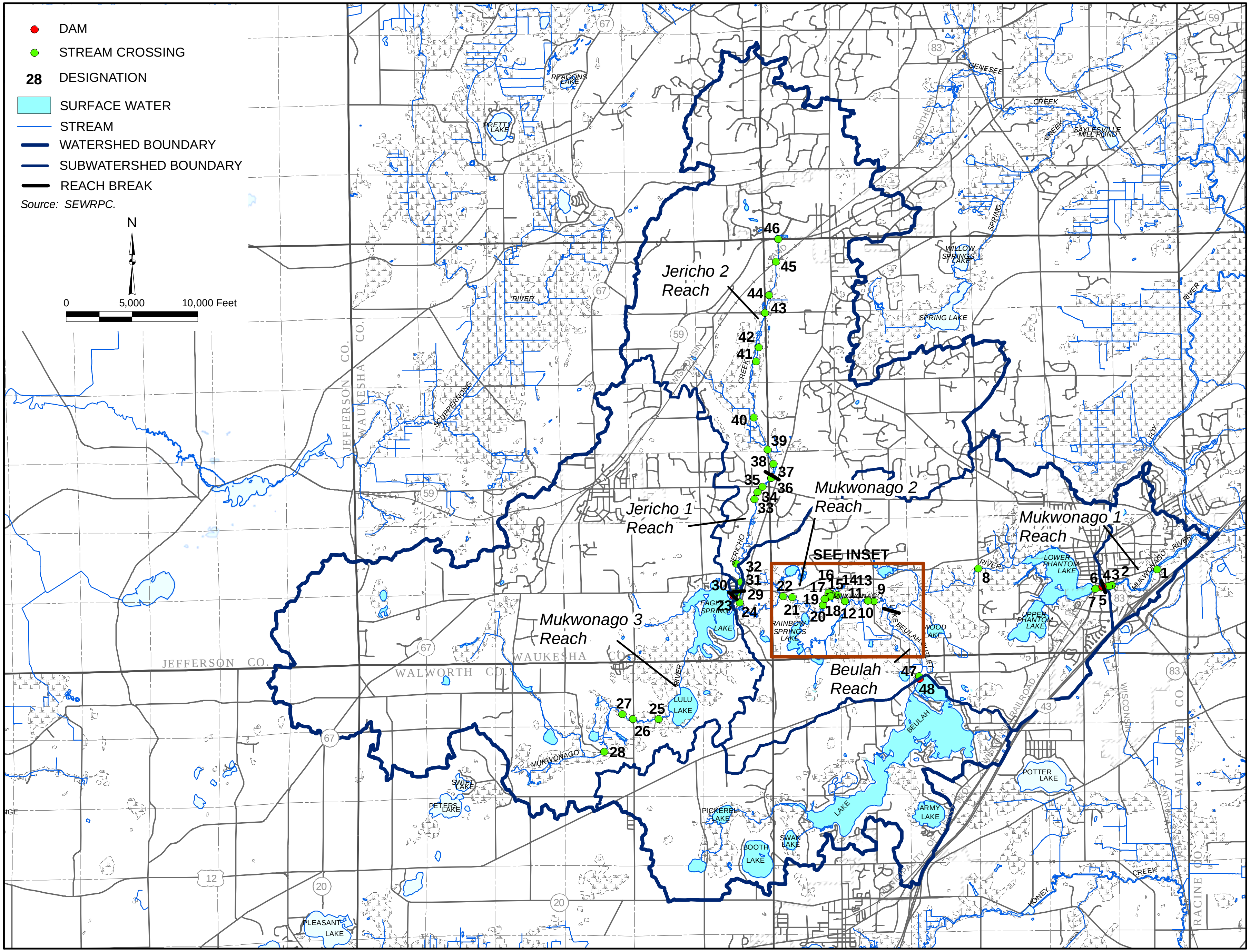
Effects of Road Crossings

There are a total of five dams, two railway crossings, and 41 road crossings (see Map 24 and Figure 30) distributed throughout the Mukwonago River watershed that are potentially affecting stream width, water and sediment depths, and substrates. There are a total of 17 culverts and 26 bridges as shown on Map 24 and further described in Table 16. In general, bridges, which are suspended above the stream channel, usually have more limited impacts on normal stream conditions (i.e., low-flow) than culverts. However, it is possible that the streambed underneath a bridge can become elevated, which is usually caused by placement of large stone to prevent erosion of the streambed and streambanks underneath the structure. This condition currently exists at the CTH NN bridge over Jericho Creek. While it was not likely to have been intentional, the stone placed on the streambed and streambanks to protect the bridge at CTH NN is causing a significant backwater effect that has created a shallow pond upstream of this structure. Although this is certainly acting like a dam, the water depths at this structure did not seem to be limiting fish passage and SEWRPC staff also observed that there were numerous spawning beds for sunfishes such as largemouth bass and bluegill along the eastern shore of this impounded area. SEWRPC staff also observed trout both within and upstream of the impounded area. Since the trout had to migrate from downstream through the restriction at the CTH NN bridge, this was further evidence that this restriction did not seem to be a significant fish passage barrier. Based upon these observations, this structure was not considered to be a dam. However, this crossing illustrates why it is important to be vigilant in the design construction and/or reconstruction of roadway crossings, which can have unintended consequences to aquatic communities. This also is a good example of why it is important to continue to monitor this and all road crossings periodically in order to ensure that they have not accumulated debris and become barriers to fish and other aquatic organisms.

Culverts are predominately located on the mainstem of the Mukwonago River within the Rainbow Springs Golf Course as well as within the headwater area of Jericho Creek. Culverts frequently impact normal stream conditions, because they are often much narrower than the actual stream width. For example, the average width of the mainstem in reach 2 of the Mukwonago River is about 36 feet, but the culverts within the Rainbow Springs Golf Course range from only three to six feet in diameter. Therefore, the stream is squeezed into culverts that are 80 to 90 percent narrower than the normal stream width. In response to this condition, stream velocities become necessarily elevated in order to pass flow through a small area of pipe relative to the stream channel area, which often leads to elevated scouring of the streambed and/or banks downstream of the culvert. Concurrently, this also creates a localized backwater effect upstream of the structure, which increases water depth and the potential for sediment deposition within this area. Therefore, the physical constraints of an undersized culvert usually lead to changes in substrate composition and they can affect larger-scale sediment dynamics associated during low and high flow conditions. These conditions were observed to different degrees among this series of culverts within the Rainbow Springs Golf Course area (see Figures 24 and 30). In addition, culverts often accumulate trash, wood, and other debris that can further obstruct flows through the structure and create conditions that act more like a dam. Increased velocities and/or debris obstructions at culverts can become significant barriers for fishes and other aquatic organisms to migrate through, which can lead to significant fragmentation of populations (see Obstructions section below). These can also be significant navigation hazards for recreation.

Map 24

STREAM CROSSINGS AND DAMS WITHIN THE MUKWONAGO RIVER WATERSHED: 2009



Inset to Map 24

STREAM CROSSINGS AND DAMS WITHIN THE MUKWONAGO RIVER WATERSHED: 2009

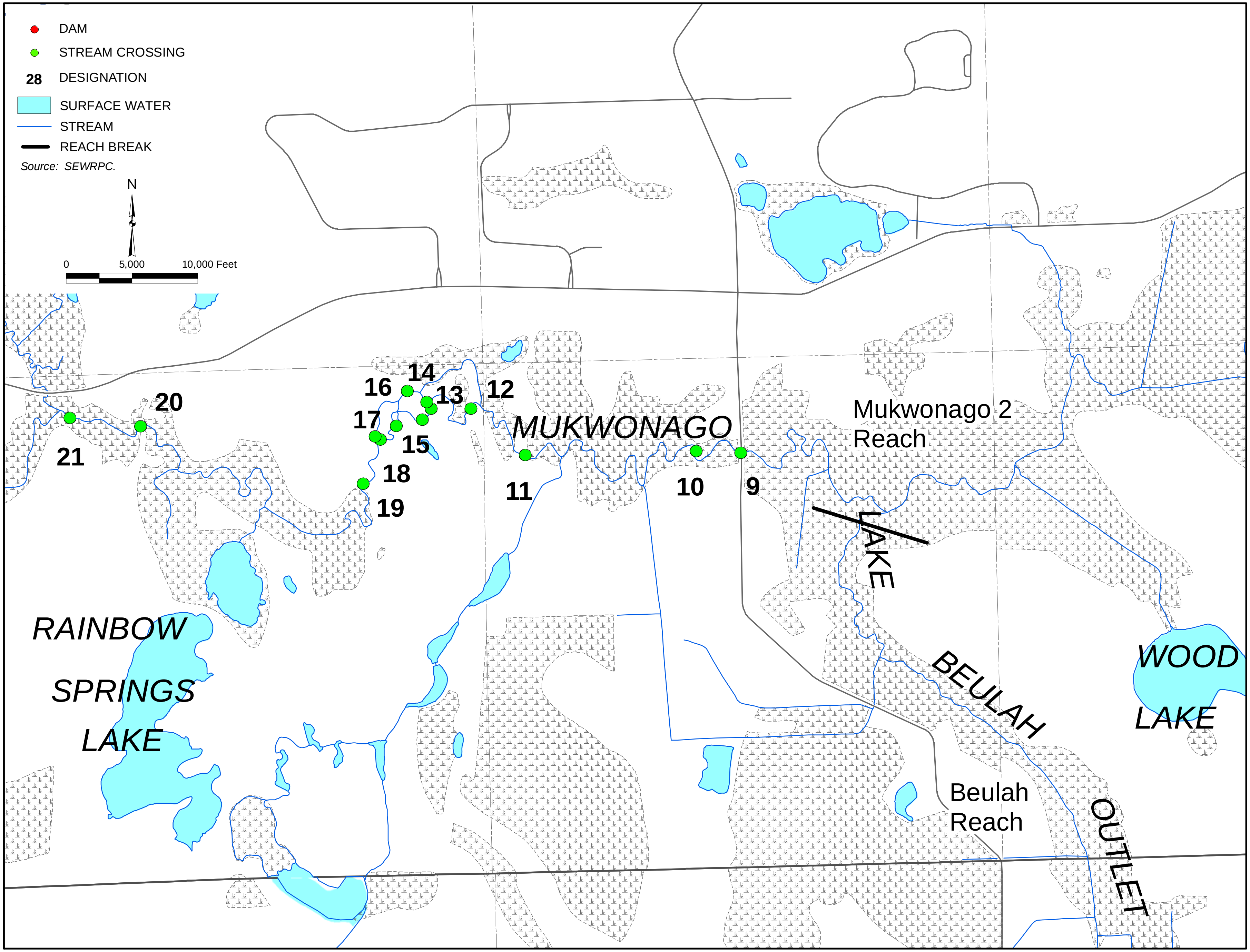


Figure 30

STREAM CROSSINGS AND DAM LOCATIONS IN THE MUKWONAGO RIVER WATERSHED: 2008

1- HOLZ PARKWAY (RM 1.12)

2- STH 83 (RM 2.09)

3- STH 83 WALKWAY (RM 2.11)

4- WISCONSIN CENTRAL LIMITED RAILROAD (RM 2.15)

5- PHANTOM LAKE DAM (RM 2.25)

6- PARK WALKWAY (RM 2.27)

7- CTH ES (RM 2.36)

9- BEULAH ROAD (RM 6.92)

10- PRIVATE BRIDGE (RM 7.06)

11- GOLF CART PATH (RM 7.70)

12- GOLF CART PATH (RM 7.90)

13- GOLF CART PATH (RM 8.08)

Figure 30 (continued)

14- GOLF CART PATH (RM 8.11)

15- GOLF CART PATH (RM 8.21)

16- GOLF CART PATH (RM 8.28)

17- GOLF CART PATH (RM 8.25)

18- GOLF CART PATH (RM 8.12)

19- GOLF CART PATH (RM 7.95)

20- GOLF CART PATH (RM 8.37)

21- RAINBOW SPRINGS ENTRANCE (RM 9.26)

22- PRIVATE DRIVE (RM 9.45)

23- CTH E (RM 10.61)

24- EAGLE SPRING LAKE DAM (RM 10.92)

25- FOOT BRIDGE (RM 13.40)

Figure 30 (continued)

26-NATURE ROAD (RM 13.99)

27- PRIVATE BRIDGE (RM 14.21)

28- BLUFF ROAD (RM15.15)

29- FOOT BRIDGE (RM 0.02)

30- FOOT BRIDGE (RM 0.04)

31- CTH LO (RM 0.27)

32- FOOT BRIDGE (RM 0.58)

33- FOOT BRIDGE (RM 1.86)

34- FOOT BRIDGE (RM 1.99)

35- CTH NN (RM 2.1)

36- FOOT BRIDGE (RM 2.29)

37- PRIVATE DAM (RM 2.31)

Figure 30 (continued)

38- FOOT BRIDGE (RM 2.52)

39- FOOT BRIDGE (RM 2.74)

40- FOOT BRIDGE (RM 3.33)

41- FOOT BRIDGE (RM 4.48)

42- FOOT BRIDGE (RM 4.74)

43- ROAD X (RM 5.36)

44- DAM/ACCESS ROAD (RM 5.63)

45- WISCONSIN AND SOUTHERN RAILROAD (RM 6.15)

46- STH 59 (RM 6.48)

47- FOOT BRIDGE (RM 1.33)

48- LAKE BEULAH DAM/CTH J (RM 1.37)

Source: SEWRPC.

Table 16

STRUCTURE DESCRIPTION, LOCATION, AND POTENTIAL FISH PASSAGE ASSESSMENT WITHIN THE MUKWONAGO RIVER WATERSHED: 2008

Structure Number on Map 24 and Figure 30	Description	Road Crossing	River Mile	Subwatershed	Condition	Potential Fisheries Passage Obstructions	
						Potential Restoration Candidate	Cause (extent) of Blockage
1	Concrete span bridge	Holz Parkway	1.12	Lower Mukwonago	OK	No	None
2	Concrete span bridge	STH 83	2.09	Lower Mukwonago	OK	No	None
3	Concrete/steel span bridge	STH 83 sidewalk	2.11	Lower Mukwonago	OK	No	None
4	Concrete/steel span bridge	Wisconsin Central Limited Railroad	2.15	Lower Mukwonago	OK	No	None
5	Concrete/steel dam	Phantom Lake dam	2.25	Lower Mukwonago	OK	- -	- -
6	Concrete span bridge	Park walkway	2.27	Phantom Subwatershed	OK	No	None
7	Concrete/steel span bridge	CTH ES	2.36	Phantom Subwatershed	OK	No	None
8	Concrete/steel span bridge	CTH I	4.45	Phantom Subwatershed	OK	No	None
9	Concrete/steel span bridge	Beulah Road	6.92	Phantom Subwatershed	OK	No	None
10	Wood plank bridge	Private bridge	7.06	Phantom Subwatershed	OK	No	None
11	One 72-inch-wide, 48-inch-high corrugated metal pipe arch culvert	Golf cart path	7.70	Phantom Subwatershed	6.5-foot deep scour hole downstream	Yes	Undersized, high velocities
12	One 68-inch-wide, 38-inch-high corrugated metal pipe arch culvert	Golf cart path	7.90	Phantom Subwatershed	10-foot deep scour hole downstream	Yes	Undersized, high velocities
13	One 72-inch-wide, 46-inch-high corrugated metal pipe arch culvert	Golf cart path	8.08	Phantom Subwatershed	3.5-foot deep scour hole upstream, six-foot deep scour hole downstream	Yes	Undersized, high velocities
14	One 68-inch-wide, 45-inch-high corrugated metal pipe arch culvert	Golf cart path	8.11	Phantom Subwatershed	4.5-foot deep scour hole upstream, six-foot scour hole downstream	Yes	Undersized, high velocities
15	One 68-inch-wide, 48-inch-high corrugated metal pipe arch culvert	Golf cart path	8.21	Phantom Subwatershed	5.5-foot deep scour hole downstream	Yes	Undersized, high velocities
16	One 68-inch-wide, 48-inch-high corrugated metal pipe arch culvert	Golf cart path	8.28	Phantom Subwatershed	Five-foot deep scour hole downstream	Yes	Undersized, high velocities
17	Wood plank bridge	Golf cart path	8.25	Phantom Subwatershed	Constricts channel	Yes	Undersized
18	One 36-inch-diameter corrugated metal culvert	Golf cart path	8.12	Phantom Subwatershed	>10-foot deep scour hole downstream	Yes	Undersized, high velocities
19	One 36-inch-diameter corrugated metal culvert	Golf cart path	7.95	Phantom Subwatershed	5.25-foot deep scour hole downstream	Yes	Undersized, high velocities
20	One 60-inch-wide, 46-inch-high corrugated metal pipe arch culvert	Golf cart path	8.37	Phantom Subwatershed	Four-foot deep scour hole upstream	Yes	Undersized, high velocities

Table 16 (continued)

Structure Number on Map 24 and Figure 30	Description	Road Crossing	River Mile	Subwatershed	Condition	Potential Fisheries Passage Obstructions	
						Potential Restoration Candidate	Cause (extent) of Blockage
21	Three 60-inch-diameter concrete culverts	Rainbow Springs Road	9.26	Phantom Subwatershed	OK	Yes	Wood jam, high velocities, split flow, limited depth
22	Concrete span bridge	Private drive	9.45	Phantom Subwatershed	OK	No	None
23	One 60-inch-wide, 55-inch-high; two 60-inch-wide, 56-inch-high corrugated metal pipe arch culverts	CTH E	10.61	Phantom Subwatershed	Failure of embankment Lannon stone failing	No	None
24	Concrete/steel dam	Eagle Spring Lake dam	10.92	Eagle Spring Subwatershed	OK	No	None
25	Wood plank bridge	Nature Conservancy footbridge	13.40	Eagle Spring Subwatershed	OK	No	None
26	Two 54-inch-wide, 38-inch-high corrugated metal pipe arch culverts	Nature Road	13.99	Eagle Spring Subwatershed	OK	No	None
27	Wood arch bridge	Private foot bridge	14.21	Eagle Spring Subwatershed	OK	No	None
28	One concrete pipe arch culvert (no measurements taken)	Bluff Road	15.15	Eagle Spring Subwatershed	OK	No	None
29	Wood plank bridge	Private foot bridge	0.02	Jericho Subwatershed	OK	Yes	Bridge deck is lower than bankfull depth
30	Wood plank bridge	Private foot bridge	0.04	Jericho Subwatershed	OK	No	None
31	Two 11-foot-wide, 66-inch-high concrete box culverts	CTH LO	0.27	Jericho Subwatershed	OK	No	None
32	Wood plank bridge	Private foot bridge	0.58	Jericho Subwatershed	OK	No	None
33	Concrete footbridge	Private foot bridge	1.86	Jericho Subwatershed	OK	No	None
34	Wood bridge	Private foot bridge	1.99	Jericho Subwatershed	Poor	No	None
35	Concrete/steel span bridge	CTH NN	2.10	Jericho Subwatershed	OK	No	None
36	Wood plank bridge	Private foot bridge	2.29	Jericho Subwatershed	Poor	No	None
37	Boulder dam	Private dam	2.31	Jericho Subwatershed	OK	No	None
38	Wood plank bridge	Private foot bridge	2.52	Jericho Subwatershed	OK	No	None
39	Wood plank bridge	Private foot bridge	2.74	Jericho Subwatershed	OK	No	None
40	Wood plank bridge	Private foot bridge	3.33	Jericho Subwatershed	OK	No	None
41	Wood plank bridge	Private foot bridge	4.48	Jericho Subwatershed	OK	No	None
42	Wood plank bridge	Private foot bridge	4.74	Jericho Subwatershed	Poor	No	None
43	Two 83-inch-wide, 52-inch-high corrugated metal pipe arch culverts	Road X	5.36	Jericho Subwatershed	Poor	No	Debris has largely blocked one culvert, but other culvert is unobstructed
44	Dam	Agricultural Access Road	5.63	Jericho Subwatershed	Poor	Yes	Total blockage – undersized old culvert; water goes under and around

Table 16 (continued)

Structure Number on Map 24 and Figure 30	Description	Road Crossing	River Mile	Subwatershed	Condition	Potential Fisheries Passage Obstructions	
						Potential Restoration Candidate	Cause (extent) of Blockage
45	One 48-inch-diameter steel culvert	Wisconsin and Southern Railroad	6.14	Jericho Subwatershed	OK	Yes	Low water depths, high velocities
46	One corrugated metal pipe arch culvert (no measurements taken)	STH 59	6.49	Jericho Subwatershed	OK	Yes	Undersized, with beaver dam both upstream and downstream
47	Wood plank bridge	Private foot bridge	1.33	Phantom Subwatershed	OK	No	None
48	Concrete dam	Lake Beulah dam/CTH J	1.38	Beulah Subwatershed	OK	No	None

Source: SEWRPC.

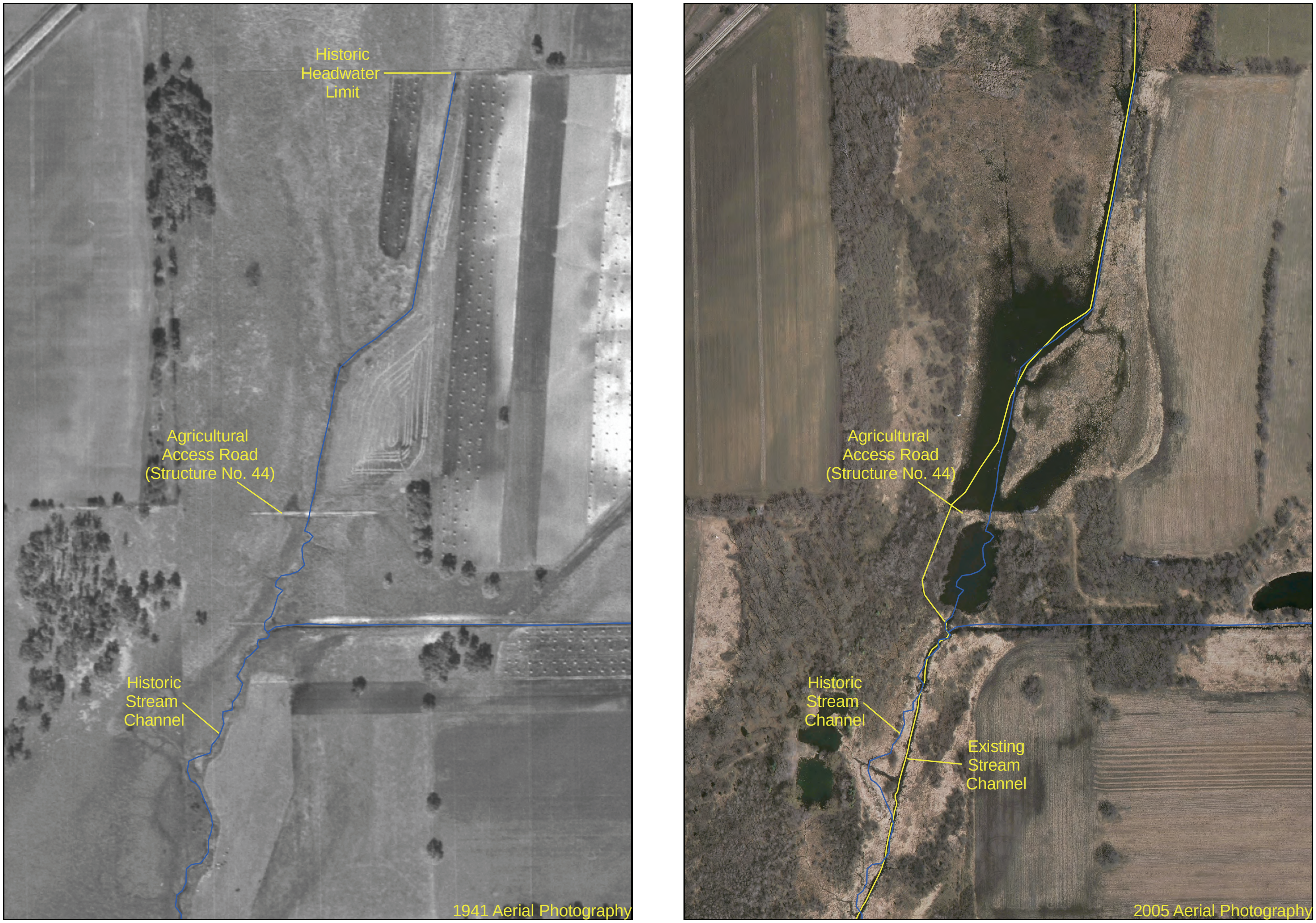
Jericho-2
Figure 28 shows the relationship between water depth, sediment depth, and dominant substrate changes that show major changes or shifts in one or more of these physical characteristics due to past stream channelization in the lower portion of this reach and the private dam in the upper portion of the reach. Road X also seems to be impounding water and causing increased sediment depths upstream of this structure. The channelized section of this reach has the greatest slope and exhibits qualitatively higher baseflow velocities and shallower depths and narrower widths than anywhere else within Jericho-2, which is why this section is also dominated by large boulder and cobble substrates. In contrast, the backwater effect of the private dam north of Road X is causing increased water depths and channel widths and a concurrent increase in sediment depths dominated by silts. This structure is an undersized culvert that is part of a dam and historical agricultural roadbed as shown in Figure 31, and water typically flows under and around this culvert. As shown in Figure 31, the dam created by the old roadbed is impounding several acres of water in the area between the Wisconsin and Southern Railroad and Road X. Historically, the Creek flowed through an impoundment on the south side of the roadbed shown in Figure 31. The Creek was rerouted when the roadbed was placed sometime between 1970 and 1980. It was observed during the field study that the southern impoundment is receiving water from the impoundment immediately upstream as seepage through the roadbed materials, in addition to groundwater input from springs. This is a good example of how the normal pattern of increasing stream width and depth from upstream to downstream can be interrupted or even reversed.

Jericho-1
As mentioned above, the CTH NN bridge is causing some significant upstream backwater, but this seems to be the only road crossing that is affecting normal low flow conditions in this reach. Average depths increase downstream of the CTH LO road crossing, but this is expected as it approaches the confluence with the Mukwonago River. Midway between road crossings CTH LO and CTH NN, there appears to be a grade change as shown in Figure 22 that seems to be associated with greater proportions of sand mixed with gravel, cobble, and boulder upstream compared to downstream areas that contain lesser amounts of sands as shown in Figure 27.

Beulah
As discussed above, approximately one-half of the upper portion of the Beulah reach has been channelized, which is associated with a change in substrates from sand in the upper channelized section to organic peat and silts in the downstream section (see Figure 26). This change in substrates is also associated with an increase in average water depths and widths in the downstream section compared to the upstream channelized section. This increase in width and depth associated with increased organics may also be a result of the backwater effects from the Mukwonago River up into the Beulah reach. As noted in Figure 26, there is an abandoned roadbed located at

Figure 31

AGRICULTURAL ACCESS ROAD AND DAM ON THE JERICHO 2 REACH



Source: SEWRPC.

transect 427 that is comprised exclusively of only gravel and cobble substrates. That is the only location were these large substrates, which form the only riffle habitat, were found within this reach. This cross section seems to be a distinct break between average water depths of less than two feet dominated by sand substrates upstream versus average water depths greater than two feet and a mixture of sand and organic substrates downstream.

Mukwonago-3

The physical width, depth, and substrate conditions within the Mukwonago-3 reach are largely determined by the backwater effects of both Eagle Spring and Lulu Lakes and by road crossings at The Nature Conservancy (TNC) bridge and Nature Road. The surface water elevation profile shown in Figure 22 indicates that the Wambold dam at the Eagle Spring Lake outlet affects the elevations of Lulu Lake and that effect extends approximately 1,650 feet upstream of Lulu Lake to the TNC bridge. The TNC bridge is located on a historical railroad bed upon which significant amounts of gravel and rock have been placed to create a foundation for the railroad. The streambed adjacent to and underneath the TNC bridge contains a significant amount of gravel and cobble substrates of the same sizes and types as observed within the fill in the railroad berms at this location. This historical fill material has established a unique riffle habitat comprised of a mixture of gravel and cobble substrates, which is the only riffle habitat found within this reach. This riffle was the only location where muck sediments were not observed and it is the shallowest of all the cross sections surveyed as shown in Figure 25. The TNC bridge riffle is a high point on the streambed that causes a backwater effect up to the Nature Road culvert approximately 2,900 linear feet upstream. The Nature Road culvert is also causing an upstream backwater effect based upon a significant increase in stream width upstream of this structure. These control points are likely to be the main cause for the observed decreasing stream width from upstream to downstream, which is opposite of what would be expected to occur. The sediment depth distribution also indicates the significant backwater effect of Lulu Lake, with the deepest sediments being located closer to Lulu Lake (see Figure 25).

Mukwonago-2

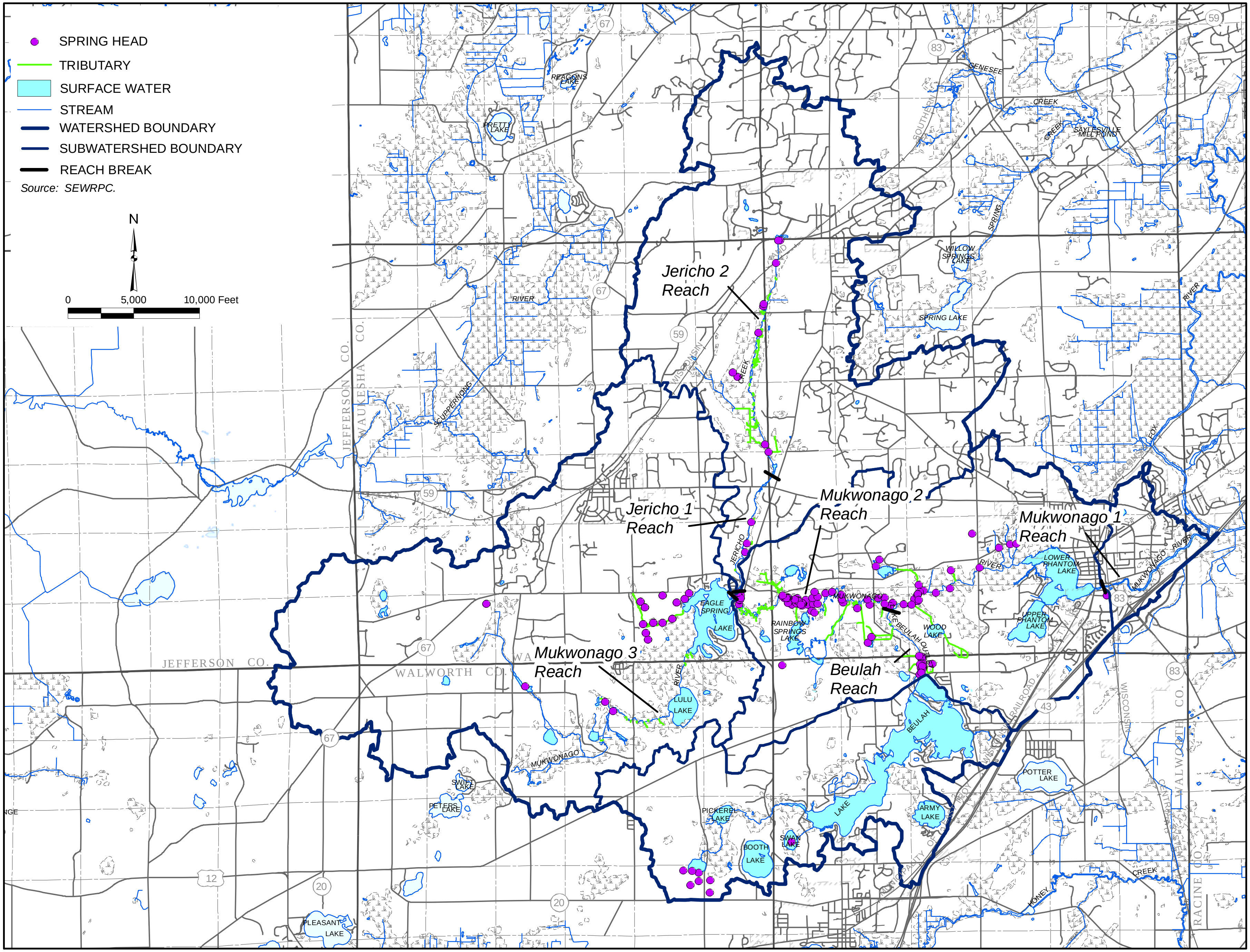
The physical width, depth, and substrate conditions within the Mukwonago-2 reach are largely influenced by the road crossings at CTH E, Beulah Road, and the series of culverts within the Rainbow Springs Golf Course. The crossing at CTH E appears to be creating a backwater effect upstream of this structure with increased water depths and deposition of silts (see Figure 24). This area also contains a high proportion of larger gravel substrates, which is consistent with the high proportion of spring discharge both in the stream and adjacent riparian areas (see the Groundwater section below and Map 25). In contrast, the division of flow in the multiple Mukwonago River channels within the Rainbow Springs Golf Course is causing a significant decrease in overall stream water depths as shown in Figure 24 due to the split flow. Some of the culverts are also contributing to localized deposition upstream and localized scour downstream (see Inset 2 on Map 23 and Inset 2 on Map 24). The Beulah Road crossing is associated with the highest proportion of gravel substrates in the entire reach as shown in Figure 24 and a significant change in gradient as shown in the stream profile in Figure 22. This increase in gravel substrates also is associated with an increase in groundwater seeps and springs as shown on Map 25. The deepest portion of the entire Mukwonago River, which extends for about 2.5 miles downstream to CTH I, is located downstream of Beulah Road. The Mukwonago River reach downstream of the confluence with the Beulah outlet is characterized by organic peat and silt substrates, and it also contains the deepest pools in the entire watershed.

Mukwonago-1

The increase in discharge in 2008 was particularly significant in the Mukwonago-1 reach, which flows into the Fox River. The Fox River also experienced elevated streamflows in 2008, and there was a significant backwater effect on the Mukwonago-1 reach that extended up to the Holz Parkway bridge as shown in Figure 23. This is also consistent with the observations of changes in the dominant sediments from gravels primarily upstream of this bridge and sands dominating downstream. This is also consistent with the elevation profile as shown in Figure 22, which shows that during normal flow conditions there is less than a two-foot difference in elevation from upstream of the bridge to the confluence with the Fox River. As can be seen in Figure 23, average water depths were greater than 2.0 feet and maximum water depths exceeded 2.5 feet downstream of this structure. This is also consistent with the Federal Emergency Management Agency flood insurance study for Waukesha County which indicates that the backwater effect from the Fox River extends up to Holz Parkway for low (less than 10-percent-

Map 25

SPRINGS DISCHARGING TO THE MUKWONAGO RIVER: 2009



annual-probability, or a 10-year recurrence interval) and high (one-percent-annual-probability, or a 100-year recurrence interval) flood events.[18] This implies that the sands are transported downstream and deposited in these backwater areas as water velocities are reduced during higher flow periods in this downstream section of the Mukwonago-1 reach, ultimately changing the proportions of sands within this area.

Hydrology/ Groundwater/Precipitation

Streamflow/Baseflow/Precipitation Interactions

The Mukwonago River provides the major inflow into Eagle Spring Lake, entering the Lake from the south where it discharges from Lulu Lake. Lulu Lake is situated immediately upstream of Eagle Spring Lake and is accessible from Eagle Spring Lake by a navigable channel. Hilary Erin Gittings in her Master of Science Thesis, submitted to the University of Wisconsin-Madison in 2005, quantified the average base flow at the TNC bridge upstream of Lulu Lake as 3.5 cfs based upon measurements obtained from September 2002 through September 2004.[19] During low flow periods, the spring complex above Nature Road contributed about 70 percent of the total volume of water flow into Lulu Lake. In a parallel investigation, Karin Marie Hollister, in her Master of Science Thesis entitled, "Hydrologic Modeling of the Upper Mukwonago River: An Investigation of the Effects of Urban Development and an Evaluation of Mitigation Schemes, Southeastern Wisconsin," submitted to the University of Wisconsin-Madison in May 2006, documented water level fluctuations within Eagle Spring Lake from June 2001 through June 2003.[20] The standard deviation of the range in elevation was documented to be plus or minus one inch around a mean stage of 820.69 feet above National Geodetic Vertical Datum, 1929 Adjustment (NGVD29).

The Eagle Spring Lake outflow is controlled by two outlet structures—a dam with a manually operated control gate (Wambold dam) and a former mill race (locally known as the Kroll dam)—both located at the east side of Eagle Spring Lake just west of CTH E. The confluence of Jericho Creek and the Mukwonago River is located about 350 feet downstream of the Wambold dam structure. The southernmost lake outlet from the former mill race joins the Mukwonago River about 500 feet downstream of the dam structure. Todd Shoemaker in his Master of Science Thesis demonstrated that the discharge from the Kroll dam was fairly constant at about 3.5 cfs during 2001, over a range of precipitation events.[21] This represents only a small fraction of the Wambold dam flow. Shoemaker also determined the long-term average baseflow in the Mukwonago River entering Eagle Spring Lake to be 14.3 cfs, with 9.6 cfs (about 70 percent) arising from groundwater sources. In addition, Shoemaker showed that, in 2001, Eagle Spring Lake and Lulu Lake essentially operated as one hydrological unit with water levels at elevations of 820.60 and 820.68 feet above NGVD29, respectively. The difference in elevation between the lakes decreases with increasing discharges at the Wambold dam, indicating that the Wambold dam influences water levels in both Lakes. This is consistent with the surface water elevation profile developed by SEWRPC staff from the 2005 Waukesha County DTM data (see Figure 22).

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[18]*Federal Emergency Management Agency National Flood Insurance Program, Waukesha County and Incorporated Areas, Flood Insurance Study Number 55133CV003A, effective date November 19, 2008.*

[19]*Hilary Erin Gittings, "Hydrogeologic Controls on Springs in the Mukwonago River Watershed, SE Wisconsin," Master of Science Thesis, University of Wisconsin-Madison, 2005.*

[20]*Karin Marie Hollister, "Hydrologic Modeling of the Upper Mukwonago River: An Investigation of the Effects of Urban Development and an Evaluation of Mitigation Schemes, Southeastern Wisconsin," Master of Science Thesis, University of Wisconsin-Madison, May 2006.*

[21]*Todd Shoemaker, "Evaluation of the Hydrology and Hydraulics of Eagle Spring Lake, Eagle, Wisconsin," Master of Science Thesis, Department of Civil and Environmental Engineering, University of Wisconsin-Madison, May 2002.*

Hilary Erin Gittings also indicated that flow in the Mukwonago River system is dependent upon groundwater discharges from multiple aquifers, including the surficial shallow sand and gravel aquifer and the shallow bedrock aquifer. Of the groundwater contributed to the spring complex upstream of Lulu Lake, about 15 to 100 percent was discharged through "boils" from a bedrock source (see Figure 32), entering the springs through preferential flow paths within the fractured bedrock; the sand and gravel aquifer was estimated to contribute from 0 to 20 percent to this flow, between the spring complex and the TNC foot bridge—total groundwater inputs during any given year could equal up to 100 percent of the inflow to Lulu Lake, with the ratio of shallow bedrock aquifer to surficial shallow sand and gravel aquifer flows varying as a function of rainfall, runoff, and degree of aquifer recharge experienced during a specific year. A similar relationship was reported for the Lake Beulah area which also received a small contribution of groundwater from the deep aquifer. Gittings further reported high levels of chloride in water samples obtained from the open water and shallow groundwater sites upstream of Lulu Lake. This is consistent with findings reported by the Eagle Spring Lake Management District's August 2008 report entitled "Mukwonago River-Watershed Nutrient Study: August 2004-October 2008."

SEWRPC staff measured low flow discharge for several sites on Jericho Creek on November 2, 2007, using a Sontek Flow Tracker (Serial Number P1202, CPU Firmware Version 3.0, Software Version 2.20). Low flow discharge increased from 1.5 cfs just downstream STH 59 to about 4.0 cfs at Road X. Total discharge equals about seven cfs at the downstream end of Jericho Creek before its confluence with the Mukwonago River. It is important to note that Jericho Creek contributes about one-third of the total low flow discharge to the Mukwonago River, with the remaining two-thirds coming from Eagle Spring Lake. This low flow discharge is similar to the range in discharges within both Rosenow Creek (located in Waukesha County) and Allenton Creek (located in Washington County), where known populations of naturally reproducing brook trout are sustained, indicating that these flows are adequate to support a coldwater brook trout fishery in Jericho Creek.

Downstream of its confluence with Jericho Creek, the Mukwonago River continues easterly, passing through Lower Phantom Lake and ultimately discharging into the Fox River in Waukesha County, about 8.5 miles downstream from Eagle Spring Lake. The Mukwonago River more than doubles its normal flow between the outlet of Eagle Spring Lake and the outlet of the Phantom Lakes. This is due to flow from numerous springs and seeps distributed throughout this section of River as shown on Map 25. In addition, the Beulah outlet discharges into the Mukwonago River prior to the River entering Lower Phantom Lake. The Beulah outlet was found to have a summer average discharge of 20.2 cfs in 2007 and 29.3 cfs in 2008 based upon data from a recent study.[22] This indicates that discharge from Lake Beulah is roughly equivalent to the discharge from Eagle Spring Lake.

Groundwater inflows within the Eagle Spring Lake and Lulu Lake basins have a direct affect on the thermal structure of the Lakes and are discussed further in the Water Quality section below. In addition, groundwater monitoring of four surface springs within Upper Phantom Lake from March 2005 to January 2007 indicates that these individual springs discharge on average between 0.5 and 2.0 gallons per minute as shown in Figure 33. Increases in discharge within these surface springs since the year 2005 indicate they are responding to increased precipitation since 2005 as documented in Chapter II of this report.

U.S. Geological Survey continuous recording stream flow gauge No. 05544200 on the Mukwonago River at STH 83 has a period of record from 1973 to 2009. The 15th and 85th discharge percentiles at that location range from about 25 to 88 cfs. The median discharge is 48 cfs and the mean discharge is 56.5 cfs. The highest recorded discharge for the period of record was 340 cfs on June 13, 2008. The years with greater discharges are consistent with the wetter years summarized in Chapter II of this report, which indicates consistency between the weather station in Waukesha and discharge within the Mukwonago River. Daily total precipitation was also recorded at the STH 83 gauge since 1998 and at Eagle Spring Lake since 2007. The precipitation recorded at these two

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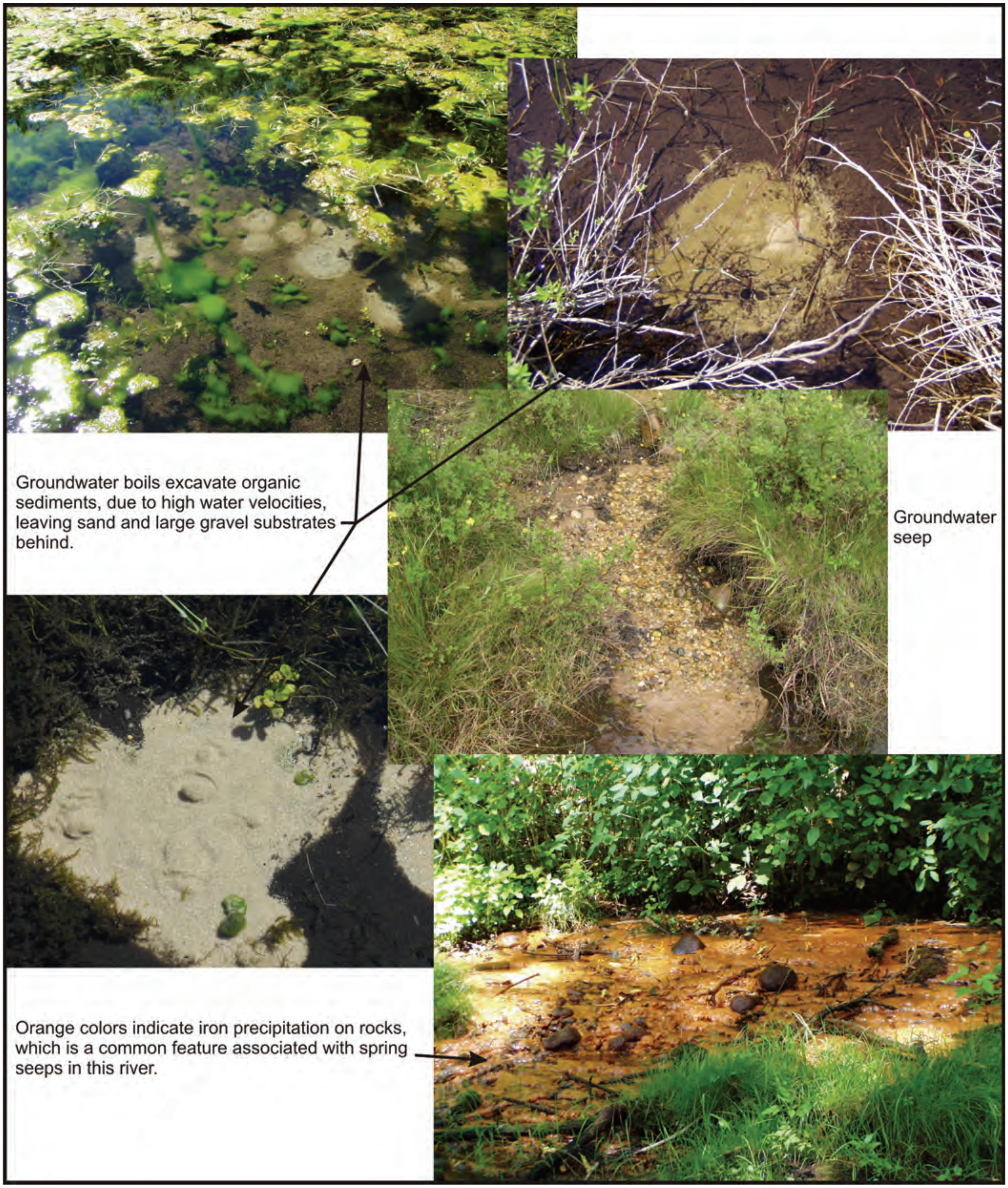
[22] *RJN Environmental Services, LLC,* Lake Beulah Management Plan, *April 1, 2010.*

Figure 32

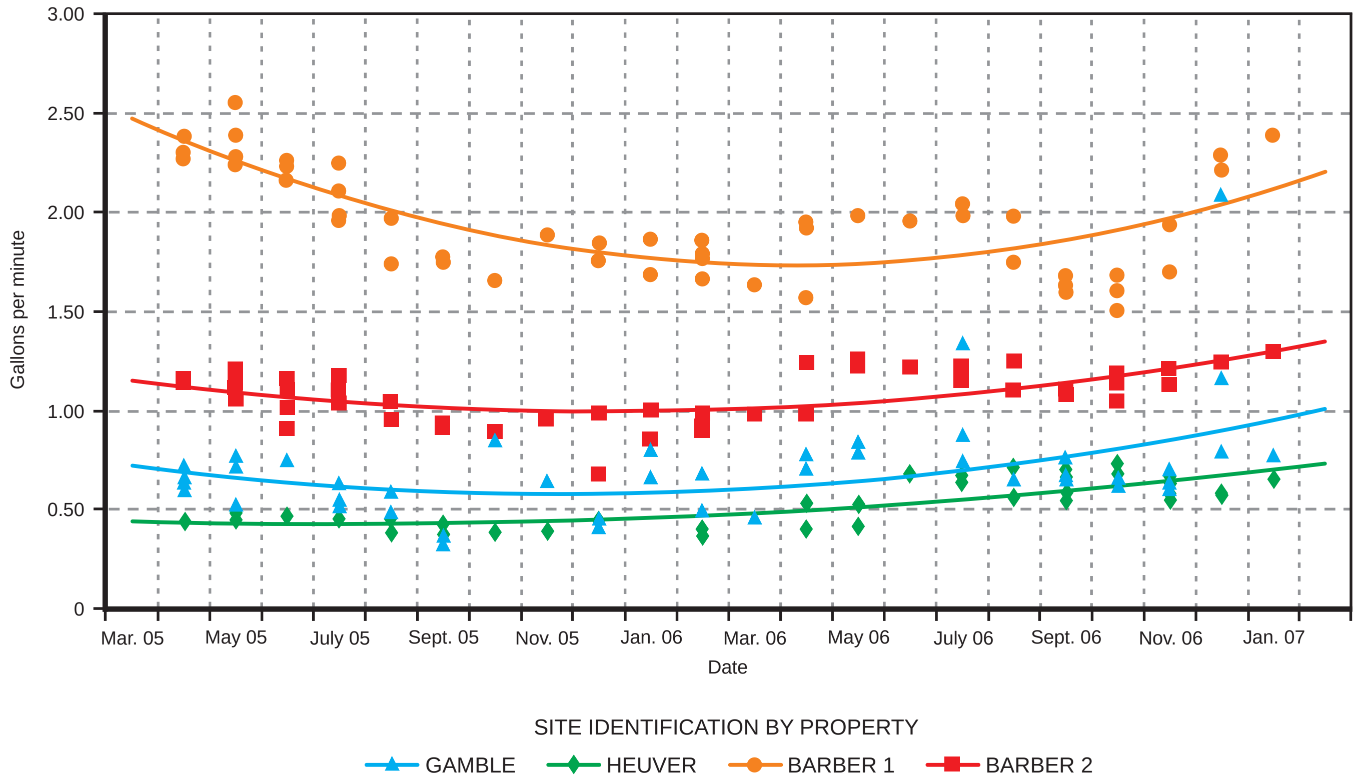
TYPICAL GROUNDWATER DISCHARGE IN THE FORM OF SEEPS AND SPRING BOILS WITHIN THE MUKWONAGO RIVER WATERSHED: 2008



Source: SEWRPC.

Figure 33

FLOW RATE ESTIMATES FOR FOUR SPRINGS WITHIN UPPER PHANTOM LAKE: 2005-2007



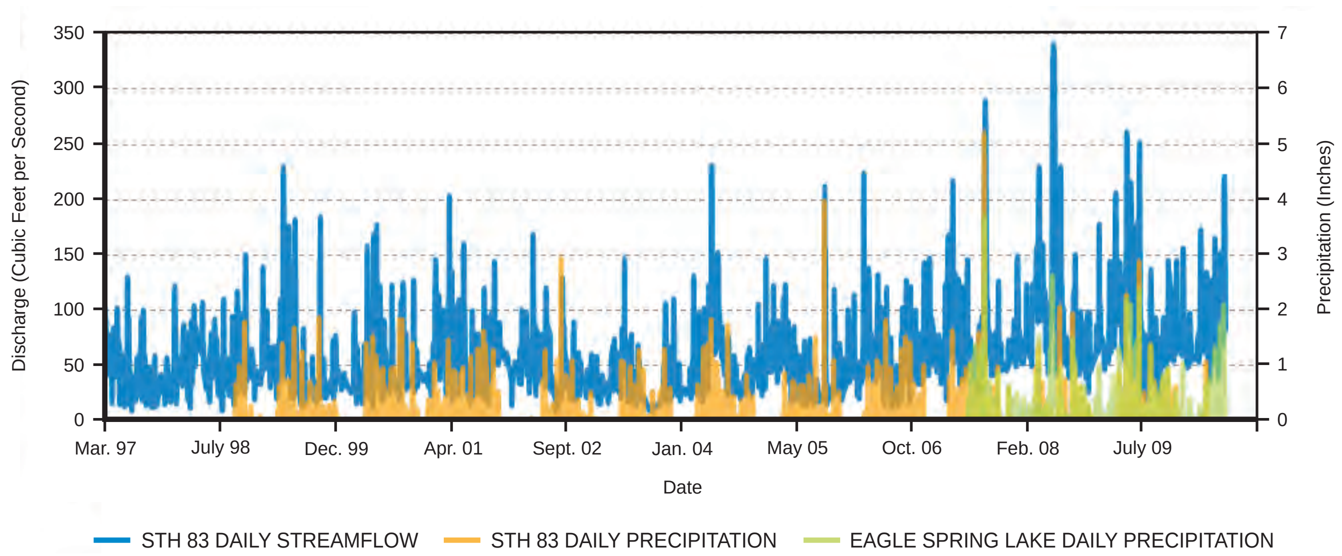
Source: Pete Kumlein, volunteer monitor and former Phantom Lakes Management District Commissioner, and SEWRPC.

locations compared with the flow on the Mukwonago River shows that they are closely associated as shown in Figure 34. When precipitation increases, streamflow increases, with the highest daily flows occurring on the highest daily precipitation days for both precipitation stations. This means that the system is responding as expected, which is not surprising, but it shows good relationship between the discharge and precipitation gauges within this system, which is important in understanding long term trends in separate data sets. For example, although local precipitation data are not available prior to 1998, given the good relationship between the datasets between 1998 and 2009, it can be concluded that precipitation was also likely to have been a strong determinant of changes in the flow recorded back to the year 1973.

One notable pattern in the 36-year hydrological record indicates that since 2006 there has been an increase in overall precipitation on the Mukwonago River as shown in Figure 35. That is reflected in average discharges of 73.9 cfs in 2007, 93.5 cfs in 2008, and 88.7 cfs in 2009, which are 31 percent, 65 percent, and 57 percent, respectively, greater than the normal average annual discharge at the USGS gauge. The year 2008 was particularly significant in that the average seasonal streamflow was also exceeded for all four seasons, which is unusual. It is not out of the ordinary to have one or two seasons with higher than normal streamflow within the same year, but it is uncommon to have higher than average flow in all four seasons. The average seasonal streamflows throughout the period of record are 52.4 cfs in the winter, 73.3 cfs in the spring, 50.2 cfs in the summer, and 50.3 cfs in the fall. The year 2008 seasonal streamflows were 72.9 cfs in the winter, 108.9 cfs in the spring, 123.3 cfs in the summer, and 68.3 cfs in the fall. Since SEWRPC field inventories were conducted in the summer of 2008, it is important to keep in mind that the average summer streamflow for 2008 was about 2.5 times the normal summer average. These elevated flows were the result of larger-than-normal annual total precipitation during these same years. It is unknown if this higher than normal average annual total precipitation and resultant discharges will continue, but they have helped to ensure more than adequate discharges for fishes on this system.

Figure 34

DAILY DISCHARGE AND PRECIPITATION WITHIN THE MUKWONAGO RIVER WATERSHED: 1997-2009



NOTE: Time periods where no rainfall is shown for long periods of time indicate missing data.

Source: U.S. Geological Survey and SEWRPC.

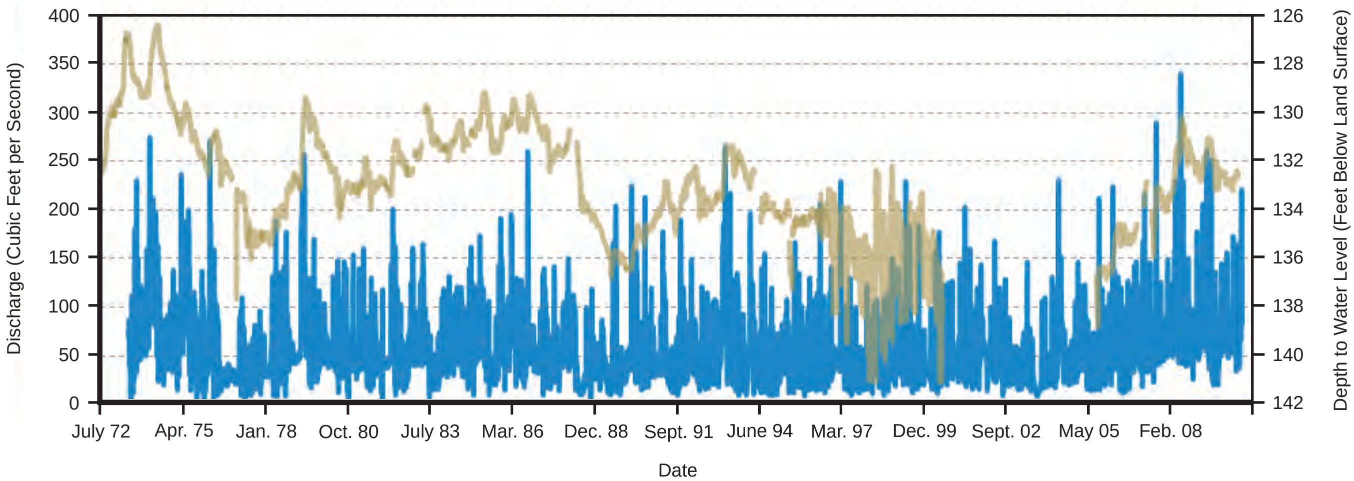
At the opposite end of the streamflow scale, as mentioned above, during 15 percent of the period of record the streamflow in the Mukwonago River was less than 25 cfs. It is not known exactly how much discharge is necessary to sustain the high quality fishery within the Mukwonago River, but assuming, based on the judgment of SEWRPC staff, that flows at and below one-half of the normal average annual discharge would potentially be limiting for sustaining a high quality fishery in this system. Low flows in summer are particularly important, due to higher average and maximum daily temperatures compared to the other seasons. Figure 36 shows the total number of days among spring, summer, and fall for which the daily streamflow was less than 25 cfs. This demonstrates that these low flow time periods vary greatly from season to season within the same year as well as from year to year. However, the greatest number of days with average flows less than 25 cfs most often occurs in the summer season, compared to the spring or fall, throughout this period of record. For example, during the summer of 1988, which was one of the worst droughts on record, there were 83 days with average daily streamflows less than 25 cfs, or nearly the entire summer. Although recent streamflow has been more than adequate within the Mukwonago River, if historical data are used to indicate future streamflow, then Figure 36 indicates that discharge can be limiting, which is an important consideration for the protection of the fishery and associated aquatic life. Therefore, efforts to protect and maintain adequate normal and low flows within the Mukwonago River should be a high priority. Such efforts would include maintaining groundwater recharge to the degree possible.

Figure 35 shows that increasing and decreasing trends in streamflow within the Mukwonago River generally follow increasing and decreasing groundwater recharge trends in the components of the shallow aquifer as indicated by the groundwater levels in the two monitoring wells located in Waukesha County. These two wells are located outside of the Mukwonago River watershed, but are considered representative of shallow groundwater aquifer variations that are likely to also be occurring within the Mukwonago River watershed. The Silurian-Devonian dolomite aquifer is located below the sand and gravel aquifer, but the peaks and valleys in groundwater elevation in both wells, which provide an indication of the amounts of groundwater recharge, generally coincide with the peaks (high) and valleys (low) in streamflow on the Mukwonago River. This is evidence that in addition to precipitation, the streamflow in the Mukwonago River is also dependent upon groundwater inflow to the River.

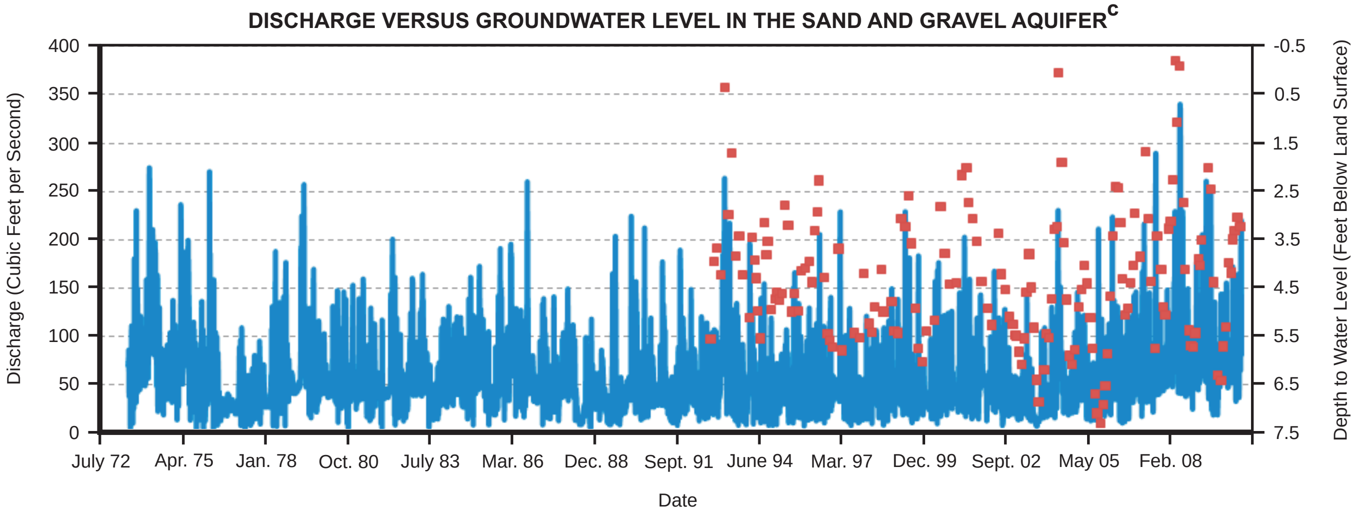
Figure 35

MUKWONAGO RIVER DAILY DISCHARGE AT THE USGS GAUGE AT STH 83 COMPARED WITH GROUNDWATER RECORDS IN TWO COMPONENTS OF THE SHALLOW AQUIFER IN WAUKESHA COUNTY, WISCONSIN: 1973-2009[a]

DISCHARGE VERSUS GROUNDWATER LEVEL IN THE SILURIAN-DEVONIAN DOLOMITE AQUIFER[b]



DISCHARGE VERSUS GROUNDWATER LEVEL IN THE SAND AND GRAVEL AQUIFER[c]



[a]*Note that these wells are located outside of the Mukwonago River watershed.*

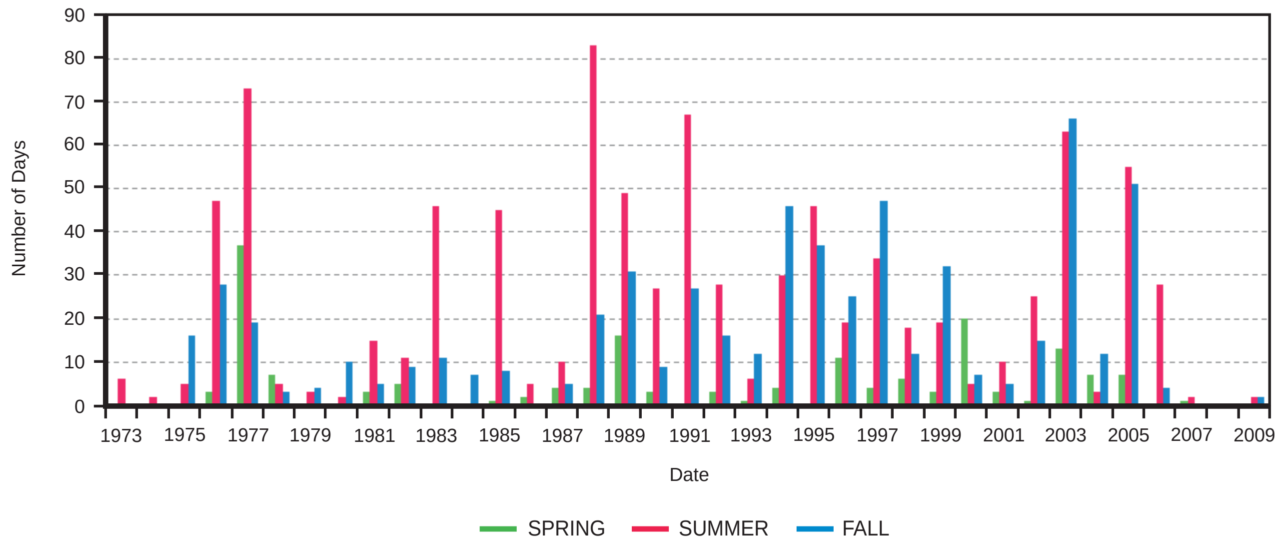
[b]*USGS monitoring well WK05/19E/31-1301 is located about five miles south of the City of Waukesha, Wisconsin. The land surface datum is 962 feet above National Geodetic Vertical Datum of 1929 at the top of the well casing, which is 1.0 foot above the land surface. The period of record is from 1947 to 2009 and measurements are taken hourly.*

[c]*USGS monitoring well WK06/19E/02-0031 is located about five miles southwest of the City of Waukesha, Wisconsin. These water level records in feet are referenced to National Geodetic Vertical Datum of 1929. The period of record is from November 1992 to January 2009 and measurements are taken quarterly. Readings above the land surface are indicated by negative values.*

Source: U.S. Geological Survey and SEWRPC.

Figure 36

NUMBER OF DAYS DAILY DISCHARGE WAS LESS THAN 25 CUBIC FEET PER SECOND AMONG SEASONS IN THE MUKWONAGO RIVER AT THE USGS GAUGE AT STH 83: 1973-2009



Source: U.S. Geological Survey and SEWRPC.

Troy Bedrock Valley Groundwater Model

The Troy Bedrock Valley, which trends through southern Milwaukee and Waukesha Counties and across Walworth County, contains up to 500 feet of glacial deposits in its deepest parts (see Figure 37). The bedrock is close to the ground surface in locations along the sides of the Valley. Several tributary bedrock valleys project outward from the Troy Bedrock Valley. Many of the smaller tributary valleys are poorly mapped and some may be currently unknown.

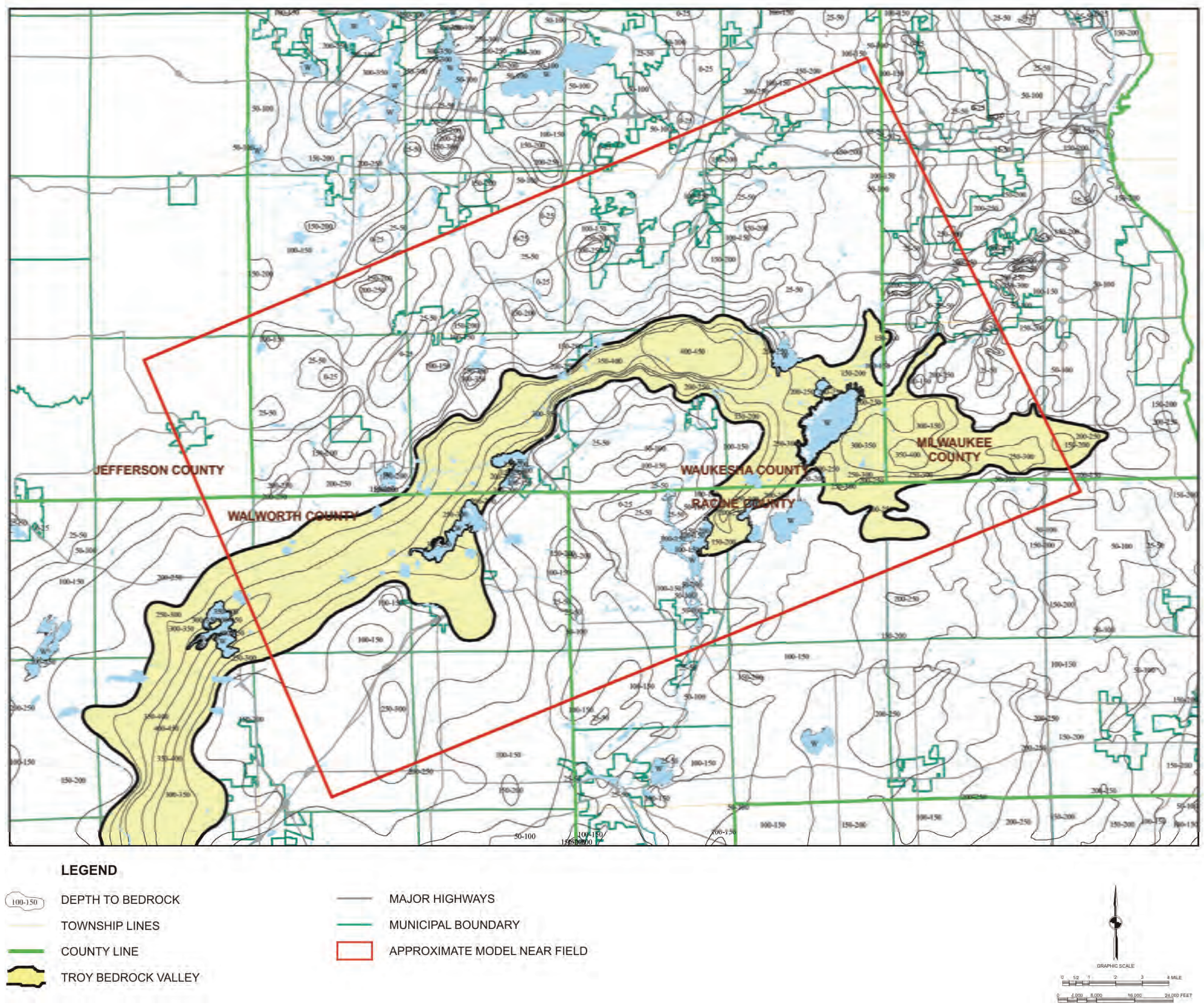
The glacial deposits within the Valley vary from dense clay to coarse sand and gravel. Many of the sand and gravel deposits are saturated and permeable and can serve as prolific shallow aquifers that can support high-capacity wells.

The Troy Bedrock Valley also contains ecologically and economically significant surface water features including streams, lakes, springs, and wetlands. Existing pumping and potential increases in pumping from the aquifers has created significant concern over the potential impact of groundwater withdrawals on these surface water features. It is difficult to quantify the impact that a well or group of wells will have on the flow system in a complex aquifer system.

SEWRPC Memorandum Report No. 188, *Troy Bedrock Valley Aquifer Model Waukesha and Walworth Counties, Wisconsin*, November 2009, prepared by Ruekert & Mielke, Inc., for the Southeastern Wisconsin Regional Planning Commission, documents a groundwater model that can be used as a management tool to assess the potential impacts of proposed new high-capacity wells in the Troy Bedrock Valley using consistent methods

Figure 37

LOCATION OF TROY BEDROCK VALLEY



Source: Ruekert & Mielke, Inc.

without duplication of effort.[23] The groundwater model is intended for use by communities, lake management districts, environmental groups, and concerned citizens. The model provides a peer reviewed common platform to simulate the impact of new high-capacity wells in the Valley. The model is suitable for simulating the effect of pumping from new and existing wells and is intended to provide reasonable predictions of the potential impacts on the major surface waterbodies of proposed well locations. The model is intended to be as complete a representation of the aquifer as is reasonably possible, but it cannot accurately account for all of the complexity present in nature. Refinements in the model design may be necessary to improve the performance in specific local applications. The model is based upon a regional model developed by SEWRPC and as such, is known as an inset model. It can also serve as a parent model for more detailed inset models created to explore more specific local proposals.

Lake Beulah Issues Related to Village of East Troy Municipal Well No. 7

Village of East Troy municipal well No. 7, which is located in the Troy Bedrock Valley near the southwestern shore of Lake Beulah, northeast of the intersection of Stringers Bridge Road and St. Peters Road, is constructed in the shallow aquifer. The well has been online and pumping, part time, since August of 2008. Concerns regarding the effect of the well on Lake Beulah and the Mukwonago River have been raised by the Lake Beulah Management District and the Lake Beulah Protective and Improvement Association. The determination of the effects of the well is an important issue that is being studied by consultants for both the Lake Management District and the Village.

Summary

In summary, the Mukwonago River streamflow is highly dependent upon groundwater discharge. Hence, it is also dependent upon recharge of the local shallow aquifer that ultimately discharges into the River. Therefore, management efforts to protect and maintain groundwater recharge will help protect and sustain discharge in the Mukwonago River and its associated high quality aquatic community.

Instream Habitat Quantity, Quality, and Diversity

The overall distribution of instream habitat types as characterized by pools (deep water and slower water velocities), riffles (shallow water, large substrates, and higher water velocities), and runs (intermediate depth and water velocities) are shown on Maps 26 through 28. Pool, riffle, and run habitat units are the fundamental instream features upon which the entire QHEI is based to determine overall habitat quality within the Mukwonago River watershed. The quality of habitat scores within the QHEI is predicated upon the presence and distribution of these discrete habitat types and their associated cover types such as woody debris, undercut banks, boulders and other substrates, submergent and emergent macrophyte vegetation, and overhanging riparian vegetation. As shown in Table 14 and Maps 26 and 27 the diversity of the pool and riffle structure (i.e., number of pools compared to the number of riffles) is very poor in the Mukwonago-3 and Beulah reaches. In fact, there was only one riffle found in each of these reaches, which was the result of a historic railway in the Mukwonago-3 reach and a roadbed in the Beulah reach. Thus, riffle habitat availability is limited within these reaches. In contrast, the pool and riffle distribution is more balanced in the remaining reaches of the watershed. However, riffle habitats within the Mukwonago-2 reach are not found beyond a few hundred feet downstream of Beulah Road as shown on Map 26. This approximately 2.5-mile-long stream reach is dominated by organic peat and silt substrates and deep pool and run habitats. Since riffle habitats are important spawning and feeding areas for many native fish species, the numbers and distribution of riffle habitats can affect fish species distribution. For example, the distribution of observed spawning areas within the Mukwonago River system were highly associated with the location and distribution of riffle habitats and these areas were also associated with the greatest diversity of fishes compared to reaches such as the Mukwonago-3 and Beulah reaches that do not contain riffle habitats.

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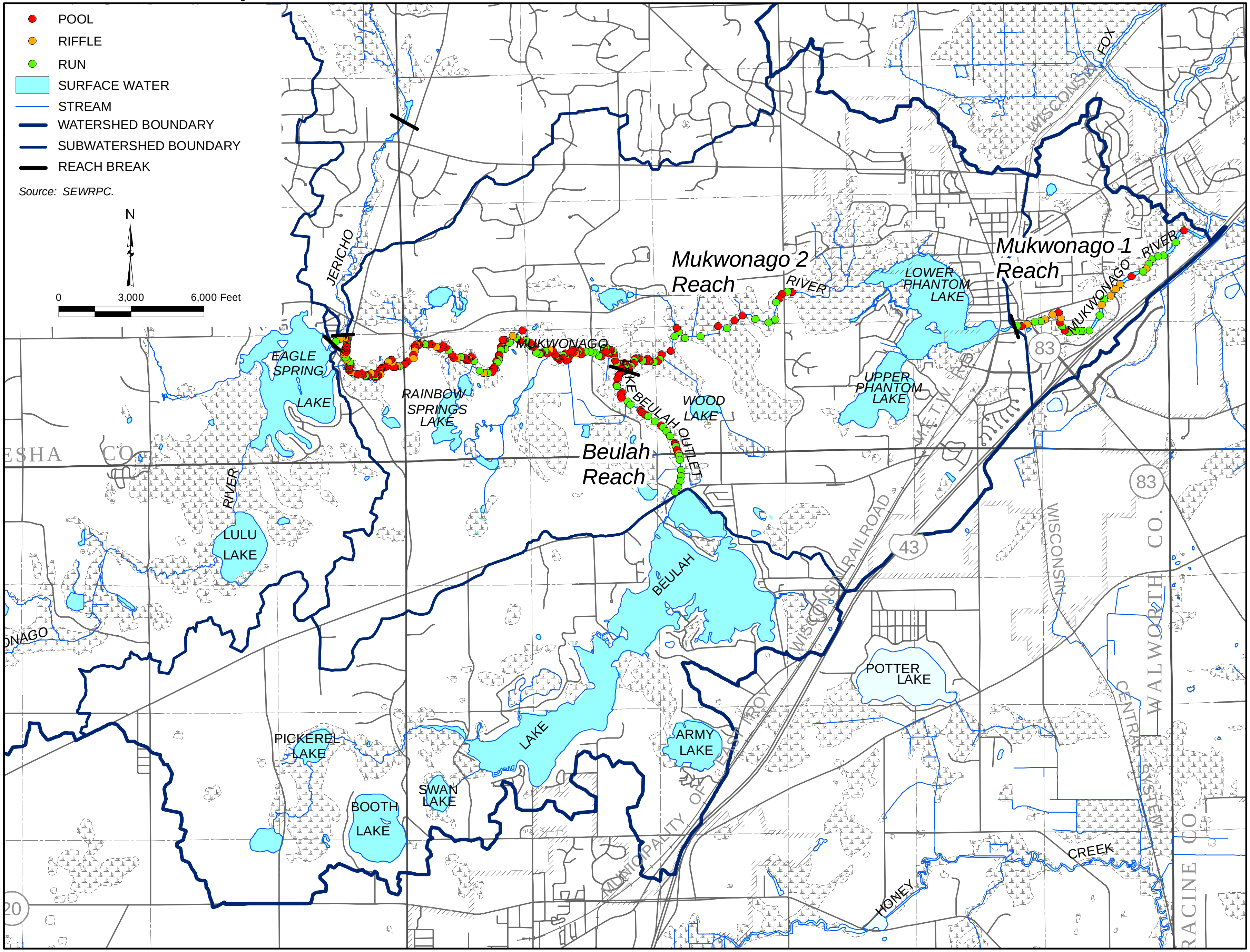
[23]*This effort was funded by a consortium of four entities, the City of Muskego, the Village of East Troy, the Village of Mukwonago, and the Waukesha Water Utility. The Southeastern Wisconsin Regional Planning Commission served as the project manager. The Wisconsin Geological and Natural History Survey provided peer review.*

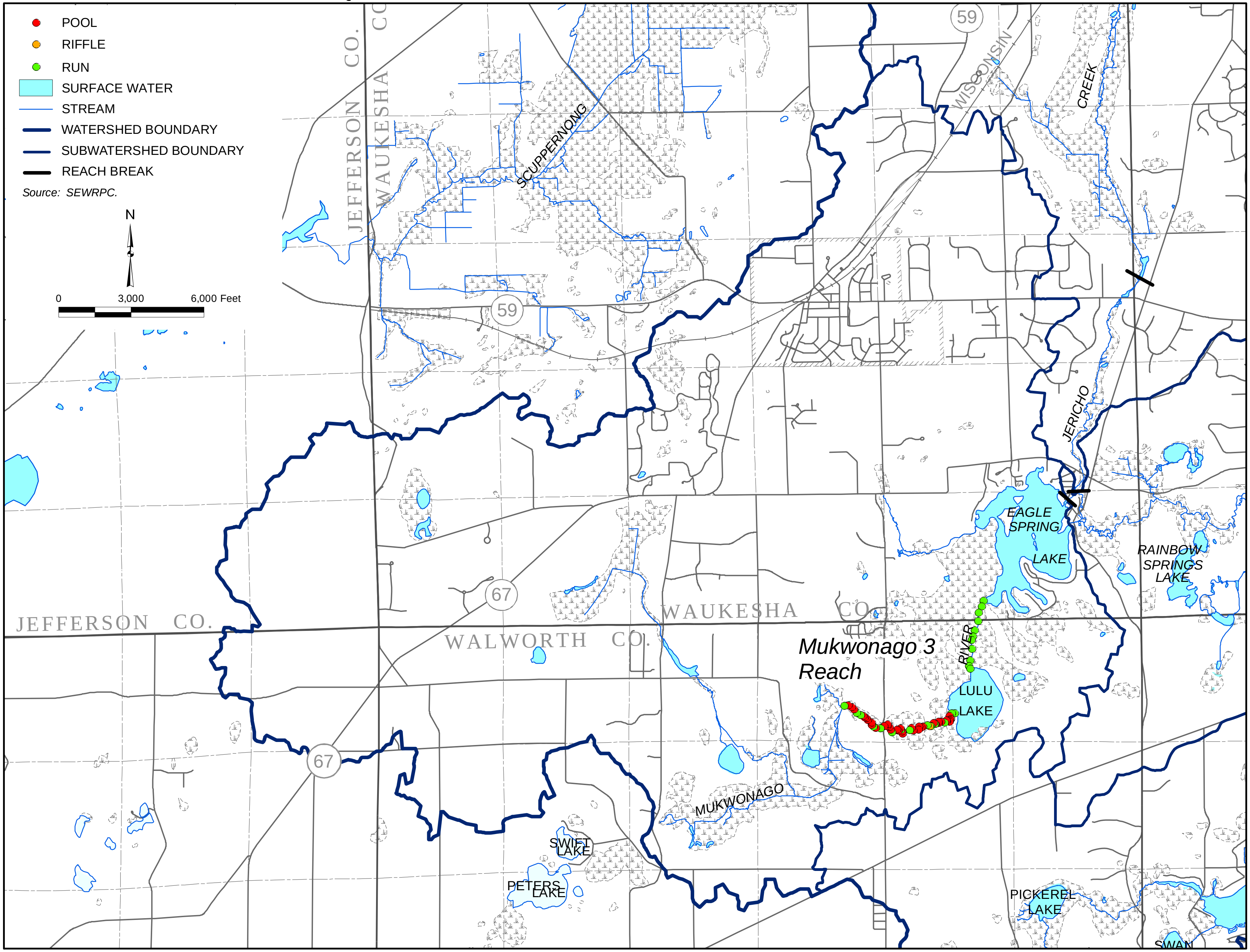
Map 26

AQUATIC HABITAT TYPE WITHIN THE BEULAH, MUKWONAGO, AND PHANTOM SUBWATERSHEDS



Map 27

AQUATIC HABITAT TYPE WITHIN THE EAGLE SPRING SUBWATERSHED



Map 28

AQUATIC HABITAT TYPE WITHIN THE JERICHO SUBWATERSHED

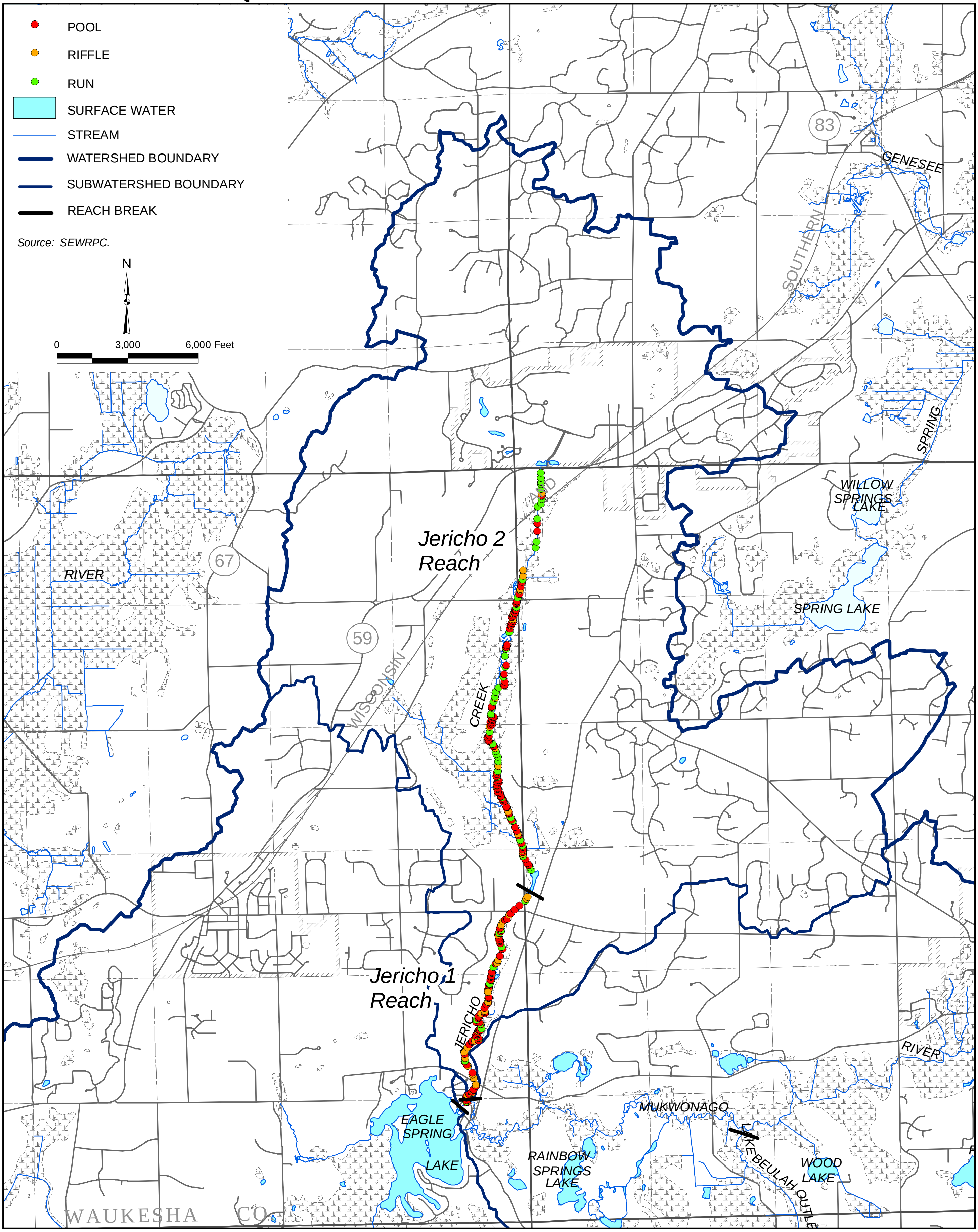
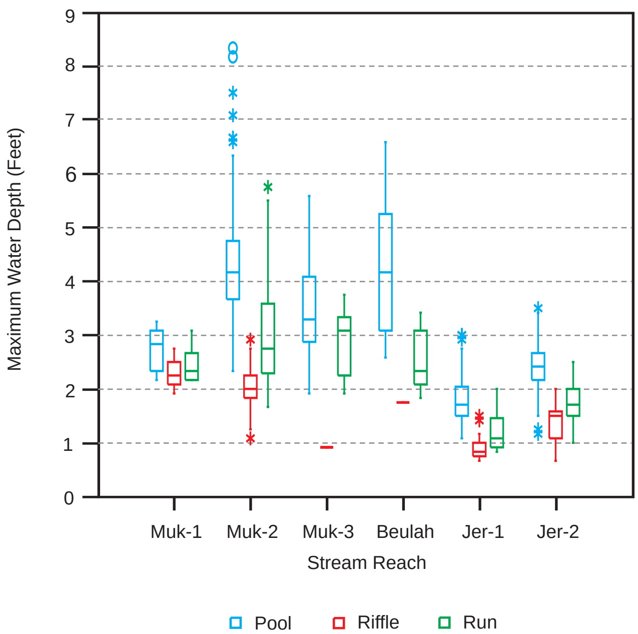


Figure 38

MAXIMUM WATER DEPTH AMONG HABITAT TYPE AND REACHES IN THE MUKWONAGO RIVER WATERSHED: 2008



NOTE: See Figure 29 for description of symbols. For the Mukwonago River and Jericho Creek, the reach numbers decrease from upstream to downstream.

Source: SEWRPC.

The maximum depth of pool, riffle, and run habitats also change from headwater areas to the confluence of the Fox River as shown on Figure 38. These differences 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 distinct hydrologic reaches, which, in effect, can result in significant differences in species composition within each of the reaches. The upstream reaches naturally contain a lower abundance and diversity of fishes compared to the downstream reaches, because these reaches contain less water volume. However, it is also important to note that these upstream areas are vital for the sustained quality and productivity of the entire fishery within the Mukwonago River watershed.

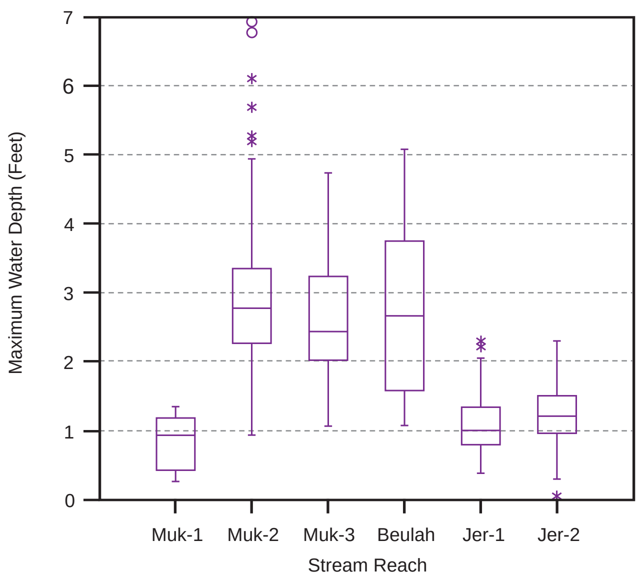
Pool habitats are the opposite of riffle habitats, but they are also vital components of fish habitat in streams, especially for larger fish, because their greater depth offers protection from predators, provides feeding areas, and provides refuge from high temperatures in the summer and cold temperatures in the winter. As shown in Figure 38, pool habitats are deepest within the Beulah, Mukwonago-2, and Mukwonago-3 reaches, with more than 75 percent of the pools in these areas greater than three feet. The remaining three reaches contain pool depths that in general are much less than three feet in depth. Pools are often monitored to follow the effects of enhancement projects and natural stream processes, but variations of water depth with discharge can complicate assessment of changes in the depth and volume of pools. To subtract the effect of discharge on depth of pools, residual depth can be measured. Residual depth is the difference in water depth or bed elevation between a pool and the downstream water depth or bed elevation of the riffle crest (upstream edge of the riffle).[24] This residual dimension represents extreme low flow conditions, which often determine the capacity of streams to produce fish, especially during summer months when water temperatures are highest.

Residual pool depth was calculated for the streams in the watershed by subtracting the average water depths of all riffles within a reach from the maximum pool depth recorded within each individual pool. As shown in Figure 39, residual pool depths were highest within the Beulah, Mukwonago-2, and Mukwonago-3 reaches with more than 50 percent of the residual pool depths greater than 2.5 feet and approximately 25 percent greater than 3.5 feet. Most surprising, is that the Mukwonago-2 reach contains the deepest residual pool depths within the entire watershed (exceeding five feet), which is very deep given the size of this watershed. It is also important to note

[24]*Thomas E. Lisle, Using "residual depths" to monitor pool depths independently of discharge, Research Note PSW-394, Berkeley California, Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, December 1987.*

Figure 39

RESIDUAL POOL DEPTH AMONG REACHES IN THE MUKWONAGO RIVER WATERSHED: 2008



NOTE: See Figure 29 for description of symbols. For the Mukwonago River and Jericho Creek, the reach numbers decrease from upstream to downstream.

Source: SEWRPC.

that the Beulah reach and Mukwonago-2 reach are connected, so fish communities have access to these deepwater areas in low flow conditions as well as access to Lower and Upper Phantom Lakes, which adds another level of protection. Similarly, the Mukwonago-3 reach is connected with the Lulu-Eagle Spring Lake complex that provides important protection in extreme low flow times.

In contrast, the Mukwonago-1 reach contains the lowest residual pool depths compared to all other areas inventoried within the watershed (see Figure 39). This indicates that this section of stream would in general not contain depths greater than one foot under low flow conditions. These low residual depths are surprising given that this area also contains the widest stream widths in the entire river system. As discussed above, these relatively low depth and high width conditions are probably the result of a combination of the highly resistant glacial tills within the streambed that prevent scour of the streambed upstream of the Holz Parkway, the backwater effects from the Fox River resulting in decreased velocities and decreased ability to scour the streambed downstream of the Holz Parkway, and this reach having the largest streamflows in the watershed. Since the streambanks contain soils that are more erodible than the streambed, the widths have become much greater in this reach than all other reaches within the system. These low residual depths seem to indicate that this reach of stream is more vulnerable to low flow extremes than the other reaches. However, this reach has contained, and continues to contain, the most diverse fishery and mussel community in the watershed. It has been theorized that this diversity and abundance of fishes is promoted or maintained by the low water depths which reduces predation on the small-bodied fishes in this reach, because these low water depths prevent and/or discourage large fishes from taking residence in these areas. In addition, the streamflows within this system are dominated by groundwater, which has consistently maintained discharges of about 50 to 100 cfs for nearly 30 years. This reach also has the added benefit of being connected with the Fox River, which provides a potential avenue of protection if water levels get too low or stream temperatures get too high within the Mukwonago-1 reach. This connection also promotes maintenance of fish species abundance and diversity by providing access to many miles of additional habitats and large populations of diverse fish species to reproduce in and/or recolonize the Mukwonago-1 reach as well as to provide genetic diversity.

The residual pool depths in the Jericho Creek reaches generally range from 0.5 to 2.0 feet in depth, with median depths between 1.0 and 1.25 feet as shown in Figure 39. These relatively shallow residual depths may be one of the reasons why Jericho Creek does not contain a high abundance of brook trout. Although both reaches within Jericho Creek contain pool depths greater than 2.5 feet, in extreme low flow time periods the majority of pools within these reaches may not be adequate for the maintenance of brook trout. For example, the lack of pool depths greater than three feet has in general been found to be a limiting factor for brook trout survival, particularly during low flow conditions in late summer and throughout the winter.[25] Although pool depths recorded within these

[25]*R.F. Raleigh, Habitat Suitability Index Models: Brook Trout, United States Fish and Wildlife Service Biological Report 83 (10.24), Fort Collins Colorado, 1982. (*http://www.nwrc.usgs.gov/wdb/pub/hsi/hsi-024.pdf*)*

reaches of Jericho Creek seem adequate, it is important to note that these measurements were taken during a high streamflow year as summarized below. Therefore, these pool depths probably represent unusually deep depths under summer conditions. Adequate pool depth is critical for maintaining trout populations; however, it should be noted that Jericho Creek may not have the potential to achieve desired pool depths due to highly armored streambeds of glacial till parent materials. In addition, the dominance of relatively large cobble substrates may be limiting brook trout reproduction. Brook trout spawn in riffle habitats with substrates that optimally range from 3-50 millimeters (0.1-2.0 inches) in size. There are riffles within Jericho Creek that contain substrates with the optimal sizes for brook trout spawning, but the vast majority of riffles within this system is dominated by larger gravel and cobble substrates ranging from two to six inches in diameter. Since brook trout need to excavate beds to deposit and bury their eggs within the riffles, these large substrates may be limiting successful reproduction, due to the inability of these fishes to move these large substrates. Despite these potential limitations to maintaining brook trout within Jericho Creek, SEWRPC staff consistently found large adult brook trout throughout this Creek, which indicates that this system contains a high potential for brook trout enhancement. This system also contains high amounts of habitat for juvenile brook trout in terms of water velocities, widths, depths, and cover. This also indicates that this system has adequate potential to support increased juvenile abundance, if brook trout reproduction were increased in this system.

In addition to water width and depth, which are major determinants of pool, riffle, and run habitat quality scores as discussed above, the QHEI scores can be further enhanced by the presence of one or more of the following features: 1) fallen trees or wood branches (woody debris), 2) undercut banks, 3) boulders and other substrates, 4) submergent and emergent macrophyte vegetation, and 5) overhanging riparian vegetation, as shown in Figure 40. In general, less than 10 percent of the inventoried stream length among reaches in the watershed had no cover or very limited cover, 4 to 38 percent had low abundance of cover, and 50 to nearly 90 percent had moderate to high abundance of cover types as shown in Table 14.

Boulders are considered to be one of the highest quality substrates in terms of providing good cover for fishes. However, all substrate types and their composition are important and contribute to overall habitat quality. Table 14 shows that there is a high diversity of substrates among reaches within the Mukwonago River watershed from smaller organic silt and peat to sand and gravel to larger cobbles and boulders. The Jericho-2 reach even contains limestone bedrock, which was only observed in the headwaters between STH 59 and Road X where the stream channel was constructed (see Channelization section above). Boulders were only observed within the downstream reaches of the Mukwonago River and Jericho Creek, with the highest proportion (16 percent) being within the Jericho-1 reach. Cobble substrates were observed in all reaches, but the highest percentages were found within the Jericho Creek reaches. Sand was the most dominant substrate throughout the Mukwonago River system, except for the Mukwonago-3 reach that was dominated by peat substrates and it came within 10 percent of the most dominant cobble substrates within the Jericho-1 reach. Silt substrates comprised about 20 percent of the Mukwonago-2, Beulah, and Jericho-2 reaches as shown in Table 14. Silts were predominantly located in the downstream sections of Mukwonago-2 and Beulah as shown on Figures 24 and 26, respectively. In contrast, silts were predominantly located in the middle and upper sections of the Jericho-2 reach as shown on Figure 28. Peat was most dominant in the Mukwonago-3 reach compared to all other areas within the watershed, but it was also a significant component of the substrate composition within the Mukwonago-2, Beulah, and Jericho-2 reaches. Not surprisingly, average and maximum depths of flocculent sediment, which were loose sediments that SEWRPC staff could easily push a survey rod through, were closely associated with the presence of organic silt and peat substrates as shown in Table 14 and on Figures 23 through 28. Organic substrates are easily erodible, which is why the deepest areas within the Mukwonago River are comprised mostly of organic sediments.

The type and amounts of riparian vegetation are significant drivers of the types and amounts of instream cover which include woody debris, undercut banks, shading, algae, and macrophytes. For example, woody debris abundance and distribution within the Mukwonago River system is highly associated with the location of riparian woodlands (see Maps 29 through 31). Instream large and small woody debris is an important component of stream ecosystems that provides essential food and habitat for aquatic organisms. Woody debris can affect

Figure 40

EXAMPLES OF INSTREAM COVER WITHIN THE MUKWONAGO RIVER WATERSHED: 2008

Source: SEWRPC.

channel morphology and form pools; retain organic matter, gravel, and sediment; influence invertebrate abundance; and provide cover and velocity refuge for fish.[26] The highest percentages of woody debris were found within the Mukwonago-2 and Jericho Creek reaches, which contain the largest amounts of forested lands adjacent to the stream. Woody debris can sometimes excessively accumulate in some areas, causing debris jams particularly at road crossings, which was observed at Structure 21 at Rainbow Springs Road (see Table 16). Debris jams can function like a dam and may cause significant disruption in the stream sediment dynamics and can lead to localized flooding and bank stability problems. Debris jams, particularly at road crossings, may inhibit fish movement to feeding and spawning areas, thereby decreasing reproduction success (see Stream Crossings and Dams section below).

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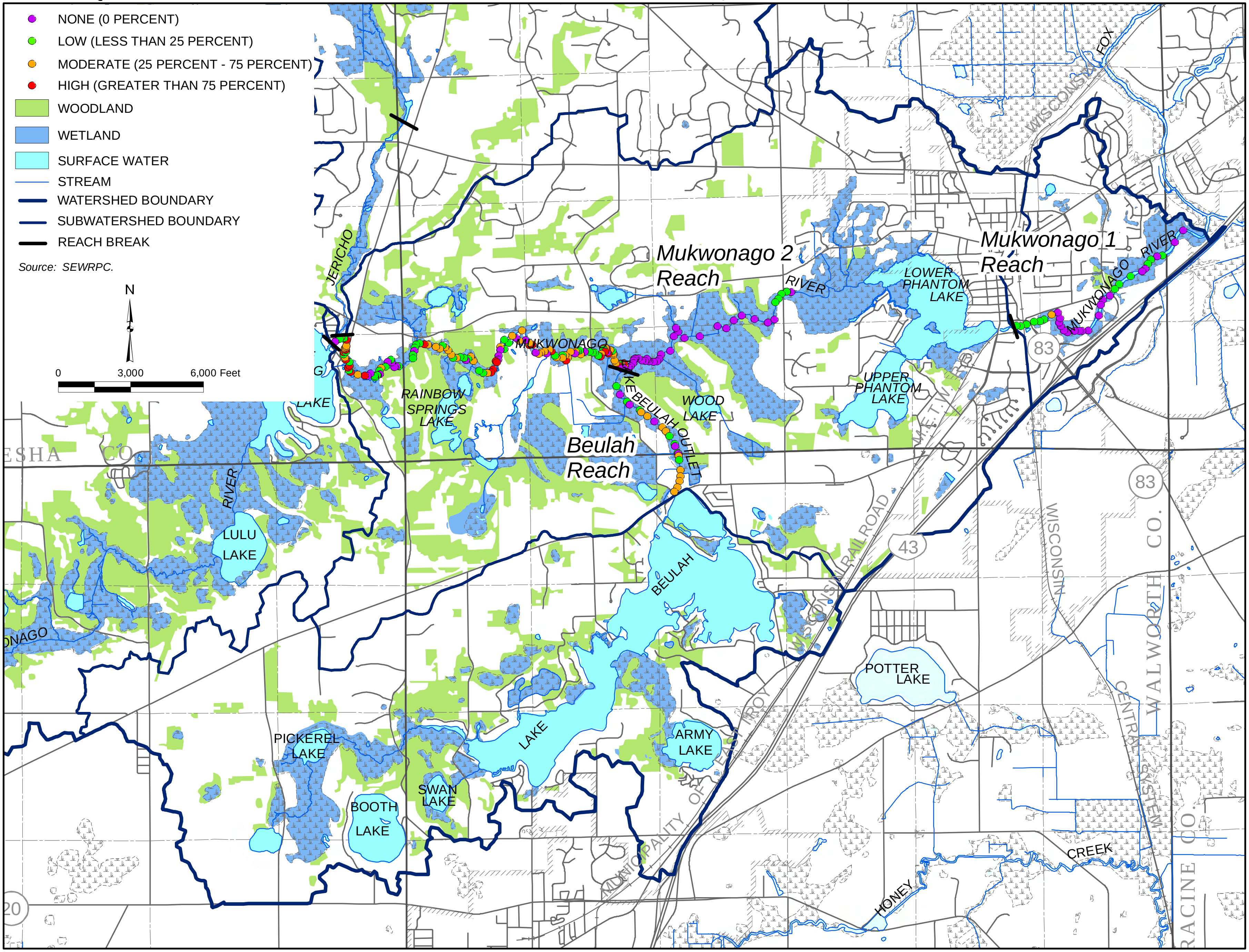
[26]*B. Mossop and M.J. Bradford, Importance of large woody debris for juvenile Chinook salmon habitat in small boreal forest streams in the upper Yukon River basin, Canada,* Canadian Journal of Forestry Resources, *Vol. 35, 2004, pages 1955-1966.*

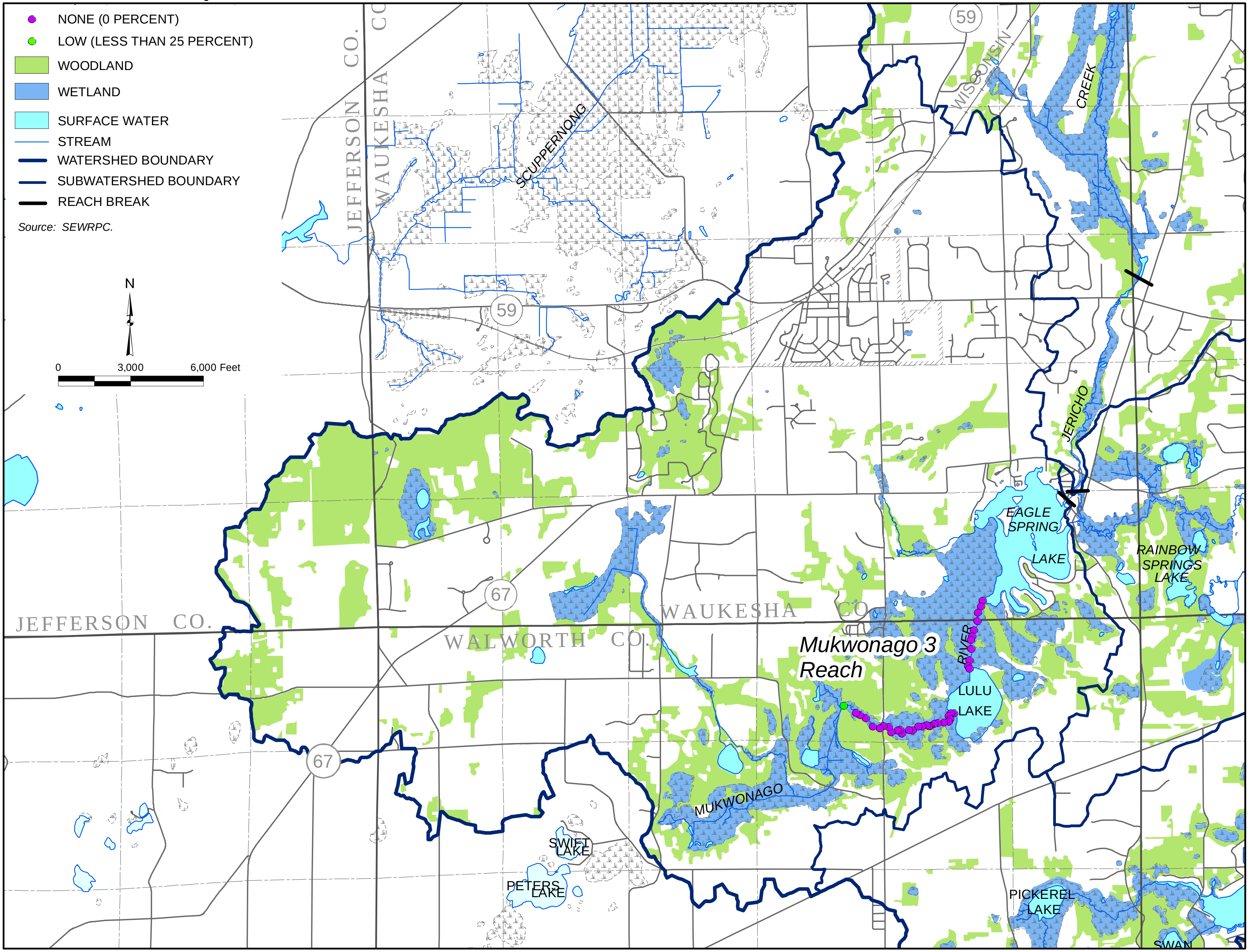
Map 29

QUALITATIVE DISTRIBUTION OF WOODY DEBRIS COVER WITHIN THE BEULAH, MUKWONAGO, AND PHANTOM SUBWATERSHEDS



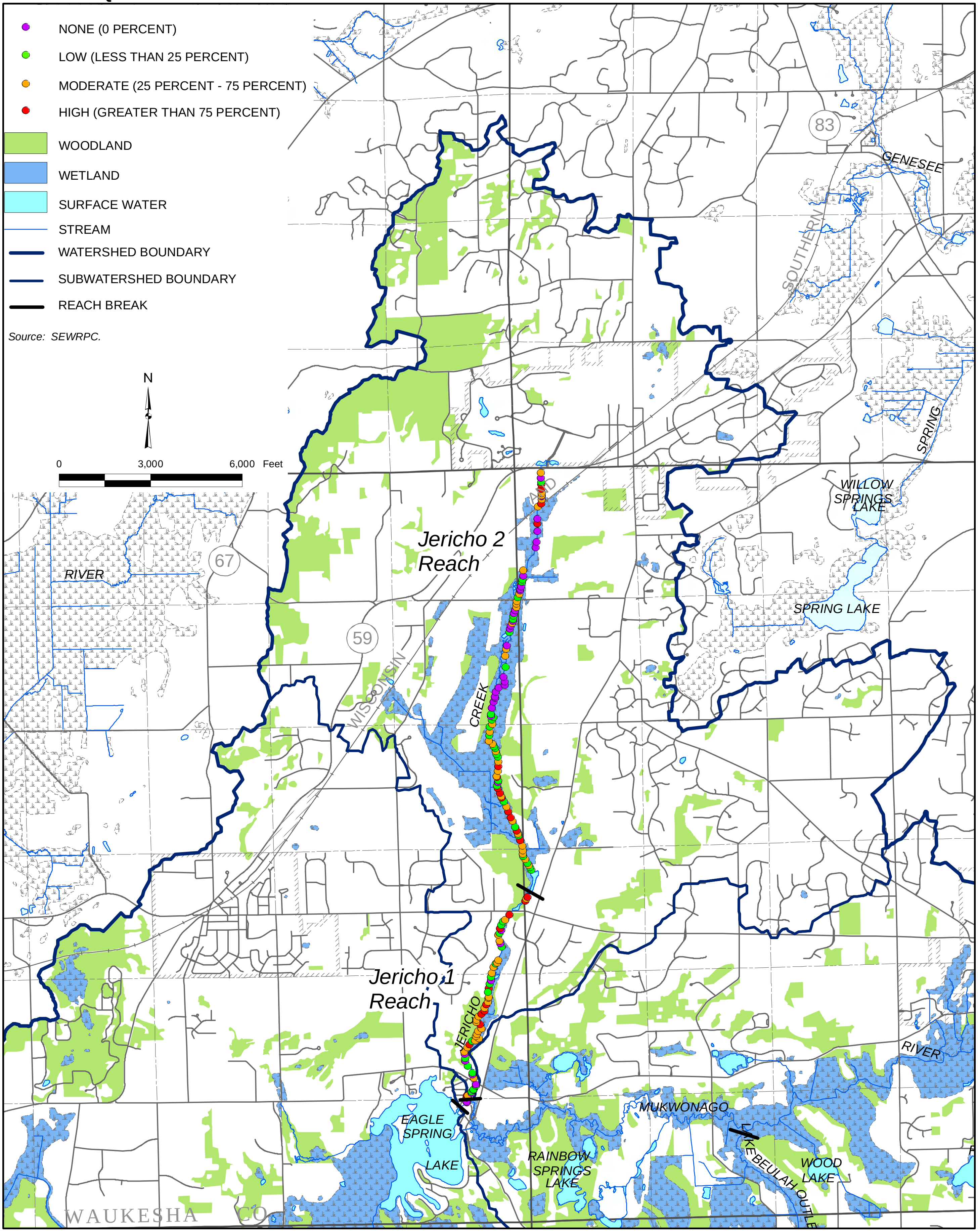
Map 30

QUALITATIVE DISTRIBUTION OF WOODY DEBRIS COVER WITHIN THE EAGLE SPRING SUBWATERSHED



Map 31

QUALITATIVE DISTRIBUTION OF WOODY DEBRIS COVER WITHIN THE JERICHO SUBWATERSHED



Similarly, the high proportions of wooded riparian areas in the Mukwonago-2 and Jericho Creek reaches also contain a high amount of shading and the stream reaches have low percentages of algae and macrophytes. The Mukwonago-2 reach also contains significant areas of riparian wetlands and the stream widens significantly within these downstream areas, which leads to a decreased amount of shading in the stream and increased amount of instream algae and macrophyte growth.

Riparian zone and floodplain quality is another important dimension included within the QHEI scoring criteria to assess instream habitat quality. More specifically, greater extent or width of riparian (stream side) vegetation is associated with a greater quality and higher score for this feature. Riparian buffers greater than 50 meters (approximately 164 feet) from each streambank are necessary to obtain the highest scores for this dimension of the index. Riparian buffers are discussed more thoroughly in the Riparian Corridor Conditions section below, but, in general, riparian buffer width and floodplain quality are excellent within the Mukwonago River system. However, there has been encroachment into the riparian buffers at road crossings and other localized areas. For example, the riparian buffer areas within the Rainbow Springs Golf Course have been significantly impacted as shown on Inset 2 of Map 23, which is the primary reason that the cross sections within this area contain the lowest QHEI scores within the entire Mukwonago-2 reach.

Although undercut banks are related to streambank stability, these are also areas of overhead protection for fishes and are ranked as an important habitat quality feature. The energy of flowing water in a stream is dissipated along the stream length by frictional resistance of the bed and banks and meanders, turbulence, streambank and bed erosion, and sediment resuspension. In general, increased urbanization may be expected to result in increased streamflow rates and volumes, with potential increases in streambank erosion and bottom scour. Streambank 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 sound land use planning combined with utilization of proper stormwater management practices. Results indicate that undercut banks are extremely uncommon throughout this watershed and are mostly less than 0.5 foot in depth. The greatest percent of undercut banks and the deepest undercuts were located within the Jericho-2 reach, which contains the greatest slope and highest energy to scour undercut banks. Based on these observations, streambank erosion is not a problem in the Mukwonago River system.

In summary the amount, quality, and diversity of available instream fisheries habitat range from fair to excellent within the Mukwonago River watershed based upon results of the QHEI that incorporates all of the dimensions described above and shown in Table 14. The Mukwonago-1 and Jericho-1 reaches contained the highest quality habitat with QHEI scores that ranged from good to excellent. The Mukwonago-2 and Jericho-2 reaches contained the next highest QHEI scores which ranged from fair to excellent, and the remaining headwater Beulah and Mukwonago-3 reaches contained QHEI scores of fair to good quality. It is important to note that the lowest habitat scores were largely associated with the modified sections of streams associated with the Rainbow Springs Golf Course within the Mukwonago-2 reach and channelized headwater area within the Jericho-2 reach north of Road X.

Obstructions and Instream Habitat

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. They can dramatically alter nutrient cycles and food webs in aquatic and terrestrial ecosystems by modifying hydrology and selectively removing riparian trees.[27] The

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

activities of beavers in streams provide an 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 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.[28]

Beaver dams are not permanent structures and without constant maintenance, the dams will be breached and blowouts will occur. In addition, dams are frequently abandoned when beavers move on to new areas, 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. 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.[29] Early research suggested that beaver dams might be detrimental to fish, primarily by hindering fish passage, and it has been demonstrated that beaver dams seasonally restrict movement of fishes.[30] 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.[31] Therefore, this is a complicated and controversial issue, so decisions to remove beaver dams should be addressed on a case-by-case basis.

Jericho Creek contained approximately six beaver dams in the headwater areas of the Jericho-2 reach and several were causing significant backwater effect within the area between River Mile 5.63 at the private dam and 6.49 at STH 59. Fortunately there were no buildings within this area, but these impoundments were backing up water to depths up to about 10 feet in some locations. These structures were not present in 2008 during the time of the SEWRPC staff field inventory for this plan, but they were present in the summer of 2009, which indicates how fast beavers can occupy an area. In addition, beavers seem to have taken residence both upstream and downstream of STH 59, where there was a pond on the upstream side with extensive beaver activity. The upstream inlet of this corrugated metal pipe was nearly completely obstructed with leftover beaver chew that without intervention could become completely blocked. There was minor beaver sign in terms of beaver chew and felled trees and several small dams on side tributaries throughout the Mukwonago River system, but there were no beaver dams observed that were obstructing fish passage on the mainstem of the Mukwonago River.

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[28]*R.J. Naiman, J.M. Melillo, J.E. Hobbie, Ecosystem alteration of boreal forest streams by Beaver (Castor canadensis),* Ecology*, Vol. 67, 1986, pages1254-1269.*

[29]*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, pages 926-942.*

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

[31]*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, pages 749-760.*

Based on these observations it is probable that beaver dams are not likely to be significantly affecting the abundance and diversity of the fishery in Mukwonago River watershed during the time of this inventory, except for the limited areas within the headwaters of Jericho Creek. Discussions with local residents indicates that beaver activity has always been a concern in the Mukwonago River and they have been trapped and removed from areas of the River on a case by case basis. Therefore, it is important to continue to monitor beaver activity and take action where appropriate and those efforts should be particularly focused within the headwaters of Jericho Creek at this time.

Stream Crossings and Dams

As previously discussed in the Effects of Road Crossings section, bridges and culverts can affect stream widths, depths, and velocities. Therefore, these structures also have the potential to pose physical and/or hydrological barriers to fisheries and other aquatic organisms, which are identified in Table 16 and on Map 24 and Figure 30. The Mukwonago-1, Mukwonago-3, Beulah, and Jericho-1 reaches did not contain problem structures during the time of this survey. In contrast, there are 11 road crossings (Structure Nos. 11 through 20) within the Mukwonago-2 reach that are potentially obstructing fish passage. Although these structures seemed to have adequate depths for passage, the high velocities within these culverts are the primary concern related to fish passage. However, the structure at Rainbow Springs Road also has significant woody debris accumulation on the upstream inlet that may be further limiting passage. In addition to the beaver dams in the Jericho-2 reach, this upper area also contains several road crossings located north of Road X (Structure Nos. 44 through 46) that are potentially obstructing passage. Structure No. 44 is a dam with an approximately 24-inch-diameter corrugated metal pipe culvert for overflow that is largely filled with debris (see Figure 31), typically causing water to flow under and around the culvert pipe. This structure is probably a complete barrier to fish passage. Structure No. 45 is a railway crossing with a 48-inch diameter steel culvert, which causes excessive water velocities and low depths that have high potential to obstruct fish passage through this structure. Finally, Structure No. 46 at STH 59 contains significant woody debris that may be limiting fish passage.

Because of the number of culverts within the Mukwonago River and Jericho Creek, their combined impact on fish communities could potentially be significant.[32] Culverts tend to have a destabilizing influence on stream morphology that can create selective barriers to fish migration because swimming abilities vary substantially among species and size-classes of fish affecting their ability to traverse the altered hydrological regime within the culverts.[33] 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.[34]

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[32]*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, pages 676-685.*

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

[34]*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.*

Summary of Habitat and Hydrology Conditions
In summary the amount, quality, and diversity of available instream fisheries habitat range from fair to excellent within the Mukwonago River watershed, which is consistent with the presence of a fair to high quality fishery also found within this River system. However, this analysis does indicate that there have been a number of modifications to this watershed and that there are opportunities to improve habitat quality. In particular, the greatest opportunities to enhance habitat quality within the Mukwonago River system are located within the Mukwonago-2 reach along Rainbow Springs Golf Course and in the channelized headwater area in the Jericho-2 reach north of Road X. Overall, this system contains a high amount and quality of habitat, therefore, the major focus of efforts should be on protection and maintenance of these high quality areas. Therefore, management efforts to protect and maintain groundwater recharge will help protect and sustain discharge in the Mukwonago River and its associated high quality habitat and resultant aquatic community.

EXISTING STORMWATER MANAGEMENT SYSTEMS

A variety of stormwater management features are located in the Mukwonago River watershed. Locations of stormwater best management practices (BMPs) in the Waukesha County portion of the watershed are shown on Map 32.[35] A total of 57 BMPs have been implemented in the watershed in Waukesha County in the form of wet and dry detention basins, grass swales, filter strips, infiltration basins and trenches, native prairies, kettles, and wetlands.

Installation and maintenance of appropriate stormwater BMPs are an important part of maintaining good water quality within the Mukwonago River watershed. Because they have been implemented over time, not all BMPs in the watershed were designed and constructed based on current technical standards. New BMPs in the watershed are designed based on current technical standards for stormwater management that include criteria intended to protect water quality. Older stormwater BMPs could have increased functionality for water quality improvement if modifications are made to bring them up to the current standards. Also, BMPs that promote infiltration of precipitation are important in the watershed for maintenance of stream baseflows and coldwater stream characteristics.

WATER QUALITY CONDITIONS

Water quality monitoring within the lakes, streams, and tributaries of the Mukwonago River watershed has been conducted for a variety of purposes by a number of agencies and organizations, including the U.S. Geological Survey; Department of Trade and Consumer Protection (DATCP); WDNR; SEWRPC; and Lake Management Districts. The studies analyzed a range of different parameters over sampling periods ranging from a single season, to a year, or multiple years. In addition, it is important to note that none of the water quality projects to date has been conducted to simultaneously assess both the lake and stream ecosystems within the Mukwonago River watershed. Rather, sampling projects have been targeted toward either a specific lake or reach of stream and usually only sampled at only one site over time, with two recent exceptions where multiple sites were sampled simultaneously throughout the Mukwonago River system by the Eagle Spring Lake Management District.[36] Very few of the same water quality parameters were collected within and/or among lakes and streams consistently enough to be able to assess changes over time. For this study, total phosphorus, chlorophyll-*a*, and Secchi depth

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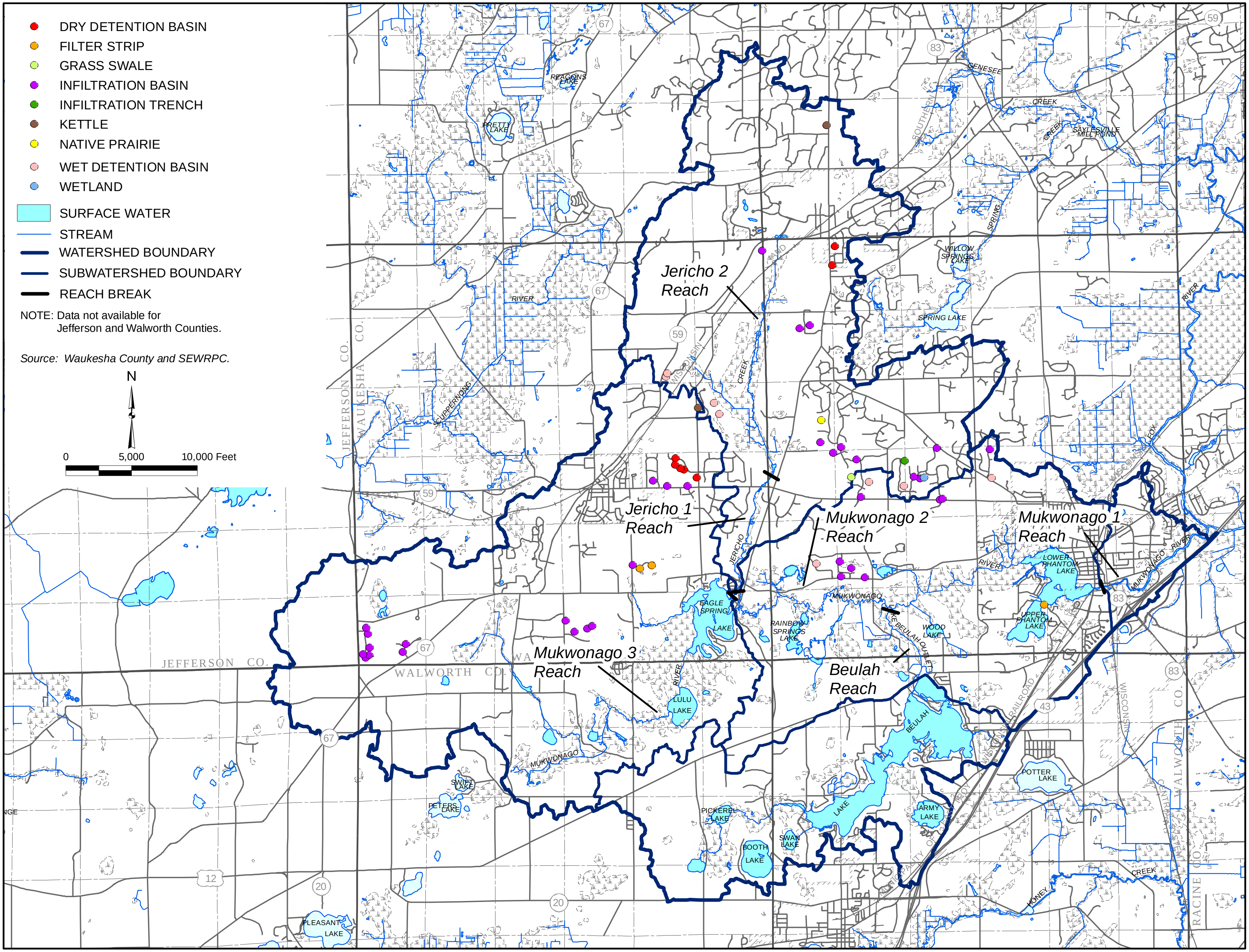
[35]*These data were compiled from field inventories and information obtained from local communities by Waukesha County. Similar BMP inventories are not available for Jefferson and Walworth Counties.*

[36]*University of Wisconsin-Milwaukee,* Status of Stream Habitat, Aquatic Biotic Integrity & Longear Sunfish Populations in the Mukwonago River Watershed, *December 2003; and Eagle Spring Lakes Management District,* Mukwonago River-Watershed Nutrient Study: August 2004-October 2007, Baseline Runoff Sampling, *April 2008.*

Map 32

STORMWATER BEST MANAGEMENT PRACTICE SITES WITHIN THE MUKWONAGO RIVER WATERSHED



parameters were used to compare water quality changes over time within and among the major lakes, whereas total phosphorus, chloride, and temperature parameters were used to assess water quality changes over time between lakes and streams within the Mukwonago River watershed. Given the limitations noted above, comparison of lakes and streams was necessarily limited to changes among years.

Lakes
Lulu Lake, Eagle Spring Lake, Lake Beulah, Lower Phantom Lake, and Upper Phantom Lake represent typical mesotrophic, hardwater, alkaline lakes that are considered to have relatively good water quality, being moderately fertile, and that are capable of supporting abundant aquatic plant growth and productive fisheries (see Figure 41).[37] Physical and chemical parameters reported for each of these lakes indicate that the water quality ranges within the "fair" to "very good" range, depending upon the parameters considered. Total phosphorus levels were found to be generally below the level considered to cause nuisance algal and macrophytic growths. Summer stratification was likely to occur in Upper Phantom Lake, but unlikely to occur in Lower Phantom Lake or Eagle Spring Lake, due to their shallow depths. The surface waters of all the lakes remain well oxygenated and support healthy fish populations. Neither summerkill nor winterkill of fishes have been reported to be problems, which indicates that the lakes provide adequate oxygenated water for fish and aquatic organisms. Internal releases of phosphorus from the bottom sediments were not considered to be a problem in any of the lakes.

Temperature and dissolved oxygen profiles indicate that complete mixing of Eagle Spring Lake is seldom restricted by thermal stratification. Lower Phantom Lake likewise does not thermally stratify for any significant period of time during summer. Temperature and dissolved oxygen concentrations, however, indicate that complete mixing of Lake Beulah, Lulu Lake, and Upper Phantom Lake is generally restricted during summer and winter by thermal stratification. The mean concentration of total phosphorus in Eagle Spring Lake, during the spring, was about 0.013 milligrams per liter (mg/l); the total phosphorus concentration during spring turnover in Lower Phantom Lake was about 0.009 mg/l; and, the total phosphorus concentrations in Lake Beulah and Upper Phantom Lake were about 0.013 mg/l and 0.012 mg/l, respectively, during spring turnover, all of which are within the Commission-recommended water quality guidelines of 0.020 mg/l during the spring turnover for recreational use and the maintenance of warmwater fish and aquatic life. Water clarity, as measured by a Secchi disc, in Eagle Spring Lake ranged from about four feet to about 7.5 feet; in Lower Phantom Lake from about six feet to about 12 feet; in Upper Phantom Lake from about five feet to about 14 feet; and Lake Beulah averaged about 10 feet. Chlorophyll-*a* concentrations ranged from about 4.0 micrograms per liter (µg/l) to 10.0 µg/l in Eagle Spring Lake; from 2.0 µg/l to 7.0 µg/l in Lower Phantom Lake; from about 3.0 µg/l to 14.5 µg/l in Upper Phantom Lake; and, averaged about 5.0 µg/l in Lake Beulah. Concentrations above 10.0 µg/l generally result in a visible green coloration of the water, especially during spring when the maximum concentrations were recorded. The slightly lower ranges in these primary water quality indicators observed in Lower Phantom Lake relative to those observed in Eagle Spring Lake are consistent with the hypotheses stated in the reservoir cascade concept, which is described in the next subsection.

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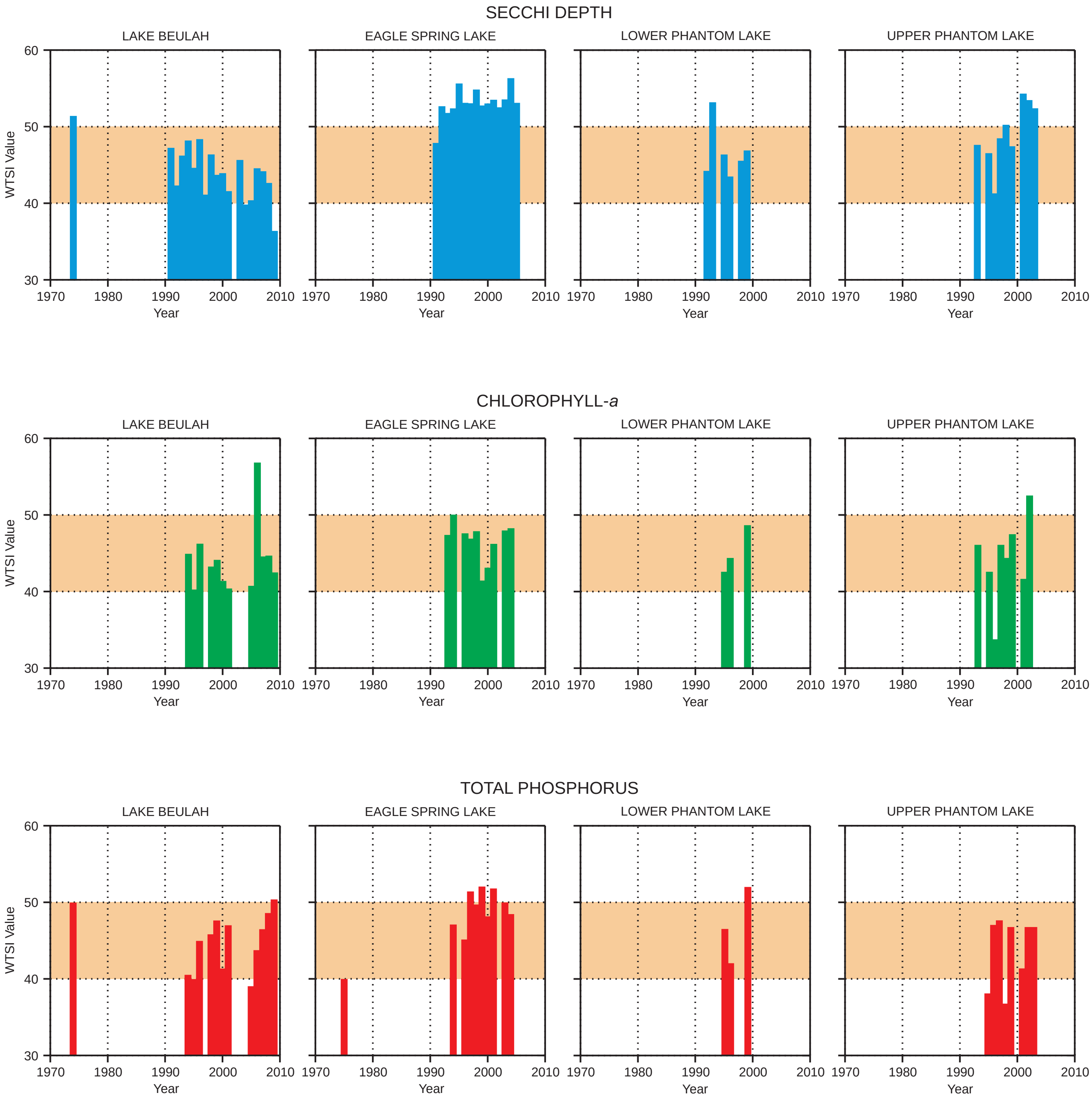
[37]*SEWRPC Community Assistance Planning Report No. 226,* A Lake Management Plan For Eagle Spring Lake, Waukesha County, Wisconsin, *October 1997; SEWRPC Community Assistance Planning Report No. 226, 2nd Edition,* A Lake Management Plan for Eagle Spring Lake, Waukesha County, Wisconsin, *in draft; SEWRPC Community Assistance Planning Report No. 230,* A Lake Management Plan for the Phantom Lakes, Waukesha County, Wisconsin, *Volume One,* Inventory Findings, *Volume Two,* Alternatives and Recommended Plan, *January 2006; and RJN Environmental Services, LLC.,* Lake Beulah Management Plan, *April 2010.*

Figure 41

MEAN ANNUAL WISCONSIN TROPHIC STATE INDICES (WTSI) FOR LAKE BEULAH, EAGLE SPRING LAKE, LOWER PHANTOM, AND UPPER PHANTOM LAKE WITHIN THE MUKWONAGO RIVER WATERSHED: 1972-2009



NOTE: WTSI Values less than 40 are oligotrophic, values 41-50 are mesotrophic, and values greater than 50 are eutrophic.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Consideration of the Mukwonago River Lakes as a Reservoir Cascade

Professor Milan Straskraba introduced the concept of reservoir cascades to explain the effects of upstream impoundments on downstream impoundments.[38] The interactions of the impoundments within these cascade systems have been briefly described by Professors Straskraba and Jose Tundisi as follows:[39]

> *"From a water quality standpoint, reservoir cascades are specific because any effect on an individual reservoir will be transferred to those below it. In a reservoir cascade, the water quality of the top reservoir is usually similar to the water quality of a solitary reservoir. The water quality of the second and lower reservoirs [is] usually all modified. The extent to which a reservoir modifies the water quality of another reservoir below it depends on whether the higher reservoir is a deep, stratified reservoir (profound effects) or a shallow reservoir (less effects). The intensity of these influences depends upon the connecting stream order, trophic levels in the reservoir and the distance between reservoirs. Reservoirs that are located on higher order streams and have greater retention times have greater effects on the outflowing river. The distance between one reservoir and another is also relevant; at a distance of several hundred kilometers from the reservoir, the river resumes a natural state and water quality effect from the upper reservoir are no longer observed. This effect is most important where reservoirs are closely situated."*

In the case of the Mukwonago River, the proximity of the Lulu Lake and Eagle Spring Lake is such that, despite the absence of an impounding structure on Lulu Lake, the surface water elevations of the two Lakes are both controlled by the Wambold dam impounding Eagle Spring Lake, as shown in Figure 22. Nevertheless, the creation of the deltaic area at the point of entry of the Mukwonago River into Lulu Lake would suggest that the combined Lulu-Eagle Spring Lake system does indeed modify the water quality of the Mukwonago River between the point of entry to the two lakes and its point of discharge from the Wambold dam, which was substantiated in a recent report.[40]

The relationship between Eagle Spring Lake and Lower Phantom Lake, about 6.5 miles downstream, provides a more classical case of the reservoir cascade, although this relationship is somewhat obscured by the entry of outflows from Lake Beulah and numerous springs discharging to the Mukwonago River upstream of Lower Phantom Lake. In this case, the impacts of Eagle Spring Lake, at an elevation of approximately 820 feet above NGVD29, on the water quality of Lower Phantom Lake, at an elevation of about 780 feet NGVD29, are also moderated by the fact that both waterbodies are shallow lakes, each with a mean depth of four feet, and each having relatively low residence times. Lake Beulah also contributes to this cascade with discharge from the Lake Beulah dam entering the Mukwonago River approximately 2.5 miles upstream of Lower Phantom Lake. Lake Beulah has a surface elevation of 808 feet NGVD29 and is about 1.4 miles upstream from the confluence with the Mukwonago River.

This cascade effect has led to the overall reduction in total phosphorus from upstream to downstream as shown in Figure 42. Previous reports also indicate a similar pattern in reduction of total phosphorus, dissolved and

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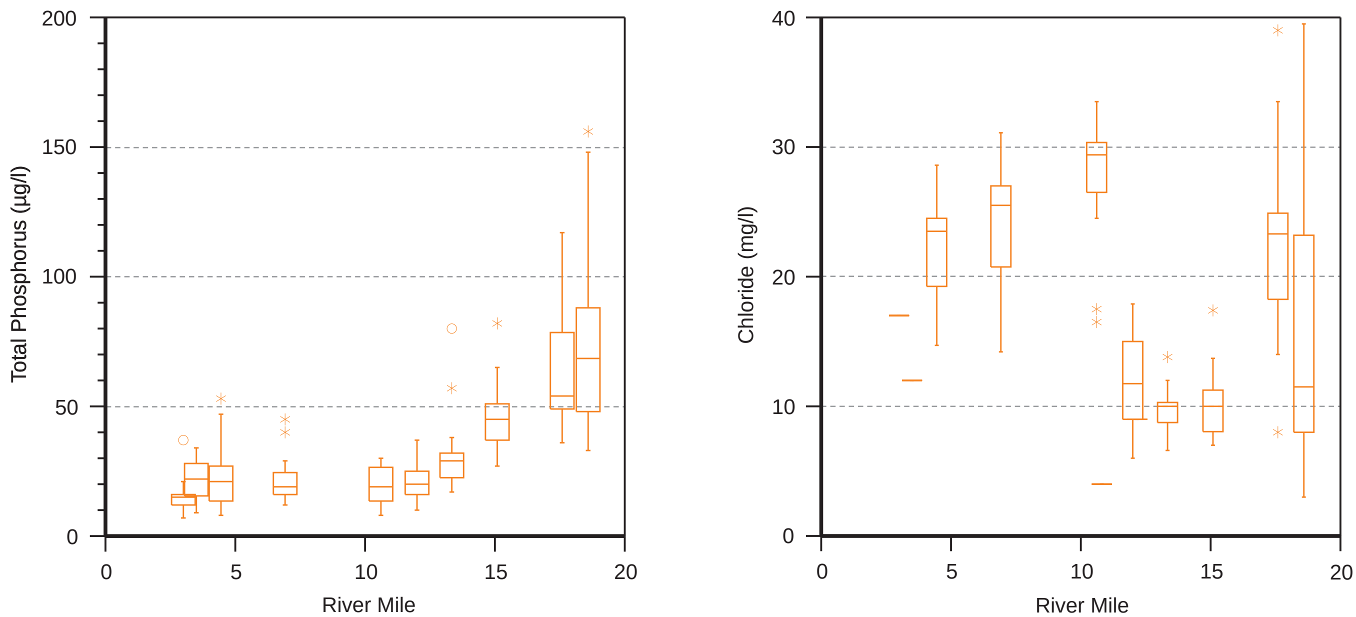
[38]*M. Straskraba, "Limnological Particularities of Multiple Reservoirs Series,"* Archiv fur Hydrobiologie, Supplement: Advances in Limnology*, Volume 33, pages 677–678, 1990.*

[39]*M. Straskraba and J.G. Tundisi,* Guidelines of Lake Management*, Volume 9,* Reservoir Water Quality Management*, International Lake Environment Committee Foundation, Kusatsu, Japan,1999. ISBN: 4-906356-26-5.*

[40]*Hey and Associates, Inc.,* Eagle Spring Lake Water Quality Summary and Management Report, Eagle Spring Lake, Eagle, Wisconsin*, January 2005.*

Figure 42

TOTAL PHOSPHORUS AND CHLORIDE CONCENTRATIONS IN THE MUKWONAGO RIVER WATERSHED: 2000-2009



NOTE: See Figure 29 for description of symbols. The river mile numbers decrease from upstream to downstream.

Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, Eagle Spring Lake Management District, and SEWRPC.

particulate phosphorus, ammonium, and nitrate.[41] These data indicate that nutrients are generally assimilated by algae and other aquatic plants as water travels from upstream to downstream.

In contrast to the limited water quality impacts between the reservoirs, the retention time effects of the Wambold dam on Lower Phantom Lake were clearly demonstrated during the June 2008 flood (see Figure 34). The U.S. Geological Survey estimated that the annual flood probabilities of occurrence at the Mukwonago River stream gauge ranged from 0.5 percent to 1 percent.[42] The Eagle Spring Lake Management District, owner and operator of the Wambold dam, made the decision to minimize the release of water from that impoundment in order to reduce flooding pressures on the Lower Phantom Lake dam, which was in danger of being over-topped. By effectively operating these reservoirs as a cascade system, the potential loss of the Lower Phantom Lake dam was prevented.

Lakes versus Streams

Nutrients

The surface water quality data for total phosphorus shows that the concentrations within all the lakes combined are much lower and less variable than within the Mukwonago River samples as shown in Figure 43, which is normal. The streams are acting more like transport systems and lakes are acting more like processing

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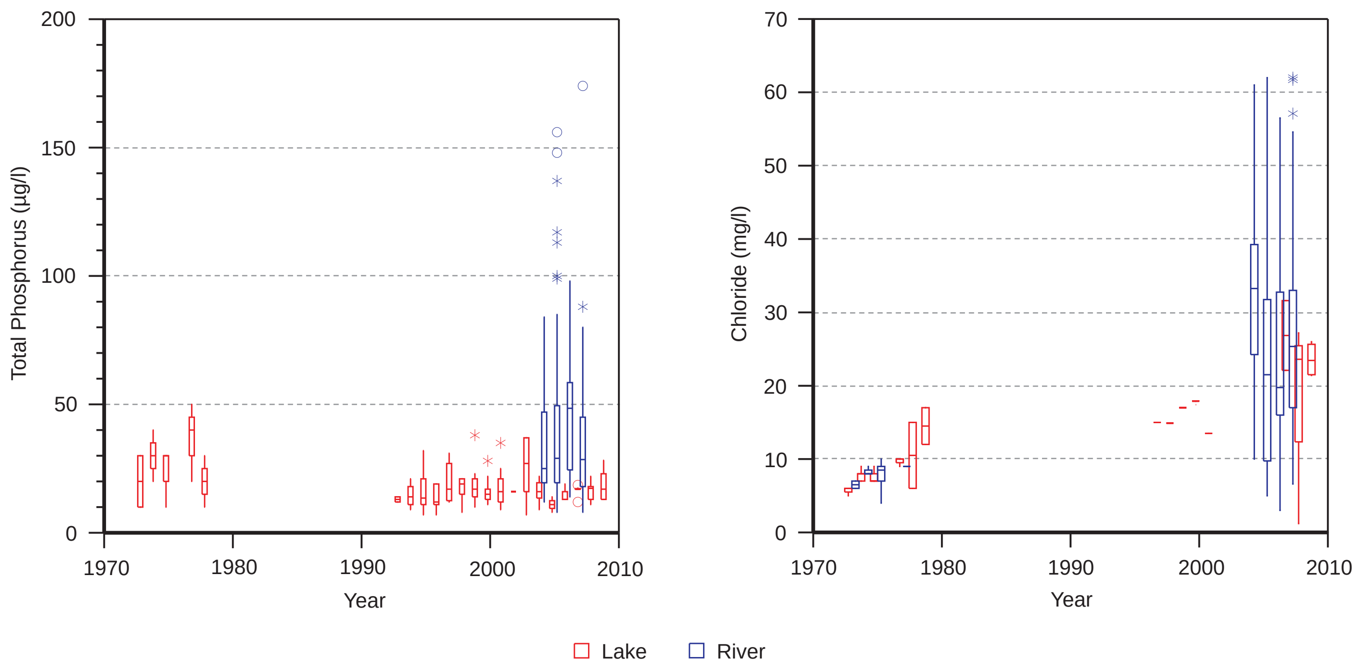
[41]*University of Wisconsin-Milwaukee,* Status of Stream Habitat, Aquatic Biotic Integrity & Longear Sunfish Populations in the Mukwonago River Watershed, *December 2003.*

[42]*U.S. Geological Survey Scientific Investigations Report 2008–5235, "Flood of June 2008 in Southern Wisconsin," 2008.*

Figure 43

TOTAL PHOSPHORUS AND CHLORIDE CONCENTRATIONS IN LAKES VERSUS STREAMS IN THE MUKWONAGO RIVER WATERSHED: 1973-2009



NOTE: See Figure 29 for description of symbols.

Source: SEWRPC.

systems. In addition to the mainstem of the Mukwonago River, Jericho Creek is a significant contributor of total phosphorus. However, the phosphorus concentrations within Jericho Creek also decrease from upstream to downstream. These total phosphorus concentrations and the concentrations of other nutrients observed in this watershed are well within the range of those reported by the USGS as being indicative of the highest quality stream systems in the State of Wisconsin.[43]

Chloride

Similarly, chloride concentrations are greater and more variable within streams compared to lakes. In addition, chloride concentration have increased in both lakes and streams from an annual mean of about 10 mg/l in 1972 to about 30 mg/l in 2009, as shown in Figure 43. Values as high as 60 mg/l and greater have been recorded in streams in recent years. This is consistent with the generally increasing trend in chloride concentrations in lakes within the Southeastern Wisconsin Region. Important sources of chlorides to lakes and streams in southeastern Wisconsin are anthropogenic in origin, and include salts used on streets and highways for winter snow and ice control, salts discharged from water softeners, and salts from sewage and animal wastes. For example, some of the highest recorded chloride concentrations in the Mukwonago River watershed were found at the STH 59 road crossing on Jericho Creek, as shown in Figure 44. Similar results have been reported by Gitttings with the highest

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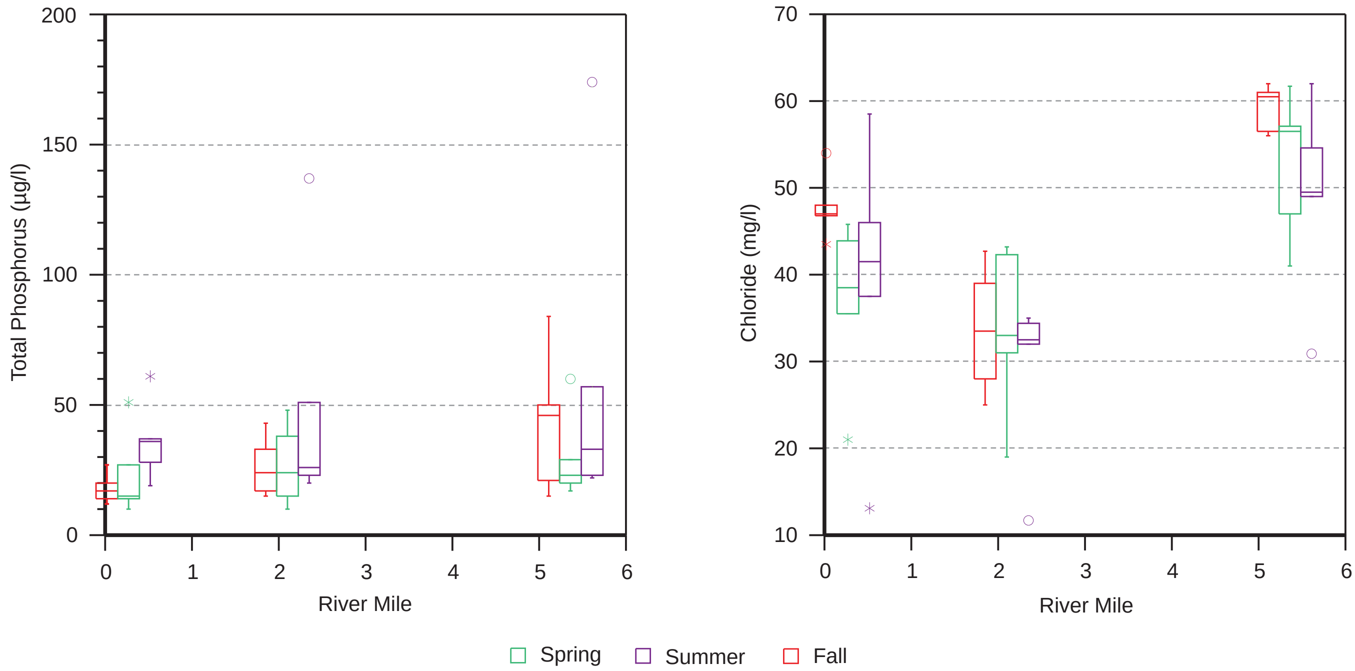
[43]*U.S. Geological Survey Professional Paper 1722, "Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin," 2006.*

Figure 44

TOTAL PHOSPHORUS AND CHLORIDE CONCENTRATIONS AMONG SEASONS IN THE JERICHO CREEK SUBWATERSHED: 2004-2007



NOTE: See Figure 29 for description of symbols. The river mile numbers decrease from upstream to downstream.

Source: Eagle Spring Lake Management District and SEWRPC.

concentrations of chloride in springs, wells, and open water locations nearest road crossings throughout the Mukwonago River watershed.[44] Chloride concentrations reported by Gittings in 2004 commonly exceeded 100 mg/l and in one case exceeded 240 mg/l in a spring. Although these concentrations are well below the WDNR standards for chronic chloride contamination (i.e., 395 mg/l) to protect fish and aquatic life, the increasing trend in chloride concentration is alarming and this is an emerging issue of concern.

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 mg/l, respectively. Minimum dissolved oxygen standards for coldwater streams are also designated to not be lower than 7.0 mg/l 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 mg/l) for many species of fishes and other aquatic organisms. Because the warmest water temperatures occur in the summer, this is the most important time of the year for determining physiological limitations based on dissolved oxygen concentrations for aquatic organisms.

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[44]*Hilary Erin Gittings, "Hydrogeologic Controls on Springs in the Mukwonago River Watershed, SE Wisconsin," Master of Science Thesis, University of Wisconsin-Madison, 2005.*

In general, dissolved oxygen concentration data were adequate to support a high quality cold and warmwater fishery. However, sites located above Lulu Lake at Nature Road and Lower Phantom Lake at CTH I are potentially limiting at night when dissolved oxygen concentrations drop to less than 2.0 mg/l. This is likely to be the result of reduced photosynthesis and increased respiration by aquatic organisms. These areas contain a high amount of organic matter, which likely has a high biological oxygen demand where oxygen is used up in the decomposition process. This may temporarily limit the fishery or restrict the fishery to specific areas, although photosynthesis generates adequate dissolved oxygen concentrations to permit fish passage during the daylight hours. This diurnal cycle is normal in streams, but potentially indicates that the system could be vulnerable to organic pollution. Consequently, maintenance of onsite sewage disposal systems and stormwater management systems that convey oxygen consuming substances is an issue of concern.

Water Temperature

Table 17 and Map 33 describe the site locations, river miles, and collection dates for temperature data used to characterize trends in the Mukwonago River watershed from 2007 through 2009. In the summer of 2007, SEWRPC staff deployed continuous monitoring devices at 42 locations to measure water temperatures and one additional site to monitor air temperatures. Some of these locations were monitored continuously over this three year time period and other sites were only monitored in one or two years. These devices were programmed to record temperature in hourly increments. In addition, there also was a weather station on Eagle Spring Lake where daily mean, minimum, and maximum temperatures were recorded along with additional variables such as precipitation, wind speed, and direction.

Average summer daily maximum air temperatures for the Eagle Spring Lake weather station were 26.7 degrees Celsius (ºC) in 2007, 25.7 ºC for 2008, and 24.3 ºC in 2009 (see Figure 45). This indicates that the summers have on average decreased in temperature during the study period. However, Figure 45 also indicates that there is a considerable range in maximum daily summer temperatures from about 17 to more than 32 ºC, which reflects variability generated by cloud cover and storm systems. Since air temperatures are major determinants of water temperatures, these differences in air temperature have important implications for water temperature changes. For example, although the year 2009 was the coldest summer on average, the hottest maximum daily water temperature recorded over the entire sampling period throughout the entire Mukwonago River system occurred on June 23, 2009, as shown on Figure 46. This occurred due to approximately seven straight days and nights of increasing air temperatures driving increasing water temperatures. Figure 46 shows several important features: 1) daily fluctuations show the increase in temperature during the day and cooling at night; 2) although the entire system is responding with increased water temperatures, the daily fluctuations and maximum temperatures overall are reduced in sections of stream with increased groundwater discharge such as shown in Reaches 1 and 2 of Jericho Creek compared to sites within Mukwonago River Reach-3; and 3) water temperatures are dependent upon both the current and preceding daily air temperature conditions. In general, Reach-3 contained the warmest sites and Jericho Creek contained the coldest, whereas reaches 1 and 2 were intermediate between these two extremes. Figure 46 also shows that the tributaries and springs range from very warm such as Site 30 that exceeded 32 ºC to very cold such as Site 14 that never exceeded 20 ºC. The warmest sites within the mainstem of the Mukwonago River were downstream of Lulu Lake (Site 30), downstream Eagle Spring Lake (Site 12), and downstream Lower Phantom Lake (Site 1), which indicates that these lakes are having a warming effect on the downstream reaches. Direct comparison of hourly water temperatures downstream of Lower Phantom Lake, Eagle Spring Lake, and Lake Beulah shows specifically how the water temperatures are significantly increased with increased air temperatures as shown in Figure 47. Figure 47 also shows that temperatures downstream of Lower Phantom Lake (Site 17) and Eagle Spring Lake (Site 12) to be much more variable than temperatures downstream of Lake Beulah (Site 37). Lower Phantom and Eagle Spring Lakes are shallow lakes and generally show increased temperatures and quicker response to changing air temperatures compared to the deeper and much larger Lake Beulah, which shows lower daily fluctuations and slower responses to changes in temperature.

Water temperatures, within a lake can be highly variable as shown in Figure 48. Figure 48 generally shows how water temperatures upstream of Eagle Spring Lake at the Nature Conservancy bridge (Site 34) are much cooler

Table 17

WATER AND AIR TEMPERATURE SAMPLING SITES AND TROUT TOLERANCE ASSESSMENT WITHIN THE MUKWONAGO RIVER WATERSHED: 2007-2009

Stream	Stream Reach and Site Number (see Map 33)	Location	River Mile	Thermal Trout Tolerance Among Years based on Daily Maximum Summer Temperatures[a] (Yes or No)			Period of Record
				2007	2008	2009	
Mukwonago River	Mukwonago 1						
	1	Downstream of STH 83	1.89	No	No	No	07/03/07-05/04/10
	Mukwonago 2						
	2	Downstream of CTH I	4.44	Yes	Yes	- -	07/03/07-05/12/09
	3	Downstream of the Lake Beulah outlet	6.30	No	- -	- -	07/03/07-11/07/07
	4	Upstream of the Lake Beulah outlet	6.42	No	- -	- -	07/03/07-11/07/07
	5	Downstream of Beulah Road	6.84	No	Yes	No	07/03/07-05/04/10
	6	Downstream of Golf Course Tributary	7.56	No	Yes	- -	07/03/07-05/11/09
	7	Upstream of Golf Course Tributary	7.61	No	Yes	- -	07/03/07-05/11/09
	8	Downstream of Rainbow Springs Lake outlet	8.69	No	Yes	No	07/03/07-05/04/10
	9	Upstream of Rainbow Springs outlet	8.85	No	Yes	No	07/03/07-05/04/10
	10	Upstream of Rainbow Springs Road	9.49	No	Yes	No	07/03/07-05/04/10
	11	Downstream of Jericho Creek	10.76	No	Yes	Yes	07/03/07-05/04/10
	12	Downstream of Eagle Spring Lake dam	10.81	No	No	No	07/03/07-05/04/10
Unnamed Tributary	Mukwonago 2 Tributaries and Springs						
	13	Upstream of CTH I	5.01[b]	- -	- -	Yes	05/14/09-05/04/10
	14	Upstream of CTH I (hairpin turn)	5.72[b]	- -	- -	Yes	05/14/09-05/04/10
	15	Wood Lake Tributary	6.02[b]	- -	- -	No	05/14/09-05/04/10
	16	Downstream of Beulah Road	0.08	- -	- -	Yes	08/07/08-08/27/08, 05/14/09-05/04/10
	17	Golf Course Tributary	0.02	Yes	Yes	- -	07/03/07-08/26/08
	18	Hogan Lake Tributary	0.02	No	Yes	Yes	07/03/07-05/04/10
	19	Downstream of Rainbow Spring Road	9.14[b]	- -	- -	Yes	08/07/08-05/04/10
	20	Upstream of Rainbow Spring Road	0.01	- -	- -	Yes	08/07/08-08/27/08, 05/19/09-08/21/09
Eagle Spring Lake	Mukwonago 3						
	21	Eagle Spring Lake-WDNR Boat Launch (surface)	- -[c]	- -	No	- -	05/06/08-09/26/08
	22	Eagle Spring Lake-Kroll Dam Bay (surface)	- -[c]	- -	No	- -	05/06/08-09/26/08
	22	Eagle Spring Lake-Kroll Dam Bay (deep)	- -[c]	- -	No	- -	05/06/08-09/26/08
	23	Eagle Spring Lake-Jack's Bay (surface)	- -[c]	- -	No	- -	05/06/08-09/26/08
	24	Eagle Spring Lake-Mary's Bay (surface)	- -[c]	- -	No	- -	05/06/08-09/26/08
	25	Eagle Spring Lake-Inlet from Lulu Lake (surface)	- -[c]	- -	No	- -	05/06/08-09/26/08
	26	Eagle Spring Lake-Waterski Channel (surface)	- -[c]	- -	No	- -	05/06/08-09/26/08
	27	Eagle Spring Lake-West Bay (surface)	- -[c]	- -	Yes	- -	05/06/08-09/26/08
	27	Eagle Spring Lake-West Bay (deep)	- -[c]	- -	Yes	- -	05/06/08-09/26/08

Table 17 (continued)

Stream	Stream Reach and Site Number (see Map 33)	Location	River Mile	Thermal Trout Tolerance Among Years based on Daily Maximum Summer Temperatures[a] (Yes or No)			Period of Record
				2007	2008	2009	
Eagle Spring Lake (continued)	28	Eagle Spring Lake-North Channel (surface)	- -[c]	- -	No	- -	05/06/08-09/26/08
	29	Eagle Spring Lake-Pickerel Bay (surface)	- -[c]	- -	No	- -	05/06/08-09/26/08
	29	Eagle Spring Lake-Pickerel Bay (deep)	- -[c]	- -	Yes	- -	05/06/08-09/26/08
Mukwonago River	30	Between Lulu and Eagle Spring Lakes	12.17	No	No	No	07/03/07-05/04/10
	31	Lulu Lake outlet	12.57	- -	No	- -	05/06/08-09/26/08
Lulu Lake	32	Lulu Lake (East)	- -[c]	- -	No	- -	05/06/08-09/26/08
	33	Lulu Lake (West)	- -[c]	- -	No	- -	05/06/08-09/26/08
Mukwonago River	34	Upstream of Nature Conservancy Bridge	13.34	No	Yes	No	07/03/07-05/04/10
	35	Upstream of Bluff Rd	15.09	- -	- -	No	04/23/09-05/04/10
Lake Beulah Outlet	Lake Beulah outlet						
	36	Upstream of Mukwonago River confluence	0.12	No	No	No	07/03/07-05/04/10
	37	Downstream of Lake Beulah dam	1.33	No	No	No	07/03/07-05/04/10
Jericho Creek	Jericho 1						
	38	Upstream of Mukwonago River	0.06	Yes	Yes	Yes	07/03/07-05/04/10
	39	Upstream of CTH NN (downstream of pond)	2.27	No	Yes	- -	07/03/07-05/14/09
	Jericho 2						
	40	Upstream of CTH NN (upstream of pond)	2.74	- -	- -	Yes	05/14/09-05/04/10
	41	Downstream of Road X	5.34	Yes	Yes	Yes	07/03/07-05/04/10
	42	Downstream of STH 59	6.44	Yes	Yes	- -	07/10/07-08/26/08
- -	Air Temperature Stations						
	43	Eagle Spring Lake Weather Station[d]	- -[e]	N/A[f]	N/A[f]	N/A[f]	07/03/07-08/31/09
	44	Nature Conservancy Air Temperature	- -[e]	N/A[f]	N/A[f]	N/A[f]	07/03/07-11/07/07, 08/25/08-05/04/10

[a]*The temperature ranges for trout tolerance are from K.E. Wehrly, L. Wang, and M. Mitro, "Field-Based Estimates of Thermal Tolerance Limits for Trout: Incorporating Exposure Time and Temperature Fluctuation,"* Transactions of the American Fisheries Society, *Vol. 139, Pages 365-374, 2007.*

[b]*The sampling site is on the small tributary. The river mile assigned is on the mainstem of the Mukwonago River at the confluence with the small tributary.*

[c]*These points are located in the lake, therefore no river mile is associated with them.*

[d]*This is a Weather Underground, Inc., site located at Eagle Springs Lake, Eagle, Wisconsin, which continuously collects numerous parameters such as temperature, wind speed, and precipitation information at six minute intervals. This data can be observed and downloaded from the following website address:* http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWIMUKWO3

[e]*These sites are not located on the River, therefore, they do not have an associated river mile designation.*

[f]*N/A means not applicable.*

Source: SEWRPC.

Map 33

TEMPERATURE LOGGER SITES WITHIN THE MUKWONAGO RIVER WATERSHED: 2007-2009

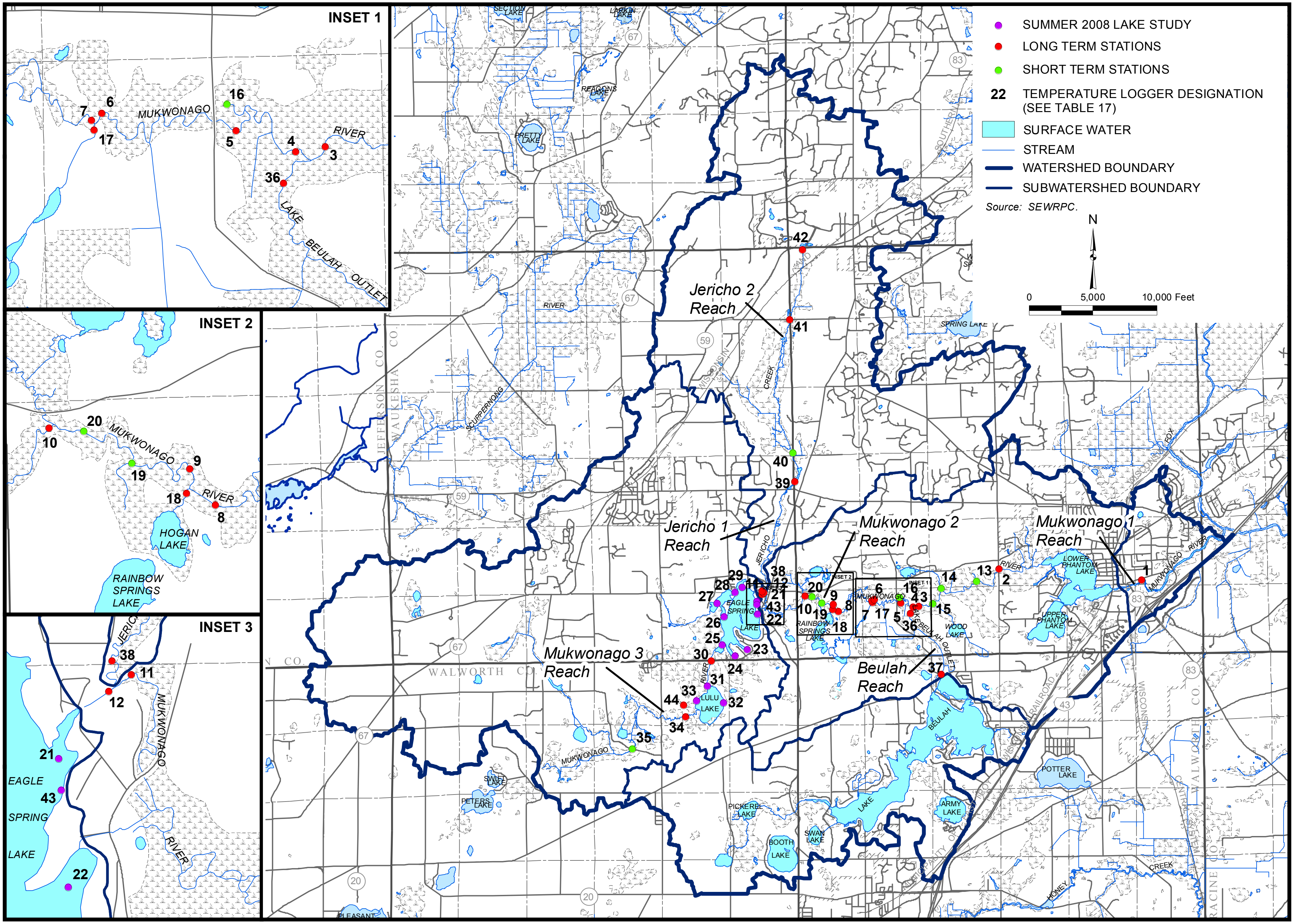
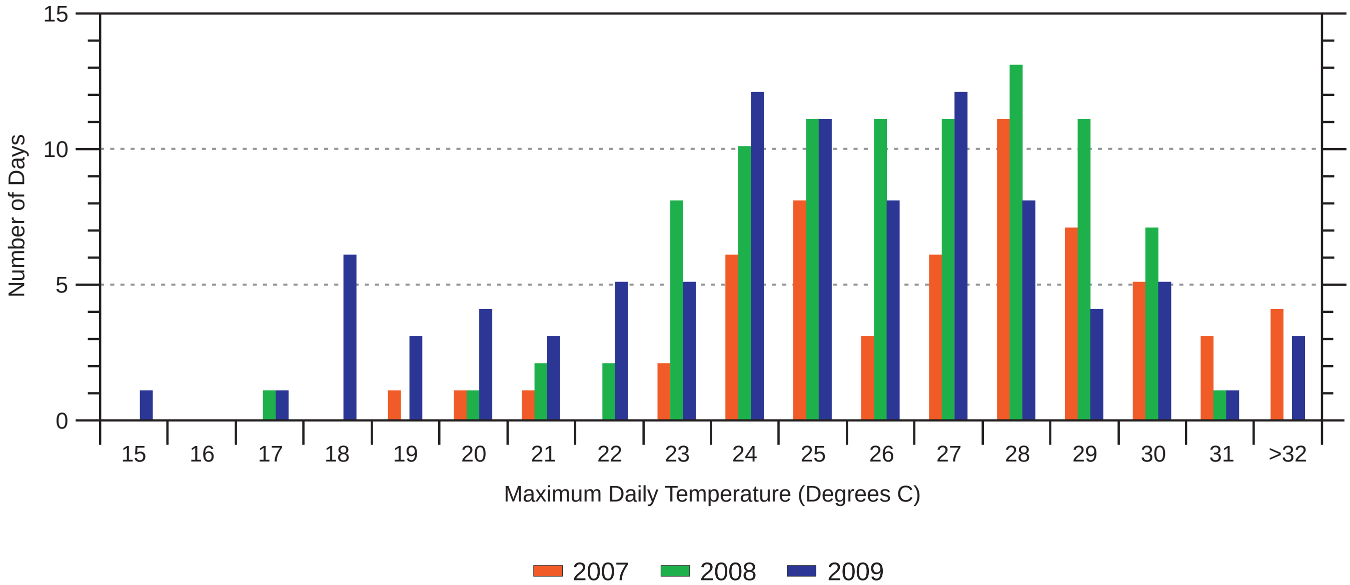


Figure 45

MAXIMUM DAILY SUMMER (JUNE-AUGUST) AIR TEMPERATURE AT THE EAGLE SPRING LAKE WEATHER STATION: 2007-2009



NOTE: Average summer daily maximum air temperature for the Eagle Spring Lake Weather Station were 26.7 degrees Celsius for the year 2007, 25.7 degrees Celsius for the year 2008, and 24.3 degrees Celsius for the year 2009.

Source: SEWRPC.

than surface water temperatures within Eagle Spring Lake. However, this figure also shows how daily temperatures can be much more variable and in some cases much warmer upstream of Eagle Spring Lake than within the Lake, particularly before the summer time period. Once the lake stratifies in the summer, water temperatures within Eagle Spring Lake consistently become much warmer than upstream of the Lake. Figure 48 also shows that groundwater inflows within Eagle Spring Lake have a direct affect on the thermal structure of the Lake. More specifically, groundwater inflows within Eagle Spring Lake significantly decreased water temperatures in the northwestern portions of that Lake and the southern portions (Sites 22 and 23) exhibited the highest maximum temperatures in the entire Lake.[45] Additionally, the temperature data show that the eastern portions of each lake are warmer than the western portions, due to prevailing winds, which seems to have important implications for thermocline stratification. This east-west phenomenon was also observed to occur within Lulu Lake.[46] This indicates that the southern bays are likely to be less well mixed and more susceptible to heating than all other areas within Eagle Spring Lake. Therefore, although water temperatures tend to increase within Eagle Spring Lake, actual water temperature changes within the Lake can be very complex, which is likely true for all the lakes within the Mukwonago River watershed.

Trout Tolerance

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, this standard has limited biological

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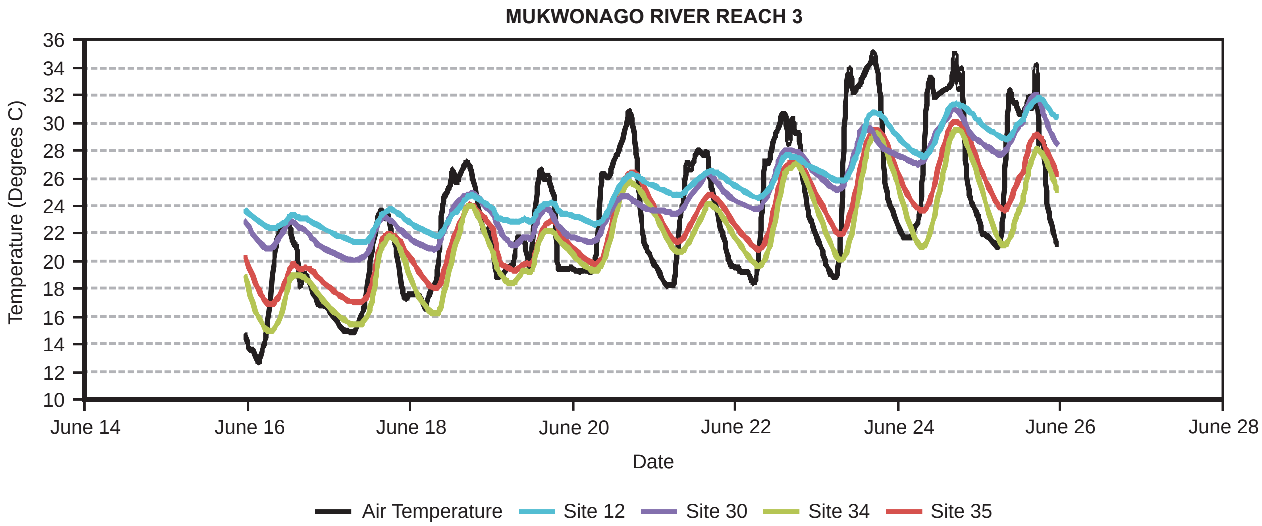
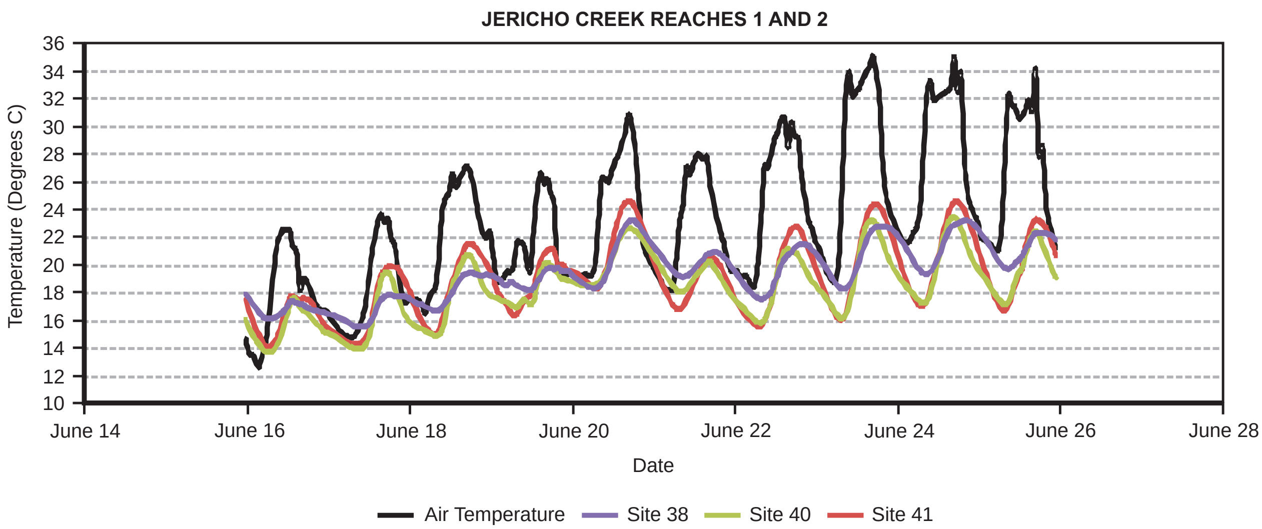
[45]*SEWRPC Community Assistance Planning Report No. 226, 2nd Edition*, A Lake Management Plan For Eagle Spring Lake, Waukesha County, Wisconsin, *in draft.*

[46]Ibid.

Figure 46

HOURLY WATER AND AIR TEMPERATURES AMONG SITES AND REACHES WITHIN THE MUKWONAGO RIVER WATERSHED: JUNE 16-26, 2009





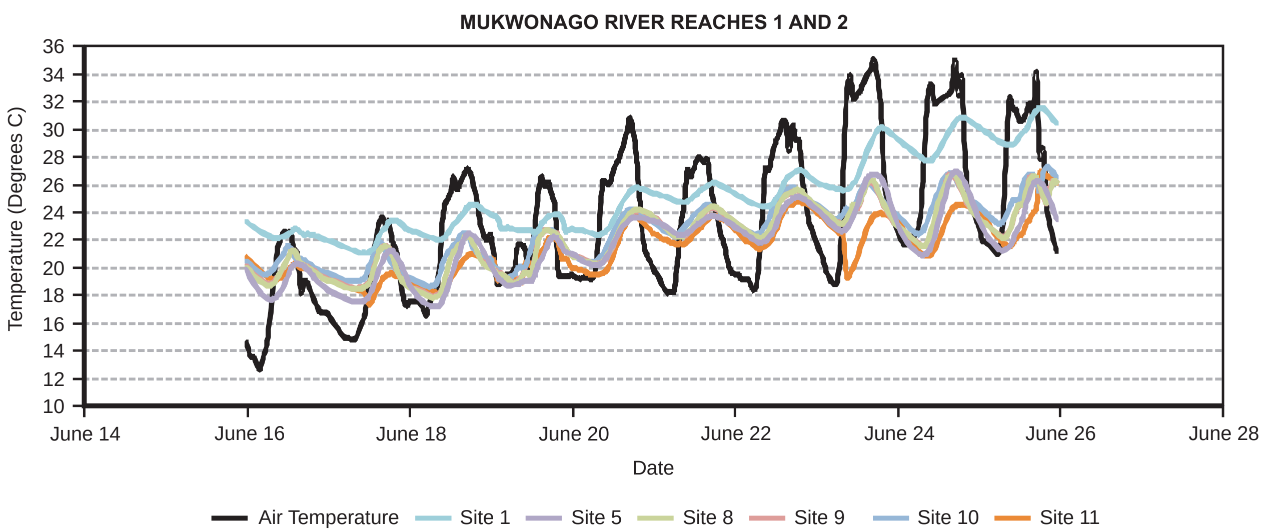
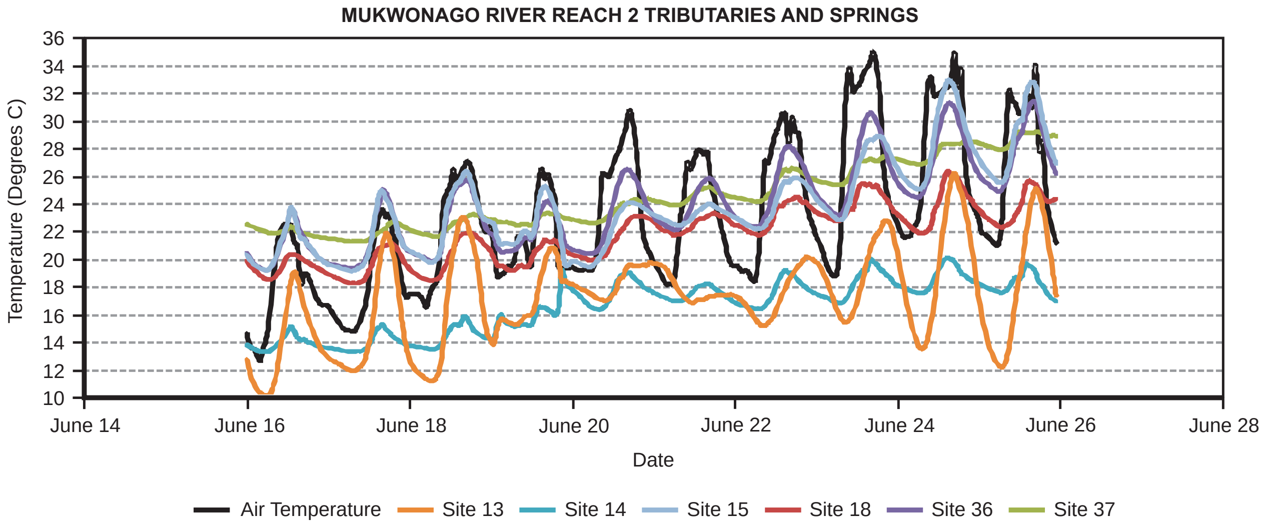


Figure 46 (continued)

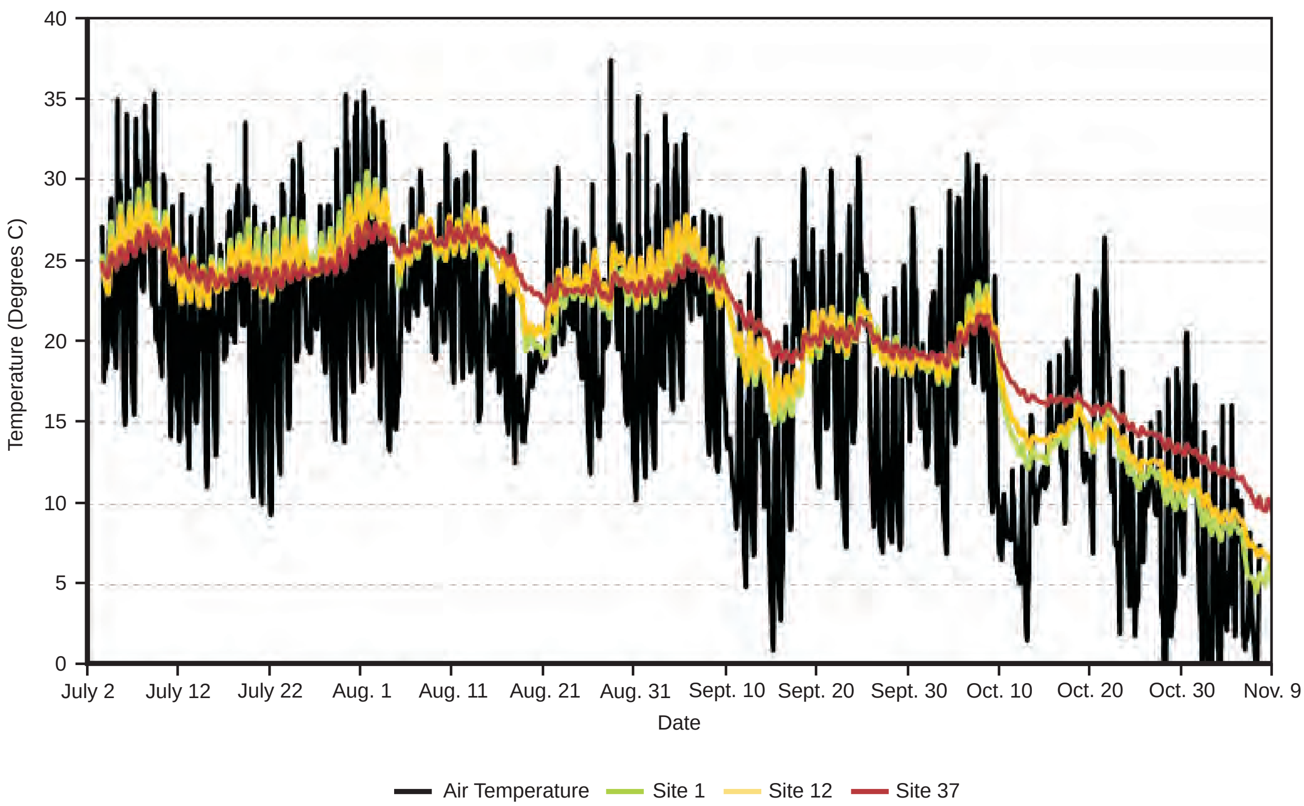


NOTE: See Map 33 for site locations.

Source: SEWRPC.

Figure 47

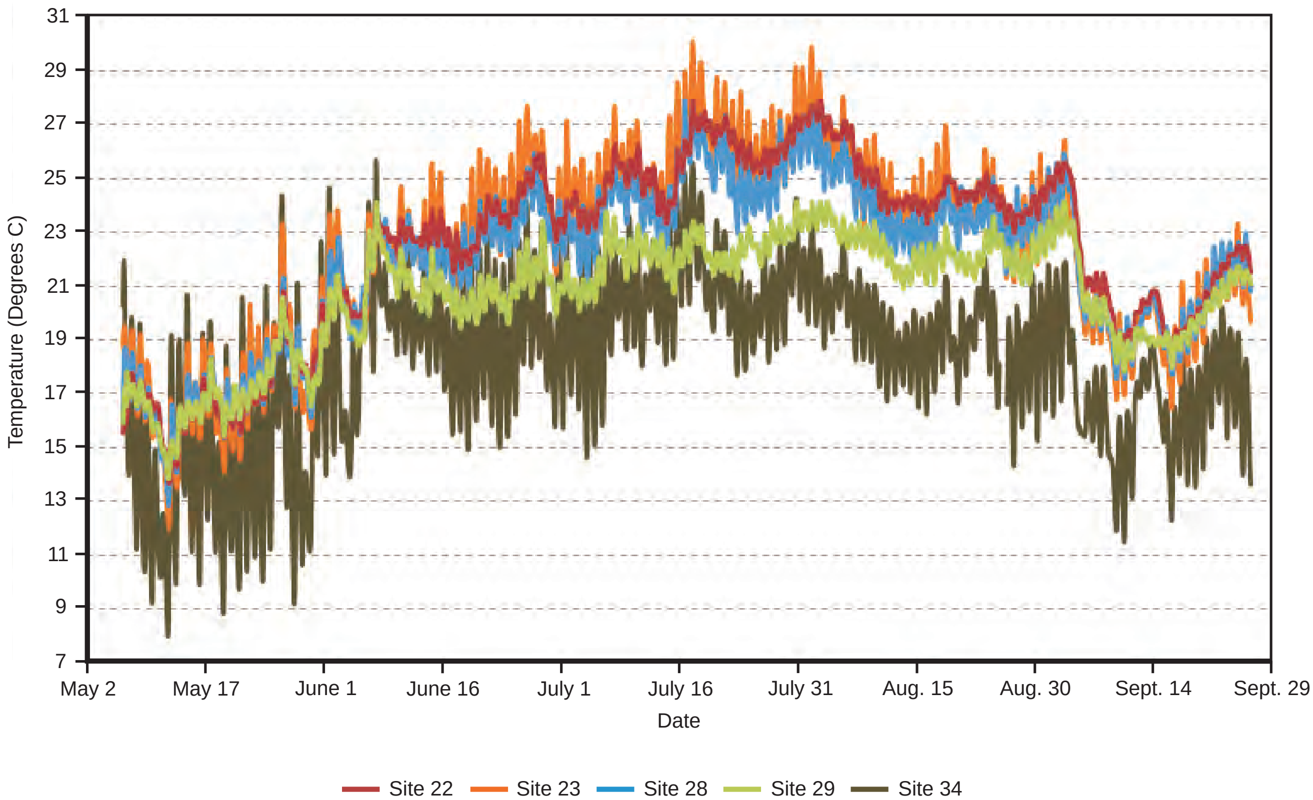
HOURLY AIR AND WATER TEMPERATURES DOWNSTREAM OF THE PHANTOM LAKES, EAGLE SPRING LAKE, AND LAKE BEULAH WITHIN THE MUKWONAGO RIVER WATERSHED: JULY-NOVEMBER 2007



Source: SEWRPC.

Figure 48

HOURLY SURFACE WATER TEMPERATURES AT ONE SITE UPSTREAM OF EAGLE SPRING LAKE VERSUS SEVERAL SITES IN THE LAKE: MAY-SEPTEMBER 2008



NOTE: Sites 22-29 are within Eagle Spring Lake and site 34 is upstream of Eagle Spring and Lulu Lakes.

Source: SEWRPC.

relevance for coldwater or warmwater streams other than the fact that 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, whereas, warmwater habitats have maximum daily mean water temperatures in excess of 24ºC.[47] In particular, brook trout and brown trout were recently found to not occur within streams where summer maximum daily water temperatures exceeded 27.6ºC,[48] which is also consistent with the fisheries survey findings summarized below.

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[47]*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,*

[48]*K.E. Wehrly, L. Wang, and M. Mitro, "Field-Based Estimates of Thermal Tolerance Limits for Trout: Incorporating Exposure Time and Temperature Fluctuation,"* Transactions of the American Fisheries Society*, Volume 139, pages 365-374, 2007.*

Based upon these findings it is possible to assess the thermal trout tolerance for each site and year as shown in Table 17 and Appendix D. In an effort to be conservative, 28.0ºC instead of the reported 27.6ºC daily maximum temperature was used to determine thermal tolerance for trout to occur within the Mukwonago River watershed as shown in Table 17 and Appendix D. Sites with daily summer maximum temperatures that equaled or exceeded 28.0ºC were identified as "no trout" streams and indicated that the section of reach upstream of this monitoring station is unlikely to have the ability to support trout (see Table 17 and Appendix D). Sites with daily summer maximum temperatures less than 28.0ºC were designated as "trout" streams likely capable of supporting trout (i.e., water temperatures are within thermal tolerance ranges for trout).

The Mukwonago River contains a variety of both warmwater (maximum daily mean temperature greater than 24ºC) and coldwater (maximum daily mean temperature less than 22ºC) stream reaches.[49] The majority of the reaches in the Mukwonago River, based upon summer (June through August) daily maximum water temperatures, can be considered warmwater fisheries; however, as shown above, this classification largely depends upon the air temperature and groundwater discharge. For example, in 2008 maximum daily summer air temperatures did not exceed 32ºC and rarely exceeded 30ºC, therefore, nearly every monitoring site within the stream except the Beulah outlet and Reach-3 of the Mukwonago River could have been classified as coldwater and able to support trout, as shown in Table 17 and Appendix D. In contrast, in 2007 and 2009, the maximum air temperatures contained a greater number of days that exceeded 30ºC and 32ºC than 2008, which indicated that many sections of the Mukwonago River system were not capable of supporting trout. This demonstrates that in some years trout have greater thermal access within areas of the Mukwonago River than other years. This is also consistent with observations that several reaches within the Mukwonago River contain both warmwater and coldwater fish species as well as a high proportion of coolwater species. Hence, the distinction between coldwater and warmwater designation within the Mukwonago River is often blurred in many areas of the watershed and based upon the temperature data changes from year to year. The 2007 and 2009 periods of increased air temperature caused the entire stream network to increase in temperature to well within the warmwater classification for each reach except for Jericho Creek and a few notable sites on the Mukwonago River such as at CTH I (Site 2) and tributaries and springs from Sites 13 through 20, which generally remained within the coldwater limits.

Seasonal water temperature data collected during the summers of 2007 through 2009 indicated that Mukwonago River would be likely to support a sustainable salmonid fishery within many areas of Mukwonago River watershed, but with greatest potential within the Jericho Creek subwatershed. As summarized within the fisheries section below, brook trout are stocked within the Mukwonago River and Jericho Creek annually, but this species has not been documented to have successfully reproduced within this watershed. It is possible that the temperatures greater than 20.0 and 25.0 ºC within this system are causing suboptimal growth and/or stress that can lead to decreased energy reserves to actually reproduce.[50] Temperature may also be inappropriate to induce spawning and/or for development of eggs after they are deposited into the stream channel. Before such relationships could be definitively established, this would have to be evaluated by assessments of brook trout population abundance and growth, integrated with more temperature monitoring.

Other Considerations

Water quality degradation is related to a number of factors that include land use (see the sections entitled "Runoff from Urban Development and Impervious Surfaces" and "Runoff from Agriculture Development" 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,[51] concentrations of

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[49]*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.*

[50]*George Becker,* Fishes of Wisconsin, *The University of Wisconsin Press, 1983.*

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

which have been shown to be increasing in every lake sampled throughout the Southeastern Wisconsin Region as well as throughout the Mukwonago River watershed.[52]

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. There are more stream crossings within Mukwonago-2 than in the other reaches within the Mukwonago River watershed (see Map 30). Consequently, the water quality impacts of roadways on the stream as a result of direct inflow from road crossings and stormwater inflows from tributary areas can be inferred, and Mukwonago-2 appears to be the most impacted reach compared to other reaches within this system. Water quality impacts in terms of increased temperatures downstream of STH 59, as shown in Figure 13 in Chapter II of this report, and increased chloride concentrations in surface water and shallow groundwater sites adjacent to road crossings summarized above indicates that this is an important issue of concern throughout the Mukwonago River watershed.

Summary

In summary, higher air temperatures lead to higher water temperatures, which have a major influence on fish and other ectothermic organisms in terms of their physiology, growth, and development, including reproduction in both lakes and streams within the Mukwonago River watershed.[53] High air temperatures which warm water and land surfaces, when combined with periods of decreased precipitation during the summer, can also negatively affect surface water dissolved oxygen concentrations. 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 lakes and streams. Figures 10 through 12 in Chapter II of this report show that the average temperature and precipitation can be highly variable from season to season and year to year, but both mean temperature and precipitation have been increasing. This is consistent with historical weather changes as well as other indicators of warmer conditions such as decreasing ice cover duration on lakes throughout the State of Wisconsin.[54] Fortunately, the Mukwonago River's discharge is supplemented by a high proportion of cold, well-oxygenated groundwater flow, which helps to mitigate temperature in critical summer periods that are warmer and/or drier than normal. However, as summarized above, discharge within the Mukwonago River watershed can be limiting and is highly dependent upon precipitation and groundwater recharge, which emphasizes that this system is vulnerable and the importance of protecting the quality and quantity of groundwater as future development occurs in this subwatershed.

The Wisconsin Initiative on Climate Change Impacts (WICCI) has documented forecast increases in both annual average temperature and precipitation as well as projected that these warmer and wetter trends will continue within the State of Wisconsin including Southeast Wisconsin.[55] It has also been established that increased chances

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

[53]*W.M. Tonn, and J.J. Magnuson, "Patterns in the Species Composition and Richness of Fish Assemblages in Northern Wisconsin Lakes,"* Ecology*, Volume 63, Number 4, pages1149-1166, 1982; and G.W. Becker,* Fishes of Wisconsin, *University of Wisconsin Press, Madison, 1983.*

[54]*J.J. Magnuson, J. Krohelski, K. Kunkel, and D. Robertson, "Wisconsin's Waters and Climate: Historical Changes and Possible Futures,"* In: Wisconsin's Waters: A Confluence of Perspectives, Transactions of the Wisconsin Academy of Sciences, Arts and Letters, *Volume 90, 2003.*

[55]*See The Wisconsin Initiative on Climate Change Impacts (WICCI) website for more information at* http://www.wicci.wisc.edu/.

of warming and/or reduced precipitation are threats that are likely to occur within the future within the Southeastern Wisconsin Region. Therefore, these trends increase the vulnerability of the high quality warmwater and coldwater fisheries within this watershed. In particular, based upon these predictions, the hypothesized effects of climate change on the physical and biological properties and processes in lakes and streams within the Mukwonago River watershed include:[56]

- Increased and longer duration of summer water temperatures—In particular, shallow lakes including Eagle Spring Lake and Lower Phantom Lake and their downstream reaches would be more susceptible to increased fishkills than deeper lakes. Wider and shallower streams are more vulnerable than narrower and deeper stream reaches, so Reach-3 of the Mukwonago River would be more vulnerable than the other reaches within the watershed. Similarly, east-west oriented streams are more vulnerable than north-south oriented streams, because they are more directly exposed to incident sunlight over the entire day. This indicates that the Mukwonago River in general is more vulnerable than Jericho Creek or the Beulah outlet;

- Increased frequency and severity of drought and flooding, particularly winter-spring flooding;

- Stronger and longer lake stratification that may alter sediment processes such as oxidation/reduction;

- More eutrophication of waterbodies due to increased nutrient loading by runoff from the land surface;

- Possible increased ultraviolet radiation leading to a shift in aquatic plant communities from rooted plants to algae dominated systems; and

- Decreased ice formation and duration resulting from warmer winters.

Based upon these potential impacts to lake and stream systems the following adaptive strategies were identified in the draft policy statement by the American Fisheries Society Governing Board on Climate Change:[57]

- "Restore/preserve geomorphological integrity of streams and rivers when management activities such as fish restoration are planned;

- Provide historic flow regime where possible. It is likely that natural flow regimes will more likely support native fish assemblages and be less likely to provide conditions suitable to non-native fishes accustomed to other biotic and abiotic conditions;

- Provide connectivity of habitat to disparate populations. Removal of structures that act as barriers to native species dispersal such as diversion dams and culverts will aid in connectivity and thus resilience. This improves the chances of species persistence and population connectivity as well as facilitates opportunity to conserve genetic integrity of species;

- Maximize local infiltration and absorption of rain water (e.g., wetland preservation/restoration, low-impact development, vegetation buffers);

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[56]*American Fisheries Society (AFS)*, Climate Change AFS Policy Statement, *Draft-RPC April 2010.*

[57]Ibid.

- Provide incentives for flood plain, riparian or watershed protection to build resiliency of the aquatic water bodies (e.g., reduce stressors such as grazing by native and non-native ungulates, recreational impacts of off-road vehicles and camping, drilling, and consumptive harvesting of forest or woodland products); and

- Incorporate prescription wildfire in long-range management plans for forested areas."

Based upon these projections, the WICCI Coldwater Fisheries Workgroup has identified several adaptation strategies to best protect and enhance coldwater resources confronted by climate change. Such adaptation strategies may include the following:

- Plan for extreme events—Many climate models suggest that a changing climate may entail an increase in extreme weather events, such as the extreme precipitation and flooding events witnessed in Wisconsin in August 2007 and June 2008. If large-scale flooding events may become more common, it may be necessary to rethink how degraded streams should be restored in order to best withstand extreme and damaging weather events. The flooding in August 2007 and June 2008 has already given insight into how different habitat restoration techniques fare in extreme precipitation events.

- Create and enhance refugia from high water temperatures—In streams that may show resilience to climate change impacts, stream habitat may be managed to create and enhance refugia from high water temperatures. For example, stream channels can be narrowed and deepened, overhead cover can be added, and deep pools can be created to provide coldwater refugia in those streams receiving sufficient groundwater input. Riparian areas can also be managed to provide shading by tall grasses or trees.

- Recognize the importance of land management in the watershed—Research has shown the importance to the quality of coldwater streams of sound land management practices in a watershed. Best management practices such as conservation tillage approaches to agriculture and the enrollment of environmentally sensitive land into the Conservation Reserve Program can be used to protect the biological integrity of coldwater streams and enhance their resiliency to climate change impacts.

In addition, it is also important to minimize the human stressors related to land development that have the potential to negatively affect stream hydrology and water temperatures within the Mukwonago River watershed. In particular, reductions in groundwater recharge may shift the thermal balance between warmer surface waters and cooler groundwater toward warmer conditions and reduce water availability in general. Such a shift would have implications for the maintenance of coldwater fish and aquatic communities in this system. While many of the factors controlling the quality of the aquatic environment in the Mukwonago River basin are limited by natural phenomena, human actions such as maintaining or enhancing buffer widths, limiting road crossings, implementing stormwater management practices, limiting the spread of nonnative exotic invasive species, and protecting groundwater recharge can and should be considered as critical elements in preserving this high-quality system.

RIPARIAN CORRIDOR CONDITIONS

Healthy riparian corridors help to protect water quality, groundwater, fisheries and wildlife, and ecological resilience to invasive species, as well as reducing potential flooding of structures and harmful effects of climate change (see Appendix B).[58] The health of riparian corridors is largely dependent upon width (size) and continuity.

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[58]*N.E. Seavy, et al., "Why Climate Change Make Riparian Restoration More Important than Ever: Recommendations for Practice and Research,"* Ecological Restoration, *Volume 27(3), pages 330-338, September, 2009; "Association of State Floodplain Managers, Natural and Beneficial Floodplain Functions: Floodplain Management—More Than Flood Loss Reduction, 2008,"* www.floods.org/NewUrgent/Other.asp.

Table 18

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.

Therefore, efforts to protect and expand the remaining riparian corridor width and continuity are the foundation for protecting and improving the fishery and recreation within the Mukwonago River watershed.

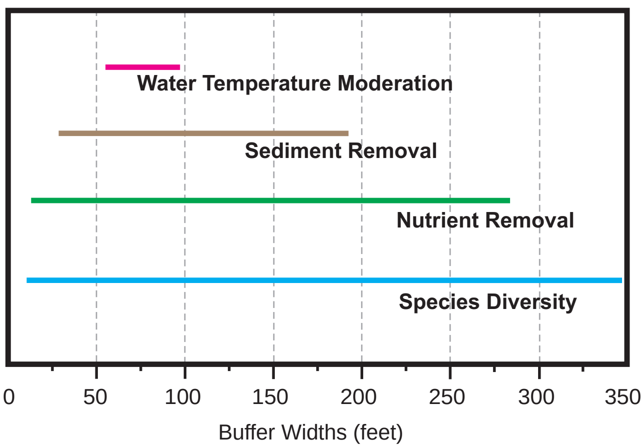
The provision of buffer strips along waterways represents an important intervention that addresses anthropogenic sources of contaminants, with even relatively small buffer strips providing a degree of environmental benefit, as suggested in Table 18 and Figure 49 and further discussed in Appendix E.[59] 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.[60] 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. Research clearly shows that riparian buffers can have many potential benefits such as flood control, prevention of channel erosion, provision of fish and wildlife habitat, enhancement of environmental corridors, and water temperature moderation, among others (see Appendix B); 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

[59]*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.*

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

Figure 49

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.*

buffer functions shown in Figure 49 are large. For example, based upon a number of studies of sediment removal, buffer widths ranging from about 25 to nearly 200 feet achieved removal efficiencies of between 33 and 92 percent, depending upon local site differences. Figure 49 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 (see Appendix B).

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. However, from an ecological point of view, 75-foot-wide buffers are inadequate for the protection and preservation of wildlife species. Riparian buffer strips greater than 75 feet in width provide significant additional 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 areas associated with streams and lakes.[61] These characteristics are discussed more fully below, with particular reference to the Mukwonago River watershed.

Physical Characteristics

Map 34 shows the current status of riparian buffers along the Mukwonago River and its major lakes and tributary streams. Buffers on Map 34 were primarily developed from 2005 aerial maps and the 2005 WDNR Wisconsin Wetland Inventory within the Mukwonago River watershed as well as primary and secondary environmental corridors and natural area designations. These riparian buffers represent contiguous natural lands (i.e., nonurban and nonagricultural lands) comprised of wetland, woodland, and other open lands based upon the most current information available and comprise a total of about 12,750 acres, or about 27 percent, of the entire Mukwonago River watershed area. The most extensive buffers were found in the Lower Phantom, Eagle Spring, and Beulah subwatersheds and comprised approximately 36, 29, and 23 percent of the total buffer area, respectively as shown on Map 34. The Jericho subwatershed contained approximately 10 percent of the total riparian buffer area and the Mukwonago subwatershed accounted for 2 percent of the entire buffer area.

Further analysis indicates that the riparian buffers within the Mukwonago River system are extensive and often exceed widths greater than 900 feet from the edge of the stream, which indicates they are providing significant water quality and wildlife protection (see Map 35). As previously mentioned, there are also a fairly limited

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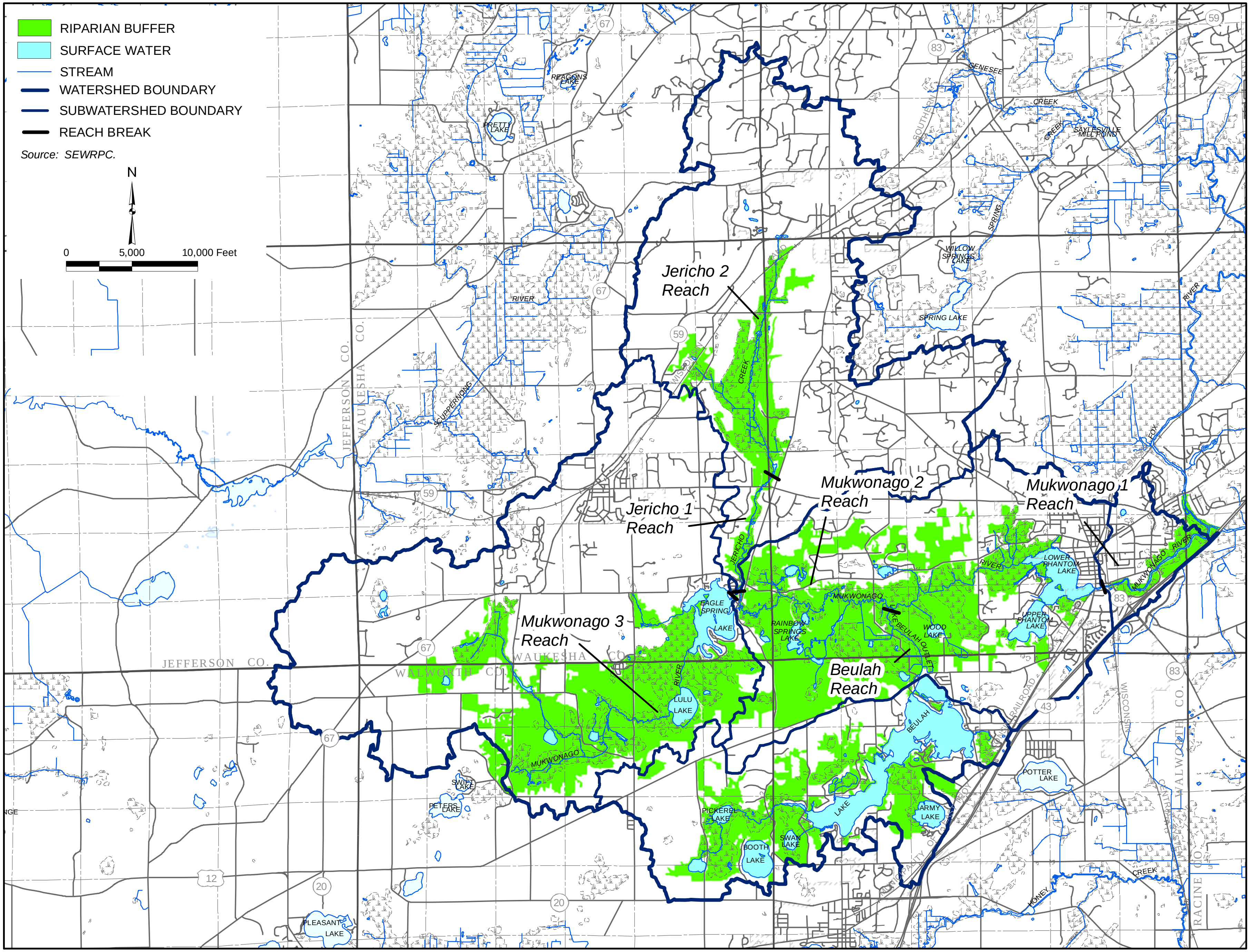
[61]*See, for example, Brian M. Weigel, Edward E. Emmons, Jana S. Stewart, and Roger Bannerman, " Buffer Width and Continuity for Preserving Stream Health in Agricultural Landscapes,"* Wisconsin Department of Natural Resources Research and Management Findings*, Issue 56, December 2005.*

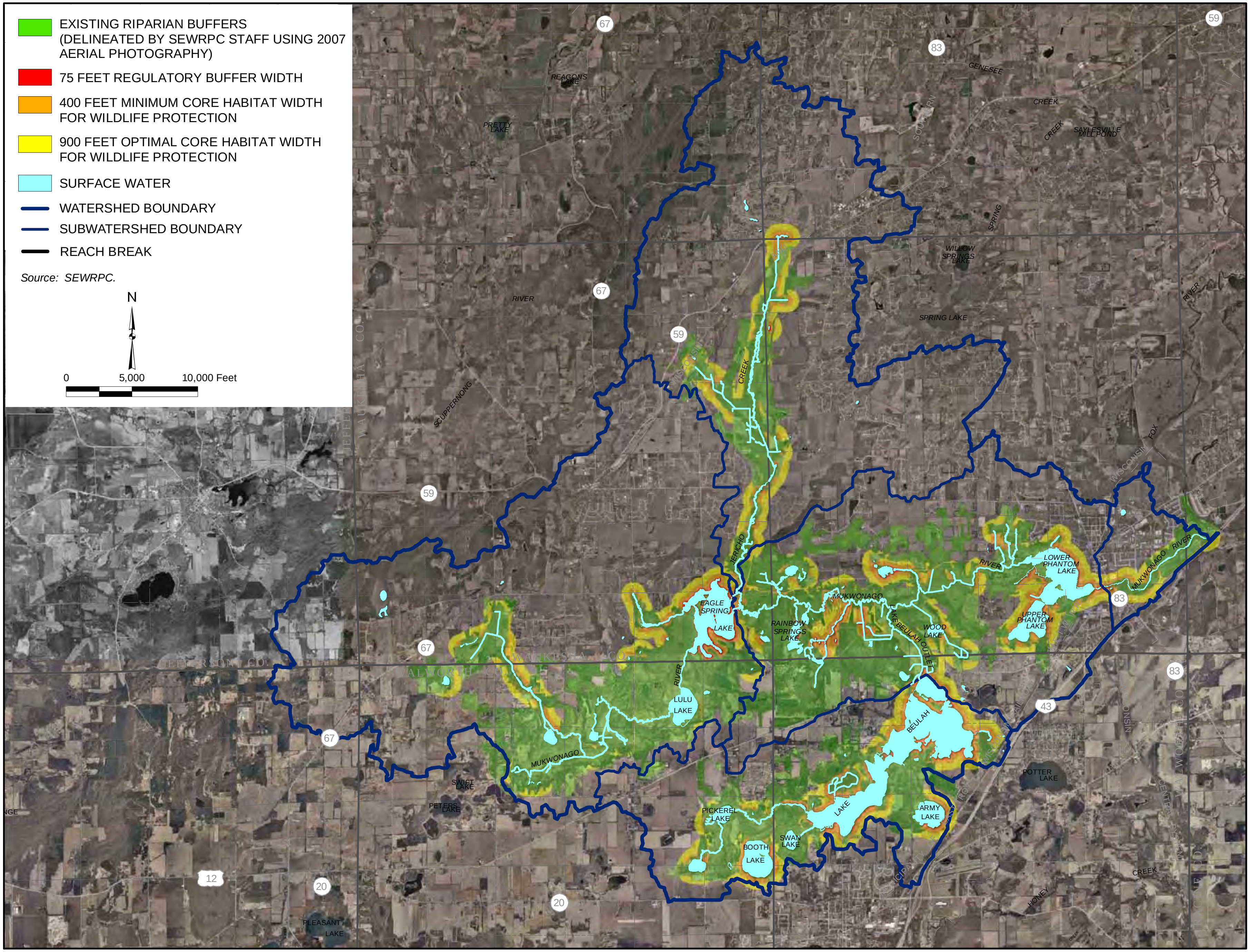
Map 34

RIPARIAN BUFFERS WITHIN THE MUKWONAGO RIVER WATERSHED: 2009



Map 35

EXISTING RIPARIAN BUFFERS AND BUFFER ZONES WITHIN THE MUKWONAGO RIVER WATERSHED: 2009



number of road crossings fragmenting the linear continuity of these corridors, which serves to increase their effectiveness. Nonetheless, there are a number of areas within Jericho Creek, upstream of Lulu Lake, and downstream of Lower Phantom Lake where there have been encroachments into the riparian buffer. In particular, the most significant encroachments into the riparian corridor are located adjacent to Eagle Spring Lake, Upper and Lower Phantom Lakes, and Lake Beulah. Lulu Lake's shoreline is entirely protected by extensive buffers greater than 900 feet. In contrast, only 20 to 30 percent of the shorelines along Eagle Spring Lake, Upper and Lower Phantom Lakes, and Lake Beulah contain natural shoreline vegetation and impacts within the riparian corridor are generally less than 75 feet in width as shown on Map 35.

Biological Characteristics

As previously identified, healthy and sustained aquatic and terrestrial wildlife diversity is dependent upon an adequate riparian buffer width. Specifically, recent research has found that the protection of wildlife species is determined by the preservation or protection of core habitat within riparian buffers ranging from minimum 400-foot to optimal 900-foot-wide buffers. These areas are essential for supporting multiple groups of organisms including birds, amphibians, mammals, reptiles, and insects and their various life stages. Hence preservation of riparian buffers to widths of 900 feet or greater represents the optimal condition for the protection of wildlife in the Mukwonago River watershed.

Map 36 shows the major natural cover types both within and outside of the riparian buffers distributed throughout the Mukwonago River watershed based upon the WDNR 2005 wetland inventory. This inventory shows that the riparian buffers are comprised of a variety of wetland, shallow marsh, deep marsh, prairie, grassland, shrubs, and forest and pine plantation vegetation communities. This combination of certain wetland and upland cover types with the riparian buffers is also consistent with the observation that these buffer areas also contain a high proportion of moderate to very high groundwater recharge potential as shown in Map 14 in Chapter II of this report.

More than 180 vegetation surveys were conducted throughout the Mukwonago River watershed from 1947 through 2006 for a variety of purposes, including wetland delineations and environmental corridor and natural area assessments. Although these surveys were conducted for different purposes by different organizations, among different seasons, and using a variety of different sampling methods, this information still provides a useful record of vegetation community quality within this watershed. For example, as shown in Figure 50, five rare State-designated threatened plant species were found to occur in several areas of the watershed. In addition, 17 State-designated species of special concern were also observed to occur within this watershed. A total of 611 native plant species were found within the Mukwonago River watershed. These native plant species can be further assigned a coefficient of Conservatism (C) representing an estimated probability that a species is likely to occur in a landscape relatively unaltered from what is believed to be a pre-settlement condition.[62] The most conservative species require a narrow range of ecological conditions, are intolerant of disturbance, and are unlikely to be found outside undegraded remnant natural areas, while the least conservative species can be found in a wide variety of settings and thrive on disturbance. Coefficients range from zero (highly tolerant of disturbance, little fidelity to any natural community) to 10 (highly intolerant of disturbance, restricted to pre-settlement remnants). Conceptually, this 10-point scale can be subdivided into several ranges as described below:

- 0-3: taxa found in a wide variety of plant communities and very tolerant of disturbance
- 4-6: taxa typically associated with a specific plant community, but tolerant of moderate disturbance

[62]*T. Bernthal,* Development of a Floristic Quality Assessment Methodology for Wisconsin, *Final report to the U.S. Environmental Protection Agency Region V, June 2003.*

Map 36

COVER TYPES AND RIPARIAN BUFFERS WITHIN THE MUKWONAGO RIVER WATERSHED: 2009

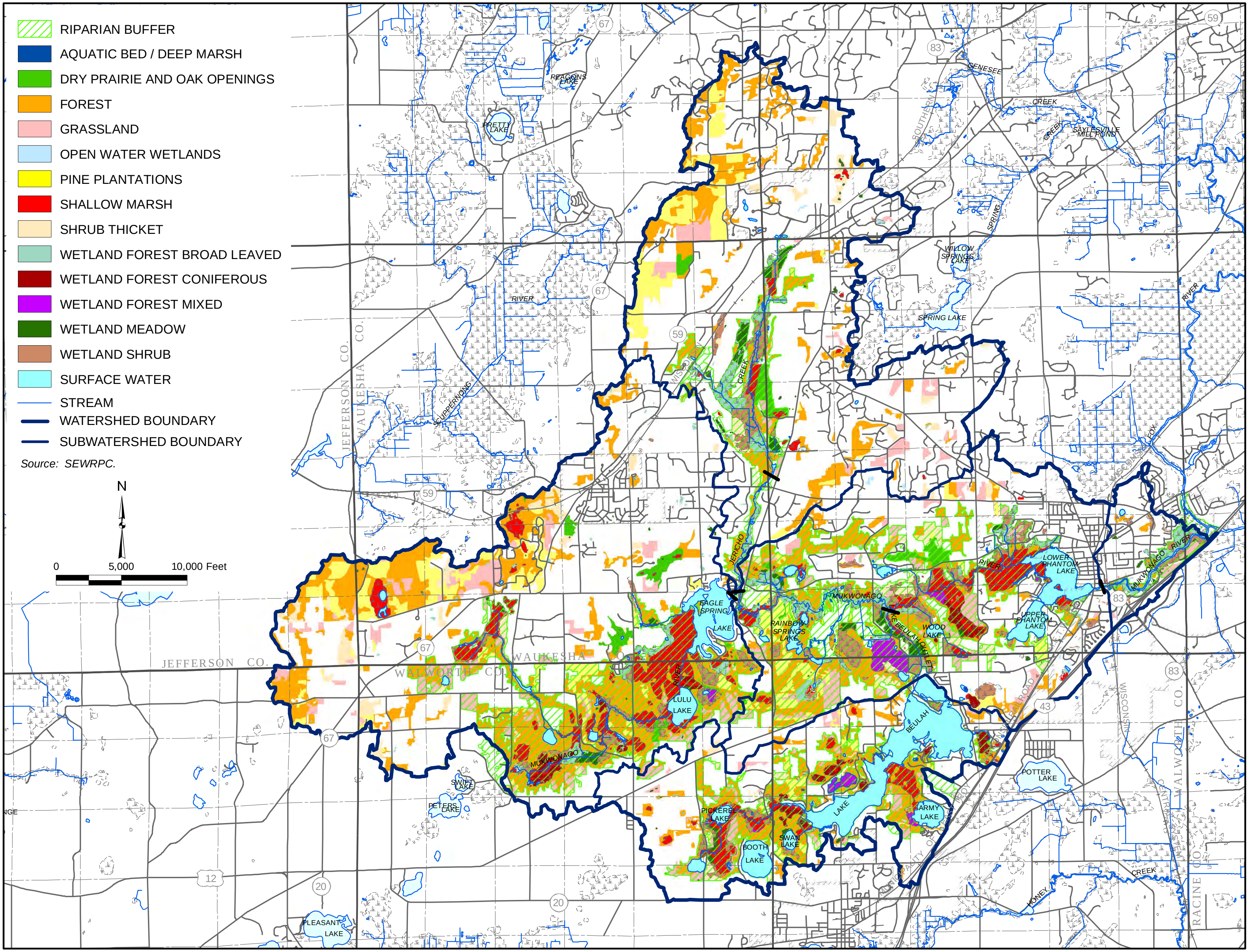


Figure 50

STATE-DESIGNATED THREATENED PLANT SPECIES WITHIN THE MUKWONAGO RIVER WATERSHED: 2006

Source: Robert W. Freckmann Herbarium, University of Wisconsin-Stevens Point; Wisconsin Department of Natural Resources; and SEWRPC.

- 7-8: taxa found in a narrow range of plant communities in advanced stages of succession, but tolerant of minor disturbance

- 9-10: taxa restricted to a narrow range of ecological conditions, with low tolerance of disturbance

Conservatism and rarity, or special conservation concern status (i.e., threatened), are not always equated, but in general, many species of conservation concern are both highly conservative and restricted to specific remnant natural communities, which is the case of plant species within the Mukwonago River watershed. Based upon this rating system 209 species were found with C values ranging from 0-3, 266 species were found with C values ranging from 4-6, 139 species were found with C values ranging from 7-8, and 76 species were found with C values ranging from 9-10. This indicates that the majority of the plant species are native and are generally of high conservation quality (i.e., C values greater than 3). The top eight most abundant species that were found in greater than 50 separate inventories within the 4-6 range in C values include marsh aster, Joe-pye weed, silky dogwood, black willow, bur oak, marsh milkweed, swamp aster, and boneset. The top eight most abundant species that were found in greater than 25 separate inventories within the 7-8 range in C values include tussock sedge, beaked willow, white oak, water hemlock, ciliated brome grass, shooting star, great water dock, and swamp thistle. The top 10 most abundant species that were found in greater than 10 separate inventories within the 9-10 range in C values include sage willow, prairie dropseed, hoary puccoon, shrubby cinquefoil, kittentails, woolly sedge, brook lobelia, Ohio goldenrod, death camas/white camas, and fen muhly grass. However, there were also 107 nonnative exotic species recorded. The top nine most dominant exotic invasive plant species included common buckthorn, hybrid honeysuckle, reed canary grass, glossy buckthorn, Kentucky bluegrass, deadly nightshade, garlic-mustard, multiflora rose, and smooth brome grass. The presence of these invasive nonnative species threaten the quality and abundance of plants and wildlife species within riparian buffers. Consequently, management of exotic invasive species is an important issue to consider in order to protect the ecological integrity of the riparian corridors within the Mukwonago River system.

The vegetation community quality within the Mukwonago River watershed based upon the Floristic Quality Index (FQI),[63] a measure of plant species diversity and native community composition, generally ranges from fair to excellent as shown on Map 37. In general, the highest FQI ratings in the good to excellent range are associated with the largest stands of plant species, but it is important to note that all of these vegetation communities provide necessary habitat for a variety of wildlife. All of the 47 sites used to assess FQI throughout the Mukwonago River watershed as shown on Map 37 are located upstream of the Mukwonago subwatershed. This high-quality vegetation is consistent with the high diversity of birds species found within this watershed (see Other Wildlife section below).

Environmental Corridors

As discussed in Chapter II of this report, there are primary and secondary environmental corridors and isolated natural resource areas (INRA) distributed throughout the Mukwonago River watershed. These corridors and INRAs 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.[64] The majority of the riparian buffers are comprised of primary environmental corridor (PEC) lands. There are also significant amounts of additional PEC lands associated with the Kettle Moraine in the western portion of the Mukwonago River watershed as well as a secondary environmental corridor (SEC) and a variety of INRAs distributed throughout the watershed, as shown on Map 37. The SEC and INRA segments provide critical links for some birds and large mammals between the two main larger and higher-quality PEC lands (see Appendix B). Some INRA segments could be expanded to connect with PEC lands to provide links for more species.

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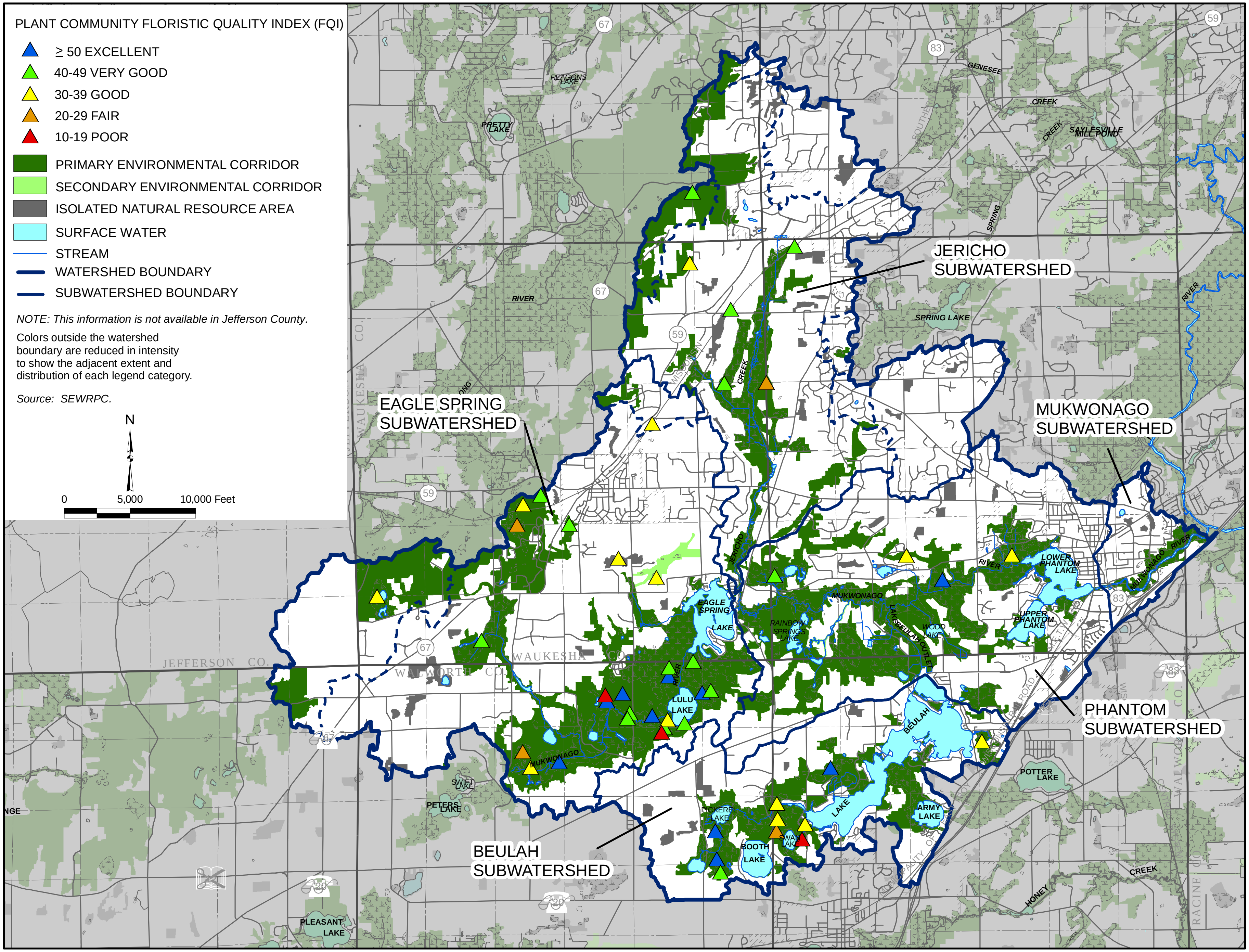
[63]*T. Bernthal,* Development of a Floristic Quality Assessment Methodology for Wisconsin, *Final report to the U.S. Environmental Protection Agency Region V, June 2003.*

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

Map 37

PLANT COMMUNITY CONDITIONS WITHIN THE MUKWONAGO RIVER WATERSHED: 2006



Summary
All riparian buffers provide some level of protection that is greater than if there were no buffer at all. However, wider buffers provide a greater number of functions (infiltration, temperature moderation, species diversity) than narrower buffers. Therefore, it is important that existing buffers be protected and expanded where possible.

Approximately 19 percent of the lands within the riparian buffer areas are protected through public and private ownership, as shown on Map 38. In addition, significant amounts of these riparian buffers are within the one-percent-annual-probability (100-year recurrence interval) regulatory floodplain, which provides additional protection for these areas. However, despite these protections there are still many areas that are not protected as shown on Map 38, as well as areas where encroachment into the corridor system has occurred as shown on Map 35. Each of these situations represents varying opportunities to enhance buffers within this watershed. In addition, connecting the SEC land and multiple INRAs throughout the Mukwonago River watershed to the larger PEC areas, as well as building and expanding upon the existing protected lands, represents a sound approach to enhance the corridor system and wildlife areas within the watershed.

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 Mukwonago River watershed. The Mukwonago River has rich aquatic biota, and is one of the highest quality streams remaining in southern Wisconsin. The most downstream reach (Mukwonago-1) has the highest fish species richness of any comparably sized stretch of stream in the State, and includes several State-threatened and endangered fish and mussel species.

The Mukwonago River can be characterized as a continuum, with the river itself forming the backbone of a varied and diverse system of plants, aquatic organisms, and terrestrial wildlife. Some of these organisms support human recreational activities, such as fishing and hunting, while others provide visual amenities and support for human activities in the watershed. Each of these ecosystem elements is discussed below.

Aquatic Macrophytes and Aquatic Plant Management
Aquatic macrophytes are an essential part of any healthy aquatic ecosystem. Macrophytes provide food and shelter for a variety of invertebrates, fish, waterfowl or shorebirds, and mammals; help to improve water quality by absorbing phosphorus, nitrogen, and other nutrients from the water that could otherwise fuel nuisance algal growth; and, protect the shoreline from wave action, stabilize the land and water interface, and capture sediment and debris that would otherwise be carried into and deposited within the waterbodies. Many factors, including waterbody configuration, depth, water clarity, nutrient availability, bottom substrate composition, wave and current action, and the type and size of fish populations present, determine the distribution and abundance of aquatic macrophytes.

Aquatic macrophytes include emergent species, such as rushes and cattails, floating-leaf species such as water lilies, and submergent species such as pondweeds, coontail, and water milfoil. Depending on their type, distribution, and abundance, they can either be classified as beneficial or a nuisance. Macrophytes that do not significantly interfere with human access to the water and recreational uses such as boating and swimming are beneficial in maintaining lake fisheries and wildlife populations as well as providing habitat for a variety of aquatic organisms. These plant communities are typically comprised of species native to the Upper Midwest. However, various nonnative species have been introduced into the Region's waterways over the last 150 years, including species such as Eurasian water milfoil and purple loosestrife that have been designated as invasive species pursuant to Chapters NR 40 and NR 109 of the *Wisconsin Administrative Code*. Control measures are

Map 38

LANDS IN PUBLIC AND PRIVATE PROTECTION WITHIN AND ADJACENT TO THE MUKWONAGO RIVER WATERSHED: 2010

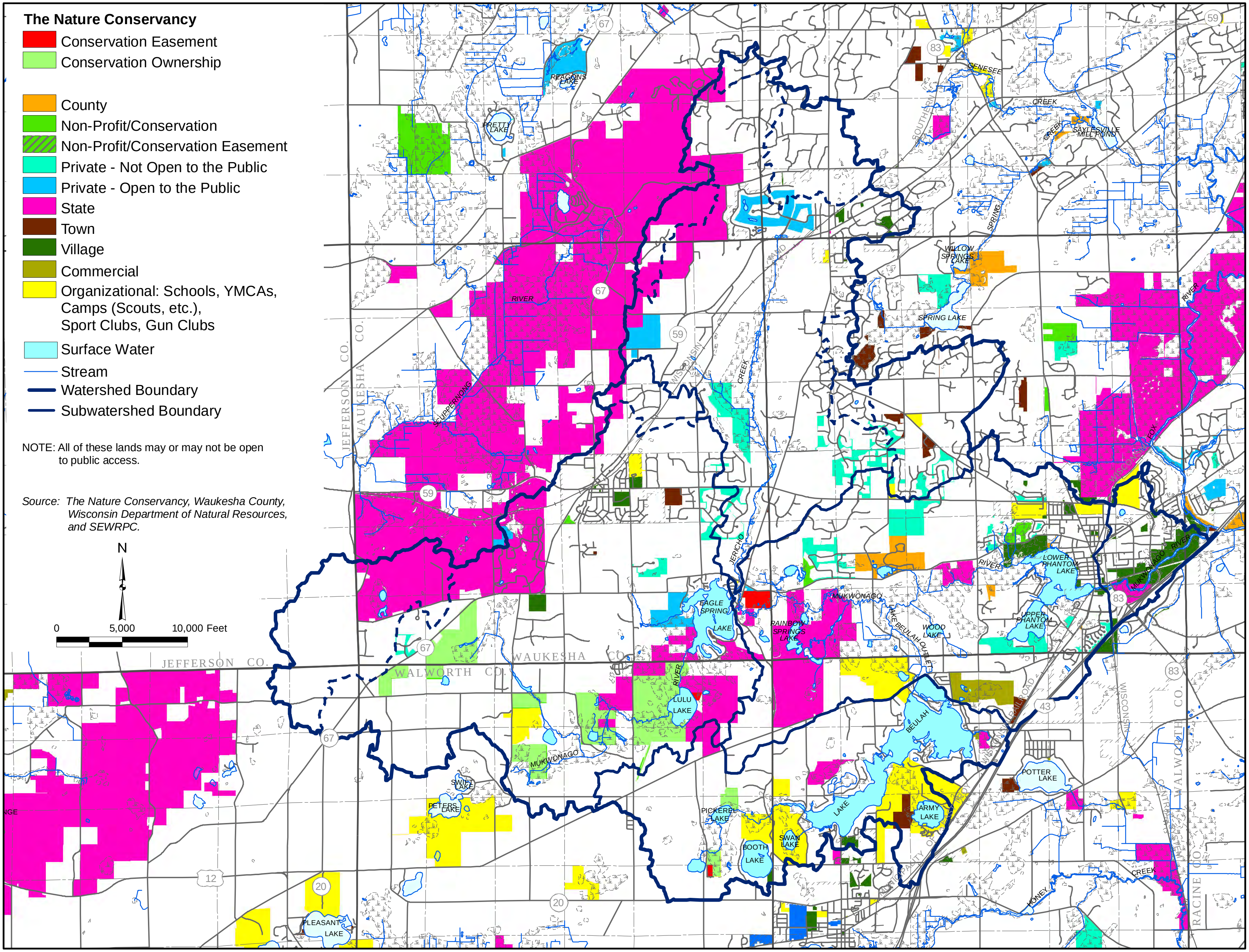


Table 19

AQUATIC PLANT SPECIES OBSERVED IN LAKES WITHIN THE MUKWONAGO RIVER WATERSHED

Common Name	Lulu Lake	Eagle Spring Lake	Lake Beulah	Upper Phantom Lake	Lower Phantom Lake
Bladderwort	X	X	X	X	X
Bushy Pondweed	X	X	X	X	X
Clasping-Leaf Pondweed	- -	X	X	X	X
Coontail	X	X	X	X	X
Curly-Leaf Pondweed	X	X	X	X	X
Ditch-Grass	- -	- -	X	- -	- -
Eel Grass/Wild Celery	X	X	X	X	X
Elodea	X	X	X	X	X
Eurasian Water Milfoil	X	X	X	X	X
Flat-Stem Pondweed	X	X	X	X	X
Floating-Leaf Pondweed	X	X	X	- -	X
Illinois Pondweed	X	X	- -	- -	X
Large-Leaf Pondweed	- -	- -	X	- -	X
Leafy Pondweed	- -	X	- -	X	- -
Muskgrass	X	X	X	X	X
Needle Spikerush	X	X	- -	- -	- -
Nitella	X	- -	- -	X	X
Northern Water Milfoil	X	X	X	X	X
Sago Pondweed	X	X	- -	X	X
Small Pondweed	- -	X	X	- -	- -
Spiny Naiad	X	X	X	X	X
Variable Pondweed	- -	X	- -	X	X
Water Bulrush	- -	- -	X	- -	- -
Water Crowfoot	X	X	- -	- -	- -
Water Stargrass	X	X	- -	X	X
White-Stem Pondweed	- -	- -	- -	X	X
Total Number of Species	18	21	17	18	20

Source: SEWRPC.

often put into place when the densities of such species become so great that they interfere with swimming and boating activities, when their growth forms limit habitat and species diversity, or when plants reduce the aesthetic appeal and quality of the resource.

Of the waterbodies that comprise the Mukwonago River system, the major lakes form the elements that have been most studied with respect to their aquatic macrophyte communities. These Lakes contain a very diverse aquatic macrophyte flora as shown in Table 19. Aquatic plant surveys were conducted periodically since 1994 on Eagle Spring and Lulu Lakes by SEWRPC staff, and on Lake Beulah by RJN Environmental Services staff and others, including the WDNR staff. The most recent aquatic plant surveys were conducted on Eagle Spring and Lulu Lakes during 2008, on Upper and Lower Phantom Lakes during 2002, and on Lake Beulah during 2009. The highest diversity and abundance of aquatic macrophytes was observed within Eagle Spring Lake and Lower Phantom Lake, reflecting the fact that these waterbodies are shallow lakes with extensive littoral zones. Nevertheless, Lulu Lake, Upper Phantom Lake, and Lake Beulah also have a high diversity of aquatic macrophytes reflecting the high quality habitats present in the waters of the Mukwonago River system.

The physical structure established by aquatic macrophytes provides habitat for fishes and other aquatic and amphibious organisms within the littoral zones of lakes and supports foraging and spawning, as well as providing shade and protective cover.[65] Recent research by the Wisconsin Cooperative Fisheries Research Unit at the University of Wisconsin-Stevens Point has shown that the characteristics and composition of macrophyte beds significantly influences fish community structure in littoral zones of northern temperate lakes, such as the lakes of the Mukwonago River system. [66] This and other research has shown that macrophytes are important to fish abundance and diversity; however, relationships between specific macrophyte characteristics and fish communities are not consistent, which highlights the fact that lake-specific differences are more important than applying across-lake strategies for managing macrophyte communities in individual lakes.

Aquatic plant management practices within the Mukwonago River system have focused on the control of nonnative and designated invasive species of both aquatic and terrestrial plants. In the protected areas maintained by the WDNR and TNC in the upper and middle portions of the watershed, significant interventions have been conducted to remove invasive terrestrial plant species such as buckthorn and garlic mustard, thereby enhancing the ability of native plant species to compete with these aggressive invaders. The three public inland lake protection and rehabilitation districts in the watershed—Eagle Spring Lake Management District, Lake Beulah Management District, and the Phantom Lakes Management District—have conducted aquatic plant management programs in concert with their local communities. These aquatic plant management activities have focused on the control of Eurasian water milfoil within the lakes and of purple loosestrife in their shoreland wetland margins. Such interventions are conducted in accordance with their respective aquatic plant management plans,[67] and with WDNR permits issued pursuant to Chapters NR 107 and NR 109 of the *Wisconsin Administrative Code*.

Fish and Fisheries

In Wisconsin, high-quality warmwater systems are characterized by many native species including cyprinids, darters, suckers, sunfish, and percids that typically dominate the fish assemblage (see Figure 51). Pollution intolerant species (species that are particularly sensitive to water pollution and habitat degradation) are also common in such high-quality warmwater systems.[68] Pollution tolerant fish species (species that are capable of persisting under a wide range of degraded conditions) are typically present, but they do not dominate the fish fauna of these systems. 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) also are generally common, but do not dominate. Simple lithophilous spawners (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 generally common.

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[65]*M.J. Weaver, et al., "Distribution of littoral zone fishes in structurally complex macrophytes,"* Canadian Journal of Fisheries and Aquatic Sciences, *Volume 54, pages 2277-2289, 1997; E.D. Dibble, et al. "Measurement of plant architecture in seven aquatic plants,"* Journal of Freshwater Ecology, *Volume 11, pages 311-318, 1996.*

[66]*K.M. Carden, "Macrophytes as Fish Habitat: The Role of Macrophyte Morphology and Bed Complexity in Fish Species Distributions," Master of Science Thesis, University of Wisconsin-Stevens Point, December 2002.*

[67]*See SEWRPC Community Assistance Planning Report No. 226,* A Lake Management Plan for Eagle Spring Lake, Waukesha County, Wisconsin, *October 1997, a second edition of which is currently in preparation; SEWRPC Community Assistance Planning Report No. 230,* A Lake Management Plan For The Phantom Lakes, Waukesha County, Wisconsin, *Volume Two,* Alternatives and Recommended Plan, *January 2006, which refined and updated SEWRPC Memorandum Report No. 81,* Aquatic Plant Management Plan for Phantom Lakes, Waukesha County, Wisconsin, *July 1993; and, RJN Environmental Services LLC,* Aquatic Plan Management Plan: Lake Beulah, Walworth County, Wisconsin, *May 2010.*

[68]*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 51

NATIVE FISH SPECIES WITHIN THE MUKWONAGO RIVER WATERSHED: 2007-2009

Source: SEWRPC.

The Mukwonago River system 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).[69] 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. 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.

Index of Biotic Integrity

Through calculation of the Index of Biotic Integrity (IBI), data on the fish community can provide insight into the overall health of the river ecosystem in this stretch. Fish catches can also reveal trends in the populations of rare and sport fish species. The overall goal of the monitoring is to better document the current status of this biologically unique piece of river and to provide an early warning of declines in environmental quality and fisheries associated with human development in the watershed. Due to the fundamental differences between warmwater versus coldwater streams, a separate Index of Biotic Integrity (coldwater IBI) was developed to assess

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[69]*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.*

the health of coldwater streams.[70] 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. The Mukwonago River watershed contains both warmwater and coldwater fisheries, so both IBI scores were used to assess the fishery among warmwater and coldwater reaches in the analysis of the fisheries abundance and distribution that are presented below.

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.[71] Hence, supplemental data for macroinvertebrates surveys conducted by the Water Action Volunteer (WAV) are summarized below.

Fishes of the Mukwonago River System

A review of the fish data collected in the Mukwonago River between 1960 and 2009 indicates an apparent gain of 35 species since 1968 as shown in Table 20. Most notable were gains in species intolerant to pollution such as the American brook lamprey, blackchin shiner, pugnose shiner, rainbow darter, rosyface shiner, weed shiner, and least darter, the latter two being species of special concern in Wisconsin. In addition to these species, other State-designated fishes found in the Mukwonago River watershed include the longear sunfish and pugnose shiner, which are designated threatened species.

The gain of 11 species during the period from 1970-1979 through 2000-2009 appears to be due, in large part, to an increased sampling effort during this period, as opposed to any significant increase in water quality or fish abundance and diversity changes. For example, during the 2000-2009 time period, the number of recorded total fishes sampled exceeded previous records by between two to 100 times, compared to all of the other time periods. Most of the new records for species occurrences were from the lower reach of the Mukwonago River (see stream reach Mukwonago-1 in Table 21 and Map 39), which had not previously been sampled.[72] This lowest reach is in close proximity to and has a good, direct connection with the Fox River. In addition, this reach contains the most diverse habitat areas (see the Stream Channel Conditions and Structures section above) within the Mukwonago River watershed.

The Mukwonago-1 reach has a highly diverse and abundant fish community, with a total of 49 fish species found between 2000 and 2009. Statewide, most stream stretches of similar length yield fewer than 20 fish species, and any stretch with more than 25 is considered to be exceptional.[73] Over the course of the WDNR monitoring, five fishes designated as rare by the State have been collected, including: the lake chubsucker (special concern); pugnose shiner, greater redhorse, and longear sunfish (threatened); and, starhead topminnow (endangered). Statewide, any site with more than three rare species is unusual. The Mukwonago River populations of longear sunfish and starhead topminnow are among the largest remaining in the state. In addition to these scarce species, a

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[70]*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.*

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

[72]*In 2003, the WDNR Fish and Habitat Research Section began an annual* ad-hoc *effort to monitor the fish community in the Mukwonago River below Lower Phantom Lake.*

[73]*John Lyons, Wisconsin Department of Natural Resources mini report,* Mukwonago River Annual Index of Biotic Integrity (IBI) Fish Survey 2009 Results.

Table 20

FISH SPECIES COMPOSITION BY YEAR IN STREAMS WITHIN THE MUKWONAGO RIVER WATERSHED: 1928-2009

Species According to Their Relative Tolerance to Temperature	Year					
	1928	1968	1970-1979	1980-1989	1990-1999	2000-2009
Primary Coldwater						
Brook Trout[a]	- -	- -	- -	- -	- -	X
Brown Trout[a]	- -	- -	X	- -	X	X
Mottled Sculpin[b]	- -	X	- -	X	X	X
Primary Coolwater						
American Brook Lamprey[b]	- -	- -	- -	X	X	X
Brook Stickleback[c]	- -	- -	X	X	- -	X
Northern Brook Lamprey[b]	- -	- -	- -	X	- -	X
Secondary Coolwater						
Blacknose Dace[c]	X	- -	X	X	X	X
Central Mudminnow[c]	X	- -	X	X	X	X
Emerald Shiner	- -	- -	X	- -	- -	X
Fathead Minnow[c]	- -	- -	X	- -	X	X
Iowa Darter[b]	- -	X	X	X	X	X
Johnny Darter	X	X	X	X	X	X
Logperch	- -	X	X	X	X	X
Longnose Dace	- -	- -	X	X	- -	- -
Northern Pike	- -	- -	- -	X	X	X
Rock Bass[b]	- -	X	X	X	X	X
Smallmouth Bass[b]	- -	- -	- -	- -	X	- -
Spottail Shiner[b]	- -	- -	X	- -	X	X
Walleye	- -	- -	X	- -	- -	X
White Sucker[c]	X	X	- -	X	X	X
Yellow Perch	- -	- -	X	X	X	X
Warmwater						
Banded Darter[b]	- -	X	X	X	X	X
Banded Killifish[d]	- -	- -	X	X	X	X
Black Bullhead	- -	- -	X	X	X	X
Black Crappie[c]	- -	X	X	X	X	X
Blackchin Shiner[b]	- -	- -	X	X	X	X
Blacknose Shiner[b]	X	X	X	X	X	X
Blackside Darter	- -	X	X	X	X	X
Blackstripe Topminnow	- -	- -	X	X	X	X
Bluegill	X	X	X	X	X	X
Bluntnose Minnow[c]	X	X	X	X	X	X
Bowfin	- -	X	X	X	X	X
Brook Silverside	- -	X	X	- -	X	X
Brown Bullhead[c]	- -	- -	- -	X	X	X
Central Stoneroller	X	- -	X	X	X	X
Channel Catfish	- -	- -	X	- -	X	X
Common Carp[c]	- -	X	- -	X	X	X
Common Shiner	X	X	X	X	X	X
Creek Chub[c]	X	X	X	X	X	X
Fantail Darter	X	X	- -	X	X	X
Golden Redhorse	- -	- -	X	X	X	X
Golden Shiner[c]	- -	- -	- -	X	X	X
Goldfish[c]	- -	- -	X	- -	- -	X
Grass Pickerel	- -	X	- -	X	X	X
Greater Redhorse[e]	- -	- -	X	- -	- -	X
Green Sunfish[c]	- -	X	X	X	X	X
Hornyhead Chub	X	X	- -	X	X	X
Lake Chubsucker[d]	- -	X	X	X	X	X
Largemouth Bass	X	X	X	X	X	X
Largescale Stoneroller	- -	- -	X	X	X	X
Least Darter[b,d]	- -	- -	X	- -	- -	X
Longear Sunfish[b,e]	- -	X	X	X	X	X
Longnose Gar	- -	- -	- -	- -	X	- -

Table 20 (continued)

Species According to Their Relative Tolerance to Temperature	Year					
	1928	1968	1970-1979	1980-1989	1990-1999	2000-2009
Warmwater (continued)						
Northern Hogsucker[b]	- -	- -	- -	- -	X	- -
Orangespotted Sunfish	- -	- -	X	- -	X	X
Pugnose Shiner[b,e]	- -	- -	X	X	- -	X
Pumpkinseed	- -	- -	X	X	X	X
Quillback	- -	- -	X	- -	X	- -
Rainbow Darter[b]	- -	- -	- -	X	X	X
Rosyface Shiner[b]	- -	- -	X	X	X	X
Sand Shiner	- -	- -	X	X	X	X
Spotfin Shiner	- -	- -	X	X	X	X
Starhead Topminnow[f]	- -	X	X	X	X	X
Stonecat	- -	- -	X	X	X	X
Suckermouth Minnow	- -	- -	X	X	X	- -
Tadpole Madtom	- -	X	X	X	X	X
Warmouth	- -	X	- -	X	X	X
Weed Shiner[b,d]	- -	- -	X	- -	- -	X
White Crappie	- -	- -	- -	- -	X	- -
Yellow Bullhead[c]	- -	X	X	X	X	X
Total Number of Species	13	28	52	52	59	63
Total Number of Samples	1	4	33	16	73	100

[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 species of special concern.*

[e] *Designated threatened species.*

[f] *Designated endangered species.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

wide variety of sport fish species occurs in this reach, with about 12 species being collected each year. In Wisconsin, fisheries based on more than eight species are considered highly diverse. Bluegills are abundant and always dominate the electroshocking catch in this reach; rock bass and largemouth bass also are usually common. Channel catfish, although usually uncommon, are of relatively large size for a small river such as the Mukwonago River, ranging in length from 12 to more than 20 inches.

The Mukwonago-2 reach also contains a diverse fishery, with a total of 41 species found. This is the only reach in the watershed that contains both the American and northern brook lamprey (see Figure 52). Both of these lamprey are nonparasitic filter feeders that are found in brooks, streams, and small rivers with sandy or mucky substrates. The American brook lamprey prefer to live in colder water than the northern brook lamprey.

Jericho-1 reach supports a very poor to good coldwater fishery based upon the coldwater IBI, and Jericho-2 reach supports a poor to fair coldwater fishery. It is important to note that since brook trout are the only native stream-dwelling salmonid in Wisconsin, the increased presence and abundance of brook trout dramatically improves the coldwater IBI scores. The presence of brook trout in the upper and lower reaches of Jericho Creek is consistent with the temperature data that shows these reaches to be colder than the middle section at CTH NN (see Water Quality section above). It is important to note that the brook trout located in the lower portion of Jericho Creek are stocked fishes, but the origin of brook trout in the upper reaches is currently unknown and there may be a

Table 21

FISH SPECIES COMPOSITION BY PHYSIOLOGICAL TOLERANCE AND REACH IN THE MUKWONAGO RIVER WATERSHED: 2000-2009

Species According to Their Relative Tolerance to Temperature	Stream Reach (see Map 22)					
	Jericho-2	Jericho-1	Beulah	Mukwonago-3	Mukwonago-2	Mukwonago-1
Primary Coldwater						
Brook Trout[a]	X	X	- -	- -	X	- -
Brown Trout[a]	- -	X	- -	- -	X	- -
Mottled Sculpin[b]	X	- -	- -	- -	X	- -
Primary Coolwater						
American Brook Lamprey	- -	- -	- -	- -	X	- -
Brook Stickleback[c]	X	X	- -	X	- -	- -
Northern Brook Lamprey	- -	- -	- -	- -	X	- -
Secondary Coolwater						
Blacknose Dace[c]	- -	X	- -	- -	X	
Central Mudminnow[c]	X	X	X	- -	X	X
Emerald Shiner	- -	- -	- -	- -	X	X
Fathead Minnow	X	- -	- -	- -	- -	- -
Iowa Darter	X	- -	X	- -	X	X
Johnny Darter	X	X	X	X	X	X
Logperch	- -	- -	- -	- -	- -	X
Northern Pike	- -	- -	- -	- -	X	X
Rock Bass[b]	- -	X	X	X	X	X
Spottail Shiner[b]	- -	- -	- -	- -	X	- -
Walleye	- -	- -	- -	- -	- -	X
White Sucker	X	X	X	- -	X	X
Yellow Perch	- -	- -	X	- -	X	X
Warmwater						
Banded Darter	- -	- -	- -	X	X	X
Banded Killifish	- -	- -	- -	- -	- -	X
Black Bullhead	X	- -	X	- -	X	X
Black Crappie	- -	- -	- -	- -	- -	X
Blackchin Shiner[b]	- -	- -	X	- -	X	- -
Blacknose Shiner[b]	X	X	- -	- -	X	X
Blackside Darter	- -	- -	- -	- -	- -	X
Blackstripe Topminnow	- -	- -	- -	- -	- -	X
Bluegill	X	X	X	X	X	X
Bluntnose Minnow[c]	X	X	- -	X	X	X
Bowfin	- -	- -	X	X	X	X
Brook Silverside	- -	- -	- -	- -	X	X
Brown Bullhead	- -	- -	- -	- -	- -	X
Central Stoneroller	X	X	- -	- -	X	- -
Channel Catfish	- -	- -	- -	- -	- -	X
Common Carp	- -	- -	- -	- -	X	X
Common Shiner	X	X	X	- -	X	X
Creek Chub[c]	X	X	- -	- -	X	- -
Fantail Darter	X	X	X	X	X	X
Golden Redhorse	- -	- -	- -	- -	- -	X
Golden Shiner[c]	X	X	- -	- -	- -	X
Goldfish	- -	- -	- -	- -	X	- -
Grass Pickerel	X	X	X	- -	X	X
Greater Redhorse	- -	- -	- -	- -	- -	X
Green Sunfish	X	- -	X	- -	X	X
Hornyhead Chub	X	X	- -	- -	X	X
Lake Chubsucker	X	X	X	X	X	X
Largemouth Bass	X	X	X	X	X	X
Largescale Stoneroller	- -	- -	- -	- -	- -	X
Least Darter	X	- -	- -	X	- -	- -
Longear Sunfish	X	- -	- -	- -	X	X
Orangespotted Sunfish	- -	- -	- -	- -	- -	X

Table 21 (continued)

Species According to Their Relative Tolerance to Temperature	Stream Reach (see Map 22)					
	Jericho-2	Jericho-1	Beulah	Mukwonago-3	Mukwonago-2	Mukwonago-1
Warmwater (continued)						
Pugnose Shiner	- -	- -	- -	- -	X	X
Pumpkinseed	X	- -	X	- -	X	X
Rainbow Darter	- -	- -	X	- -	- -	X
Rosyface Shiner	- -	- -	- -	- -	- -	X
Sand Shiner	X	X	- -	- -	- -	X
Spotfin Shiner	- -	- -	- -	- -	- -	X
Starhead Topminnow	- -	- -	- -	- -	X	X
Stonecat	- -	- -	- -	- -	- -	X
Tadpole Madtom	- -	- -	X	- -	X	X
Warmouth	- -	- -	X	- -	X	X
Weed Shiner	X	- -	- -	- -	- -	- -
Yellow Bullhead	X	X	X	X	X	X
Total Number of Species	28	22	21	12	41	49
Total Number of Samples	14	12	6	2	33	33
Warmwater IBI Range	Very poor-fair	Very poor-fair	Fair-Good	Very poor- fair	Very poor-fair	Excellent
Coldwater IBI Range	Poor-Fair	Very poor-good	Not applicable	Poor-Fair	Poor-Good	Not applicable

[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.

naturally reproducing population of brook trout. The coolwater and warmwater fish community in Jericho Creek is primarily located near CTH NN and it seems that the impoundments may be contributing to the maintenance of this assemblage of fishes. The lowest portion of reach Jericho-1 near the confluence with the Mukwonago River can switch between a coldwater and warmwater fishery. For example, based upon the temperature data that was collected between 2007 and 2009, during the summer of 2007, a fishery survey of this section of stream yielded a large number of brook trout. Based upon the temperature data (see Temperature section above), these brook trout must have been confined to this section of stream because temperatures both upstream and downstream were too warm to support trout. This also explains why a repeat survey of the same area during 2009 yielded no brook trout.

The warmwater IBI results are consistent with the species abundances shown in Table 21, which indicate that the quality of the fishery in the Mukwonago River watershed ranges from very poor (IBI score 0-20) in all reaches except Mukwonago-1 and Beulah outlet, to excellent (IBI score 70 to 85) in reach Mukwonago-1. Low warmwater IBI scores identify the vulnerability of the system to a variety of factors and influences on the fishery community, including; time of year (season) sampled, differences in gear type, discharge, and temperature. The excellent IBI score in Mukwonago-1 reach is consistent with the higher number of species recorded in that reach. Based on the temperature data acquired during the study period (2007-2009), the Mukwonago-1 and Beulah reaches are consistently warmwater streams, as reflected in the fish community structures within these reaches.

Map 39

FISH SAMPLING SITES WITHIN THE MUKWONAGO WATERSHED

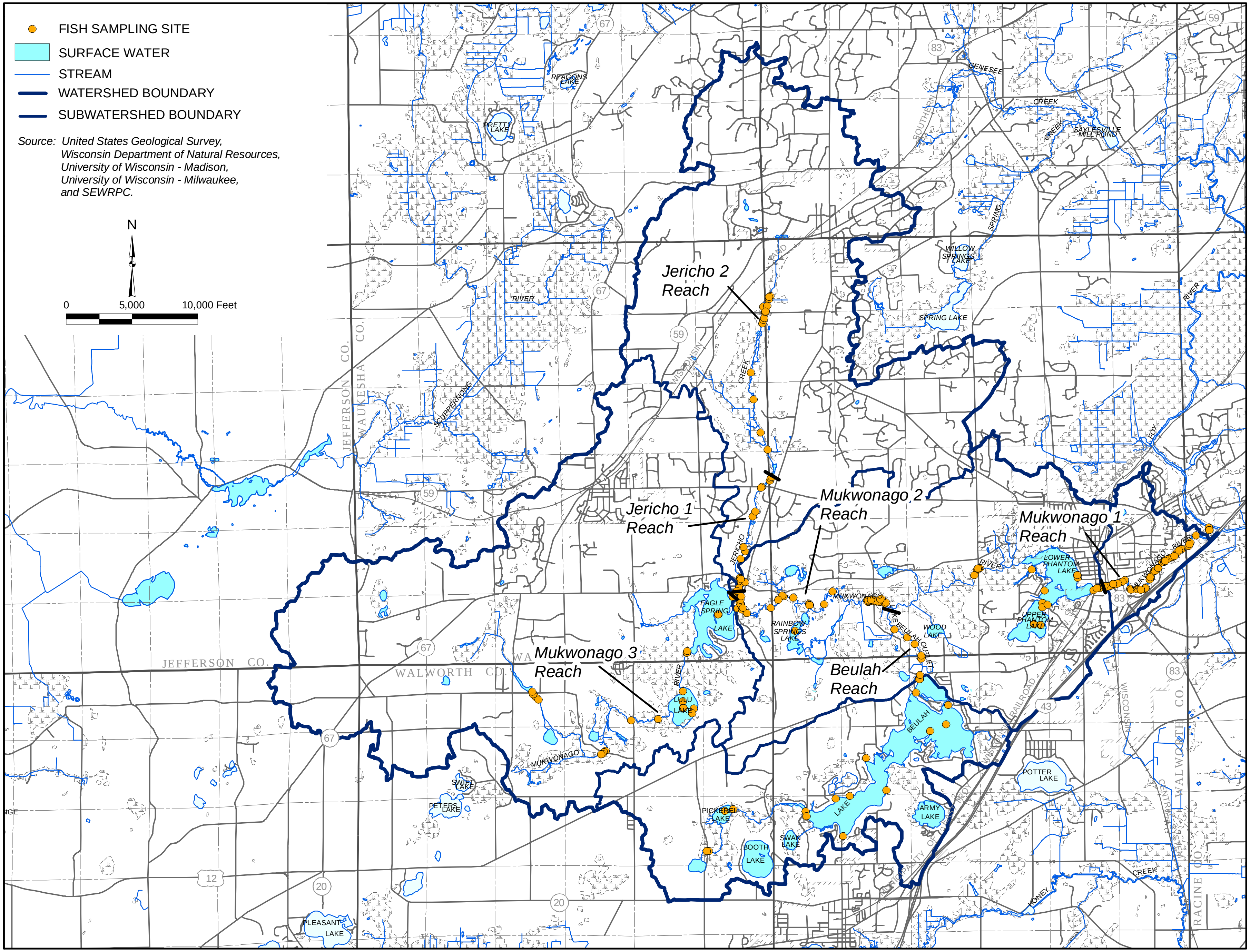

Figure 52

AMERICAN/NORTHERN BROOK LAMPREY IN THE MUKWONAGO RIVER WATERSHED: 2007

Source: SEWRPC.

Since the WDNR study began in 2003, the Mukwonago-1 reach has maintained consistently good environmental quality.[74] The warmwater IBI scores have varied little, ranging from 70-85 out of a possible 100 points, and have always rated as excellent. Fluctuations in IBI scores of 10-15 points or less are not considered to represent meaningful changes in environmental quality but rather are the result of normal natural fluctuations in fish community structure and sampling effectiveness. Although IBI scores have been stable and many species have been either consistently common (e.g., bluegill, longear sunfish, logperch) or consistently uncommon (e.g., common carp, channel catfish, yellow perch), some species have shown major inter-annual fluctuations in abundance. For example, only one black crappie was collected in 2005, eight in 2007, and 11 in 2009, but 220 were taken in 2008. Three or fewer bowfin were collected in each of the sampling years 2003, 2005, and 2006, but much higher numbers were captured in 2004 (101), 2007 (94), and 2008 (239). For most of the species with major year-to-year variations in abundance, when numbers were high, populations were dominated by small, young (young-of-the-year or yearling) individuals. This suggests that much of the variation among years was caused by fluctuations in reproductive success. Fish catches in 2009 were relatively high. The total catch of fish (3,762) and the IBI score (85) were the highest in seven years of sampling, and the total number of species (39) was the second highest. Several species had their greatest catches, most notably the longear sunfish with 707 individuals being caught during 2009. High fish abundances may have been a consequence of elevated baseflows in the river during 2008 and 2009, caused by the record rainfall in June 2008.

Historic fisheries records from WDNR files indicate that both brook and brown trout have been stocked almost annually within the Mukwonago River since 1988 and within Jericho Creek since 2001, as shown in Table 22. Adult brown and brook trout have been observed in the Mukwonago River and Jericho Creek, but there is no evidence to date that these species are successfully reproducing within either system.

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[74]Ibid.

Table 22

FISH STOCKING REPORT FOR STREAMS IN THE MUKWONAGO RIVER WATERSHED: 1988-2008

Stream and Year	Species	Strain	Age Class	Number Stocked	Average Length (inches)
Mukwonago River[a]					
1988	Brown trout	Unspecified	Fingerling	10,000	7.00
1990	Brown trout	Unspecified	Fingerling	5,000	7.00
1990	Brown trout	Unspecified	Yearling	5,000	6.00
1992	Brown trout	Unspecified	Yearling	1,250	9.00
1993	Brown trout	Unspecified	Yearling	1,000	8.60
1994	Brown trout	Unspecified	Fingerling	9,000	5.60
1994	Brown trout	Unspecified	Yearling	3,000	9.00
1994	Rainbow trout	Unspecified	Yearling	800	10.00
1995	Brown trout	Unspecified	Fingerling	4,000	5.30
1996	Brown trout	Unspecified	Fingerling	6,670	6.30
1997	Brown trout	St. Croix	Large fingerling	6,775	5.20
1998	Brown trout	St. Croix	Large fingerling	4,960	6.20
1999	Brown trout	Timber Coulee-Southwest Feral	Fry	16,000	0.90
1999	Brown trout	St. Croix	Large fingerling	5,000	- -
2000	Brown trout	St. Croix	Large fingerling	5,000	- -
2001	Brown trout	St. Croix	Large fingerling	5,000	- -
2001	Brown trout	Timber Coulee-Southwest Feral	Large fingerling	2,000	2.90
2002	Brook trout	St. Croix	Large fingerling	5,000	6.20
2002	Brown trout	St. Croix	Large fingerling	6,500	5.20
2003	Brook trout	St. Croix	Large fingerling	4,317	6.10
2003	Brown trout	St. Croix	Large fingerling	6,500	5.60
2004	Brook trout	St. Croix	Large fingerling	5,000	6.50
2004	Brown trout	St. Croix	Large fingerling	5,000	5.00
2005	Brook trout	Ash Creek-Southwest Feral	Large fingerling	2,160	4.40
2005	Brown trout	Timber Coulee-Southwest Feral	Large fingerling	5,000	3.40
2006	Brook trout	St. Croix	Large fingerling	5,000	5.80
2006	Brown trout	St. Croix	Large fingerling	5,415	5.10
2007	Brook trout	Ash Creek - Southwest Feral	Large fingerling	300	4.00
2007	Brook trout	St. Croix	Large fingerling	5,000	5.90
2007	Brown trout	St. Croix	Large fingerling	5,000	5.70
2008	Brook trout	St. Croix	Large fingerling	6,000	5.70
Jericho Creek[b]					
2001	Brown trout	Timber Coulee-Southwest Feral	Large fingerling	750	2.90
2002	Brook trout	St. Croix	Large fingerling	1,500	6.30
2004	Brook trout	St. Croix	Large fingerling	1,200	6.50
2004	Brown trout	St. Croix	Large fingerling	1,500	5.00
2005	Brook trout	Ash Creek-Southwest Feral	Large fingerling	648	4.20
2005	Brown trout	Timber Coulee-Southwest Feral	Large fingerling	1,500	3.00
2006	Brook trout	St. Croix	Large fingerling	1,500	5.80
2006	Brown trout	St. Croix	Large fingerling	1,622	5.10
2007	Brook trout	St. Croix	Large fingerling	1,500	5.90
2007	Brown trout	St. Croix	Large fingerling	1,500	5.70
2008	Brook trout	St. Croix	Large fingerling	1,800	5.70

[a]*Fish are stocked into the Mukwonago River at CTH E downstream of Eagle Spring Lake.*

[b]*Fish are stocked into Jericho Creek at CTH LO.*

Source: Wisconsin Department of Natural Resources.

Fishes of the Mukwonago River Watershed Lakes

There have been no known fish kills reported by the WDNR for any of the lakes within the Mukwonago River watershed. However, these lakes have been reported as having unbalanced fish communities, containing a high proportion of largemouth bass with low average sizes, an abundance of small predatory fishes, and low numbers of large predatory fishes; namely, largemouth bass and northern pike. Fish community diversity within the Lakes is shown in Table 23. The differences in the numbers of fish species caught in each Lake is likely to be due to differences in gear type, sampling effort, and time of year sampled.

Table 23

FISH SPECIES PRESENCE AMONG LAKES WITHIN THE MUKWONAGO RIVER WATERSHED: 1958-2009

	Waterbody and Year											
	Lulu Lake		Eagle Spring Lake		Rainbow Springs Lake	Upper Phantom Lake		Lower Phantom Lake		Pickerel Lake	Lake Beulah	
Species and Tolerance	1958-1999	2000-2009	1958-1999	2000-2009	1958-1999	1958-1999	2000-2009	1958-1999	2000-2009	1958-1999	1958-1999	2000-2009
Intermediate												
Banded Killifish[a]	X	- -	X	X	- -	X	X	X	- -	X	X	X
Black Crappie	- -	X	X	- -	- -	X	X	X	X	- -	X	X
Blackside Darter	- -	- -	- -	- -	- -	X	- -	- -	- -	- -	- -	- -
Blackstripe Topminnow	- -	X	- -	- -	- -	X	- -	- -	- -	- -	- -	- -
Bluegill	X	X	X	X	X	X	X	X	X	X	X	X
Bowfin	X	X	X	X	X	X	X	X	X	- -	X	X
Brook Silverside	X	X	X	X	X	X	X	X	X	- -	X	X
Brown Trout	X	X	X	X	X	X	X	- -	- -	- -	- -	X
Cisco	X	- -	X	- -	- -	- -	- -	- -	- -	- -	- -	- -
Common Shiner	- -	- -	- -	- -	- -	X	- -	- -	- -	- -	- -	- -
Emerald Shiner	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X	- -
Fantail Darter	- -	- -	X	X	- -	X	X	X	X	- -	X	X
Grass Pickerel	- -	X	X	X	- -	X	X	X	X	- -	X	X
Johnny Darter	- -	- -	- -	- -	- -	X	X	X		- -	X	X
Lake Chubsucker[a]	X	X	X	X	- -	X	X	X	X	- -	X	X
Largemouth Bass	X	X	X	X	X	X	X	X	X	X	X	X
Longnose Gar	- -	- -	- -	- -	- -	- -	X	- -	- -	- -	X	X
Northern Pike	X	X	X	X	- -	X	X	X	X	- -	X	X
Pumpkinseed	X	X	X	X	- -	X	X	X	X	- -	X	X
Sand Shiner	- -	- -	X	- -	- -	- -	- -	- -	- -	- -	X	X
Starhead Topminnow[b]	- -	- -	X	- -	- -	X	- -	X	- -	- -	X	X
Walleye	- -	- -	X	X	- -	X	X	- -	X	- -	X	X
Warmouth	X	X	X	X	X	X	X	X	X	X	X	X
White Bass	- -	X	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
White Crappie	- -	- -	- -	X	- -	- -	- -	X	- -	- -	X	- -
Yellow Perch	X	X	X	X	X	X	X	X	X	X	X	X
Intolerant												
Blackchin Shiner	X	X	X	X	- -	X	X	X	X	- -	X	X
Blacknose Shiner	X	X	X	X	- -	X	X	X	X	- -	X	X
Iowa Darter	X	- -	X	- -	- -	X	X	X	- -	- -	X	X
Least Darter[a]	- -	- -	- -	X	- -	- -	X	- -	- -	- -	X	- -
Pugnose Shiner[c]	- -	X	X	- -	X	X	X	X	X	- -	X	- -
Rainbow Darter	- -	- -	- -	- -	- -	X	- -	X	- -	- -	X	X
Rock Bass	X	X	X	X	- -	X	X	X	X	- -	X	X
Smallmouth Bass	- -	- -	- -	- -	- -	- -	X	X	- -	- -	X	- -

Table 23 (continued)

Species and Tolerance	Waterbody and Year											
	Lulu Lake		Eagle Spring Lake		Rainbow Springs Lake	Upper Phantom Lake		Lower Phantom Lake		Pickerel Lake	Lake Beulah	
	1958-1999	2000-2009	1958-1999	2000-2009	1958-1999	1958-1999	2000-2009	1958-1999	2000-2009	1958-1999	1958-1999	2000-2009
Tolerant												
Black Bullhead	X	X	- -	X	X	X	- -	- -	- -	- -	X	X
Bluntnose Minnow	X	X	X	X	- -	X	X	X	X	X	X	X
Brown Bullhead	X	X	X	X	- -	X	X	X	X	- -	X	X
Central Mudminnow	- -	- -	- -	- -	- -	- -	X	X	- -	- -	X	X
Common Carp	X	X	- -	X	- -	- -	X	- -	X	- -	- -	- -
Fathead Minnow	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	X	- -
Golden Shiner	- -	- -	- -	- -	- -	X	X	X	- -	- -	X	X
Green Sunfish	- -	- -	X	X	- -	X	X	X	X	- -	X	- -
White Sucker	- -	X	- -	- -	- -	- -	- -	- -	- -	- -	X	- -
Yellow Bullhead	X	X	X	X	- -	X	X	X	X	- -	X	X
Total Species	21	24	27	25	43	32	31	29	23	6	37	30
Total Samples	10	15	20	20	1	11	17	13	3	1	33	24

[a] *Designated species of special concern.*

[b] *Designated endangered species.*

[c] *Designated threatened species.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Eagle Spring Lake and Lulu Lake are well-connected and contain a moderately diverse fish community. Northern pike fingerlings were stocked annually into Eagle Spring Lake from 1992 to 2006 in an effort to establish a larger population of this gamefish species (see Table 24), and to redress the imbalance in the largemouth bass population. However, the northern pike fishery continues to remain limited in this system.[75] Consequently, mandatory slot size regulations excluding 14- to 18-inch largemouth bass from the harvest were established by the WDNR to protect and enhance this species. There are no minimum size limits for largemouth bass of less than 14 inches and a bag limit of one largemouth bass greater than 18 inches, with a maximum of three largemouth bass in total. Recent data suggest that these management measures, geared toward reversing the unbalanced fishery, have begun to be effective. However, to complicate matters, it is also not known how much the fishery within Eagle Spring Lake depends upon Lulu Lake. It has been well documented in the mark-recapture surveys conducted by the WDNR that limited numbers of marked largemouth bass and carp in Eagle Spring Lake were found in Lulu Lake and *vice versa*. Likewise, these lakes are well within the documented normal movement ranges of bluegill,[76] largemouth bass,[77] and northern pike,[78] and the size frequency distributions of bluegill and largemouth bass are very similar between Eagle Spring and Lulu Lakes, which seems to support the idea that these species may be readily immigrating and emigrating between these lakes.[79]

In 2009, a comprehensive fishery survey was completed by the WDNR on the Phantom Lakes, with the goal of estimating the abundance and size structure of the gamefish, panfish, and nongame fish species. Walleye and northern pike fingerlings have been stocked into the Phantom Lakes almost annually since 1997, as shown in Table 24. During the 2009 WDNR survey, very few northern pike were captured, and they were below the 26-inch-slot size, which indicated a high angler harvest and predation from largemouth bass. Largemouth bass were the dominant gamefish in the system, and had a large variety of year classes which indicated good recruitment and spawning success. The minimum size limit for largemouth bass is 14 inches on both Upper and Lower Phantom Lakes. Bluegill dominated the panfish catch, and their high abundance and slow growth rates are indicative of shallow weedy lakes such as Lower Phantom Lake. A good diversity of warmouth, pumpkinseed, black crappie, and green sunfish was also present in the sample.

Lake Beulah contained a moderately diverse fish community. Fish stocking in this Lake has fluctuated since the program began in 1973 (see Table 24). Brown trout have been stocked almost annually since 1978, and more recently, northern pike and walleye have been added to the list of stocked fish.

Carp have been a part of the fish communities in all of the major lakes within the watershed for a long time; however, this species has not historically been a dominant component of the fishery. However, carp have increased in abundance within Eagle Spring and Lulu Lakes as documented in WDNR targeted surveys and efforts

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[75]*SEWRPC Community Assistance Planning Report No. 226, 2nd Edition,* A Lake Management Plan for Eagle Spring Lake, Walworth County, Wisconsin, *in preparation.*

[76]*Paukert, et al., "Movement, home range, and site fidelity of bluegills in a Great Plains lake,"* North American Journal of Fisheries Management, *Volume 24, pages 154-161, 2004.*

[77]*Hanson, et al., "Assessment of largemouth bass (Micropterus salmoides) behavior and activity at multiple spatial and temporal scales utilizing a whole-lake telemetry array"* Hydrobiologia, *Volume 58, pages 243-256, 2007.*

[78]*Kobler, et al., Contrasting northern pike (Esox lucius L.) movement and habitat choice between summer and winter in a small lake,* Hydrobiologia, *Volume 601, Number 1, pages 17-27, 2008; Vehanen, et al., Patterns of movement of adult northern pike (*Esox lucius L*) in a regulated river,* Ecology of Freshwater Fish, *Volume 15, Number 2, pages 154-160, 2006.*

[79]*SEWRPC Community Assistance Planning Report No. 226, 2nd Edition,* op. cit.

Table 24

FISH STOCKING REPORT FOR LAKES IN THE MUKWONAGO RIVER WATERSHED: 1973-2008

Year	Species	Strain	Age Class	Number Stocked	Average Length (inches)
Eagle Spring Lake					
1992	Northern pike	Unspecified	Fingerling	307	8.00
1993	Northern pike	Unspecified	Fingerling	500	8.00
1994	Northern pike	Unspecified	Fingerling	3,110	5.75
1996	Northern pike	Unspecified	Fingerling	1,820	4.30
1998	Northern pike	Unspecified	Small fingerling	1,500	- -
1999	Northern pike	Unspecified	Small fingerling	1,740	2.40
2000	Northern pike	Unspecified	Small fingerling	1,600	3.45
2001	Northern pike	Lake Puckaway	Small fingerling	3,620	2.60
2002	Northern pike	Lake Puckaway	Small fingerling	1,555	3.10
2005	Northern pike	Lake Puckaway	Small fingerling	1,555	2.20
2006	Northern pike	Lake Puckaway	Large fingerling	1,250	6.00
2008	Northern pike	Unspecified	Large fingerling	2,000	7.00
Lake Beulah					
1973	Rainbow trout	Unspecified	Yearling	30,007	8.56
1974	Rainbow trout	Unspecified	Adult	210	15.00
1974	Rainbow trout	Unspecified	Fingerling	7,000	9.00
1974	Rainbow trout	Unspecified	Yearling	18,000	7.00
1975	Rainbow trout	Unspecified	Yearling	16,001	- -
1976	Rainbow trout	Unspecified	Yearling	12,000	- -
1978	Brown trout	Unspecified	Yearling	6,000	- -
1978	Rainbow trout	Unspecified	Yearling	6,000	- -
1979	Brown trout	Unspecified	Yearling	6,000	- -
1979	Rainbow trout	Unspecified	Yearling	10,500	- -
1980	Brown trout	Unspecified	Fingerling	8,100	7.00
1980	Brown trout	Unspecified	Yearling	7,600	- -
1982	Northern pike	Unspecified	Yearling	130	- -
1984	Brown trout	Unspecified	Fingerling	1,000	5.00
1985	Brown trout	Unspecified	Fingerling	1,000	5.00
1986	Brown trout	Unspecified	Fingerling	1,500	4.00
1987	Brown trout	Unspecified	Fingerling	3,000	5.00
1988	Brown trout	Unspecified	Fingerling	2,000	7.00
1990	Brown trout	Unspecified	Fingerling	1,000	7.00
1994	Brown trout	Unspecified	Fingerling	1,000	5.60
1999	Brown trout	St. Croix	Yearling	1,000	- -
2000	Brown trout	St. Croix	Yearling	1,000	9.00
2001	Brown trout	St. Croix	Yearling	1,500	1.00
2002	Brown trout	St. Croix	Yearling	1,000	9.20
2003	Brown trout	St. Croix	Yearling	5,500	9.30
2005	Walleye	Lake Michigan	Small fingerling	32,701	1.40
2005	Walleye	Rock-Fox	Small fingerling	8,999	1.60
2006	Northern pike	Puckaway	Large fingerling	5,010	7.00
2006	Brown trout	St. Croix	Yearling	6,088	9.70
2007	Brown trout	St. Croix	Yearling	8,340	9.20
2008	Northern pike	Mud Lake	Large fingerling	2,176	10.20
2008	Brown trout	St. Croix	Yearling	8,340	9.10
Lower Phantom Lake					
1997	Walleye	Unspecified	Large fingerling	40,000	2.70
1998	Northern pike	Unspecified	Small fingerling	2,166	3.90
1999	Northern pike	Unspecified	Small fingerling	3,280	2.40
2000	Northern pike	Unspecified	Small fingerling	2,300	3.45
2000	Walleye	Unspecified	Small fingerling	43,000	1.70
2001	Northern pike	Unspecified	Small fingerling	6,495	3.60
2001	Walleye	Unspecified	Small fingerling	55,500	2.40
2002	Walleye	Mississippi Headwaters	Large fingerling	4,330	6.60
2002	Northern pike	Puckaway	Small fingerling	1,100	3.10
2005	Northern pike	Puckaway	Small fingerling	2,100	2.70
2006	Northern pike	Puckaway	Small fingerling	2,535	2.40
2006	Walleye	Mississippi Headwaters	Small fingerling	15,189	1.50
2008	Northern pike	Unspecified	Large fingerling	1,988	7.30

Table 24 (continued)

Year	Species	Strain	Age Class	Number Stocked	Average Length (inches)
Upper Phantom Lake					
1995	Walleye	Unspecified	Fingerling	5,550	2.10
1997	Walleye	Unspecified	Large fingerling	68,490	2.30
1998	Largemouth bass	Unspecified	Large fingerling	9,600	3.75
2000	Walleye	Unspecified	Small fingerling	10,700	1.70
2002	Walleye	Mississippi Headwaters	Large fingerling	1,070	6.60
2008	Northern pike	Unspecified	Large fingerling	924	9.30
Mukwonago Park (Roxy) Pond					
1986	Brown trout	Unspecified	Fingerling	4,500	3.00
1988	Brown trout	Unspecified	Yearling	1,200	9.00
1988	Largemouth bass	Unspecified	Fingerling	200	5.00
1988	Rainbow trout	Unspecified	Yearling	2,000	9.00

Source: Wisconsin Department of Natural Resources

to reduce their numbers are being considered by the WDNR and the Eagle Spring Lake Management District. Carp are a tolerant fish species that can significantly degrade water quality and habitat conditions for other fish species when they become dominant; hence, they are considered an injurious species in lakes. Carp can be extremely disruptive to the aquatic vegetation that provides habitat and shelter for more desirable species of fishes,[80] as well as increase lake turbidity levels through resuspension of sediments when carp densities get high enough.[81] Carp are benthivorous fishes and ingest sediment to obtain food particles by filtering material through their gill rakers.[82] Carp can process up to five times their body weight per day and the fine particles that are not retained by the fish become suspended in the water. Recent studies have shown that the small pits on the sediment surface that are left over from feeding carp greatly reduce erosion resistance, making the sediment more susceptible to resuspension through wind and/or motor boat activity.[83] Since shallow lakes are naturally much more susceptible to increased turbidity levels from wind and motor boat activity than deep lakes, carp potentially have a much greater synergistic impact on water quality within the shallow Eagle Spring and Lower Phantom Lakes.

Loss of habitat is a primary concern of any fisheries management program, and it has become well understood that littoral zone habitat and fishery degradation is highly associated with lake shore residential development.[84]

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[80]*Becker,* Fishes of Wisconsin, *University of Wisconsin Press, Madison, 1983.*

[81]*Breukelaar, et al., "Effect of benthivorous bream (*Abamis brama*) and carp (*Cyprinus carpio*) on resuspension,"* Internationale Vereinigung für Theoretische und Angewandte Limnologie: Verhandlungen, *Volume 25, Number 4, pages 2144-2147, 1994.*

[82]*Lammens and Hoogenboezem,* "Diets and feeding behavior," *In Cyprinid Fishes: Systematics, biology, and exploitation, Chapman and Hall, New York. Pages 353-376, 1991.*

[83]*Scheffer, et al., "Catastrophic regime shifts in ecosystems: Linking theory to observatioin,"* TRENDS in Ecology and Evolution, *Volume 18, Number 12, pages 648-656, 2003.*

[84]*Jennings, et al., "Is littoral habitat affected by residential development and land use in watersheds of Wisconsin lakes?,"* Lake and Reservoir Management, *Volume 19, Number 3, pages 272-279, 1999, 2003; Schindler, et al., "Patterns of fish growth along a residential development gradient in north temperate lakes,"* Ecosystems, *Volume 3, pages 229-237, 2000.*

The shorelines of Eagle Spring Lake, Upper and Lower Phantom Lakes, and Lake Beulah are largely fully developed as residential communities, and generally have disturbed or modified shoreland areas. Thus, there is significant fisheries value in protecting the remaining highest quality natural shoreline on each Lake. Since the types and quality of habitat for bluegill, largemouth bass, and northern pike have not been quantified, it is not known if a particular habitat type is limiting one or more of these species or one or more parts of their life histories (i.e., spawning, egg development, fry, juvenile, adults) within the Lakes.

Mussels

Freshwater mussels are large bivalve (two-shelled) mollusks that live in the sediments of rivers, streams, and some lakes. Mussels are considered one of the most endangered families of animals in North America. These soft-bodied animals are enclosed by two shells made mostly of calcium and connected by a hinge. Mussels can typically be found anchored in the substrate, with only their siphons occasionally exposed. They typically favor sand, gravel, and cobble substrates (see Figure 53). They play an important part in aquatic ecosystems by helping stabilize river bottoms; serving as natural water filters; providing excellent spawning habitat for fish; and serving as food for fish, birds, and some mammals. Live mussels and relic shells provide a relatively stable substrate in dynamic riverine environments for a variety of other macroinvertebrates such as caddis flies and mayflies and for algae.

Mussels require moving water to provide incoming food and oxygen and to eliminate waste. They draw in water from which they filter fine organic matter such as algae and detritus. A single mussel can filter several gallons of water per day, which means mussels can improve water quality by removing sediment and associated contaminants from water. Many species are slow growing and long-lived animals, surviving for as long as 100 years. Most mussel species are sessile, moving only short distances their entire life, maneuvering by way of a muscular fleshy foot extended from the shell. Movement is often triggered by changing water levels or other environmental conditions. During periods of stress (temperature extremes, drought, pollutants), many species will burrow deep into the sediment, sometimes surviving until the stressor has passed. Growth rings on mussel shells can determine their age; accumulating a defined line indicating a period of no growth, and these lines can be used to glean information about historical water quality and disturbance. Mussels serve as good indicators of ecosystem health because they are relatively long-lived and sessile, and depend on good water quality and physical habitat.

Mussels are viewed as important, sensitive indicators of changing environmental conditions. Water and sediment quality are important habitat criteria for mussels. Most species of freshwater mussels prefer clean running water with high oxygen content, and all species are susceptible to pollution including pesticides, heavy metals, ammonia, and algal toxins. Mussels can be used to document changes in water quality over long periods of time since they are long-lived. Shells accumulate metals from both water and sediment, so testing heavy metal concentrations in shells can tell researchers when water in a given area was first contaminated. The presence or absence of a particular mussel species provides information about long-term water health. Because juvenile forms of mussels are more susceptible to pollution than the adult forms, finding juveniles with few adults nearby may indicate a newly colonized area. In general, having healthy diverse populations of mussels means the water quality is good.

The freshwater mussel has a unique life cycle, including a short parasitic stage attached to a fish.[85] Reproduction occurs when a male mussel releases sperm into the water column, which is siphoned into the female mussel to fertilize the eggs. Reproduction may be triggered by increasing water temperature and/or day length, and development and retention of larvae within the female may last from one to 10 months. Glochidia (immature mussels) are generally released from the female in spring and early summer (April to July). The glochidia

[85]*U.S. Geological Survey, Ecological Status and Trends of the Upper Mississippi River System, 1998: A Report of the Long Term Resource Monitoring Program, April 1999, LTRMP 99-T001.*

Figure 53

EXAMPLE OF LIVE AND DEAD MUSSELS IN GRAVEL AND SAND SUBSTRATES ON THE MUKWONAGO RIVER: 2008

Source: SEWRPC.

(immature mussels) must attach to the gills of a fish to obtain nutrients from blood serum. Mussels need host fish to carry their young through the waterways in order for them to survive, grow, and disperse. Female mussels either release the glochidia into the water in a sac called a conglutinate (made to look like food for their host fish), wherein the glochidia can survive for only a short period of time without a fish host, or they have developed specific adaptations including an enlarged mantle tissue flap that look like the prey organisms (worms, insect larva, small fish, or crayfish) which attract a fish host looking for food. When fish nip at these structures which resemble potential food items, the female releases glochidia into the water column that attach to the gills or fins of the fish host. As parasites, glochidia are dependent on fish for their nutrition at this stage in their life. Some mussels may depend on only a single fish species, whereas others can parasitize many different fishes. The attachment of glochidia causes no problems for the host fish. After the glochidia take at least a two- to three-week ride on the fish as a benign parasite, they drop off and land in the bed of a new stretch of a stream, river, or lake where they may grow and stay for more than a half century. Mussels have a variety of fish host species, and can range in number from as little as one to as many as 35 for species found within the Mukwonago River watershed. Mussel characteristics and potential host fish species are shown in Table 25.

Exploitation, changing water quality, and invasive species all are threats to these invertebrates. Siltation, chemical pollution, loss of habitat through creation of impoundments, channelization or other stream modifications, predation, and impacts from invasive species are common factors responsible for the decline of freshwater mussels (see Figure 54). Adult mussels are eaten by muskrats, otters, and raccoons; young mussels are eaten by ducks, wading birds, and fish. Historically, freshwater mussels were used by Native Americans as food, source materials for tools, and ornamental objects. They were also important commercially in modern society, beginning around the 1890s, when mussels were harvested and used in the manufacture of buttons for clothing.

Invasive species such as zebra mussels pose a significant threat to native mussel populations for several reasons. Their reproduction is much simpler than other freshwater mussels because they do not require a fish host; rather, they develop as planktonic organisms called veligers that drift in the current until they become large enough to attach to the stream bottom or another object. Zebra mussels produce thousands of veligers and can reproduce several times per year. Zebra mussels have the ability to attach to the shells of native mussels, allowing them to directly interfere with successful reproduction in addition to competing for food (see Figure 54). Other invasive mussel species include the Asian clam, and the quagga mussel, which will also compete with native mussels for habitat and food.

Table 25

CHARACTERISTICS OF MUSSEL SPECIES FOUND TO OCCUR WITHIN THE MUKWONAGO RIVER WATERSHED

Species	Maximum Size	Habitat	Potential Host Fish Species[a]	
			Occur in Mukwonago River	Not Found in Mukwonago
Creek Heelsplitter[b]	4 inches	Creeks and small streams, in sand and fine gravel	Black bullhead, yellow bulhead, brook stickleback, green sunfish, orangespotted sunfish, bluegill, smallmouth bass, emerald shiner, yellow perch, longnose dace, black crappie, creek chub, spotfin shiner	Slimy sculpin, gizzard shad, shortnose gar, mimic shiner, flathead catfish, brassy minnow, silver shiner
Creeper	4 inches	Creeks, small streams, and occasionally large rivers in mud, sand, and gravel	Rock bass, yellow bullhead, black bullhead, channel catfish, central stoneroller, brook stickleback, fantail darter, Iowa darter, rainbow darter, blackside darter, johnny darter, logperch, green sunfish, pumpkinseed, bluegill, longear sunfish, white crappie, black crappie, creek chub, common shiner, spotfin shiner, sand shiner, bluntnose minnow, fathead minnow, blacknose dace, longnose dace, central mudminnow, yellow perch, largemouth bass, smallmouth bass	Northern redbelly dace, burbot, walleye
Cylindrical Papershell	3.5 inches	Creeks and small streams, in sand and mud; common headwater species	White sucker, mottled sculpin, spotfin shiner, brook stickleback, Iowa darter, bluegill, common shiner, largemouth bass, blacknose shiner, bluntnose minnow, fathead minnow, black crappie	Sea lamprey
Elktoe[b]	4 inches	Medium to large rivers, in sand and gravel	Rock bass, white sucker, northern hogsucker, warmouth	Shorthead redhorse
Ellipse[c]	3 inches	Sand, gravel, and small cobble in small to large streams	Mottled sculpin, slimy sculpin, brook stickleback, Iowa darter, johnny darter, fantail darter, greenside darter, rainbow darter, logperch, blackside darter, and orange throat darter	Slimy sculpin, greenside darter, orange throat darter
Fatmucket	5 inches	Small streams to large rivers as well as ponds and lakes in silt, sand, and gravel	Smallmouth bass, largemouth bass, white bass, tadpole madtom, yellow perch, bluntnose minnow, white crappie, black crappie, sauger, walleye, bluegill, green sunfish, longear sunfish, sand shiner, rock bass, white sucker, pumpkinseed, warmouth, striped shiner, common shiner	White bass, sauger, walleye, striped shiner
Giant Floater	10 inches	Small streams to large rivers, ponds to lakes; silt, sand, and gravel	- -[d]	- -
Lilliput	1.5 inches	Rivers, ponds, and lakes in mud, sand, or gravel	Bluegill, green sunfish, orangespotted sunfish, warmouth, white crappie	- -
Plain Pocketbook	7 inches	Small streams to large rivers in stable, compacted mud, through stable sand or gravel	Green sunfish, bluegill, smallmouth bass, largemouth bass, yellow perch, white crappie	Tiger salamander, sauger, walleye
Rainbow[e]	3 inches	Small to medium sized rivers in silty sand to gravel	Mottled sculpin, greenside darter, rainbow darter, green sunfish, largemouth bass, smallmouth bass, striped shiner, yellow perch, rock bass	Greenside darter, striped shiner

Table 25 (continued)

Species	Maximum Size	Habitat	Potential Host Fish Species[a]	
			Occur in Mukwonago River	Not Found in Mukwonago
Round Pigtoe[b]	3-4 inches	Small to large streams in mud, sand, and gravel	Spotfin shiner, central stoneroller, bluntnose minnow, bluegill	Northern redbelly dace, southern redbelly dace
Slippershell	1.5 inches	Creeks and headwater streams, in sand, mud, or fine gravel	Johnny darter, mottled sculpin	Banded sculpin
Spike	5.5 inches	Small stream to large rivers and occasionally in lakes; silt, sand, and gravel	White crappie, black crappie	Gizzard shad, flathead catfish
Threeridge	8 inches	Compacted mud, sandy or gravel areas of smaller streams to large rivers	Rock bass, northern pike, green sunfish, pumpkinseed, warmouth, bluegill, largemouth bass, yellow perch, white crappie, black crappie	Shortnose gar, sauger, white bass, flathead catfish
Wabash Pigtoe	4 inches	Creeks, small streams, and large rivers in mud, sand, and gravel	Bluegill, white crappie, black crappie, creek chub	Silver shiner
White Heelsplitter	8 inches	Small streams to large rivers in mud, sand, and gravel	Common carp, banded killifish, green sunfish, orangespotted sunfish, largemouth bass, longnose gar, white crappie	Gizzard shad, river redhorse, walleye

[a]*This information is adapted from "A Field Guide to the Freshwater Mussels of Chicago Wilderness" and can be found at* www.fieldmuseum.org*.*

[b]*Designated species of special concern.*

[c]*Designated threatened species.*

[d]*This mussel species is listed as having over 35 potential fish hosts that were not listed in the field guide referenced above.*

[e]*Designated endangered species.*

Source: SEWRPC.

Figure 54

THREATS TO NATIVE MUSSEL POPULATIONS: 2008

INVASIVE SPECIES

PREDATION

Source: SEWRPC.

The Mukwonago River is one of the most biologically rich mussel habitats in the state, with 16 mussel species having been found, including the only remaining viable population in the State of Wisconsin of the State-endangered rainbow shell *(Villosa iris)* (see Map 40, Table 26, and Figure 55). The Mukwonago-1 reach is the most diverse, containing all 16 of the mussel species found within the watershed. The only additional reaches sampled for mussels were the Mukwonago-2 and Jericho-1 reaches, each of which contained a total of six species. Differences in the total number of species between the reaches can be attributed to several possible reasons, including the abundance and diversity of fish host species—Mukwonago-1 reach has the most abundant and diverse fishery in the watershed, so it follows that the mussel population would be equally diverse—and the total number of samples (there were 19 more sites sampled in the Mukwonago-1 reach than the Mukwonago-2 or Jericho-1 reaches). Jericho Creek also may contain fewer species than the Mukwonago reaches due to its smaller overall size.

Prior to 2006, many of the mussel beds in the Mukwonago River and its tributaries were seriously depleted due to intentional harvesting. At the time, the harvesting was not illegal, and rules were in place that allowed each individual to harvest up to 50 pounds of mussels per day, although threatened and endangered species could not be harvested. One problem with that rule was the fact that even experts had a hard time identifying individual mussel species. In 2006, the Conservation Congress closed all inland waters to mussel harvest, which greatly benefited the population of mussels in the Mukwonago River. Signs to this effect are posted at sites along the Mukwonago River as shown in Figure 56.

Currently, the WDNR Bureau of Endangered Resources is working with citizen scientists to create a new mussel monitoring program to update the data on mussel distribution statewide. Researchers are enlisting the help of volunteers by contracting with schools, nature centers, and interested individuals, and are providing training to conduct stream surveys under the auspices of the Mussel Monitoring Program of Wisconsin.[86] Volunteers wade in

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[86]*Heather Kaarakka, Wisconsin Department of Natural Resources, "Several paths to build up mussels,"* Wisconsin Natural Resources Magazine, *June 2010.(*http://dnr.wi.gov/wnrmag/2010/06/mussels.htm).

Map 40

MUSSEL SAMPLE LOCATIONS WITHIN THE MUKWONAGO RIVER WATERSHED: 1973 - 2001

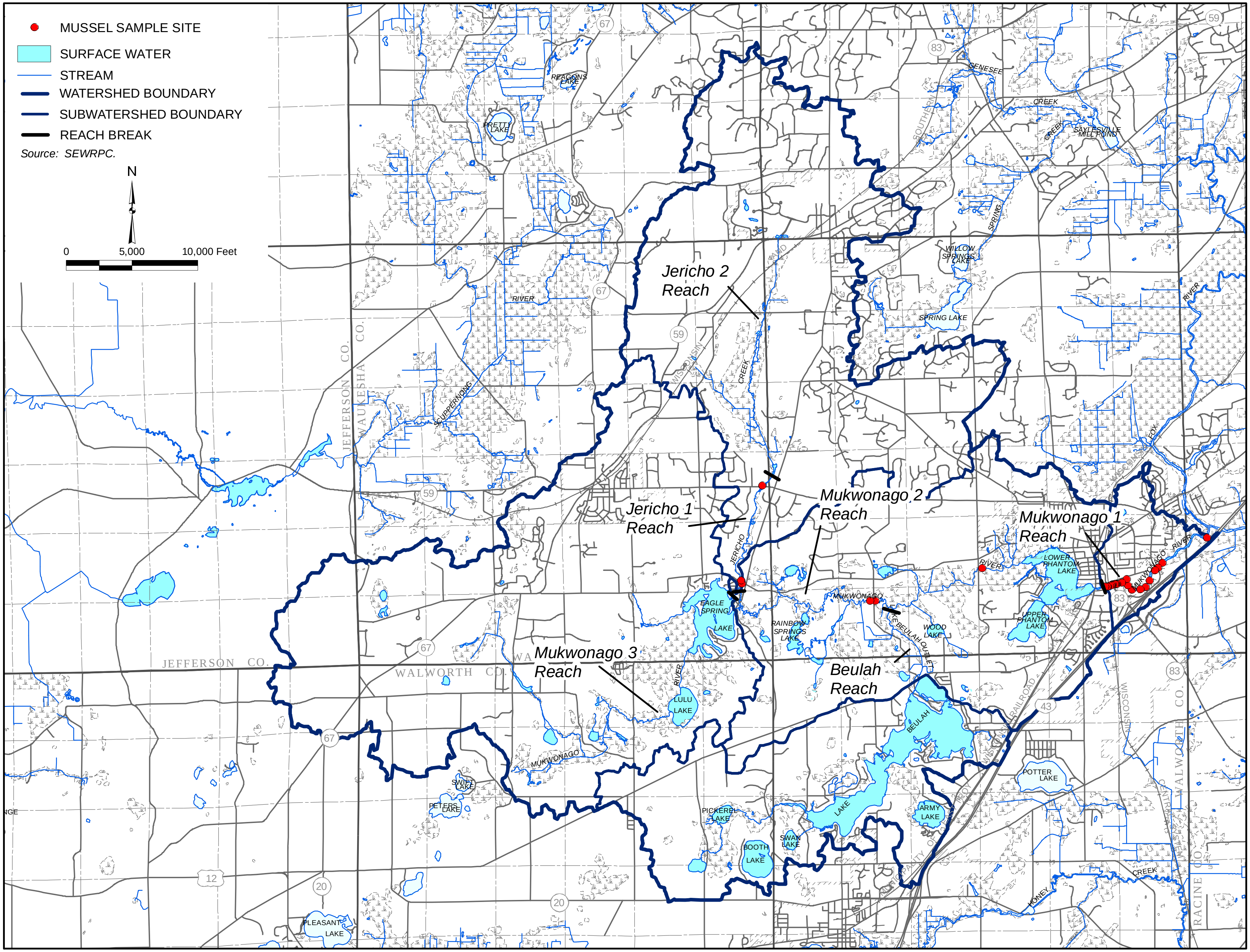


Table 26

MUSSEL SPECIES BY REACH IN THE MUKWONAGO RIVER WATERSHED: 1973-2009

Species	Stream Reach (see Map 22)		
	Jericho-1	Mukwonago-2	Mukwonago-1
Warmwater			
Creek Heelsplitter[a]	- -	- -	11
Creeper	1	- -	11
Cylindrical Papershell	1	- -	1
Elktoe[a]	- -	- -	10
Ellipse[b]	2	3	16
Fatmucket	1	- -	15
Giant Floater	1	- -	13
Lilliput	- -	- -	10
Plain Pocketbook	- -	- -	2
Rainbow[c]	- -	2	14
Round Pigtoe[a]	- -	1	16
Slippershell	- -	2	9
Spike	- -	- -	16
Threeridge	- -	1	2
Wabash Pigtoe	- -	- -	4
White Heelsplitter	- -	- -	8
Total Number of Species	6	6	16
Total Number of Samples	3	3	22

[a]*Designated species of special concern.*

[b]*Designated threatened species.*

[c]*Designated endangered species.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

the water and walk stream banks looking for live and dead mussels. Live mussels are identified and photographed before they are returned to the stream. Empty shells and dead specimens are collected along with information and photos that are sent to the mussel monitoring program at the WDNR central office. Identifying mussels can sometimes be tricky; basic shape, color, size, and beak structure are all used to determine the species. As with most invertebrates, there is some overlap between species description and even sexual dimorphism.

Macroinvertebrates

The WAV Biotic Index was used to classify the macroinvertebrate and environmental quality of the stream system using survey data from one site at CTH LO on Jericho Creek.[87] Macroinvertebrate surveys conducted under the auspices of the WAV program from 2003 through 2009 showed that biotic index scores generally range from fair to good on Jericho Creek. Overall, the results of the WAV biotic index indicate that the Jericho Creek site has a fair to good value, with a high proportion of macroinvertebrate groups sensitive or semi-sensitive to pollution and a lower proportion of groups tolerant to pollution.

Since the Jericho Creek station has been sampled consistently for five years using WAV monitoring protocol, the data collected at this station are potentially useful in distinguishing qualitative differences between this site and future monitoring sites. However, it is important to note that the WAV biotic index has not been calibrated against a set of reference streams, which makes it difficult to interpret the magnitude of the differences in water quality or stream health that a difference in the index reflects.

Other Wildlife

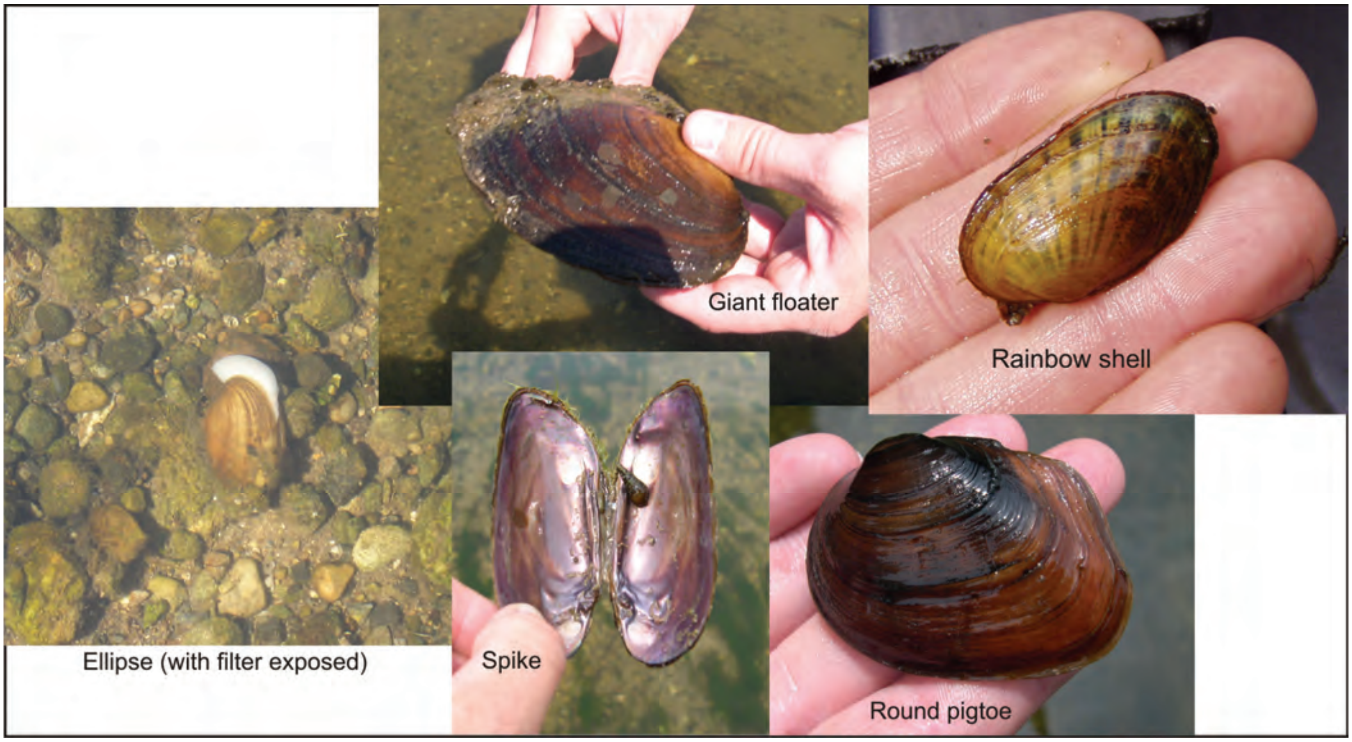
Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of this study, a list of species observed during the field visits made for this project includes: whitetail deer, beaver, raccoon, opossum, squirrel, chipmunk, rabbit, green frog, Butler’s garter snake, Blanding’s turtle, sandhill cranes, great blue herons, and various songbirds (see Figure 57).

A June 2010 breeding bird survey was conducted at the Kettle Moraine State Forest-Mukwonago River Unit by John Bielefeldt and Terri Beth Peters of the Kettle Moraine Natural History Association. Eighty-eight presumably breeding bird species were found during the survey, including two State-threatened species (the hooded warbler and cerulean warbler), and 10 species of special concern (the black-billed cuckoo, yellow-billed cuckoo, whip-poor-will, willow flycatcher, veery, wood thrush, blue-winged warbler, field sparrow, bobolink, and Eastern meadowlark). The presence of these numerous and diverse bird species is consistent with the overall high quality of the riparian buffer areas within the Mukwonago River watershed and emphasizes the need for careful management of lands to protect shrubland and forest habitats for these species.

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

Figure 55

NATIVE MUSSEL SPECIES WITHIN THE MUKWONAGO RIVER WATERSHED: 2008



Source: SEWRPC.

Figure 56

SIGN POSTED IN HEAVY TRAFFIC AREAS OF THE RIVER TO PROTECT MUSSEL POPULATIONS

Source: SEWRPC.

Figure 57

WILDLIFE SPECIES WITHIN THE MUKWONAGO RIVER WATERSHED: 2007-2009

Stinkpot Turtle

Green Frog

Blandings Turtle

Painted Turtle

Goldfinch

Northern Hog Snake

Snapping Turtle

Sandhill Crane

Source: SEWRPC.

Exotic Invasive Species
As previously mentioned, common carp, an exotic invasive species, have been found within the Mukwonago-1, Mukwonago-2, Mukwonago-3, and Beulah reaches and in the lakes. Other exotic invasive species known to exist within the stream are the rusty crayfish, zebra mussel, and Asian clams. Invasive aquatic plant species known to occur include Eurasian water milfoil and curly-leaf pondweed.

Nonaquatic invasive vegetation species include reed canary grass that is very dominant throughout the watershed, as shown on Map 41. Areas with phragmites infestations have also been located, and are shown on Map 41. Invasive terrestrial vegetation species found include: garlic mustard, European buckthorn, and purple loosestrife, which were found among the nonnative plants on streambanks and shoreland areas throughout the watershed (see Riparian Corridor Conditions section above.)

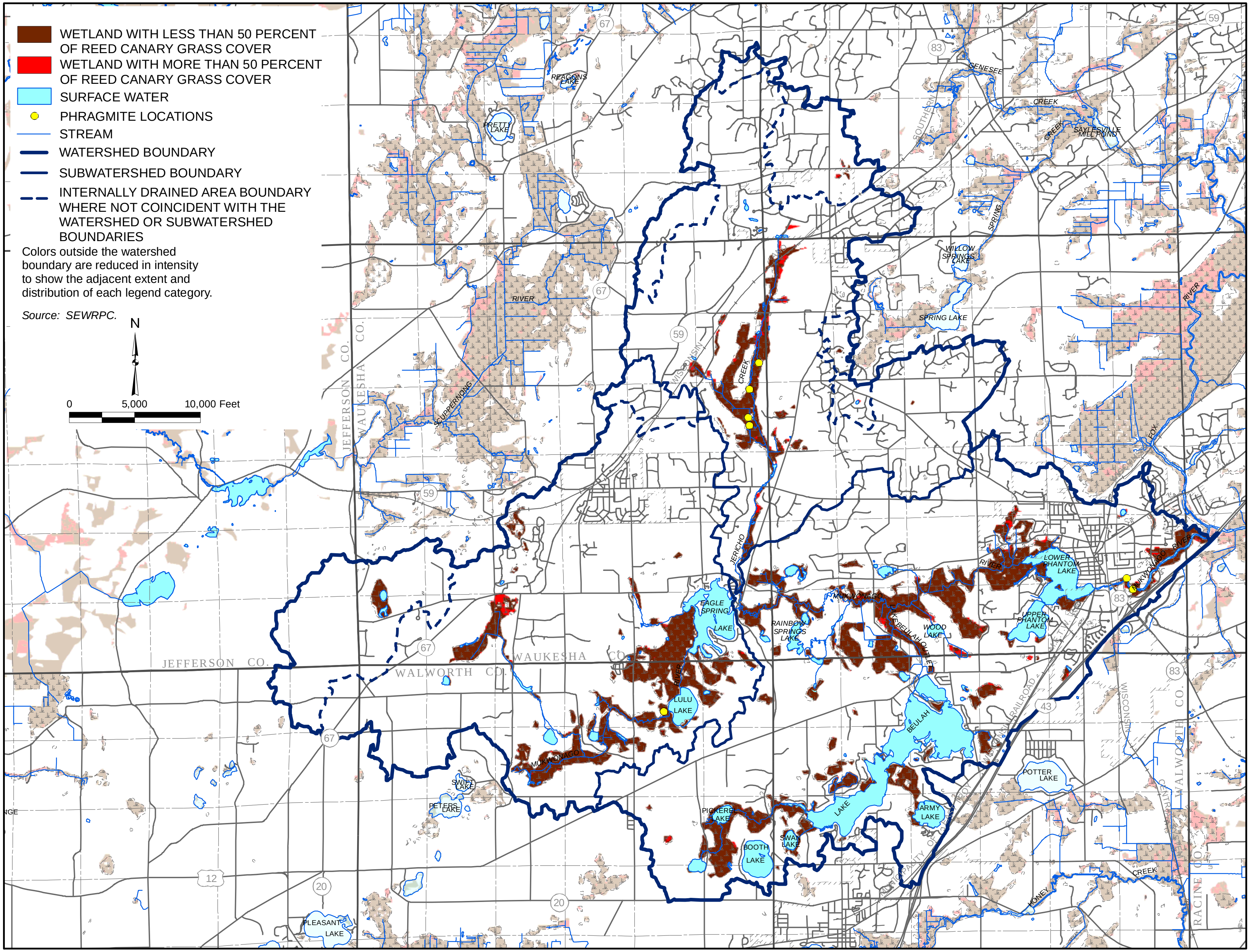
As noted above, the WDNR, TNC, and the three public inland lake protection and rehabilitation districts in the watershed—Eagle Spring Lake Management District, Lake Beulah Management District, and the Phantom Lakes Management District—have conducted a variety of management programs in concert with their local communities, to control these nonnative and invasive species within the watershed.

CONCLUDING REMARKS

The Mukwonago River basin contains a diverse and high quality flora and fauna within a naturally functioning river system, and forms one of the most significant ecological assets in the southern portion of the State of Wisconsin. This significance has been recognized through the Chapter NR 102 designations of the Mukwonago River and Lulu Lake as outstanding and exceptional water resources of the State, and by the acquisition and extension of State ownership of lands within the Southern Unit of the Kettle Moraine State Forest. Such recognition has been further acknowledged through the actions of The Nature Conservancy, Friends of the Mukwonago River, and by the local communities who have established, among other entities, public inland lake protection and rehabilitation districts around the major lakes within this watershed. Consequently, the issues of concern, summarized in Chapter V, and the watershed-based management recommendations set forth in Chapter VI of this plan, seek to support, maintain, and protect the exceptional natural character and assets of the Mukwonago River Watershed.

Map 41

DISTRIBUTION OF EXOTIC INVASIVE REED CANARY GRASS AND PHRAGMITES NON-NATIVE PLANT SPECIES WITHIN THE MUKWONAGO RIVER WATERSHED: 2006



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Chapter V

WATERSHED ISSUES AND CONCERNS

INTRODUCTION

There are a number of issues of concern that impact the water quality and recreational use of the Mukwonago River system. These issues were identified in Chapters II through IV and include issues of concern related to the existing and forecast changes in land use in the Mukwonago River watershed, and to their associated potential effects on hydrology, groundwater recharge, water quality including temperature, habitat and bank stability, and aquatic and terrestrial wildlife community.

As noted in Chapter I of this report, this protection plan was prepared as part of a coordinated planning effort conducted in cooperation with the Mukwonago River Watershed Protection Advisory Group (see Appendix A). The Advisory Group was assembled throughout the planning process over several meetings by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) in cooperation with the Eagle Spring Lake Management District, the Phantom Lakes Management District, The Nature Conservancy (TNC), the Friends of the Mukwonago River, and other interested parties representing Walworth and Waukesha Counties, the Wisconsin Department of Natural Resources (WDNR), and local municipalities from across the watershed. This informal committee represents the diversity of interests and perspectives that affect the watershed, including State, County, and local governments; residents; developers; and, environmental groups. The selection of the issues of concern within the Basin that form the basis for the recommended plan, set forth in Chapter VI of this Plan, followed an extensive review by the Advisory Group.

In developing the alternative and recommended plan elements set forth in Chapter VI, the SEWRPC staff, in cooperation with the Advisory Group, sought to develop a comprehensive set of specific actions designed to ensure the enhancement and/or preservation of the surface water quality of the streams and lakes in the Mukwonago River watershed, and the preservation of the quality of the groundwater which affects the base flow of the streams. A primary consideration in the selection of issues of concern to be addressed in the recommended plan was the degree to which those concerns could be mitigated by either structural or nonstructural measures that, functioning together as a watershed-based system, would be expected to achieve the agreed-upon water use objectives. It is also important to note that the Advisory Group understands that the Mukwonago River and its environs contain many assets as shown in Figure 58. Therefore, given the extremely high quality and ecological integrity of the Mukwonago River system, the goals and objectives and issues addressed in this plan emphasize maintaining and protecting this valuable resource.

In this chapter, issues associated with the major project goals have been identified by the Mukwonago River Watershed Advisory Group, and include the following:

Figure 58

PHYSICAL, CHEMICAL, BIOLOGICAL, AND RECREATIONAL ASSETS OF THE MUKWONAGO RIVER SYSTEM

BIOLOGICAL CHARACTERISTICS:

- Generally good health of stream and wildlife diversity
- Highly diverse warmwater fishery
- Diverse and abundant mussels
- Diverse and abundant aquatic insects
- High quality coldwater stream
- Large trout
- Good quality lake sport fisheries
- High diversity and abundance of wildlife species
- Numerous threatened, and endangered species, and species of special concern

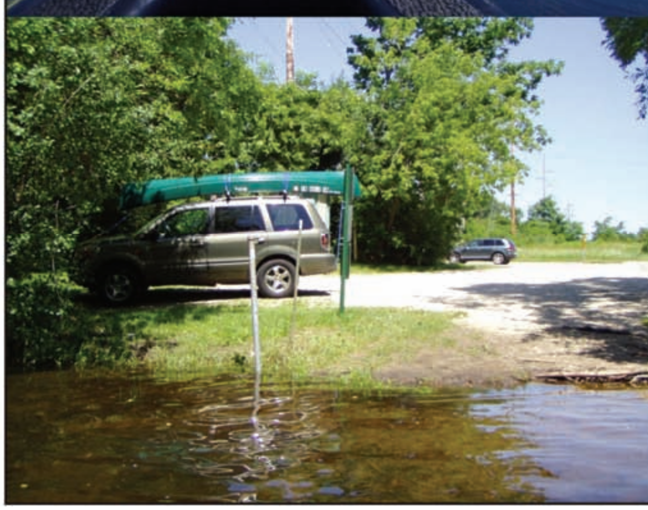
HIGH QUALITY AND DIVERSITY OF INSTREAM AND IN-LAKE HABITATS:

- Flows
- Pool-riffle structure
- Substrates and water depths
- Aquatic vegetation
- Woody cover

Figure 58 (continued)

HIGH QUALITY AND DIVERSE RECREATIONAL EXPERIENCES:

- Boating/Skiing
- Canoeing
- Hunting
- Fishing
- Wildlife viewing
- Golfing
- Biking
- Picnicking
- Public access



PHYSICAL AND CHEMICAL CHARACTERISTICS:

- Well connected floodplain
- Stable streambed and banks
- Low density of development
- Significant amount of infiltration areas/ groundwater recharge potential
- High groundwater discharge
- Natural meanders-limited channelization/ diversions
- Low number of road crossings
- Extensive riparian buffers

Source: Mukwonago River Watershed Protection Plan Working Group and SEWRPC.

- Protect and improve wildlife, land, surface water, and groundwater resources
- Minimize impacts of land development by controlling agricultural and urban runoff pollution and flooding
- Build partnerships and inform public to promote protection and use of natural resources

Measures to address these concerns are discussed in Chapter VI of this report.

PROTECT AND IMPROVE WILDLIFE, LAND, SURFACE WATER, AND GROUNDWATER RESOURCES

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 and the associated environment in the Mukwonago River 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 foundation for the land use element of the plan is described in Chapter II of this report.

Land Management Measures

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.

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 and ambience 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

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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.*

the least 100 acres in size and one mile long. In addition, smaller concentrations of natural resource features that have been separated physically from the environmental corridors by intensive urban or agricultural land uses have also been identified. These areas, which are at least five acres in size, are referred to as isolated natural resource areas.

It is important to point out that, because of the many interlocking and interacting relationships between living organisms and their environment, the destruction or deterioration of any one element of the total environment may lead to a chain reaction of deterioration and destruction among the others. The drainage of wetlands, for example, may have far-reaching effects, since such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas of interconnecting lake and stream systems. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater. Groundwater serves as a source of domestic, municipal, and industrial water supply and provides 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 Mukwonago River watershed thus becomes apparent, and is an important issue to be considered.

As noted in Chapter II, large areas adjacent to the Mukwonago River system including the Lakes within that system have been maintained, protected, or have reverted to a largely natural condition. This situation provides opportunities for continued protection and expansion of these areas, and the actions of the WDNR, Lake Management Districts, and TNC have contributed to the maintenance of these areas on behalf of the citizens of Wisconsin and others. In addition, the three public inland lake protection and rehabilitation districts situated around major lakes in the watershed—Eagle Spring Lake, Lake Beulah, and the Phantom Lakes—have played a significant role in establishing an informed and aware constituency. All of these agencies and entities, working cooperatively with the Friends of the Mukwonago River and through the Mukwonago River Partnership, have effectively worked with many of the towns and villages in protecting the ambience of the River, the lower portions of which, within the Town and Village of Mukwonago, also fall within the jurisdiction of the Southeastern Wisconsin Fox River Commission.[2] Encouraging and continuing the synergies between these various entities is an important issue of concern to be considered, affecting the ability and willingness to protect and preserve the Mukwonago River corridor and its associated ecosystems, to the benefit of the stakeholders living in and visiting the watershed.

Fisheries and Wildlife Enhancement

Objective—Protect lakes and streams to support a high quality sustainable coldwater and warmwater fishery and associated aquatic community, habitat, and water quality.

Stream Corridor Management, and Fish and Wildlife Enhancement

The maintenance and rehabilitation of the warmwater and coldwater sport fishery, key natural resources in the Mukwonago River System watershed, are important issues to be considered in this protection plan. As described in Chapter III of this report, the Mukwonago River and Jericho Creek systems are generally capable of supporting coldwater sport fish and partial water recreation use objectives. Downstream of Phantom Lakes to the confluence with the Fox River, the Mukwonago River System is capable of supporting warmwater sport fish and partial water recreation use objectives. Based upon analysis and review of historic and recent fisheries surveys, summarized in

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[2]*See SEWRPC Planning Program Report,* Southeastern Wisconsin Fox River Commission Water Resources Implementation Plan, March 1998, *March 1998.*

Chapter IV of this report, fishery conditions in the Mukwonago River System watershed demonstrate the ability to support both cold and warmwater fisheries that generally range from fair to excellent.

The watershed ecosystem is a continuum including the stream, the lakes, and the surrounding lands which form the basic support system and structure for sustaining the wildlife, other natural resources, and most importantly, the local citizens who reside there. In order to sustain the ecology of the watershed, actions should focus on the key natural resource features located throughout the Mukwonago River watershed study area. Consequently, actions to preserve and enhance the interconnection between the watershed's ecosystems are important considerations. Such actions should focus on the restoration and management of habitats not only within the stream, but also within the lakes and the entire watershed as a whole.

There are a number of issues that specifically affect the quality of the fisheries resource that are of concern and which should be considered in order to ensure the continued maintenance and future production of the fishery. These issues are related to existing and planned changes in land use, and the associated effects of those land use changes on stream hydrology, groundwater recharge and discharge, water quality including temperature, and aquatic habitat quality. Actions taken to manage land use, nonpoint source pollution, and stormwater runoff, together with environmental monitoring, complement and support actions necessary to sustain the fisheries and other aquatic life.

The recommendations set forth in Chapter VI 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 recommendations set forth below related to the control of urban and rural nonpoint sources of pollution, protection and maintenance of riparian buffers, and the restoration or rehabilitation of aquatic organism passage at selected road crossings. Consideration of these actions would help to protect or reestablish a high quality native warmwater and/or coldwater fishery where appropriate.

Lake Management Plan Measures Incorporated

Each of the major lakes in the Mukwonago River watershed—Lulu Lake, Eagle Spring Lake, Lake Beulah, and Upper and Lower Phantom Lakes—has a lake-specific management plan.[3] Each of the three public inland lake protection and rehabilitation districts serving Eagle Spring Lake, Lake Beulah, and the Phantom Lakes is continuing to implement these plans. In addition, the WDNR and the TNC are continuing to implement the plans related to Lulu Lake. These plans should be reviewed and updated on a regular basis, and refined as necessary. Consequently, lake management planning continues to be an issue of importance. In this regard, it is noted that, at the time of writing, the Eagle Spring Lake Management District is in the process of undertaking a refinement leading to a second edition of their comprehensive lake management plan.

Groundwater Protection Measures

Objective—Preserve groundwater recharge areas and prevent groundwater contamination from stormwater infiltration practices.

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[3]*For Lulu Lake see: Wisconsin Department of Natural Resources Publication No. PUB-ER-641 2005,* Wisconsin's Strategy for Wildlife Species of Greatest Conservation Need, *2005; see also recommended actions set forth in SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, *September 1997. For Eagle Spring Lake, Lake Beulah, and the Phantom Lakes see: SEWRPC Community Assistance Planning Report No. 226,* A Lake Management Plan for Eagle Spring Lake, Waukesha County, Wisconsin, *October 1997; Lake Beulah Management District,* Lake Beulah Management Plan, *RJN Environmental Services LLC, 2010; and, SEWRPC Community Assistance Planning Report No. 230,* A Lake Management Plan for the Phantom Lakes, Waukesha County, Wisconsin, *Volume One,* Inventory Findings, *and Volume Two,* Alternatives and Recommended Plan, *January 2006.*

Under the regional water supply planning process,[4] groundwater sustainability analyses were made for six selected demonstration areas, each selected to represent a range of hydrogeological 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 analytical results could be applied to the evaluation of similar developments throughout the Region. The groundwater sustainability guidance developed through this planning program is an issue that should be considered by municipalities in this watershed in local land use planning and in evaluating the sustainability of proposed developments.

In addition, the groundwater contamination potential of shallow aquifers in the Southeastern Wisconsin Region was mapped under the regional groundwater management planning program. As the groundwater contamination potential in the Mukwonago River System watershed is considered to be moderate to very high,[5] the groundwater contamination potential of the shallow aquifers is an issue to be considered in locating new development and/or redeveloping sites within the watershed.

Groundwater protection measures are an integral part of the Waukesha County Land and Water Resources Management Plan, [6] which recognizes the need to protect groundwater recharge areas and minimize the impacts of stormwaterborne contaminants on groundwater, under Goal 3 of the plan. Consequently, consideration of groundwater protection and management remains an important issue in the Mukwonago River watershed.

Climate Change

Objective—Protect the system from the potential negative physical and biological impacts associated with climate change.

Global climate models indicate that climate change will have significant impacts on mid-latitude regions such as the Upper Midwest, but little is known about specific effects on Wisconsin's environment, economy, and human health, or how to address potential threats or opportunities. Effective responses will require the best available science and meaningful participation of public and private stakeholders. Therefore, the Wisconsin Initiative on Climate Change Impacts (WICCI) was formed in response to questions raised by a bipartisan committee of State legislators who wanted to know how climate change could impact their districts and constituents.[7] More than 40 scientists from the University of Wisconsin-Madison, the Wisconsin Department of Natural Resources and other agencies and institutions met in June 2007 to explore ways to identify and measure the impacts of climate change and variability at local and regional scales. The group also discussed the development of adaptation strategies for Wisconsin ecosystem and natural resource management, agriculture, business, human health and other vital components of our quality of life. WICCI represents the outgrowth of those efforts.

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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. See especially Map 33 in Chapter VII of SEWRPC Technical Report No. 37.*

[6]*Waukesha County Department of Parks and Land Use,* Waukesha County Land and Water Resource Management Plan: 2006-2010*, March 2006; and The Walworth County Land Conservation Committee,* Walworth County Land and Water Resource Management Plan 2010-2020*, April 2010.*

[7]*Wisconsin Initiative on Climate Change (WICCI) assesses and anticipates climate change impacts on specific Wisconsin natural resources, ecosystems and regions; evaluates potential effects on industry, agriculture, tourism and other human activities; and develops and recommends adaptation strategies that can be implemented by businesses, farmers, public health officials, municipalities, resource managers and other stakeholders. See website,* http://www.wicci.wisc.edu/about.php

Unlike the Governor's Global Warming Task Force, which targets mitigation of greenhouse gases—how humans affect the climate—WICCI focuses solely on the impacts of climate change—addressing how the climate affects us and how to adapt to changes in climate.

WICCI is governed by a Science Council whose members are chosen from an array of disciplines within the University of Wisconsin System, the Wisconsin Department of Natural Resources and other State and Federal agencies, universities and institutions. The primary function of the Science Council is to organize and coordinate Working Groups that have the scientific expertise to assess climate change impacts pertinent to specific issues or areas of concern. An Operations and Outreach Unit in the Nelson Institute for Environmental Studies at UW-Madison facilitates the operations of the Science Council and is responsible for the outreach mission of WICCI. It also coordinates the activities of an Advisory Committee.

Specific working groups were created by the Science Council to conduct science-based assessments of potential climate change impacts on specific regions, ecosystems, communities and industries in Wisconsin and to make recommendations on adaptation strategies. Scientists, experts and practitioners work together in each group and have identified a number of concerns and potential mitigative measures that are further refined in Chapter VI of this report. Among these issues relative to the Mukwonago River system are coldwater fish and fisheries, human health, plants and natural communities, soil conservation, stormwater management,[8] water resources, and wildlife.

MINIMIZE IMPACTS OF LAND DEVELOPMENT BY CONTROLLING AGRICULTURAL AND 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, utilization of 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 watershed, and the protection of environmentally sensitive lands, are the fundamental building blocks for protecting stream water quality and habitat and for 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 services, along with application of wastewater treatment technologies, can mitigate the delivery of contaminants to receiving waters, and have proven effective in reducing levels of enrichment in 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 areas tributary to individual streams. Each of these issues forms an important element to be considered, and are discussed further below.

Urban Land Use Planning and Zoning Measures

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.

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 Mukwonago River 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.

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[8]*The SEWRPC staff serves on the Stormwater Management Working Group.*

Existing year 2000, planned year 2035 land use patterns, and refined year 2035 land use projections based upon the Walworth and Waukesha County comprehensive plans, and existing zoning regulations, in the Mukwonago River System watershed have been described in Chapter II. While each of the year 2035 plans has specific nuances, all of the land use plans suggest that urban residential development within the watershed would increase 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 also 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 in the Mukwonago River watershed. Accordingly, given the potential impact of riparian development and redevelopment throughout the watershed, future development proposals are an issue of concern, which should be evaluated for potential impacts on the Mukwonago River system as proposals are advanced.

In addition, the adopted regional and local land use and water quality management plans set forth management measures directed at other urban and rural nonpoint source contaminants within the Mukwonago River watershed (see Table 9 in Chapter III of this report for a list of applicable plans). Sediment and total phosphorus load reduction goals for the Mukwonago River watershed called for up to 20 percent reductions in urban nonpoint source pollution loads to the Phantom Lakes and reductions of between 60 and 85 percent in rural nonpoint source pollution loads to Eagle Spring Lake, Lulu Lake, the Phantom Lakes, and Lake Beulah. Recent studies of the potential impact of riparian landscaping activities on 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.[9] For this reason, the State of Wisconsin has enacted limitations on the application of fertilizers containing phosphorus pursuant to 2009 Wisconsin Act 9, and has taken action to limit runoff and sediment transport from urban areas and transportation corridors under Chapter NR 151 of the *Wisconsin Administrative Code*. Additional actions to minimize the presence of contaminants in the waters of the State are being considered pursuant to proposed refinements of Chapters NR 102 and NR 106 of the *Wisconsin Administrative Code*, focusing on standards and criteria for phosphorus. The adopted Waukesha County Land and Water Resources Management Plan specifically incorporates recommendations under Goal 1 calling for control of urban runoff pollution and flooding. Consequently, the need to periodically review requirements for the control of nonpoint source pollution is an important issue to be considered.

Stormwater and Floodland Management Measures

Objective—Preserve floodwater storage areas and control the quantity of runoff from new urban development.

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. The legal requirements for, and extent and placement of, stormwater and flood control infrastructure directly affects the hydrologic and hydraulic behavior of the river within 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 lying outside the environmental corridors in open uses is also critical, as is encouraging the use of floodland areas for outdoor recreational and open space activities. Hence, the improvement of stormwater management facilities, control of runoff from areas of future development, protection of wetlands, and the prevention of future development in floodprone areas are issues to be considered.

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[9] *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.*

With respect to stormwater management, as noted in Chapter III, all of the municipalities have adopted stormwater management ordinances, except for Jefferson County and the Town of Palmyra in Jefferson County. The Towns of Eagle, East Troy, and LaGrange, and the Villages of Eagle, East Troy, and Mukwonago have adopted their own stormwater management ordinances, while the other municipalities have adopted their respective County stormwater ordinance as indicated in Table 11 in Chapter III of this report. The Walworth and Waukesha County 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 the Mukwonago River system, and to minimize the impacts of urban runoff on the natural resources of the Mukwonago River watershed. This would be consistent with the provisions of Goal 2 of the Waukesha County Land and Water Resources Management Plan. Hence, management of runoff from urban areas is an issue to be considered.

Rural Land Use Planning and Zoning Measures

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.

The aforementioned Walworth and Waukesha County comprehensive plans and County Land and Water Resources Management Plans promote the protection of agricultural lands most of which occur within the Walworth County portion of the Mukwonago River watershed. These plans seek to accommodate incremental rural density residential development without adversely impacting highly productive farmland. The applicable land use plans for the Mukwonago River watershed envision some conversion of farmland, located in the vicinity of existing urban service areas, to urban uses. Such conversion 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. This development could be expected to result in the additional loss of farmland, and, hence, is an issue to be considered.

Encouraging the continuation of open land uses (such as parkland, conservation areas, open lands reserved as a result of cluster development or equivalent, and agricultural land) in the watershed was identified as one of the overall goals of this plan because such uses are considered to be “good” for the water resources. This is because open lands may allow rainfall and melting snow to more efficiently infiltrate through soil surface and recharge the shallow aquifer, thus maintaining stream baseflows and minimizing negative impacts downstream. This is in contrast to hardened urban surfaces—comprised of rooftops and roadways, for example—and compacted agricultural soils, where infiltration is limited and runoff from the land surface is proportionately greater contributing to increase nutrient and sediment loading.

Agricultural Pollution Control Measures

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

Chapter III of this plan contains a review of the State and local nonpoint pollution control standards that apply to agricultural operations, principally contained in Chapters NR 151 and ATCP 50 of the *Wisconsin Administrative Code*. Details of how these performance standards will be implemented in Waukesha County are set forth 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, supported by County staff making landowner contacts in targeted watersheds. The Mukwonago River watershed was identified as one of the targeted watersheds.

One of the State performance standards requires the maintenance of cropland soil erosion rates at or below tolerable—or "T"—values.[10] 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, however, that maintaining erosion rates at "T" values may not adequately protect water quality from sediment delivery. Consequently, agricultural nonpoint source control measures remain an issue to be considered.

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 pollution.[11] Based upon this review it was determined that a general buffer width of 75 feet is appropriate for water quality modeling purposes in terms of representing: 1) a reasonably high level of effectiveness for the control of nitrogen, phosphorus, and total suspended solids; 2) practicality of implementation; and, 3) consistency with regulatory requirements such as structural setbacks (see Appendix B). It is important to note that riparian buffers are only a single component of a comprehensive watershed management strategy, which would likely include other measures to control point and nonpoint sources of nutrients and sediments, protection of aquatic and terrestrial habitat, and management of floodwaters. Nevertheless, the application of buffer requirements in the Mukwonago River basin is an issue to be considered.

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 essential components of environmental corridors. The riparian corridors form 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 fish species, and with groundwater recharge areas that allow precipitation to infiltrate into the groundwater aquifers. 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 water resources for water quality, wildlife habitat, and groundwater recharge purposes, which is consistent with the Mukwonago River Watershed Advisory Group goal calling for control of agricultural runoff pollution. Consequently, the establishment and maintenance of riparian buffers are important issues to be considered.

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. Reductions in agricultural loadings may be anticipated on a case by case basis as a result of the implementation of the State administrative rule provisions. Hence, control of runoff from agricultural areas remains an issue to be considered.

BUILD PARTNERSHIPS AND INFORM PUBLIC TO PROMOTE PROTECTION AND USE OF NATURAL RESOURCES

As part of the overall citizen informational and educational programming to be conducted in the Mukwonago River watershed, residents in, and visitors to, the watershed should be made aware of the value of the ecologically

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[10]*"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.*

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

significant areas to the overall structure and functioning of the watershed ecosystems. Specifically, informational programming related to the protection of ecologically valuable areas in the watershed should focus on the need to maintain the integrity of riparian corridors, minimize the spread of nuisance aquatic species such as purple loosestrife, and utilize good urban housekeeping and yard care practices in order to mitigate and moderate the impacts of humans on this River system. Likewise, educational activities within the watershed's school districts should make use of the proximity of this waterway and focus on the unique attributes of the River system within the Region, especially given the fact that it contains both Exceptional and Outstanding Resource Waters of the State. In this regard, informational and educational programming are issues to be considered.

Educational and informational brochures and pamphlets, of interest to homeowners and others, are available from the University of Wisconsin-Extension (UWEX), the WDNR, SEWRPC, and the County Land Use or Land and Water Resources Divisions, and many Federal agencies. The informational content of these brochures could be provided to homeowners through local media, the Internet, direct distribution, and/or targeted library and 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. Within the school districts, much of the information contained in these publications could be used to supplement texts in environmental science, art, biology, and mathematics, among other subject areas. This is consistent with the recommendations set forth in the Walworth and Waukesha County Land and Water Resource Management Plans related to monitoring water quality/flow of local lakes and streams, and, hence, is an issue to be considered. Specifically, informational and educational programming in three areas should be considered, as summarized below; namely, in school-based educational programming, in general community-based informational programming, and in specific informational programming in communities with municipal separate storm sewer (MS4) systems that are implementing State stormwater management permit requirements.

Targeted Educational Programming

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

Promotion of local support for environmentally sensitive and sustainable measures can be enhanced through targeted educational programming. School-based programs utilized within the Basin include participation in programs such as Adopt-a-Lake, Project WET, Project WILD, and Project Learning Tree (PLT).

Community-Based Informational Programming

Objective—Continue cooperation among community organizations and municipalities, and develop public participation opportunities.

Experience suggests that coordinating individual efforts is a valuable and useful element of an informational and educational 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, the Friends of the Mukwonago River and the TNC both provide opportunities for public participation in decision-making processes, and have supported opportunities for shared decision-making such as the creation of citizen advisory committees, completion of memoranda of understanding with lake and river organizations within the Fox River basin, and support for rehabilitation activities that benefit all aspects of watershed management. The Friends of the Mukwonago River, established as a private, nonprofit watershed protection organization, continues to play a leading role in coordinating and garnering citizen and community participation in support of the implementation of stewardship activities to enhance the natural resources within the Mukwonago River Watershed.

Targeted Waukesha County MS4 Stormwater Permit-Related Programming

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

The Waukesha County Department of Parks and Land Use, Land Resources Division, through an intergovernmental agreement with the participating municipalities—the Village of North Prairie and the Towns of Genesee, Ottawa, and Vernon—has taken the lead on implementing these activities and providing support services to the municipalities, as needed. Consequently, informational and educational programming associated with the implementation of MS4 stormwater permit activities remains an issue to be considered.

Recreational Development

Objective—Promote and expand safe recreational opportunities.

The Mukwonago River and its associated tributary streams and lakes form an important element of the natural resource base of the municipalities within the area. The location of these waterbodies within environmental corridors and open space areas provides an opportunity for people to utilize and enjoy these resources for recreational and aesthetic viewing purposes. Consequently, these resources can provide an essential avenue for relief of stressors among the human population and improve quality of life in neighborhoods throughout the area. Such water resources, and their associated recreational uses, also sustain industries associated with outfitting and support recreational and other uses of the natural environment, and, therefore, provide economic opportunities for the local communities. Both the Walworth and Waukesha County comprehensive plans anticipate increases in lands dedicated to recreational uses. Hence, recreational use is an important issue to be considered.

SUMMARY

A number of priority issues of concern facing the Mukwonago River, the lakes and streams within the watershed, and the resident communities have been identified. While these issues of concern generally fall within the three areas of concern initially identified by Working Group—namely, protect and improve wildlife, land, surface water, and groundwater resources; minimize impacts of land development by controlling agricultural and urban runoff pollution and flooding; and building partnerships to inform the public to promote protection and use of natural resources—the foregoing analysis suggests that there are 12 areas of priority concern that should be addressed in order to preserve and protect the environmental quality, the ecological structure and integrity of the Mukwonago River watershed, as well as public health, safety, and quality of life. These 12 areas can be summarized as follows:

To protect and improve wildlife, land, surface water, and groundwater resources:

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

2. Protect lakes and streams to support a high quality sustainable coldwater and warmwater fishery and associated aquatic community, habitat, and water quality.

3. Preserve groundwater recharge areas and prevent groundwater contamination from stormwater infiltration practices.

4. Protect the system from the potential negative physical and biological impacts associated with climate change.

To minimize impacts of land development by controlling agricultural and urban runoff pollution and flooding:

5. 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.

6. Preserve floodwater storage areas and control the quantity of runoff from new urban development.

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

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

To build partnerships and inform the public to promote protection and use of natural resources:

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

10. Continue cooperation among community organizations and municipalities, and develop public participation opportunities.

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

12. Promote and expand safe recreational opportunities.

Recommendations to give effect to priority actions to address these 12 elements are set forth in Chapter VI of this report.

Chapter VI

RECOMMENDED ACTIONS

INTRODUCTION

This chapter provides a strategic framework for decision-making and project prioritization for the purposes of 1) protecting and improving recreation, water quality, and fisheries and 2) cost-effectively and efficiently implementing projects to meet improvement goals for those purposes. Although not mutually exclusive, the recommended prioritization strategies are different for land-based versus instream and lake-based measures as summarized below. The differences in prioritization strategies are related to the fundamental differences potentially limiting the aquatic versus terrestrial communities and habitat quality within the Mukwonago River watershed. However, each of these prioritization strategies is based upon the main premise of protecting the existing quality areas—either in water or on land—and expanding those areas through reconnection of stream reaches and/or land areas to reduce fragmentation.

The recommendations set forth herein focus on those measures which are applicable to the stakeholders and agencies with jurisdiction within the Mukwonago River watershed. However, the general purpose units of government within the Mukwonago River watershed—counties, villages, and towns—are specifically encouraged to adopt these recommendations and implement this protection plan through local policies, practices, programs, and ordinances where appropriate. In addition, many actions can be implemented by other stakeholders, including special purpose units of government, nonprofit conservation organizations, and individual citizens as summarized in the Roles and Responsibilities section below.

Cost Considerations and Funding Sources

A major cost element in the plan relates to the manner in which development occurs in the watershed. Implementation of the recommended plan would entail capital expenditures for the implementation of stormwater management and water quality management measures within the watershed and along the lands riparian to the Mukwonago River and its tributaries. A New Hampshire study on the economic values of surface waters concluded that, even though the initial development costs to provide environmental protection features beyond what may typically be required may be slightly higher, 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 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.*

Typically environmentally-targeted recommendations, such as those included in this watershed protection plan, have minimal 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 recover some of those additional costs by selling lots at a higher price. A Chesapeake Bay study of the effects of implementing environmental protection measures developed through watershed planning 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] That 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 one-percent-annual-probability (100-year recurrence interval) floodplain, they are a very cost-effective form of flood damage mitigation, 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 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 Water Pollution Abatement And Storm Water Management 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 Mukwonago River watershed under the previously funded Upper Fox River Priority Watershed Program.

Roles and Responsibilities

Roles of Jefferson, Walworth, and Waukesha Counties

The suggested lead agencies for implementation of the watershed protection plan are the Counties in which the watershed is located: for Jefferson County, the lead agency would be the Land and Water Conservation Department (LWCD); for Walworth County, the lead agency would be the Land Use and Resource Management Department (LURM); and, for Waukesha County, the lead agency would be the Department of Parks and Land Use, Land Resources Division (LRD). In general, these agencies should continue to provide a coordinating role in cooperation with the appropriate local government units and state agencies. Specifically, the three departments have oversight of shoreland, floodland, and shoreland/wetland zoning in unincorporated areas within each respective county within the watershed. They also regulate the installation and maintenance of all private onsite wastewater treatment systems and stormwater management facilities for new development in unincorporated areas. In addition, the departments have compiled, updated, and administered the implementation of the county

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[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.*

land and water resources management plans,[5] which, together with the wetland regulations and the shoreland and floodland zoning functions, have immediate relevance to the Mukwonago River watershed and its development. In the case of Jefferson County, the land and water resources management plan is silent with regard to the Mukwonago River; however, the general principles and duties of the County that are inherent in the plan apply to the small portion of the Mukwonago River watershed within Jefferson County. In this regard, all three counties have an additional direct role in the management of the River and its tributaries through their informational and educational programming that is undertaken on a countywide basis.

Roles of Municipalities

Sound land management is an integral part of the maintenance and protection of the Mukwonago River watershed and its natural resources. 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 Mukwonago River watershed develop, update, and implement land use, park and open space, and stormwater management plans consistent with the recommendations contained in this plan.

Role of the Wisconsin Department of Natural Resources

The Wisconsin Department of Natural Resources (WDNR) 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 the State. It is the agency charged with coordinating the many disciplines and programs necessary to protect the environment and to provide a full range of outdoor recreational opportunities for Wisconsin citizens and visitors. Part of the WDNR 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 participation in the Mukwonago River Watershed Advisory Group.

WDNR staff serves a variety of functions from legal enforcement (including community and construction site stormwater runoff under Chapters NR 151, "Runoff Management," and NR 216, "Storm Water Discharge Permits," of the *Wisconsin Administrative Code*, agricultural performance standards under Chapter NR 151, control of nonnative species under Chapter NR 40, angling under Chapter NR 20, recreational boating under Chapter NR 7, and review of local implementation of wetland regulations and shoreland and floodplain zoning ordinances under Chapter 30 of the *Wisconsin Statutes* and associated section of the *Wisconsin Administrative Code*) to science-based management of waste, air, land, and water resources.

With respect to the Mukwonago River, the WDNR staff 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 Mukwonago River watershed to help ensure the sustained protection and improvement of this valuable resource. The WDNR fisheries biologist is charged with protecting and managing the fishery, other aquatic biota, and their habitats. The WDNR wildlife biologist has similar responsibilities with regard to terrestrial wildlife. In addition, WDNR property managers have responsibility for WDNR properties located within the watershed, including those at Lulu Lake and Rainbow Springs. WDNR conservation wardens enforce State laws and regulations, especially those related to recreational boating, fishing, and hunting.

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[5]*See Jefferson County Land and Water Conservation Department,* Jefferson County Land and Water Resource Management Plan: 2006-2010, *2006; Walworth County Land Conservation Committee,* Walworth County 2010 Land & Water Resource Management Plan, *April 2010; Waukesha County Department of Parks and Land Use,* Waukesha County Land and Water Resource Management Plan: 2006-2010, *March 2006.*

The WDNR water management specialist has responsibility for wetland regulations and shoreland zoning issues, while the WDNR water regulation and zoning engineer works cooperatively with the water management specialist and has specific responsibility for floodlands and dam safety issues, which are of immediate concern to the dam owners and operators at Eagle Spring Lake, Lake Beulah, and Lower Phantom Lake. It is important to note that one or more of the recommended measures, particularly actions associated with any instream work, may require State permits administered by the WDNR staff prior to implementation. The WDNR water resources management specialist can provide assistance in lake and river management and planning and water quality management, while the WDNR financial assistance specialist and natural resources program specialist can advise on grants and related financial matters.

The WDNR staff also is 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. To this end, WDNR research scientists conduct site-specific assessments and investigations into specific issues of concern; in the case of the Mukwonago River system, WDNR researchers have conducted investigations into fishes and mussels, and lake sediment histories.

WDNR staff can assist communities and individuals with contacts in other state agencies, including the UWEX lakes partnership, among others. Through cooperative programs with Federal agencies, the WDNR staff also forms an important link to the resources provided through agencies such as the Natural Resources Conservation Service (NRCS), U.S. Geological Survey (USGS), and Fish and Wildlife Service (FWS), among others, who have responsibilities for, and administer grant programs with respect to, agriculture, data acquisition and research, and goose management, respectively.

Role of the Public Inland Lake Protection and Rehabilitation Districts

Public inland lake protection and rehabilitation districts, or lake districts (or lake management districts), are special purpose units of government with responsibility for undertaking a program of protection and rehabilitation of a public lake. These districts can be created by municipalities, or by petition of landowners, pursuant to the process set forth in Chapter 33 of the *Wisconsin Statutes*. In the Mukwonago River watershed, there are lake districts established for Eagle Spring Lake, Lake Beulah, and the Phantom Lakes. All three districts are self-governed by a board of commissioners.

Each of the three lake management districts in the Mukwonago River watershed has developed a lake management plan. These plans include an aquatic plant management element, as noted in Chapter IV of this report. Aquatic plant management forms a major service provided by the three lake districts. In addition, the districts have undertaken an active program of informational programming within their respective communities, encourage and support educational programming in their local school districts, and maintain involvement in the WDNR Citizen Lake Monitoring Network program, supplemented periodically by additional studies. This report was prepared in part with financial support from the Eagle Spring Lake Management District and Phantom Lakes Management District, and with the participation of the Lake Beulah Management District. Commissioners of the three districts meet periodically to informally discuss issues of mutual concern.

In addition to the public inland lake protection and rehabilitation districts created under Chapter 33 of the *Wisconsin Statutes*, another Chapter 33 organization has jurisdiction within a portion of the Mukwonago River Basin; namely, the Southeastern Wisconsin Fox River Commission (FRC) created pursuant to Subchapter VI. The FRC includes the Town and Village of Mukwonago. The FRC is governed by a board of commissioners appointed by the counties and municipalities that comprise the Commission—Racine and Waukesha Counties, the City of Waukesha, the Villages of Big Bend, Mukwonago, and Waterford, and the Towns of Mukwonago, Vernon, Waterford, and Waukesha—with *ex officio* representation by WDNR and SEWRPC staff. The FRC executes an operations plan,[6] and, to date, has partnered with both the Town and Village of Mukwonago in shoreland restoration and protection programs within the Phantom Lakes basins and the lower Mukwonago River watershed.

Role of the Nongovernmental Sector

The nongovernmental organizations (NGOs) within the Mukwonago River watershed include the Friends of the Mukwonago River, The Nature Conservancy (TNC), and the Kettle Moraine Land Trust (KMLT). These NGOs are active partners with the local governments and lake management districts in providing informational programming to the Mukwonago River communities, conducting public lectures, field days, and environmental management activities throughout the watershed. In the case of the TNC and KMLT, these NGOs have undertaken extensive programs of land acquisition and restoration, in partnership with the WDNR, among others. Their actions have helped to place significant portions of the riparian corridor associated with the Mukwonago River into conservancy, either through fee-simple purchase or purchase of conservation easements. Collectively, all three NGOs have worked to promote environmentally-sensitive and environmentally-friendly behaviors within the watershed. In the vicinity of Lake Beulah, their efforts have been aided by the Lake Beulah Protective and Improvement Association, one of the oldest lake associations in the State, having been founded in 1894 for the purpose of providing its members and Lake Beulah residents a voice to protect the Lake environs and to create a clean, enjoyable, and safe environment for all who share in the opportunities that the lake affords. The Lake Beulah Protective and Improvement Association has been active in informing citizens, elected officials, and interested persons on topics of community interest, including water quality education, monitoring of water conditions, invasive species education, fishing, groundwater management education, and property identification for safety and security.

RECOMMENDED PRIORITIZATION STRATEGY

Based upon the inventory and analyses set forth in Chapters II through IV of this plan, 12 priority objectives were identified in Chapter V. In this chapter the recommended management actions necessary to address those key issues are set forth. Those key issues have been divided into Land-Based versus Instream and Lake-Based measures.

Each of these two categories has been further broken down into several dimensions that include:

Land-Based Measures

- Zoning and Regulations
- Riparian Corridors
- Hydrology and Groundwater
- Water Quality
- Land-Based Monitoring and Informational Programming

Instream and Lake-Based Measures

- Aquatic Organism Passage
- Aquatic Habitat
- Aquatic Organisms
- Instream and Lake Monitoring and Informational Programming

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[6]*See SEWRPC Planning Program Report,* Southeastern Wisconsin Fox River Commission Water Resources Implementation Plan, March 1998*, March 1998. An update to this plan is in progress.*

Instream and Lake-Based Measures
This framework is based upon a three-tiered approach, focused on the reconnection of the main waterways that collectively form the Mukwonago River system. As indicated in Figure 59, the three components of this strategy are:

- Tier 1–Restoring connectivity and habitat quality between the mainstem of the Mukwonago River and the Fox River, the mainstem of the Mukwonago River upstream of Lower Phantom Lake, the mainstem of the Mukwonago River flowing into Eagle Spring-Lulu Lakes, and the unnamed tributary stream upstream of Lake Beulah and Lake Beulah;

- Tier 2–Restoring connectivity and habitat quality between the tributary streams and the mainstem of the Mukwonago River, and

- Tier 3–Expanding the connection of highest-quality fish, mussels and other invertebrates, and habitat sites within subwatersheds (see Table 27).

The third tier is a "catch-all" that enables stakeholders to link the goals of habitat restoration and improvement of recreational options with ongoing activities throughout the watershed. This strategic element provides the flexibility for communities and stakeholders to take advantage of opportunities throughout the watershed that may arise independently of the primary strategy of restoring linkages with the Fox River and major Lakes within the Mukwonago River system. An example of this latter strategic approach would be using the opportunity provided by scheduled reconstruction of area roadways to remove obstructions or modify channelized stream segments that might not fully conform to the first two strategic priorities. To this end, it is further noted that provision of fish passage will provide passage for other aquatic organisms such as invertebrates.[7] By providing restored connectivity, and associated habitat, it is envisioned that implementation of this plan will not only further the purpose of maintaining a sustainable fishery but also enhance human economic opportunities and recreational and aesthetic values associated with the streams and lakes of the watershed.

Within this framework opportunities will arise that should be acted upon. For example, even though it is a general principle of this strategy that activities progress from downstream to upstream, the completion of an action in headwaters areas or on a tributary stream should not be passed up or ignored simply because it does not conform to the downstream to upstream strategy. Rather, all opportunities should be seized as they become available. However, where multiple opportunities exist, and where limited funds are available, this strategic framework is intended to assist decision-makers in allocating resources where they would be most appropriate and effective in achieving the goals of this watershed protection plan.

The Tier 1 prioritization is based upon the understanding that the Fox River and major lakes including Eagle Spring-Lulu, Phantom, and Beulah are the most diverse resources and greatest assets in the watershed for the maintenance of high quality recreation as well as a sustainable fishery. This prioritization is also based upon the understanding that within river systems the widest and deepest downstream areas are generally associated with a greater abundance and diversity of fishes compared to narrower and shallower upstream areas.[8] Position within a stream network also is an important determinant of fish species assemblage structure with greater abundance and

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[7]*D.M. Vaughan,* Potential Impact of Road-Stream Crossings (Culverts) on the Upstream Passage of Aquatic Macroinvertebrates*, U.S. Forest Service Report, March 21, 2002.*

[8]*I.J. Schlosser, "A conceptual framework for fish communities in small warmwater streams," pages 17-24 in W.J. Matthews and D.C. Heins (editors),* Community and Evolutionary Ecology of North American Stream Fishes, *University of Oklahoma Press, 1987.*

Figure 59

INSTREAM THREE-TIER PRIORITIZATION STRATEGY WITHIN THE MUKWONAGO RIVER WATERSHED

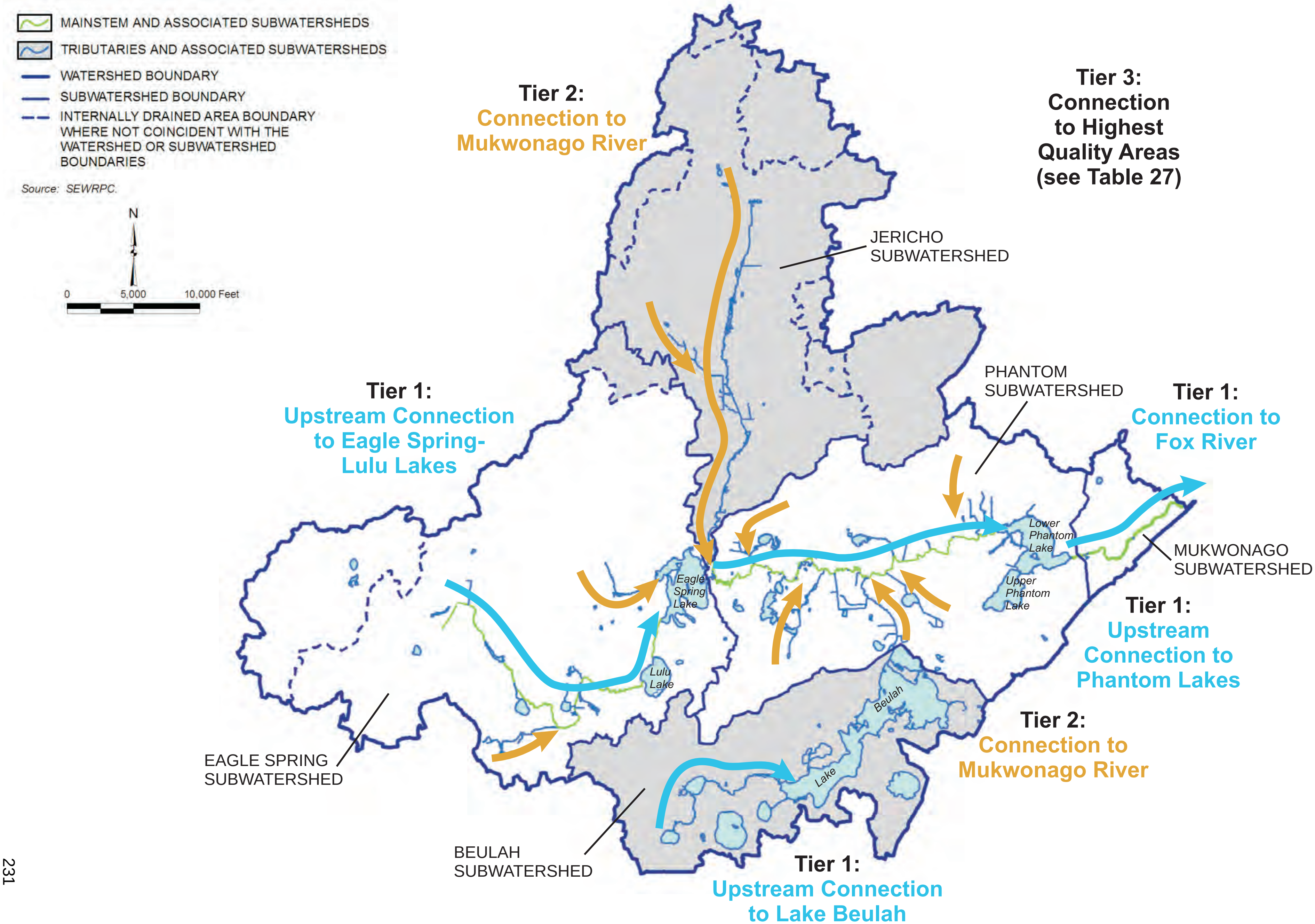

Table 27

FISH PASSAGE ASSESSMENT AT ROAD CROSSINGS, CALCULATED STREAM LENGTH BETWEEN STRUCTURES, NAVIGATIONAL OBSTRUCTIONS, AND BIOLOGICAL (FISH, INVERTEBRATES) AND HABITAT QUALITY DETERMINATIONS AMONG SUBWATERSHEDS WITHIN THE MUKWONAGO RIVER WATERSHED: 2000-2009

Subwatershed	River Mile	Fish Passage Obstruction	Navigation Hazard	Structure Identification	Distance between Structures	Number of Springs/ Seeps	Fish Spawning Sites	Warmwater IBI	Coldwater IBI	Mussel Species Abundance[a,b]	Endangered, Threatened, Species of Concern[c,d]	Habitat Quality
Lower Mukwonago					1.12		5	good	N/A	abundant	abundant	excellent
	1.12	No	No	Holz Parkway		- -	- -	- -	- -	- -	- -	- -
					0.97		10	good	N/A	abundant	abundant	good
	2.09	No	No	STH 83		- -	- -	- -	- -	- -	- -	- -
					0.02			excellent	N/A	abundant	abundant	good
	2.11	No	No	STH 83 sidewalk		- -	- -	- -	- -	- -	- -	- -
					0.04		1	excellent	N/A	common	abundant	excellent
	2.15	No	No	Wisconsin Central Limited Railroad		- -	- -	- -	- -	- -	- -	- -
					0.10		1	excellent	N/A	abundant	abundant	good
	2.25	Yes	Yes	Phantom Lake Dam		- -	- -	- -	- -	- -	- -	- -
Phantom					0.02			- -	- -	- -	- -	- -
	2.27	No	No	Park walkway		- -	- -	- -	- -	- -	- -	- -
					0.09			- -	- -	- -	present	- -
	2.36	No	No	CTH ES		- -	- -	- -	- -	- -	- -	- -
					2.09	1		- -	- -	present	present	good
	4.45	No	No	CTH I		- -	- -	- -	- -	- -	- -	- -
					2.47	30	3	good	good	common	abundant	good
	6.92	No	No	Beulah Road		- -	- -	- -	- -	- -	- -	- -
					0.14			good	good	common	common	excellent
	7.06	No	Yes	Private bridge		- -	- -	- -	- -	- -	- -	- -
					0.64		2	good	fair	- -	- -	good
	7.70	Yes	Yes	Golf cart path		- -	- -	- -	- -	- -	- -	- -
					0.20	6				- -	- -	fair
	7.90	Yes	Yes	Golf cart path		- -	- -	- -	- -	- -	- -	- -
					0.18	3				- -	- -	fair
	8.08	Yes	Yes	Golf cart path		- -	- -	- -	- -	- -	- -	- -
					0.03					- -	- -	- -
	8.11	Yes	Yes	Golf cart path		- -	- -	- -	- -	- -	- -	- -
					0.10					- -	- -	fair
	8.21	Yes	Yes	Golf cart path		- -	- -	- -	- -	- -	- -	- -
					0.07					- -	- -	fair
	8.28	Yes	Yes	Golf cart path		- -	- -	- -	- -	- -	- -	- -
					0.13	1	1			- -	- -	fair
	8.25	Yes	Yes	Golf cart path		- -	- -	- -	- -	- -	- -	- -
					0.42	1		good	fair	- -	present	good
	8.12	Yes	Yes	Golf cart path		- -	- -	- -	- -	- -	- -	- -
					0.05					- -	- -	- -
	7.95	Yes	Yes	Golf cart path		- -	- -	- -	- -	- -	- -	- -
					0.09	1		fair	poor	- -	present	fair
	8.37	Yes	Yes	Golf cart path		- -	- -	- -	- -	- -	- -	- -
					0.89	19	3	fair	fair	- -	present	fair

Table 27 (continued)

Subwatershed	River Mile	Fish Passage Obstruction	Navigation Hazard	Structure Identification	Distance between Structures	Number of Springs/ Seeps	Fish Spawning Sites	Warmwater IBI	Coldwater IBI	Mussel Species Abundance[a,b]	Endangered, Threatened, Species of Concern[c,d]	Habitat Quality
Phantom (continued)	9.26	Yes	Yes	Rainbow Springs Road		- -	- -	- -	- -	- -	- -	- -
					0.19	7	2	fair	fair	- -	- -	good
	9.45	No	Yes	Private drive		- -	- -	- -	- -	- -	- -	- -
					1.16	33	2	good	good	- -	- -	good
	10.61	No	Yes	CTH E		- -	- -	- -	- -	- -	- -	- -
					0.31	6		good	fair	- -	- -	excellent
Eagle Spring	10.92	Yes	Yes	Eagle Spring Lake Dam		- -	- -	- -	- -	- -	- -	- -
					2.48	1		- -	- -	- -	- -	fair
	13.40	No	Yes	The Nature Conservancy footbridge		- -	- -	- -	- -	- -	- -	- -
					0.59	3		very poor	poor	- -	- -	good
	13.99	No	Yes	Nature Road		- -	- -	- -	- -	- -	- -	- -
					0.22	3		fair	fair	- -	present	good
	14.21	No	No	Private foot bridge		- -	- -	- -	- -	- -	- -	- -
					0.94	3		- -	- -	- -	- -	good
	15.15	No	No	Bluff Road		- -	- -	- -	- -	- -	- -	- -
Jericho					0.02			- -	- -	- -	- -	good
	0.02	No	Yes	Private foot bridge		- -	- -	- -	- -	- -	- -	- -
					0.02			- -	- -	- -	- -	- -
	0.04	No	Yes	Private foot bridge		- -	- -	- -	- -	- -	- -	- -
					0.23		2	very poor	fair	present	- -	good
	0.27	No	No	CTH LO		- -	- -	- -	- -	- -	- -	- -
					0.31	1	4	poor	fair	present	present	good
	0.58	No	Yes	Private foot bridge		- -	- -	- -	- -	- -	- -	- -
					1.28	3	10	poor	good	- -	- -	excellent
	1.86	No	Yes	Private foot bridge		- -	- -	- -	- -	- -	- -	- -
					0.13		7	- -	- -	- -	- -	excellent
	1.99	No	Yes	Private foot bridge		- -	- -	- -	- -	- -	- -	- -
					0.11		2	- -	- -	- -	- -	good
	2.10	No	No	CTH NN		- -	- -	- -	- -	- -	- -	- -
					0.19		9	fair	poor	common	present	good
	2.29	No	Yes	Private foot bridge		- -	- -	- -	- -	- -	- -	- -
					0.02			fair	poor	- -	- -	- -
	2.31	No	Yes	Private dam		- -	- -	- -	- -	- -	- -	- -
					0.21		21	- -	- -	- -	- -	- -
	2.52	No	No	Private foot bridge		- -	- -	- -	- -	- -	- -	- -
					0.22		2	- -	- -	- -	- -	good

Table 27 (continued)

Subwatershed	River Mile	Fish Passage Obstruction	Navigation Hazard	Structure Identification	Distance between Structures	Number of Springs/ Seeps	Fish Spawning Sites	Warmwater IBI	Coldwater IBI	Mussel Species Abundance[a,b]	Endangered, Threatened, Species of Concern[c,d]	Habitat Quality
Jericho (continued)	2.74	No	Yes	Private foot bridge		- -	- -	- -	- -	- -	- -	- -
					0.59	1	1	fair	fair	- -	- -	good
	3.33	No	Yes	Private foot bridge		- -	- -	- -	- -	- -	- -	- -
					1.15	6		fair	poor	- -	present	fair
	4.48	No	Yes	Private foot bridge		- -	- -	- -	- -	- -	- -	- -
					0.26	7		- -	- -	- -	- -	good
	4.74	Yes	Yes	Private foot bridge		- -	- -	- -	- -	- -	- -	- -
					0.62	2		poor	fair	- -	present	good
	5.36	No	Yes	Road X		- -	- -	- -	- -	- -	- -	- -
					0.27	7		fair	poor	- -	present	good
	5.63	Yes	Yes	Dam/abandoned agricultural access road		- -	- -	- -	- -	- -	- -	- -
					0.51	4		- -	- -	- -	- -	fair
	6.14	No	Yes	Wisconsin and Southern Railroad		- -	- -	- -	- -	- -	- -	- -
					0.35	4		- -	- -	- -	present	fair
	6.49	No	Yes	STH 59		- -	- -	- -	- -	- -	- -	- -
Beulah					1.33	17		good	N/A	- -	present	good
	1.33	No	No	Private foot bridge		- -	- -	- -	- -	- -	- -	- -
					0.05			- -	N/A	- -	- -	fair
	1.38	Yes	Yes	Lake Beulah dam/CTH J		- -	- -	- -	- -	- -	- -	- -

NOTE: N/A represents sites where a coldwater IBI ranking is not applicable.

[a]*Mussel abundance data comes from studies conducted from 1975 through 2001.*

[b]*Mussel abundance categories are defined as: present = 1-3 occurrences, common = 4-6 occurrences, and abundant = more than 6 occurrences.*

[c]*Endangered, threatened, and species of special concern abundance categories are defined as: present = 1-2 occurrences, common = 3-4 occurrences, and abundant = more than 5 occurrences.*

[d]*Endangered, threatened, and species of special concern include fish species, mussel species and one reptile species (Blanding's turtle).*

Source: SEWRPC.

diversity generally associated with tributary streams located in lower portions of the stream network.[9] Therefore, the highest priority, or Tier 1, approach focuses on restoring continuity of passage and habitat restoration for native fishes on the mainstem of the Mukwonago River to its headwaters upstream as shown in Figure 59. This approach is designed to maintain and expand the fishery through reconnection and restoration of the strongest determinants of overall fish species diversity and assemblage structure, namely the Fox River and major lakes and their tributary networks and associated habitats from downstream to upstream.

The Tier 2 prioritization is based upon the understanding that, through their connection with the mainstem of the Mukwonago River, the tributaries are the next most diverse resources and greatest assets that have the potential to restore and maintain a sustainable fishery. Tributary streams that are connected to the associated mainstem of stream systems have a greater potential for increased fish abundance and diversity via access to feeding, rearing, and spawning, as well as refuge from thermal stress or low-water periods.[10] Hence, the second tier approach is focused on addressing fish passage continuity and habitat quality from the tributary streams to the mainstem and major lakes of the Mukwonago River watershed. The Tier 2 prioritization component is illustrated graphically in Figure 59.

The Tier 3 approach is designed to focus on improving fish passage and habitat quality throughout the entire watershed. Prioritization of projects to improve the fishery quality should be based upon areas where fish passage obstructions have been identified to be a problem and where improvement in ecosystem structure and function can be attained. Factors to be considered include connection to one or more tributaries, length of stream between structures, and/or connection to high-quality fish and habitat areas as indicated in Table 27. It is recommended that these structures and crossings as shown on Map 24 and in Table 27 be examined at the time of replacement or major modification with the intent of minimizing the numbers of crossings, and improving crossings to eliminate barriers to fish migration. Further, it is anticipated that new development or redevelopment may provide opportunities for interventions that do not conform to the first and second tier approaches. These opportunities should not be ignored; rather, where there are opportunities to enhance passage of fish and aquatic organism and/or to improve instream habitat, and where funds can be obtained, it is recommended that actions be taken to implement those opportunities.

Land-Based Measures

This prioritization is similar to the Three-Tier Instream Fisheries approach, and is designed to focus on protecting the existing highest-quality terrestrial wildlife habitat areas as well as to preserve instream quality for the short- and long-term through expansion of riparian corridors. Prioritization of sites for improving riparian corridors should be based upon improvement in ecosystem structure and function where possible. Such improvements include protection of groundwater recharge areas, expansion of existing corridor widths and/or connection to high-quality wildlife and critical species habitat areas (see Maps 42 and 43). It is also recommended that this prioritization build upon prior open space planning efforts that include: environmental corridors delineated by the Regional Planning Commission; the open space preservation elements of adopted County park and open space plans; land and water resource management plans; and the recently completed Walworth and Waukesha County

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[9]*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: 671-681, 1992.*

[10]*T.M. Slawski and others, "Effects of tributary spatial position, urbanization, and multiple low-head dams on warmwater fish community structure in a Midwestern stream,"* North American Journal of Fisheries Management, *Volume 28: 1020-1035, 2008.*

comprehensive plans.[11] In addition, lands currently held in public ownership by the State, counties, villages, towns, and nongovernmental organizations form the structural framework for prioritization of the land-based measures from which to expand protections. The high-priority lands for the Mukwonago River watershed are shown on Maps 42 and 43. The high-priority lands identified to be protected represent a synthesis of recommendations from the multiple planning efforts described in Chapter V.

RECOMMENDED LAND-BASED PROTECTION ACTIONS

The following subsections are structured to 1) indicate a habitat protection feature, such as riparian buffers; 2) identify a target to achieve relative to that feature; and 3) discuss issues, objectives, and recommended actions needed to meet the target, and potential quantifiable means of assessment related to the target.

Zoning and Regulations

The most fundamental and basic element of this protection plan is the land use element. The distribution of urban and rural land uses will largely determine the character, magnitude, and distribution of nonpoint sources of pollution and ultimately, the quality and quantity of the surface water and groundwater within the Mukwonago River watershed.

Land Management Target 1

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

- Integration of the Mukwonago River Watershed Protection Plan recommendations into regional and local level development plans, including an updated comprehensive watershed management plan for the Fox River basin,[12] and the updated implementation plan for the Southeastern Wisconsin Fox River Commission, whose jurisdiction includes the lower portion of the Mukwonago River watershed in the Town and Village of Mukwonago;[13]

- Consideration by WDNR of expanding the existing Cold Water Biological Community and Outstanding Resource Water designations throughout the Mukwonago River watershed (see Map 20):

    — Upgrade the currently designated Exceptional Resource Water reach of the Mukwonago River from the upstream end of Phantom Lakes to the outlet of Eagle Spring Lake dam to Outstanding Resource Water;

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[11]*SEWRPC Planning Report No. 42 (PR No. 42),* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, *September 1997; SEWRPC Planning Report No. 48 (PR No. 48),* A Regional Land Use Plan for Southeastern Wisconsin: 2035, *June 2006; SEWRPC Community Assistance Planning Report No. 288,* A Multi-Jurisdictional Comprehensive Plan for Walworth County: 2035, *November 2009; and Waukesha County Department of Parks and Land Use, Waukesha County University of Wisconsin-Extension, and Waukesha County Municipalities,* A Comprehensive Development Plan for Waukesha County, *February 24, 2009.*

[12]*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.*

[13]*SEWRPC Planning Program Report,* Southeastern Wisconsin Fox River Commission Water Resources Implementation Plan, March 1998, *March 1998.*

- Upgrade the currently designated cold water stream reaches that include Jericho Creek, the Mukwonago River upstream of Lulu Lake, the Mukwonago River between Lulu and Eagle Spring Lakes, and the Mukwonago River downstream of Lower Phantom Lake dam to an Outstanding Resource Water designation;

- Upgrade the remaining waterbodies and stream reaches within the Mukwonago River watershed that are currently not designated to Cold Water Biological Community and Outstanding Resource waters including Eagle Spring Lake, Upper Phantom Lake, Lower Phantom Lake, Lake Beulah, Pickerel Lake, Swan Lake, Rainbow Springs Lake, Wood Lake, Beulah outlet, and any Unnamed Tributaries.

• Observe and implement the conservation and development guidelines set forth in regional, county, and local land use and comprehensive plans, and the county land and water resource management plans, to protect environmentally sensitive lands as recommended in the regional natural areas and critical species habitat protection and management plan;[14]

• Limiting development within the SEWRPC-delineated primary and secondary environmental corridors and isolated natural resource areas, and promote connection of fragmented ecologically valuable lands by: connecting environmental corridors and isolated natural resource areas with other larger corridors and natural areas where and when possible, encouraging expansion and connection of natural areas by means of the environmental corridor network, and promoting preservation and enlargement of open space lands, especially within and adjacent to floodlands and riverine wetlands through voluntary perpetual conservation easements, conservation development practices, and/or fee simple purchase by appropriate entities;

• Updating and implementing zoning standards to ensure preservation of targeted lands including:

  - Protection and enhancement of wetland areas 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;[15]

  - Consideration of creating a Mukwonago River Protection Overlay District for the protection and enhancement of instream and riparian habitat and improvement of stream water quality as discussed below in the Riparian Corridors subsection.

• Consideration of applying 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:

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[14]*SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, *September 1997. See also SEWRPC Community Assistance Planning Report No. 288,* A Multi-Jurisdictional Comprehensive Plan for Walworth County: 2035, *November 2009; and, SEWRPC Community Assistance Planning Report No. 209,* A Development Plan for Waukesha County, Wisconsin, *August 1996, as refined.*

[15]*Chapter NR 151,* Runoff Management, *of the* Wisconsin Administrative Code, *currently requires protective zones adjacent to wetlands ranging from 10 to 75 feet in width, depending on the quality of the wetland. Proposed revisions to NR 151 call for expanding the protective zone to 50 feet in certain cases. Thus, the overall recommendation of this watershed protection plan, in some cases, is more stringent than the existing or proposed requirements of NR 151.*

— Exclusive Agricultural Zoning. Exclusive agricultural or farmland preservation zoning can be used to preserve farmland in agricultural-related uses. Traditionally, a key feature of such zoning in the Region and throughout the State is a requirement for a minimum parcel size of 35 acres, although that provision is no longer part of the State's definition of farmland preservation zoning. Changes in the State Farmland Preservation Law enacted as part of the 2009-2011 State budget bill essentially require counties in Wisconsin to update their farmland preservation plans and farmland preservation zoning. That legislation also modified the minimum standards for certifiable farmland preservation zoning (see *Wisconsin Statutes*, Chapter 91). Farmland preservation zoning is the primary means through which farmers become eligible for State farmland preservation tax credits.

— Land Division Ordinances. These ordinances are used to regulate the division of land into smaller parcels, usually for nonagricultural purposes such as residential subdivisions. While Chapter 236 of the *Wisconsin Statutes* contains minimum requirements that must be followed for land divisions that create five or more parcels or building sites of 1.5 acres each or less in area, local regulations vary widely. In the Mukwonago River watershed, all communities have adopted and administer a land division ordinance, although Waukesha County's only applies to the statutory shoreland zone.

— Purchase of Development Rights. The purchase of development rights (PDR) or granting of conservation easements 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. The 2009-2011 State budget bill created a matching grant program that supports local efforts to purchase agricultural conservation easements, or "PACE" programs—which are essentially the same as agricultural land PDR programs. There is currently no active PDR program in the Mukwonago River watershed.

— Transfer of Development Rights. The 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 pay 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 than authorized by the zoning code. There is currently no TDR program established in the Mukwonago River watershed.

- Utilize conservation subdivision designs in areas identified for future suburban or rural residential development to create a transition to open space in agricultural areas, to protect environmentally sensitive lands,[16] and to minimize land use conflicts, especially between built areas and the natural areas surrounding the Mukwonago River and its principal tributaries.

- Develop boundary agreements between communities to jointly protect environmentally sensitive lands.[17]

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[16]*SEWRPC Planning Report No. 42,* op. cit.

[17]Ibid.; *See also SEWRPC Community Assistance Planning Report No. 288,* op. cit.*; SEWRPC Community Assistance Planning Report No. 209,* op. cit.

Riparian Corridors

Based upon the summary of the best available science, preservation of riparian buffers is a key to the existing and future economic, social, and recreational well being of the Mukwonago River watershed and the residents living within it. Healthy riparian corridors help to protect water quality, groundwater, fisheries and wildlife, and ecological resilience to invasive species, as well as reducing potential flooding of structures and harmful effects of climate change.[18] In turn, the health of riparian corridors is largely dependent upon width and continuity. Therefore, efforts to protect and expand the remaining riparian corridor width and continuity are the foundation for protecting and improving the fishery and recreation within the Mukwonago River watershed. More specifically, beyond the 75-foot regulatory shoreland setback width, the 400-foot minimum width and 900-foot optimum width core wildlife protection areas as described in Chapter IV and Appendix B of this report should be considered for protection within a proposed overlay district or other appropriate means that would include purchase or easement. These areas are shown on Map 42. It is important to note that significant areas are encompassed within the one-percent-annual-probability regulatory floodplain boundary, a fact that already limits development within this riparian area. In contrast, the regulatory floodplain boundaries generally do not extend up into tributaries to the mainstem of the Mukwonago River, with the exception of the Beulah outlet and the lower reach of Jericho Creek. The lack of delineated regulatory floodplain boundaries leaves these areas more vulnerable to development. Other portions of the 400- to 900-foot zones are comprised of wetland and primary environmental corridor, or included within State natural areas or other protected ownership such as by The Nature Conservancy or municipalities. Therefore, the nonwetland uplands (i.e., agricultural lands, prairie, woodland, or other open lands) within the 900-foot zone remain the most vulnerable to development pressures. Priority should be given to protecting lands within the 900-foot boundary.

Corridor Target 1

Expand and protect riparian buffers.

Issue

All riparian buffers provide some level of protection that is greater than if there were no buffer at all. In addition, wider buffers provide a greater number of functions (infiltration, temperature moderation, species diversity) than narrower buffers. In the Mukwonago River watershed, increased development without significant mitigating actions within the 900-foot zone adjacent to the lakes, River, and tributary streams could lead to increased degradation to the fishery, water quality, wildlife, and recreational opportunities. Therefore, it is important that existing buffers be protected and expanded, where possible. The protection, preservation, and expansion of riparian buffer widths where possible among mainstem and tributary waterways throughout the Mukwonago River system are the most important aspects of this protection plan.

Recommended Actions

The following actions, or combinations of those actions, should be considered in identifying opportunities for establishment or expansion of riparian buffers:

- Walworth and Waukesha Counties and the concerned towns and villages should consider creating and implementing a "Mukwonago River Overlay Zoning District" that would establish zones along the stream corridors of the Mukwonago River system that would be designed to protect these high quality resource waters. Based on the riparian buffer concepts described in Chapter IV and Appendix B of this report, this District would ideally extend 900 feet from significant streams and lakes, or to the outer limit of the existing primary environmental corridor, whichever is greater. The regulatory

[18]*N.E. Seavy and others, "Why Climate Change Make Riparian Restoration More Important than Ever: Recommendations for Practice and Research,"* Ecological Restoration, *Volume 27(3): pages 330-338, September, 2009; "Association of State Floodplain Managers, Natural and Beneficial Floodplain Functions: Floodplain Management—More Than Flood Loss Reduction, 2008,"* www.floods.org/NewUrgent/Other.asp.

shoreland zone is defined as extending 1,000 feet from the ordinary high water mark of lakes, ponds, and flowages and 300 feet from the ordinary high water mark of navigable streams, or to the outer limit of the floodplain, whichever is greater. To be consistent with that concept and to avoid confusion, it is recommended that the zoning overlay district boundary extend 1,000 feet from the ordinary high water mark on both sides of the lakes, ponds, and navigable streams in the Mukwonago River watershed, or to the outer limits of the floodplain or connected wetlands, whichever is greater. One possible representation of the district boundaries, subject to navigability determinations, is shown by the outer boundary of the colored area on Map 42 (yellow or green). Within that zoning district, specific requirements would be established regarding existing and new urban and sub-urban development and agricultural lands.

The objectives of establishing a "Mukwonago River Overlay Zoning District" would be to provide buffers along waterbodies to maintain or enhance the integrity and quality of aquatic and terrestrial communities, promote recharge of groundwater, promote development principles that would maintain pre-development hydrologic conditions to the degree feasible, and provide control of nonpoint source pollution from both urban and rural lands. The recharge and pre-development hydrology objectives are important components of maintaining groundwater conditions that would support the current cold water baseflow regime in the streams and lakes of the watershed.

The district would include SEWRPC delineated environmental corridor lands, SEWRPC identified natural areas and critical species habitat, regulatory floodplains, shoreland wetlands, shoreland areas, drainageways, steeply sloped lands, and important uplands including prairie, woodlands, and other open lands. All, or portions of, those lands in both Walworth and Waukesha Counties are currently included within conservancy zoning districts within which new development is restricted. Consequently, implementation of the recommended Mukwonago River Overlay Zoning District would be likely to have a minimal impact on existing development outside of the developed lake shore areas. Within these lake shore areas, rigorous enforcement of the regulatory 75-foot shoreland setback is recommended. Consideration should be given to encouraging the placement of vegetated riparian buffers within these lake shore areas as part of the implementation of this overlay zoning district. Such an approach is generally consistent with the existing on the ground conditions within the basin or watershed as shown on Map 42. Similar approaches have been adopted in the Village of Fontana on Geneva Lake through their environmental corridor overlay districts and the City of Milwaukee through their Milwaukee River Greenway Overlay Zone.

- Formation of an intergovernmental task force to consider issues that would need to be addressed in establishing a "Mukwonago River Overlay Zoning District" and to make recommendations to the units of government with zoning authority. Some of the issues to be considered include:

  — Along which streams and lakes would the district be established

  — How the extent of undeveloped riparian buffers would be optimized to meet multiple water quality and habitat objectives

  — What restrictions, if any, would be imposed on existing development

  — How formation of such a district can be accomplished without imposing an unnecessary financial burden on residents and other landowners within the district

  — What requirements would apply to agricultural lands

  — What types and sizes of new development would be permitted

- What should be the characteristics of new development (e.g., clustering, low environmental impact features)
- What stormwater management approaches would be required
- What building setbacks from water features would be established within the 1,000-foot zone
- What limits would there be on removal of vegetation and trees

- Preservation and/or restoration of natural vegetation and topography along perennial and intermittent streams, lakes, and ephemeral wetlands by seeking voluntary, perpetual conservation easements on targeted lands; fee simple purchase; application of conservation development practices; and/or, implementation of shoreland best management practices, including enforcement of setbacks, restoration and revegetation of disturbed areas, and installation of effective riparian buffers within the zone extending 1,000 feet from the ordinary high water mark or within the boundaries defined by floodplains or wetlands, whichever is greater.
  - Existing homes or businesses within the 1,000-foot zone should consider landscaping that would enhance wildlife by providing connections (see Appendix B page 12) or lanes through the lots as well as using native plants to provide cover and food for wildlife.
  - Natural vegetation should be established and/or maintained within the riparian corridors along perennial, intermittent, and ephemeral waterways in both urban and rural areas, preferably using native species, in accordance with WDNR and NRCS technical standards for filter strips and turf management to the extent applicable, and SEWRPC guidance for riparian buffers (see Appendix B);
- Continue to limit development in SEWRPC delineated primary environmental corridors and extend such limitations to secondary environmental corridors and isolated natural resource areas, and promote defragmentation of ecologically valuable lands by 1) connecting environmental corridors and isolated natural resource areas with other larger corridors and natural areas where and when possible (see Map 43), 2) encouraging expansion and connection of natural areas by means of the environmental corridor network, and 3) promoting preservation and enlargement of open space lands, especially within and adjacent to floodlands and riverine wetlands through voluntary perpetual conservation easements, conservation development practices, and/or fee simple purchase by appropriate entities;
- Maintenance and/or enhancement of existing linkages between terrestrial and aquatic biological communities, including fish, amphibians, and other wildlife through maintaining or restoring connectivity between the River and its floodplain;
- Expansion of riparian buffers on the WDNR Rainbow Springs property from approximately River Mile 7.5 through 8.4 to protect water quality and wildlife.[19]

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[19]*As noted in Chapter IV of this report, the State of Wisconsin has purchased the Rainbow Springs property using resources from the Knowles-Nelson Stewardship Fund. As of the date of publication of this report, the golf course was still in operation and inquiries had been made to the WDNR regarding continuation of that operation. Stewardship Fund requirements may not allow continued operation of the golf course on the property. The determination of acceptable uses of the property will be made by WDNR.*

- If operation of the golf course is going to be discontinued, it is recommended that, to the extent practical, 1) minimum 1,000-foot-wide buffers be established and maintained adjacent to all streams, lakes, ponds, and wetlands on the property, 2) golf cart stream crossings be removed, and 3) abandoned buildings be removed from the site.

- If the golf course is going to continue operation, the following elements are recommended:

  - Convert the two separate 18-hole courses into a single 18-hole golf course

  - Abandon all golfing areas north of the mainstem of the Mukwonago River, including the island area that is currently being used, and establish native vegetation. This eliminates the need to cross the River and allows for expansion of riparian buffers, as well as removal of the golf cart crossings that are obstructing aquatic organism passage and that present navigation hazards (see Aquatic Organism Passage section below).

  - Where practical, establish 75-foot minimum "no-touch" buffer widths as well as 75- to 400-foot-wide minimum limited mowing/rough areas adjacent to all streams, lakes, and ponds on the golf course. Note that this recommended reconfiguration assumes conversion of lands on which there are abandoned buildings and parking lots to accommodate the movement of holes away from the Mukwonago River and into those areas of the property.

  - Redevelopment of the golf course should also consider flooding impacts in its design and should consider removal of historical fill within the areas proposed to be abandoned on the north side of the Mukwonago River, including the islands. This would improve connection of the stream to its floodplain, and would allow for the course to be located outside of the more-frequently flooded areas, enabling it to be used throughout the entire golfing season.

- Eradication of purple loosestrife and other nonnative invasive species, to the extent possible, through partnerships between communities, schools, volunteer groups, service organizations, and local governments, and through participation in the WDNR purple loosestrife beetle rearing program, (see Exotic Invasive Species section in Chapter IV of this report);

- When lands are converted from rural to urban land uses and funding can be obtained, consideration should be given to restoring undeveloped wetlands that were previously converted to agricultural uses, reconnecting shorelands with floodplains, and maintaining groundwater recharge and discharge areas to protect the essential character and ecological integrity of the Mukwonago River system;

- Establishment of buffers on public lands, on lands purchased with donations or grant funds, or on private lands on which conservation easements are acquired.

- Locating open space adjacent to existing natural areas or conservancy lands should be considered as part of proposed cluster development or conservation subdivisions, thus expanding larger areas to provide additional wildlife habitat quantity and quality benefits.

Potential Means of Assessment

- Number of stream miles with buffer width of 1,000 feet or greater preserved, established, or protected.

- Volume of fill and/or trash removed from riparian areas.

- Area of native wetland or upland reconstructed.

- Number of native species restored.

- Area of exotic invasive species removed.

Corridor Target 2
Expand and protect riparian buffer continuity and connectivity.

Issue
Fragmentation of riparian buffers by roads, railways, and utilities combined with encroachment by development impacts the structure and function of riparian corridors and their ability to adequately protect waterways and wildlife habitat. Stream crossings tend to have a cumulative impact on the stream and associated lands and on the quality of water and the fishery. Therefore, it is important to reduce the linear fragmentation of the existing riparian buffers by either removing crossings where possible or at least not increasing the number of crossings of waterways within the Mukwonago River system, where practical. The human safety need to preserve access by police, fire protection, and emergency medical services is an overriding consideration that must be applied in determining whether the objective of removing a crossing is feasible. This issue is only meant to apply to situations where more road crossings exist than are necessary to ensure adequate access for emergency services.

Recommended Actions
The following actions, or combinations of those actions, should be considered in identifying opportunities to expand riparian buffer continuity:

- Establishment of buffers on public lands, on lands purchased with donations or grant funds, or on private lands on which conservation easements are acquired.

- Preservation and expansion, to the extent possible, of small wetlands, woodlands, and prairies not identified as part of an environmental corridor or an isolated natural resource area and linking such features by providing corridors connected to larger natural areas, as determined in county and local plans.

- Removal of abandoned or nonessential roads where appropriate.

- Where possible, limit creation of new road crossings of the mainstem or tributaries within the Mukwonago River system to limit negative impacts to water quality and wildlife.

- Purchase of lands by governmental, nongovernmental, or private organization, or other private entities to expand buffers within the SEWRPC-delineated primary and secondary environmental corridors and isolated natural resources areas, especially along the River mainstem and tributary streams.

Potential Means of Assessment
- Number of stream miles of continuous buffer widths preserved or established.

- Number of stream channel crossings and/or impediments to flow removed and/or retrofitted to restore continuity of riparian buffers.

Corridor Target 3
Protection of high-quality areas or environmentally sensitive lands.

Issue
The existing plant communities, natural areas, and critical species habitat areas are the most vital wildlife areas remaining within the Mukwonago River watershed, and those areas need to be protected. Such areas help provide

local and regional ecological resilience within an urbanizing watershed. In addition, protection of primary and secondary environmental corridors, isolated natural resource areas, and groundwater recharge areas throughout the watershed should also be a priority. Therefore, protecting and managing environmentally sensitive lands to maximize native plant and animal biodiversity, as well as groundwater recharge, is an important element of this plan.

Recommended Actions
The following actions, or combinations of those actions, should be considered in identifying opportunities to protect high-quality areas or environmentally sensitive lands:

- Protection of wetlands, woodlands, and groundwater recharge areas through land use regulation, public land acquisition via donation or purchase, establishment of conservation easements on critical lands, and/or possible expansion of environmental corridors. These protections are recommended for the priority lands indentified on Map 43 within the Mukwonago River watershed.

- Consideration of establishing additional protections for preservation of high and very high groundwater recharge potential areas within internally drained areas within the Mukwonago River watershed as shown on Map 43.

- Wetland areas are currently largely protected through the existing regulatory framework provided by the U.S. Army Corps of Engineers permit program, State wetland regulations and shoreland zoning requirements, and local zoning ordinances. Many wetland areas in the watersheds are included in the environmental corridors delineated by SEWRPC and protected under one or more of the existing Federal, State, county, and local regulations. Consistent and effective application of the provisions of these regulations is recommended.

- Certain wetland and woodland areas have been identified for acquisition in the adopted regional natural areas and critical species habitat protection and management plan.[20] Implementation of these recommendations, in addition to those set forth in the adopted park and open space plan for Walworth and Waukesha Counties,[21] would complement the protection and preservation of environmentally sensitive lands.

- Consideration of adopting and enforcing shoreland setback requirements in the villages in the watershed and continuation of active enforcement of construction site erosion control and stormwater management ordinances.

- Provision of informational materials to shoreland property owners.

- Enforcement of local zoning regulations to discourage development within the one-percent-annual-probability floodplain.

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

[21]*SEWRPC Community Assistance Planning Report No. 137,* A Park and Open Space Plan for Waukesha County, *December 1989, as amended in 1996 (CAPR No. 209), and in 2009 in the 2035 Waukesha County Comprehensive Development Plan and SEWRPC Community Assistance Planning Report No. 135 (2nd Edition),* A Park and Open Space Plan for Walworth County, *September 2000, as amended in September 2004.*

- Identification of specific candidate sites for restoration of native wetland and/or upland prairie communities, using information presented in this report and also compiled by Jefferson, Walworth, and Waukesha Counties and SEWRPC, as shown on Maps 35 and 36. Those lands should be purchased or easements should be obtained, and the lands should ultimately be restored through modification of agricultural drainage systems, removal of nonnative exotic invasive species, removal of historical fill, and/or establishment of native vegetation, among other best management practices.

- Conduct of additional surveys to inventory environmentally sensitive lands.

Potential Means of Assessment

- Number of stream miles inventoried and areal extent of potential buffer identified.

- Number of stream miles or areal extent of land protected.

- Monitor enforcement of local shoreland and floodplain zoning ordinances.

Information Needs

Identify and delineate the extent and distribution of additional internally drained areas throughout the Mukwonago River watershed to assist local planning efforts.

Conduct wildlife species surveys and vegetation surveys to identify high-value riparian buffer and/or environmental corridor lands throughout the Mukwonago River watershed (e.g. conduct inventories within isolated natural resource areas). These areas would then become the focus of protection and reconnection with possible additional corridor lands.

Maintain current inventories on riparian buffer conditions and widths throughout the watersheds and expand riparian buffer inventories within tributaries not assessed.

Hydrology and Groundwater

Urban development brings with it significant changes in the landscape. These changes historically have included modification of the drainage pattern (primarily tributaries), hardening of surfaces, and alteration of groundwater infiltration, all of which can affect water quality and quantity. All of these changes generally increase the volume and rate of runoff from precipitation events. Historically, managing these increases in rates and volumes of runoff would often involve construction of storm sewer and/or open channel systems to convey stormwater as quickly and efficiently as possible to streams and ultimately to the Fox River. In recent years, however, flooding, water quality impairment, and environmental degradation have demonstrated the need for an alternative approach to stormwater management. Consequently, current stormwater management practices seek to manage runoff using a variety of measures, including detention, retention, infiltration, and filtration, better mimicking the disposition of precipitation on an undisturbed landscape.

Hydrology Target 1

Maintain natural flow regimes to protect adequate baseflows and prevent flashiness, stream erosion, and habitat degradation.

Issue

Urbanization increases the area of impervious surfaces, which can lead to an increase in “flashiness” (or the rate at which flow responds to a precipitation event) and can subsequently affect streambank and streambed stability, pollutant loading, and sediment dynamics, which, in turn, affect habitat availability and quality. Therefore, increased flashiness has been determined to be a cause of degradation of aquatic communities. Although the overall levels of urban development in the watershed have been relatively low, there are localized areas of more intensive urban development. The amounts of urban development within the watershed are at high enough levels to potentially be negatively affecting water quality and water quantity. In particular, algal, invertebrate, and fish communities are sensitive to increases in average flow magnitude, high flow magnitude, high flow event frequency, and/or durations of high flows associated with urbanization. Increased impervious surfaces also can lead to reduced infiltration rates into the shallow aquifer and reductions in baseflows within the Mukwonago River system, which is largely dependent upon groundwater discharge. This could lead to substantial loss in stream depth and volume, increased water temperatures, and increased potential for summer fish kills from low dissolved oxygen as well as loss of the coldwater fishery. The projected increases in urban development throughout the watershed indicate that development pressures and associated water quality and quantity issues are a major concern to be addressed. Fortunately, given the large amounts of existing open land, extensive riparian buffers, and large areas of high quality groundwater recharge areas throughout the watershed, there are opportunities to protect the natural hydrology of the Mukwonago River system.

Recommended Actions

The following actions, or combinations of those actions, should be considered in identifying opportunities to maintain natural flow regimes and protect from flashiness, stream erosion, and habitat degradation:

- Management of stormwater runoff to meet, to the maximum extent practicable, the agricultural performance standards and the nonagricultural standards for existing development, new development, and redevelopment as established under Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code*. The objectives of the first tier and second tier approaches would be to ensure that new development and redevelopment conform to the water quantity and quality control requirements of Chapter NR 151. The objective of the third tier approach would be to address runoff from existing development as opportunities arise, so that the quality of stormwater runoff meets the requirements of Chapter NR 151.

- Promotion of urban nonpoint source pollution abatement through local stormwater management ordinances and through meeting the conditions of the Wisconsin Pollutant Discharge Elimination System municipal separate storm sewer system (MS4) discharge permits for the Village of North Prairie and the Towns of Genesee, Ottawa, and Vernon. Stormwater management planning could be undertaken by municipalities to promote cost-effective urban nonpoint source pollution abatement.

- In addition to the adoption and enforcement of stormwater management ordinances, the most viable measures to control urban nonpoint sources of pollution appear to be good urban land management and urban housekeeping practices.[22] Such practices consist of fertilizer and pesticide use management, litter and pet waste controls, lawn watering, and management of leaf litter and yard waste. These measures should be promoted under the public informational programs being conducted under the conditions of the municipal MS4 discharge permits.

- Implementation and maintenance of stormwater management practices at the subwatershed and neighborhood levels.

- Consistent with local floodplain zoning ordinances, continue to regulate filling and development within the floodplain, so that connectivity with the stream system can be maintained.

[22]*UW-Extension, Water Resources Education Publications,* http://clean-water.uwex.edu/pubs/index.htm.

- Improvement of infiltration of rainfall and snowmelt through innovative best management practices (BMP) that are associated with low-impact development, including bioretention and rain garden projects,[23] installation of rain barrels, disconnection of downspouts, and porous pavement projects.

Groundwater Target 1

Preserve groundwater recharge areas in accordance with the recommendations of the regional water supply plan, prevent groundwater contamination from stormwater infiltration practices, and maintain the integrity of the shallow and deep groundwater aquifers by protecting recharge areas and balancing abstraction.

- The protection and preservation of groundwater recharge areas classified as having a high or very high recharge potential are recommended. These recharge areas are shown on Map 43. Such protection should also incorporate preservation of environmental corridors, isolated natural resource areas, prime and other agricultural areas, and preservation of open lands that are associated with conservation developments and that facilitate recharge.

- Review, and updating as necessary, of local and County land use regulations to require conservation development practices providing for the clustering of any new development within the watershed so as to minimize nonpoint source pollution impacts on groundwater and to also minimize potential reductions in groundwater recharge and resultant stream baseflow;

- Consideration of groundwater conditions when locating buildings, especially in internally drained areas. This should include review of development proposals to avoid locating structures and other infrastructure in areas prone to flooding as a result of high groundwater levels, especially in areas that are internally drained;[24]

- Maintenance of infiltration and recharge rates as close to existing rates as practicable by incorporating runoff management recommendations for enhancing infiltration using low-impact design standards in accordance with the regional water supply plan that is currently being prepared;[25, 26]

- Consideration of groundwater impacts during the installation of sewer and water lines and other buried utilities which could intercept groundwater flows.

- Preparation of studies related to the siting of all new high-capacity wells, including analyses of potential, and subsequent monitoring of the actual impacts of such wells on the shallow aquifer, existing wells, and surface waters. The siting studies should be designed to develop the necessary under

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[23]*Roger Bannerman, WDNR and partners;* Menasha biofiltration retention research project, *Middleton, WI, 2008; N.J. LeFevre, J.D. Davidson, and G.L. Oberts,* Bioretention of Simulated Snowmelt: Cold Climate Performance and Design Criteria, *Water Environment Research Foundation (WERF), 2008; William R. Selbig and Nicholas Balster,* Evaluation of Turf Grass and Prairie Vegetated Rain Gardens in a Clay and Sand Soil: Madison, Wisconsin, Water Years 2004-2008, *In cooperation with the City of Madison and Wisconsin Department of Natural Resources, USGS Scientific Investigations Report, in draft.*

[24]*See the* "Basement Wetness and Flooding Prevention Standards" *applied under the Waukesha County Storm Water Management and Erosion Control Ordinance.*

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

[26]*SEWRPC Technical Report No. 48,* Shallow Groundwater Quantity Sustainability Analysis Demonstration for the Southeastern Wisconsin Region, *November 2009.*

standing of the hydrogeological system associated with each candidate site and to assess the likelihood of impacts of proposed wells upon nearby existing wells and surface waterbodies. The studies should include identification of significant potential negative impacts, needed mitigative actions, or site location revisions. Water levels in the vicinity of new high-capacity wells in the shallow aquifer should be monitored before and after wells are constructed and placed into operation to establish a baseline including levels expected to be maintained in private wells and to develop performance and impact data during the test well phase of well development and during the subsequent operation of the well over time. This is a preliminary recommendation from the ongoing regional water supply plan.

- Water supply withdrawals can affect surface water levels within lakes if wells are situated in proximity to surface waterbodies including lakes and streams. Therefore, water conservation measures; groundwater recharge protection and enhancement measures; and implementation of high-capacity well development siting, monitoring, and impact mitigation protocols, as is preliminarily recommended in the ongoing SEWRPC regional water supply plan, are imperative to minimize water use conflicts and ecosystem impairment in the Mukwonago River watershed.[27,28]

Information Needs
Continue working towards understanding the interactions between groundwater, surface water, and wetlands in order to sustain conjunctive use of this hydrologic system, to minimize water use conflicts, and to ensure adequate allocation and quality of water to sustain the integrity of the coldwater and warmwater aquatic communities.

Flooding Target 1
Preserve floodwater storage areas, mitigate flow increases and floodwater storage losses, and control the quantity of runoff from new urban development.

Recommended Actions

- Use of SEWRPC regional rainfall frequency data and 2005 SEWRPC revised design storm temporal rainfall distributions in the calculation of flood elevations and the design of stormwater management infrastructure to more accurately reflect current conditions within the watershed and Southeastern Wisconsin Region;[29]

- When the results of an ongoing National Weather Service (NWS) rainfall-frequency study for the Midwestern United States[30] are available, that study will replace the current SEWRPC information. At

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[27]*See State of Wisconsin Court of Appeals District II decision on appeal number 2008AP3170 dated June 16, 2010, which affirms that "…information from a scientist that the proposed well 'would cause adverse environmental impacts to the wetland and navigable surface waters of Lake Beulah'…" must be considered in the granting by the WDNR of municipal well permits.*

[28]*The groundwater model documented in SEWRPC Memorandum Report No. 188,* Troy Bedrock Valley Aquifer Model—Waukesha and Walworth Counties, Wisconsin, *November 2009, prepared by Ruekert & Mielke, Inc. for SEWRPC, provides a framework for such studies within the Mukwonago River watershed.*

[29]*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.*

[30]*National Weather Service,* Precipitation Frequency Project for the Midwestern States, *in progress.*

that time, local stormwater management ordinances should be updated to call for use of rainfall and storm temporal distribution information developed under the NWS study;

- Development of new stormwater and floodland management facilities, or retrofitting of existing facilities as necessary, to minimize or prevent damage from inundation events up to and including the one-percent-annual-probability flood;

  — Development and maintenance of up-to-date inventories and maps to identify areas and structures at risk of flooding;

- In addition to the lake-specific actions set forth in the applicable lake management plans, a hydrologic and hydraulic analysis of the relationship between the Eagle Spring-Lulu Lake system, the main stem of the Mukwonago River, Lower Phantom Lake, and Lake Beulah should be conducted to assess whether the dams impounding the lakes can be operated in concert to potentially reduce the possibility of dam failures during large floods, especially in light of the benefit of coordinated management of these reservoirs demonstrated during the June 2008 flood. Such a study should include review of the operating permits for each of the impoundments to ensure that coordinated management of the three lakes can be implemented in a manner that is consistent with the permitting and other requirements set forth in Chapters 30 and 31 of the *Wisconsin Statutes.* Each of these lakes should begin to monitor lake levels and/or discharge simultaneously, to the extent practicable.

- Delineation of the one-percent-annual-probability floodplain wherever approximate floodplain boundaries are delineated in the watershed, including the headwaters of Jericho Creek, Mukwonago River headwater areas upstream of Lulu Lake, and Lake Beulah.

Potential Means of Assessment

- Numbers of infiltration facilities installed, drainage area controlled by regenerative stormwater practices that achieve quality and quantity control, area of permeable paving materials installed, acres of wetland and upland restored, area of low-impact development.

- Number of rain gardens or rain barrels installed and downspouts disconnected, green roofs installed.

- Maintenance of adequate baseflows and no increase in stream erosion (i.e. no increase in average flow magnitude, high flow magnitude, high flow event frequency, and/or high flow duration)

- Continued maintenance of good water quality.[31]

Water Quality

Water Quality Target 1

Maintain or improve water quality within streams and lakes.

Issue

The overall water quality in terms of nutrients and pesticides within the stream and lake systems of the Mukwonago River watershed is generally very good. However, specific constituents such as pesticide metabolites and increasing chloride concentrations indicate the potential vulnerability of this system to contamination. The

[31]*Because of the complex nature of the stream systems in the Mukwonago River watershed, a long-term time frame may be needed to identify significant changes in instream or lake water quality. Thus, maintenance of a long-term network of streamflow and water quality monitoring gauges is recommended (see the Monitoring and Information section below).*

quality and quantity of water entering the Mukwonago River system during lower flow periods is dependent upon groundwater recharge and discharge. Therefore, changes in water quality and quantity are linked to the groundwater recharge and discharge of the local shallow aquifer, which may also be affected by local high-capacity water supply wells. These factors combined with the existing and proposed development within the watershed could lead to the degradation of water quality, decreased low-flow quantity, increased high-flow quantity, and associated habitat loss, in the absence of mitigation.

Recommended Actions
The following actions, or combinations of those actions, should be considered in identifying opportunities to maintain and improve water quality within streams and lakes:

- Maintenance of connections between streams and overbank floodplains so as to continue to protect and preserve fish and wildlife habitat and water quality benefits, making use of open space lands, riparian corridors, and park lands in floodprone areas, as appropriate;

- Identification of spring seeps, spring boils, and/or stream reaches with high chloride concentrations and target them for pilot programs;

- Evaluation of existing road deicing and anti-icing programs with an emphasis on salt reduction;[32] establish new road deicing and anti-icing programs in communities that do not have programs; and promote optimal application of deicing agents on commercial, industrial, governmental and institutional, airport, and residential properties.

- Protection of groundwater recharge and discharge areas (see recommendations above)

- Consideration of investigating modification or retrofitting of the dam outfalls from Eagle Spring, Lake Beulah, and Lower Phantom to draw water from variable depths below the surface to reduce thermal impacts of increased water temperatures to downstream reaches, but to avoid discharging anoxic water downstream.

    — Consideration of continued monitoring of water temperature simultaneously downstream of these impoundments on an hourly basis.

Stormwater Target 1
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
As noted below, 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, infiltration trenches, infiltration swales, bioretention facilities, rain gardens, proprietary stormwater sedimentation devices, and wet

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[32] *Calcium chloride application could be reduced through implementing practices such as applying salt only at intersections, mixing salt with sand, and calibrating spreaders and also through substitution of less environmentally damaging anti-icing and deicing agents.*

detention basins.[33] These standards include provisions intended to protect groundwater quality, and it is recommended that the standards be applied in the design of stormwater management facilities.

An important emerging issue in southeastern Wisconsin is the application of salts for snow and ice control on roads and other surfaces, and the use and discharge of salts in water softeners used to treat water for domestic supply. Chloride associated with these salts is a persistent constituent that is often transported by stormwater runoff and wastewater discharges. Stormwater and wastewater management practices do not treat or remove dissolved chloride in runoff. As a consequence, concentrations of dissolved chloride in both surface and ground waters are increasing, and, while these concentrations currently remain below those levels necessary to cause significant changes in the plant and animal communities in the River system, special safeguards must be considered in order to avoid future adverse effects. State technical standards recognize the inability of current technologies to remove chloride from stormwater runoff and wastewater. Reducing or eliminating the use of chloride-containing salts for roadway and parking lot anti-icing and deicing in the area tributary to a waterway or a stormwater management device and reducing chloride concentrations from water softeners that discharge to private onsite wastewater treatment systems constitute viable approaches to minimizing the risk to the Mukwonago River system from environmental and other changes associated with high concentrations of chlorides. To this end, alternative measures to manage snow and ice, such as use of salt brine, use of alternative anti-icing and deicing substances that do not contain chlorides, and sand-salt mixtures, and alternative technologies for softening potable water, such as reverse osmosis filters, should be considered as recommended below.

- Preparation of detailed regional stormwater management plans addressing areas where future urban development is planned and areas of existing development where controls need to be upgraded to protect and maintain the quality of the water resources of the Mukwonago River system;

- Implementation of stormwater management practices, emphasizing infiltration facilities, that promote:

  — Achievement of recommended water use objectives and supporting water quality standards and criteria for the Mukwonago River system, and that do not degrade existing habitat conditions for fish and aquatic life;

  — Minimization of disruption to primary and secondary environmental corridors, including the incorporated woodlands, wetlands, and wildlife habitat areas;

  — Protection of valuable and sensitive wetlands from the adverse impacts of stormwater runoff;

  — Continued control of sedimentation in receiving streams and lakes to prevent the loss of fish and aquatic life.

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

- Evaluate existing stormwater management BMPs for the potential to make modifications to improve water quality and water quantity functionality.

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

- Minimization of stormwater pollutant loading, runoff temperature increases, and changes in downstream hydrology that would otherwise result from development, and maintain adequate baseflow through the establishment and maintenance of riparian buffers, stormwater infiltration practices, and other urban best management practices (BMPs);

- Preparation and periodic review and updating of local land use, park and open space, stormwater management, and transportation plans consistent with the recommendations contained in this plan;

- Protection of water resources when adding, improving, or upgrading urban infrastructure:

  — For planned road construction, 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;

  — For installation of sewer systems and other buried utilities, including proposed sanitary sewer extensions, ensure adequate erosion and sediment control techniques are used;

  — For all road, bridge and culvert construction or reconstruction, employ good planning and enforcement of erosion control and stormwater management practices;

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

- Coordination of activities for stormwater management throughout the entire watershed—for example, continue development of, data entry into, and expansion of the Internet-based Waukesha County Storm Water BMP Tracking System by encouraging municipalities to request training and access to utilize the system;

- Consideration of the formation of stormwater utility districts within local jurisdictions, and/or the adoption of an intergovernmental stormwater management entity, pursuant to Section 66.0301, *Wisconsin Statutes*, with responsibility for stormwater management throughout the Mukwonago River watershed, which would have authority to fund, implement, and maintain stormwater facilities and BMPs;

- Review of road salt/sand use and consider alternatives such as salting intersections only, use of salt brine, use of alternative anti-icing and deicing substances that do not contain chlorides, and sand-salt mixtures wherever practicable to limit the introduction of chloride to surface water and groundwater in the Mukwonago River watershed;

- Working cooperatively with area fueling and automotive service stations to decrease potentially contaminated runoff;

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

- Continue promoting informational and educational activities intended to draw attention to the water resources in the Mukwonago River watershed, including activities such as: a) storm drain informational marking; b) volunteer stream water quality monitoring; c) distributing information on proper management of materials that may cause water pollution from sources such as automobiles, pets, household hazardous wastes, and household practices; d) promoting beneficial onsite reuse of composted leaves and grass clippings, and proper use of lawn and garden fertilizers and pesticides; and, e) promoting infiltration practices for residential stormwater runoff, such as “rain gardens.”

Potential Means of Assessment

- Maintenance or improvement in water quality constituents.

- Improvement in instream water quality through obtaining water quality and biological data.

- Number of stormwater management facilities installed that promote enhanced infiltration of runoff, tributary area treated by those facilities. That inventory would be facilitated by the Waukesha County Storm Water BMP Tracking System. Such a system could also be created in Jefferson and Walworth Counties.

- Number of communities implementing road salt reduction programs; reduction in amount of road salt applied by municipalities; number of commercial owners, contractors, operators, municipalities, and the public contacted through information programs on use of salt on driveways and other areas.

Agricultural Target 1

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

Recommended Actions

- Evaluate remaining agricultural operations in the watershed for compliance with State standards for control of barnyard runoff, manure storage, and application of integrated nutrient and pest management practices, and undertake corrective measures; county and UWEX agricultural extension staff should work with landowners to secure cost-share funding required to install practices, such as those provided through the following NRCS programs: 1) Conservation Reserve Program (CRP), 2) Conservation Reserve Enhancement Program (CREP), and 3) Environmental Quality Improvement Program (EQIP);

- The County staffs, UWEX agricultural extension staff, and NRCS staff should work with landowners to control cropland erosion by reviewing and refining as necessary conservation plans intended to control cropland erosion rates to levels that meet or exceed the State standards for nonpoint pollution runoff control;

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

- Installation of 75-foot-wide minimum permanent vegetative buffers along perennial and intermittent streams where adjacent to cropland or livestock pastures.

Potential Means of Assessment

- Maintenance or improvement in water quality constituents.

- Improvement in instream water quality through obtaining water quality and biological data.

- Number of stream miles of riparian buffer installed, categorized by buffer width.

- New land area enrolled in CRP and CREP.

Land-Based Monitoring and Informational Programming

It is important that steps be taken to ensure the existence of a sound program of water quality monitoring to determine the extent to which physical, chemical, and biological conditions are being maintained or improving over time; to measure temporal and spatial trends; to provide data to evaluate the effectiveness of water pollution control measures; and to detect new and emerging water quality problems specifically linked to land use and land management issues in the watershed. Therefore, monitoring of land-based activities should be coordinated and linked with instream and in-lake monitoring programs (see Instream-Based Monitoring and Informational Programming section below) in order to optimize the use of the scarce monitoring resources of multiple agencies and groups, generate monitoring data that are scientifically defensible and relevant to the decision-making process, and manage and report water quality data in ways that are meaningful and understandable to decision makers and other affected parties.

Monitoring and Information Target 1
Continue and expand monitoring and informational programming.

Issue
It is critical to determine whether water quality and biological communities are being improved or degraded and to establish the physical conditions of the streams and associated corridor lands, in response to land use changes throughout the watershed. Therefore, it is important to continue existing monitoring efforts and expand monitoring and informational programming when possible.

Recommended Actions
The following actions, or combinations of actions, should be considered in identifying opportunities to continue and expand monitoring and informational programming:

- Support of the efforts of the Lake Management Districts, Friends of the Mukwonago River, Kettle Moraine Land Trust, and other citizen-based organizations in promoting wise resource management and assistance in implementation of watershed protection activities through development and distribution of educational materials, staging of displays, and conduct of events;

- Contribution to watershed protection through informational and educational programs at facilities such as local schools:

  — Provide local residents, businesses, developers and government officials with a basic understanding of the geography, natural resources, and environmental issues facing the Mukwonago River watershed;

  — Inform local residents, businesses, developers and government officials about the types of practical actions and behaviors that will contribute to the health or destruction of the watershed;

  — Provide opportunities and incentives for local residents, businesses, developers and government officials to make those behavioral changes and take those actions that will protect and preserve the watershed, the river, and its natural resources.

- Encouragement of citizen participation in:

  — Storm drain informational marking and related informational programming to encourage residents to dispose of waste products safely, avoiding discharge directly to surface waters;

  — Litter and pet waste clean ups and “Clean Sweep” programs;

  — Water quality monitoring through the Water Action Volunteers;

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

- Encouragement of business owner participation in:

- Using grocery bags, posters, and place mats printed with an awareness message;
- Placement of revolving displays;
- Employee education on waste minimization and recycling;
- Using natural landscaping and stormwater management in yards and parking areas.

- Encouragement of participation of builders and developers in:
  - Workshops on special and alternative design considerations supporting the preservation of the streams in the Mukwonago River watershed; use of erosion control and construction site stormwater management practices; and, environmentally friendly building, landscaping and conservation development practices (green building);
  - Informing clients about the process of making positive environmental choices with respect to remodeling, rebuilding, and constructing homes and other premises;
  - Preserving green space, use of natural landscaping, and good housekeeping practices.

- Encouragement of participation of local government in:
  - Informational programming using workshops, informational packets, etc.;
  - Developing stewardship activities for watershed residents;
  - Minimizing and managing solid and hazardous waste;
  - Managing stormwater and preventing water pollution;
  - Street sweeping and leaf collection programs;
  - Using alternative salts and deicers, and snow removal;
  - Storm sewer and catch basin maintenance;
  - Naturalized highway and roadway plantings/maintenance.

- Development and implementation of a comprehensive monitoring and evaluation plan for the Mukwonago River watershed in order to assess the degree to which proposed watershed management measures meet the objectives of this protection plan. (See the Recommended Actions subsection of the Instream and Lake Monitoring and Informational Programming section below.)

- Continuation and expansion of coordination of terrestrial monitoring, sampling schedules, and sharing of data and results among government agencies, nongovernment agencies, citizen monitoring, and research institutions. Specifically, such monitoring would include periodic bird counts, transect sampling of upland habitat, and species counts of vegetation, invertebrates (butterflies, beetles, etc.), mammals, amphibians, and reptiles when possible.

- Continuation of the development and support of outreach projects such as the Turtle Crossing signage provided by Waukesha County and the Friends of the Mukwonago River to promote awareness of breeding turtle habitat as well as vulnerability and protection of turtles at roadways.

- Continuation of the development and support of outreach projects such as the trout and longear sunfish signage provided by the Friends of the Mukwonago River at river crossings to promote awareness of fisheries and habitat quality to the public.

- Promotion and encouragement of the use of green infrastructure, monitoring implementation and effectiveness of such practices, and maintenance of practices as required.

- Promotion of citizen-based monitoring efforts through participation in state and local sampling and awareness building programs, especially with regard to emerging pollutants and potential nonnative, invasive species infestations;

- Continuation of the current informal consultations between the three public inland lake protection and rehabilitation districts—Eagle Spring Lake Management District, Lake Beulah Management District, and the Phantom Lakes Management District—as a basis for coordinating lake management activities in the shared Mukwonago River watershed;[34]

- Continuation by the public inland lake protection and rehabilitation districts of their programs of public awareness and citizen participation that contribute to an informed citizenry within the watershed, including provision of information not only of lake-interest but also relating to the streams of the watershed, in the lake district newsletters, meetings, and other media outlets;

- Continuation of the citizen volunteer monitoring programs—the WDNR Citizen Lake Monitoring Network (CLMN) in the case of the lakes and the Project WET (Water Education for Teachers) and Water Action Volunteers (WAV) programs for streams;

- Because of the participation of municipal- and county-appointed commissioners on each of the boards of commissioners of the public inland lake protection and rehabilitation districts, the three lake management districts should continue their roles in ensuring communication of lake- and river-related issues to the respective towns and counties, and in communicating such issues and concerns from the towns and counties to the electors and property owners of the districts;

- Review of this watershed protection plan by the general purpose units of government—Jefferson, Walworth, and Waukesha Counties; the Villages of Eagle, East Troy, Mukwonago, and North Prairie; and, the Towns of Eagle, East Troy, Genesee, LaGrange, Mukwonago, Ottawa, Palmyra, Troy, and Vernon—and consideration of incorporating pertinent recommendations into their "Smart Growth" comprehensive multi-jurisdictional and other local level plans;[35]

- Continuation of awareness programming and implementation of monitoring and management of nonnative invasive species such as buckthorn, gypsy moth, emerald ash borer, and purple loosestrife, among other species identified or that may be identified in Chapter NR 40 of the *Wisconsin Administrative Code*.

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[34]*In this regard, the Walworth County Lakes Association and/or the Fox River Partnership may form vehicles for the conduct of such coordination within this trans-jurisdictional basin; the Wisconsin Association of Lakes (WAL) may also facilitate this coordination, especially with regard to the WDNR and University of Wisconsin-Extension (UWEX) at the state level—WDNR, UWEX, and WAL form the Wisconsin Lakes Partnership.*

[35]*See SEWRPC Community Assistance Planning Report No. 288,* op. cit.*; SEWRPC Community Assistance Planning Report No. 209,* op. cit.

- Compliance with the informational and educational component of Municipal Separate Storm Sewer System (MS4) permit requirements pursuant to Chapter NR 216 of the *Wisconsin Administrative Code*, applicable to the Village of North Prairie, and the Towns of Genesee, Ottawa, and Vernon.

Potential Means of Assessment

- Number of monitoring stations established, expansion of the biological database, and number of data analysis and interpretation efforts continued or increased.

- Number of stormwater management and green infrastructure practices installed and/or maintained.

- Number of citizen monitoring stations established.

- Amounts of invasive species removed and/or treated within an area.

- Number of informational programs developed or workshops held.

- Continued participation in the Mukwonago River Initiative Committee, the Mukwonago Fish Committee (which is a subcommittee of the Mukwonago River Initiative Committee), the Fox River Partnership, Friends of the Mukwonago River, and Southeastern Wisconsin Fox River Commission meetings.

INSTREAM AND LAKE HABITAT PROTECTION MEASURES

Aquatic Organism Passage

Aquatic Organism Passage Target 1

Maintain and restore fish and aquatic organism passage to the Fox River and major Lakes in the Mukwonago River watershed to the headwaters and tributaries (i.e., follow three-tiered prioritization strategy as outlined in Figure 59).

Issue

Recreational fishing is an important economic activity within the lakes and streams of the Mukwonago River watershed. The maintenance and continuity of both the game fish species of economic importance and those species on which they depend (i.e. forage fishes) is associated to a large degree with the protection and restoration of appropriate habitat. To this end, efforts to remove obstructions to fish migration along the mainstem and tributaries of the Mukwonago River are a key element to the long-term maintenance and protection of the fishery. These obstructions are primarily due to culverts at roadways. Removal and/or retrofitting of these obstructions should be accompanied by the restoration or re-creation of habitat within the stream and riparian corridor that is essential for resting, rearing, feeding, and spawning of fishes and other organisms. The strategy of reducing fragmentation within the stream system is predicated upon a tiered approach:

- Tier 1–Restoring connectivity and habitat quality between 1) the mainstem of the Mukwonago River and the Fox River, 2) the mainstem of the Mukwonago River upstream of Lower Phantom Lake, 3) the mainstem of the Mukwonago River flowing into Eagle Spring-Lulu Lakes, and 4) the unnamed tributary upstream of Lake Beulah and Lake Beulah;

- Tier 2–Restoring connectivity and habitat quality between the tributary streams and the mainstem of the Mukwonago River, and

- Tier 3–Expanding the connection of highest-quality fish, mussels and other invertebrates, and habitat sites within subwatersheds as shown in Table 27.

As structures are removed or retrofitted to promote fish passage over time, there will be improved access to the highest-quality habitat areas for feeding, rearing, and spawning, leading to restoration of a more sustainable fishery within the watershed.

Recommended Actions

The following actions, or combinations of actions, should be considered in identifying opportunities to restore fish and aquatic organism passage to the Fox River and major lakes in the Mukwonago River watershed from the Mukwonago River mainstem and associated headwaters and tributaries:

- Development of plans for improving aquatic organism passage and navigation within the mainstem of the Mukwonago River within the WDNR Rainbow Springs property from approximately River Mile 7.7 through 9.3 that includes structures 11 through 21 (see Table 16 in Chapter IV of this report):

- If the golf course is going to continue operation, the following elements are recommended:

  — Convert the two separate 18-hole courses into a single 18-hole golf course;

  — Abandon all golfing areas north of the mainstem of the Mukwonago River, including the island area that is currently being used, and establish native vegetation.

  — Develop plans for removal of Mukwonago River structures 11 through 20 (see Tables 16 and 27 and Map 24, all in Chapter IV of this report). Note this is recommended to be undertaken simultaneously with restoring appropriate stream widths and depths, protecting streambed and streambank stability, reconnection with the floodplain, and expanding riparian buffers (see Riparian Buffer section above) within this reach.

  — Develop plans for replacement of structure 21 at Rainbow Springs Road (see Table 16 and Map 24). with a single span bridge or single culvert (see Fish Passage Guidelines in Appendix F) to improve fish passage as well as provide safe human recreational passage.

  — Redevelopment of the golf course should also consider flooding impacts in its design and should consider removal of historical fill within the areas proposed to be abandoned on the north side of the Mukwonago River, including the islands. This would improve connection of the stream to its floodplain, and would allow for the course to be located outside of the more-frequently flooded areas, enabling it to be used throughout the entire golfing season.

- If operation of the golf course is going to be discontinued, it is recommended that, to the extent practical, 1) minimum 1,000-foot-wide buffers be established and maintained adjacent to all streams, lakes, ponds, and wetlands on the property, 2) golf cart stream crossings be removed, and 3) abandoned buildings be removed from the site.

- Development of plans for removal of the dam/abandoned agricultural access road (Structure No. 44, see Table 16 and Map 24) and restoration/remeandering of the stream reach from about River Mile 5.6 through 6.1 on Jericho Creek. This removal should be completed in such a way as to protect the existing aquatic community from excessive sediment deposition downstream, and it should include plans for the restoration of a stable streambed and streambanks, and re-establishment of the historic stream channel or remeandering of the channelized areas upstream of the impoundment if practical.

- Development of plans for replacement and/or retrofitting of additional obstructions at mainstem and tributary road crossings and implementation of improvements to aquatic organism passage over time as opportunities present themselves (e.g., structure failure, major blockage, or bridge reconstruction or replacement). Table 27 sets forth a list of the number of road crossings or obstructions for each subwatershed within the Mukwonago River watershed and the relationship of those features to fish passage, stream length, habitat quality, and biological quality sample sites. These plans should be developed in partnership with the relevant municipality and County Highway Departments.

- Consideration of annual or biannual surveys on the Mukwonago River system to assess capabilities to maintain fish passage at road crossings (e.g., the accumulation of debris at the CTH NN bridge on Jericho Creek may create an obstruction to fish passage), and to identify where actions need to be taken to improve passage. Actions to improve passage would have to be coordinated with the WDNR, County Highway Departments, local public works departments, and/or the Wisconsin Department of Transportation.

- Consideration of annual or biannual surveys on the Mukwonago River system to monitor beaver activity and address beaver dams that are obstructing aquatic organism passage, presenting impediments to navigation, or creating flooding conditions on a case by case basis as necessary.

  — Consider removal of the beaver dam causing blockage of the culvert pipe at STH 59 (Structure No. 46 in Table 16), which could cause flooding associated with the ponds and land areas upstream of this roadway if permanently obstructed.

  — During the time of this study the only significant obstructions caused by beaver dams were found in the headwaters of Jericho Creek, which makes this tributary system a priority area to continue to monitor for beaver activities.

Potential Means of Assessment

- Number of native species present, increased abundance, or some equivalent biological indicator.

- Number of structures removed, replaced, or retrofitted (e.g., road crossings or beaver dams).

- Number of stream miles connected to mainstem or to high quality fish and invertebrate sites.

Information Needs

Continue assessment of fish passage obstructions throughout the Mukwonago River watershed (see Appendix F).

Aquatic Habitat

Aquatic Habitat Target 1

Protect and enhance fish and aquatic organism habitat throughout the Mukwonago River watershed (i.e., follow three-tiered prioritization strategy as outlined in Figure 59).

Issue

The objective is to preserve and improve, to the extent practical, physical, chemical, and hydrological characteristics related to habitat conditions throughout the Mukwonago River watershed. The prioritization strategy is based upon the three-tiered approach as previously described and is focused on restoring habitat in a number of ways primarily including improving fish passage at problem road crossings or structures; protecting baseflows, groundwater recharge/discharge, and habitat integrity through preservation of riparian buffers; and restoring streambeds and banks where appropriate. These actions are designed to maintain and improve several dimensions of habitat that include, but are not limited to, elements such as adequate water depth, pool-riffle structure, stream hydrology, variable substrate composition, and instream cover such as overhanging vegetation or large woody debris as well as access to these variable habitats. As habitat among reaches and the connectedness of the stream system are improved over time, there will be improved access to the highest-quality habitat areas for feeding, rearing, and spawning, as well as access to refuge areas (deep pools or lakes) from increased temperatures leading to continued maintenance and improvement of a healthy and sustainable fishery within this watershed.

Recommended Actions
The following actions, or combinations of those actions, should be considered in identifying opportunities to enhance fish and aquatic organism habitat throughout the Mukwonago River watershed:

- Protection and expansion of existing highest-quality fishery and aquatic habitat within the Mukwonago River watershed (see Table 27).

- To the extent practicable, design and implementation of stormwater management and conveyance facilities that avoid enclosure of tributary streams, especially those identified as having significant and valuable biological and recreational uses;

- Maintenance of baseflows and minimization of fluctuations of instream water temperatures through preservation of groundwater recharge and discharge areas, establishment and maintenance of adequate riparian buffers, and implementation of sound urban stormwater BMPs that meet or exceed Chapter NR 151 stormwater quality requirements;

- Restoration of wetlands, woodlands, and grasslands adjacent to stream channels and establishment of buffers (see Riparian Buffer section above) to reduce pollutant loads entering streams, protecting water quality and providing habitat for terrestrial, amphibious, and aquatic life;

- Restoration, enhancement, and/or rehabilitation of stream channels to provide increased quality and quantity of available fish habitat—through improvement of water quality, creation or preservation of fish passage, provision of shelter/cover, maintenance of food production, and protection of spawning opportunities;

- Minimization of the number of stream crossings and other obstructions that fragment stream reaches (see Table 27 and Appendix F). As opportunities arise, when roadways crossing streams are replaced or reconstructed, implementation of this recommendation could include modification of bridge installations and/or removal and replacement of culverts with clear span bridges in areas where current structures limit healthy fish and invertebrate populations. Such crossing alterations would defragment stream reaches and ensure continuity of flow, habitat, and passage;

- Monitoring of fish and macroinvertebrate populations in order to periodically evaluate the effectiveness of the lake and stream protection program, and to provide for early detection of, and response to, potential nonnative invasive species in the River and lakes;

- Maintenance and/or enhancement of existing linkages between terrestrial and aquatic biological communities, including fish, amphibians, and other wildlife through maintenance or restoration of connectivity between the River and is floodplain;

- Protection and management of the Mukwonago River system to mitigate potential impacts from climate change:

    - Provision of connectivity of habitat to multiple populations of fishes and aquatic organism to improve chances of population persistence and species genetics and integrity

    - Preservation of groundwater recharge and discharge through riparian buffers, wetland and woodland preservation/restoration, floodplain protection, low-impact development, and conservation development

    - Preservation of the natural flow regime and geomorphological integrity of the River system

    - Management of riparian vegetated buffers to maximize biodiversity through removal of exotic invasive species

- Maintenance of water quality conditions conducive to a sustainable fishery.

- Removal of trash and other debris from the stream channel and adjacent riparian areas where appropriate.

- Expansion of riparian and instream clean-up efforts throughout the Mukwonago River system, such as those currently implemented by the Friends of the Mukwonago River.

Potential Means of Assessment

- Number of stream miles of habitat protected.

- Number of miles connected and functioning as fish and aquatic organism habitat.

- Number of native species present or some equivalent biological indicator (see biological assessment section above).

- Tons of trash and debris removed.

- Improvements in water quality, especially as related to thermal regime, oxygen concentrations and/or fluctuations, turbidity, and chlorides.

Information Needs

Complete periodic streambank and streambed erosion assessments to identify areas for protection.

Aquatic Organisms

Aquatic Organism Target 1

Maintain and enhance a high quality sustainable fishery.

Issue

The Mukwonago River system has remained largely intact and has not been substantially channelized as have many stream systems within Southeastern Wisconsin. However, the system has been impacted by agricultural and urban development, road construction, and stormwater runoff. Despite these impacts, historical and present day actions have lead to a high quality aquatic and semi-aquatic community of fishes, amphibians, and invertebrates. In addition, there also are a number of records documenting the existence throughout the watershed of rare, threatened, and endangered species and species of special concern. Therefore, the objective is to maintain and enhance the high quality fishery and associated aquatic and semi-aquatic communities that currently exist in this system. The prioritization strategy is based upon the three-tiered approach as previously described and is focused on maintaining and expanding where appropriate the most diverse and highest-quality aquatic communities within the Mukwonago River watershed (see Table 27).

Recommended Actions

The following actions, or combinations of those actions, should be considered in identifying opportunities to maintain and enhance a high quality sustainable fishery in the Mukwonago River system:

- Protection and expansion of the remaining or existing highest-quality aquatic communities within the Mukwonago River watershed (see Table 27).

- Development and implementation of plans for control and removal of nonnative species:

- Continuation of carp eradication efforts on Eagle Spring Lake and potential expansion of this effort to other lakes and mainstream reaches within the Mukwonago River system

- To reduce the spread of Eurasian water milfoil and curly leaf pondweed, floating plant pieces should be limited during plant harvesting operations.

- Continuation of stocking warmwater and coldwater gamefish species to supplement and enhance the fishery in the streams and lakes of the Mukwonago River system as appropriate.

- Consideration of intensive assessment of Jericho Creek to develop a sustainable native brook trout management plan in that subwatershed.

Potential Means of Assessment

- Number, type, and life stages of native species observed.

- Area cleared or tons removed of nonnative species.

Information Needs

Identify brook trout spawning and juvenile rearing areas within Jericho Creek to better protect and enhance natural reproduction of this species.

Instream and Lake Monitoring and Informational Programming

Target

Continue and expand monitoring and informational programming.

Issue

Knowledge of land use and instream conditions is essential for good planning and implementation of management measures that will be both acceptable to communities and sustainable from an ecological and economic perspective. In addition, creation of awareness of the multiple values of the waterways of the Mukwonago River watershed is an important element of any restoration or protection effort. Without such awareness and "buy in" from communities, efforts to affect land use decisions and improve instream conditions could be of limited success. Consequently, integration of public awareness building into the framework of interventions planned in the Mukwonago River watershed will be a key element of the success of the proposed ecosystem restoration projects. Toward these ends, the following section summarizes the ongoing and recommended monitoring efforts within this watershed.

Generally, the fisheries management practices, water quality monitoring, and public awareness programs currently being implemented by the lake management districts in partnership with the WDNR and UWEX, are recommended to be continued with refinements as proposed below. Some aspects of these programs lend themselves to citizen involvement through participation in school-based monitoring programs, and identification with environmentally sound owner-based land management activities. It is recommended that the counties, in cooperation with the local municipalities, assume the lead in promoting such citizen actions within the Mukwonago River watershed, with a view toward building community commitment and involvement, although, in this regard, the lake management districts are recommended to retain their key roles with respect to lake management planning and programming within the watershed. Assistance in these tasks is generally available from agencies such as the WDNR, UWEX, and SEWRPC.

Given that it is desirable 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, both including agency programs such as the WDNR baseline monitoring program and the UWEX and other citizen-based monitoring programs. To this end, the WDNR Surface Water Integrated Monitoring System

(SWIMS) plays an important role in gathering and documenting water data from throughout the State. These data can be accessed through the internet (http://dnr.wi.gov/org/water/swims/) and can be utilized by municipalities and others in supporting local decision making and planning processes. In order to facilitate the coordination of sampling and the dissemination of water quality data, it is recommended that this data management system be maintained and upgraded.

Citizen-based monitoring programs such as the Water Action Volunteers (WAV) and Citizen Lake Monitoring Network (CLMN) can not only act to increase awareness and understanding of local water quality issues but also can support local decisions and actions to protect water quality. Currently, both the WAV and CLMN programs are being actively executed within the Mukwonago River watershed. CLMN data are being collected on Lake Beulah and the Phantom Lakes. Data collected by Level I WAV volunteers are submitted to the WAV Program database, while data collected by Level II WAV volunteers are submitted for incorporation into the WDNR database. In addition to these water quality monitoring programs, the citizen-based Clean Boats, Clean Waters Program of UWEX is also being actively implemented in the watershed. This program trains local volunteers to work with the recreational boaters to minimize the spread of nonnative species between lakes, by creating awareness of nonnative species and the consequences of their introductions to the inland waters of Wisconsin. It is recommended that citizen-based monitoring efforts be continued and supported.

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 the water pollution control and river protection measures. It is recommended that the findings of monitoring programs be summarized 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.

Recommended Actions
The following actions, or combinations of those actions, should also be considered in identifying opportunities to continue and expand monitoring and informational programming in the Mukwonago River watershed:

- A comprehensive monitoring and evaluation plan should be developed and implemented for the Mukwonago River watershed 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 and lake health;
  - Continued coordination of sampling efforts between organizations;
  - Communication of monitoring results to stakeholders; and,
  - Qualitative and quantitative assessment of actions.

- It is recommended that a periodic review of the plan recommendations and the effectiveness of management measures be undertaken on a five- to 10-year cycle. Such a review should include the following actions:

  - Continuation of cooperation among agencies and organizations involved in implementing the necessary measures identified in the Mukwonago River Watershed Protection Plan, and refinement of these plans as necessary and appropriate based upon the outcomes of the implemented actions;

- Evaluation of site-specific management measures such as fish habitat and streambank stability treatments in the Mukwonago River using both quantitative and qualitative indicators;

- Modification of existing, and development of new, management measures as necessary and appropriate based upon the monitoring and assessment program findings; and,

- Refinement of the river protection plan based upon both a qualitative and quantitative assessment of progress toward plan implementation.

- As this Plan is implemented by the Lake Districts and other nongovernmental organizations, liaison with the ongoing WDNR and USGS monitoring programs is recommended, and modification of these programs is suggested so they can provide site-specific information on potential priority project areas within the Mukwonago River watershed. Where appropriate, these programs should include collection, dissemination, and analysis of data on a range of parameters, including physical (stream morphological and hydrological data), chemical, and biological (fisheries and invertebrate population data) parameters. The selection of specific parameters should be guided not only by existing data collection programs, to ensure consistency and continuity of data collection, but also by the likely interventions to be considered at specific sites. Again, these data should be collected both before and after the interventions are designed and implemented. Such data will provide the basis for evaluating the effectiveness of the specific interventions and support future implementation of similar, successful actions elsewhere in the watersheds.

- Continuation and expansion of citizen- and student-supported monitoring efforts and maintenance of inventories for fish passage, habitat, aquatic organisms, and water quality. Such efforts should be supported and integrated into the data collection and analysis process associated with the professional programs noted above. These programs form a vehicle for ongoing data collection that frequently extend beyond the specific project period, and can contribute both to enhanced civic awareness and to the education of youth.

- Identification and development of new monitoring sites in cooperation with citizen and other monitoring programs and sharing of knowledge with stakeholders.

- Because prevention remains the first line of defense in the protection of the ecological integrity of the waters of the Mukwonago River, programs to reduce the spread of nonnative and invasive species as well as programs to inform and educate the public on these issues should be continued and supported.

Potential Means of Assessment

- Number of monitoring stations continued and/or established and conditions documented and shared with stakeholders.

- Amounts of invasive species removed and/or treated within a reach.

- Number of informational programs delivered.

Recreation

Recreation Target 1

Maintain and improve recreational opportunities.

Issue
The Mukwonago River and its lakes and tributary streams form an important element of the natural resource base of the watershed. The location of the River and tributary streams within environmental corridors and open space areas provides an opportunity for people to utilize and enjoy these resources for recreational and aesthetic viewing purposes. Consequently, these resources can provide an essential avenue for relief of urban stressors among the population and improve quality of life in local neighborhoods and the entire watershed. Such uses also sustain industries associated with outfitting and support recreational and other uses of the natural environment, and, therefore, provide economic opportunities for the local communities. As embodied in the regional park and open space plan and county and local open space plans, County land and water resource management plans, and County comprehensive development plans, the objective of this element is to ensure continuity of access to the water resources of the Mukwonago River watershed. Maintaining these waterways as an attractive and welcoming part of the open space system will enhance public awareness and commitment to these resources.

Recommended Actions
The following actions, or combinations of those actions, should be considered in identifying opportunities to improve recreational opportunities in the Mukwonago River watershed:

- With respect to the regulation and management of fishing, boating, and related land-based recreational opportunities offered in the Mukwonago River watershed, current levels of enforcement should be maintained and programs such as Operation Dry Water should be supported and expanded.[36]

- Promotion and implementation of opportunities to expand safe use/recreational access to the lakes, rivers, and adjacent corridors, where appropriate.

  — Consideration of expanding parking areas and/or improved trail access to the Mukwonago River to provide increased recreational safety for loading and unloading watercraft at CTH I (River Mile 4.45) and at Beulah Road (River Mile 6.92).

- Recreational boating access users should be made aware of the presence of the exotic invasive species Eurasian water milfoil, zebra mussel, and rusty crayfish, among others. Appropriate signage should be placed at public and private recreational boating sites, and supplemental materials on the control of invasive species should be made available to the public. These materials could be provided to riparian householders by means of mail drops or distribution of informational materials at public buildings, such as municipal buildings and public libraries, and to nonriparian users by means of informational materials provided at the entrance to all municipal public recreational boating access sites.

- Bins for disposal of plant materials and other refuse removed from watercraft using the public recreational boating access sites should be made available at the public recreational boating access sites.

- Continuation of monitoring and removal of trash and debris from streams and lakes.

- The River, tributary streams, and their associated parkways, and proximity to other economic and cultural resources of the watershed provide further opportunities for linking recreation through both land-based and water-based trails. Connecting these landscape features through an integrated system

[36]*Operation Dry Water is a joint law enforcement program to prevent boat operators from driving while under the influence of alcohol. This is a national program that is conducted in partnership with WDNR wardens, municipal boat patrols, the National Association of State Boating Administrators and the U.S. Coast Guard (see* www.operationdrywater.org*).*

of roads, trails, paths, and waterways will further expand recreational opportunities. Increased recreation will help build awareness of the value of the natural environment to the Region, and create a base for citizen and stakeholder action to underpin the needed investments in ecosystem management.

- Landowner relationships should be built and conservation easements, land donation, or land purchase should be pursued within the recommend priority lands indentified on Maps 42 and 43.

- Where feasible, and subject to land access considerations related to the efficient movement of vehicles and trains and the provision of emergency services, consideration should be given to removal of bridges and other structures that pose hazards to recreational navigation (see Map 24). Also consider removal of fences that impede navigation and create unsafe recreational conditions.

- Design and install trail connections and interpretive signs to identify habitat types, trails, and canoeing and fishing access areas.

Potential Means of Assessment

- Number of facilities maintained or added for public access to streams

- Miles of trials established or managed

- Numbers of signs installed to identify navigational hazards, number of navigational hazards removed or retrofitted, number of new public access sites or facilities created, number of informational signs installed

- Number of safe recreation days, number of areas identified as safe for recreation

- Number of trash and debris accumulation locations identified, improvement of trash and debris accumulation points in the watershed, and tons of trash and debris collected and disposed of

ANCILLARY RECOMMENDATIONS

In addition to the numerous recommended actions and potential projects identified above, there are many additional actions that the Lake Management Districts, NGOs, municipalities, and citizens could undertake, but that do not necessarily fit within the confines of the targets identified. To that end, the following list of ideas or examples are intended to help share ideas from past projects or experiences that have been successful in protecting the environment.

- Provide input to municipal plan commissions on land use decisions affecting the Mukwonago River.

- Maintain a geographic information system database of existing projects to monitor and improve water quality. For example, riparian buffer width changes through purchase or easements or other types of agreements.

- Maintain contact with State, county and local elected officials and inform them of concerns regarding protection of the Rivers and associated tributaries. Consider introduction of a program such as the Rock River Coalition “Send your Legislator Down the River” awareness program.

- Encourage inclusion of river-oriented curricula in local schools. Promote river monitoring and storm drain informational marking in cooperation with community organizations such as the Friends of the Mukwonago River.

- Share inventory information with counties, municipalities, WDNR, and SEWRPC to incorporate into planning documents.

- Consider establishment of demonstration projects on private properties. Encourage implementation of demonstration projects or sustainable landscaping in public parks.

- Create and erect signage identifying watershed boundaries or stream crossings on local roadways with appropriate permission.

- Develop and distribute newsletters at municipal buildings and public libraries. Also consider distributing recycled paper placemats containing river access points and activities of interest, to local restaurants.

- Create a recreational opportunity map showing locations such as access points, parks, or viewing areas for bird watching (seek sponsorship of publication cost from businesses or agencies).

- Sponsor a poster, photograph, essay, or video contest to promote awareness and protections of the Mukwonago River and its watershed. Solicit prizes and support from community businesses and/or service organizations.

- Identify activities appropriate to community youth and service organizations and share these with the leadership of these groups (e.g., Eagle Scout projects, community garden projects)

- Promote synergies with existing community activities and organizations such as recycling and public health, among others. Develop partnerships with the Wisconsin Department of Tourism and local tourism outlets and offices to promote river-oriented outdoor recreation. Partner with local businesses (e.g., bike shops, canoe liveries, ice cream parlors).

- Develop a "River Day" annual event to promote awareness of the ongoing efforts to protect and enhance fisheries and recreation. Encourage public access television stations to develop, obtain, and screen programs related to the natural history of the specific rivers.

- Compile an oral and/or photographic history of the rivers in partnership with county historical societies. Sponsor a river-oriented display in community centers and libraries, focused on local neighborhoods.

- Develop a revolving grant program to support various activities to protect and enhance water quality throughout the watershed similar to the program created by the Root-Pike Watershed Initiative Network (WIN).[37]

SUMMARY AND SYNTHESIS

Maintenance and improvement of habitat for fish and aquatic organisms in the Mukwonago River watershed is important to the quality of life of the residents throughout that area. The provision of fish and aquatic life passage is closely linked with the restoration and re-creation of instream and riparian habitat. This habitat provides not only refuges for fishes and aquatic life, but also forms feeding and breeding areas necessary for the survival of these organisms. Shoreland habitat, in the form of vegetated buffers, contributes to the natural ambience of the river systems and their tributaries, and provides important ecosystem functions related to flood mitigation, groundwater recharge, water quality enhancement, and terrestrial wildlife. Maintaining connection of the rivers

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[37] *For more details see Root-Pike Watershed Initiative Network at* http://www.rootpikewin.org/.

and streams to their floodplains provides ecological benefits and helps to protect and promote human activities in the watersheds, limiting flood damage and promoting good public health, while at the same time enhancing the visual landscape and providing the human inhabitants with recreational opportunities, including angling, boating, hunting, and scenic viewing opportunities. Protection of the lands indicated on Maps 42 and 43 through appropriate zoning provisions, purchase, and/or acquisition of easements as opportunities arise is an important aspect of the land-based and instream-based prioritization strategies developed to protect the Mukwonago River watershed. These prioritization strategies are based upon the main premise of protecting the existing quality areas—either within water or on land—and expanding those areas through reconnection of streams and land to reduce fragmentation. Ultimately, these actions will not only ensure progress toward achievement of the fishable and swimmable goals of the Federal Clean Water Act, but also enhance the quality of life of the resident populations of these watersheds and their visitors.

Continued monitoring of aquatic (physical, chemical, biological) and terrestrial conditions is an essential component of both the land-based and instream-based priority actions in order to document achievement of goals and objectives set forth in Chapter V of this report and to refine the objectives as necessary as remedial measures are implemented.

Key Priority Actions

Within the context described above, the following groups of management measures represent critical priorities for action to protect and enhance land-based and instream and lake-based actions within the Mukwonago River watershed.

Land-based recommendations:

1. Protect and expand riparian buffers and connectivity with isolated natural resource areas outside the buffers with a priority on reducing fragmentation through linking public, private, and other protected lands.

2. Preserve groundwater recharge and discharge through innovative planning and zoning as well as conservation developments, protection of agricultural lands, and stormwater management.

3. Regulate and manage the entire watershed consistently to protect the Outstanding and Exceptional wildlife and coldwater aquatic community.

Instream and lake-based recommendations:

1. To the degree possible, preserve the natural hydrology, groundwater discharge locations, and floodplain connectivity to protect the integrity of the coldwater and warmwater aquatic communities.

2. Maintain and/or restore fish and aquatic organism passage to enhance connectivity of streams and lakes within the Mukwonago River watershed.

3. Regulate and manage the entire Mukwonago River system of lakes and streams and their adjacent wetlands consistently to the highest level of protection to meet Coldwater Community and the Outstanding Resource Water standards.

4. Continue working towards understanding the interactions between groundwater, surface water, and wetlands in order to sustain conjunctive use of this hydrologic system, to minimize water use conflicts, and to ensure adequate allocation and quality of water to sustain the integrity of the coldwater and warmwater aquatic communities.

With regard to the implementation of the foregoing actions, the public inland lake protection and rehabilitation districts, as special purpose units of government, are key entities for implementing this river protection plan. In addition, both the general purpose, local units of government—Jefferson, Walworth and Waukesha Counties; the

Villages of Eagle, East Troy, Mukwonago, and North Prairie; and, the Towns of Eagle, East Troy, Genesee, LaGrange, Mukwonago, Ottawa, Palmyra, Troy, and Vernon—and the nongovernmental organizations within the watershed—especially the Friends of the Mukwonago River, The Nature Conservancy, the Kettle Moraine Land Trust Ltd., and Lake Beulah Protection and Improvement Association Inc.—form essential partners with the public inland lake protection and rehabilitation districts in informational programming within the Mukwonago River Basin. The governmental entities have specific responsibilities with respect to land use planning and management that are critical to the protection and preservation of the Mukwonago River watershed and its lakes and streams.

CONCLUSION

The Mukwonago River watershed is a natural resource treasure for the Southeastern Wisconsin Region and the State of Wisconsin. Therefore, the protection strategy in this plan is primarily based on preserving existing resources through a combination of regulatory measures, restoration project measures, and continued informational and outreach programming. These elements are necessary to help balance the needs of the resource to maintain the high quality aquatic and terrestrial communities within this system as well as accommodate the expected increases in development pressures in the future. This plan also recognizes that regulations alone will not be adequate to protect this invaluable resource. Rather, the future protection of the Mukwonago River watershed will depend upon the continued vigilance, cooperation, and partnership among the State and regional agencies, Counties, municipalities, Lake Management Districts, nongovernmental organizations, and citizen stewardship to implement measures recommended within this plan. These recommended measures in turn will provide the water quality and habitat protection necessary to maintain conditions in the watershed suitable for the maintenance of the natural beauty and ambience of the River and its ecosystems, and the enjoyment of its human population today and in the future.

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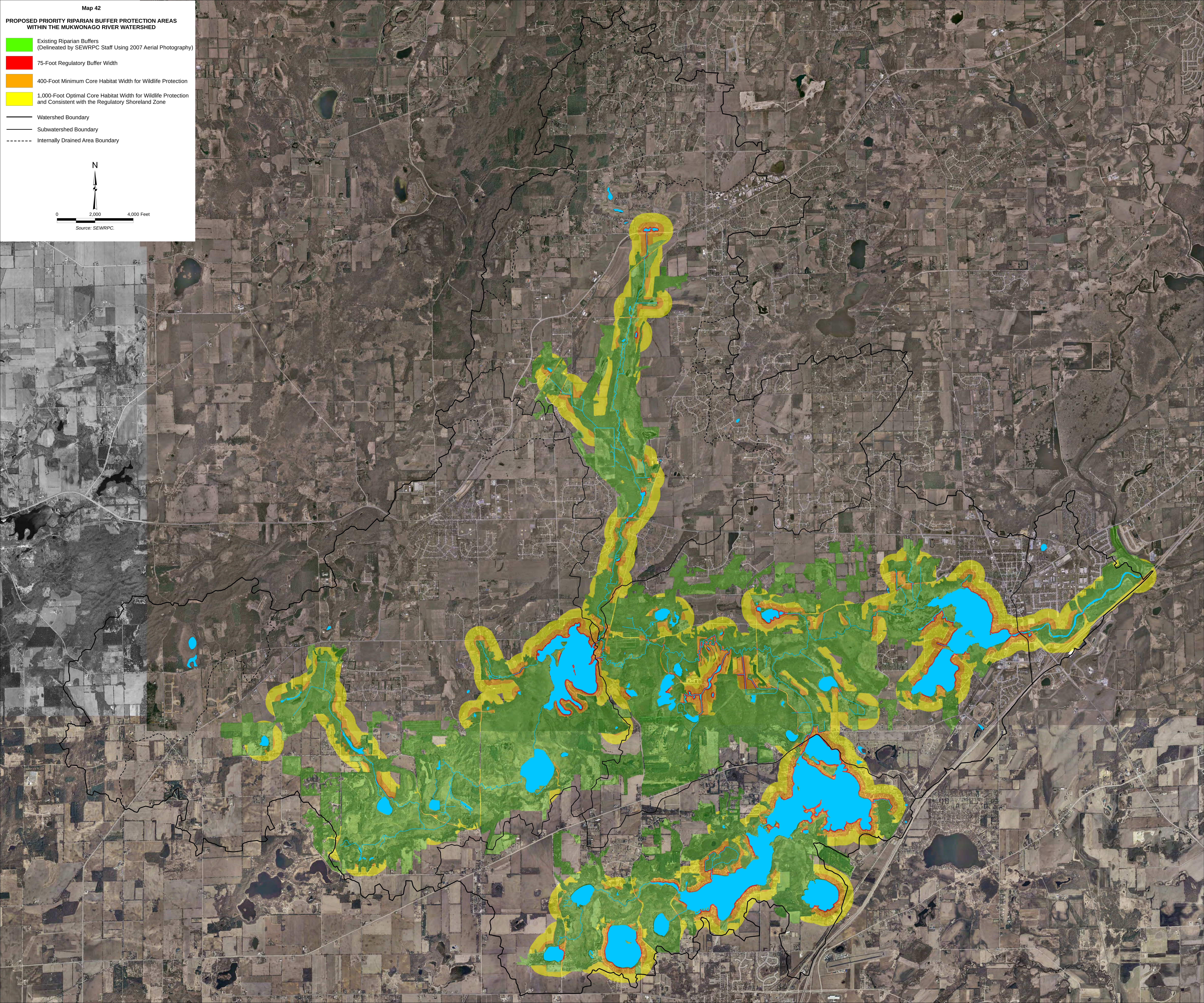
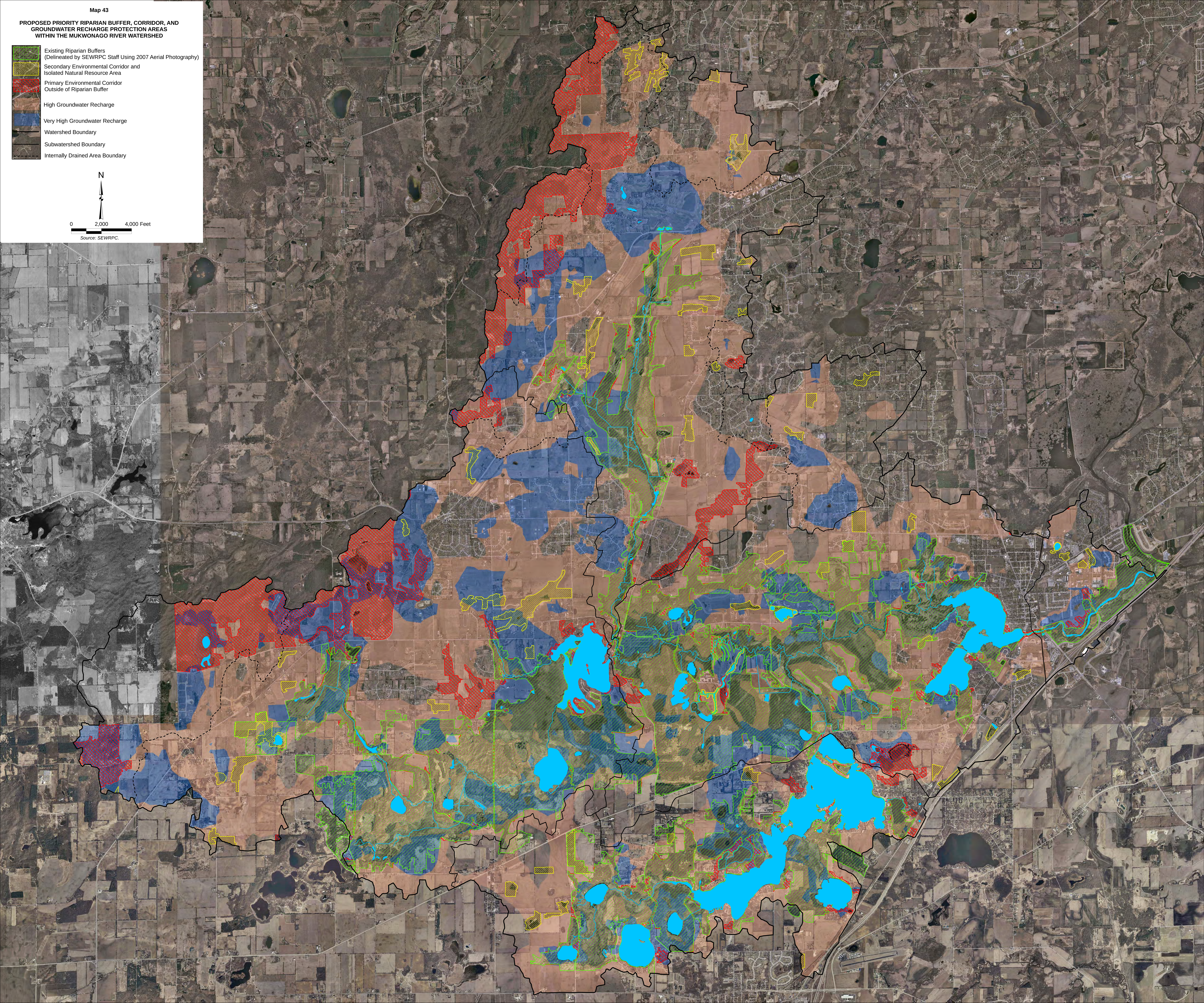
Map 42

PROPOSED PRIORITY RIPARIAN BUFFER PROTECTION AREAS WITHIN THE MUKWONAGO RIVER WATERSHED



Source: SEWRPC.



Map 43

PROPOSED PRIORITY RIPARIAN BUFFER, CORRIDOR, AND GROUNDWATER RECHARGE PROTECTION AREAS WITHIN THE MUKWONAGO RIVER WATERSHED

APPENDICES

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Appendix A

MUKWONAGO RIVER WATERSHED PROTECTION PLAN WORKING GROUP MEMBERS AND MEETINGS

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MEMBERS OF THE MUKWONAGO RIVER WATERSHED PROTECTION PLAN ADVISORY GROUP

Dean Achtenhagen, Landowner
Fay U. Amerson, Urban & Non-Metallic Mining, Walworth County
Lori Artiomow, General Manager, Kettle Moraine Land Trust, Ltd.
Alan Barrows, Land Resources Division, Waukesha County
Jill Bedford, Conservation Committee, Tall Pines Conservancy
Susan Beyler, Fisheries Team Supervisor, Wisconsin Department of Natural Resources
Mike Bolan, Citizen
Mark Bromley, Supervisor, Town of LaGrange
Colin Butler, Citizen
Mark Carlson, Chair, Phantom Lakes District
Patricia Cicero, Water Resources Management Specialist, Jefferson County
John Davis, Citizen
Thomas A. Day, Chair, Eagle Spring Lake Management District
Dave Dubey, Chair, Town of Mukwonago
Ray Fisher, Citizen
Jason Fruth, Senior Planner, Waukesha County
Mike Garber, Citizen
Nancy Gloe, Past President, Friends of Mukwonago River
Bryan Hartsook, Water Resources Engineer, Wisconsin Department of Natural Resources
Jeffrey Hermann, Administrator/Planner, Town of Genesee
Chris Hinz, Citizen
Joe Hoelkinger, Citizen
Andy Holtz, Citizen
Barb Holtz, Plan Commission, Southeastern Wisconsin Fox River Commission, Town of Mukwonago
Jean Holtz, Citizen
Richard Jenks, Citizen, Phantom Lakes District
Bruce S. Kaniewski, Former Planner Village of Mukwonago
Gregory Kessler, Citizen
Rob Klussendorf, Citizen
Bob Kwiatkowski, Citizen
Laurie Lawlor, Wisconsin Wetlands Association
Jacki Lewis, Citizen, Plan Commission, Town of Eagle
William Loesch, Citizen
Don Malek, County Board Supervisor, Waukesha County
Julie Mann, Citizen, Eagle Spring Lake District
John Mann, Citizen, Eagle Spring Lake District
Ezra Meyer, Friends of Mukwonago River
Pamela Meyer, County Board Supervisor, Waukesha County, Friends of Mukwonago River
Robert Miller, Citizen
Paul J. Moderacki, Administrator, Village of Mukwonago
Patricia Morton, The Nature Conservancy
Steve Muth, Citizen
Larry Nicoson, Citizen
Ruth Ann Nicoson, Citizen
Gerald Petersen, Board President, Kettle Moraine Land Trust, Ltd.
Mary Pires, Citizen
Brian Rudy, Citizen
Jamie Rybartczyk, Citizen
Tim Schwecke, Town Planner, Town of Mukwonago
Don Scott, Citizen

Chuck Shepherd, Citizen
David Skotarsak, President, Lake Beulah Management District
Dick Smith, Citizen
Richard Spurrell, President, Village of Eagle
Allen Stasiewski, Citizen
Bill Tarman-Ramcheck, Citizen
Eric Tarman-Ramcheck, Citizen
Steve Todd, Chair, Phantom Lakes Management District
Nick Wambach, Board Member, Eagle Spring Lake Management District
Craig Webster, Environmental Analysis and Review Specialist, Wisconsin Department of Natural Resources
Jean Weedman, Citizen
Dan West, Citizen
Diane Zak, Citizen
Maggie Zoellner, Citizen; Project Manager, Kettle Moraine Land Trust, Ltd.

PROJECT STAFF

Michael G. Hahn, Chief Environmental Engineer, SEWRPC
Thomas M. Slawski, Principal Planner, SEWRPC
Jeffrey A. Thornton, Principal Planner, SEWRPC
Sara W. Teske, Research Analyst, SEWRPC

MEETINGS OF THE MUKWONAGO RIVER WATERSHED PROTECTION ADVISORY GROUP

Date	Agency	Description
04-09-09	Eagle Spring and Phantom Lake Districts	First meeting
06-29-09	Eagle Spring and Phantom Lake Districts	Second meeting-review Chapters I-III
09-29-09	Eagle Spring and Phantom Lake Districts	Third meeting-review Chapter IV
04-08-10	Eagle Spring and Phantom Lake Districts	Fourth meeting-review plan recommendations

Appendix B

MANAGING THE WATER'S EDGE
MAKING NATURAL CONNECTIONS

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Managing the Water's Edge

Making Natural Connections

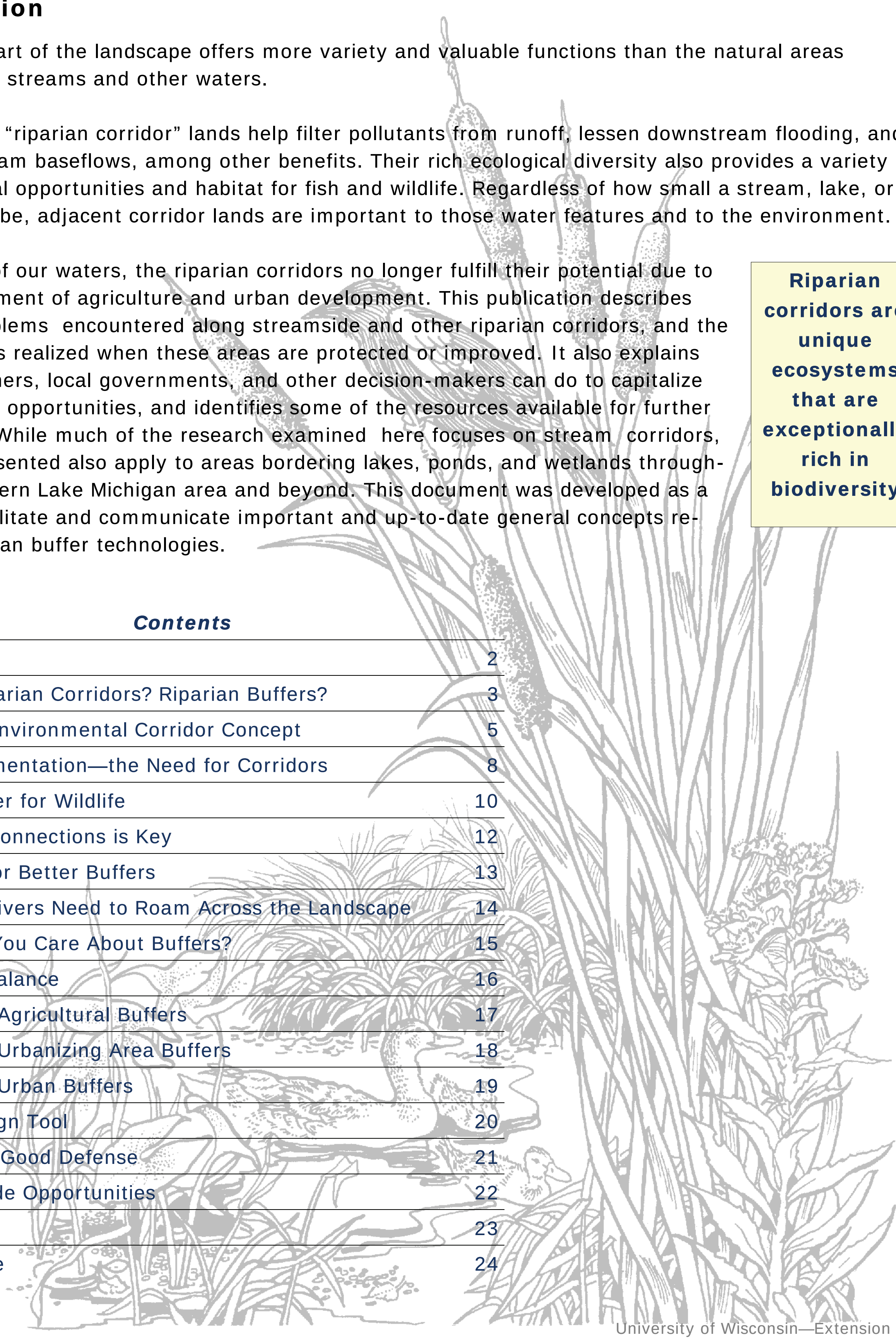
Problem Statement:
Despite significant research related to buffers, there remains no consensus as to what constitutes optimal riparian buffer design or proper buffer width for effective pollutant removal, water quality protection, prevention of channel erosion, provision of fish and wildlife habitat, enhancement of environmental corridors, augmentation of stream baseflow, and water temperature moderation.

Southeastern Wisconsin Regional Planning Commission

Our purpose in this document is to help protect and restore water quality, wildlife, recreational opportunities, and scenic beauty.

This material was prepared in part with funding from the U.S. Environmental Protection Agency Great Lakes National Program Office provided through CMAP, the Chicago Metropolitan Agency for Planning.

Introduction



Perhaps no part of the landscape offers more variety and valuable functions than the natural areas bordering our streams and other waters.

These unique “riparian corridor” lands help filter pollutants from runoff, lessen downstream flooding, and maintain stream baseflows, among other benefits. Their rich ecological diversity also provides a variety of recreational opportunities and habitat for fish and wildlife. Regardless of how small a stream, lake, or wetland may be, adjacent corridor lands are important to those water features and to the environment.

Along many of our waters, the riparian corridors no longer fulfill their potential due to the encroachment of agriculture and urban development. This publication describes common problems encountered along streamside and other riparian corridors, and the many benefits realized when these areas are protected or improved. It also explains what landowners, local governments, and other decision-makers can do to capitalize on waterfront opportunities, and identifies some of the resources available for further information. While much of the research examined here focuses on stream corridors, the ideas presented also apply to areas bordering lakes, ponds, and wetlands throughout the southern Lake Michigan area and beyond. This document was developed as a means to facilitate and communicate important and up-to-date general concepts related to riparian buffer technologies.

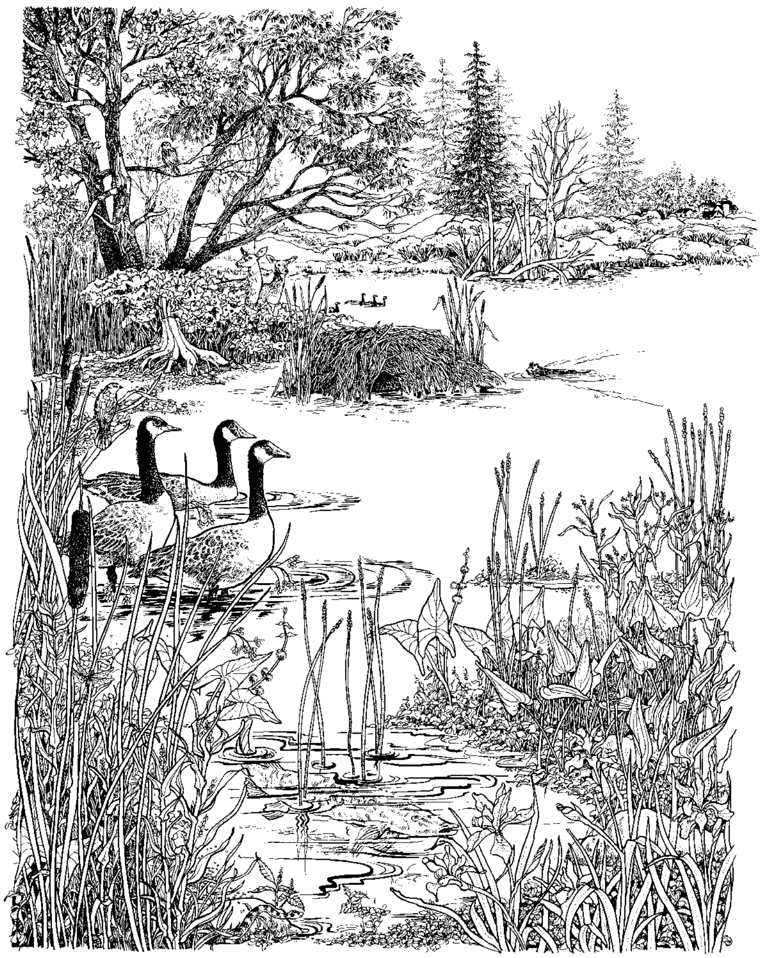
Riparian corridors are unique ecosystems that are exceptionally rich in biodiversity

Contents

What Are Riparian Corridors? Riparian Buffer Zones?

The word riparian comes from the Latin word *ripa*, which means bank. However, in this document we use riparian in a much broader sense and refer to land adjoining any water body including ponds, lakes, streams, and wetlands. This term has two additional distinct meanings that refer to 1) the "natural or relatively undisturbed" corridor lands adjacent to a water body inclusive of both wetland and upland flora and fauna and 2) a buffer zone or corridor lands in need of protection to "buffer" the effects of human impacts such as agriculture and residential development.

The word buffer literally means something that cushions against the shock of something else (noun), or to lessen or cushion that shock (verb). Other useful definitions reveal that a buffer can be something that serves to separate features, or that is capable of neutralizing something, like filtering pollutants from stormwater runoff. Essentially, buffers and buffering help protect against adverse effects.



University of Wisconsin—Extension

Riparian buffer zones function as core habitat as well as travel corridors for many wildlife species.

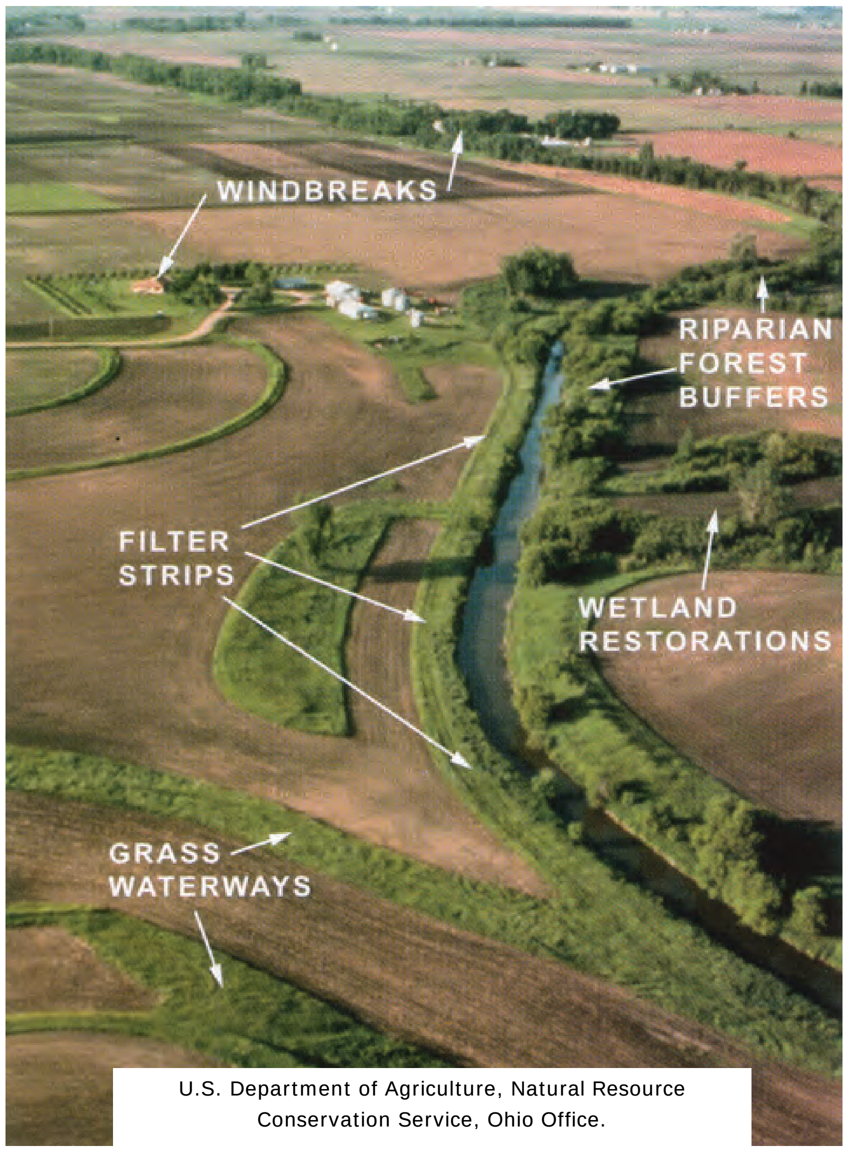
Riparian buffers are zones adjacent to waterbodies such as lakes, rivers, and wetlands that simultaneously protect water quality and wildlife, including both aquatic and terrestrial habitat. These zones minimize the impacts of human activities on the landscape and contribute to recreation, aesthetics, and quality of life. **This document summarizes how to maximize both water quality protection and conservation of aquatic and terrestrial wildlife populations using buffers.**

What Are Riparian Corridors? Riparian Buffer Zones?

Buffers **can** include a range of complex vegetation structure, soils, food sources, cover, and water features that offer a variety of habitats contributing to diversity and abundance of wildlife such as mammals, frogs, amphibians, insects, and birds. Buffers can consist of a variety of canopy layers and cover types including ephemeral (temporary-wet for only part of year) wetlands/seasonal ponds/spring pools, shallow marshes, deep marshes, wetland meadows, wetland mixed forests, grasslands, shrubs, forests, and/or prairies. Riparian zones are areas of transition between aquatic and terrestrial ecosystems, and they can potentially offer numerous benefits to wildlife and people such as pollution reduction and recreation.

In the water resources literature, riparian buffers are referred to in a number of different ways. Depending on the focus and the intended function of a buffer, or a buffer-related feature, buffers may be referred to as stream corridors, critical transition zones, riparian management areas, riparian management zones, floodplains, or green infrastructure.

It is important to note that within an agricultural context, the term buffer is used more generally to describe filtering best management practices most often at the water's edge. Other practices which can be interrelated may also sometimes be called buffers. These include grassed waterways, contour buffer strips, wind breaks, field border, shelterbelts, windbreaks, living snow fence, or filter strips. These practices may or may not be adjacent to a waterway as illustrated in the photo to the right. For example, a grassed waterway is designed to filter sediment and reduce erosion and may connect to a riparian buffer. These more limited-purpose practices may link to multipurpose buffers, but by themselves, they are not adequate to provide the multiple functions of a riparian buffer as defined here.



U.S. Department of Agriculture, Natural Resource Conservation Service, Ohio Office.

Beyond the Environmental Corridor Concept

The term "environmental corridors" (also known as "green infrastructure") refers to an interconnected green space network of natural areas and features, public lands, and other open spaces that provide natural resource value. Environmental corridor planning is a process that promotes a systematic and strategic approach to land conservation and encourages land use planning and practices that are good for both nature and people. It provides a framework to guide future growth, land development, and land conservation decisions in appropriate areas to protect both community and natural resource assets.

Environmental corridors are an essential planning tool for protecting the most important remaining natural resource features in Southeastern Wisconsin and elsewhere. Since development of the environmental corridor concept, there have been significant advancements in landscape ecology that have furthered understanding of the spatial and habitat needs of multiple groups of organisms. In addition, advancements in pollutant removal practices, stormwater control, and agriculture have increased our understanding of the effectiveness and limitations of environmental corridors. In protecting water quality and providing aquatic and terrestrial habitat, there is a need to better integrate new technologies through their application within riparian buffers.

SEWRPC has embraced and applied the environmental corridor concept developed by Philip Lewis (Professor Emeritus of Landscape Architecture at the University of Wisconsin-Madison) since 1966 with the publication of its first regional land use plan. Since then, SEWRPC has refined and detailed the mapping of environmental corridors, enabling the corridors to be incorporated directly into regional, county, and community plans and to be reflected in regulatory measures. The preservation of environmental corridors remains one of the most important recommendations of the regional plan. Corridor preservation has now been embraced by numerous county and local units of government as well as by State and Federal agencies. The environmental corridor concept conceived by Lewis has become an important part of the planning and development culture in Southeastern Wisconsin.

Beyond the Environmental Corridor Concept

Environmental corridors are divided into the following three categories.

- **Primary environmental corridors** contain concentrations of our most significant natural resources. They are at least 400 acres in size, at least two miles long, and at least 200 feet wide.

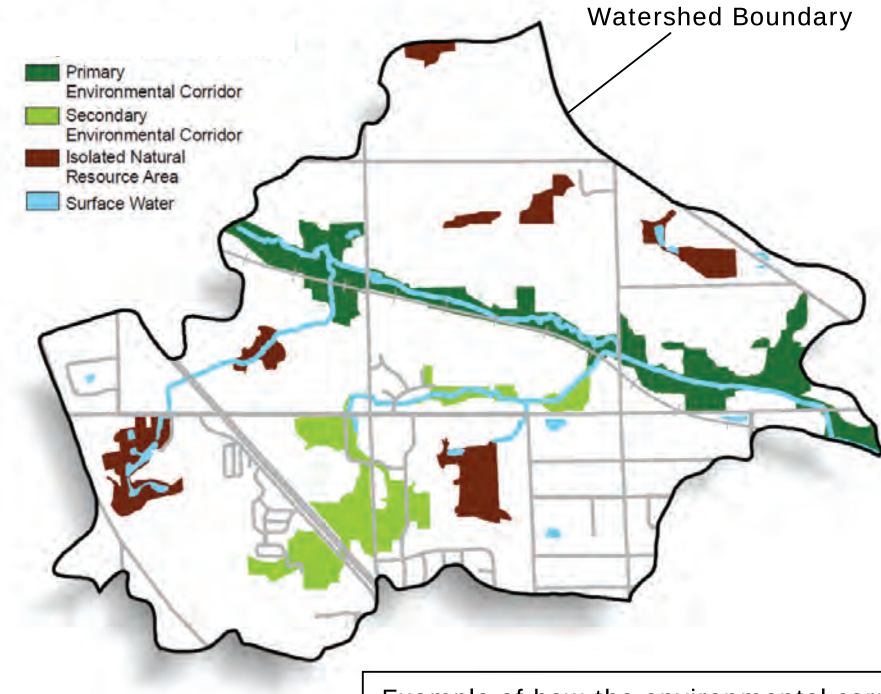
- **Secondary environmental corridors** contain significant but smaller concentrations of natural resources. They are at least 100 acres in size and at least one mile long, unless serving to link primary corridors.

- **Isolated natural resource areas** contain significant remaining resources that are not connected to environmental corridors. They are at least five acres in size and at least 200 feet wide.

Key Features of Environmental Corridors

- Lakes, rivers, and streams
- Undeveloped shorelands and floodlands
- Wetlands
- Woodlands
- Prairie remnants
- Wildlife habitat
- Rugged terrain and steep slopes
- Unique landforms or geological formations
- Unfarmed poorly drained and organic soils
- Existing outdoor recreation sites
- Potential outdoor recreation sites
- Significant open spaces
- Historical sites and structures
- Outstanding scenic areas and vistas

Beyond the Environmental Corridor Concept

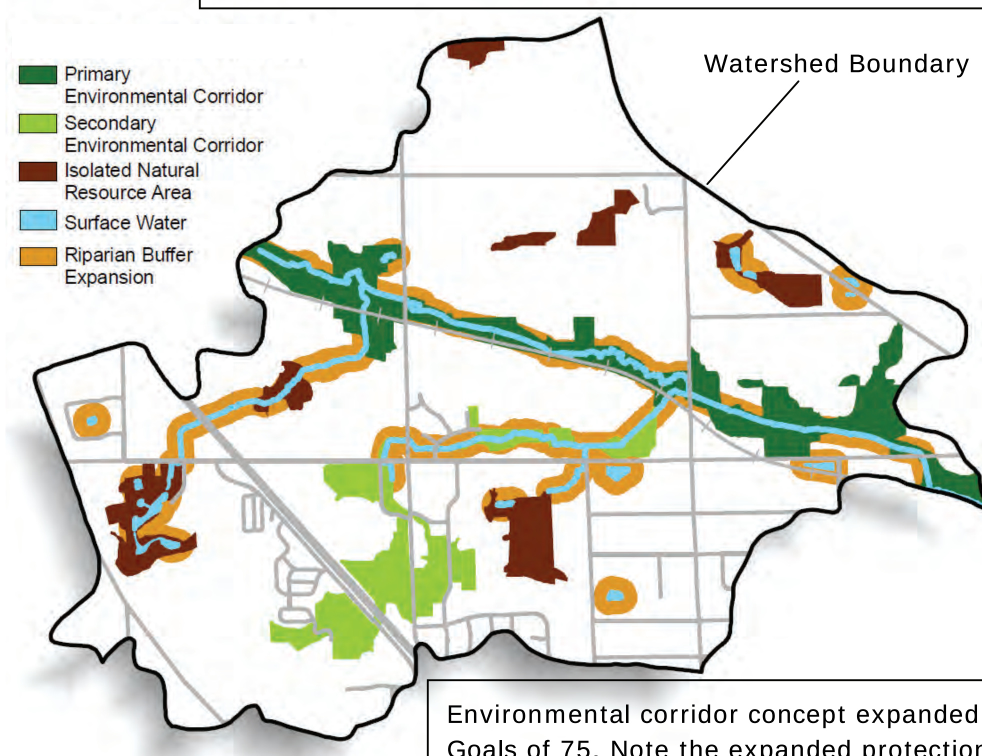


The Minimum Goals of **75** within a Watershed

75% minimum of total stream length should be naturally vegetated to protect the functional integrity of the water resources. (Environment Canada, How Much Habitat is Enough? A Framework for Guiding Habitat Rehabilitation in Great lakes Areas of Concern, Second Edition, 2004)

75 foot wide minimum riparian buffers from the top edge of each stream bank should be naturally vegetated to protect water quality and wildlife. (SEWRPC Planning Report No 50, A Regional Water Quality Management Plan for the Greater Milwaukee Watersheds, December 2007)

Example of how the environmental corridor concept is applied on the landscape. For more information see “Plan on It!” series **Environmental Corridors: Lifelines of the Natural Resource Base** at http://www.sewrpc.org/SEWRPC/LandUse/EnvironmentalCorridors.htm



Environmental corridor concept expanded to achieve the Goals of 75. Note the expanded protection in addition to the connection of other previously isolated areas.

Habitat Fragmentation—The Need for Corridors

Southeastern Wisconsin is a complex mosaic of agricultural and urban development. Agricultural lands originally dominated the landscape and remain a major land use. However, such lands continue to be converted to urban uses. Both of these dominant land uses fragment the landscape by creating islands or isolated pockets of wetland, woodland, and other natural lands available for wildlife preservation and recreation. By recognizing this fragmentation of the landscape, we can begin to mitigate these impacts.

New developments should incorporate water quality and wildlife enhancement or improvement objectives as design criteria by looking at the potential for creating linkages with adjoining lands and water features.

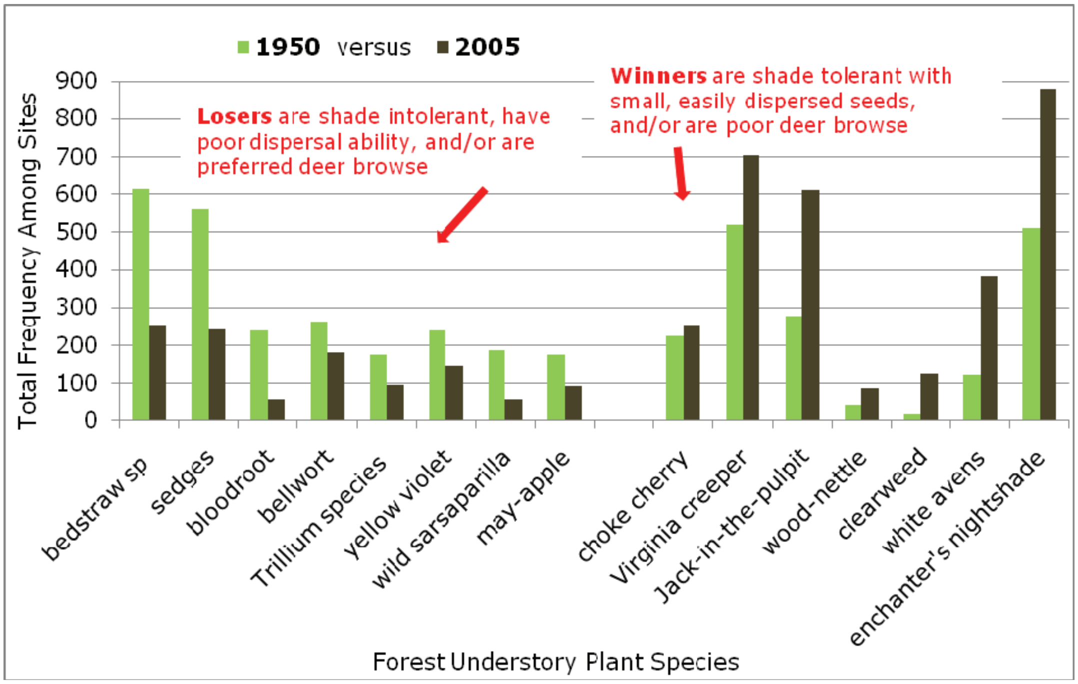
At the time of conversion of agricultural lands to urban uses, there are opportunities to re-create and expand riparian buffers and environmental corridors reconnecting uplands and waterways and restoring ecological integrity and scenic beauty locally and regionally. For example, placement of roads and other infrastructure across stream systems could be limited so as to maximize continuity of the riparian buffers. This can translate into significant cost savings in terms of reduced road maintenance, reduced salt application, and limited bridge or culvert maintenance and replacements. This simple practice not only saves the community significant amounts of money, but also improves and protects quality of life. Where necessary road crossings do occur, they can be designed to provide for safe fish and wildlife passage.

Overland travel routes for wildlife are often unavailable, discontinuous, or life endangering within the highly fragmented landscapes of Southeastern Wisconsin and elsewhere.

State Threatened Species: Blanding's turtle

Habitat Fragmentation—The Need for Corridors

Forest understory plant species abundance among stands throughout Southern Wisconsin



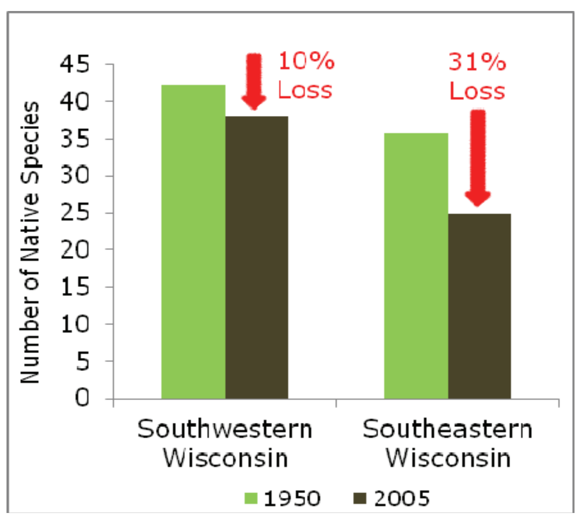
Forest fragmentation has led to significant plant species loss within Southern Wisconsin

(Adapted from David Rogers and others, 2008, Shifts in Southern Wisconsin Forest Canopy and Understory Richness, Composition, and Heterogeneity, Ecology, 89 (9): 2482-2492)

"...these results confirm the idea that large intact habitat patches and landscapes better sustain native species diversity. It also shows that people are a really important part of the system and their actions play an increasingly important role in shaping patterns of native species diversity and community composition. Put together, it is clear that one of the best and most cost effective actions we can take toward safeguarding native diversity of all types is to protect, enhance and create corridors that link patches of natural habitat."
Dr. David Rogers, Professor of Biology at the University of Wisconsin-Parkside

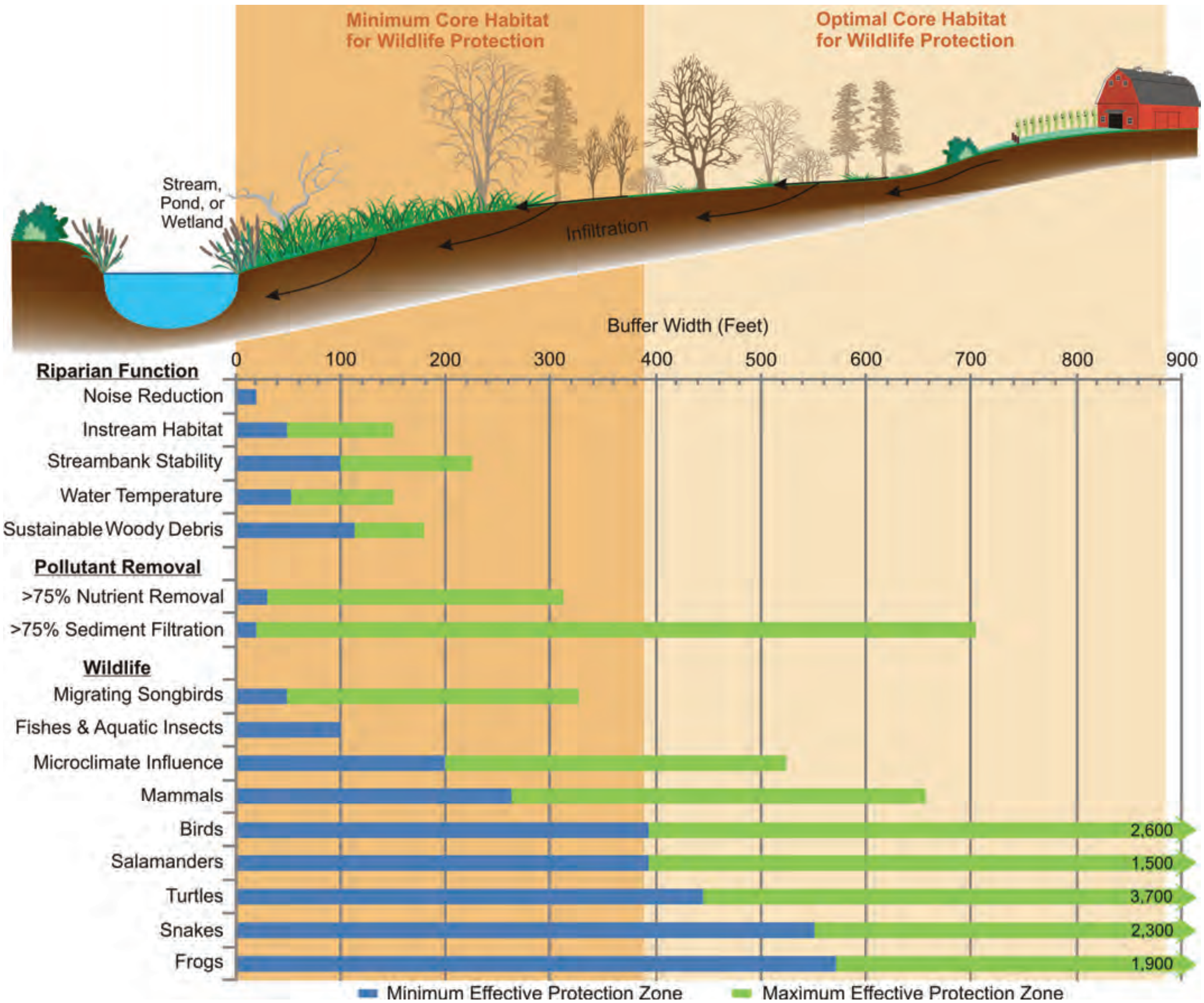
Since the 1950s, forests have increasingly become more fragmented by land development, both agricultural and urban, and associated roads and infrastructure, which have caused these forests to become isolated "islands of green" on the landscape. In particular, there has been significant loss of forest understory plant species over time (shrubs, grasses, and herbs covering the forest floor.) It is important to note that **these forests lost species diversity even when they were protected as parks or natural areas**.

One major factor responsible for this decline in forest plant diversity is that routes for native plants to re-colonize isolated forest islands are largely cut-off within fragmented landscapes. For example, the less fragmented landscapes in Southwestern Wisconsin lost fewer species than the more fragmented stands in Southeastern Wisconsin. In addition, the larger-sized forests and forests with greater connections to surrounding forest lands lost fewer species than smaller forests in fragmented landscapes.



Wider is Better for Wildlife

Why? Because buffer size is the engine that drives important natural functions like food availability and quality, access to water, habitat variety, protection from predators, reproductive or resting areas, corridors to safely move when necessary, and help in maintaining the health of species' gene pools to prevent isolation and perhaps extinction.



One riparian buffer size does not fit all conditions or needs. There are many riparian buffer functions and the ability to effectively fulfill those functions is largely dependent on width. Determining what buffer widths are needed should be based on what functions are desired as well as site conditions. For example, as shown above, water temperature protection generally does not require as wide a buffer as provision of habitat for wildlife. Based on the needs of wildlife species found in Wisconsin, the minimum core habitat buffer width is about 400 feet and the optimal width for sustaining the majority of wildlife species is about 900 feet. Hence, the value of large undisturbed parcels along waterways which are part of, and linked to, an environmental corridor system. The minimum effective buffer width distances are based on data reported in the scientific literature and the quality of available habitats within the context of those studies.

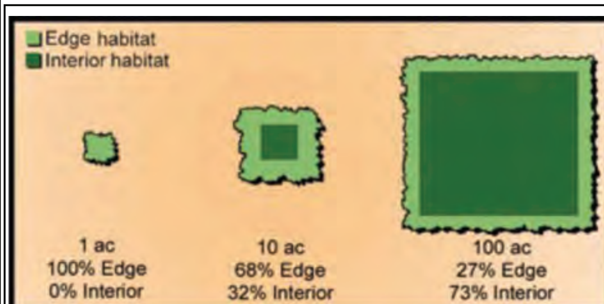
Wider is Better for Wildlife

Wildlife habitat needs change within and among species. **Minimum Core Habitat and Optimum Core Habitat distances were developed from numerous studies to help provide guidance for biologically meaningful buffers to conserve wildlife biodiversity.** These studies documented distances needed for a variety of biological (life history) needs to sustain healthy populations such as breeding, nesting, rearing young, foraging/feeding, perching (for birds), basking (for turtles), and overwintering/dormancy/hibernating. These life history needs require different types of habitat and distances from water, for example, one study found that Blanding's turtles needed approximately 60-foot-wide buffers for basking, 375 feet for overwintering, and up to 1,200 feet for nesting to bury their clutches of eggs. Some species of birds like the Blacked-capped chickadee or white breasted nuthatch only need about 50 feet of buffer, while others like the wood duck or great blue heron require 700-800 feet for nesting. Therefore, **understanding habitat needs for wildlife species is an important consideration in designing riparian buffers.**

Although *Ambystoma* salamanders require standing water for egg laying and juvenile development, most other times of the year they can be found more than 400 feet from water foraging for food.

Wisconsin Species	Mimimum Core Habitat (feet)	Optimum Core Habitat (feet)	Number of Studies
Frogs	571	1,043	9
Salamanders	394	705	14
Snakes	551	997	5
Turtles	446	889	27
Birds	394	787	45
Mammals	263	No data	11
Fishes and Aquatic Insects	100	No data	11
Mean	388	885	

This approach was adapted from *R.D. Semlitsch and J.R. Bodie, 2003, Biological Criteria for Buffer Zones around Wetlands and Riparian Habitats for Amphibian and Reptiles, Conservation Biology, 17(5):1219-1228*. These values are based upon studies examining species found in Wisconsin and represent mean linear distances extending outward from the edge of an aquatic habitat. The Minimum Core Habitat and Optimum Core Habitat reported values are based upon the mean minimum and mean maximum distances recorded, respectively. Due to a low number of studies for snake species, the recommended distances for snakes are based upon values reported by *Semlitsch and Bodie.*

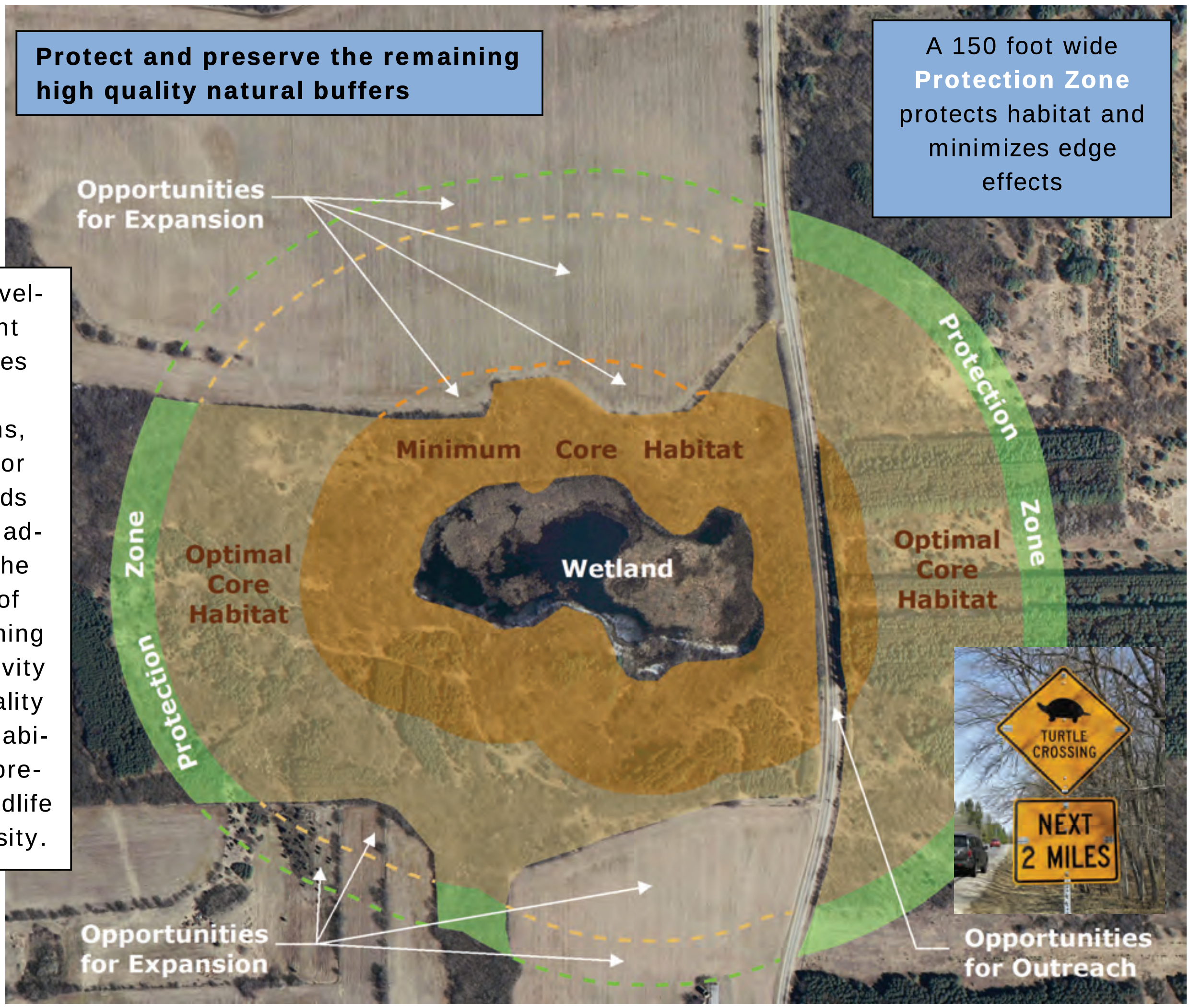


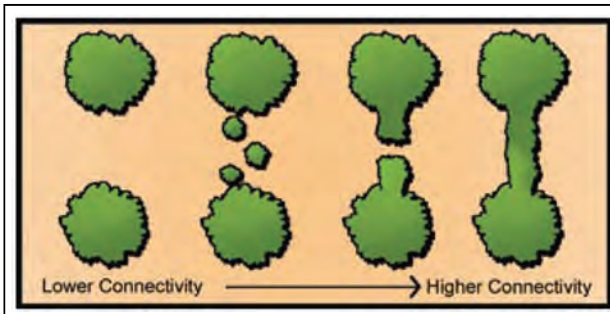
*"**Large patches typically conserve a greater variety and quality of habitats, resulting in higher species diversity and abundance.**" Larger patches contain greater amounts of interior habitat and less edge effects, which benefits interior species, by providing safety from parasitism, disease, and invasive species.*
(Bentrup, G. 2008. Conservation buffers: design guidelines for buffers, corridors, and greenways. Gen. Tech. Rep. SRS-109. Asheville, NC: Department of Agriculture, Forest Service, Southern Research Station)

Maintaining Connections is Key

Like humans, all forms of wildlife require access to clean water. Emerging research has increasingly shown that, in addition to water, more and more species such as amphibians and reptiles cannot persist without landscape connectivity between quality wetland and upland habitats. Good connectivity to upland terrestrial habitats is essential for the persistence of healthy sustainable populations, because these areas provide vital feeding, overwintering, and nesting habitats found nowhere else. Therefore, both aquatic and terrestrial habitats are essential for the preservation of biodiversity and they should ideally be managed together as a unit.

Land development practices near streams, lakes, or wetlands need to address the issue of maintaining connectivity with quality upland habitats to preserve wildlife biodiversity.



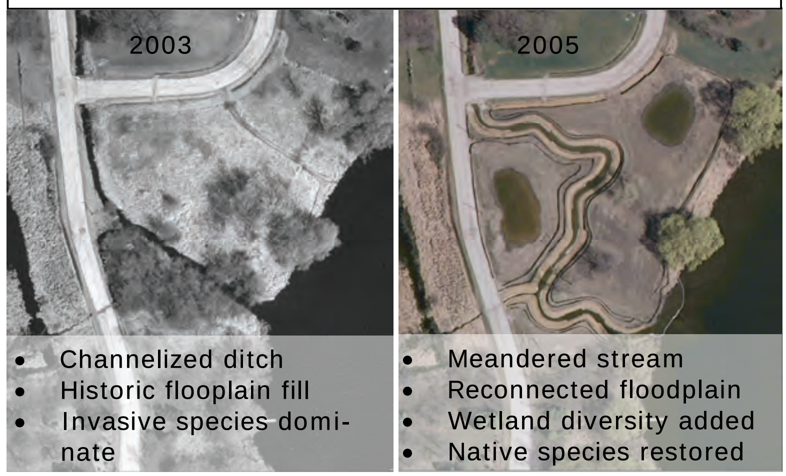


Increasing connectivity among quality natural landscapes (wetlands, woodlands, prairies) can benefit biodiversity by providing access to other areas of habitat, increasing gene flow and population viability, enabling recolonization of patches, and providing habitat (Bentrup 2008).

Basic Rules to Better Buffers

Protecting the integrity of native species in the region is an objective shared by many communities. The natural environment is an essential component of our existence and contributes to defining our communities and neighborhoods. Conservation design and open space development patterns in urbanizing areas and farm conservation programs in rural areas have begun to address the importance of maintaining and restoring riparian buffers and connectivity among corridors.

There are opportunities to improve buffer functions to improve water quality and wildlife habitat, even in urban situations

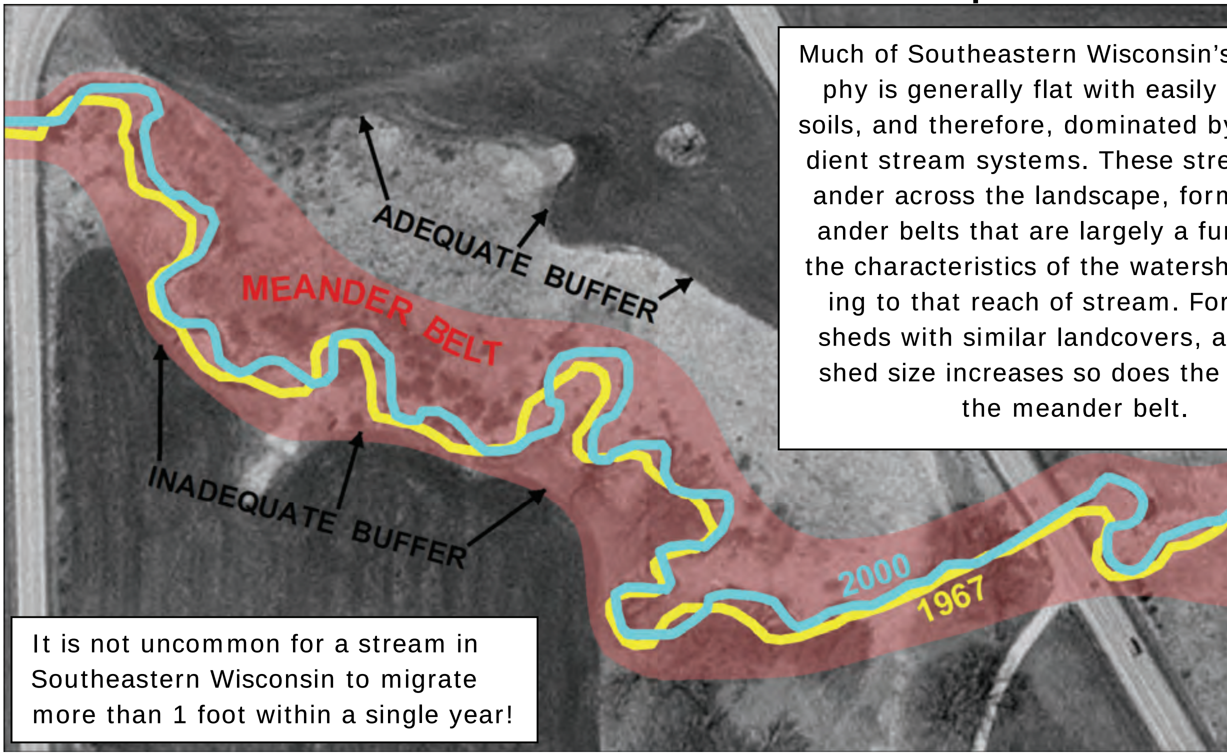


How wide should the buffer be? Unfortunately, there is no one-size-fits all buffer width adequate to protect water quality, wildlife habitat, and human needs. Therefore, the answer to this question depends upon the predetermined needs of the landowner and community objectives or goals.
As riparian corridors become very wide, their pollutant removal (buffering) effectiveness may reach a point of diminishing returns compared to the investment involved. However, the prospects for species diversity in the corridor keep increasing with buffer width. For a number of reasons, 400- to 800-foot-wide buffers are not practical along all lakes, streams, and wetlands within Southeastern Wisconsin. Therefore, communities should develop guidelines that remain flexible to site-specific needs to achieve the most benefits for water resources and wildlife as is practical.

Key considerations to better buffers / corridors:

- Wider buffers are better than narrow buffers for water quality and wildlife functions
- Continuous corridors are better than fragmented corridors for wildlife
- Natural linkages should be maintained or restored
- Linkages should not stop at political boundaries
- Two or more corridor linkages are better than one
- Structurally diverse corridors (e.g., diverse plant structure or community types, upland and wetland complexes, soil types, topography, and surficial geology) are better than corridors with simple structures
- Both local and regional spatial and temporal scales should be considered in establishing buffers
- Corridors should be located along dispersal and migration routes
- Corridors should be located and expanded around rare, threatened, or endangered species
- Quality habitat should be provided in a buffer whenever possible
- Disturbance (e.g. excavation or clear cutting vegetation) of corridors should be minimized during adjacent land use development
- Native species diversity should be promoted through plantings and active management
- Non-native species invasions should be actively managed by applying practices to preserve native species
- Fragmentation of corridors should be reduced by limiting the number of crossings of a creek or river where appropriate
- Restoration or rehabilitation of hydrological function, streambank stability, instream habitat, and/or floodplain connectivity should be considered within corridors.
- Restoration or retrofitting of road and railway crossings promotes passage of aquatic organisms

Creeks and Rivers Need to Roam Across the Landscape



Much of Southeastern Wisconsin’s topography is generally flat with easily erodible soils, and therefore, dominated by low gradient stream systems. These streams meander across the landscape, forming meander belts that are largely a function of the characteristics of the watershed draining to that reach of stream. For watersheds with similar landcovers, as watershed size increases so does the width of the meander belt.

It is not uncommon for a stream in Southeastern Wisconsin to migrate more than 1 foot within a single year!

Healthy streams naturally meander or migrate across a landscape over time. Streams are transport systems for water and sediment and are continually eroding and depositing sediments, which causes the stream to migrate. When the amount of sediment load coming into a stream is equal to what is being transported downstream—and stream widths, depths, and length remain consistent over time—it is common to refer to that stream as being in a state of **“dynamic equilibrium.”** In other words the stream retains its physical dimensions (equilibrium), but those physical features are shifted, or migrate, over time (dynamic).

Room to Roam

Riparian buffer widths should take into account the amount of area that a stream needs to be able to self-adjust and maintain itself in a state of dynamic equilibrium. ... These are generally greater than any minimum width needed to protect for pollutant removal alone.

Streams are highly sensitive, and they respond to changes in the amounts of water and sediment draining to them, which are affected by changing land use conditions. For example, streams can respond to increased discharges of water by increased scour (erosion) of bed and banks that leads to an increase in stream width and depth—or “degradation.” Conversely, streams can respond to increased sedimentation (deposition) that leads to a decrease in channel width and depth—or “aggradation.”

Why Should You Care About Buffers?

Economic Benefits:

- Increased value of riparian property
- Reduced lawn mowing time and expense
- Increased shade to reduce building cooling costs
- Natural flood mitigation protection for structures or crops
- Pollution mitigation (reduced nutrient and contaminant loading)
- Increased infiltration and groundwater recharge
- Prevented loss of property (land or structures) through erosion
- Greater human and ecological health through biodiversity

Recreational Benefits:

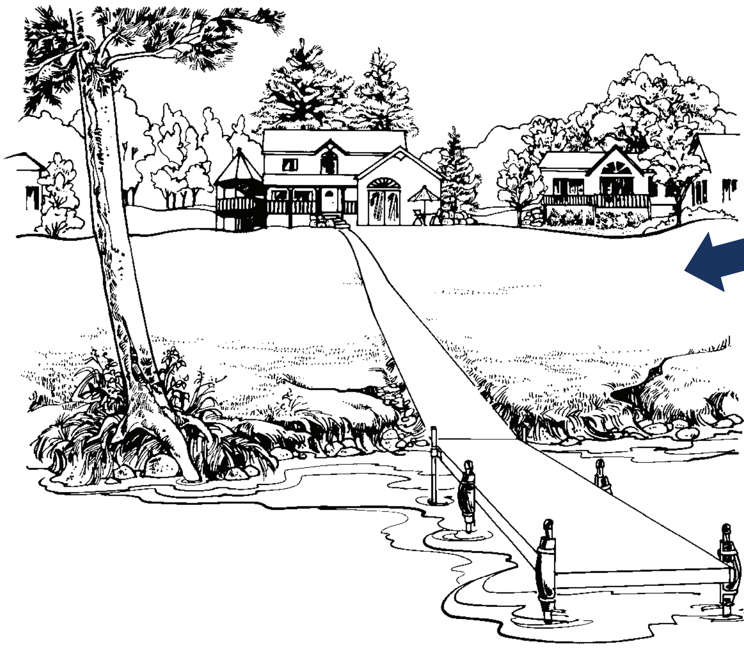
- Increased quality of the canoeing/kayaking experience
- Improved fishing and hunting quality by improving habitat
- Improved bird watching/wildlife viewing quality and opportunities
- Increased potential for expansion of trails for hiking and bicycling
- Opportunities made available for youth and others to locally reconnect with nature

Riparian buffers make sense and are profitable monetarily, recreationally, and aesthetically!

Social Benefits:

- Increased privacy
- Educational opportunities for outdoor awareness
- Improved quality of life at home and work
- Preserved open space/balanced character of a community
- Focal point for community pride and group activities
- Visual diversity
- Noise reduction

A Matter of Balance

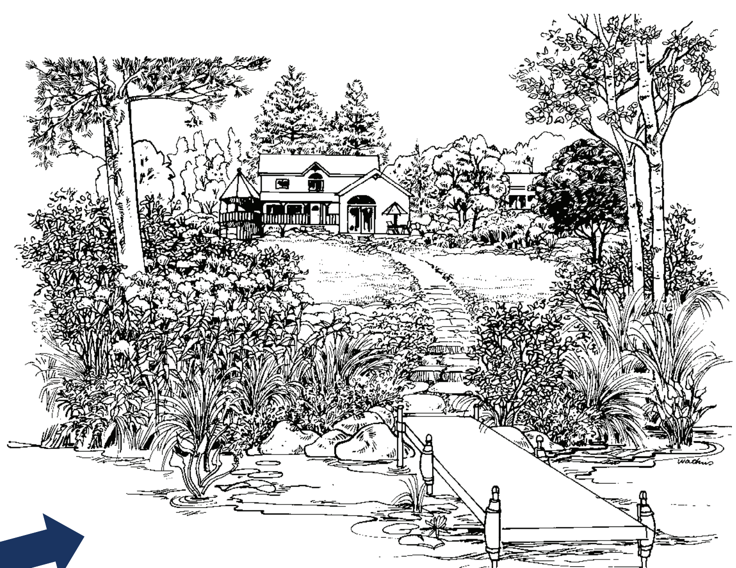

University of Wisconsin—Extension

Although neatly trimmed grass lawns are popular, these offer limited benefits for water quality or wildlife habitat. A single house near a waterbody may not seem like a "big deal," but the cumulative effects of many houses can negatively impact streams, lakes, and wetlands.

All the lands within Southeastern Wisconsin ultimately flow into either the Mississippi River or the Great Lakes systems. The cumulative effects of agriculture and urban development in the absence of mitigative measures, ultimately affects water quality in those systems. Much of this development causes increases in water runoff from the land into wetlands, ponds, and streams. This runoff transports water, sediments, nutrients, and other pollutants into our waterways that can lead to a number of problems, including flooding that can cause crop loss or building damage; unsightly and/or toxic algae blooms; increased turbidity; damage to aquatic organisms from reduced dissolved oxygen, lethal temperatures, and/or concentrations of pollutants; and loss of habitat.

Riparian buffers are one of the most effective tools available for defending our waterways. Riparian buffers can be best thought of as forming a living, self-sustainable protective shield. This shield protects investments in the land and all things on it as well as our quality of life locally, regionally, and, ultimately, nationally. Combined with stormwater management, environmentally friendly yard care, effective wastewater treatment, conservation farming methods, and appropriate use of fertilizers and other agrichemicals, **riparian buffers complete the set of actions that we can take to minimize impacts to our shared water resources.**

Lakeshore buffers can take many forms, which require a balancing act between lake viewing, access, and scenic beauty. Lakeshore buffers can be integrated into a landscaping design that complements both the structural development and a lakeside lifestyle. Judicious placement of access ways and shoreline protection structures, and preservation or reestablishment of native vegetation, can enhance and sustain our use of the environment.


University of Wisconsin—Extension

Case Study—Agricultural Buffers

Agricultural nonpoint source pollution runoff continues to pose a threat to water quality and aquatic ecosystems within Wisconsin and elsewhere. In an effort to address this problem, the Wisconsin Buffer Initiative was formed with the goal of designing a buffer implementation program to achieve science-based, cost-effective, water quality improvements (report available online at http://www.soils.wisc.edu/extension/nonpoint/wbi.php).

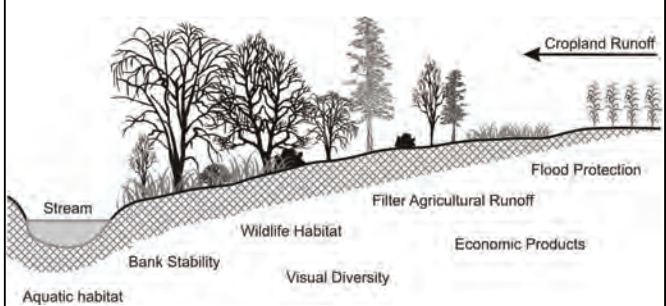
While it is true that riparian buffers alone may not always be able to reduce nutrient and sediment loading from agricultural lands, WBI researchers found that "...***riparian buffers are capable of reducing large percentages of the phosphorus and sediment that are currently being carried by Wisconsin streams. Even in watersheds with extremely high loads (top 10%), an average of about 70% of the sediment and phosphorus can be reduced through buffer implementation***." (*Diebel, M.J. and others, 2009, Landscape planning for agricultural nonpoint source pollution reduction III: Assessing Phosphorus and sediment reduction potential, Environmental Management, 43:69-83.*).

Challenge:
Buffers may take land out of cultivated crop production and require additional cost to install and maintain. Cost sharing, paid easements, and purchase of easements or development rights may sometimes be available to offset costs.

Benefits:
Buffers may offset costs by producing perennial crops such as hay, lumber, fiber, nuts, fruits, and berries. In addition, they provide visual diversity on the landscape, help maintain long-term crop productivity, and help support healthier fish populations for local enjoyment.

Federal and state natural resource agencies have long recognized the need to apply a wide range of Best Management Practices on agricultural lands to improve stream water quality. Although there are many tools available in the toolbox to reduce pollutant runoff from agricultural lands, such as crop rotations, nutrient and manure management, conservation tillage, and contour plowing, riparian buffers are one of the most effective tools to accomplish this task. Their multiple benefits and inter-connectedness from upstream to downstream make riparian buffers a choice with watershed-wide benefits.

Determine what benefits are needed.



The USDA in *Agroforestry Notes* (AF Note-4, January 1997) outlines a four step process for designing riparian buffers for Agricultural lands:

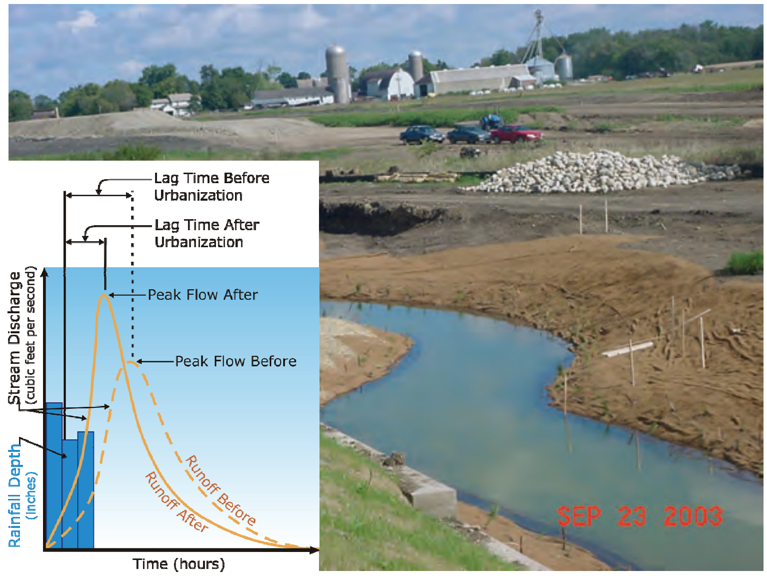
1-Determine what buffers functions are needed
2-Identify the best types of vegetation to provide the needed benefits
3-Determine the minimum acceptable buffer width to achieve desired benefits
4-Develop an installation and maintenance plan

Drain tiles can bypass infiltration and filtration of pollutants by providing a direct pathway to the water and "around" a buffer. This is important to consider in design of a buffer system which integrates with other agricultural practices.

Case Study—Urbanizing Area Buffers

When development occurs near a waterbody, the area in driveways, rooftops, sidewalks, and lawns increases, while native plants and undisturbed soils decrease. As a result, 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, one the consequences of urban development is an increase in the amount of stormwater, which runs off the land instead of infiltrating into the ground. Therefore, **urbanization impacts the watershed, not only by reducing groundwater recharge, but also by changing stream hydrology** through increased stormwater runoff volumes and peak flows. This means less water is available to sustain the baseflow regime. The urban environment also contains increased numbers of pollutants and generates greater pollutant concentrations and loads than any other land use. This reflects the higher density of the human population and associated activities, which demand measures to protect the urban water system.

Mitigation of urban impacts may be as simple as not mowing along a stream corridor or changing land management and yard care practices, or as complex as changing zoning ordinances or widening riparian corridors through buyouts.

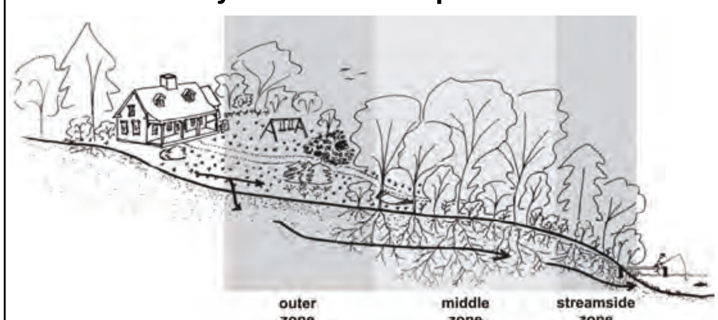


Comparison of hydrographs before and after urbanization. Note the rapid runoff and greater peak streamflow tied to watershed development. (Adapted from Federal Interagency Stream Restoration Working Group (FISRWG), Stream Corridor Restoration: Principles, Processes, and Practices, October 1998)

Challenge:
Urban development requires balancing flood protection, water quality protection, and the economic viability of the development.

Opportunities:
Buffers may offset costs by providing adequate space for providing long-term water quantity and water quality protection. In addition, they provide visual diversity on the landscape, wildlife habitat and connectedness, and help maintain property values.

Anatomy of an urban riparian buffer



The most effective urban buffers have three zones:

Outer Zone-Transition area between the intact buffer and nearest permanent structure to capture sediment and absorb runoff.

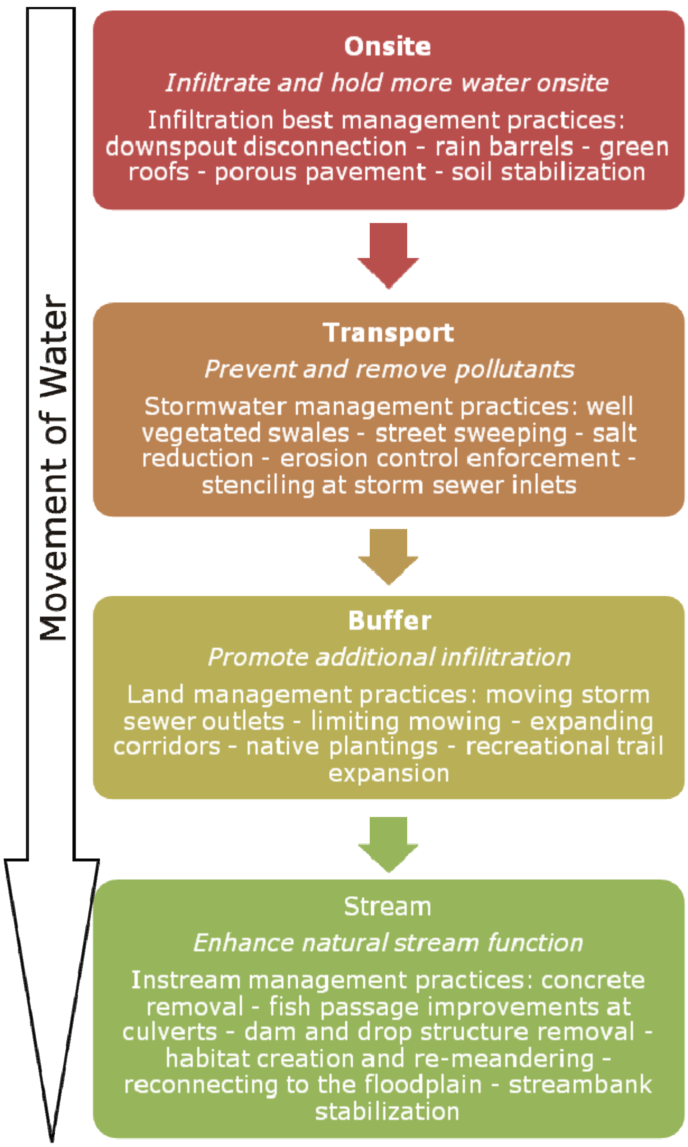
Middle Zone-Area from top of bank to edge of lawn that is composed of natural vegetation that provides wildlife habitat as well as improved filtration and infiltration of pollutants.

Streamside Zone-Area from the water's edge to the top of the bank or uplands that provides critical connection between water, wetland, and upland habitats for wildlife as well as protect streams from bank erosion

(Fact sheet No. 6 Urban Buffer in the series Riparian Buffers for Northern New Jersey)

Case Study—Urban Buffers

Placement of riparian buffers in established urban areas is a challenge that requires new and innovative approaches. In these areas, historical development along water courses limits options and requires balancing flood management protection versus water quality and environmental protection needs. Consequently, some municipalities have begun to recognize the connections between these objectives and are introducing programs to remove flood-prone structures and culverts from the stream corridors and allow recreation of the stream, restoring floodplains, and improving both the quality of life and the environment.



In urban settings it may be necessary to limit pollution and water runoff before it reaches the buffer.

Challenge:
There are many potential constraints to establishing, expanding, and/or managing riparian buffers within an urban landscape. Two major constraints to establishment of urban buffers include:

1) **Limited or confined space to establish buffers** due to encroachment by structures such as buildings, roadways, and/or sewer infrastructure;

2) **Fragmentation of the landscape** by road and railway crossings of creeks and rivers that disrupt the linear connectedness of buffers, limiting their ability to provide quality wildlife habitat.

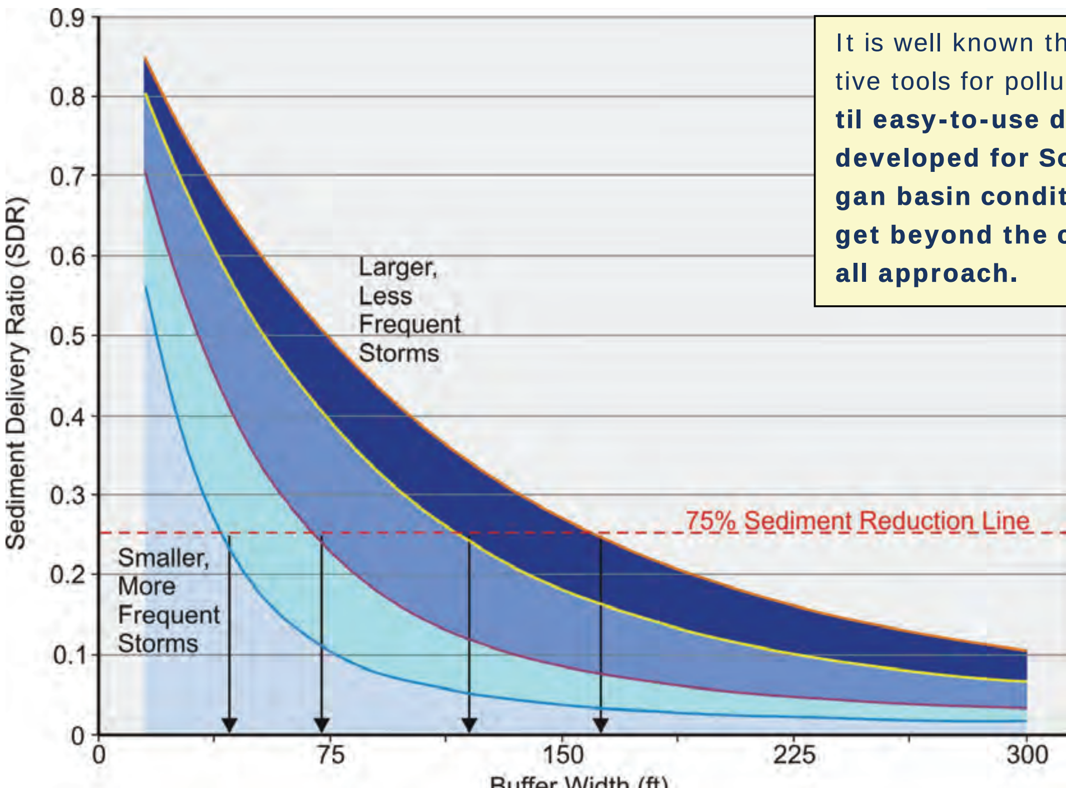
Much traditional stormwater infrastructure intercepts runoff and diverts it directly into creeks and rivers, bypassing any benefits of buffers to infiltrate or filter pollutants. This is important to consider in design of a buffer system for urban waterways, which begin in yards, curbsides, and construction sites, that are figuratively as close to streams as the nearest storm sewer inlet.

A Buffer Design Tool

Design aids are needed to help municipalities, property owners, and others take the "guesswork" out of determining adequate buffer widths for the purpose of water resource quality protection. While there are various complex mathematical models that can be used to estimate sediment and nutrient removal efficiencies, they are not easily applied by the people who need them including homeowners, farmers, businesses and developers.

To fill this gap, design aid tools are being developed using factors such as slope, soils, field length, incoming pollutant concentrations, and vegetation to allow the user to identify and test realistic buffer widths with respect to the desired percent pollutant load reduction and storm characteristics. By developing a set of relationships among factors that determine buffer effectiveness, the width of buffer needed to meet specific goals can be identified.

In the example below, 50-foot-wide buffers are necessary to achieve 75 % sediment removal during small, low intensity storms, while buffers more than 150 feet wide are necessary to achieve the same sediment reduction during more severe storms. Based on this information, decision-makers have the option of fitting a desired level of sediment removal into the context of their specific conditions. Under most conditions, a 75-foot width will provide a minimum level of protection for a variety of needs (SEWRPC PR No. 50, Appendix O.)



It is well known that buffers are effective tools for pollutant removal, but **until easy-to-use design aid tools are developed for Southern Lake Michigan basin conditions, we can never get beyond the current one size fits all approach.**

This generalized graph depicts an example of model output for an optimal buffer width to achieve a 75% sediment reduction for a range of soil and slope, vegetation, and storm conditions characteristic of North Carolina. *(Adapted from Muñoz-Carpena R., Parsons J.E.. 2005. VFSMOD-W: Vegetative Filter Strips Hydrology and Sediment Transport Modeling System v.2.x. Homestead, FL: University of Florida. http://carpena.ifas.ufl.edu/vfsmod/citations.shtml)*

Buffers Are A Good Defense

Today's natural resources are under threat. These threats are immediate as in the case of chemical accidents or manure spills, and chronic as in the case of stormwater pollution carrying everything from eroded soil, to fertilizer nutrients, to millions of drips from automobiles and other sources across the landscape. Non-native species have invaded, and continue to invade, key ecosystems and have caused the loss of native species and degradation of their habitats to the detriment of our use of important resources.

> ***"Riparian ecosystems are naturally resilient,*** *provide linear habitat connectivity, link aquatic and terrestrial ecosystems, and create thermal refugia for wildlife: all characteristics that can contribute to ecological adaptation to climate change."*
>
> *(N. E. Seavy and others, Why Climate Change Makes Riparian Restoration More Important Than Ever: Recommendations for Practice and Research, 2009, Ecological Restoration 27(3):330-338)*

A more subtle, but growing, concern is the case of stresses on the environment resulting from climate change. Buffers present an opportunity for natural systems to adapt to such changes by providing the space to implement protective measures while also serving human needs. **Because riparian buffers maintain an important part of the landscape in a natural condition, they offer opportunities for communities to adjust to our changing world.**

Well-managed riparian buffers are a good defense against these threats. In combination with environmental corridors, buffers maintain a sustainable reserve and diversity of habitats, plant and animal populations, and genetic diversity of organisms, all of which contribute to the long-term preservation of the landscape. Where they are of sufficient size and connectivity, riparian buffers act as reservoirs of resources that resist the changes that could lead to loss of species.

Refuge or protection from increased water temperatures as provided by natural buffers is important for the preservation of native cold-water, cool-water, and warm-water fishes and their associated communities.

Buffers Provide Opportunities

River, lake, and wetland systems and their associated riparian lands form an important element of the natural resource base, create opportunities for recreation, and contribute to attractive and well-balanced communities. These resources can provide an essential avenue for relief of stress among the population and improve quality of life in both urban and rural areas. Such uses also sustain industries associated with outfitting and supporting recreational and other uses of the natural environment, providing economic opportunities. Increasing access and assuring safe use of these areas enhances public awareness and commitment to natural resources. Research has shown that property values are higher adjoining riparian corridors, and that such natural features are among the most appreciated and well-supported parts of the landscape for protection.

We demand a lot from our riparian buffers!

Sustaining this range of uses requires our commitment to protect and maintain them.

Summary

The following guidance suggestions highlight key points to improve riparian corridor management and create a more sustainable environment.

Riparian corridors or buffers along our waters may contain varied features, but all are best preserved or designed to perform multiple important functions.

Care about buffers because of their many benefits. Riparian buffers make sense and are profitable monetarily, recreationally, aesthetically, as well as environmentally.

Enhance the environmental corridor concept. Environmental corridors are special resources which deserve protection. They serve many key riparian corridor functions, but in some cases, could also benefit from additional buffering.

Avoid habitat fragmentation of riparian corridors. It is important to preserve and link key resource areas, making natural connections and avoiding habitat gaps.

Employ the adage “wider is better” for buffer protection. While relatively narrow riparian buffers may be effective as filters for certain pollutants, that water quality function along with infiltration of precipitation and runoff and the provision of habitat for a host of species will be improved by expanding buffer width where feasible.

Allow creeks and rivers room to roam across the landscape. Streams are dynamic and should be buffered adequately to allow for natural movement over time while avoiding problems associated with such movement.

Consider and evaluate buffers as a matter of balance. Riparian buffers are a living, self-sustainable shield that can help balance active use of water and adjoining resources with environmental protection.

Agricultural buffers can provide many benefits. Riparian buffers in agricultural settings generally work well, are cost-effective, and can provide multiple benefits, including possibly serving as areas to raise certain crops.

Urban buffers should be preserved and properly managed. Though often space-constrained and fragmented, urban buffers are important remnants of the natural system. Opportunities to establish or expand buffers should be considered, where feasible, complemented by good stormwater management, landscaping, and local ordinances, including erosion controls.

A buffer design tool is needed and should be developed. Southeastern Wisconsin and the Southern Lake Michigan Basin would benefit from development of a specific design tool to address the water quality function of buffers. Such a tool would improve on the currently available general guidance on dimensions and species composition.

Buffers are a good defense. Combined with environmental corridors, riparian buffers offer a good line of defense against changes which can negatively impact natural resources and the landscape.

MORE TO COME

Future editions in a riparian buffer planning series are being explored with the intent of focusing on key elements of this critical land and water interface. Topics may include:

- Information sharing and development of ordinances to integrate riparian buffers into existing land management plans and programs
- Integration of stormwater management practices and riparian buffer best management practices
- Application of buffers within highly constrained urban corridors with and without brownfield development
- Installation of buffers within rural or agricultural lands being converted to urban uses
- Utilization of buffers in agricultural areas and associated drainage systems
- Integration of riparian buffers into environmental corridors to support resources preservation, recreation and aesthetic uses
- Preservation of stream courses and drainageways to minimize maintenance and promote protection of infrastructure
- Guidance for retrofitting, replacement, or removal of infrastructure such as dams and road crossings, to balance transportation, recreation, aesthetic, property value, and environmental considerations.
- Protection of groundwater recharge and discharge areas
- Protection of high quality, sensitive coastal areas, including preservation of recreational potential

MORE INFORMATION

This booklet can be found at http://www.sewrpc.org/SEWRPC/Environment.htm . Please visit the website for more information, periodic updates, and a list of complementary publications.

* * *

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May 7, 2010

Appendix C

MUKWONAGO RIVER CROSS-SECTION SURVEY SUMMER 2008: LOCATION AND DESCRIPTION OF FIELD MEASUREMENTS

STREAMBANK CHARACTERISTICS

Bankfull Width: The stream channel that is formed by the dominant discharge, also referred to as the active channel, which meanders across the floodplain as it forms pools and riffles. Defined by the discharge that occurs when water just begins to leave the channel and spread onto the floodplain.

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.

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 lowest point of the streambed.

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 Mukwonago River 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

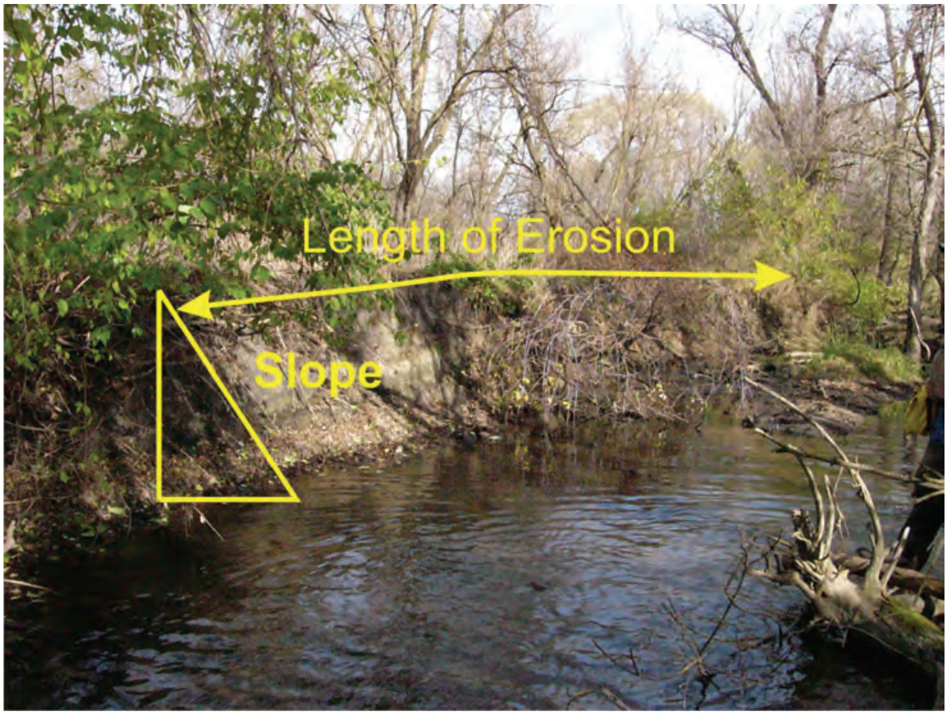
EXAMPLE OF BANK HEIGHT AND UNDERCUT DEPTH MEASURED AT AN ACTIVELY ERODING SITE

NOTE: These photos were not taken within the Mukwonago River watershed and are for illustrative purposes only.

Source: SEWRPC.

Figure C-2

EXAMPLE OF LENGTH OF EROSION AND BANK SLOPE MEASURED AT AN ACTIVELY ERODING SITE



NOTE: Erosion was not significant within the Mukwonago River watershed. This photo was not taken within the Mukwonago River watershed and is for illustrative purposes only.

Source: SEWRPC.

Figure C-3

TYPICAL POOL HABITATS IN THE MUKWONAGO RIVER WATERSHED: 2008

Mukwonago River

Jericho Creek

Source: SEWRPC.

Figure C-4

TYPICAL RIFFLE HABITATS IN THE MUKWONAGO RIVER WATERSHED: 2008

Mukwonago River

Jericho Creek

Source: SEWRPC.

Substrates: Refers to the materials that make up the streambed. Substrate composition in the streams of the Mukwonago River watershed was determined visually by recording the dominant substrate types within the transect. The following categories of substrate type were used.

- Bedrock: Solid rock forming a continuous surface.
- Boulder: Rocks with a diameter of 10 to 20 inches.
- Cobble: Rocks with a diameter of 2.5 to 10 inches.
- Gravel: Rocks with a diameter of 0.07 to 2.5 inches.
- Sand: Inorganic particles smaller than gravel, but coarser than silt with a diameter of 0.002 to 0.07 inch.
- 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 diameter of less than 0.0001 inch.
- Peat: A fibrous mass of organic matter in various stages of decomposition, generally dark brown to black in color and of spongy consistency.
- Clay: Very fine, inorganic, dark brown or gray particles. Individual particles are barely visible 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 diameter of less than 0.0001 inch.

Sediment Depth: The depth of fine sediments (usually silt) that overlay or comprise the streambed. Sediment depth is an indicator of sediment deposition and was measured to the nearest 0.5 inch.

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.

Cover: This can be one, or any combination, of characteristics that include undercut banks, overhanging vegetation, water velocities, logs or woody debris, deep pools, oxbows, backwaters, or side channels, boulders and other substrates, aquatic macrophytes, and algae that provide 1) protection from predators, 2) feeding areas, 3) spawning habitat, or 4) some other benefit such as shading.

Tables C-1 through C-3 indentify the total number of transects surveyed within the Mukwonago River watershed and their associated habitat characteristics.

Table C-1

CROSS-SECTION LOCATION, HABITAT TYPES, AND INSTREAM COVER VARIABLES WITHIN THE MUKWONAGO RIVER WATERSHED: 2008

Subwatershed and Reach	Transect Number (see Map C-1)	River Mile	Sample Date	Longitude[a]	Latitude[a]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Mukwonago												
Mukwonago 1	1	0.34	08-Jul-08	2454808.825	320677.0603	Pool	Slow	2	0	2	2	1
Mukwonago 1	2	0.46	08-Jul-08	2454421.249	320143.154	Run	Slow	2	0	2	1	0
Mukwonago 1	3	0.61	08-Jul-08	2453945.347	319615.8391	Run	Slow	2	1	2	2	1
Mukwonago 1	4	0.65	08-Jul-08	2453740.026	319588.9329	Run	Slow	2	0	2	2	1
Mukwonago 1	5	0.70	08-Jul-08	2453461.901	319445.1829	Run	Slow	2	1	2	2	1
Mukwonago 1	6	0.74	08-Jul-08	2453308.776	319264.9746	Run	Moderate	3	1	2	2	0
Mukwonago 1	7	0.79	08-Jul-08	2453190.026	319062.8912	Riffle	Moderate	2	0	2	1	0
Mukwonago 1	8	0.82	08-Jul-08	2453100.443	318961.8496	Run	Moderate	2	0	2	1	1
Mukwonago 1	9	0.92	09-Jul-08	2452629.61	318752.4746	Pool	Slow	2	1	2	1	1
Mukwonago 1	10	1.03	09-Jul-08	2452153.568	318406.6412	Riffle	Slow	2	1	1	1	1
Mukwonago 1	11	1.08	09-Jul-08	2451948.36	318222.2662	Riffle	Moderate	1	1	1	1	0
Mukwonago 1	12	1.15	09-Jul-08	2451789.972	317935.1824	Riffle	Fast	1	0	1	2	0
Mukwonago 1	13	1.21	09-Jul-08	2451445.235	317791.0162	Run	Fast	2	0	2	1	0
Mukwonago 1	14	1.26	09-Jul-08	2451352.526	317534.7662	Riffle	Moderate	0	0	2	0	0
Mukwonago 1	15	1.35	10-Jul-08	2451282.735	317098.3079	Run	Slow	1	0	1	1	0
Mukwonago 1	16	1.49	10-Jul-08	2450874.401	316508.7246	Run	Moderate	0	0	2	1	0
Mukwonago 1	17	1.54	10-Jul-08	2450643.151	316481.6412	Run	Slow	2	0	1	1	0
Mukwonago 1	18	1.56	10-Jul-08	2450542.11	316504.5579	Run	Slow	0	0	1	1	0
Mukwonago 1	19	1.60	10-Jul-08	2450324.401	316477.4746	Run	Moderate	0	0	2	1	0
Mukwonago 1	20	1.65	10-Jul-08	2450042.11	316430.5996	Run	Moderate	1	0	2	1	0
Mukwonago 1	21	1.69	10-Jul-08	2449874.401	316455.5996	Pool	Moderate	2	0	2	1	0
Mukwonago 1	22	1.73	10-Jul-08	2449757.735	316653.5162	Run	Moderate	1	0	1	1	0
Mukwonago 1	23	1.76	10-Jul-08	2449680.651	316801.4329	Pool	Moderate	1	0	1	0	0
Mukwonago 1	24	1.80	10-Jul-08	2449700.443	316984.7662	Riffle	Fast	2	0	2	1	0
Mukwonago 1	25	1.85	10-Jul-08	2449627.526	317198.3079	Pool	Moderate	2	0	2	1	0
Mukwonago 1	26	1.90	10-Jul-08	2449406.693	317111.8496	Riffle	Moderate	1	2	0	1	0
Mukwonago 1	27	1.98	10-Jul-08	2449072.318	316958.7246	Riffle	Moderate	1	1	1	1	0
Mukwonago 1	28	2.02	15-Jul-08	2448893.151	316909.7662	Run	Moderate	1	1	2	2	1
Mukwonago 1	29	2.06	15-Jul-08	2448644.193	316860.8079	Run	Slow	1	1	1	1	1
Mukwonago 1	30	2.12	15-Jul-08	2448345.235	316769.1412	Riffle	Fast	1	1	1	1	2
Mukwonago 1	31	2.17	15-Jul-08	2448106.693	316724.3496	Pool	Moderate	2	1	2	2	0
Mukwonago 1	32	2.21	15-Jul-08	2447931.693	316720.1829	Run	Fast	1	1	1	1	0
Phantom												
Mukwonago 2	33	4.40	17-Jul-08	2438624.401	318089.9746	Pool	Moderate	2	0	2	1	0
Mukwonago 2	34	4.42	17-Jul-08	2438422.318	318107.6829	Run	Slow	2	1	2	1	0
Mukwonago 2	35	4.46	17-Jul-08	2438197.318	317989.9746	Pool	Moderate	3	1	2	1	0
Mukwonago 2	36	4.51	17-Jul-08	2438090.026	317780.5996	Pool	Moderate	2	1	3	0	0
Mukwonago 2	37	4.56	17-Jul-08	2437960.86	317637.8912	Run	Moderate	2	1	3	1	1
Mukwonago 2	38	4.60	17-Jul-08	2437854.61	316930.5996	Run	Moderate	3	0	3	0	0
Mukwonago 2	39	4.74	17-Jul-08	2437657.735	316849.3496	Run	Slow	2	0	3	0	0
Mukwonago 2	40	4.82	17-Jul-08	2437132.735	316972.2662	Run	Moderate	3	0	3	1	0
Mukwonago 2	41	4.93	17-Jul-08	2436563.985	317137.8912	Pool	Moderate	3	0	3	1	0
Mukwonago 2	42	5.05	17-Jul-08	2436245.235	316928.5162	Pool	Slow	3	0	3	0	0
Mukwonago 2	43	5.13	17-Jul-08	2435945.235	316601.4329	Run	Slow	3	0	3	0	0
Mukwonago 2	44	5.22	17-Jul-08	2435529.61	316649.3496	Pool	Slow	3	0	3	1	0
Mukwonago 2	45	5.31	17-Jul-08	2434822.318	316302.4746	Run	Slow	3	0	3	1	0

Table C-1 (continued)

Subwatershed and Reach	Transect Number (see Map C-1)	River Mile	Sample Date	Longitude[a]	Latitude[a]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Phantom (continued)												
Mukwonago 2	46	5.52	17-Jul-08	2434215.026	316182.6829	Run	Slow	3	0	3	2	0
Mukwonago 2	47	5.64	17-Jul-08	2433960.86	316436.8496	Run	Moderate	3	0	3	1	0
Mukwonago 2	48	5.72	17-Jul-08	2433847.318	316607.6829	Pool	Moderate	3	0	3	1	0
Mukwonago 2	49	5.75	17-Jul-08	2433730.651	316238.9329	Run	Moderate	3	0	2	2	0
Mukwonago 2	50	5.82	17-Jul-08	2433612.943	315647.2662	Pool	Moderate	3	0	3	1	0
Mukwonago 2	51	5.95	17-Jul-08	2433226.485	315511.8496	Pool	Moderate	3	0	3	1	0
Mukwonago 2	52	6.02	17-Jul-08	2433131.693	315287.8912	Run	Moderate	3	0	2	1	0
Mukwonago 2	53	6.07	17-Jul-08	2433073.36	315208.7246	Pool	Moderate	3	0	3	1	0
Mukwonago 2	54	6.09	17-Jul-08	2432917.11	315195.1829	Run	Slow	3	0	3	2	0
Mukwonago 2	55	6.12	18-Jul-08	2432749.401	315206.6412	Pool	Moderate	1	0	0	0	0
Mukwonago 2	56	6.17	18-Jul-08	2432716.068	315270.1829	Run	Slow	1	0	1	1	0
Mukwonago 2	57	6.18	18-Jul-08	2432648.36	315326.4329	Pool	Slow	1	0	1	0	0
Mukwonago 2	58	6.19	18-Jul-08	2432575.443	315246.2246	Pool	Slow	3	0	3	1	0
Mukwonago 2	59	6.21	18-Jul-08	2432455.651	315264.9746	Run	Slow	2	0	2	1	0
Mukwonago 2	60	6.24	18-Jul-08	2432313.985	315352.4746	Pool	Slow	2	0	2	1	0
Mukwonago 2	61	6.27	18-Jul-08	2432179.61	315344.1412	Run	Slow	1	0	2	0	0
Mukwonago 2	62	6.30	18-Jul-08	2432133.776	315328.5162	Pool	Slow	2	0	2	0	0
Mukwonago 2	63	6.30	18-Jul-08	2432075.443	315230.5996	Run	Slow	3	0	3	2	0
Mukwonago 2	64	6.32	18-Jul-08	2432059.818	315122.2662	Pool	Slow	3	0	2	1	0
Mukwonago 2	65	6.34	18-Jul-08	2431958.776	315013.9329	Run	Slow	2	0	2	1	0
Mukwonago 2	66	6.38	18-Jul-08	2431877.526	314971.2246	Pool	Slow	2	0	2	1	0
Mukwonago 2	67	6.39	22-Jul-08	2431752.526	315060.8079	Run	Slow	2	2	3	1	0
Mukwonago 2	68	6.43	22-Jul-08	2431706.693	315134.7662	Pool	Slow	3	3	3	2	0
Mukwonago 2	70	6.45	22-Jul-08	2431607.735	315110.8079	Run	Moderate	3	2	3	2	1
Mukwonago 2	71	6.47	22-Jul-08	2431549.401	315124.3496	Pool	Moderate	3	2	2	2	1
Mukwonago 2	72	6.48	22-Jul-08	2431508.776	315102.4746	Run	Moderate	2	1	2	2	1
Mukwonago 2	73	6.48	22-Jul-08	2431470.235	315067.0579	Pool	Slow	3	3	2	3	1
Mukwonago 2	74	6.50	22-Jul-08	2431390.026	315155.5996	Run	Moderate	2	2	2	1	2
Mukwonago 2	75	6.52	22-Jul-08	2431324.401	315236.8496	Pool	Moderate	2	2	2	1	1
Mukwonago 2	76	6.54	22-Jul-08	2431285.86	315468.0996	Run	Moderate	3	2	3	2	1
Mukwonago 2	77	6.59	22-Jul-08	2431272.318	315533.7246	Pool	Moderate	3	2	2	2	0
Mukwonago 2	78	6.60	22-Jul-08	2431242.11	315638.9329	Run	Moderate	2	1	1	2	2
Mukwonago 2	79	6.62	22-Jul-08	2431117.11	315683.7246	Pool	Slow	2	2	2	2	2
Mukwonago 2	81	6.66	22-Jul-08	2431068.151	315547.2662	Pool	Slow	3	3	2	2	2
Mukwonago 2	82	6.68	22-Jul-08	2431018.151	315585.8079	Run	Moderate	0	0	0	0	3
Mukwonago 2	84	6.71	22-Jul-08	2431007.735	315746.2246	Pool	Moderate	3	3	2	2	3
Mukwonago 2	85	6.73	22-Jul-08	2430941.068	315773.3079	Run	Moderate	3	2	2	2	2
Mukwonago 2	86	6.75	22-Jul-08	2430819.193	315754.5579	Pool	Moderate	3	3	2	2	1
Mukwonago 2	87	6.77	22-Jul-08	2430861.901	315695.1829	Run	Moderate	3	1	2	1	1
Mukwonago 2	88	6.79	22-Jul-08	2430910.86	315608.7246	Pool	Moderate	3	3	2	2	1
Mukwonago 2	89	6.81	22-Jul-08	2430758.776	315503.5162	Pool	Moderate	3	2	2	2	1
Mukwonago 2	90	6.84	22-Jul-08	2430730.651	315424.3496	Pool	Moderate	3	3	3	2	0
Mukwonago 2	91	6.87	22-Jul-08	2430651.485	315439.9746	Run	Moderate	3	1	3	2	1
Mukwonago 2	92	6.89	22-Jul-08	2430506.693	315564.9746	Run	Moderate	3	1	2	2	1
Mukwonago 2	93	6.93	22-Jul-08	2430406.693	315581.6412	Run	Fast	2	1	2	2	1
Mukwonago 2	94	6.94	22-Jul-08	2430296.276	315609.7662	Run	Fast	2	1	1	1	2
Mukwonago 2	95	6.97	22-Jul-08	2430056.693	315610.8079	Run	Moderate	3	0	2	3	1

Table C-1 (continued)

Subwatershed and Reach	Transect Number (see Map C-1)	River Mile	Sample Date	Longitude[a]	Latitude[a]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Phantom (continued)												
Mukwonago 2	96	7.03	22-Jul-08	2429912.943	315496.2246	Pool	Moderate	3	2	0	3	1
Mukwonago 2	97	7.07	29-Jul-08	2429883.776	315661.8496	Pool	Moderate	2	1	3	3	0
Mukwonago 2	98	7.11	29-Jul-08	2429769.193	315648.3079	Run	Moderate	0	1	3	1	0
Mukwonago 2	99	7.13	29-Jul-08	2429702.526	315606.6412	Pool	Moderate	3	2	3	0	1
Mukwonago 2	100	7.14	29-Jul-08	2429663.985	315525.3912	Riffle	Fast	0	0	0	0	1
Mukwonago 2	102	7.21	29-Jul-08	2429492.11	315601.4329	Pool	Slow	3	2	2	2	1
Mukwonago 2	103	7.23	29-Jul-08	2429363.985	315370.1829	Pool	Slow	2	2	3	2	1
Mukwonago 2	105	7.30	29-Jul-08	2429321.276	315251.4329	Pool	Slow	3	3	2	1	2
Mukwonago 2	106	7.32	29-Jul-08	2429284.818	315451.4329	Run	Moderate	3	2	3	2	1
Mukwonago 2	108	7.38	29-Jul-08	2429147.318	315454.5579	Run	Moderate	3	1	3	2	1
Mukwonago 2	108.1	7.41	29-Jul-08	2429149.401	315364.9746	Pool	Moderate	3	2	3	2	1
Mukwonago 2	112	7.48	29-Jul-08	2428927.526	315377.4746	Pool	Moderate	3	2	2	2	1
Mukwonago 2	113	7.49	29-Jul-08	2428875.443	315435.8079	Run	Moderate	0	1	3	2	0
Mukwonago 2	115	7.51	29-Jul-08	2428722.318	315614.9746	Pool	Slow	3	3	3	2	1
Mukwonago 2	117	7.57	29-Jul-08	2428620.235	315706.6412	Riffle	Moderate	3	2	3	2	0
Mukwonago 2	118	7.59	29-Jul-08	2428507.735	315543.0996	Pool	Moderate	2	0	3	1	0
Mukwonago 2	119	7.63	29-Jul-08	2428428.568	315623.3079	Run	Moderate	3	2	3	2	1
Mukwonago 2	120	7.66	30-Jul-08	2428263.985	315588.9329	Pool	Moderate	3	2	2	1	1
Mukwonago 2	123	7.71	30-Jul-08	2428190.026	315536.8496	Run	Fast	0	2	3	0	0
Mukwonago 2	124	7.73	30-Jul-08	2428070.235	315581.6412	Run	Moderate	3	0	2	2	0
Mukwonago 2	126	7.80	30-Jul-08	2427927.526	315898.3079	Pool	Moderate	3	3	2	1	2
Mukwonago 2	128	7.84	30-Jul-08	2427811.901	315881.6412	Run	Moderate	3	3	3	1	0
Mukwonago 2	129	7.86	30-Jul-08	2427810.86	315971.2246	Pool	Moderate	3	2	2	2	0
Mukwonago 2	130	7.88	31-Jul-08	2427650.443	316102.4746	Run	Moderate	0	0	0	0	0
Mukwonago 2	131	7.92	31-Jul-08	2427408.776	316054.5579	Pool	Moderate	2	2	1	1	1
Mukwonago 2	132	8.04	31-Jul-08	2427249.401	316181.6412	Run	Slow	1	0	1	1	0
Mukwonago 2	133	8.08	31-Jul-08	2426958.776	315967.0579	Run	Moderate	2	1	2	2	0
Mukwonago 2	134	8.17	31-Jul-08	2426753.568	315724.3496	Run	Slow	2	1	1	1	1
Mukwonago 2	135	8.28	31-Jul-08	2427466.068	316473.3079	Pool	Slow	2	2	2	1	2
Mukwonago 2	136	7.99	31-Jul-08	2427071.276	316257.6829	Riffle	Moderate	3	2	2	2	3
Mukwonago 2	137	8.09	31-Jul-08	2426760.86	316123.3079	Run	Moderate	1	1	1	1	0
Mukwonago 2	140	8.18	31-Jul-08	2426574.401	315802.4746	Run	Moderate	2	2	2	2	0
Mukwonago 2	142	8.24	31-Jul-08	2426560.86	315681.6412	Run	Moderate	2	0	2	1	1
Mukwonago 2	144	8.37	31-Jul-08	2426490.026	315439.9746	Pool	Moderate	3	0	2	2	0
Mukwonago 2	145	8.37	31-Jul-08	2426497.318	315298.3079	Run	Fast	2	0	0	0	0
Mukwonago 2	146	8.42	06-Aug-08	2426361.901	315225.3912	Pool	Moderate	3	3	2	1	1
Mukwonago 2	147	8.44	06-Aug-08	2426441.068	315138.9329	Run	Moderate	0	3	2	2	1
Mukwonago 2	150	8.61	06-Aug-08	2426293.151	314853.5162	Pool	Moderate	3	3	1	0	2
Mukwonago 2	151	8.61	06-Aug-08	2426196.276	314753.5162	Pool	Moderate	3	3	2	1	1
Mukwonago 2	152	8.66	06-Aug-08	2426060.86	314738.9329	Run	Moderate	2	2	2	1	1
Mukwonago 2	153	8.68	06-Aug-08	2425886.901	314749.3496	Riffle	Moderate	1	1	1	1	2
Mukwonago 2	154	8.72	06-Aug-08	2425736.901	314835.8079	Run	Moderate	1	1	1	1	2
Mukwonago 2	155	8.75	06-Aug-08	2425510.86	315228.5162	Run	Moderate	2	2	2	2	1
Mukwonago 2	156	8.86	06-Aug-08	2425382.735	315419.1412	Pool	Moderate	1	2	1	1	1
Mukwonago 2	157	8.91	06-Aug-08	2425249.401	315321.2246	Riffle	Moderate	1	1	2	1	1
Mukwonago 2	159	8.95	06-Aug-08	2425212.943	315259.7662	Pool	Moderate	1	0	1	1	1

Table C-1 (continued)

Subwatershed and Reach	Transect Number (see Map C-1)	River Mile	Sample Date	Longitude[a]	Latitude[a]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Phantom (continued)												
Mukwonago 2	161	9.03	06-Aug-08	2425118.151	315357.6829	Pool	Moderate	2	1	2	2	2
Mukwonago 2	162	9.04	06-Aug-08	2424916.068	315405.5996	Run	Moderate	1	1	2	1	2
Mukwonago 2	163	9.08	06-Aug-08	2424802.526	315359.7662	Riffle	Moderate	2	2	1	1	3
Mukwonago 2	164	9.12	06-Aug-08	2424648.36	315369.1412	Pool	Moderate	2	1	2	2	1
Mukwonago 2	166	9.15	06-Aug-08	2424577.526	315466.0162	Pool	Moderate	2	2	1	2	1
Mukwonago 2	167	9.19	06-Aug-08	2424450.443	315670.1829	Run	Moderate	2	2	2	2	1
Mukwonago 2	168	9.23	06-Aug-08	2424319.193	315784.7662	Pool	Moderate	3	2	1	3	1
Mukwonago 2	169	9.28	06-Aug-08	2424212.943	315859.7662	Pool	Fast	2	1	1	2	1
Mukwonago 2	170	9.31	07-Aug-08	2424088.985	315749.3496	Pool	Moderate	3	2	2	2	1
Mukwonago 2	171	9.34	07-Aug-08	2423943.151	315808.7246	Riffle	Moderate	3	2	3	3	0
Mukwonago 2	173	9.42	07-Aug-08	2423597.318	315894.1412	Pool	Moderate	2	2	2	2	1
Mukwonago 2	174	9.45	07-Aug-08	2423451.485	315924.3496	Run	Moderate	3	3	1	2	2
Mukwonago 2	175	9.48	07-Aug-08	2423234.818	315955.5996	Riffle	Moderate	1	1	1	1	0
Mukwonago 2	178	9.54	07-Aug-08	2423127.526	315891.0162	Riffle	Moderate	1	1	1	1	0
Mukwonago 2	180	9.59	07-Aug-08	2423034.818	315762.8912	Pool	Slow	2	1	2	1	1
Mukwonago 2	181	9.61	07-Aug-08	2423017.11	315639.9746	Riffle	Slow	1	0	2	1	0
Mukwonago 2	182	9.63	07-Aug-08	2422957.735	315479.5579	Pool	Slow	2	1	2	1	1
Mukwonago 2	183	9.66	07-Aug-08	2422949.401	315323.3079	Riffle	Moderate	2	1	2	1	1
Mukwonago 2	186	9.79	07-Aug-08	2422400.443	315008.7246	Run	Moderate	0	1	2	1	0
Mukwonago 2	187	9.84	07-Aug-08	2422296.276	315018.0996	Riffle	Moderate	1	0	1	0	0
Mukwonago 2	188	9.86	07-Aug-08	2422211.901	314978.5162	Pool	Moderate	1	0	1	1	0
Mukwonago 2	190	9.89	07-Aug-08	2422126.485	315160.8079	Riffle	Moderate	1	0	2	0	0
Mukwonago 2	191	9.93	08-Aug-08	2422054.61	315274.3496	Pool	Moderate	1	1	1	1	0
Mukwonago 2	193	9.96	08-Aug-08	2421934.818	315189.9746	Riffle	Fast	1	0	1	1	0
Mukwonago 2	194	9.98	08-Aug-08	2421834.818	314993.0996	Pool	Moderate	1	1	2	1	1
Mukwonago 2	195.1	10.04	08-Aug-08	2421631.693	314946.2246	Pool	Slow	1	2	2	1	0
Mukwonago 2	197	10.07	08-Aug-08	2421602.526	314813.9329	Run	Moderate	2	1	3	2	0
Mukwonago 2	200	10.09	08-Aug-08	2421578.568	314688.9329	Riffle	Moderate	2	0	2	1	0
Mukwonago 2	201	10.12	08-Aug-08	2421523.36	314652.4746	Pool	Moderate	2	1	2	2	0
Mukwonago 2	202	10.14	08-Aug-08	2421483.776	314646.2246	Pool	Moderate	2	1	1	2	0
Mukwonago 2	204	10.15	08-Aug-08	2421425.443	314561.8496	Pool	Moderate	2	1	2	2	0
Mukwonago 2	205	10.18	08-Aug-08	2421400.443	314607.6829	Run	Moderate	2	1	2	2	0
Mukwonago 2	207	10.20	08-Aug-08	2421223.36	314717.0579	Riffle	Moderate	2	0	2	0	0
Mukwonago 2	208	10.23	08-Aug-08	2421109.818	314603.5162	Pool	Slow	2	0	3	2	1
Mukwonago 2	210	10.28	08-Aug-08	2420980.651	314628.5162	Run	Slow	3	3	2	0	2
Mukwonago 2	213	10.37	08-Aug-08	2420705.651	314672.2662	Riffle	Moderate	2	2	1	0	1
Mukwonago 2	215	10.44	08-Aug-08	2420431.693	314771.2246	Riffle	Moderate	2	3	2	1	2
Mukwonago 2	216	10.46	08-Aug-08	2420346.276	314844.1412	Pool	Slow	2	1	2	1	0
Mukwonago 2	218	10.49	08-Aug-08	2420319.193	314951.4329	Riffle	Moderate	0	3	1	1	2
Mukwonago 2	220	10.51	08-Aug-08	2420365.026	315016.0162	Pool	Fast	3	3	1	1	2
Mukwonago 2	223	10.54	08-Aug-08	2420360.86	315198.3079	Run	Moderate	1	1	1	1	2
Mukwonago 2	224	10.58	08-Aug-08	2420223.36	315259.7662	Riffle	Moderate	3	3	1	1	2
Mukwonago 2	225	10.60	08-Aug-08	2420187.943	315366.0162	Run	Moderate	1	2	1	0	3
Mukwonago 2	226	10.63	11-Aug-08	2420126.485	315493.0996	Riffle	Fast	2	1	1	1	2
Mukwonago 2	227	10.65	11-Aug-08	2420110.86	315577.4746	Riffle	Fast	2	3	0	0	3
Mukwonago 2	228	10.66	11-Aug-08	2420144.193	315623.3079	Pool	Fast	2	2	1	1	2

Table C-1 (continued)

Subwatershed and Reach	Transect Number (see Map C-1)	River Mile	Sample Date	Longitude[a]	Latitude[a]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Phantom (continued)												
Mukwonago 2	230	10.67	11-Aug-08	2420195.235	315597.2662	Pool	Moderate	2	1	1	1	2
Mukwonago 2	232	10.70	11-Aug-08	2420216.068	315678.5162	Pool	Moderate	3	3	1	1	3
Mukwonago 2	233	10.70	11-Aug-08	2420190.026	315691.0162	Pool	Moderate	3	3	1	1	3
Mukwonago 2	234	10.72	11-Aug-08	2420188.985	315735.8079	Run	Moderate	2	2	1	1	3
Mukwonago 2	236	10.73	11-Aug-08	2420207.735	315782.6829	Pool	Fast	2	2	1	1	3
Mukwonago 2	237	10.74	11-Aug-08	2420240.026	315846.2246	Pool	Moderate	1	2	1	1	3
Mukwonago 2	239	10.79	11-Aug-08	2420262.943	316094.1412	Run	Fast	3	3	1	1	3
Mukwonago 2	241	10.82	11-Aug-08	2420143.151	316179.5579	Riffle	Fast	1	1	1	1	3
Mukwonago 2	243	10.85	11-Aug-08	2419988.985	316180.5996	Riffle	Fast	1	2	0	1	3
Mukwonago 2	244	10.87	11-Aug-08	2419939.332	316138.2385	Riffle	Fast	1	1	0	1	3
Mukwonago 2	245	10.91	11-Aug-08	2419757.735	316021.2246	Run	Moderate	2	0	2	1	3
Eagle Spring												
Mukwonago 3	246	12.07	11-Aug-08	2416122.318	311763.9329	Run	Slow	2	0	2	1	0
Mukwonago 3	247	12.12	11-Aug-08	2416051.485	311525.3912	Run	Slow	2	0	2	1	0
Mukwonago 3	248	12.17	11-Aug-08	2415937.943	311268.0996	Run	Slow	2	0	2	1	0
Mukwonago 3	249	12.24	11-Aug-08	2415905.651	310925.3912	Run	Slow	2	0	2	1	0
Mukwonago 3	250	12.32	11-Aug-08	2415769.193	310560.8079	Run	Slow	2	0	2	1	0
Mukwonago 3	251	12.38	11-Aug-08	2415698.36	310280.5996	Run	Slow	2	0	2	1	0
Mukwonago 3	252	12.41	11-Aug-08	2415635.86	310132.6829	Run	Slow	2	0	2	1	0
Mukwonago 3	253	12.47	11-Aug-08	2415651.485	309776.4329	Run	Slow	2	0	2	1	0
Mukwonago 3	254	12.57	11-Aug-08	2415579.61	309298.3079	Run	Slow	2	0	0	1	0
Mukwonago 3	255	12.62	11-Aug-08	2415537.943	309064.9746	Run	Slow	2	0	2	1	0
Mukwonago 3	256	12.64	11-Aug-08	2415590.026	308929.5579	Run	Slow	2	0	2	1	0
Mukwonago 3	257	13.08	12-Aug-08	2414858.776	307164.9746	Run	Slow	1	0	0	0	0
Mukwonago 3	258	13.11	12-Aug-08	2414831.693	307120.1829	Run	Slow	1	0	1	0	0
Mukwonago 3	259	13.14	12-Aug-08	2414727.526	307006.6412	Pool	Slow	3	0	2	2	0
Mukwonago 3	260	13.17	12-Aug-08	2414783.776	306855.5996	Pool	Slow	1	0	1	1	0
Mukwonago 3	262	13.19	12-Aug-08	2414743.151	306764.9746	Pool	Moderate	2	0	2	1	0
Mukwonago 3	265	13.24	12-Aug-08	2414538.985	306731.6412	Run	Slow	2	0	2	2	0
Mukwonago 3	267	13.31	12-Aug-08	2414295.235	306717.0579	Pool	Slow	1	0	1	1	0
Mukwonago 3	270	13.35	12-Aug-08	2414148.36	306664.9746	Run	Slow	1	0	1	1	0
Mukwonago 3	272	13.40	12-Aug-08	2413973.36	306592.0579	Run	Slow	1	0	1	1	0
Mukwonago 3	273	13.41	12-Aug-08	2413920.235	306576.4329	Riffle	Fast	1	0	0	1	0
Mukwonago 3	274	13.43	12-Aug-08	2413826.485	306627.4746	Run	Slow	2	0	2	1	0
Mukwonago 3	275	13.46	12-Aug-08	2413646.276	306571.2246	Pool	Slow	2	0	2	1	0
Mukwonago 3	277	13.50	12-Aug-08	2413476.485	306562.8912	Pool	Slow	2	0	3	2	0
Mukwonago 3	279	13.57	12-Aug-08	2413248.36	306397.2662	Pool	Slow	2	0	2	1	0
Mukwonago 3	281	13.64	12-Aug-08	2413087.943	306425.3912	Run	Slow	3	0	3	1	0
Mukwonago 3	282	13.71	12-Aug-08	2412795.235	306264.9746	Pool	Slow	3	0	3	2	0
Mukwonago 3	284	13.74	12-Aug-08	2412731.693	306464.9746	Run	Slow	2	0	2	1	0
Mukwonago 3	286	13.78	12-Aug-08	2412631.693	306401.4329	Pool	Slow	2	0	3	1	0
Mukwonago 3	288	13.85	12-Aug-08	2412375.443	306326.4329	Run	Slow	3	0	3	2	0
Mukwonago 3	290	13.90	12-Aug-08	2412278.568	306548.3079	Pool	Slow	2	0	2	1	0
Mukwonago 3	293	13.98	12-Aug-08	2412040.026	306579.5579	Pool	Slow	3	0	3	2	0
Mukwonago 3	294	14.02	12-Aug-08	2411888.985	306499.3496	Run	Slow	2	0	2	2	0
Mukwonago 3	296	14.09	12-Aug-08	2411601.485	306578.5162	Run	Slow	3	0	3	1	0

Table C-1 (continued)

Subwatershed and Reach	Transect Number (see Map C-1)	River Mile	Sample Date	Longitude[a]	Latitude[a]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Eagle Spring (continued)												
Mukwonago 3	300	14.19	12-Aug-08	2411316.068	306911.8496	Pool	Slow	2	0	2	2	0
Mukwonago 3	303	14.25	12-Aug-08	2411062.943	307049.3496	Run	Slow	2	0	2	2	0
Mukwonago 3	304	14.29	12-Aug-08	2410788.985	307279.5579	Run	Slow	2	0	3	2	0
Mukwonago 3	307	14.44	12-Aug-08	2410396.276	307432.6829	Run	Slow	2	1	2	2	0
Beulah												
Beulah	400	0.03	18-Jul-08	2431694.54	314936.1551	Run	Slow	2	0	2	1	0
Beulah	401	0.05	18-Jul-08	2431592.457	314914.2801	Pool	Slow	2	0	2	1	0
Beulah	407	0.21	18-Jul-08	2431375.79	314179.9051	Run	Slow	3	1	3	2	0
Beulah	409	0.30	18-Jul-08	2431520.582	313840.3218	Pool	Slow	2	0	3	2	0
Beulah	411	0.41	18-Jul-08	2431816.415	313533.0301	Run	Slow	3	1	3	2	0
Beulah	412	0.46	21-Jul-08	2431947.665	313417.4051	Run	Slow	3	0	3	2	0
Beulah	413	0.55	21-Jul-08	2432380.999	313240.3218	Pool	Slow	3	1	3	2	0
Beulah	414	0.57	21-Jul-08	2432407.04	313092.4051	Pool	Slow	3	2	3	2	0
Beulah	416	0.63	21-Jul-08	2432662.249	312920.5301	Run	Slow	3	2	2	2	0
Beulah	417	0.70	21-Jul-08	2432950.79	312715.3218	Run	Slow	3	0	2	2	0
Beulah	419	0.78	21-Jul-08	2433267.457	312473.6551	Run	Slow	2	2	2	1	0
Beulah	420	0.82	21-Jul-08	2433424.749	312303.8635	Run	Slow	3	2	2	2	0
Beulah	421	0.87	21-Jul-08	2433576.832	312108.0301	Run	Slow	0	1	3	2	0
Beulah	423	0.95	21-Jul-08	2433797.665	311786.1551	Pool	Slow	3	1	3	2	0
Beulah	424	0.97	21-Jul-08	2433814.332	311677.8218	Run	Slow	0	0	2	1	0
Beulah	426	1.02	21-Jul-08	2433924.749	311424.6968	Pool	Slow	3	1	3	1	0
Beulah	427	1.03	21-Jul-08	2433922.665	311372.6135	Riffle	Slow	1	0	1	1	0
Beulah	428	1.05	21-Jul-08	2433946.624	311284.0718	Run	Slow	2	2	2	1	0
Beulah	429	1.08	21-Jul-08	2433968.499	311124.6968	Run	Slow	2	1	2	1	0
Beulah	430	1.16	21-Jul-08	2434022.665	310711.1551	Run	Slow	2	2	0	1	1
Beulah	431	1.21	21-Jul-08	2434030.999	310458.0301	Run	Slow	2	2	2	0	1
Beulah	432	1.25	21-Jul-08	2433985.165	310259.0718	Run	Moderate	2	2	2	1	1
Beulah	433	1.30	21-Jul-08	2433893.499	310006.9885	Run	Moderate	2	2	2	1	0
Beulah	434	1.34	21-Jul-08	2433779.957	309810.1135	Run	Fast	2	2	1	1	2
Jericho												
Jericho 1	500	0.00	12-May-08	2419904.957	316137.1968	Pool	Slow	3	0	0	0	3
Jericho 1	502	0.02	12-May-08	2419890.374	316174.6968	Run	Moderate	3	0	0	0	3
Jericho 1	504	0.07	12-May-08	2419878.915	316353.8635	Pool	Moderate	3	2	0	0	3
Jericho 1	506	0.08	12-May-08	2419917.457	316369.4885	Riffle	Fast	3	1	0	0	3
Jericho 1	508	0.10	12-May-08	2419935.165	316403.8635	Pool	Slow	3	3	0	0	3
Jericho 1	509	0.12	12-May-08	2419949.749	316451.7801	Riffle	Moderate	1	2	0	0	3
Jericho 1	511	0.16	12-May-08	2420108.082	316546.5718	Riffle	Fast	1	0	0	1	3
Jericho 1	512	0.17	12-May-08	2420109.124	316597.6135	Pool	Fast	0	1	0	0	2
Jericho 1	513	0.19	12-May-08	2420188.29	316667.4051	Riffle	Fast	1	0	0	2	2
Jericho 1	514	0.19	12-May-08	2420190.374	316692.4051	Pool	Fast	2	1	0	0	3
Jericho 1	515	0.24	12-May-08	2420291.415	316858.0301	Pool	Fast	1	1	0	2	1
Jericho 1	516	0.25	12-May-08	2420289.332	316897.6135	Riffle	Fast	1	0	0	2	1
Jericho 1	517	0.30	12-May-08	2420177.874	317166.3635	Riffle	Fast	1	2	0	0	3
Jericho 1	518	0.34	12-May-08	2420124.749	317337.1968	Riffle	Fast	0	0	0	0	3
Jericho 1	519	0.35	12-May-08	2420122.665	317396.5718	Pool	Moderate	1	1	0	0	3

Table C-1 (continued)

Subwatershed and Reach	Transect Number (see Map C-1)	River Mile	Sample Date	Longitude[a]	Latitude[a]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Jericho (continued)												
Jericho 1	520	0.42	12-May-08	2419937.249	317675.7385	Riffle	Fast	1	1	0	0	3
Jericho 1	523	0.48	14-May-08	2419818.499	317902.8218	Run	Moderate	1	0	0	1	1
Jericho 1	524	0.50	12-May-08	2419826.832	318035.1135	Riffle	Fast	0	1	0	0	0
Jericho 1	525	0.54	14-May-08	2419799.749	318202.8218	Pool	Moderate	1	0	2	0	2
Jericho 1	526	0.55	14-May-08	2419792.457	318292.4051	Riffle	Fast	2	2	0	2	3
Jericho 1	527	0.60	14-May-08	2419911.207	318486.1551	Riffle	Fast	2	2	0	2	3
Jericho 1	528	0.63	14-May-08	2420012.249	318608.0301	Pool	Moderate	3	3	0	0	3
Jericho 1	530	0.67	14-May-08	2420133.082	318760.1135	Pool	Moderate	0	1	0	0	2
Jericho 1	531	0.69	14-May-08	2420252.874	318772.6135	Riffle	Fast	2	2	0	0	3
Jericho 1	533	0.74	14-May-08	2420408.082	318859.0718	Run	Moderate	2	2	0	1	3
Jericho 1	535	0.77	14-May-08	2420294.54	318959.0718	Run	Moderate	2	2	0	1	3
Jericho 1	537	0.80	14-May-08	2420325.79	319063.2385	Pool	Moderate	1	2	0	0	2
Jericho 1	539	0.82	14-May-08	2420392.457	319169.4885	Riffle	Fast	1	2	0	2	2
Jericho 1	542	0.86	14-May-08	2420526.832	319289.2801	Run	Moderate	2	2	0	2	3
Jericho 1	544	0.90	14-May-08	2420468.499	319466.3635	Run	Slow	2	3	0	0	2
Jericho 1	546	0.95	14-May-08	2420300.79	319543.4468	Pool	Slow	2	2	0	0	3
Jericho 1	547	0.97	14-May-08	2420313.29	319648.6551	Run	Moderate	2	2	0	0	3
Jericho 1	550	1.01	14-May-08	2420438.29	319824.6968	Pool	Moderate	2	2	0	0	3
Jericho 1	552	1.06	14-May-08	2420539.332	319914.2801	Riffle	Moderate	1	3	2	0	1
Jericho 1	555	1.11	14-May-08	2420652.874	320031.9885	Riffle	Slow	2	3	0	0	3
Jericho 1	556	1.16	14-May-08	2420658.082	320156.9885	Pool	Moderate	2	2	0	0	3
Jericho 1	557	1.20	14-May-08	2420728.915	320302.8218	Pool	Moderate	2	3	0	0	3
Jericho 1	559	1.23	14-May-08	2420810.165	320419.4885	Riffle	Fast	3	2	0	0	3
Jericho 1	560	1.26	14-May-08	2420821.624	320575.7385	Run	Moderate	1	2	0	0	1
Jericho 1	562	1.27	15-May-08	2420836.207	320629.9051	Pool	Moderate	3	2	0	0	3
Jericho 1	563	1.31	15-May-08	2420802.874	320837.1968	Riffle	Fast	2	1	0	3	0
Jericho 1	566	1.35	15-May-08	2420839.332	320998.6551	Riffle	Fast	2	3	0	1	3
Jericho 1	570	1.39	15-May-08	2420859.124	321187.1968	Run	Moderate	2	1	1	1	1
Jericho 1	571	1.42	15-May-08	2420924.749	321329.9051	Run	Moderate	3	0	0	1	2
Jericho 1	573	1.46	15-May-08	2420926.832	321477.8218	Pool	Moderate	2	1	0	0	3
Jericho 1	575	1.49	15-May-08	2420965.374	321635.1135	Riffle	Fast	3	2	0	3	3
Jericho 1	577	1.54	15-May-08	2421034.124	321911.1551	Run	Moderate	2	2	0	1	3
Jericho 1	578	1.58	19-May-08	2421130.999	322058.0301	Pool	Moderate	2	1	0	2	2
Jericho 1	579	1.59	19-May-08	2421177.874	322096.5718	Riffle	Fast	2	2	0	1	3
Jericho 1	580	1.61	19-May-08	2421230.999	322189.2801	Riffle	Fast	2	2	0	0	3
Jericho 1	583	1.74	19-May-08	2421382.04	322751.7801	Run	Moderate	2	1	0	2	3
Jericho 1	584	1.76	19-May-08	2421322.665	322898.6551	Pool	Slow	1	0	0	0	0
Jericho 1	586	1.80	19-May-08	2421290.374	323017.4051	Riffle	Fast	2	2	0	1	3
Jericho 1	590	1.85	19-May-08	2421237.249	323268.4468	Riffle	Fast	2	2	0	0	3
Jericho 1	592	1.88	19-May-08	2421293.499	323354.9051	Run	Moderate	2	1	0	2	3
Jericho 1	594	1.90	19-May-08	2421363.29	323465.3218	Run	Moderate	1	0	0	2	1
Jericho 1	595	1.93	20-May-08	2421305.999	323546.5718	Pool	Moderate	2	3	0	1	3
Jericho 1	596	1.96	20-May-08	2421372.665	323689.2801	Riffle	Fast	2	1	2	2	2
Jericho 1	597	1.98	20-May-08	2421428.915	323831.9885	Riffle	Fast	2	1	1	3	2
Jericho 1	598	2.01	20-May-08	2421539.332	323916.3635	Pool	Slow	1	2	2	0	1

Table C-1 (continued)

Subwatershed and Reach	Transect Number (see Map C-1)	River Mile	Sample Date	Longitude[a]	Latitude[a]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Jericho (continued)												
Jericho 1	600	2.07	20-May-08	2421699.749	324135.1135	Riffle	Fast	3	3	0	2	3
Jericho 1	604	2.25	03-Jul-08	2422387.249	324727.8218	Run	Fast	3	3	0	0	3
Jericho 1	605	2.26	03-Jul-08	2422414.332	324800.7385	Riffle	Fast	1	2	0	0	3
Jericho 1	606	2.28	03-Jul-08	2422480.999	324880.9468	Riffle	Fast	3	3	0	1	3
Jericho 2	607	2.52	23-May-08	2422651.832	326026.7801	Run	Moderate	2	1	0	1	3
Jericho 2	608	2.55	23-May-08	2422588.29	326145.5301	Run	Fast	2	1	0	1	3
Jericho 2	609	2.57	23-May-08	2422544.54	326227.8218	Riffle	Fast	2	2	0	2	2
Jericho 2	611	2.59	23-May-08	2422487.249	326324.6968	Pool	Moderate	1	1	0	2	2
Jericho 2	612	2.62	22-May-08	2422397.665	326491.3635	Pool	Moderate	2	2	0	1	1
Jericho 2	613	2.65	22-May-08	2422293.499	326611.1551	Run	Fast	1	1	0	1	3
Jericho 2	614	2.67	17-Jun-08	2422279.957	326714.2801	Riffle	Fast	2	2	0	0	3
Jericho 2	616	2.70	17-Jun-08	2422272.665	326848.6551	Riffle	Fast	2	2	0	1	3
Jericho 2	619	2.74	17-Jun-08	2422254.957	327055.9468	Run	Fast	2	2	0	1	2
Jericho 2	621	2.79	17-Jun-08	2422178.915	327285.1135	Run	Moderate	3	3	1	1	3
Jericho 2	622	2.83	17-Jun-08	2422096.624	327491.3635	Pool	Moderate	1	1	0	1	3
Jericho 2	623	2.84	17-Jun-08	2422068.499	327555.9468	Riffle	Fast	1	2	0	1	2
Jericho 2	624	2.87	17-Jun-08	2422014.332	327685.1135	Pool	Moderate	3	3	0	0	3
Jericho 2	625	2.90	17-Jun-08	2421946.624	327851.7801	Pool	Moderate	2	1	0	2	3
Jericho 2	626	2.95	17-Jun-08	2421833.082	328110.1135	Run	Moderate	2	2	0	0	2
Jericho 2	628	2.98	17-Jun-08	2421779.957	328249.6968	Run	Moderate	3	3	0	0	3
Jericho 2	631	3.04	17-Jun-08	2421667.457	328508.0301	Riffle	Fast	3	3	0	0	3
Jericho 2	634	3.08	17-Jun-08	2421578.915	328718.4468	Pool	Moderate	2	2	0	0	0
Jericho 2	635	3.17	17-Jun-08	2421465.374	328929.9051	Pool	Moderate	1	1	0	0	0
Jericho 2	638	3.20	19-Jun-08	2421379.957	329088.2385	Run	Moderate	2	3	0	0	0
Jericho 2	640	3.22	19-Jun-08	2421365.374	329160.1135	Pool	Moderate	2	2	0	0	0
Jericho 2	641	3.26	19-Jun-08	2421310.165	329288.2385	Pool	Moderate	3	3	0	0	0
Jericho 2	644	3.32	19-Jun-08	2421211.207	329502.8218	Pool	Moderate	2	3	0	0	0
Jericho 2	645	3.35	19-Jun-08	2421165.374	329615.3218	Run	Slow	1	1	1	0	0
Jericho 2	648	3.39	19-Jun-08	2421220.582	329748.6551	Pool	Moderate	1	0	2	0	0
Jericho 2	650	3.41	19-Jun-08	2421246.624	329851.7801	Pool	Moderate	1	1	1	0	0
Jericho 2	652	3.45	19-Jun-08	2421188.29	329966.3635	Run	Moderate	1	3	1	0	0
Jericho 2	653	3.46	23-Jun-08	2421155.999	330003.8635	Pool	Slow	0	2	0	0	0
Jericho 2	656	3.52	23-Jun-08	2421223.707	330244.4885	Run	Moderate	2	2	0	0	0
Jericho 2	657	3.57	23-Jun-08	2421233.082	330425.7385	Riffle	Moderate	3	3	0	0	0
Jericho 2	658	3.63	23-Jun-08	2421226.832	330624.6968	Run	Moderate	2	2	0	0	0
Jericho 2	659	3.66	23-Jun-08	2421224.749	330831.9885	Run	Moderate	2	1	2	0	0
Jericho 2	660	3.71	25-Jun-08	2421165.374	330945.5301	Run	Moderate	0	1	3	0	0
Jericho 2	661	3.74	25-Jun-08	2421130.999	331083.0301	Run	Slow	2	2	3	0	0
Jericho 2	662	3.77	25-Jun-08	2421101.832	331190.3218	Riffle	Moderate	1	1	1	0	0
Jericho 2	663	3.79	25-Jun-08	2421042.457	331268.4468	Pool	Moderate	1	1	0	0	0
Jericho 2	665	3.81	25-Jun-08	2421000.79	331384.0718	Run	Moderate	2	2	0	0	2
Jericho 2	666	3.86	25-Jun-08	2420833.082	331516.3635	Pool	Slow	2	2	1	0	0
Jericho 2	670	3.91	25-Jun-08	2420855.999	331749.6968	Pool	Moderate	2	1	2	0	0
Jericho 2	671	3.94	25-Jun-08	2420863.29	331901.7801	Run	Moderate	2	2	2	0	0
Jericho 2	672	3.99	25-Jun-08	2420878.915	332104.9051	Riffle	Fast	2	1	2	0	0
Jericho 2	674	4.02	25-Jun-08	2420974.749	332225.7385	Pool	Moderate	2	2	2	0	0
Jericho 2	678	4.08	25-Jun-08	2420961.207	332396.5718	Pool	Moderate	2	1	2	0	0

Table C-1 (continued)

Subwatershed and Reach	Transect Number (see Map C-1)	River Mile	Sample Date	Longitude[a]	Latitude[a]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Jericho (continued)												
Jericho 2	681	4.13	25-Jun-08	2421028.915	332516.3635	Run	Moderate	1	1	0	1	0
Jericho 2	684	4.16	25-Jun-08	2420924.749	332580.9468	Pool	Moderate	2	0	0	0	0
Jericho 2	685	4.17	25-Jun-08	2420924.749	332642.4051	Run	Moderate	2	1	0	0	0
Jericho 2	686	4.23	25-Jun-08	2420968.499	332919.4885	Run	Moderate	2	0	0	0	0
Jericho 2	689	4.28	25-Jun-08	2421048.707	333175.7385	Run	Moderate	1	0	0	0	0
Jericho 2	690	4.32	25-Jun-08	2421122.665	333344.4885	Riffle	Fast	1	0	0	0	0
Jericho 2	691	4.40	26-Jun-08	2421236.207	333572.6135	Run	Moderate	1	0	0	0	0
Jericho 2	691	4.33	25-Jun-08	2421212.249	333342.4051	Run	Moderate	2	0	0	0	0
Jericho 2	692	4.46	26-Jun-08	2421259.124	333779.9051	Run	Moderate	2	0	2	0	0
Jericho 2	694	4.53	26-Jun-08	2421509.124	333898.6551	Pool	Moderate	2	0	2	0	0
Jericho 2	695	4.56	26-Jun-08	2421512.249	334036.1551	Pool	Fast	1	0	1	0	0
Jericho 2	696	4.61	26-Jun-08	2421467.457	334228.8635	Run	Fast	2	0	1	2	0
Jericho 2	698	4.69	26-Jun-08	2421557.04	334652.8218	Run	Moderate	2	1	3	1	0
Jericho 2	700	4.79	26-Jun-08	2421540.374	335134.0718	Run	Moderate	1	2	0	1	0
Jericho 2	701	4.86	26-Jun-08	2421565.374	335425.7385	Run	Moderate	3	2	3	0	0
Jericho 2	703	4.90	26-Jun-08	2421616.415	335576.7801	Pool	Moderate	1	0	0	0	0
Jericho 2	705	5.05	27-Jun-08	2421717.457	336135.1135	Run	Moderate	2	1	0	0	0
Jericho 2	706	5.08	27-Jun-08	2421733.082	336289.2801	Pool	Moderate	2	0	0	0	0
Jericho 2	707	5.10	27-Jun-08	2421773.707	336413.2385	Riffle	Moderate	1	0	1	0	0
Jericho 2	709	5.13	27-Jun-08	2421832.04	336529.9051	Pool	Moderate	2	2	2	0	1
Jericho 2	710	5.15	27-Jun-08	2421852.874	336624.6968	Pool	Moderate	1	0	1	0	0
Jericho 2	711	5.16	27-Jun-08	2421859.124	336686.1551	Riffle	Moderate	2	1	0	0	0
Jericho 2	713	5.20	27-Jun-08	2421870.582	336840.3218	Pool	Moderate	2	1	1	2	0
Jericho 2	715	5.23	27-Jun-08	2421901.832	336944.4885	Riffle	Fast	1	0	1	0	0
Jericho 2	716.1	5.27	27-Jun-08	2421966.415	337092.4051	Pool	Moderate	2	0	1	0	0
Jericho 2	718	5.29	27-Jun-08	2422014.332	337191.3635	Run	Moderate	2	2	3	1	1
Jericho 2	719	5.32	27-Jun-08	2422001.832	337333.0301	Pool	Moderate	2	2	2	0	0
Jericho 2	721	5.35	27-Jun-08	2422035.165	337455.9468	Pool	Slow	2	2	1	0	0
Jericho 2	722	5.38	01-Jul-08	2422068.499	337616.3635	Run	Slow	2	1	3	0	0
Jericho 2	723	5.42	01-Jul-08	2422141.415	337774.6968	Pool	Slow	2	2	2	0	0
Jericho 2	723	5.44	01-Jul-08	2422171.624	337916.3635	Riffle	Moderate	0	0	0	0	0
Jericho 2	724	5.45	01-Jul-08	2422172.665	337976.7801	Riffle	Moderate	3	0	3	0	0
Jericho 2	725	5.48	01-Jul-08	2422203.915	338080.9468	Pool	Moderate	2	0	3	0	0
Jericho 2	726	5.51	01-Jul-08	2422243.499	338271.5718	Pool	Moderate	2	1	1	2	0
Jericho 2	727	5.53	01-Jul-08	2422264.332	338375.7385	Run	Moderate	2	1	3	2	0
Jericho 2	728	5.57	01-Jul-08	2422294.54	338531.9885	Riffle	Fast	1	0	0	1	3
Jericho 2	729	5.62	01-Jul-08	2422309.124	338763.2385	Riffle	Fast	2	2	1	1	3
Jericho 2	730	5.84	01-Jul-08	2422813.29	339735.1135	Run	Slow	3	0	3	3	0
Jericho 2	731	5.88	01-Jul-08	2422859.124	339971.5718	Run	Slow	2	0	2	0	1
Jericho 2	732	5.97	01-Jul-08	2422904.957	340426.7801	Pool	Slow	2	0	1	2	0
Jericho 2	733	6.03	01-Jul-08	2422902.874	340763.2385	Pool	Slow	3	3	3	2	0
Jericho 2	734	6.07	01-Jul-08	2422899.749	340963.2385	Run	Slow	0	0	0	0	0
Jericho 2	735	6.18	01-Jul-08	2422922.665	341481.9885	Run	Slow	2	2	1	1	0
Jericho 2	736	6.21	01-Jul-08	2423058.082	341598.6551	Run	Slow	3	3	3	3	0
Jericho 2	737	6.25	01-Jul-08	2423093.499	341790.3218	Run	Slow	2	2	1	0	3
Jericho 2	738	6.27	01-Jul-08	2423085.165	341909.0718	Run	Slow	2	0	0	2	3
Jericho 2	739	6.28	03-Jul-08	2423087.249	341947.6135	Pool	Slow	2	2	0	0	3

Table C-1 (continued)

Subwatershed and Reach	Transect Number (see Map C-1)	River Mile	Sample Date	Longitude[a]	Latitude[a]	Habitat Type	Water Velocity	Amount of Cover (rank)	Woody Debris (rank)	Macrophytes (rank)	Algae (rank)	Shading (rank)
Jericho (continued)												
Jericho 2	740	6.30	03-Jul-08	2423079.957	342038.2385	Riffle	Moderate	2	2	0	0	3
Jericho 2	741	6.33	03-Jul-08	2423074.749	342228.8635	Run	Moderate	3	3	0	0	3
Jericho 2	742	6.37	03-Jul-08	2423069.54	342427.8218	Run	Slow	3	3	0	2	2
Jericho 2	743	6.39	03-Jul-08	2423066.415	342525.7385	Run	Moderate	2	1	1	2	0
Jericho 2	744	6.42	03-Jul-08	2423058.082	342701.7801	Run	Moderate	3	0	3	2	0
Jericho 2	745	6.46	03-Jul-08	2423047.665	342923.6551	Run	Slow	2	2	3	2	0

NOTE: Instream cover variable rank numbers are defined as follows: 0 = none or nearly absent (< 5.0 percent), 1 = low abundance (5 to 25 percent), 2 = moderate abundance (25 to 75 percent), and 4 = high abundance (greater than 75 percent).

[a]*These coordinates are in North American Datum (NAD) 1927 State Plane Wisconsin South Federal Information Processing Standard (FIPS) 4803.*

Source: SEWRPC.

Table C-2

CROSS-SECTION LOCATION AND STREAMBANK CHARACTERISTICS WITHIN THE MUKWONAGO RIVER WATERSHED: 2008

Watershed and Reach	Transect Number (see Map C-1)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (inches)	Length (feet)	Height (feet)	Slope	Undercut (inches)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Mukwonago																	
Mukwonago 1	1	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	2	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	3	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	4	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	5	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	6	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	7	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	8	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	9	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	10	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	11	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	12	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	13	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	14	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	15	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	16	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	17	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	18	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	19	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	20	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	21	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	22	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	23	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	24	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	25	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	26	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	27	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	28	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	29	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	30	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	31	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 1	32	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Phantom																	
Mukwonago 2	33	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	34	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	35	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	36	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	37	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	38	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	39	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	40	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	41	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	42	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	43	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	44	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	45	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -

Table C-2 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (inches)	Length (feet)	Height (feet)	Slope	Undercut (inches)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Phantom (continued)																	
Mukwonago 2	46	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	47	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	48	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	49	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	50	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	51	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	52	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	53	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	54	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	55	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	56	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	57	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	58	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	59	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	60	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	61	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	62	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	63	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	64	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	65	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	66	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	67	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	68	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	70	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	71	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	72	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	73	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	74	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	75	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	76	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	77	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	78	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	79	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	81	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	82	- -	- -	- -	6	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	84	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	85	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	86	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	87	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	88	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	89	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	90	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	91	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	92	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	93	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	94	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	95	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	96	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	97	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	98	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	99	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -

Table C-2 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (inches)	Length (feet)	Height (feet)	Slope	Undercut (inches)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Phantom (continued)																	
Mukwonago 2	100	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	102	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	103	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	105	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	106	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	108	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	108.1	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	112	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	113	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	115	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	117	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	118	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	119	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	120	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	123	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	124	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	126	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	128	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	129	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	130	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	131	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	132	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	133	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	134	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	135	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	136	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	137	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	140	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	142	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	144	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	145	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	146	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	147	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	150	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	151	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	152	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	153	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	154	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	155	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	156	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	157	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	159	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	161	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	162	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	163	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	164	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	166	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	167	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	168	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	169	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -

Table C-2 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Left Bank Length (feet)	Left Bank Height (feet)	Left Bank Slope	Left Bank Undercut (inches)	Right Bank Length (feet)	Right Bank Height (feet)	Right Bank Slope	Right Bank Undercut (inches)	Bankfull Width (feet)	Bankfull Depth-1 (feet)	Bankfull Depth-2 (feet)	Bankfull Depth-3 (feet)	Bankfull Depth-4 (feet)	Bankfull Depth-5 (feet)	Bankfull Mean Depth (feet)	Bankfull Maximum Depth (feet)
Phantom (continued)																	
Mukwonago 2	170	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	171	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	173	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	174	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	175	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	178	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	180	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	181	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	182	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	183	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	186	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	187	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	188	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	190	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	191	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	193	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	194	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	195.1	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	197	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	200	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	201	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	202	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	204	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	205	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	207	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	208	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	210	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	213	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	215	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	216	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	218	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	220	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	223	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	224	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	225	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	226	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	227	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	228	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	230	- -	- -	- -	0	- -	- -	- -	18	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	232	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	233	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	234	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	236	- -	- -	- -	0	- -	- -	- -	36	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	237	- -	- -	- -	0	- -	- -	- -	6	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	239	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	241	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	243	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	244	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 2	245	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -

Table C-2 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (inches)	Length (feet)	Height (feet)	Slope	Undercut (inches)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Eagle Spring																	
Mukwonago 3	246	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	247	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	248	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	249	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	250	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	251	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	252	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	253	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	254	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	255	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	256	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	257	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	258	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	259	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	260	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	262	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	265	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	267	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	270	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	272	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	273	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	274	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	275	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	277	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	279	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	281	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	282	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	284	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	286	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	288	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	290	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	293	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	294	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	296	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	300	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	303	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	304	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Mukwonago 3	307	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah																	
Beulah	400	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	401	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	407	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	409	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	411	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	412	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	413	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	414	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	416	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	417	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	419	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -

Table C-2 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (inches)	Length (feet)	Height (feet)	Slope	Undercut (inches)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Beulah (continued)																	
Beulah	420	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	421	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	423	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	424	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	426	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	427	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	428	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Beulah	429	- -	- -	- -	0	- -	- -	- -	0	30.2	- -	- -	- -	- -	- -	- -	- -
Beulah	430	- -	- -	- -	0	- -	- -	- -	0	30.8	- -	- -	- -	- -	- -	- -	- -
Beulah	431	- -	- -	- -	0	- -	- -	- -	0	29.4	1.9	2.0	2.0	1.8	1.5	1.9	2.0
Beulah	432	3.0	2.2	1.38	0	0.7	1.6	0.44	12	35.6	2.1	2.3	2.2	2.0	1.8	2.1	2.3
Beulah	433	1.9	2.2	0.88	0	1.4	1.9	0.73	0	27.3	2.5	2.5	2.1	2.1	2.2	2.3	2.5
Beulah	434	1.4	2.2	0.65	0	0.9	2.0	0.45	0	15.9	2.3	2.8	2.8	2.7	2.3	2.6	2.8
Jericho																	
Jericho 1	500	0.6	0.9	0.65	0	0.8	1.9	0.42	0	16.2	1.4	1.8	2.3	2.8	2.8	2.2	2.8
Jericho 1	502	1.5	1.5	1.00	0	0.6	1.8	0.34	9	18.1	2.0	2.3	2.3	2.1	1.8	2.1	2.3
Jericho 1	504	0.7	1.1	0.65	0	1.0	1.4	0.71	0	18.5	2.9	3.5	3.3	2.8	2.5	3.0	3.5
Jericho 1	506	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Jericho 1	508	1	0.8	1.20	0	1.1	1.1	1.02	0	18.5	1.8	1.4	1.8	2.5	2.8	2.1	2.8
Jericho 1	509	0.9	0.8	1.20	0	1.5	1.3	1.13	6	19.4	1.3	1.5	1.5	1.8	2.2	1.7	2.2
Jericho 1	511	0.2	1.6	0.13	4	1.9	1.8	1.09	0	18.1	1.8	1.8	1.9	2.0	1.9	1.9	2.0
Jericho 1	512	0.3	1.3	0.23	4	0.2	2.2	0.09	12	15.2	2.0	2.3	2.3	2.4	2.3	2.3	2.4
Jericho 1	513	3.0	0.7	4.50	0	1.1	0.8	1.47	0	19.4	1.5	1.5	1.5	1.3	1.1	1.4	1.5
Jericho 1	514	0.9	1.3	0.68	0	0.5	1.9	0.26	6	16.4	1.8	1.8	2.3	2.7	2.7	2.2	2.7
Jericho 1	515	- -	- -	- -	0	- -	- -	- -	5	- -	- -	- -	- -	- -	- -	- -	- -
Jericho 1	516	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Jericho 1	517	1.3	1.2	1.11	0	1.4	1.2	1.20	0	18.6	1.3	1.4	1.6	1.6	1.7	1.5	1.7
Jericho 1	518	0.5	0.8	0.67	0	1.2	0.8	1.60	0	21.0	1.1	1.3	1.4	1.3	1.3	1.3	1.4
Jericho 1	519	0.8	0.9	0.87	0	1.7	0.7	2.55	0	36.6	1.8	1.2	2.1	0.5	1.1	1.3	2.1
Jericho 1	520	0.8	1.2	0.69	0	1.3	1.2	1.11	0	22.4	1.8	1.4	1.4	1.4	1.2	1.5	1.8
Jericho 1	523	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Jericho 1	524	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Jericho 1	525	13.2	0.8	17.60	0	23.2	0.8	27.84	0	59.7	1.6	1.5	1.2	1.3	1.3	1.4	1.6
Jericho 1	526	0.3	1.1	0.28	0	15.9	0.8	19.08	0	41.7	1.1	1.3	1.4	1.4	1.1	1.3	1.4
Jericho 1	527	2.1	1.1	1.94	0	3.0	0.7	4.50	0	19.8	1.4	1.9	1.7	1.8	1.3	1.6	1.9
Jericho 1	528	1.3	1.5	0.87	0	16.3	0.8	21.73	0	33.4	1.8	2.0	1.6	1.7	1.7	1.7	2.0
Jericho 1	530	0.3	1.2	0.26	0	1.0	1.9	0.52	0	14.7	1.9	1.9	2.0	1.8	1.8	1.9	2.0
Jericho 1	531	2.1	1.4	1.48	0	1.4	0.9	1.53	0	17.4	1.6	1.4	1.3	1.3	1.2	1.3	1.6
Jericho 1	533	1.1	0.8	1.32	0	0.8	1.0	0.80	0	24.9	1.4	1.4	1.5	1.3	1.4	1.4	1.5
Jericho 1	535	1.1	1.2	0.94	0	1.3	1.5	0.87	0	20.7	1.5	1.7	1.8	1.7	1.7	1.7	1.8
Jericho 1	537	1.5	1.7	0.90	0	1.8	1.5	1.20	0	17.2	2.2	2.3	2.3	2.2	1.8	2.2	2.3
Jericho 1	539	0.8	1.5	0.53	0	1.6	1.6	1.01	0	27.3	1.3	1.4	1.5	1.5	1.6	1.5	1.6
Jericho 1	542	0.7	1.3	0.56	0	1.7	1.8	0.93	0	19.8	1.7	1.8	1.4	1.5	1.5	1.6	1.8
Jericho 1	544	0.9	1.7	0.54	0	1.4	1.4	0.99	0	17.4	2.2	2.0	2.3	1.6	1.1	1.8	2.3
Jericho 1	546	0.3	1.8	0.17	0	0.5	1.3	0.40	0	15.2	2.3	2.3	1.9	1.9	1.3	2.0	2.3
Jericho 1	547	0.9	1.7	0.54	0	0.9	1.1	0.83	0	17.8	1.8	1.8	1.8	1.8	1.4	1.7	1.8
Jericho 1	550	0.7	1.3	0.53	0	1.4	1.3	1.05	0	15.7	2.0	2.4	2.4	2.4	1.8	2.2	2.4
Jericho 1	552	0.0	1.6	0.00	12	0.5	1.4	0.35	6	27.3	1.4	1.7	1.5	1.5	1.3	1.5	1.7
Jericho 1	555	0.4	1.6	0.25	12	0.6	1.8	0.33	12	23.1	2.0	2.0	2.2	1.8	2.0	2.0	2.2

Table C-2 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (inches)	Length (feet)	Height (feet)	Slope	Undercut (inches)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Jericho (continued)																	
Jericho 1	556	0.2	2.5	0.08	18	0.6	1.5	0.40	0	13.1	2.5	2.3	2.3	2.3	1.8	2.2	2.5
Jericho 1	557	1.2	1.2	1.03	0	0.6	1.2	0.50	0	18.6	2.1	2.7	2.8	2.4	1.4	2.3	2.8
Jericho 1	559	0.2	1.0	0.20	6	1.0	1.5	0.67	12	16.9	1.3	1.3	1.3	1.4	1.4	1.4	1.4
Jericho 1	560	0.2	1.2	0.17	12	1.0	1.2	0.86	0	20.8	1.4	1.4	1.4	1.4	1.3	1.4	1.4
Jericho 1	562	0.8	1.4	0.56	0	0.7	1.6	0.44	12	12.8	1.9	2.3	2.1	2.0	1.8	2.0	2.3
Jericho 1	563	0.6	1.2	0.51	0	0.8	1.4	0.56	0	18.9	1.3	1.3	1.0	1.2	1.4	1.2	1.4
Jericho 1	566	1.5	1.3	1.20	0	1.0	1.5	0.67	4	19.1	1.5	1.5	1.6	1.7	1.6	1.6	1.7
Jericho 1	570	0.6	1.3	0.48	3	0.8	1.1	0.74	3	16.4	1.8	2.0	2.2	1.9	1.7	1.9	2.2
Jericho 1	571	0.7	1.3	0.56	2	1.9	1.8	1.09	0	25.3	1.3	1.5	1.5	1.5	1.8	1.5	1.8
Jericho 1	573	0.3	2.3	0.13	12	1.2	1.4	0.85	5	13.6	2.4	2.3	2.3	1.8	1.8	2.1	2.4
Jericho 1	575	0.7	0.8	0.84	0	1.0	0.8	1.20	0	28.2	1.0	1.0	1.2	0.9	0.9	1.0	1.2
Jericho 1	577	0.3	1.3	0.24	12	1.3	1.3	1.04	5	19.6	1.4	1.6	1.9	2.0	2.0	1.8	2.0
Jericho 1	578	0.7	1.0	0.70	0	0.5	1.1	0.46	6	15.9	1.3	2.1	2.3	2.2	1.8	1.9	2.3
Jericho 1	579	0.7	1.0	0.70	0	1.6	1.3	1.28	0	26.1	1.3	1.3	1.2	1.2	1.3	1.2	1.3
Jericho 1	580	1.0	1.0	1.00	0	0.9	0.8	1.08	0	15.5	1.3	1.3	1.3	1.3	1.1	1.3	1.3
Jericho 1	583	1.2	1.4	0.85	0	1.5	1.2	1.29	0	23.1	1.8	1.7	1.6	1.6	1.6	1.6	1.8
Jericho 1	584	0.8	1.4	0.56	12	1.0	1.7	0.60	0	14.6	1.9	1.9	1.8	1.9	2.1	1.9	2.1
Jericho 1	586	0.7	1.0	0.70	0	1.6	1.3	1.28	0	26.1	1.3	1.3	1.2	1.2	1.3	1.2	1.3
Jericho 1	590	1.0	1.0	1.00	0	0.9	0.8	1.08	0	15.5	1.3	1.3	1.3	1.3	1.1	1.3	1.3
Jericho 1	592	1.2	1.4	0.85	0	1.5	1.2	1.29	0	23.1	1.8	1.7	1.6	1.6	1.6	1.6	1.8
Jericho 1	594	1.0	1.4	0.71	0	1.2	1.6	0.76	0	13.3	1.8	1.8	1.8	1.8	1.7	1.8	1.8
Jericho 1	595	0.9	1.3	0.72	12	3.3	1.3	2.64	0	25.9	1.3	1.5	1.8	2.1	1.8	1.7	2.1
Jericho 1	596	1.4	1.0	1.40	0	4.2	1.2	3.60	0	26.2	1.2	1.2	1.2	1.2	1.0	1.1	1.2
Jericho 1	597	1.0	0.8	1.20	0	6.2	1.0	6.20	0	23.2	0.9	1.0	1.2	1.1	1.2	1.1	1.2
Jericho 1	598	24.0	1.6	15.16	0	6.6	1.4	4.66	0	66.3	1.7	1.9	1.8	1.8	1.8	1.8	1.9
Jericho 1	600	1.7	1.4	1.20	0	2.3	1.3	1.73	0	32.1	1.4	1.3	1.6	1.6	1.4	1.5	1.6
Jericho 1	604	0.9	1.6	0.57	0	1.3	1.7	0.78	0	17.4	1.9	2.0	2.1	1.9	1.7	1.9	2.1
Jericho 1	605	1.6	1.6	1.01	0	1.8	1.3	1.44	0	16.5	1.7	1.6	1.6	1.4	1.4	1.5	1.7
Jericho 1	606	1.3	1.7	0.78	0	1.7	1.4	1.20	0	17.1	2.0	1.9	1.9	2.1	2.1	2.0	2.1
Jericho 2	607	1.6	1.2	1.37	0	1.7	1.0	1.70	0	20.5	1.8	1.6	1.3	1.7	1.4	1.5	1.8
Jericho 2	608	1.8	1.4	1.27	0	3.6	1.1	3.32	0	17.5	1.6	1.7	1.7	1.9	1.9	1.8	1.9
Jericho 2	609	1.2	1.4	0.85	7	4.6	1.6	2.91	3	17.3	1.3	1.1	1.3	1.3	1.4	1.3	1.4
Jericho 2	611	3.0	1.3	2.25	0	0.5	1.8	0.29	0	17.4	1.7	2.0	2.0	2.1	2.0	2.0	2.1
Jericho 2	612	0.8	0.9	0.87	0	1.4	0.9	1.53	0	15.4	1.4	1.7	1.8	1.9	1.7	1.7	1.9
Jericho 2	613	0.7	1.8	0.40	0	0.8	1.8	0.44	0	13.7	2.3	2.5	2.5	2.3	2.2	2.4	2.5
Jericho 2	614	0.2	1.3	0.16	0	1.7	1.2	1.46	0	14.2	- -	- -	- -	- -	- -	- -	- -
Jericho 2	616	0.4	0.9	0.44	0	1.5	1.3	1.20	0	14.2	- -	- -	- -	- -	- -	- -	- -
Jericho 2	619	1.6	1.3	1.28	0	2.0	1.0	2.00	0	15.7	- -	- -	- -	- -	- -	- -	- -
Jericho 2	621	0.8	1.4	0.56	6	1.9	1.1	1.75	0	20.6	- -	- -	- -	- -	- -	- -	- -
Jericho 2	622	1.0	1.4	0.71	0	2.2	1.4	1.55	0	20.2	- -	- -	- -	- -	- -	- -	- -
Jericho 2	623	3.9	1.5	2.60	0	1.7	1.3	1.28	0	16.8	- -	- -	- -	- -	- -	- -	- -
Jericho 2	624	1.3	1.7	0.78	0	2.2	1.8	1.26	0	18.9	- -	- -	- -	- -	- -	- -	- -
Jericho 2	625	0.9	1.6	0.57	0	2.5	1.0	2.50	0	17.4	- -	- -	- -	- -	- -	- -	- -
Jericho 2	626	2.4	1.8	1.37	0	4.6	1.5	3.07	0	20.9	- -	- -	- -	- -	- -	- -	- -
Jericho 2	628	1.1	1.4	0.78	0	3.8	1.1	3.51	0	22.1	- -	- -	- -	- -	- -	- -	- -
Jericho 2	631	0.6	1.9	0.31	0	2.1	1.4	1.48	0	19.8	- -	- -	- -	- -	- -	- -	- -
Jericho 2	634	4.0	1.8	2.18	0	1.9	1.8	1.04	0	17.4	- -	- -	- -	- -	- -	- -	- -
Jericho 2	635	1.7	1.1	1.57	0	3.3	1.5	2.20	0	15.5	- -	- -	- -	- -	- -	- -	- -
Jericho 2	638	3.0	1.4	2.12	0	2.3	1.1	2.12	0	14.9	- -	- -	- -	- -	- -	- -	- -

Table C-2 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (inches)	Length (feet)	Height (feet)	Slope	Undercut (inches)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Jericho (continued)																	
Jericho 2	640	1.7	1.3	1.36	0	1.1	1.1	1.02	0	11.3	- -	- -	- -	- -	- -	- -	- -
Jericho 2	641	0.9	1.0	0.90	0	1.5	0.8	2.00	0	11.2	- -	- -	- -	- -	- -	- -	- -
Jericho 2	644	0.7	1.1	0.65	0	0.7	2.3	0.31	0	11.1	- -	- -	- -	- -	- -	- -	- -
Jericho 2	645	1.3	0.9	1.42	0	1.7	0.7	2.55	0	16.1	- -	- -	- -	- -	- -	- -	- -
Jericho 2	648	1.0	1.0	1.00	0	0.4	2.0	0.20	0	12.9	- -	- -	- -	- -	- -	- -	- -
Jericho 2	650	1.0	1.8	0.57	0	1.3	1.7	0.78	0	12.5	2.3	2.6	2.6	2.7	2.8	2.6	2.8
Jericho 2	652	1.0	1.9	0.52	0	1.4	1.4	0.99	0	13.0	2.3	1.9	1.7	1.3	1.6	1.8	2.3
Jericho 2	653	0.0	1.0	0.00	0	0.8	1.8	0.46	0	10.3	1.7	2.2	2.3	2.5	2.1	2.2	2.5
Jericho 2	656	0.4	0.9	0.44	0	0.6	1.7	0.36	0	8.1	1.5	1.9	2.1	2.2	1.9	1.9	2.2
Jericho 2	657	0.2	1.2	0.17	0	0.6	1.3	0.45	0	8.7	1.4	1.7	2.0	2.0	1.5	1.7	2.0
Jericho 2	658	0.3	1.2	0.26	0	0.1	1.3	0.07	0	9.2	1.7	2.1	2.3	1.9	1.9	2.0	2.3
Jericho 2	659	0.8	1.1	0.74	0	0.7	1.7	0.42	0	9.8	1.2	1.8	2.0	2.0	1.9	1.8	2.0
Jericho 2	660	0.3	1.5	0.20	0	0.9	2.1	0.43	0	12.1	1.7	1.7	1.8	2.1	2.3	1.9	2.3
Jericho 2	661	0.3	1.8	0.16	0	0.7	1.2	0.60	0	8.8	1.6	2.1	1.9	1.8	1.7	1.8	2.1
Jericho 2	662	0.5	1.6	0.32	0	0.7	0.8	0.93	0	8.1	1.7	1.7	1.7	1.5	0.9	1.5	1.7
Jericho 2	663	0.4	1.8	0.22	0	1.1	0.6	1.89	0	8.3	2.3	2.3	2.3	1.8	0.8	1.9	2.3
Jericho 2	665	0.2	1.3	0.16	12	1.4	1.3	1.05	0	8.5	1.7	2.1	1.9	2.1	1.6	1.9	2.1
Jericho 2	666	0.5	2.3	0.22	0	0.7	1.1	0.65	0	6.4	2.4	1.9	1.3	- -	- -	1.9	2.4
Jericho 2	670	0.6	1.2	0.50	0	0.8	1.2	0.69	0	10.7	- -	- -	- -	- -	- -	- -	- -
Jericho 2	671	0.7	1.1	0.65	0	1.4	0.9	1.53	0	9.5	- -	- -	- -	- -	- -	- -	- -
Jericho 2	672	0.2	0.9	0.22	0	0.4	1.3	0.32	0	9.3	- -	- -	- -	- -	- -	- -	- -
Jericho 2	674	0.8	0.7	1.20	7	0.8	1.9	0.42	8	8.1	- -	- -	- -	- -	- -	- -	- -
Jericho 2	678	1.3	1.1	1.20	0	1.2	2.5	0.48	0	8.9	- -	- -	- -	- -	- -	- -	- -
Jericho 2	681	0.8	1.3	0.60	0	0.8	1.8	0.46	8	8.2	1.5	1.7	1.7	1.5	1.8	1.6	1.8
Jericho 2	684	0.9	2.4	0.37	0	0.2	0.6	0.32	0	8.5	2.5	2.5	1.9	1.4	0.8	1.8	2.5
Jericho 2	685	0.3	1.7	0.18	0	0.4	1.8	0.23	0	5.4	1.8	1.8	2.1	- -	- -	1.9	2.1
Jericho 2	686	0.5	1.8	0.27	0	0.4	2.0	0.20	0	5.5	2.1	2.3	2.2	- -	- -	2.2	2.3
Jericho 2	689	1.0	1.6	0.63	0	0.8	1.5	0.53	0	6.4	- -	- -	- -	- -	- -	- -	- -
Jericho 2	690	0.8	1.5	0.53	0	0.4	1.5	0.27	0	- -	- -	- -	- -	- -	- -	- -	- -
Jericho 2	691	0.4	1.8	0.23	0	0.4	1.5	0.27	0	4.5	1.8	1.8	1.8	- -	- -	1.8	1.8
Jericho 2	691	0.8	1.2	0.69	0	1.0	1.4	0.71	0	5.3	- -	- -	- -	- -	- -	- -	- -
Jericho 2	692	0.8	1.5	0.53	0	0.6	1.2	0.51	0	6.1	- -	- -	- -	- -	- -	- -	- -
Jericho 2	694	3.7	1.8	2.11	0	0.5	1.5	0.33	0	10.3	- -	- -	- -	- -	- -	- -	- -
Jericho 2	695	0.5	1.9	0.26	13	0.4	1.9	0.21	0	3.9	- -	- -	- -	- -	- -	- -	- -
Jericho 2	696	0.4	1.1	0.37	0	1.0	1.3	0.75	0	7.6	- -	- -	- -	- -	- -	- -	- -
Jericho 2	698	1.3	1.7	0.78	0	0.3	1.6	0.19	0	6.3	- -	- -	- -	- -	- -	- -	- -
Jericho 2	700	0.6	1.3	0.48	0	0.2	1.5	0.13	0	3.4	- -	- -	- -	- -	- -	- -	- -
Jericho 2	701	0.5	1.0	0.50	0	0.4	1.3	0.32	0	3.2	- -	- -	- -	- -	- -	- -	- -
Jericho 2	703	0.3	1.1	0.28	0	0.4	2.0	0.20	0	5.3	- -	- -	- -	- -	- -	- -	- -
Jericho 2	705	1.1	1.0	1.10	0	0.7	1.8	0.38	0	8.1	- -	- -	- -	- -	- -	- -	- -
Jericho 2	706	0.5	1.8	0.27	0	0.4	2.0	0.20	0	6.8	- -	- -	- -	- -	- -	- -	- -
Jericho 2	707	0.8	1.6	0.51	0	1.6	1.0	1.60	0	10.2	1.9	2.0	2.0	2.0	1.3	1.9	2.0
Jericho 2	709	1.2	0.7	1.80	0	0.8	2.1	0.38	0	8.2	1.9	2.1	2.3	- -	- -	2.1	2.3
Jericho 2	710	1.3	2.2	0.60	0	1.0	1.8	0.57	0	7.4	2.5	2.5	2.3	- -	- -	2.4	2.5
Jericho 2	711	0.5	1.4	0.35	0	1.3	1.1	1.20	0	8.4	1.8	1.8	1.5	- -	- -	1.7	1.8
Jericho 2	713	1.6	0.8	1.92	0	2.0	1.7	1.20	0	10.5	1.7	2.2	2.8	2.7	2.5	2.4	2.8
Jericho 2	715	0.4	2.2	0.18	0	1.2	1.0	1.20	0	7.8	2.1	1.8	1.5	- -	- -	1.8	2.1
Jericho 2	716.1	0.6	2.4	0.25	0	1.4	2.0	0.70	0	7.4	2.8	2.8	3.2	- -	- -	2.9	3.2
Jericho 2	718	0.6	0.9	0.65	0	1.4	1.9	0.73	0	11.1	1.4	1.8	1.8	1.8	1.6	1.7	1.8
Jericho 2	719	0.6	1.8	0.33	0	1.3	1.8	0.71	0	9.8	2.2	2.4	2.6	2.5	2.3	2.4	2.6

Table C-2 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Left Bank				Right Bank				Bankfull							
		Length (feet)	Height (feet)	Slope	Undercut (inches)	Length (feet)	Height (feet)	Slope	Undercut (inches)	Width (feet)	Depth-1 (feet)	Depth-2 (feet)	Depth-3 (feet)	Depth-4 (feet)	Depth-5 (feet)	Mean Depth (feet)	Maximum Depth (feet)
Jericho (continued)																	
Jericho 2	721	1.6	1.6	1.01	0	2.0	1.8	1.14	0	12.3	2.6	3.1	3.1	3.0	2.7	2.9	3.1
Jericho 2	722	5.3	2.1	2.54	0	0.6	1.5	0.40	0	12.3	1.9	2.0	2.0	2.2	2.0	2.0	2.2
Jericho 2	723	2.4	1.8	1.37	0	1.2	2.6	0.46	0	9.8	2.3	2.6	3.1	3.1	2.8	2.8	3.1
Jericho 2	723	0.3	1.8	0.17	0	5.2	2.0	2.60	0	11.9	2.2	2.5	2.7	2.4	2.3	2.4	2.7
Jericho 2	724	9.9	2.0	4.95	0	1.3	1.1	1.20	0	17.2	2.2	2.3	2.0	1.8	1.6	2.0	2.3
Jericho 2	725	2.4	1.5	1.60	0	1.1	1.3	0.88	0	13.8	2.0	2.0	2.8	2.3	1.9	2.2	2.8
Jericho 2	726	5.2	2.5	2.08	0	2.7	2.2	1.25	0	12.9	2.7	2.8	2.8	2.7	2.3	2.7	2.8
Jericho 2	727	3.4	1.7	2.04	0	4.7	1.2	4.03	0	15.2	1.9	2.1	1.8	1.1	1.3	1.6	2.1
Jericho 2	728	2.8	1.8	1.60	0	0.6	2.0	0.30	20	11.8	1.9	1.8	2.1	2.2	1.9	2.0	2.2
Jericho 2	729	1.0	1.2	0.86	0	1.6	1.2	1.37	0	9.4	1.7	2.0	1.7	1.8	1.5	1.7	2.0
Jericho 2	730	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Jericho 2	731	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Jericho 2	732	- -	- -	- -	0	- -	- -	- -	0	- -	- -	- -	- -	- -	- -	- -	- -
Jericho 2	733	0.7	2.2	0.32	0	1.6	1.4	1.13	0	15.7	2.5	2.6	2.3	2.8	2.7	2.6	2.8
Jericho 2	734	1.8	2.4	0.74	0	0.9	1.4	0.64	0	16.6	2.8	2.6	2.6	2.7	2.7	2.7	2.8
Jericho 2	735	4.9	1.8	2.67	0	3.6	1.4	2.54	0	14.2	1.8	1.8	1.9	1.8	1.6	1.8	1.9
Jericho 2	736	1.9	1.7	1.14	0	1.7	1.5	1.13	0	21.6	2.4	2.1	2.0	2.1	1.9	2.1	2.4
Jericho 2	737	1.3	1.3	1.04	0	1.3	1.2	1.11	0	18.2	1.8	1.8	2.0	1.8	1.6	1.8	2.0
Jericho 2	738	0.9	0.9	0.98	0	2.4	1.3	1.92	0	15.1	1.5	1.8	1.8	1.4	1.3	1.5	1.8
Jericho 2	739	1.9	1.7	1.14	0	2.4	1.8	1.31	0	17.9	2.0	2.3	2.3	2.3	2.1	2.2	2.3
Jericho 2	740	3.8	1.3	2.85	0	4.8	1.7	2.88	0	12.8	1.7	1.6	1.9	- -	- -	1.7	1.9
Jericho 2	741	3.1	1.2	2.66	0	2.0	1.1	1.85	0	15.9	1.4	1.5	2.2	1.9	1.3	1.7	2.2
Jericho 2	742	1.9	1.2	1.63	0	2.0	1.1	1.85	0	14.6	1.6	2.3	2.6	2.4	1.8	2.2	2.6
Jericho 2	743	1.2	1.3	0.90	0	2.0	1.4	1.41	0	14.9	1.7	1.8	2.3	2.1	1.7	1.9	2.3
Jericho 2	744	1.1	1.3	0.83	0	1.0	1.0	1.00	0	17.9	1.8	2.1	2.1	2.3	1.8	2.0	2.3
Jericho 2	745	0.9	1.2	00.77	0	1.8	1.1	1.66	0	23.3	2.2	2.6	2.6	2.8	2.3	2.5	2.8

NOTE: Due to the generally high-flow conditions during the time of this survey, bankfull width was only taken within the Beulah outlet and Jericho Creek tributaries.

Source: SEWRPC.

Table C-3

CROSS-SECTION LOCATION AND INSTREAM HABITAT CHARACTERISTICS WITHIN THE MUKWONAGO RIVER WATERSHED: 2008

Watershed and Reach	Transect Number (see Map C-1)	Water Width (feet)	Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Water Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Mukwonago														
Mukwonago 1	1	114.5	35	35	33	35	36	37	36	39	38	38	3.3	3.0
Mukwonago 1	2	94.6	30	31	31	32	31	34	36	34	35	37	3.1	2.8
Mukwonago 1	3	108.9	31	29	28	27	25	27	32	29	30	32	2.7	2.4
Mukwonago 1	4	80.4	30	30	31	34	32	31	32	29	29	27	2.8	2.5
Mukwonago 1	5	104.7	25	27	29	31	28	25	25	25	33	34	2.8	2.4
Mukwonago 1	6	151.4	27	25	24	24	25	27	25	25	28	27	2.3	2.1
Mukwonago 1	7	118.3	30	29	31	29	27	23	21	22	23	28	2.6	2.2
Mukwonago 1	8	90.0	26	25	23	23	26	29	33	31	29	25	2.8	2.3
Mukwonago 1	9	160.8	31	37	32	31	26	24	24	25	19	20	3.1	2.2
Mukwonago 1	10	100.3	24	24	24	24	26	28	28	29	26	20	2.4	2.1
Mukwonago 1	11	100.7	33	33	25	22	23	20	21	22	25	29	2.8	2.1
Mukwonago 1	12	86.4	25	25	25	25	25	27	22	20	20	14	2.3	1.9
Mukwonago 1	13	133.2	18	20	26	26	20	19	19	20	18	22	2.2	1.7
Mukwonago 1	14	135.2	25	21	19	25	23	19	18	17	16	21	2.1	1.7
Mukwonago 1	15	125.4	20	20	21	22	23	25	26	22	22	23	2.2	1.9
Mukwonago 1	16	108.2	22	20	22	25	26	24	21	21	21	19	2.2	1.8
Mukwonago 1	17	110.6	20	25	26	25	26	26	25	24	20	20	2.2	2.0
Mukwonago 1	18	53.1	25	26	26	26	27	25	24	23	23	21	2.3	2.1
Mukwonago 1	19	120.8	20	26	26	26	28	28	25	22	19	19	2.3	2.0
Mukwonago 1	20	88.9	21	23	23	24	25	26	26	26	22	20	2.2	2.0
Mukwonago 1	21	50.6	30	31	30	29	28	29	29	27	22	21	2.6	2.3
Mukwonago 1	22	54.2	24	27	27	26	26	25	25	24	23	21	2.3	2.1
Mukwonago 1	23	72.3	25	26	24	24	24	22	24	23	20	16	2.2	1.9
Mukwonago 1	24	63.4	19	22	23	25	24	23	23	19	19	20	2.1	1.8
Mukwonago 1	25	54.5	20	27	28	28	28	27	27	28	26	22	2.3	2.2
Mukwonago 1	26	71.7	20	22	23	23	24	25	25	21	19	20	2.1	1.9
Mukwonago 1	27	77.2	20	20	23	23	23	23	23	22	22	20	1.9	1.8
Mukwonago 1	28	109.5	27	26	25	27	27	28	29	28	27	25	2.4	2.2
Mukwonago 1	29	82.8	25	26	28	27	27	25	24	23	23	22	2.3	2.1
Mukwonago 1	30	65.8	25	28	28	29	30	29	28	25	21	15	2.5	2.2
Mukwonago 1	31	115.4	25	33	37	36	33	31	29	29	29	26	3.1	2.6
Mukwonago 1	32	86.9	25	27	28	27	29	31	32	31	31	22	2.7	2.4
Phantom														
Mukwonago 2	33	49.4	30	43	56	80	73	63	28	37	- -	- -	6.7	4.3
Mukwonago 2	34	35.4	30	47	61	66	58	27	- -	- -	- -	- -	5.5	4.0
Mukwonago 2	35	35.5	27	71	73	80	53	39	21	- -	- -	- -	6.7	4.3
Mukwonago 2	36	44.4	29	21	25	47	46	45	38	31	28	- -	3.9	2.9
Mukwonago 2	37	39.6	15	22	46	56	39	23	27	29	38	35	4.7	2.8
Mukwonago 2	38	90.6	28	29	16	24	20	27	30	41	32	22	3.4	2.2
Mukwonago 2	39	90.7	17	45	39	19	17	35	28	27	53	28	4.4	2.6
Mukwonago 2	40	74.3	21	38	23	46	45	51	31	39	- -	- -	4.3	3.1
Mukwonago 2	41	80.6	27	39	53	38	30	28	33	28	- -	- -	4.4	2.9
Mukwonago 2	42	73.0	31	55	53	37	33	53	55	62	50	25	5.2	3.8
Mukwonago 2	43	78.2	24	21	28	29	36	43	59	37	28	23	4.9	2.7
Mukwonago 2	44	79.3	38	34	53	39	45	34	28	27	30	31	4.4	3.0
Mukwonago 2	45	83.1	23	37	39	36	37	33	31	26	28	38	3.3	2.7

Table C-3 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Water												
		Width (feet)	Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Water Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Phantom (continued)														
Mukwonago 2	46	34.6	32	41	50	62	65	64	53	29	16	- -	5.4	3.8
Mukwonago 2	47	46.8	25	41	69	48	34	35	37	27	36	- -	5.8	3.3
Mukwonago 2	48	58.4	17	19	27	38	64	84	79	85	66	50	7.1	4.4
Mukwonago 2	49	46.1	31	43	34	37	36	39	35	34	- -	- -	3.6	3.0
Mukwonago 2	50	36.8	30	37	41	39	45	48	39	30	25	- -	4.0	3.1
Mukwonago 2	51	35.4	26	27	28	30	33	57	60	76	31	- -	6.3	3.4
Mukwonago 2	52	50.1	24	58	50	31	28	25	25	31	- -	- -	4.8	2.8
Mukwonago 2	53	28.1	20	45	43	48	55	60	61	30	- -	- -	5.1	3.8
Mukwonago 2	54	37.6	22	49	52	52	41	37	34	37	26	- -	4.3	3.2
Mukwonago 2	55	27.2	20	76	98	86	56	35	36	27	24	- -	8.2	4.2
Mukwonago 2	56	31.7	30	24	29	35	38	41	61	28	17	- -	5.1	2.8
Mukwonago 2	57	45.5	30	38	50	72	79	100	79	63	26	- -	8.3	5.0
Mukwonago 2	58	51.3	30	45	60	40	35	32	34	29	24	22	5.0	2.9
Mukwonago 2	59	47.8	30	39	51	53	48	46	44	38	24	24	4.4	3.3
Mukwonago 2	60	35.6	25	26	29	47	51	64	72	71	28	16	6.0	3.6
Mukwonago 2	61	27.5	25	24	23	31	39	54	57	60	30	16	5.0	3.0
Mukwonago 2	62	33.2	26	25	30	43	56	78	90	50	17	- -	7.5	3.8
Mukwonago 2	63	44.4	22	35	45	41	46	37	30	22	29	23	3.8	2.8
Mukwonago 2	64	32.9	39	72	74	73	52	38	28	26	22	27	6.2	3.8
Mukwonago 2	65	42.9	22	39	44	29	30	44	41	42	40	31	3.7	3.0
Mukwonago 2	66	40.1	21	28	55	64	61	74	58	39	29	25	6.2	3.8
Mukwonago 2	67	32.7	26	40	39	36	39	38	24	- -	- -	- -	3.3	2.9
Mukwonago 2	68	33.1	17	22	47	70	28	- -	- -	- -	- -	- -	5.8	3.1
Mukwonago 2	70	34.0	24	32	30	32	36	32	14	- -	- -	- -	3.0	2.4
Mukwonago 2	71	31.3	29	60	40	50	46	65	27	26	- -	- -	5.4	3.6
Mukwonago 2	72	29.5	19	25	27	25	30	28	29	- -	- -	- -	2.5	2.2
Mukwonago 2	73	31.7	22	67	59	42	26	38	21	15	- -	- -	5.6	3.0
Mukwonago 2	74	36.1	32	19	25	32	40	31	- -	- -	- -	- -	3.3	2.5
Mukwonago 2	75	25.9	30	38	49	54	42	40	26	- -	- -	- -	4.5	3.3
Mukwonago 2	76	33.4	27	30	33	38	40	43	33	28	- -	- -	3.6	2.8
Mukwonago 2	77	22.9	20	33	52	64	64	36	30	- -	- -	- -	5.3	3.6
Mukwonago 2	78	31.9	19	36	30	34	32	29	25	20	- -	- -	3.0	2.3
Mukwonago 2	79	34.0	21	27	33	42	42	37	27	- -	- -	- -	3.5	2.7
Mukwonago 2	81	30.5	19	37	47	55	53	37	26	21	7	- -	4.6	2.8
Mukwonago 2	82	29.7	29	32	32	27	26	23	18	20	- -	- -	2.7	2.2
Mukwonago 2	84	27.2	12	27	45	56	52	40	20	- -	- -	- -	4.7	3.0
Mukwonago 2	85	32.2	22	36	30	26	23	37	35	21	- -	- -	3.1	2.4
Mukwonago 2	86	35.5	27	31	35	33	55	54	38	33	- -	- -	4.6	3.2
Mukwonago 2	87	28.4	26	35	35	34	29	29	26	14	- -	- -	2.9	2.4
Mukwonago 2	88	25.6	22	48	64	48	32	21	- -	- -	- -	- -	5.3	3.3
Mukwonago 2	89	42.3	24	43	50	49	44	39	22	- -	- -	- -	4.2	3.2
Mukwonago 2	90	34.6	23	43	51	45	38	33	27	19	- -	- -	4.3	2.9
Mukwonago 2	91	25.2	27	27	35	38	43	48	38	19	- -	- -	4.0	2.9
Mukwonago 2	92	19.1	20	24	22	28	28	24	17	- -	- -	- -	2.3	1.9
Mukwonago 2	93	31.4	26	30	33	31	30	27	22	12	- -	- -	2.8	2.2
Mukwonago 2	94	40.7	18	23	26	22	21	18	15	- -	- -	- -	2.2	1.7
Mukwonago 2	95	45.2	12	17	20	19	26	21	16	- -	- -	- -	2.2	1.6
Mukwonago 2	96	30.5	14	27	31	31	29	28	19	- -	- -	- -	2.6	2.1
Mukwonago 2	97	32.1	12	31	37	35	32	29	21	15	- -	- -	3.1	2.2
Mukwonago 2	98	38.4	12	13	15	18	26	29	18	- -	- -	- -	2.4	1.6
Mukwonago 2	99	37.1	16	22	31	43	50	35	22	- -	- -	- -	4.2	2.6

Table C-3 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Water Width (feet)	Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Water Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Phantom (continued)														
Mukwonago 2	100	31.7	15	23	25	26	23	16	8	- -	- -	- -	2.2	1.6
Mukwonago 2	102	29.5	34	57	60	40	20	19	19	11	- -	- -	5.0	2.7
Mukwonago 2	103	28.6	21	22	25	33	43	53	39	31	- -	- -	4.4	2.8
Mukwonago 2	105	25.4	33	43	60	63	65	41	29	15	- -	- -	5.4	3.6
Mukwonago 2	106	25.0	12	26	29	27	38	32	23	13	- -	- -	3.2	2.1
Mukwonago 2	108	45.8	20	21	18	21	31	19	26	21	- -	- -	2.6	1.8
Mukwonago 2	108.1	32.7	25	46	54	42	26	20	18	- -	- -	- -	4.5	2.8
Mukwonago 2	112	31.2	18	35	50	66	54	28	15	7	- -	- -	5.5	2.8
Mukwonago 2	113	28.3	36	21	27	31	35	25	21	11	- -	- -	3.0	2.2
Mukwonago 2	115	34.6	30	31	37	37	33	48	25	13	- -	- -	4.0	2.6
Mukwonago 2	117	27.2	9	12	24	27	27	19	17	- -	- -	- -	2.3	1.6
Mukwonago 2	118	31.9	15	21	41	42	41	38	13	- -	- -	- -	3.5	2.5
Mukwonago 2	119	27.2	19	22	25	30	28	32	19	- -	- -	- -	2.7	2.1
Mukwonago 2	120	29.5	12	27	35	30	39	48	23	- -	- -	- -	4.0	2.5
Mukwonago 2	123	42.9	23	23	30	31	26	23	21	- -	- -	- -	2.6	2.1
Mukwonago 2	124	37.3	14	35	29	19	20	17	10	- -	- -	- -	2.9	1.7
Mukwonago 2	126	26.9	9	17	40	48	34	20	15	- -	- -	- -	4.0	2.2
Mukwonago 2	128	31.9	25	28	26	20	13	13	15	- -	- -	- -	2.3	1.7
Mukwonago 2	129	29.0	20	25	39	52	47	38	20	- -	- -	- -	4.3	2.9
Mukwonago 2	130	57.6	13	17	19	22	20	12	- -	- -	- -	- -	1.8	1.4
Mukwonago 2	131	27.3	12	12	17	36	31	38	34	26	- -	- -	3.2	2.1
Mukwonago 2	132	55.8	11	16	12	18	18	18	21	- -	- -	- -	1.8	1.4
Mukwonago 2	133	28.7	6	10	16	12	20	25	- -	- -	- -	- -	2.1	1.2
Mukwonago 2	134	37.9	12	13	17	13	20	18	18	12	- -	- -	1.7	1.3
Mukwonago 2	135	27.8	8	22	26	30	25	18	- -	- -	- -	- -	2.5	1.8
Mukwonago 2	136	45.4	6	7	9	18	14	25	19	- -	- -	- -	2.1	1.2
Mukwonago 2	137	51.1	20	26	17	13	12	13	10	- -	- -	- -	2.2	1.3
Mukwonago 2	140	34.4	18	29	21	13	21	28	30	- -	- -	- -	2.5	1.9
Mukwonago 2	142	60.4	29	29	13	13	9	13	8	20	19	13	2.4	1.4
Mukwonago 2	144	37.6	33	25	19	19	19	13	10	- -	- -	- -	2.8	1.6
Mukwonago 2	145	44.6	23	29	25	17	11	14	23	29	- -	- -	2.4	1.8
Mukwonago 2	146	42.8	13	18	20	24	26	28	18	- -	- -	- -	2.3	1.8
Mukwonago 2	147	43.4	16	31	30	20	19	16	12	- -	- -	- -	2.6	1.7
Mukwonago 2	150	40.5	24	36	48	43	38	28	- -	- -	- -	- -	4.0	3.0
Mukwonago 2	151	32.2	24	35	48	43	40	24	- -	- -	- -	- -	4.0	3.0
Mukwonago 2	152	47.0	17	24	23	26	22	25	14	- -	- -	- -	2.2	1.8
Mukwonago 2	153	32.9	25	24	25	26	29	23	16	- -	- -	- -	2.4	2.0
Mukwonago 2	154	34.7	16	21	24	31	30	24	15	- -	- -	- -	2.6	1.9
Mukwonago 2	155	50.8	9	20	25	19	17	24	23	- -	- -	- -	2.1	1.6
Mukwonago 2	156	37.6	11	11	12	24	42	43	34	19	- -	- -	3.6	2.0
Mukwonago 2	157	44.4	16	19	22	17	25	35	27	- -	- -	- -	2.9	1.9
Mukwonago 2	159	30.7	29	39	42	35	21	16	9	- -	- -	- -	3.5	2.3
Mukwonago 2	161	35.6	19	28	38	27	19	20	15	- -	- -	- -	3.2	2.0
Mukwonago 2	162	33.6	14	17	17	15	23	25	23	- -	- -	- -	2.1	1.6
Mukwonago 2	163	43.5	12	17	14	21	20	15	24	- -	- -	- -	2.0	1.5
Mukwonago 2	164	34.4	19	25	32	37	32	32	21	- -	- -	- -	3.1	2.4
Mukwonago 2	166	22.1	9	12	25	32	47	43	42	36	- -	- -	3.9	2.6
Mukwonago 2	167	33.4	16	28	28	33	35	31	22	- -	- -	- -	2.9	2.3
Mukwonago 2	168	31.3	5	14	29	35	33	28	26	- -	- -	- -	2.9	2.0
Mukwonago 2	169	34.3	20	32	30	27	23	23	20	- -	- -	- -	2.7	2.1

Table C-3 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Water: Width (feet)	Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Water Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Phantom (continued)														
Mukwonago 2	170	24.0	32	35	35	36	29	13	8	- -	- -	- -	3.0	2.2
Mukwonago 2	171	32.2	10	14	21	22	23	25	20	- -	- -	- -	2.1	1.6
Mukwonago 2	173	17.7	15	31	31	31	28	15	8	- -	- -	- -	2.6	1.9
Mukwonago 2	174	27.3	12	21	26	29	30	23	9	9	- -	- -	2.5	1.7
Mukwonago 2	175	34.3	22	20	18	12	18	21	21	- -	- -	- -	1.8	1.6
Mukwonago 2	178	35.2	10	14	9	15	17	16	20	32	- -	- -	2.7	1.4
Mukwonago 2	180	27.6	19	36	50	42	36	12	- -	- -	- -	- -	4.2	2.7
Mukwonago 2	181	42.4	13	14	15	20	11	16	18	21	- -	- -	1.8	1.3
Mukwonago 2	182	30.8	12	24	34	45	36	19	11	- -	- -	- -	3.8	2.2
Mukwonago 2	183	35.8	12	18	22	23	23	22	17	11	9	4	1.9	1.3
Mukwonago 2	186	32.4	15	26	27	26	20	22	17	- -	- -	- -	2.3	1.8
Mukwonago 2	187	37.6	13	12	13	16	19	20	22	24	- -	- -	2.0	1.4
Mukwonago 2	188	30.5	12	46	44	29	12	8	- -	- -	- -	- -	3.8	2.1
Mukwonago 2	190	34.4	14	14	18	18	14	11	27	20	- -	- -	2.3	1.4
Mukwonago 2	191	25.4	18	23	36	48	40	31	12	- -	- -	- -	4.0	2.5
Mukwonago 2	193	34.4	22	23	18	18	13	14	15	16	- -	- -	1.9	1.4
Mukwonago 2	194	27.3	17	14	17	30	36	30	23	- -	- -	- -	3.0	2.0
Mukwonago 2	195.1	55.9	11	30	48	50	45	35	20	16	- -	- -	4.2	2.7
Mukwonago 2	197	22.8	16	17	15	26	30	21	10	- -	- -	- -	2.5	1.6
Mukwonago 2	200	28.9	11	11	15	18	18	23	29	27	20	- -	2.4	1.6
Mukwonago 2	201	14.5	37	49	51	30	36	19	16	- -	- -	- -	4.3	2.8
Mukwonago 2	202	23.6	5	16	25	36	47	56	57	22	- -	- -	4.8	2.8
Mukwonago 2	204	20.8	26	37	45	54	52	43	26	14	- -	- -	4.5	3.1
Mukwonago 2	205	21.1	15	15	21	29	38	26	15	- -	- -	- -	3.2	1.9
Mukwonago 2	207	23.4	12	15	18	29	33	27	24	- -	- -	- -	2.8	1.9
Mukwonago 2	208	27.5	20	22	34	43	46	50	43	29	- -	- -	4.2	3.0
Mukwonago 2	210	30.4	19	22	31	34	21	25	19	12	- -	- -	2.8	1.9
Mukwonago 2	213	33.7	7	10	9	20	24	12	12	- -	- -	- -	2.0	1.1
Mukwonago 2	215	28.2	12	12	16	16	20	30	22	14	- -	- -	2.5	1.5
Mukwonago 2	216	29.4	16	30	46	39	30	9	- -	- -	- -	- -	3.8	2.4
Mukwonago 2	218	24.4	9	14	19	21	19	17	6	- -	- -	- -	1.8	1.3
Mukwonago 2	220	28.1	21	10	30	51	28	12	8	- -	- -	- -	4.3	1.9
Mukwonago 2	223	24.8	4	14	18	24	27	24	14	- -	- -	- -	2.3	1.5
Mukwonago 2	224	24.4	17	25	18	14	19	27	16	- -	- -	- -	2.3	1.6
Mukwonago 2	225	23.7	22	26	27	26	20	17	6	- -	- -	- -	2.3	1.7
Mukwonago 2	226	14.5	12	14	17	21	22	- -	- -	- -	- -	- -	1.8	1.4
Mukwonago 2	227	41.6	8	10	10	11	11	13	12	- -	- -	- -	1.1	0.9
Mukwonago 2	228	23.2	22	27	38	42	32	22	15	11	- -	- -	3.5	2.2
Mukwonago 2	230	18.8	6	12	29	39	45	43	40	34	- -	- -	3.8	2.6
Mukwonago 2	232	17.6	44	42	46	39	29	12	- -	- -	- -	- -	3.8	2.9
Mukwonago 2	233	25.1	12	23	36	31	26	29	22	4	- -	- -	3.0	1.9
Mukwonago 2	234	23.0	17	24	24	26	21	25	18	- -	- -	- -	2.2	1.8
Mukwonago 2	236	12.7	14	20	36	45	46	49	25	- -	- -	- -	4.1	2.8
Mukwonago 2	237	19.6	9	15	25	36	38	39	18	- -	- -	- -	3.3	2.1
Mukwonago 2	239	20.4	23	24	25	24	23	12	- -	- -	- -	- -	2.1	1.8
Mukwonago 2	241	19.7	11	17	18	21	20	19	19	- -	- -	- -	1.8	1.5
Mukwonago 2	243	22.4	7	10	15	14	14	14	15	- -	- -	- -	1.3	1.1
Mukwonago 2	244	23.2	8	10	13	17	15	12	11	- -	- -	- -	1.4	1.0
Mukwonago 2	245	24.9	16	20	23	23	23	24	22	- -	- -	- -	2.0	1.8

Table C-3 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Water Width (feet)	Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Water Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Eagle Spring														
Mukwonago 3	246	48.8	22	34	36	37	40	29	12	- -	- -	- -	3.3	2.5
Mukwonago 3	247	39.9	15	28	37	38	31	- -	- -	- -	- -	- -	3.2	2.5
Mukwonago 3	248	22.8	31	36	43	45	39	36	20	- -	- -	- -	3.8	3.0
Mukwonago 3	249	42.8	22	37	43	43	32	28	- -	- -	- -	- -	3.6	2.8
Mukwonago 3	250	43.9	20	32	37	42	36	26	17	14	- -	- -	3.5	2.3
Mukwonago 3	251	31.0	13	26	36	43	41	33	17	- -	- -	- -	3.6	2.5
Mukwonago 3	252	43.3	12	32	34	38	37	40	34	22	15	- -	3.3	2.4
Mukwonago 3	253	42.8	16	25	30	40	40	37	30	21	- -	- -	3.3	2.5
Mukwonago 3	254	34.6	18	17	31	36	39	36	30	19	- -	- -	3.3	2.4
Mukwonago 3	255	25.1	16	29	29	33	42	43	37	14	- -	- -	3.6	2.5
Mukwonago 3	256	51.7	33	28	36	44	40	38	25	21	- -	- -	3.7	2.8
Mukwonago 3	257	153.0	3	10	7	11	23	11	3	- -	- -	- -	1.9	0.8
Mukwonago 3	258	20.2	8	20	34	33	17	- -	- -	- -	- -	- -	2.8	1.9
Mukwonago 3	259	18.0	11	33	39	34	32	30	- -	- -	- -	- -	3.3	2.5
Mukwonago 3	260	21.0	24	36	27	25	16	- -	- -	- -	- -	- -	3.0	2.1
Mukwonago 3	262	33.0	27	38	44	55	62	62	35	15	- -	- -	5.2	3.5
Mukwonago 3	265	10.3	32	37	33	36	30	- -	- -	- -	- -	- -	3.1	2.8
Mukwonago 3	267	17.0	10	47	52	32	12	- -	- -	- -	- -	- -	4.3	2.6
Mukwonago 3	270	15.1	24	36	39	24	13	- -	- -	- -	- -	- -	3.3	2.3
Mukwonago 3	272	15.0	26	27	26	25	26	25	- -	- -	- -	- -	2.3	2.2
Mukwonago 3	273	10.6	9	11	10	11	10	- -	- -	- -	- -	- -	0.9	0.9
Mukwonago 3	274	20.0	19	23	26	25	22	- -	- -	- -	- -	- -	2.2	1.9
Mukwonago 3	275	13.4	18	27	38	36	25	- -	- -	- -	- -	- -	3.2	2.4
Mukwonago 3	277	21.0	7	35	34	36	21	- -	- -	- -	- -	- -	3.0	2.2
Mukwonago 3	279	16.0	29	37	35	24	- -	- -	- -	- -	- -	- -	3.1	2.6
Mukwonago 3	281	23.7	14	16	27	36	8	- -	- -	- -	- -	- -	3.0	1.7
Mukwonago 3	282	23.0	22	31	40	28	10	- -	- -	- -	- -	- -	3.3	2.2
Mukwonago 3	284	13.0	30	28	29	30	20	- -	- -	- -	- -	- -	2.5	2.3
Mukwonago 3	286	20.0	26	44	41	24	9	- -	- -	- -	- -	- -	3.7	2.4
Mukwonago 3	288	16.4	21	34	25	24	21	- -	- -	- -	- -	- -	2.8	2.1
Mukwonago 3	290	16.9	19	28	48	49	22	- -	- -	- -	- -	- -	4.1	2.8
Mukwonago 3	293	11.4	26	39	37	34	28	- -	- -	- -	- -	- -	3.3	2.7
Mukwonago 3	294	17.3	27	32	26	21	12	- -	- -	- -	- -	- -	2.7	2.0
Mukwonago 3	296	32.0	15	23	26	24	17	- -	- -	- -	- -	- -	2.2	1.8
Mukwonago 3	300	17.0	18	24	27	29	34	- -	- -	- -	- -	- -	2.8	2.2
Mukwonago 3	303	30.0	24	26	27	23	11	- -	- -	- -	- -	- -	2.3	1.9
Mukwonago 3	304	27.0	26	22	21	18	19	- -	- -	- -	- -	- -	2.2	1.8
Mukwonago 3	307	18.0	17	21	25	24	23	- -	- -	- -	- -	- -	2.1	1.8
Beulah														
Beulah	400	18.0	36	33	34	36	40	35	28	- -	- -	- -	3.3	2.9
Beulah	401	26.3	34	29	34	37	35	37	- -	- -	- -	- -	3.1	2.9
Beulah	407	35.2	29	34	38	29	31	31	30	- -	- -	- -	3.2	2.6
Beulah	409	30.8	24	31	37	32	34	26	21	- -	- -	- -	3.1	2.4
Beulah	411	63.6	37	26	27	26	28	29	31	32	24	- -	3.1	2.4
Beulah	412	39.6	20	41	33	26	24	21	18	- -	- -	- -	3.4	2.2
Beulah	413	65.6	30	26	22	28	24	31	26	25	28	- -	2.6	2.2
Beulah	414	26.1	27	30	31	29	29	46	52	20	- -	- -	4.3	2.8
Beulah	416	28.4	30	31	27	31	38	20	26	- -	- -	- -	3.2	2.4
Beulah	417	27.3	25	25	22	23	25	25	- -	- -	- -	- -	2.1	2.0
Beulah	419	31.0	21	30	31	27	31	19	- -	- -	- -	- -	2.6	2.2

Table C-3 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Water												
		Width (feet)	Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Water Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Beulah (continued)														
Beulah	420	20.0	25	27	28	27	22	26	- -	- -	- -	- -	2.3	2.2
Beulah	421	40.6	24	26	23	17	19	26	28	31	- -	- -	2.6	2.0
Beulah	423	19.8	27	25	25	28	36	43	21	- -	- -	- -	3.6	2.4
Beulah	424	34.4	28	26	24	20	20	20	18	21	- -	- -	2.3	1.8
Beulah	426	34.6	25	37	64	68	43	32	27	23	- -	- -	5.7	3.3
Beulah	427	46.4	15	18	21	21	21	18	16	- -	- -	- -	1.8	1.5
Beulah	428	28.2	18	20	17	20	20	24	- -	- -	- -	- -	2.0	1.7
Beulah	429	29.6	22	19	18	18	21	- -	- -	- -	- -	- -	1.8	1.6
Beulah	430	29.5	25	20	19	20	17	- -	- -	- -	- -	- -	2.1	1.7
Beulah	431	28.9	21	22	22	20	16	- -	- -	- -	- -	- -	1.8	1.7
Beulah	432	33.7	20	22	21	19	17	- -	- -	- -	- -	- -	1.8	1.7
Beulah	433	25.2	27	27	22	20	20	- -	- -	- -	- -	- -	2.3	1.9
Beulah	434	14.9	20	27	28	26	22	- -	- -	- -	- -	- -	2.3	2.1
Jericho														
Jericho 1	500	14.9	7	11	19	25	25	- -	- -	- -	- -	- -	2.1	1.5
Jericho 1	502	16.7	16	19	20	18	15	- -	- -	- -	- -	- -	1.7	1.5
Jericho 1	504	16.6	24	30	26	20	16	- -	- -	- -	- -	- -	2.5	1.9
Jericho 1	506	13.8	10	12	14	13	11	- -	- -	- -	- -	- -	1.2	1.0
Jericho 1	508	16.4	10	9	14	20	24	- -	- -	- -	- -	- -	2.0	1.3
Jericho 1	509	16.9	8	11	11	14	17	- -	- -	- -	- -	- -	1.4	1.0
Jericho 1	511	16.4	8	8	11	11	7	- -	- -	- -	- -	- -	0.9	0.8
Jericho 1	512	15.2	9	12	13	12	10	- -	- -	- -	- -	- -	1.1	0.9
Jericho 1	513	16.5	11	11	11	8	5	- -	- -	- -	- -	- -	0.9	0.8
Jericho 1	514	15.1	7	8	15	20	20	- -	- -	- -	- -	- -	1.7	1.2
Jericho 1	515	12.3	8	12	16	18	17	- -	- -	- -	- -	- -	1.5	1.2
Jericho 1	516	13.9	12	11	11	9	4	- -	- -	- -	- -	- -	1.0	0.8
Jericho 1	517	15.9	5	7	10	10	9	- -	- -	- -	- -	- -	0.8	0.7
Jericho 1	518	18.9	5	8	10	8	7	- -	- -	- -	- -	- -	0.8	0.6
Jericho 1	519	34.3	21	14	25	6	13	- -	- -	- -	- -	- -	2.1	1.3
Jericho 1	520	20.2	12	8	8	8	4	- -	- -	- -	- -	- -	1.0	0.7
Jericho 1	523	15.3	19	24	23	15	5	- -	- -	- -	- -	- -	2.0	1.4
Jericho 1	524	33.4	7	7	6	8	5	- -	- -	- -	- -	- -	0.7	0.6
Jericho 1	525	23.3	11	13	6	8	8	- -	- -	- -	- -	- -	1.1	0.8
Jericho 1	526	25.7	3	8	9	9	5	- -	- -	- -	- -	- -	0.8	0.6
Jericho 1	527	16.2	12	18	15	16	8	- -	- -	- -	- -	- -	1.5	1.2
Jericho 1	528	15.1	14	17	12	13	14	- -	- -	- -	- -	- -	1.4	1.2
Jericho 1	530	13.7	13	13	14	13	12	- -	- -	- -	- -	- -	1.2	1.1
Jericho 1	531	14.7	12	10	9	9	8	- -	- -	- -	- -	- -	1.0	0.8
Jericho 1	533	23.3	9	9	11	9	10	- -	- -	- -	- -	- -	0.9	0.8
Jericho 1	535	18.8	7	10	11	10	10	- -	- -	- -	- -	- -	0.9	0.8
Jericho 1	537	14.9	16	17	18	17	14	- -	- -	- -	- -	- -	1.5	1.4
Jericho 1	539	24.9	5	6	8	8	9	- -	- -	- -	- -	- -	0.8	0.6
Jericho 1	542	17.9	9	10	6	7	7	- -	- -	- -	- -	- -	0.8	0.7
Jericho 1	544	15.8	19	17	21	12	6	- -	- -	- -	- -	- -	1.8	1.3
Jericho 1	546	14.2	19	19	15	15	7	- -	- -	- -	- -	- -	1.6	1.3
Jericho 1	547	16.7	12	12	11	11	7	- -	- -	- -	- -	- -	1.0	0.9
Jericho 1	550	14.3	15	21	21	20	12	- -	- -	- -	- -	- -	1.8	1.5
Jericho 1	552	26.8	6	10	7	8	4	- -	- -	- -	- -	- -	0.8	0.6
Jericho 1	555	22.4	8	9	13	8	11	- -	- -	- -	- -	- -	1.1	0.8

Table C-3 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Water												
		Width (feet)	Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Water Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Jericho (continued)														
Jericho 1	556	12.7	17	16	16	16	11	- -	- -	- -	- -	- -	1.4	1.3
Jericho 1	557	15.9	15	23	25	20	7	- -	- -	- -	- -	- -	2.1	1.5
Jericho 1	559	16.1	7	8	8	9	9	- -	- -	- -	- -	- -	0.8	0.7
Jericho 1	560	18.8	9	9	9	9	16	- -	- -	- -	- -	- -	1.3	0.9
Jericho 1	562	12.2	14	19	16	14	10	- -	- -	- -	- -	- -	1.6	1.2
Jericho 1	563	17.5	6	7	5	7	10	- -	- -	- -	- -	- -	0.8	0.6
Jericho 1	566	17.3	7	8	10	10	9	- -	- -	- -	- -	- -	0.8	0.7
Jericho 1	570	15.6	13	17	19	17	13	- -	- -	- -	- -	- -	1.6	1.3
Jericho 1	571	22.4	7	9	9	8	11	- -	- -	- -	- -	- -	0.9	0.7
Jericho 1	573	12.9	20	19	19	13	15	- -	- -	- -	- -	- -	1.7	1.4
Jericho 1	575	26.8	6	7	9	6	5	- -	- -	- -	- -	- -	0.8	0.6
Jericho 1	577	18.9	7	10	16	16	16	- -	- -	- -	- -	- -	1.3	1.1
Jericho 1	578	15.1	7	17	19	18	12	- -	- -	- -	- -	- -	1.6	1.2
Jericho 1	579	24.2	6	8	6	6	6	- -	- -	- -	- -	- -	0.7	0.5
Jericho 1	580	13.1	10	10	10	9	7	- -	- -	- -	- -	- -	0.8	0.8
Jericho 1	583	21.9	10	11	10	10	10	- -	- -	- -	- -	- -	0.9	0.9
Jericho 1	584	13.3	17	17	14	16	18	- -	- -	- -	- -	- -	1.5	1.4
Jericho 1	586	24.2	6	8	6	6	6	- -	- -	- -	- -	- -	0.7	0.5
Jericho 1	590	13.1	10	10	10	9	7	- -	- -	- -	- -	- -	0.8	0.8
Jericho 1	592	21.9	10	11	10	10	10	- -	- -	- -	- -	- -	0.9	0.9
Jericho 1	594	11.6	12	12	13	12	11	- -	- -	- -	- -	- -	1.1	1.0
Jericho 1	595	22.2	7	10	14	18	15	- -	- -	- -	- -	- -	1.5	1.1
Jericho 1	596	21.6	8	9	9	8	6	- -	- -	- -	- -	- -	0.8	0.7
Jericho 1	597	16.9	6	7	9	7	7	- -	- -	- -	- -	- -	0.8	0.6
Jericho 1	598	46.9	13	17	17	16	12	- -	- -	- -	- -	- -	1.4	1.3
Jericho 1	600	28.3	6	6	10	9	6	- -	- -	- -	- -	- -	0.8	0.6
Jericho 1	604	15.7	12	13	14	12	8	- -	- -	- -	- -	- -	1.2	1.0
Jericho 1	605	13.6	10	10	10	9	8	- -	- -	- -	- -	- -	0.8	0.8
Jericho 1	606	15.3	10	9	10	11	12	- -	- -	- -	- -	- -	1.0	0.9
Jericho 2	607	17.7	12	11	7	11	8	- -	- -	- -	- -	- -	1.0	0.8
Jericho 2	608	12.4	10	11	12	14	12	- -	- -	- -	- -	- -	1.2	1.0
Jericho 2	609	11.6	7	5.5	8	7	6	- -	- -	- -	- -	- -	0.7	0.6
Jericho 2	611	13.7	11	15	15	15	12	- -	- -	- -	- -	- -	1.3	1.1
Jericho 2	612	13.6	7	11	13	14	11	- -	- -	- -	- -	- -	1.2	0.9
Jericho 2	613	12.5	7	12	12	11	8	- -	- -	- -	- -	- -	1.0	0.8
Jericho 2	614	14.2	15	17	19	19	14	- -	- -	- -	- -	- -	1.6	1.4
Jericho 2	616	13.6	10	11	12	12	9	- -	- -	- -	- -	- -	1.0	0.9
Jericho 2	619	14.8	15	15	17	16	11	- -	- -	- -	- -	- -	1.4	1.2
Jericho 2	621	19.1	15	16	18	16	13	- -	- -	- -	- -	- -	1.5	1.3
Jericho 2	622	18.9	9	16	20	20	18	- -	- -	- -	- -	- -	1.7	1.4
Jericho 2	623	13.7	11	13	14	10	9	- -	- -	- -	- -	- -	1.2	1.0
Jericho 2	624	17.8	12	17	19	23	17	- -	- -	- -	- -	- -	1.9	1.5
Jericho 2	625	15.6	11	17	21	17	8	- -	- -	- -	- -	- -	1.8	1.2
Jericho 2	626	16.9	14	16	19	18	13	- -	- -	- -	- -	- -	1.6	1.3
Jericho 2	628	19.2	10	12	14	14	13	- -	- -	- -	- -	- -	1.2	1.1
Jericho 2	631	18.2	9	12	14	8	10	- -	- -	- -	- -	- -	1.2	0.9
Jericho 2	634	15.7	23	25	24	22	21	- -	- -	- -	- -	- -	2.1	1.9
Jericho 2	635	12.5	15	20	21	22	21	- -	- -	- -	- -	- -	1.8	1.7
Jericho 2	638	14.9	16	17	18	15	11	- -	- -	- -	- -	- -	1.5	1.3

Table C-3 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Water Width (feet)	Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Water Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Jericho (continued)														
Jericho 2	640	11.3	24	29	21	17	15	- -	- -	- -	- -	- -	2.4	1.8
Jericho 2	641	11.2	29	24	24	21	18	- -	- -	- -	- -	- -	2.4	1.9
Jericho 2	644	11.1	14	24	36	31	29	- -	- -	- -	- -	- -	3.0	2.2
Jericho 2	645	16.1	13	21	21	23	14	- -	- -	- -	- -	- -	1.9	1.5
Jericho 2	648	12.9	15	27	32	33	26	- -	- -	- -	- -	- -	2.8	2.2
Jericho 2	650	11.6	25	28	28.5	30	31	- -	- -	- -	- -	- -	2.6	2.4
Jericho 2	652	12.2	24	20	16	11	14	- -	- -	- -	- -	- -	2.0	1.4
Jericho 2	653	10.3	18	24.5	27	28	23	- -	- -	- -	- -	- -	2.3	2.0
Jericho 2	656	8.1	15	20	21	22	19	- -	- -	- -	- -	- -	1.8	1.6
Jericho 2	657	8.7	14	17	20	20	13	- -	- -	- -	- -	- -	1.7	1.4
Jericho 2	658	9.2	17	23	25	21	20	- -	- -	- -	- -	- -	2.1	1.8
Jericho 2	659	9.8	12	20	22	21	19	- -	- -	- -	- -	- -	1.8	1.6
Jericho 2	660	12.1	18	16	20	22	25	- -	- -	- -	- -	- -	2.1	1.7
Jericho 2	661	8.8	18	24	22	20	19	- -	- -	- -	- -	- -	2.0	1.7
Jericho 2	662	8.1	19	19	19	17.5	10.5	- -	- -	- -	- -	- -	1.6	1.4
Jericho 2	663	8.3	25	26	26	20	9	- -	- -	- -	- -	- -	2.2	1.8
Jericho 2	665	8.5	17	23	21	24	17	- -	- -	- -	- -	- -	2.0	1.7
Jericho 2	666	6.4	28	22	15	- -	- -	- -	- -	- -	- -	- -	2.3	1.8
Jericho 2	670	10.7	13	25	33	27	25	- -	- -	- -	- -	- -	2.8	2.1
Jericho 2	671	9.5	16	19	17	20	17	- -	- -	- -	- -	- -	1.7	1.5
Jericho 2	672	9.3	17	17	13	12	15	- -	- -	- -	- -	- -	1.4	1.2
Jericho 2	674	8.1	8	15	24	25	25	- -	- -	- -	- -	- -	2.1	1.6
Jericho 2	678	8.9	20	25	28	30	30	- -	- -	- -	- -	- -	2.5	2.2
Jericho 2	681	8.2	15	17	17	16	20	- -	- -	- -	- -	- -	1.7	1.4
Jericho 2	684	8.5	28	29	22	16	9	- -	- -	- -	- -	- -	2.4	1.7
Jericho 2	685	5.4	21	21	24	- -	- -	- -	- -	- -	- -	- -	2.0	1.8
Jericho 2	686	5.5	24	26	25	- -	- -	- -	- -	- -	- -	- -	2.2	2.1
Jericho 2	689	6.4	21	24	21	- -	- -	- -	- -	- -	- -	- -	2.0	1.8
Jericho 2	690	5.7	19	18	17	- -	- -	- -	- -	- -	- -	- -	1.6	1.5
Jericho 2	691	4.5	19	20	21	- -	- -	- -	- -	- -	- -	- -	1.8	1.7
Jericho 2	691	5.3	17	17	17	- -	- -	- -	- -	- -	- -	- -	1.4	1.4
Jericho 2	692	6.1	15	15	13	- -	- -	- -	- -	- -	- -	- -	1.3	1.2
Jericho 2	694	10.3	25	25	20	- -	- -	- -	- -	- -	- -	- -	2.1	1.9
Jericho 2	695	3.9	23	24	23	- -	- -	- -	- -	- -	- -	- -	2.0	1.9
Jericho 2	696	7.6	18	19	18	- -	- -	- -	- -	- -	- -	- -	1.6	1.5
Jericho 2	698	6.3	19	26	24	- -	- -	- -	- -	- -	- -	- -	2.2	1.9
Jericho 2	700	3.4	22	23	20	- -	- -	- -	- -	- -	- -	- -	1.9	1.8
Jericho 2	701	3.2	12	14	14	- -	- -	- -	- -	- -	- -	- -	1.2	1.1
Jericho 2	703	5.3	13	22	25	- -	- -	- -	- -	- -	- -	- -	2.1	1.7
Jericho 2	705	8.1	19	21	22	22	21	- -	- -	- -	- -	- -	1.8	1.8
Jericho 2	706	6.8	25	25	27	0	0	- -	- -	- -	- -	- -	2.3	1.3
Jericho 2	707	9.6	21	22	22	22	15	- -	- -	- -	- -	- -	1.8	1.7
Jericho 2	709	7.6	21	23	25	- -	- -	- -	- -	- -	- -	- -	2.1	1.9
Jericho 2	710	6.7	27	27	25	- -	- -	- -	- -	- -	- -	- -	2.3	2.2
Jericho 2	711	7.1	18	18	16	- -	- -	- -	- -	- -	- -	- -	1.5	1.4
Jericho 2	713	9.3	17	24	30	29	27	- -	- -	- -	- -	- -	2.5	2.1
Jericho 2	715	7.2	23	19	16	- -	- -	- -	- -	- -	- -	- -	1.9	1.6
Jericho 2	716.1	6.4	30	30	35	- -	- -	- -	- -	- -	- -	- -	2.9	2.6
Jericho 2	718	10.0	15	19	20	19	17	- -	- -	- -	- -	- -	1.7	1.5
Jericho 2	719	8.7	22	25	27	25	23	- -	- -	- -	- -	- -	2.3	2.0

Table C-3 (continued)

Watershed and Reach	Transect Number (see Map C-1)	Water												
		Width (feet)	Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Water Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Jericho (continued)														
Jericho 2	721	10.8	28	35	35	34	30	- -	- -	- -	- -	- -	2.9	2.7
Jericho 2	722	11.8	17	18	18	20	18	- -	- -	- -	- -	- -	1.7	1.5
Jericho 2	723	9.1	25	28	35	34	30	- -	- -	- -	- -	- -	2.9	2.5
Jericho 2	723	8.9	16	21	24	21	21	- -	- -	- -	- -	- -	2.0	1.7
Jericho 2	724	8.4	17	19	17	14	13	- -	- -	- -	- -	- -	1.6	1.3
Jericho 2	725	12.8	16	17	26	22	18	- -	- -	- -	- -	- -	2.2	1.7
Jericho 2	726	7.1	23	25	26	25	21	- -	- -	- -	- -	- -	2.2	2.0
Jericho 2	727	9.2	16	18	15	7	9	- -	- -	- -	- -	- -	1.5	1.1
Jericho 2	728	9.6	5	5	8	10	7	- -	- -	- -	- -	- -	0.8	0.6
Jericho 2	729	7.6	8	13	10	10	8	- -	- -	- -	- -	- -	1.1	0.8
Jericho 2	730	22.3	28	27	27	- -	- -	- -	- -	- -	- -	- -	2.3	2.3
Jericho 2	731	16.7	27	28	26	21	- -	- -	- -	- -	- -	- -	2.3	2.1
Jericho 2	732	18.6	17	26	27	26	22	- -	- -	- -	- -	- -	2.3	2.0
Jericho 2	733	18.7	27	28	24	29	26	- -	- -	- -	- -	- -	2.4	2.2
Jericho 2	734	16.8	28	28	29	29	28	- -	- -	- -	- -	- -	2.4	2.4
Jericho 2	735	12.9	18	18	19	18	15	- -	- -	- -	- -	- -	1.6	1.5
Jericho 2	736	20.4	23	19	19	20	17	- -	- -	- -	- -	- -	1.9	1.6
Jericho 2	737	16.6	16	17	19	15	12	- -	- -	- -	- -	- -	1.6	1.3
Jericho 2	738	12.9	12	14	14	10	9	- -	- -	- -	- -	- -	1.2	1.0
Jericho 2	739	15.9	17	22	22	22	19	- -	- -	- -	- -	- -	1.8	1.7
Jericho 2	740	5.3	7	7	10	- -	- -	- -	- -	- -	- -	- -	0.8	0.7
Jericho 2	741	12.0	6	7	16	14	6	- -	- -	- -	- -	- -	1.3	0.8
Jericho 2	742	12.2	10	19	23	22	15	- -	- -	- -	- -	- -	1.9	1.5
Jericho 2	743	12.8	12	14	20	15	10	- -	- -	- -	- -	- -	1.7	1.2
Jericho 2	744	16.8	17	21	21	22	14	- -	- -	- -	- -	- -	1.8	1.6
Jericho 2	745	21.9	20	26	27	30	22	- -	- -	- -	- -	- -	2.5	2.1

Table C-3 (continued)

Watershed and Reach	Transect Number (See Map C-1)	Sediment											
		Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Mukwonago													
Mukwonago 1	1	3	4	4	5	2	3	4	3	2	0	5.0	0.4
Mukwonago 1	2	2	1	1	1	1	1	3	6	3	2	6.0	0.5
Mukwonago 1	3	2	3	3	2	3	0	1	3	2	0	3.0	0.3
Mukwonago 1	4	2	2	1	0	1	1	0	1	1	1	2.0	0.2
Mukwonago 1	5	2	1	1	1	3	1	2	2	2	2	3.0	0.3
Mukwonago 1	6	3	2	1	0	1	4	3	2	3	6	6.0	0.5
Mukwonago 1	7	1	2	2	4	4	4	1	1	3	2	4.0	0.3
Mukwonago 1	8	0	2	1	1	1	3	3	5	2	2	5.0	0.4
Mukwonago 1	9	0	4	2	4	7	3	1	1	3	0	7.0	0.6
Mukwonago 1	10	1	0	1	1	0	1	2	2	0	0	2.0	0.2
Mukwonago 1	11	2	4	5	2	4	4	4	2	5	2	5.0	0.4
Mukwonago 1	12	0	0	0	0	0	0	6	4	3	3	6.0	0.5
Mukwonago 1	13	2	1	1	6	4	1	2	4	1	3	6.0	0.5
Mukwonago 1	14	3	3	6	1	4	1	4	4	7	7	7.0	0.6
Mukwonago 1	15	1	3	3	2	2	3	2	5	5	3	5.0	0.4
Mukwonago 1	16	2	1	1	1	2	3	2	2	1	10	10.0	0.8
Mukwonago 1	17	2	0	0	0	0	0	0	0	2	1	2.0	0.2
Mukwonago 1	18	4	0	0	0	0	0	0	0	0	0	4.0	0.3
Mukwonago 1	19	0	1	0	0	0	0	1	1	2	2	2.0	0.2
Mukwonago 1	20	0	0	0	0	0	0	0	0	0	2	2.0	0.2
Mukwonago 1	21	0	0	0	0	0	0	0	0	4	1	4.0	0.3
Mukwonago 1	22	1	0	0	0	0	0	1	2	1	2	2.0	0.2
Mukwonago 1	23	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Mukwonago 1	24	4	2	0	0	0	0	0	1	0	0	4.0	0.3
Mukwonago 1	25	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Mukwonago 1	26	0	0	0	0	0	0	0	0	1	0	1.0	0.1
Mukwonago 1	27	2	1	2	0	0	0	0	0	0	0	2.0	0.2
Mukwonago 1	28	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Mukwonago 1	29	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Mukwonago 1	30	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Mukwonago 1	31	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Mukwonago 1	32	0	0	0	0	0	0	0	0	0	0	0.0	0.0
Phantom													
Mukwonago 2	33	37	21	5	2	3	13	26	7	- -	- -	37.0	3.1
Mukwonago 2	34	21	13	2	0	23	21	- -	- -	- -	- -	23.0	1.9
Mukwonago 2	35	30	0	0	0	11	15	0	- -	- -	- -	30.0	2.5
Mukwonago 2	36	29	19	27	1	0	0	0	0	0	- -	29.0	2.4
Mukwonago 2	37	3	4	0	1	13	17	23	23	15	16	23.0	1.9
Mukwonago 2	38	5	6	57	14	14	16	15	9	8	5	57.0	4.8
Mukwonago 2	39	4	0	20	26	32	9	0	0	0	9	32.0	2.7
Mukwonago 2	40	22	13	20	11	18	0	23	9	- -	- -	23.0	1.9
Mukwonago 2	41	0	0	7	24	7	27	21	13	- -	- -	27.0	2.3
Mukwonago 2	42	21	0	0	10	40	23	27	0	0	8	40.0	3.3
Mukwonago 2	43	14	18	22	19	11	12	11	10	0	0	22.0	1.8
Mukwonago 2	44	9	5	0	11	3	18	15	19	10	0	19.0	1.6
Mukwonago 2	45	4	4	4	0	18	18	16	23	29	13	29.0	2.4

Table C-3 (continued)

Watershed and Reach	Transect Number (See Map C-1)	Sediment											
		Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Phantom (continued)													
Mukwonago 2	46	0	0	0	0	0	0	0	0	0	- -	0.0	0.0
Mukwonago 2	47	0	0	0	11	19	2	5	16	14	- -	19.0	1.6
Mukwonago 2	48	7	0	8	14	0	0	3	2	0	0	14.0	1.2
Mukwonago 2	49	10	4	13	0	6	0	0	0	- -	- -	13.0	1.1
Mukwonago 2	50	4	15	10	9	1	0	0	3	2	- -	15.0	1.3
Mukwonago 2	51	2	5	7	5	19	0	0	0	14	- -	19.0	1.6
Mukwonago 2	52	0	0	0	3	5	1	1	7	- -	- -	7.0	0.6
Mukwonago 2	53	0	6	16	2	0	0	0	11	- -	- -	16.0	1.3
Mukwonago 2	54	3	0	0	0	0	0	3	0	0	- -	3.0	0.3
Mukwonago 2	55	0	7	0	6	21	22	2	10	14	- -	22.0	1.8
Mukwonago 2	56	11	12	7	8	11	18	2	15	0	- -	18.0	1.5
Mukwonago 2	57	0	3	0	5	6	10	0	11	18	- -	18.0	1.5
Mukwonago 2	58	0	0	2	12	0	2	0	3	5	0	12.0	1.0
Mukwonago 2	59	19	5	0	0	0	4	1	0	11	9	19.0	1.6
Mukwonago 2	60	9	11	14	7	5	6	5	12	3	0	14.0	1.2
Mukwonago 2	61	10	15	16	16	9	10	5	0	5	0	16.0	1.3
Mukwonago 2	62	7	7	5	8	16	4	0	0	0	- -	16.0	1.3
Mukwonago 2	63	10	8	0	0	0	8	11	16	5	0	16.0	1.3
Mukwonago 2	64	0	0	0	0	0	18	20	5	8	0	20.0	1.7
Mukwonago 2	65	0	0	0	14	13	0	3	2	1	9	14.0	1.2
Mukwonago 2	66	0	0	0	0	0	0	2	7	6	9	9.0	0.8
Mukwonago 2	67	0	3	1	0	3	4	2	- -	- -	- -	4.0	0.3
Mukwonago 2	68	0	4	13	0	14	- -	- -	- -	- -	- -	14.0	1.2
Mukwonago 2	70	8	5	13	11	12	8	17		- -	- -	17.0	1.4
Mukwonago 2	71	0	0	9	12	0	0	16	16	- -	- -	16.0	1.3
Mukwonago 2	72	11	15	24	25	13	18	8	- -	- -	- -	25.0	2.1
Mukwonago 2	73	0	0	0	5	4	10	5	8	- -	- -	10.0	0.8
Mukwonago 2	74	3	14	9	5	7	5	- -	- -	- -	- -	14.0	1.2
Mukwonago 2	75	0	11	0	0	0	2	0	- -	- -	- -	11.0	0.9
Mukwonago 2	76	8	2	0	0	0	0	0	12	- -	- -	12.0	1.0
Mukwonago 2	77	15	11	0	0	0	1	0	- -	- -	- -	15.0	1.3
Mukwonago 2	78	0	0	6	0	0	0	0	0	- -	- -	6.0	0.5
Mukwonago 2	79	2	2	0	0	0	4	5	- -	- -	- -	5.0	0.4
Mukwonago 2	81	4	6	0	0	0	6	3	0	7	- -	7.0	0.6
Mukwonago 2	82	0	0	2	8	8	8	14	12	- -	- -	14.0	1.2
Mukwonago 2	84	2	5	3	0	0	0	8	- -	- -	- -	8.0	0.7
Mukwonago 2	85	3	1	7	7	11	0	0	3	- -	- -	11.0	0.9
Mukwonago 2	86	7	8	8	1	0	0	0	0	- -	- -	8.0	0.7
Mukwonago 2	87	0	3	3	0	0	2	0	7	- -	- -	7.0	0.6
Mukwonago 2	88	0	0	0	0	0	4	- -	- -	- -	- -	4.0	0.3
Mukwonago 2	89	15	0	0	0	0	0	3	- -	- -	- -	15.0	1.3
Mukwonago 2	90	0	0	0	0	0	0	0	3	- -	- -	3.0	0.3
Mukwonago 2	91	0	0	0	0	0	0	0	0	- -	- -	0.0	0.0
Mukwonago 2	92	0	0	0	0	0	0	0	- -	- -	- -	0.0	0.0
Mukwonago 2	93	0	0	0	0	0	0	0	8	- -	- -	8.0	0.7
Mukwonago 2	94	0	0	0	0	0	0	0	- -	- -	- -	0.0	0.0
Mukwonago 2	95	0	0	0	0	0	0	4	- -	- -	- -	4.0	0.3
Mukwonago 2	96	4	0	0	0	0	0	5	- -	- -	- -	5.0	0.4
Mukwonago 2	97	11	5	0	0	0	0	0	0	- -	- -	11.0	0.9
Mukwonago 2	98	3	11	5	3	6	1	4	- -	- -	- -	11.0	0.9
Mukwonago 2	99	4	2	5	1	0	11	3	- -	- -	- -	11.0	0.9

Table C-3 (continued)

Watershed and Reach	Transect Number (See Map C-1)	Sediment											
		Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Phantom (continued)													
Mukwonago 2	100	0	0	0	0	1	10	3	- -	- -	- -	10.0	0.8
Mukwonago 2	102	0	0	0	5	0	0	3	6	- -	- -	6.0	0.5
Mukwonago 2	103	9	0	0	0	0	0	3	5	- -	- -	9.0	0.8
Mukwonago 2	105	9	6	2	0	2	20	3	0	- -	- -	20.0	1.7
Mukwonago 2	106	4	3	8	0	0	9	5	0	- -	- -	9.0	0.8
Mukwonago 2	108	2	3	7	1	0	11	2	4	- -	- -	11.0	0.9
Mukwonago 2	108.1	0	2	0	0	9	9	11	- -	- -	- -	11.0	0.9
Mukwonago 2	112	0	3	11	2	8	13	4	4	- -	- -	13.0	1.1
Mukwonago 2	113	8	12	4	0	0	0	0	0	- -	- -	12.0	1.0
Mukwonago 2	115	6	0	0	4	0	0	11	1	- -	- -	11.0	0.9
Mukwonago 2	117	9	5	0	0	0	0	0	- -	- -	- -	9.0	0.8
Mukwonago 2	118	2	8	0	0	0	0	8	- -	- -	- -	8.0	0.7
Mukwonago 2	119	2	6	2	1	4	5	18	- -	- -	- -	18.0	1.5
Mukwonago 2	120	3	9	0	7	3	0	7	- -	- -	- -	9.0	0.8
Mukwonago 2	123	0	9	0	0	0	0	0	- -	- -	- -	9.0	0.8
Mukwonago 2	124	0	0	0	12	9	12	12	- -	- -	- -	12.0	1.0
Mukwonago 2	126	9	3	3	0	6	0	0	- -	- -	- -	9.0	0.8
Mukwonago 2	128	9	0	2	5	10	0	14	- -	- -	- -	14.0	1.2
Mukwonago 2	129	2	4	3	0	0	4	4	- -	- -	- -	4.0	0.3
Mukwonago 2	130	0	6	5	2	2	4	- -	- -	- -	- -	6.0	0.5
Mukwonago 2	131	2	14	15	0	0	0	0	6	- -	- -	15.0	1.3
Mukwonago 2	132	16	13	6	10	10	9	11	- -	- -	- -	16.0	1.3
Mukwonago 2	133	2	13	1	2	2	2	- -	- -	- -	- -	13.0	1.1
Mukwonago 2	134	12	14	14	8	0	0	0	5	- -	- -	14.0	1.2
Mukwonago 2	135	0	0	0	0	15	15	- -	- -	- -	- -	15.0	1.3
Mukwonago 2	136	16	18	10	0	25	12	27	- -	- -	- -	27.0	2.3
Mukwonago 2	137	3	6	11	5	3	3	13	- -	- -	- -	13.0	1.1
Mukwonago 2	140	0	2	2	0	0	0	0	- -	- -	- -	2.0	0.2
Mukwonago 2	142	0	13	14	13	12	10	18	0	8	0	18.0	1.5
Mukwonago 2	144	0	4	13	11	10	12	3	- -	- -	- -	13.0	1.1
Mukwonago 2	145	0	0	0	0	0	9	6	0	- -	- -	9.0	0.8
Mukwonago 2	146	5	6	1	5	8	6	0	- -	- -	- -	8.0	0.7
Mukwonago 2	147	2	3	4	8	20	20	6	- -	- -	- -	20.0	1.7
Mukwonago 2	150	0	0	0	6	2	9	- -	- -	- -	- -	9.0	0.8
Mukwonago 2	151	5	8	0	0	0	4	- -	- -	- -	- -	8.0	0.7
Mukwonago 2	152	14	2	2	1	2	2	11	- -	- -	- -	14.0	1.2
Mukwonago 2	153	4	1	1	1	0	3	11	- -	- -	- -	11.0	0.9
Mukwonago 2	154	12	3	0	0	0	0	0	- -	- -	- -	12.0	1.0
Mukwonago 2	155	8	10	0	4	6	4	0	- -	- -	- -	10.0	0.8
Mukwonago 2	156	5	2	6	2	0	0	3	2	- -	- -	6.0	0.5
Mukwonago 2	157	3	2	2	12	6	2	10	- -	- -	- -	12.0	1.0
Mukwonago 2	159	2	0	0	6	7	1	3	- -	- -	- -	7.0	0.6
Mukwonago 2	161	9	8	0	3	2	2	2	- -	- -	- -	9.0	0.8
Mukwonago 2	162	7	5	1	7	2	1	4	- -	- -	- -	7.0	0.6
Mukwonago 2	163	7	4	5	0	16	26	27	- -	- -	- -	27.0	2.3
Mukwonago 2	164	7	4	1	0	2	6	0	- -	- -	- -	7.0	0.6
Mukwonago 2	166	5	4	3	10	0	0	0	0	- -	- -	10.0	0.8
Mukwonago 2	167	4	2	1	0	0	4	0	- -	- -	- -	4.0	0.3
Mukwonago 2	168	2	4	0	0	0	0	0	- -	- -	- -	4.0	0.3
Mukwonago 2	169	0	0	0	0	0	0	0	- -	- -	- -	0.0	0.0

Table C-3 (continued)

Watershed and Reach	Transect Number (See Map C-1)	Sediment											
		Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Phantom (continued)													
Mukwonago 2	170	0	0	0	0	7	20	26	- -	- -	- -	26.0	2.2
Mukwonago 2	171	23	18	7	2	3	2	6	- -	- -	- -	23.0	1.9
Mukwonago 2	173	9	0	0	0	0	3	4	- -	- -	- -	9.0	0.8
Mukwonago 2	174	1	0	0	0	0	1	15	18	- -	- -	18.0	1.5
Mukwonago 2	175	0	2	2	5	4	3	7	- -	- -	- -	7.0	0.6
Mukwonago 2	178	12	22	15	19	11	27	18	3	- -	- -	27.0	2.3
Mukwonago 2	180	7	0	0	0	0	15		- -	- -	- -	15.0	1.3
Mukwonago 2	181	6	13	2	0	1	1	2	0	- -	- -	13.0	1.1
Mukwonago 2	182	21	6	4	0	1	1	15	- -	- -	- -	21.0	1.8
Mukwonago 2	183	0	0	0	0	0	0	3	4	6	17	17.0	1.4
Mukwonago 2	186	0	0	0	2	5	2	2	- -	- -	- -	5.0	0.4
Mukwonago 2	187	5	1	1	4	1	3	2	5	- -	- -	5.0	0.4
Mukwonago 2	188	0	0	0	10	13	3	- -	- -	- -	- -	13.0	1.1
Mukwonago 2	190	7	4	2	0	1	13	1	3	- -	- -	13.0	1.1
Mukwonago 2	191	0	16	12	0	0	2	0	- -	- -	- -	16.0	1.3
Mukwonago 2	193	6	0	6	6	3	1	5	0	- -	- -	6.0	0.5
Mukwonago 2	194	0	4	2	0	2	1	0	- -	- -	- -	4.0	0.3
Mukwonago 2	195.1	3	9	0	0	0	0	10	12	- -	- -	12.0	1.0
Mukwonago 2	197	3	2	10	2	0	4	3	- -	- -	- -	10.0	0.8
Mukwonago 2	200	10	4	7	1	14	0	3	0	0	- -	14.0	1.2
Mukwonago 2	201	0	0	0	14	1	1	8	- -	- -	- -	14.0	1.2
Mukwonago 2	202	2	3	1	3	4	2	0	0	- -	- -	4.0	0.3
Mukwonago 2	204	0	0	0	0	0	0	0	0	- -	- -	0.0	0.0
Mukwonago 2	205	4	7	4	2	0	0	0	- -	- -	- -	7.0	0.6
Mukwonago 2	207	3	1	2	1	2	0	0	- -	- -	- -	3.0	0.3
Mukwonago 2	208	6	5	2	2	10	2	4	0	- -	- -	10.0	0.8
Mukwonago 2	210	9	23	3	5	8	4	1	7	- -	- -	23.0	1.9
Mukwonago 2	213	3	5	2	2	1	12	18	- -	- -	- -	18.0	1.5
Mukwonago 2	215	0	8	7	6	1	1	0	0	- -	- -	8.0	0.7
Mukwonago 2	216	2	5	0	0	3	3	- -	- -	- -	- -	5.0	0.4
Mukwonago 2	218	0	0	0	0	1	0	0	- -	- -	- -	1.0	0.1
Mukwonago 2	220	2	10	4	0	9	2	4	- -	- -	- -	10.0	0.8
Mukwonago 2	223	1	6	3	3	2	0	0	- -	- -	- -	6.0	0.5
Mukwonago 2	224	0	0	1	2	2	0	2	- -	- -	- -	2.0	0.2
Mukwonago 2	225	7	0	0	0	0	2	4	- -	- -	- -	7.0	0.6
Mukwonago 2	226	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Mukwonago 2	227	0	0	0	0	0	0	0	- -	- -	- -	0.0	0.0
Mukwonago 2	228	2	9	0	1	0	3	1	6	- -	- -	9.0	0.8
Mukwonago 2	230	3	25	8	3	0	0	0	0	- -	- -	25.0	2.1
Mukwonago 2	232	0	0	0	0	0	0	- -	- -	- -	- -	0.0	0.0
Mukwonago 2	233	2	0	0	0	2	3	0	2	- -	- -	3.0	0.3
Mukwonago 2	234	14	3	0	0	0	0	0	- -	- -	- -	14.0	1.2
Mukwonago 2	236	1	6	4	0	0	0	0	- -	- -	- -	6.0	0.5
Mukwonago 2	237	3	2	3	0	0	0	0	- -	- -	- -	3.0	0.3
Mukwonago 2	239	0	0	0	0	0	0	- -	- -	- -	- -	0.0	0.0
Mukwonago 2	241	3	0	2	0	0	0	0	- -	- -	- -	3.0	0.3
Mukwonago 2	243	0	0	0	0	0	0	0	- -	- -	- -	0.0	0.0
Mukwonago 2	244	0	0	0	0	0	0	0	- -	- -	- -	0.0	0.0
Mukwonago 2	245	3	1	2	2	0	0	0	- -	- -	- -	3.0	0.3

Table C-3 (continued)

Watershed and Reach	Transect Number (See Map C-1)	Sediment											
		Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Eagle Spring													
Mukwonago 3	246	38	17	21	24	33	40	15	- -	- -	- -	40.0	3.3
Mukwonago 3	247	0	45	35	18	49	- -	- -	- -	- -	- -	49.0	4.1
Mukwonago 3	248	17	38	29	39	53	47	0	- -	- -	- -	53.0	4.4
Mukwonago 3	249	0	0	0	0	0	0	- -	- -	- -	- -	0.0	0.0
Mukwonago 3	250	39	40	39	21	21	27	10	37	- -	- -	40.0	3.3
Mukwonago 3	251	0	0	16	13	11	0	0	- -	- -	- -	16.0	1.3
Mukwonago 3	252	31	28	7	5	9	17	2	25	37	- -	37.0	3.1
Mukwonago 3	253	34	29	28	11	13	17	26	31	- -	- -	34.0	2.8
Mukwonago 3	254	24	25	12	4	5	7	11	0	- -	- -	25.0	2.1
Mukwonago 3	255	0	22	21	8	9	10	10	0	- -	- -	22.0	1.8
Mukwonago 3	256	2	0	6	4	9	9	6	- -	- -	- -	9.0	0.8
Mukwonago 3	257	59	50	58	66	53	53	66	- -	- -	- -	66.0	5.5
Mukwonago 3	258	68	54	30	30	41	- -	- -	- -	- -	- -	68.0	5.7
Mukwonago 3	259	38	35	4	11	0	0	- -	- -	- -	- -	38.0	3.2
Mukwonago 3	260	0	0	14	17	13	- -	- -	- -	- -	- -	17.0	1.4
Mukwonago 3	262	0	32	31	20	0	0	39	62	- -	- -	62.0	5.2
Mukwonago 3	265	0	23	32	33	30	- -	- -	- -	- -	- -	33.0	2.8
Mukwonago 3	267	0	0	0	32	49	- -	- -	- -	- -	- -	49.0	4.1
Mukwonago 3	270	0	0	8	22	41	- -	- -	- -	- -	- -	41.0	3.4
Mukwonago 3	272	5	3	0	0	0	6	- -	- -	- -	- -	6.0	0.5
Mukwonago 3	273	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Mukwonago 3	274	24	5	3	2	4	- -	- -	- -	- -	- -	24.0	2.0
Mukwonago 3	275	21	13	0	0	0	- -	- -	- -	- -	- -	21.0	1.8
Mukwonago 3	277	30	1	0	0	0	- -	- -	- -	- -	- -	30.0	2.5
Mukwonago 3	279	12	0	4	14	- -	- -	- -	- -	- -	- -	14.0	1.2
Mukwonago 3	281	33	42	23	14	5	- -	- -	- -	- -	- -	42.0	3.5
Mukwonago 3	282	0	0	0	14	40	- -	- -	- -	- -	- -	40.0	3.3
Mukwonago 3	284	0	0	9	0	0	- -	- -	- -	- -	- -	9.0	0.8
Mukwonago 3	286	0	0	0	19	38	- -	- -	- -	- -	- -	38.0	3.2
Mukwonago 3	288	4	0	8	11	14	- -	- -	- -	- -	- -	14.0	1.2
Mukwonago 3	290	31	26	7	0	15	- -	- -	- -	- -	- -	31.0	2.6
Mukwonago 3	293	0	0	0	12	15	- -	- -	- -	- -	- -	15.0	1.3
Mukwonago 3	294	0	6	17	20	32	- -	- -	- -	- -	- -	32.0	2.7
Mukwonago 3	296	10	5	10	13	19	- -	- -	- -	- -	- -	19.0	1.6
Mukwonago 3	300	20	13	12	12	0	- -	- -	- -	- -	- -	20.0	1.7
Mukwonago 3	303	0	4	5	12	23	- -	- -	- -	- -	- -	23.0	1.9
Mukwonago 3	304	0	5	4	3	9	- -	- -	- -	- -	- -	9.0	0.8
Mukwonago 3	307	11	4	0	0	0	- -	- -	- -	- -	- -	11.0	0.9
Beulah													
Beulah	400	9	15	10	7	7	7	7	- -	- -	- -	15.0	1.3
Beulah	401	3	8	10	10	11	5	- -	- -	- -	- -	11.0	0.9
Beulah	407	4	0	5	10	4	6	10	- -	- -	- -	10.0	0.8
Beulah	409	0	0	2	6	9	0	0	- -	- -	- -	9.0	0.8
Beulah	411	0	37	44	26	3	0	0	8	0	- -	44.0	3.7
Beulah	412	0	0	8	7	7	24	10	- -	- -	- -	24.0	2.0
Beulah	413	5	27	20	0	0	0	0	0	13	- -	27.0	2.3
Beulah	414	3	3	4	0	3	3	3	9	- -	- -	9.0	0.8
Beulah	416	8	3	2	1	0	3	9	- -	- -	- -	9.0	0.8
Beulah	417	0	2	4	6	5	2	0	- -	- -	- -	6.0	0.5
Beulah	419	0	4	4	0	3	13	0	- -	- -	- -	13.0	1.1

Table C-3 (continued)

Watershed and Reach	Transect Number (See Map C-1)	Sediment											
		Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Beulah (continued)													
Beulah	420	4	0	0	0	5	3	0	- -	- -	- -	5.0	0.4
Beulah	421	9	3	0	0	0	5	0	0	- -	- -	9.0	0.8
Beulah	423	13	4	0	0	0	0	0	0	- -	- -	13.0	1.1
Beulah	424	0	0	0	0	0	0	0	0	- -	- -	0.0	0.0
Beulah	426	0	0	0	0	0	0	0	0	- -	- -	0.0	0.0
Beulah	427	0	0	0	0	0	0	0	- -	- -	- -	0.0	0.0
Beulah	428	0	0	0	0	0	0	- -	- -	- -	- -	0.0	0.0
Beulah	429	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Beulah	430	2	0	0	0	0	- -	- -	- -	- -	- -	2.0	0.2
Beulah	431	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Beulah	432	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Beulah	433	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Beulah	434	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho													
Jericho 1	500	4	6	4	2	0	- -	- -	- -	- -	- -	6.0	0.5
Jericho 1	502	1	3	4	3	8	- -	- -	- -	- -	- -	8.0	0.7
Jericho 1	504	1	0	0	0	0	- -	- -	- -	- -	- -	1.0	0.1
Jericho 1	506	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	508	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	509	3	2	0	3	2	- -	- -	- -	- -	- -	3.0	0.3
Jericho 1	511	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	512	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	513	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	514	1	0	0	0	0	- -	- -	- -	- -	- -	1.0	0.1
Jericho 1	515	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	516	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	517	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	518	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	519	0	9	0	9	10	- -	- -	- -	- -	- -	10.0	0.8
Jericho 1	520	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	523	0	0	1	3	11	- -	- -	- -	- -	- -	11.0	0.9
Jericho 1	524	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	525	0	0	2	0	0	- -	- -	- -	- -	- -	2.0	0.2
Jericho 1	526	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	527	1	0	0	0	0	- -	- -	- -	- -	- -	1.0	0.1
Jericho 1	528	0	0	3	3	0	- -	- -	- -	- -	- -	3.0	0.3
Jericho 1	530	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	531	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	533	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	535	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	537	0	0	0	0	2	- -	- -	- -	- -	- -	2.0	0.2
Jericho 1	539	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	542	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	544	0	2	0	3	10	- -	- -	- -	- -	- -	10.0	0.8
Jericho 1	546	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	547	2	1	0	0	3	- -	- -	- -	- -	- -	3.0	0.3
Jericho 1	550	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	552	2	0	0	0	2	- -	- -	- -	- -	- -	2.0	0.2
Jericho 1	555	2	3	0	3	0	- -	- -	- -	- -	- -	3.0	0.3

Table C-3 (continued)

Watershed and Reach	Transect Number (See Map C-1)	Sediment											
		Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Jericho (continued)													
Jericho 1	556	0	0	0	0	3	- -	- -	- -	- -	- -	3.0	0.3
Jericho 1	557	1	0	0	0	12	- -	- -	- -	- -	- -	12.0	1.0
Jericho 1	559	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	560	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	562	1	0	0	0	0	- -	- -	- -	- -	- -	1.0	0.1
Jericho 1	563	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	566	2	1	0	0	1	- -	- -	- -	- -	- -	2.0	0.2
Jericho 1	570	0	0	2	0	2	- -	- -	- -	- -	- -	2.0	0.2
Jericho 1	571	3	0	0	0	0	- -	- -	- -	- -	- -	3.0	0.3
Jericho 1	573	0	0	0	3	2	- -	- -	- -	- -	- -	3.0	0.3
Jericho 1	575	2	2	0	0	0	- -	- -	- -	- -	- -	2.0	0.2
Jericho 1	577	6	4	0	0	0	- -	- -	- -	- -	- -	6.0	0.5
Jericho 1	578	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	579	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	580	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	583	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	584	4	2	0	2	0	- -	- -	- -	- -	- -	4.0	0.3
Jericho 1	586	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	590	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	592	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	594	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	595	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	596	0	0	0	0	2	- -	- -	- -	- -	- -	2.0	0.2
Jericho 1	597	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	598	1	1	1	1	0	- -	- -	- -	- -	- -	1.0	0.1
Jericho 1	600	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	604	0	0	0	0	1	- -	- -	- -	- -	- -	1.0	0.1
Jericho 1	605	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 1	606	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	607	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	608	0	0	2	1	0	- -	- -	- -	- -	- -	2.0	0.2
Jericho 2	609	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	611	2	2	1	1	0	- -	- -	- -	- -	- -	2.0	0.2
Jericho 2	612	3	2	1	0	2	- -	- -	- -	- -	- -	3.0	0.3
Jericho 2	613	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	614	0	0	0	0	2	- -	- -	- -	- -	- -	2.0	0.2
Jericho 2	616	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	619	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	621	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	622	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	623	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	624	3	0	1	1	0	- -	- -	- -	- -	- -	3.0	0.3
Jericho 2	625	0	0	0	0	3	- -	- -	- -	- -	- -	3.0	0.3
Jericho 2	626	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	628	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	631	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	634	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	635	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	638	4	8	2	10	5	- -	- -	- -	- -	- -	10.0	0.8

Table C-3 (continued)

Watershed and Reach	Transect Number (See Map C-1)	Sediment											
		Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Jericho (continued)													
Jericho 2	640	6	0	0	3	0	- -	- -	- -	- -	- -	6.0	0.5
Jericho 2	641	0	3	4	7	9	- -	- -	- -	- -	- -	9.0	0.8
Jericho 2	644	6	9	0	1	7	- -	- -	- -	- -	- -	9.0	0.8
Jericho 2	645	3	5	10	11	7	- -	- -	- -	- -	- -	11.0	0.9
Jericho 2	648	10	11	0	0	0	- -	- -	- -	- -	- -	11.0	0.9
Jericho 2	650	1	0	0	0	5	- -	- -	- -	- -	- -	5.0	0.4
Jericho 2	652	5	10	8	3	10	- -	- -	- -	- -	- -	10.0	0.8
Jericho 2	653	0	0	1	1	5	- -	- -	- -	- -	- -	5.0	0.4
Jericho 2	656	8	1	0	0	0	- -	- -	- -	- -	- -	8.0	0.7
Jericho 2	657	1	2	0	0	3	- -	- -	- -	- -	- -	3.0	0.3
Jericho 2	658	5	1	0	2	0	- -	- -	- -	- -	- -	5.0	0.4
Jericho 2	659	10	0	0	0	0	- -	- -	- -	- -	- -	10.0	0.8
Jericho 2	660	16	16	16	12	19	- -	- -	- -	- -	- -	19.0	1.6
Jericho 2	661	19	12	8	6	7	- -	- -	- -	- -	- -	19.0	1.6
Jericho 2	662	0	0	0	3	11	- -	- -	- -	- -	- -	11.0	0.9
Jericho 2	663	0	0	0	7	14	- -	- -	- -	- -	- -	14.0	1.2
Jericho 2	665	0	0	0	5	0	- -	- -	- -	- -	- -	5.0	0.4
Jericho 2	666	0	4	13			- -	- -	- -	- -	- -	13.0	1.1
Jericho 2	670	2	12	4	7	2	- -	- -	- -	- -	- -	12.0	1.0
Jericho 2	671	2	1	4	7	6	- -	- -	- -	- -	- -	7.0	0.6
Jericho 2	672	3	5	12	4	3	- -	- -	- -	- -	- -	12.0	1.0
Jericho 2	674	5	6	0	0	3	- -	- -	- -	- -	- -	6.0	0.5
Jericho 2	678	2	1	0	0	0	- -	- -	- -	- -	- -	2.0	0.2
Jericho 2	681	3	3	3	6	8	- -	- -	- -	- -	- -	8.0	0.7
Jericho 2	684	0	0	8	11	4	- -	- -	- -	- -	- -	11.0	0.9
Jericho 2	685	4	5	2	- -	- -	- -	- -	- -	- -	- -	5.0	0.4
Jericho 2	686	0	0	0	- -	- -	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	689	0	0	0	- -	- -	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	690	0	0	0	- -	- -	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	691	0	0	0	- -	- -	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	691	0	2	0	- -	- -	- -	- -	- -	- -	- -	2.0	0.2
Jericho 2	692	3	2	1	- -	- -	- -	- -	- -	- -	- -	3.0	0.3
Jericho 2	694	5	0	0	- -	- -	- -	- -	- -	- -	- -	5.0	0.4
Jericho 2	695	0	0	0	- -	- -	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	696	0	0	0	- -	- -	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	698	1	2	0	- -	- -	- -	- -	- -	- -	- -	2.0	0.2
Jericho 2	700	2	0	0	- -	- -	- -	- -	- -	- -	- -	2.0	0.2
Jericho 2	701	0	0	0	- -	- -	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	703	6	2	0	- -	- -	- -	- -	- -	- -	- -	6.0	0.5
Jericho 2	705	2	0	0	0	0	- -	- -	- -	- -	- -	2.0	0.2
Jericho 2	706	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	707	2	0	0	0	9	- -	- -	- -	- -	- -	9.0	0.8
Jericho 2	709	0	0	0	- -	- -	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	710	0	0	0	- -	- -	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	711	0	0	0	- -	- -	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	713	11	4	1	0	0	- -	- -	- -	- -	- -	11.0	0.9
Jericho 2	715	0	1	9	- -	- -	- -	- -	- -	- -	- -	9.0	0.8
Jericho 2	716.1	1	0	2	- -	- -	- -	- -	- -	- -	- -	2.0	0.2
Jericho 2	718	6	3	4	1	9	- -	- -	- -	- -	- -	9.0	0.8
Jericho 2	719	0	0	0	0	1	- -	- -	- -	- -	- -	1.0	0.1

Table C-3 (continued)

Watershed and Reach	Transect Number (See Map C-1)	Sediment Depth-1 (inches)	Depth-2 (inches)	Depth-3 (inches)	Depth-4 (inches)	Depth-5 (inches)	Depth-6 (inches)	Depth-7 (inches)	Depth-8 (inches)	Depth-9 (inches)	Depth-10 (inches)	Maximum Depth (feet)	Mean Depth (feet)
Jericho (continued)													
Jericho 2	721	9	2	0	0	5	- -	- -	- -	- -	- -	9.0	0.8
Jericho 2	722	16	6	16	12	3	- -	- -	- -	- -	- -	16.0	1.3
Jericho 2	723	0	0	2	3	6	- -	- -	- -	- -	- -	6.0	0.5
Jericho 2	723	11	0	0	0	2	- -	- -	- -	- -	- -	11.0	0.9
Jericho 2	724	4	2	7	5	1	- -	- -	- -	- -	- -	7.0	0.6
Jericho 2	725	10	0	0	2	3	- -	- -	- -	- -	- -	10.0	0.8
Jericho 2	726	1	2	1	0	1	- -	- -	- -	- -	- -	2.0	0.2
Jericho 2	727	0	0	2	0	1	- -	- -	- -	- -	- -	2.0	0.2
Jericho 2	728	0	1	0	0	0	- -	- -	- -	- -	- -	1.0	0.1
Jericho 2	729	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	730	7	18	12.5	- -	- -	- -	- -	- -	- -	- -	18.0	1.5
Jericho 2	731	26	27	14	4	- -	- -	- -	- -	- -	- -	27.0	2.3
Jericho 2	732	23	29	28	19	9	- -	- -	- -	- -	- -	29.0	2.4
Jericho 2	733	1	0	5	0	1	- -	- -	- -	- -	- -	5.0	0.4
Jericho 2	734	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	735	3	2	3	3	1	- -	- -	- -	- -	- -	3.0	0.3
Jericho 2	736	1	7	9	13	9	- -	- -	- -	- -	- -	13.0	1.1
Jericho 2	737	4	5	4	7	3	- -	- -	- -	- -	- -	7.0	0.6
Jericho 2	738	0	0	0	1	0	- -	- -	- -	- -	- -	1.0	0.1
Jericho 2	739	5	0	0	0	0	- -	- -	- -	- -	- -	5.0	0.4
Jericho 2	740	0	0	0	- -	- -	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	741	0	0	0	0	0	- -	- -	- -	- -	- -	0.0	0.0
Jericho 2	742	0	0	0	0	4	- -	- -	- -	- -	- -	4.0	0.3
Jericho 2	743	2	0	0	3	0	- -	- -	- -	- -	- -	3.0	0.3
Jericho 2	744	3	3	1	3	1	- -	- -	- -	- -	- -	3.0	0.3
Jericho 2	745	4	12	3	2	0	- -	- -	- -	- -	- -	12.0	1.0

NOTE: The number of points taken within a cross-section was dependent upon stream width. In general, if wetted width was less than 10 feet, only three points per transect were taken; for widths ranging from 10 to 75 feet, five to 10 points per transect were taken; and where width was greater than 75 feet, 10 points per transect were taken.

Source: SEWRPC.

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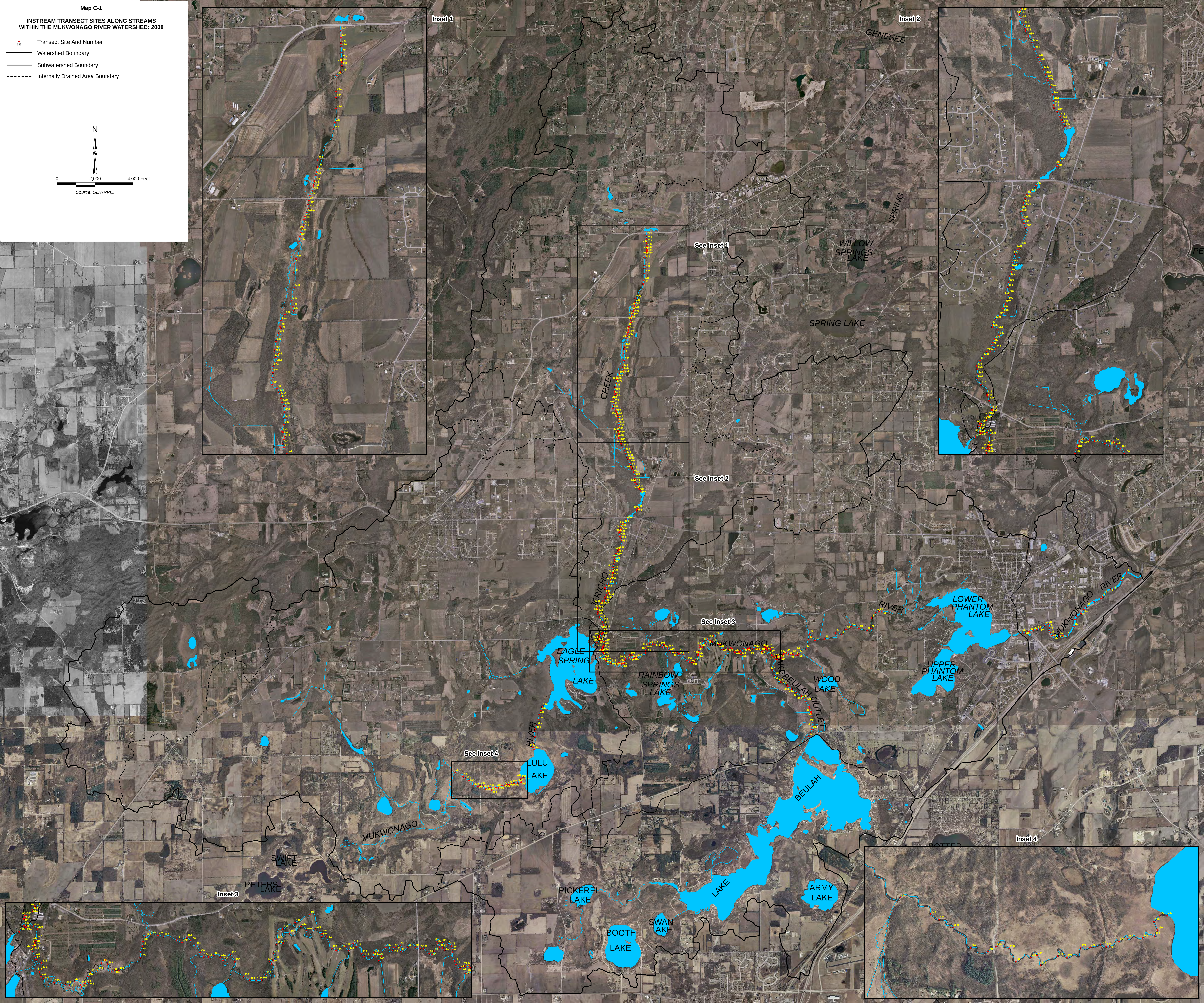
Map C-1

INSTREAM TRANSECT SITES ALONG STREAMS WITHIN THE MUKWONAGO RIVER WATERSHED: 2008



Source: SEWRPC.

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Appendix D

SUMMER MAXIMUM DAILY WATER TEMPERATURES AMONG SAMPLING SITES AND TROUT TOLERANCE ASSESSMENT WITHIN THE MUKWONAGO RIVER WATERSHED: 2007-2009

The temperature ranges shown for trout daily maximum summer temperatures tolerances are from K.E. Wehrly, L. Wang, and M. Mitro, "Field-Based Estimates of Thermal Tolerance Limits for Trout: Incorporating Exposure Time and Temperature Fluctuation," Transactions of the American Fisheries Society, Vol. 139, Pages 365-374, 2007.

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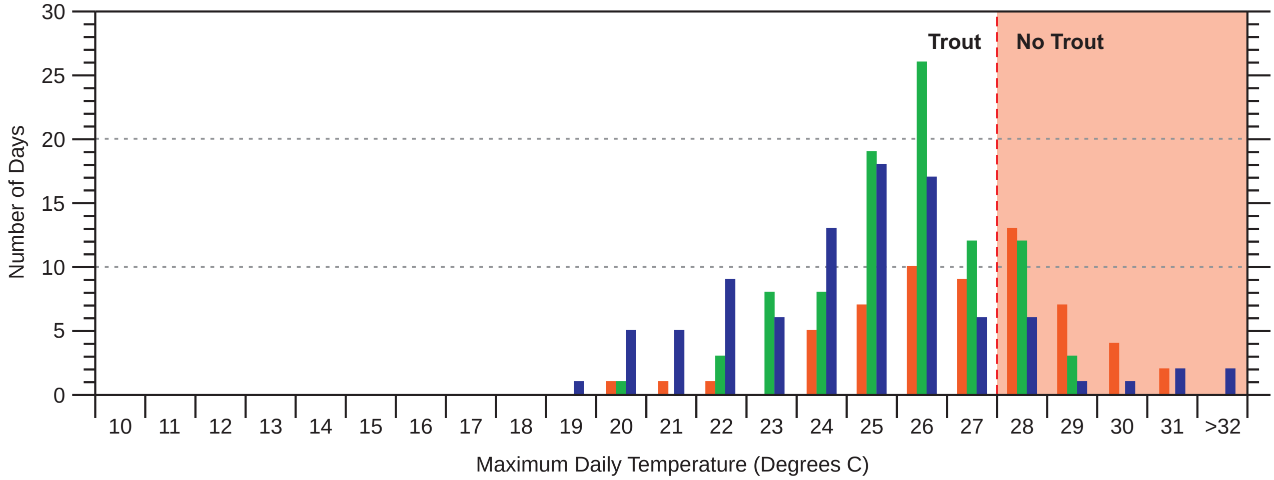
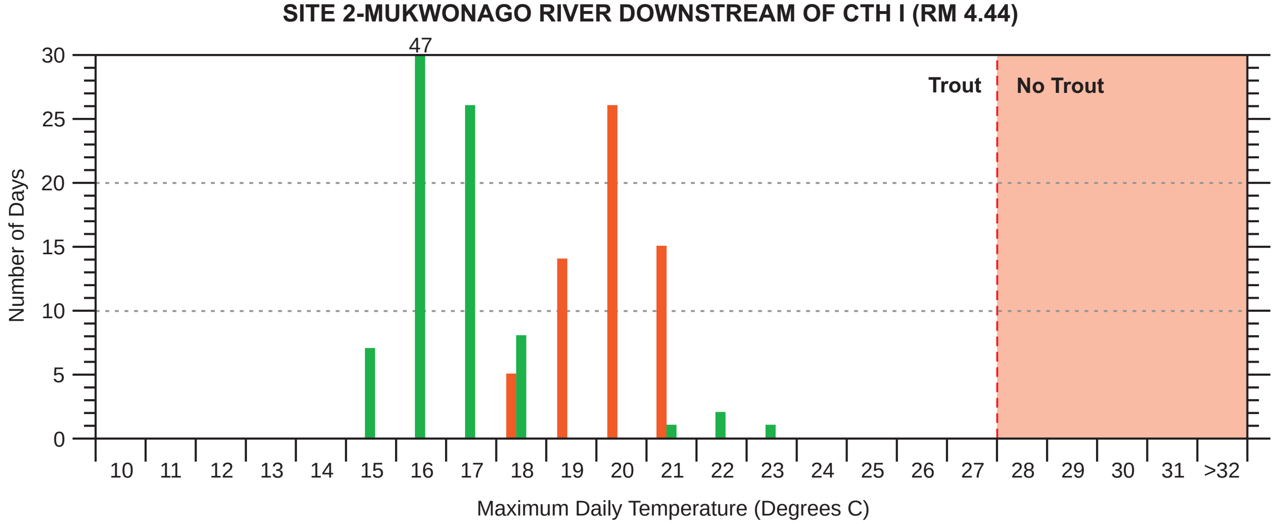
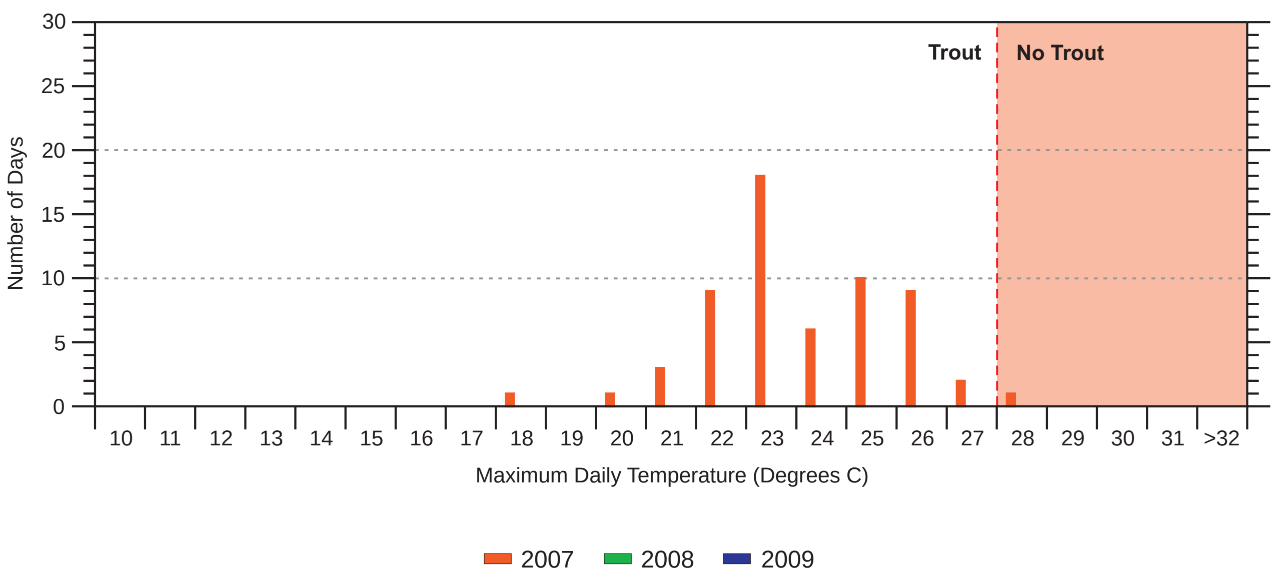
SITE 1-MUKWONAGO RIVER DOWNSTREAM OF STH 83 (RM 1.89)



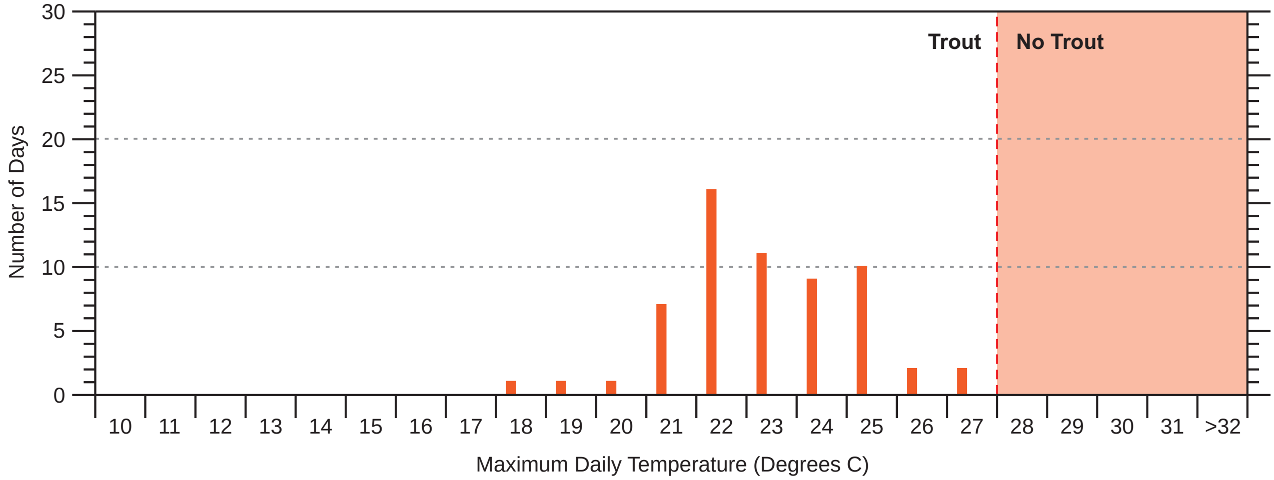
SITE 2-MUKWONAGO RIVER DOWNSTREAM OF CTH I (RM 4.44)



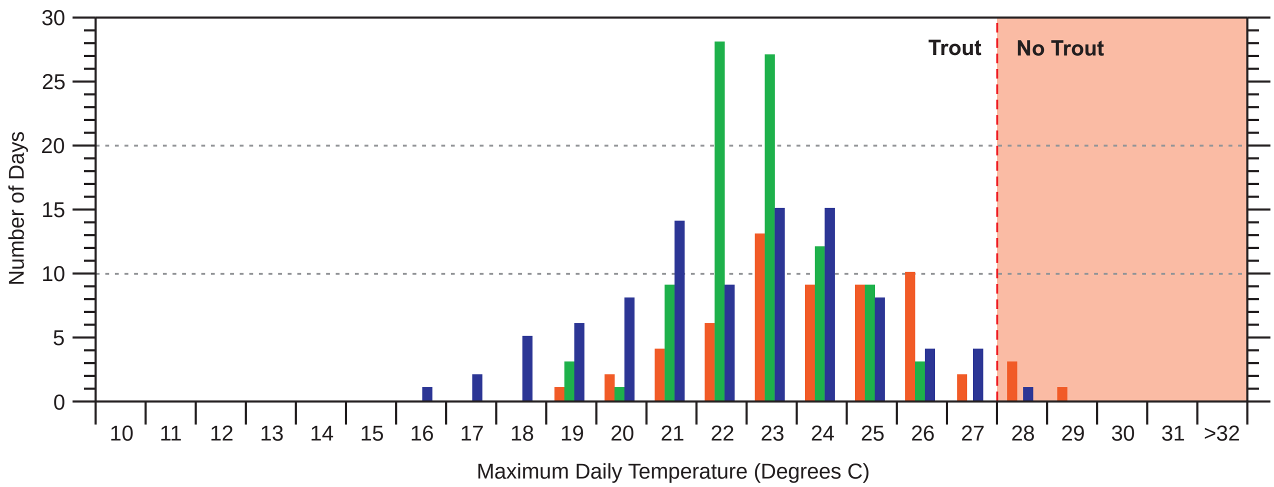
SITE 3-MUKWONAGO RIVER DOWNSTREAM OF LAKE BEULAH OUTLET (RM 6.30)



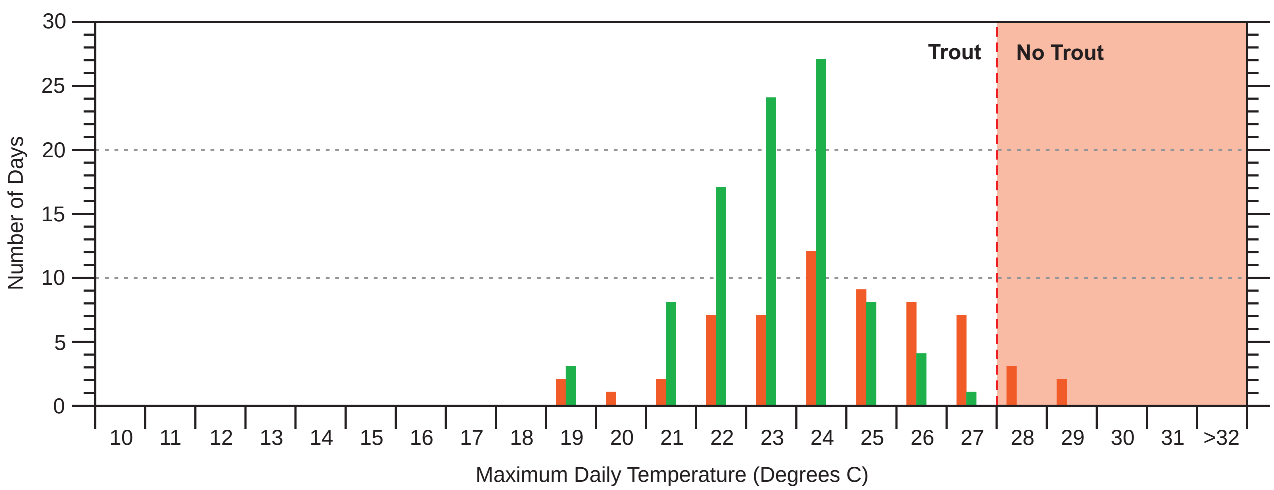
SITE 4-MUKWONAGO RIVER UPSTREAM OF LAKE BEULAH OUTLET (RM 6.42)



SITE 5-MUKWONAGO RIVER DOWNSTREAM OF BEULAH ROAD (RM 6.84)

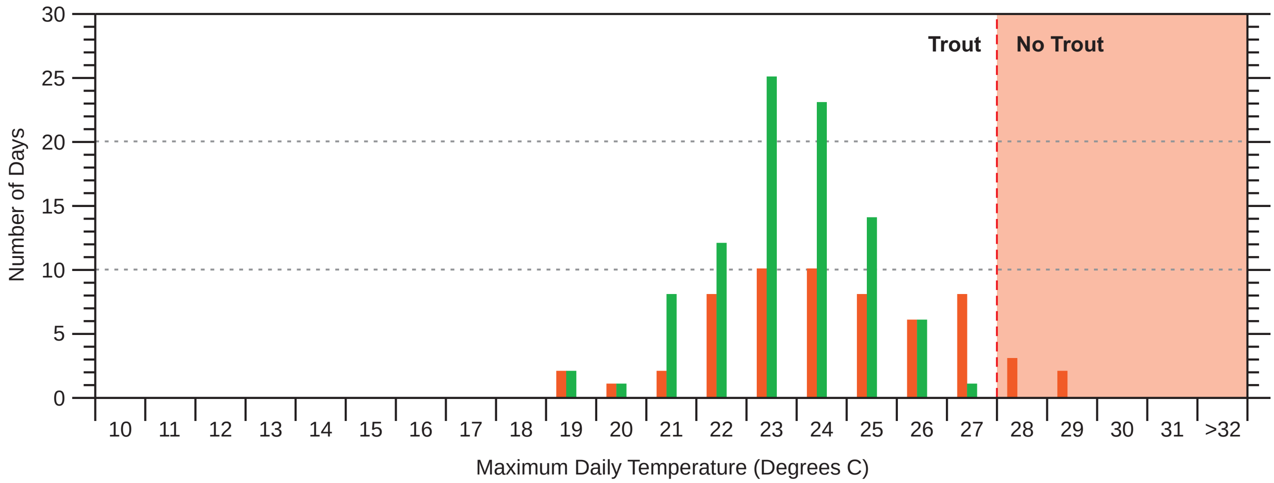


SITE 6-MUKWONAGO RIVER DOWNSTREAM OF GOLF COURSE TRIBUTARY (RM 7.56)

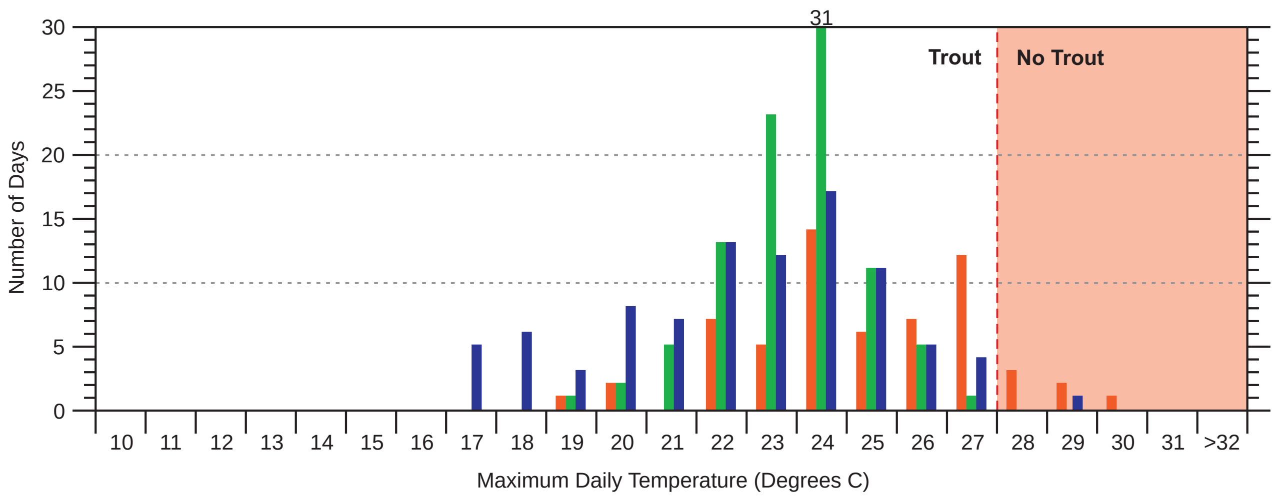


2007 2008 2009

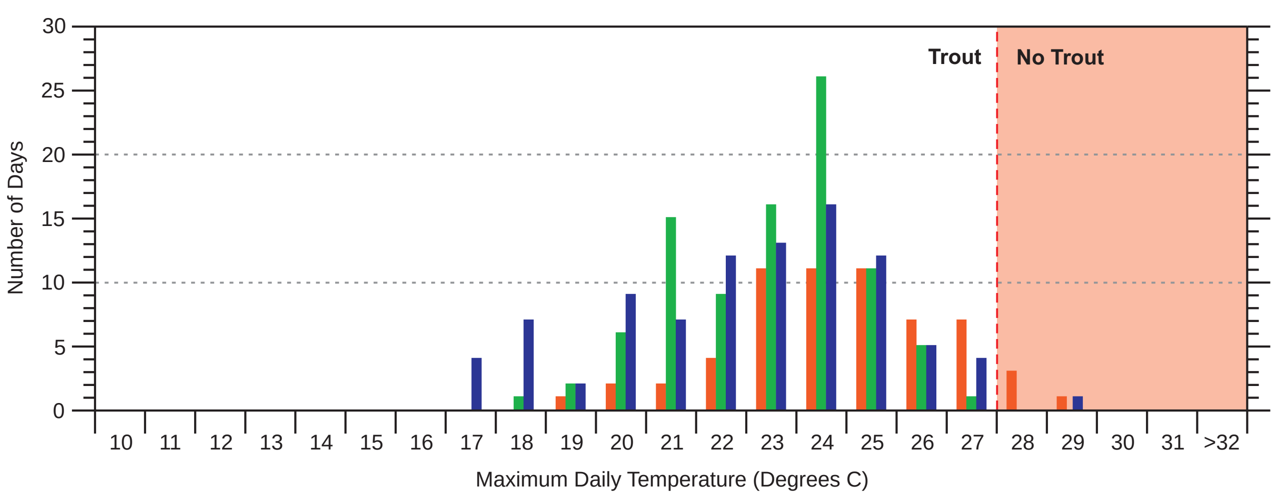
SITE 7-MUKWONAGO RIVER UPSTREAM OF GOLF COURSE TRIBUTARY (RM 7.61)

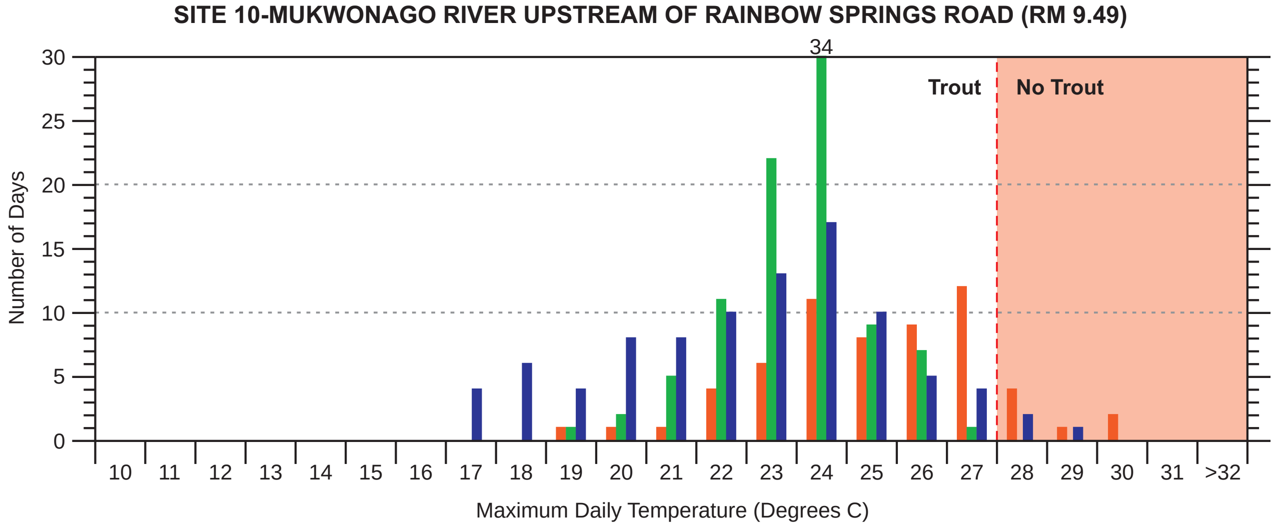


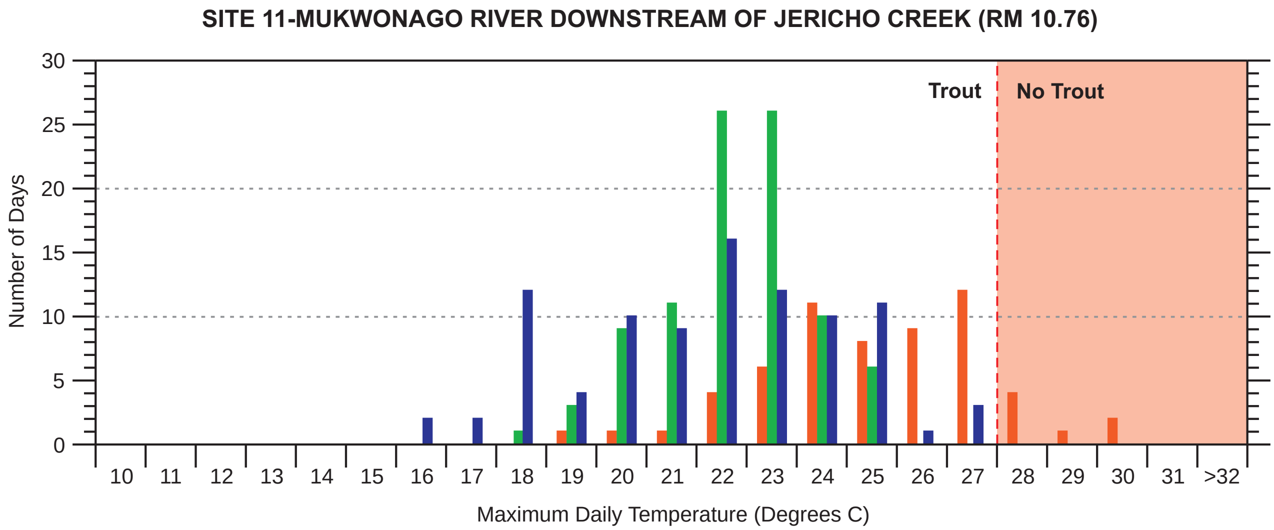
SITE 8-MUKWONAGO RIVER DOWNSTREAM OF RAINBOW SPRINGS LAKE OUTLET (RM 8.69)

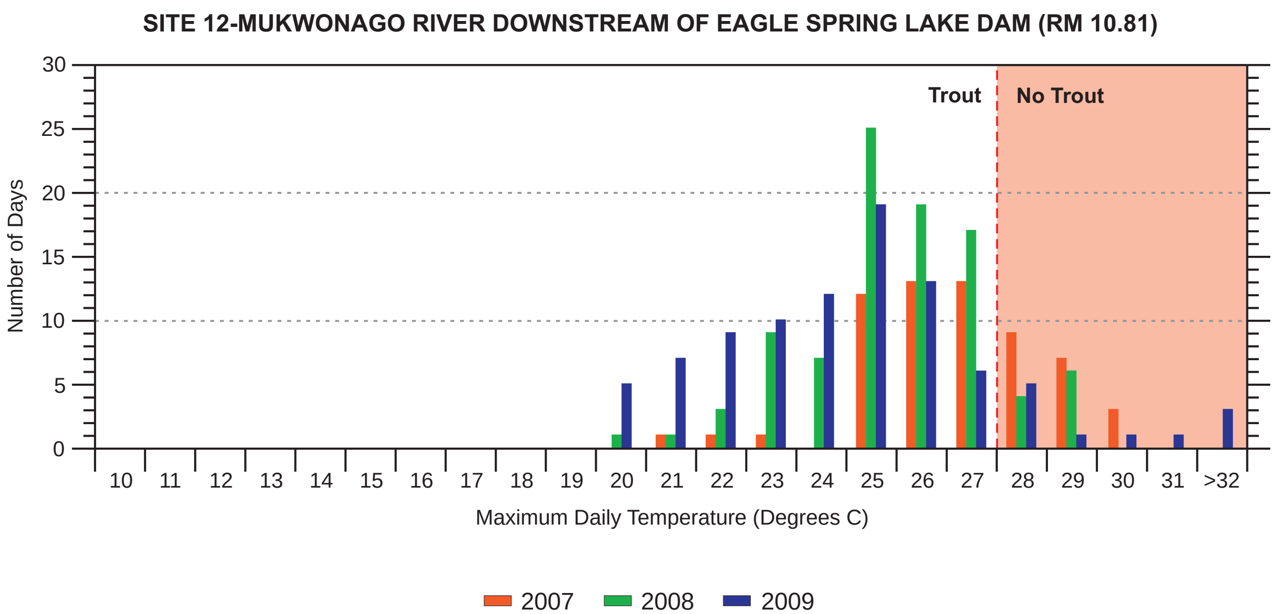


SITE 9-MUKWONAGO RIVER UPSTREAM OF RAINBOW SPRINGS LAKE OUTLET (RM 8.85)

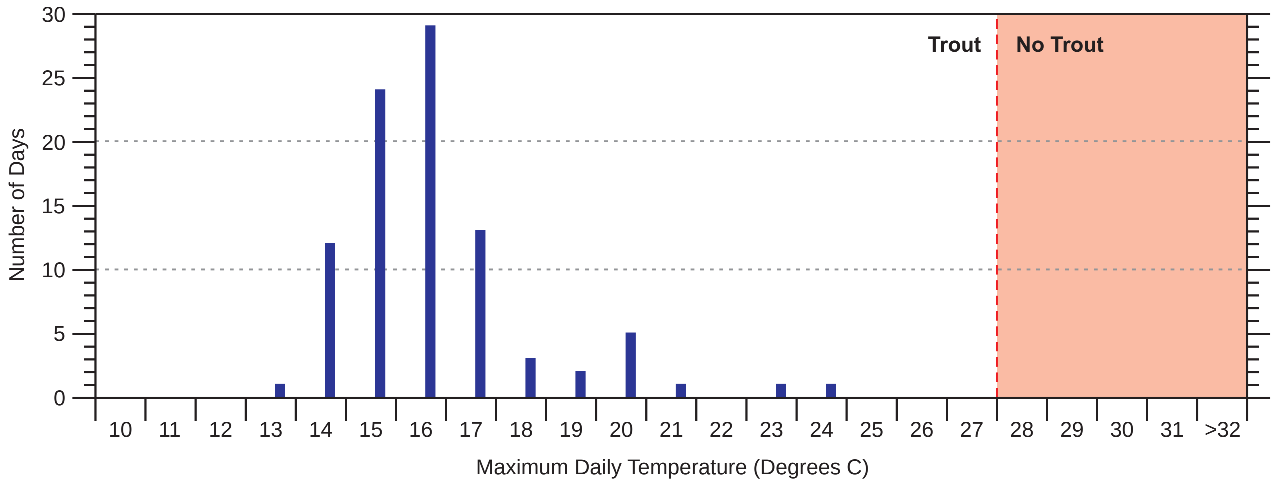



SITE 10-MUKWONAGO RIVER UPSTREAM OF RAINBOW SPRINGS ROAD (RM 9.49)
34
Trout
No Trout
Number of Days
Maximum Daily Temperature (Degrees C)

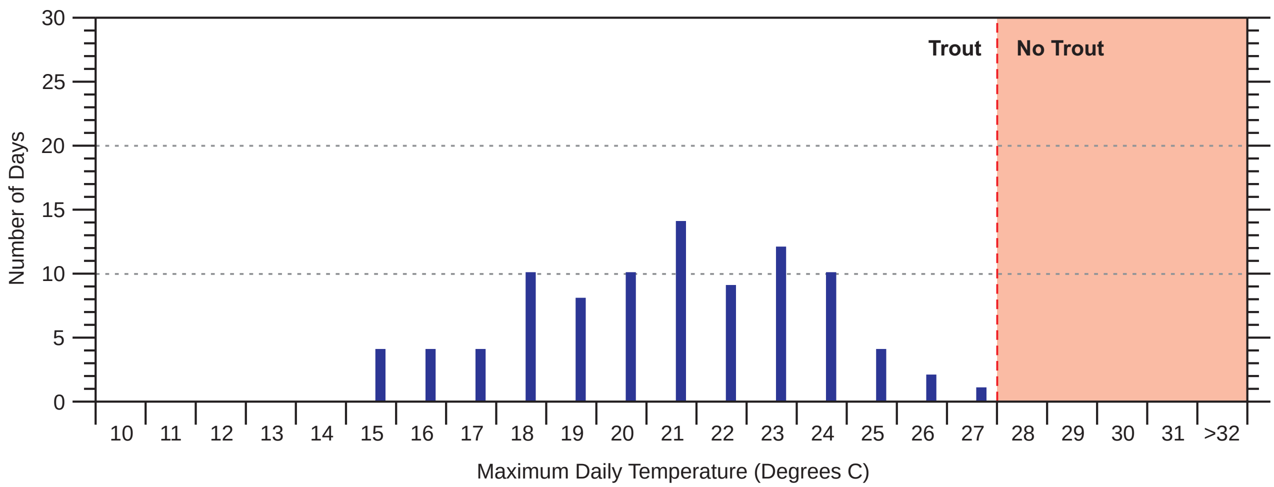

SITE 11-MUKWONAGO RIVER DOWNSTREAM OF JERICHO CREEK (RM 10.76)
Trout
No Trout
Number of Days
Maximum Daily Temperature (Degrees C)


SITE 12-MUKWONAGO RIVER DOWNSTREAM OF EAGLE SPRING LAKE DAM (RM 10.81)
Trout
No Trout
Number of Days
Maximum Daily Temperature (Degrees C)
2007
2008
2009

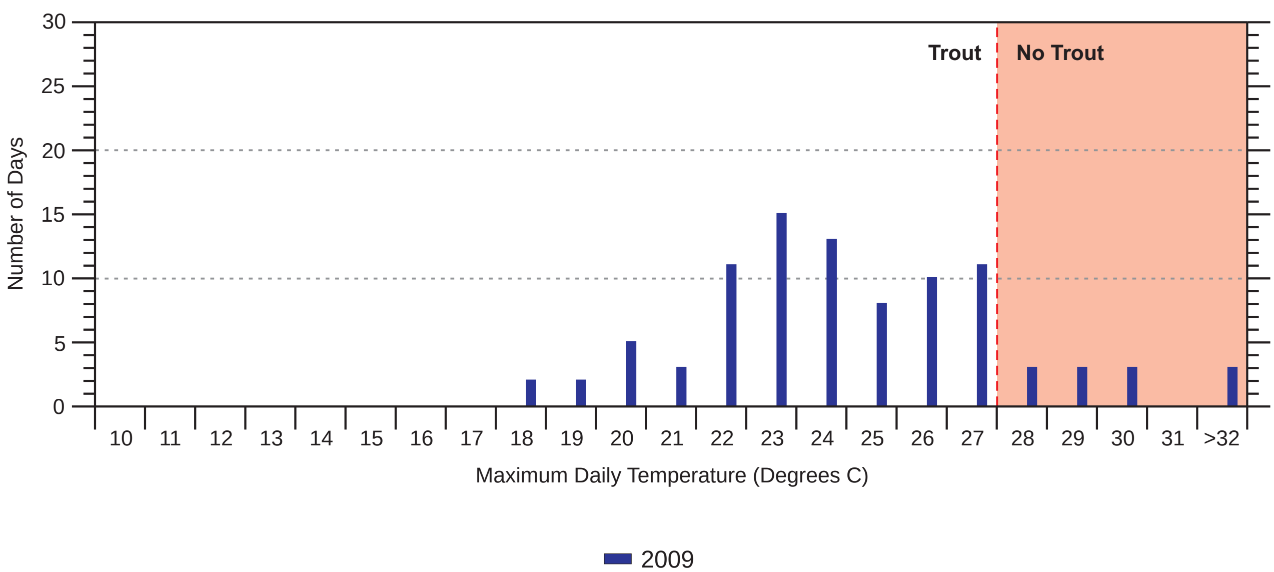
SITE 13-MUKWONAGO RIVER UPSTREAM OF CTH I (RM 5.01)



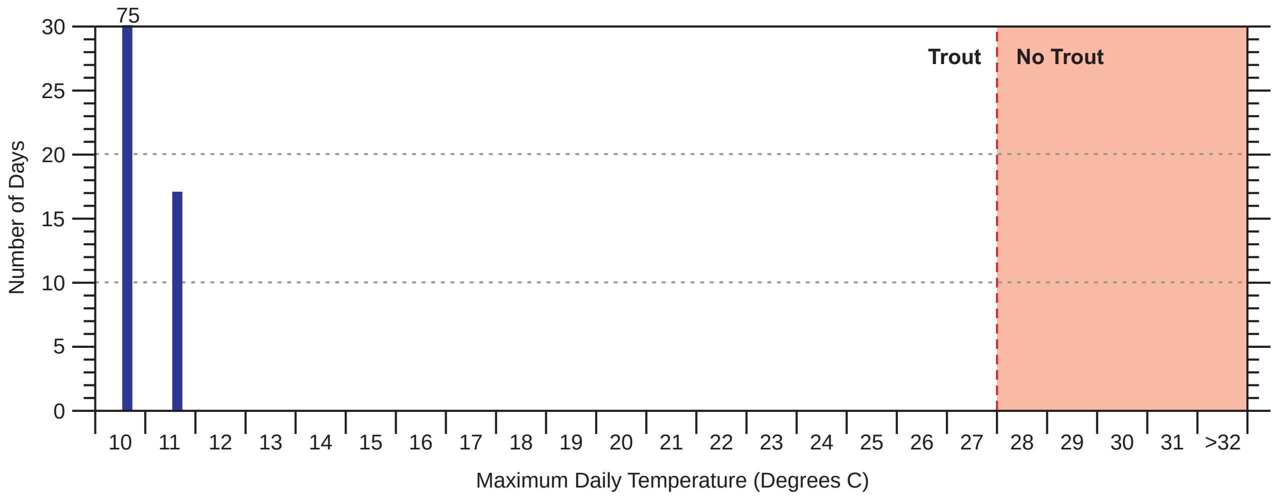
SITE 14-MUKWONAGO RIVER UPSTREAM OF CTH I (HAIRPIN TURN) (RM 5.72)



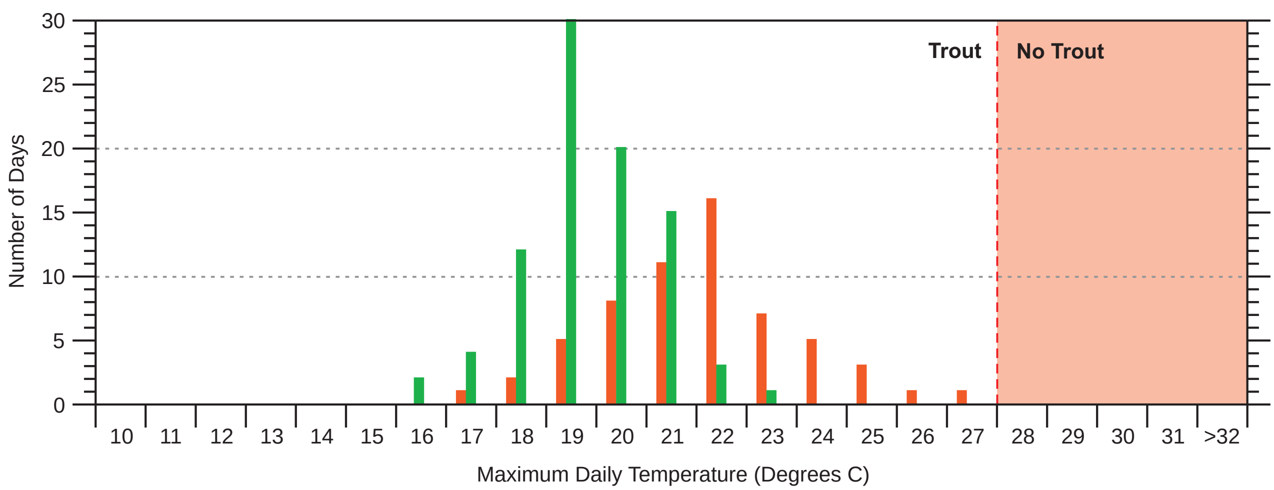
SITE 15-MUKWONAGO RIVER AT WOOD LAKE TRIBUTARY (RM 6.02)



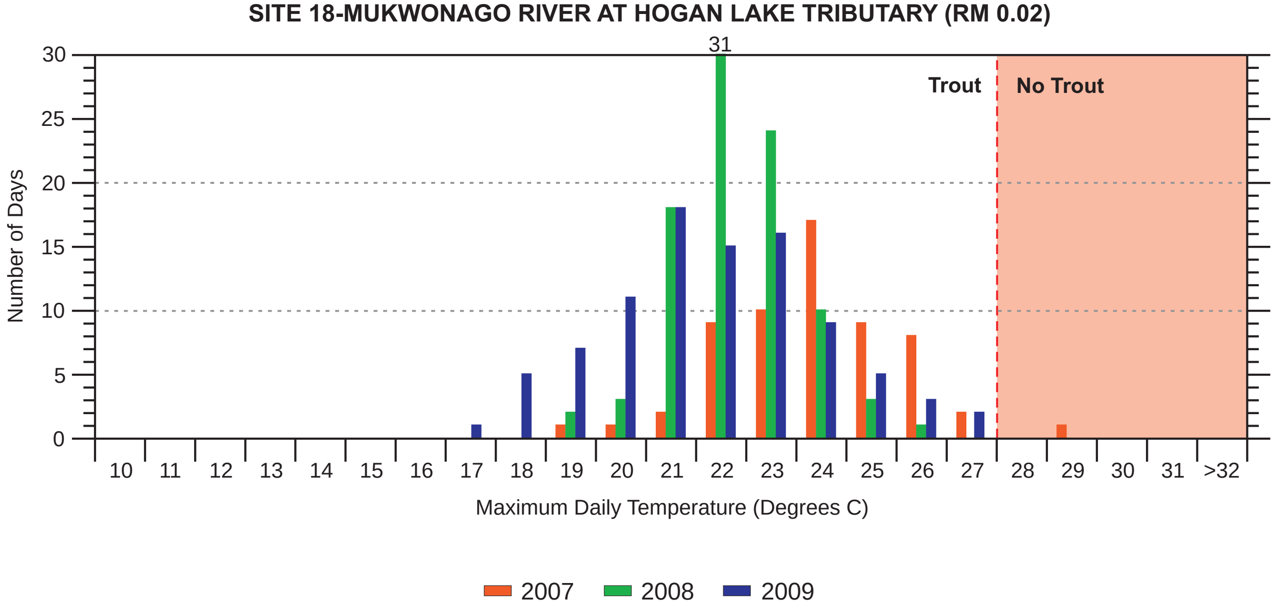
SITE 16-MUKWONAGO RIVER DOWNSTREAM OF BEULAH ROAD (RM 0.08)



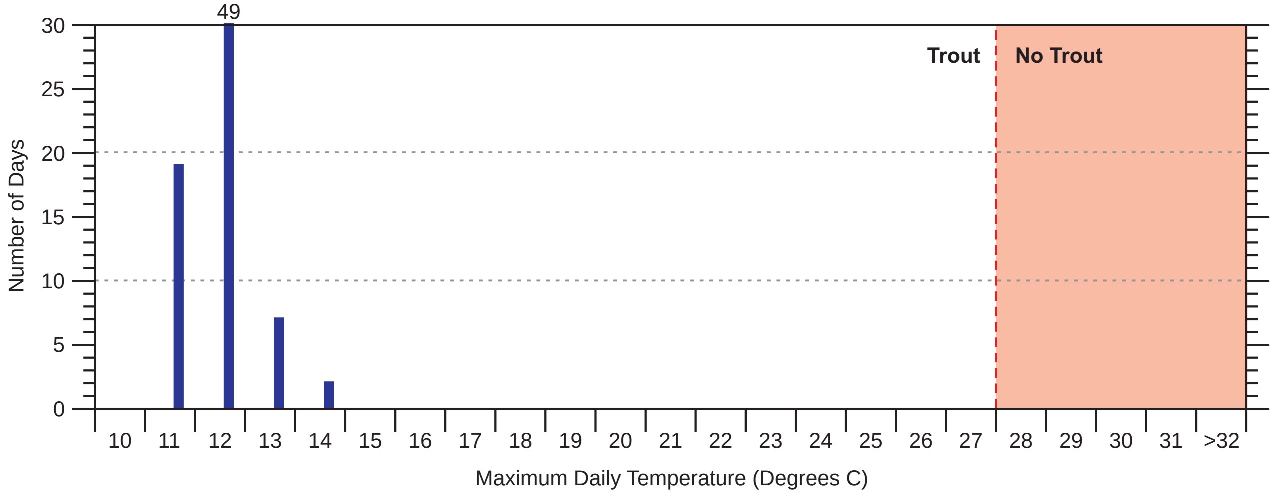
SITE 17-MUKWONAGO RIVER AT GOLF COURSE TRIBUTARY (RM 0.02)



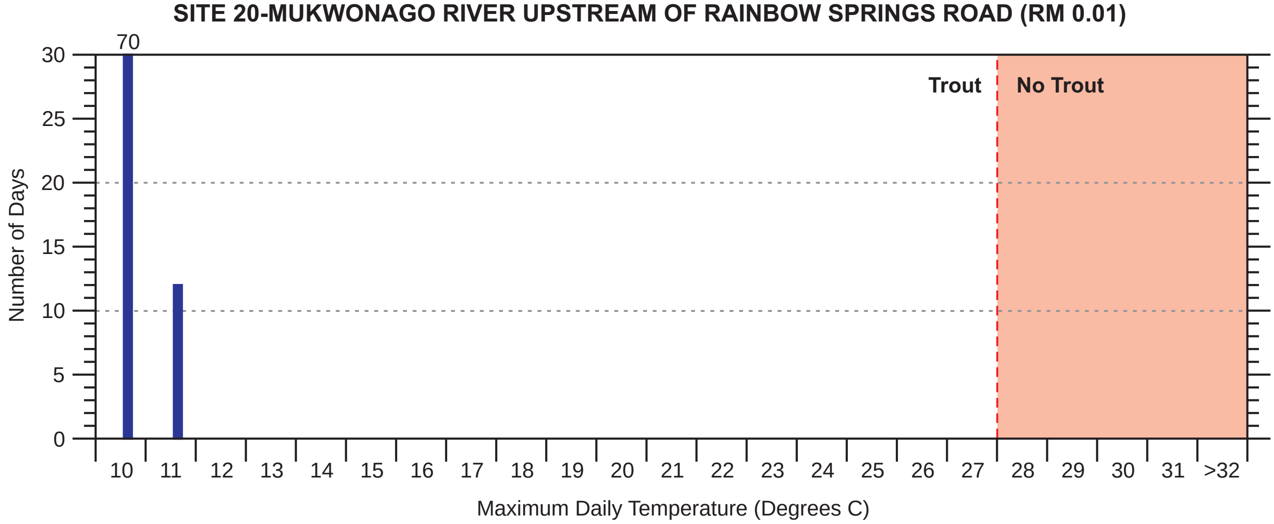
SITE 18-MUKWONAGO RIVER AT HOGAN LAKE TRIBUTARY (RM 0.02)



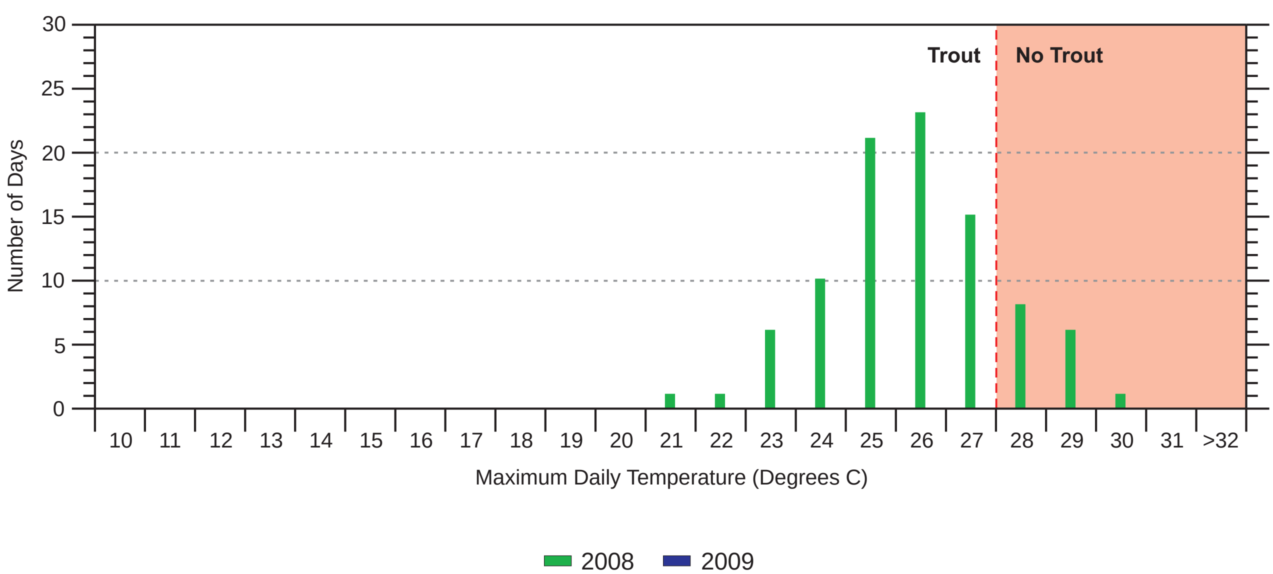
SITE 19-MUKWONAGO RIVER DOWNSTREAM OF RAINBOW SPRINGS ROAD (RM 9.14)



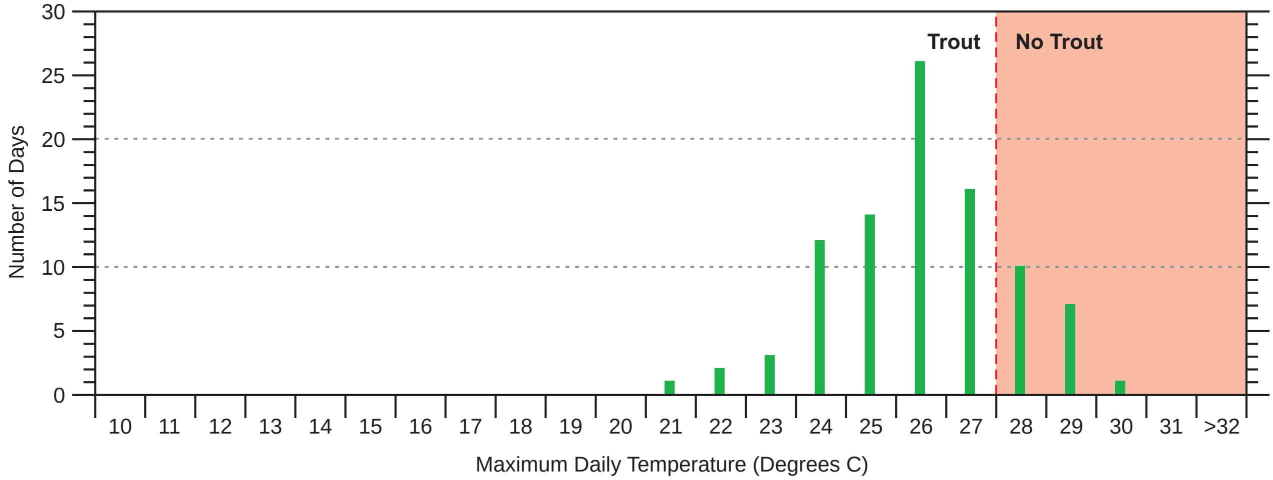
SITE 20-MUKWONAGO RIVER UPSTREAM OF RAINBOW SPRINGS ROAD (RM 0.01)



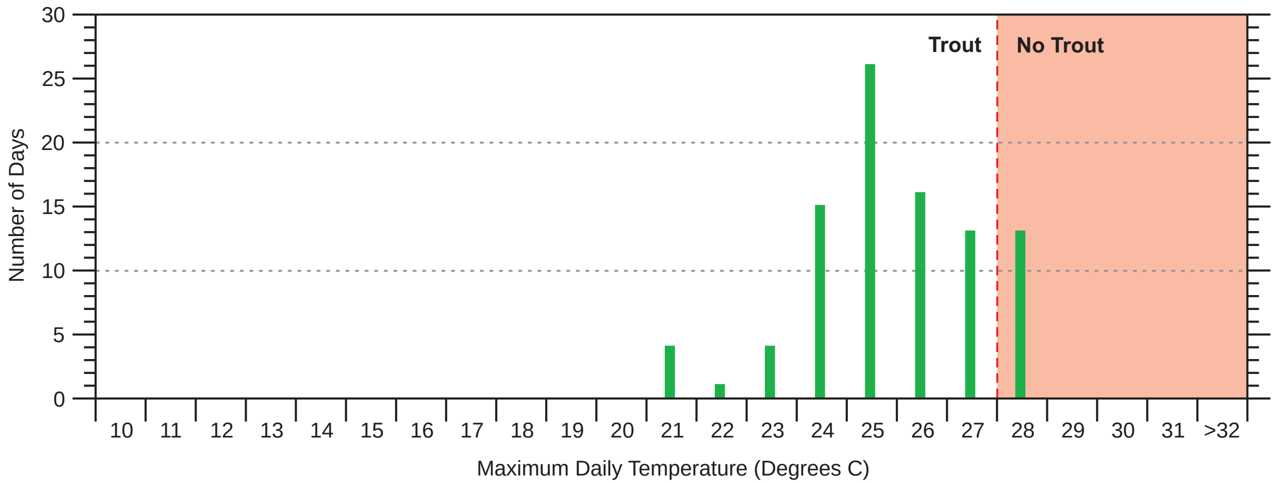
SITE 21-EAGLE SPRING LAKE AT WDNR BOAT LAUNCH (SURFACE)



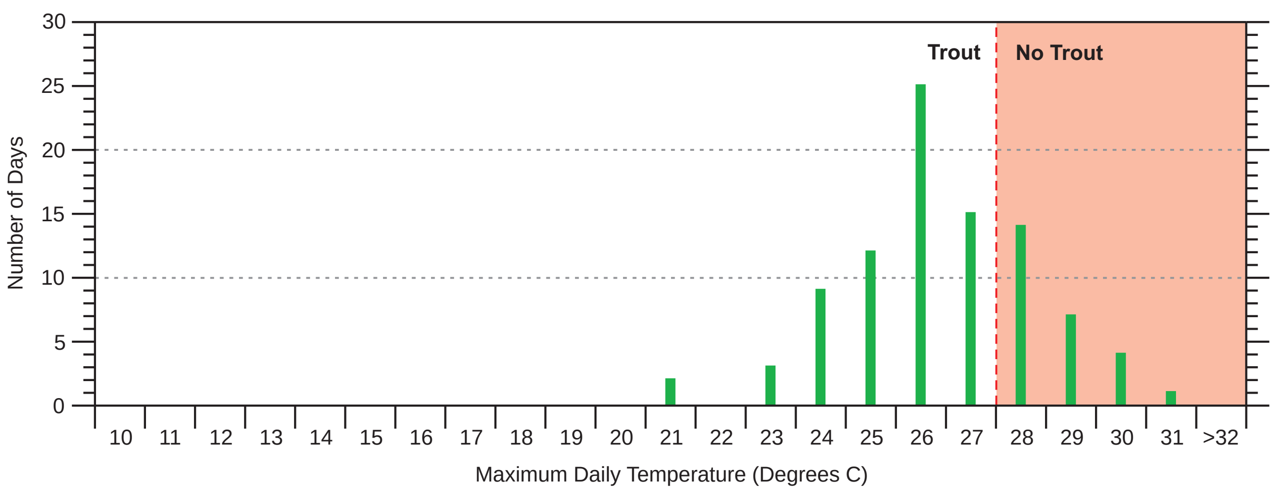
SITE 22-EAGLE SPRING LAKE AT KROLL DAM BAY (SURFACE)



SITE 22-EAGLE SPRING LAKE AT KROLL DAM BAY (DEEP)



SITE 23-EAGLE SPRING LAKE AT JACK'S BAY (SURFACE)



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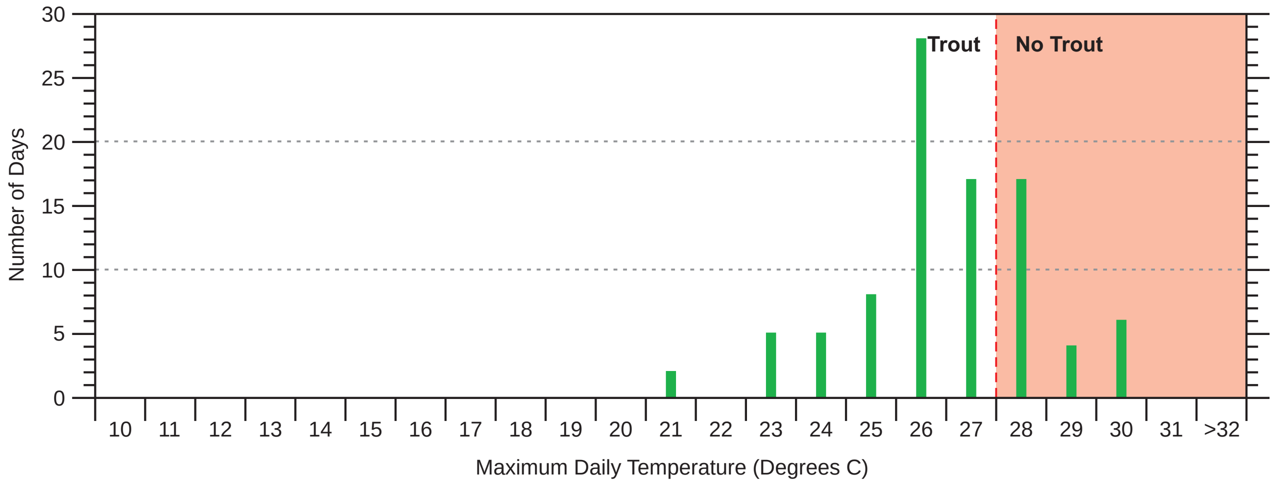
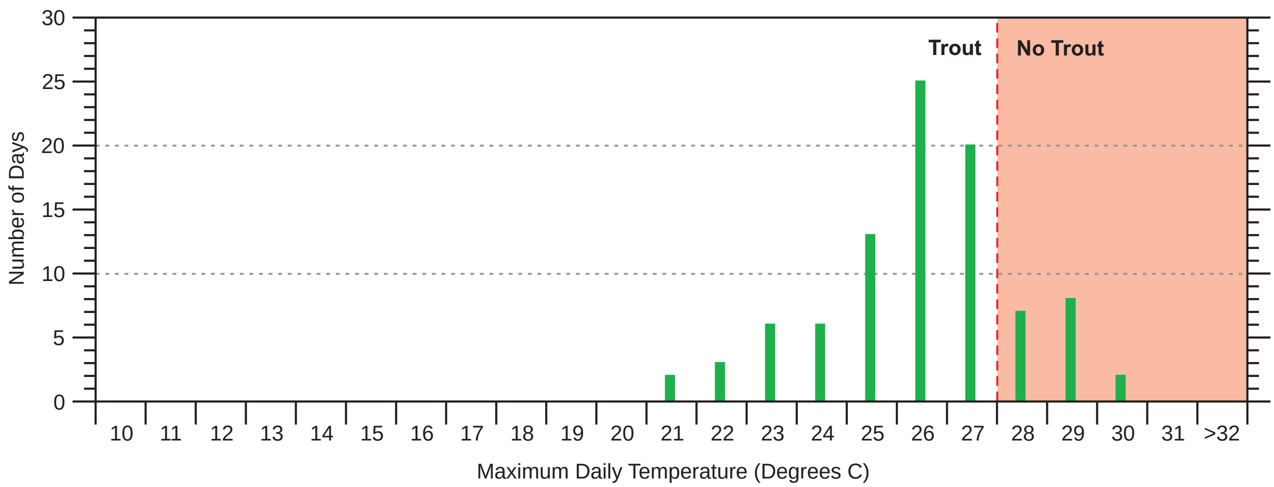
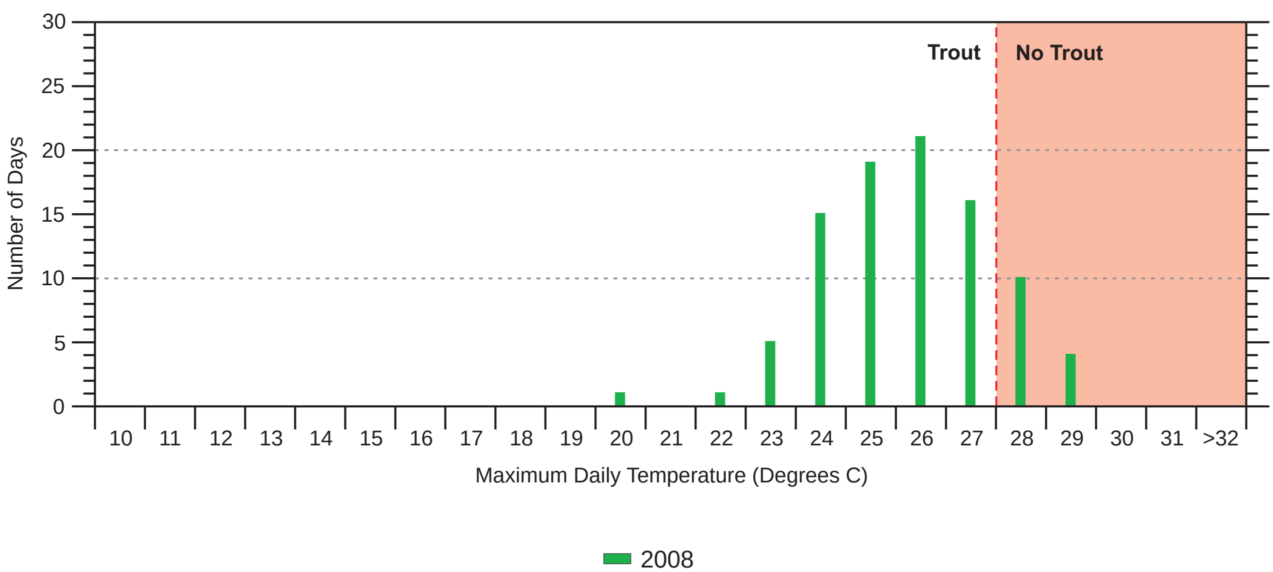
SITE 24-EAGLE SPRING LAKE AT MARY'S BAY (SURFACE)



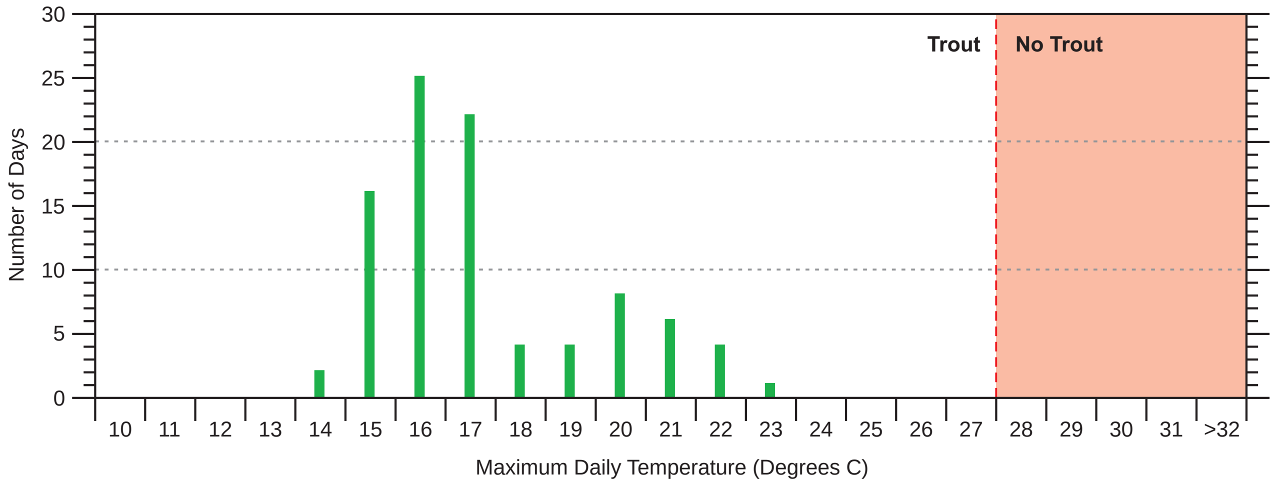
SITE 25-EAGLE SPRING LAKE AT INLET FROM LULU LAKE (SURFACE)



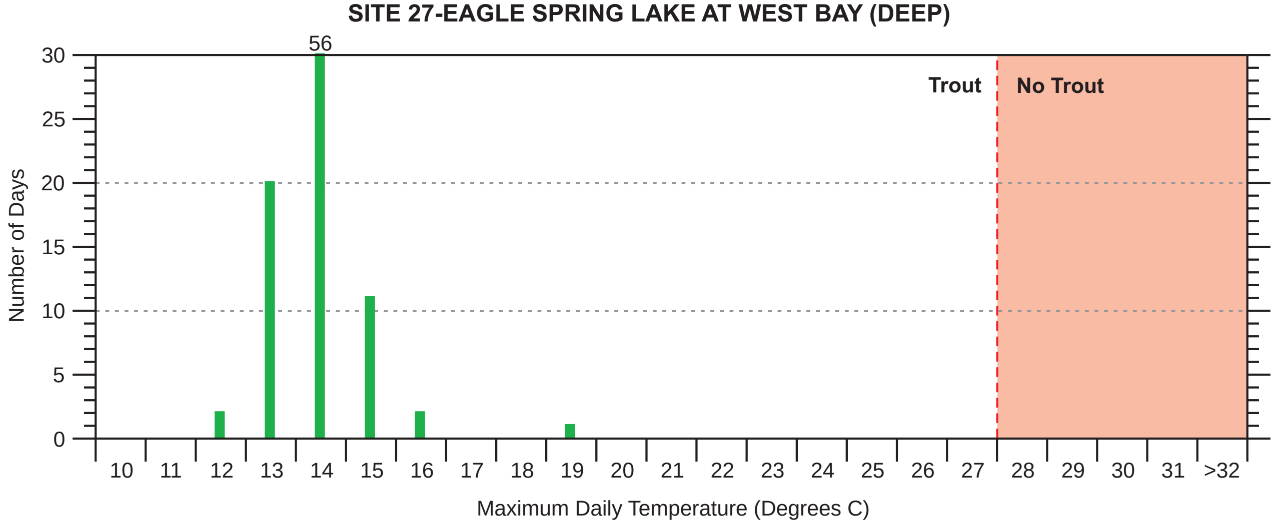
SITE 26-EAGLE SPRING LAKE AT WATERSKI CHANNEL (SURFACE)



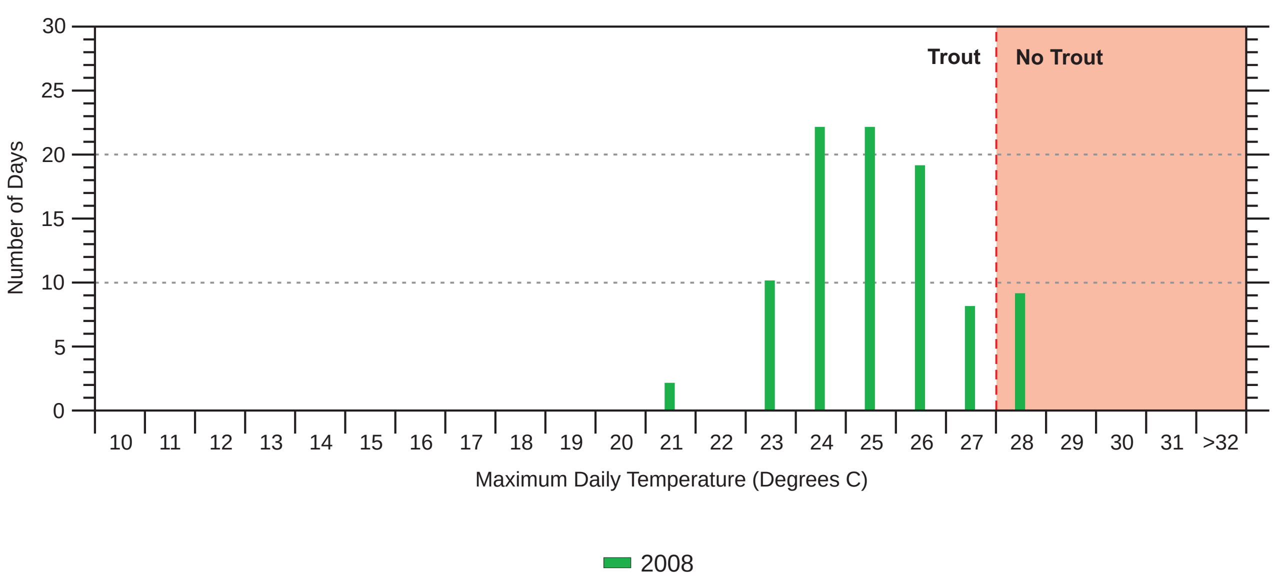
SITE 27-EAGLE SPRING LAKE AT WEST BAY (SURFACE)



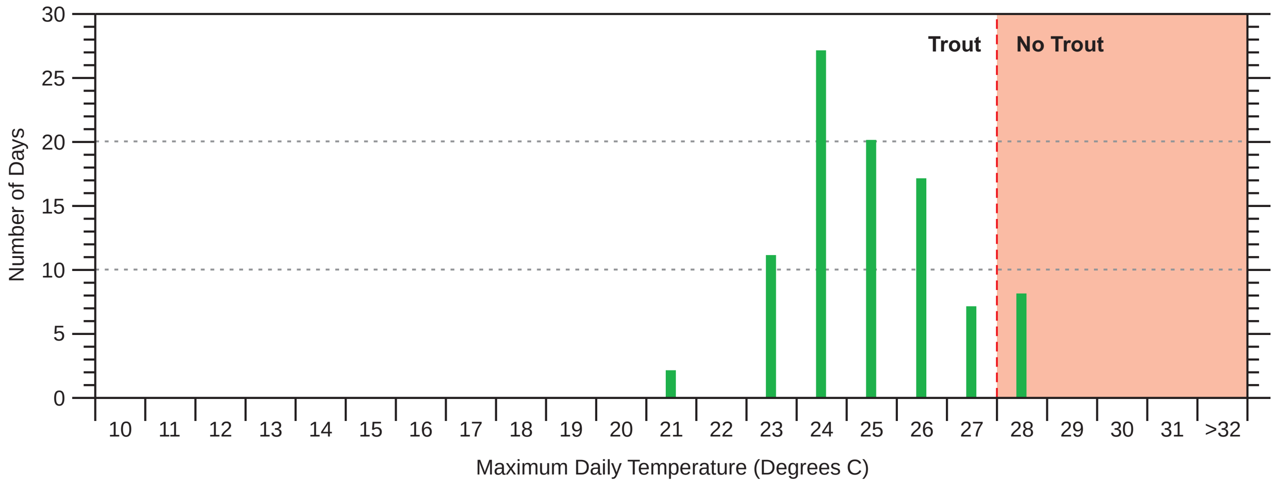
SITE 27-EAGLE SPRING LAKE AT WEST BAY (DEEP)



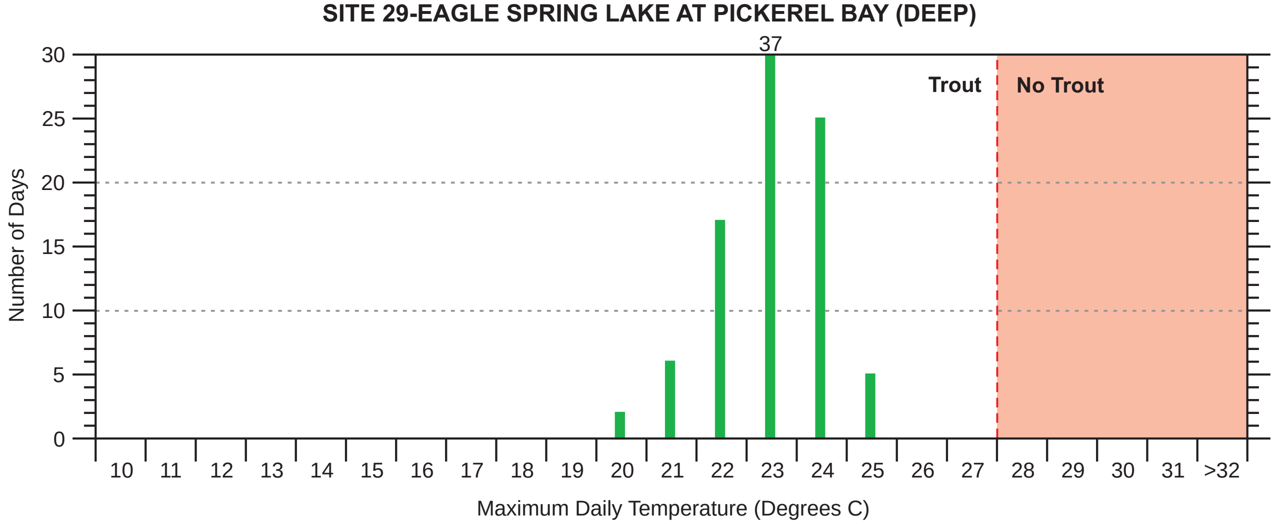
SITE 28-EAGLE SPRING LAKE AT NORTH CHANNEL (SURFACE)



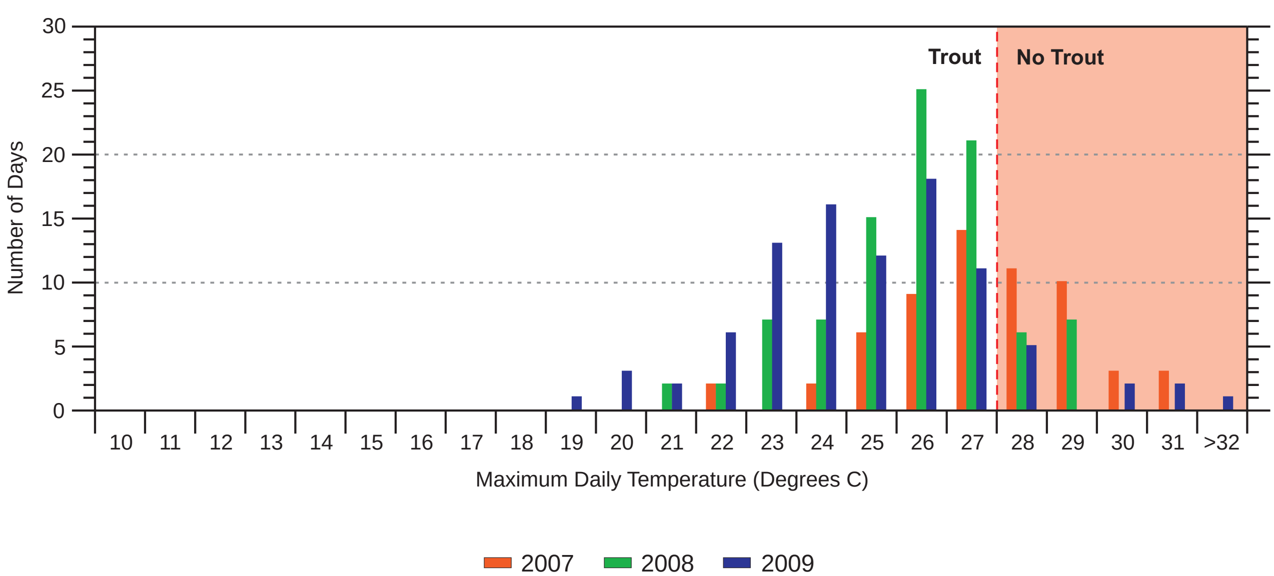
SITE 29-EAGLE SPRING LAKE AT PICKEREL BAY (SURFACE)



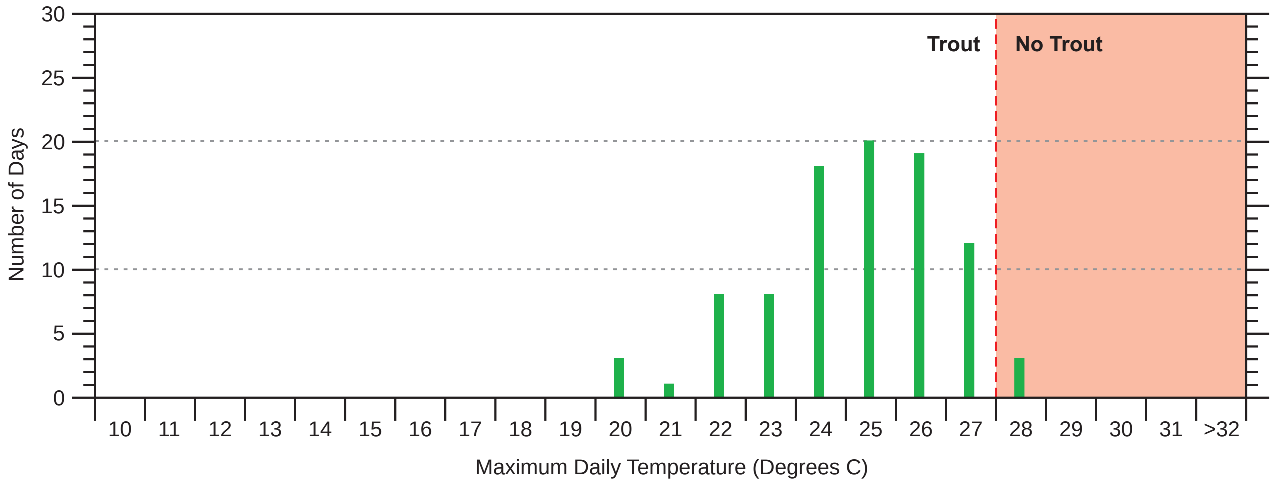
SITE 29-EAGLE SPRING LAKE AT PICKEREL BAY (DEEP)



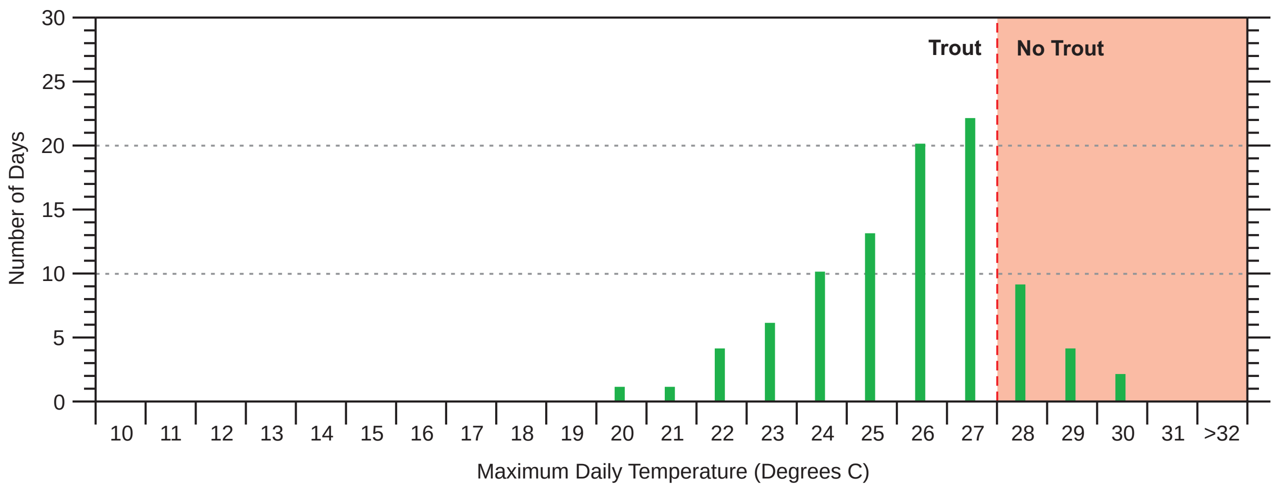
SITE 30-MUKWONAGO RIVER BETWEEN LULU AND EAGLE SPRING LAKES (RM 12.17)



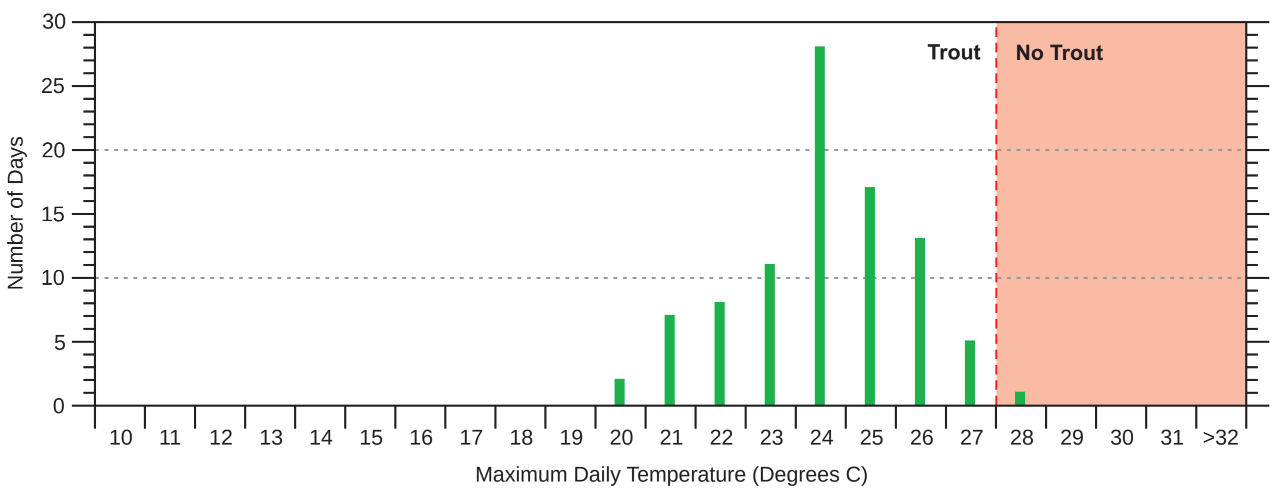
SITE 31-MUKWONAGO RIVER AT LULU LAKE OUTLET (RM 12.57)



SITE 32-LULU LAKE (EAST)



SITE 33-LULU LAKE (WEST)



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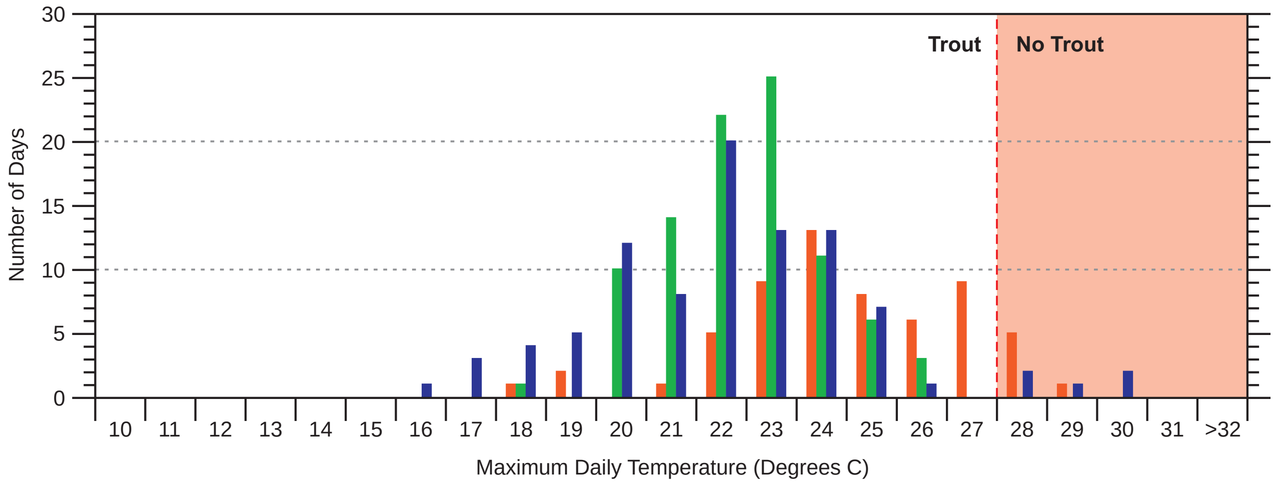
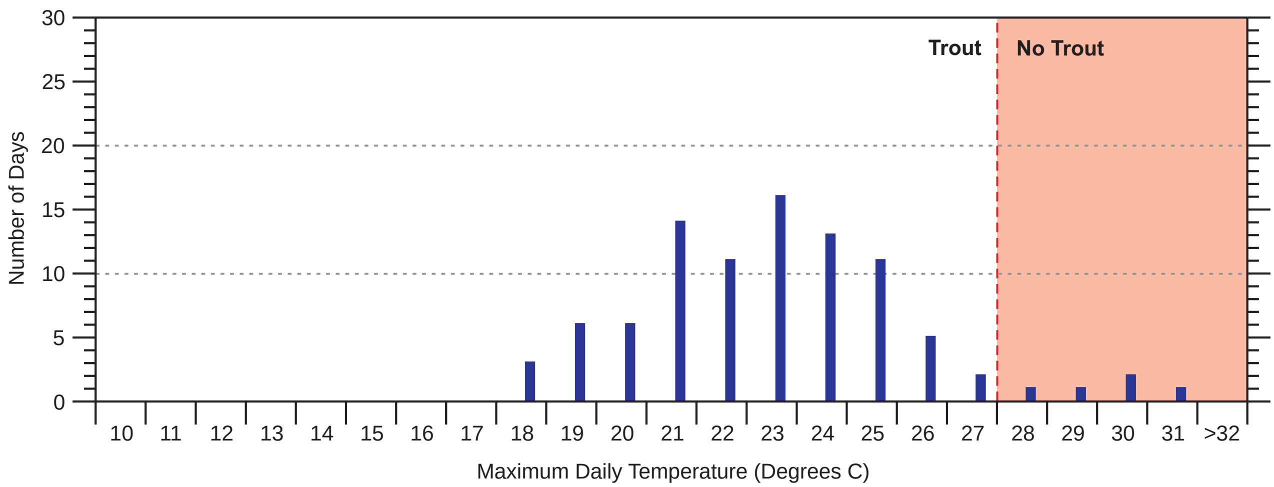
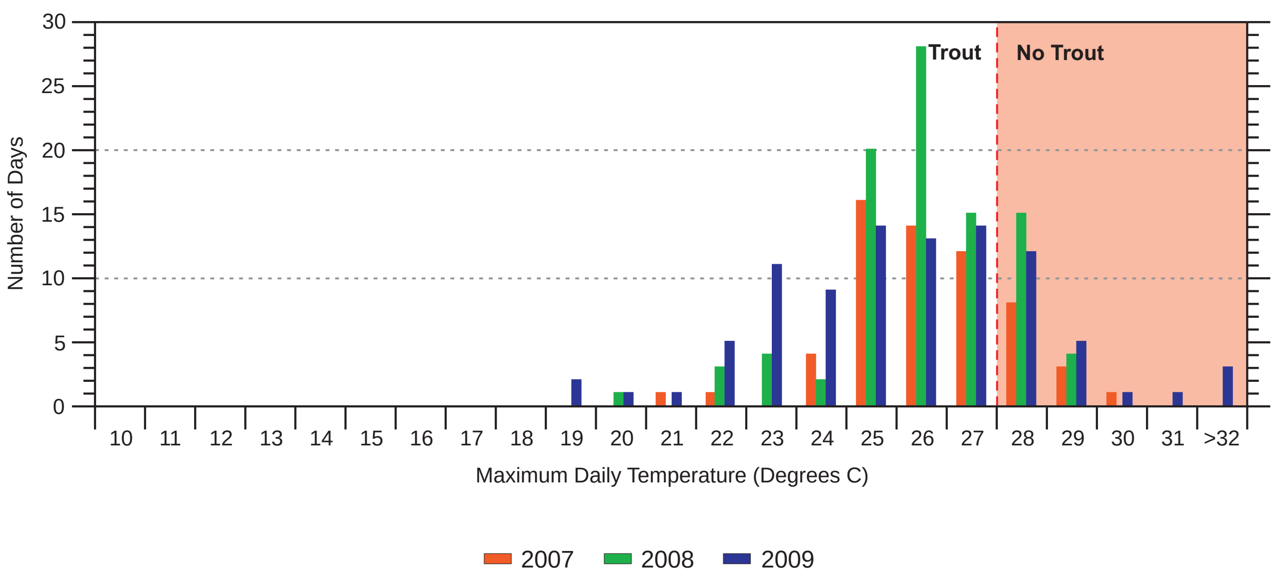
SITE 34-MUKWONAGO RIVER UPSTREAM OF NATURE CONSERVANCY BRIDGE (RM 13.34)



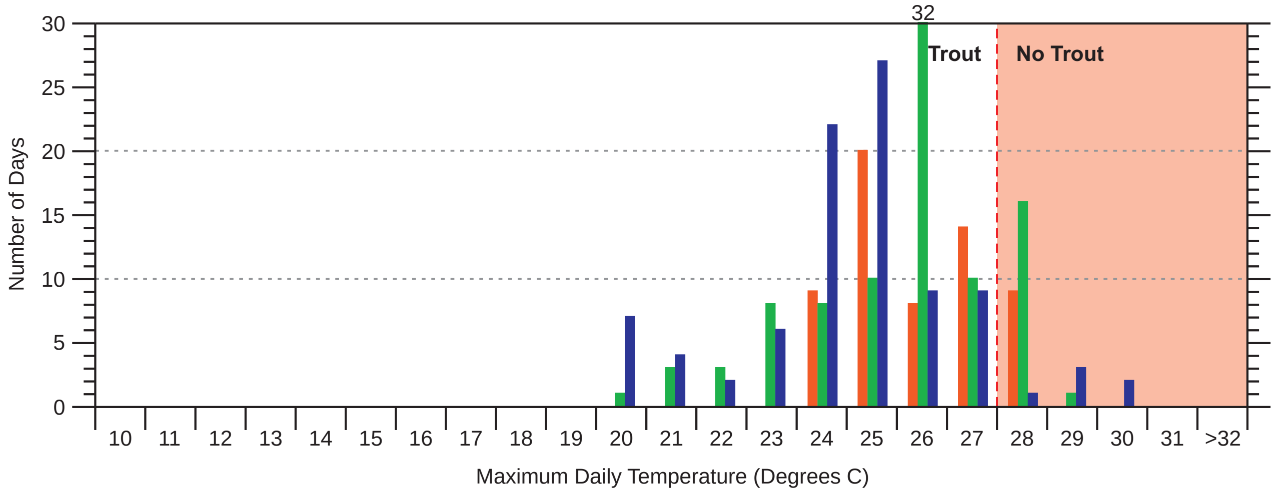
SITE 35-MUKWONAGO RIVER UPSTREAM OF BLUFF ROAD (RM 15.09)



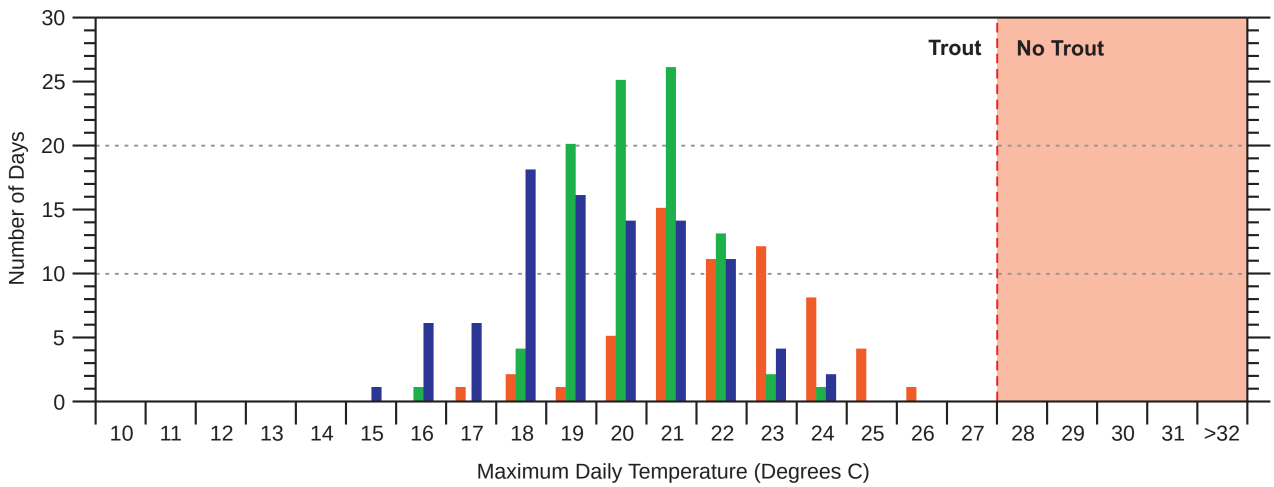
SITE 36-LAKE BEULAH OUTLET UPSTREAM OF MUKWONAGO RIVER CONFLUENCE (RM 0.12)



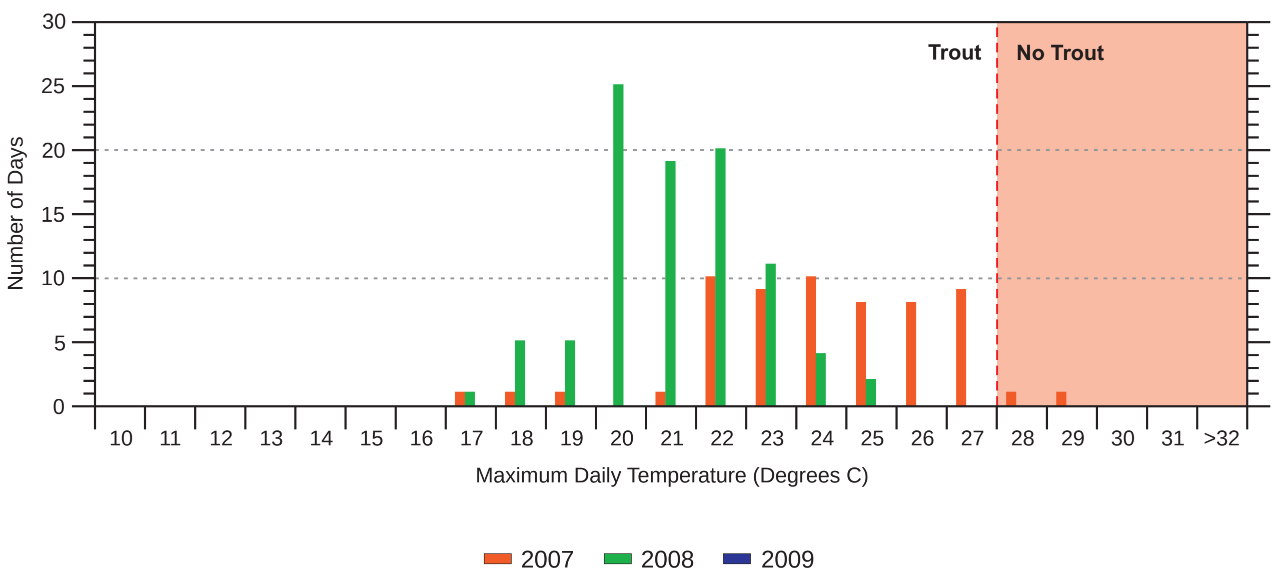
SITE 37-LAKE BEULAH OUTLET DOWNSTREAM OF LAKE BEULAH DAM (RM 1.33)



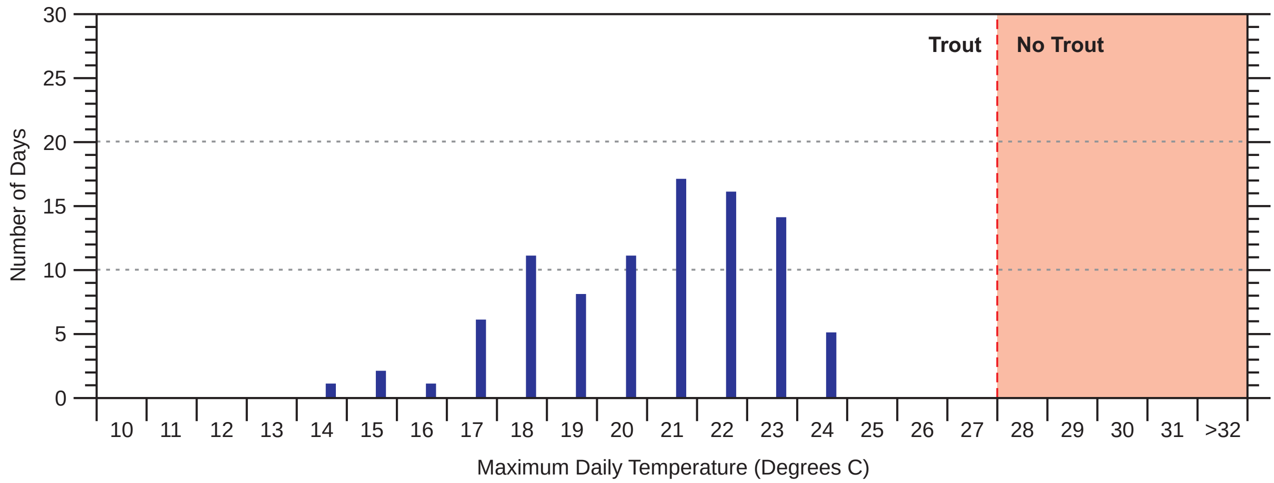
SITE 38-JERICHO CREEK UPSTREAM OF MUKWONAGO RIVER (RM 0.06)



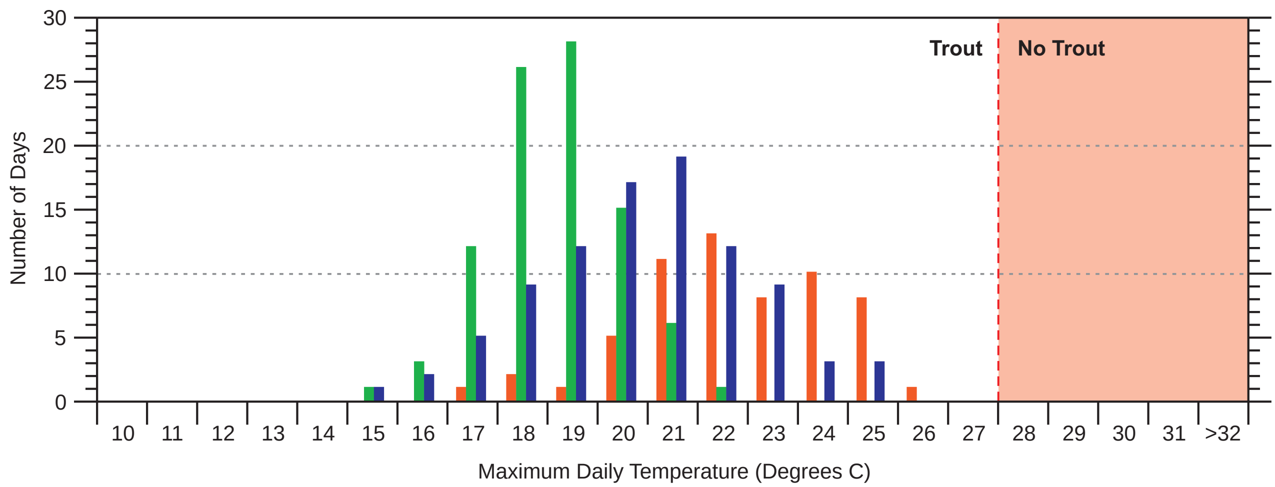
SITE 39-JERICHO CREEK UPSTREAM OF CTH NN (DOWNSTREAM OF POND) (RM 2.27)



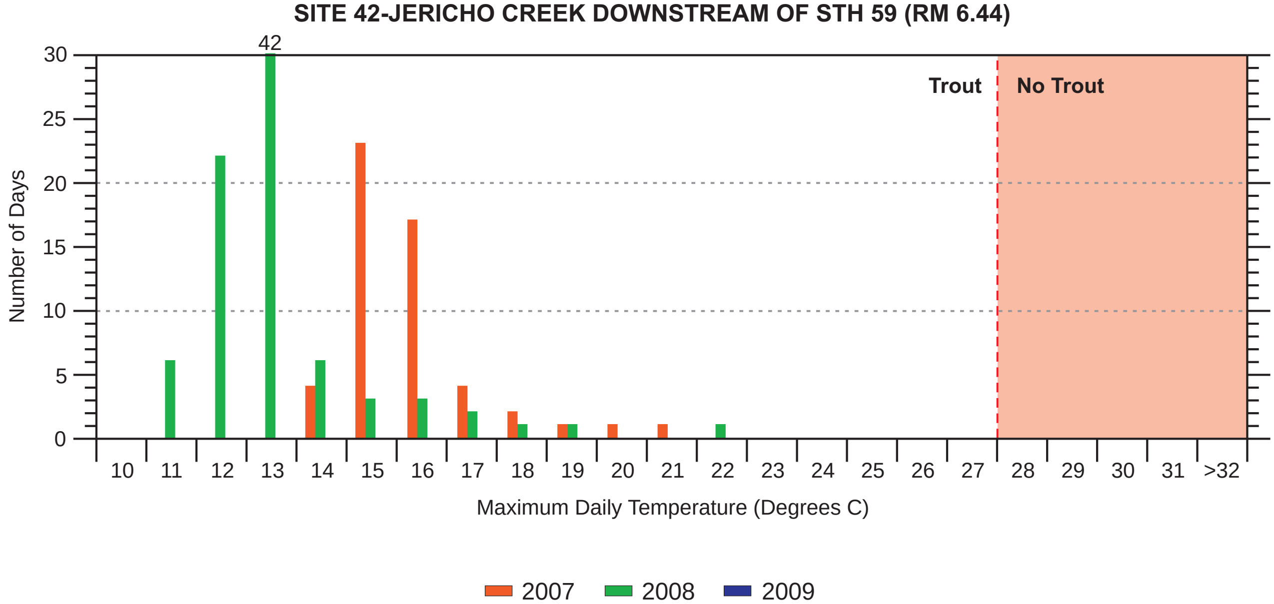
SITE 40-JERICHO CREEK UPSTREAM OF CTH NN (UPSTREAM OF POND) (RM 2.74)



SITE 41-JERICHO CREEK DOWNSTREAM OF ROAD X (RM 5.34)



SITE 42-JERICHO CREEK DOWNSTREAM OF STH 59 (RM 6.44)



Source: SEWRPC.

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Appendix E

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 as part of this comprehensive water quality management plan update.

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 amongst 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.

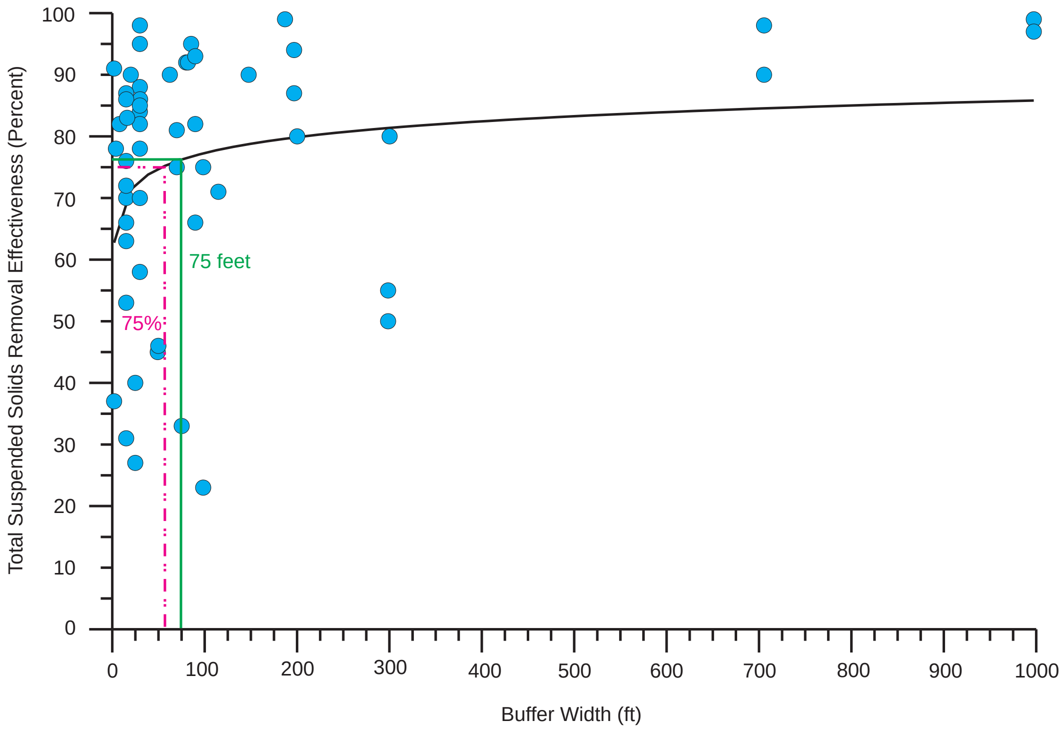
- To Filter Sediment and Attached Contaminants from Runoff: For slopes of less than 15 percent, most sediment settling occurs within a 35-foot-wide buffer of grass. Greater width is needed on steeper slopes, for shrubs and trees, or where sediment loads are particularly high.

- 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 E-1 through E-4, and consistent with the water quality modeling assumptions applied in 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 E-1

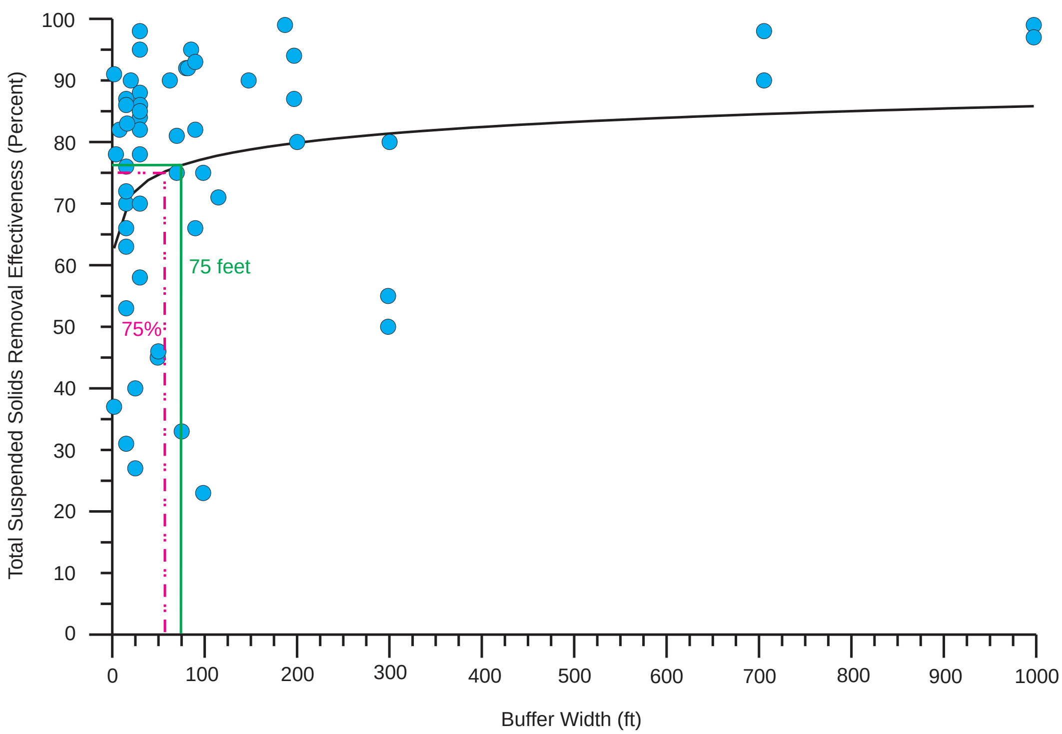
RELATIONSHIP OF TOTAL SUSPENDED SOLIDS REMOVAL EFFECTIVENESS TO RIPARIAN BUFFER WIDTH



Source: SEWRPC.

Figure E-2

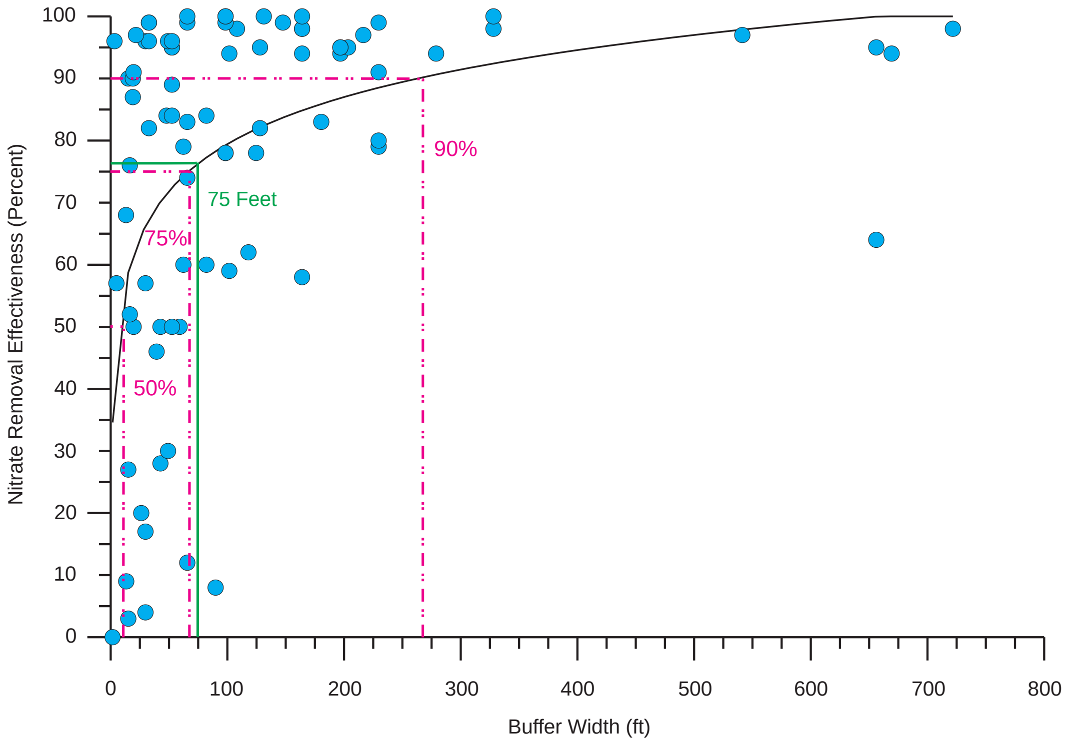
RELATIONSHIP OF TOTAL NITROGEN REMOVAL EFFECTIVENESS TO RIPARIAN BUFFER WIDTH



Source: SEWRPC.

Figure E-3

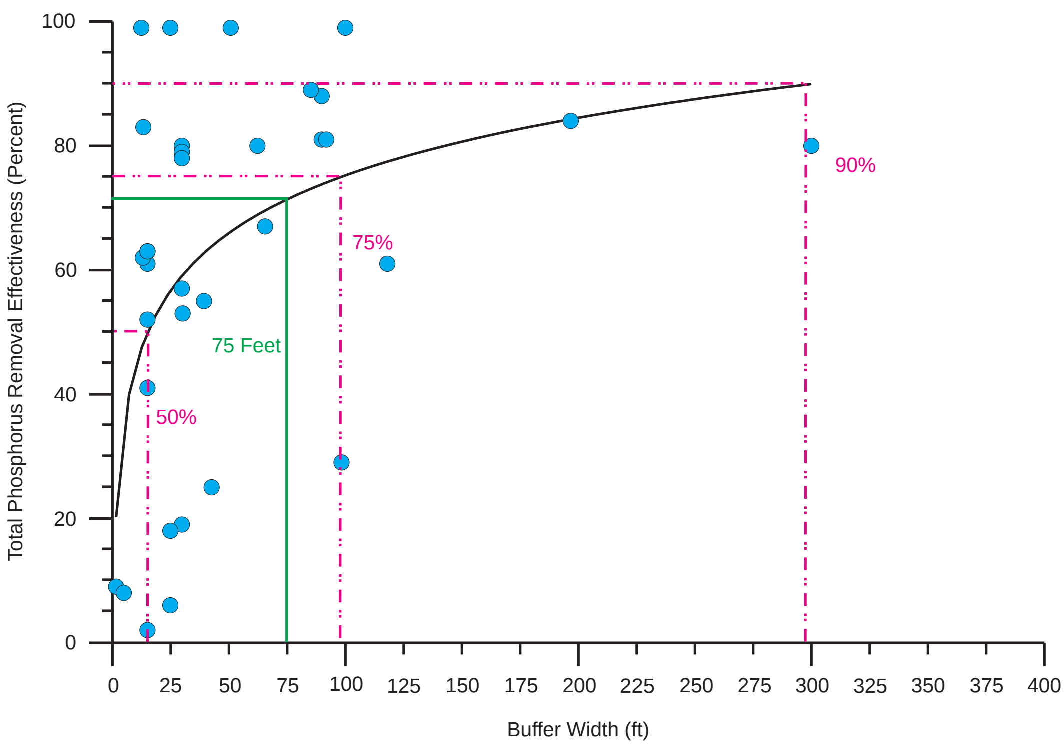
RELATIONSHIP OF NITRATE REMOVAL EFFECTIVENESS TO RIPARIAN BUFFER WIDTH



Source: SEWRPC.

Figure E-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 E-1 through E-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 as 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 to 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 to 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 E-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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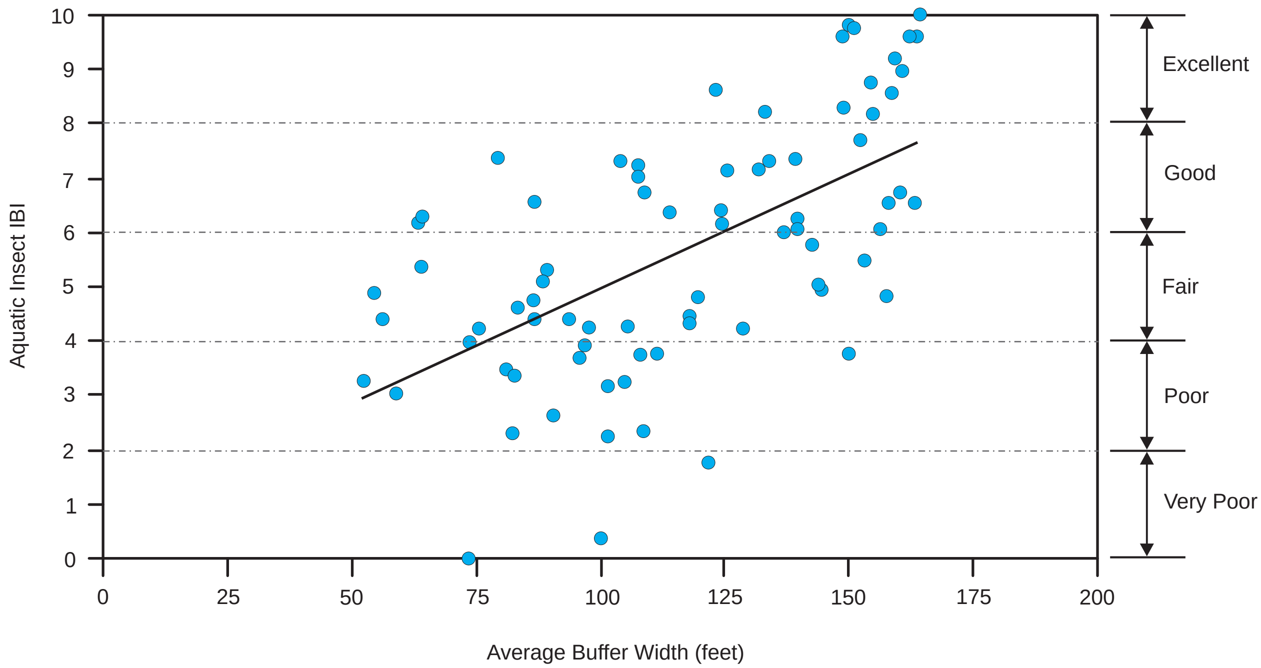
[4]*Jana S. Stewart, Lizhu Wang, John Lyons, Judy A. Horwatich, Roger Bannerman, "Influences of watershed, riparian-corridor, and reach-scale characteristics on aquatic biota in agricultural watersheds,"* Journal of the American Water Resources Association*, Vol. 37, No. 6, 1475-1487, 2001; Wisconsin 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 E-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 E-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.

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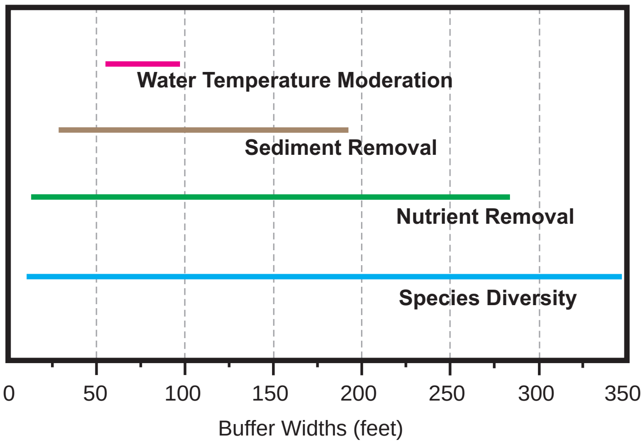
[6]*Lizhu Wang, John Lyons, and Paul Kanehl, "Effects of watershed best management practices on habitat and fish in Wisconsin streams,"* Journal of the American Water Resources Association, *Vol. 38, No. 3, 663-680, June 2002.*

Figure E-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 E-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 F

CRITERIA AND GUIDELINES FOR STREAM CROSSINGS TO ALLOW FISH PASSAGE AND MAINTAIN STREAM STABILITY WITHIN THE REGIONAL WATER QUALITY MANAGEMENT PLAN UPDATE STUDY AREA

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 preferable; therefore, bridges spanning streams are preferable to other structures.

- If a culvert is necessary, open bottom structures are preferable to 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 design period rainfall event.

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 designed 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[4] (see Minnesota DNR guidelines[5])

- 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 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 F-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.[6]

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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]*The thalweg is the lowest point of the streambed.*

[5]*Minnesota DNR, Best Practices for Meeting DNR General Public Waters Work Permit GP 2004-0001, March 2006.*

[6]*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 F-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.

Road/Stream Crossing Inspection Data Sheet

Site ID: ___________

Name of Observer(s)______________________________ **Date**_____________

GPS coordinates (lat/long.) ________________________________ OR **T/R**____________ **Sec**____ ¼____

Road Name____________________________ **Road Number** _________ **Structure ID** _________

Stream Name__________________________________ **Road type** State County Town Private Federal Other

Land Use In Surrounding Area: (circle all that apply)
Forest Wetland Open/Field Pasture Cultivated Urban Other

Additional comments about location (milepost, etc.)**:**

Road Surface (circle all that apply) Paved Gravel Native **Road Width** _______ft. **with shoulders** _______ft.

Erosion of road near crossing? **Y N**
(if YES, also fill out Section F)

Is there a trash rack or beaver prevention structure? **Y N**

Evidence of crossing blow-out? **Y N** **Evidence of beaver activity?** **Y N**

Structure Type (circle one) Culvert Bridge Ford No Structure

A. Crossing Characteristics:

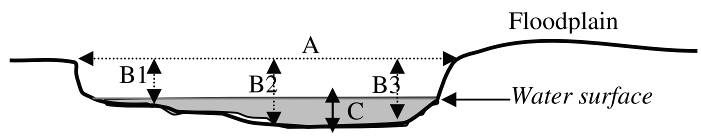
		Inlet/Upstream	Outlet/Downstream	Comments/Notes
Embankment or Side Slopes (not applicable to Fords)	Protection	vegetation armor other	vegetation armor other	
	Erosion *(if Y, fill out Section F)*	Y N	Y N	
Channel	Aligned	Y N	Y N	
	Pool present	Y N	Y N	
	Pool scour width	ft.	ft.	
	Pool water depth (max.)	ft.	ft.	
	Protection	armor other none	armor other none	
Ditch	Present	Y N	Y N	
	Protection	vegetation armor other	vegetation armor other	
	Connected to stream	Y N	Y N	
	Erosion *(if Y, fill out Section F)*	Y N	Y N	

B. Stream Measurements (*See standard procedure in instruction sheet*)**:**

A: Bankfull Width __________feet

B: Bankfull Depth (left to right facing downstream)
B1:______feet B2:______feet B3:______feet

C: Water depth _______ feet



Cross-section of stream channel

Flow conditions: overbank at bankfull below bankfull very low none

Fish present? **Y N**

C. Photos: (At a minimum take photos of the structure inlet and outlet and upstream and downstream conditions). Record photo number and camera number if applicable (example: Photo 6 or Camera 1 Photo 6).

Inlet __________ Upstream __________

Outlet _________ Downstream ________

Additional Photos (as needed to identify issues). Provide location and/or description of issue:

Location ___________________________ Photo Number (and camera number if applicable) ____________

Location ___________________________ Photo Number (and camera number if applicable) ____________

D. Culvert Characteristics (For multiple culverts fill out table below.)

Culvert Shape (circle one)
- Round
- Square/Rectangle
- Open Bottom Square/Rectangle
- Open Bottom Arch
- Pipe Arch
- Ellipse

Culvert Material
- Metal
- Concrete
- Plastic
- Wood

Condition of Structure (check all that apply)
- General condition: new good fair poor
- Plugged ____% where? inlet outlet in pipe
- Crushed ____% where? inlet outlet in pipe
- Rusted through ☐
- Condition comments: _____________________________

Culvert Measurements:

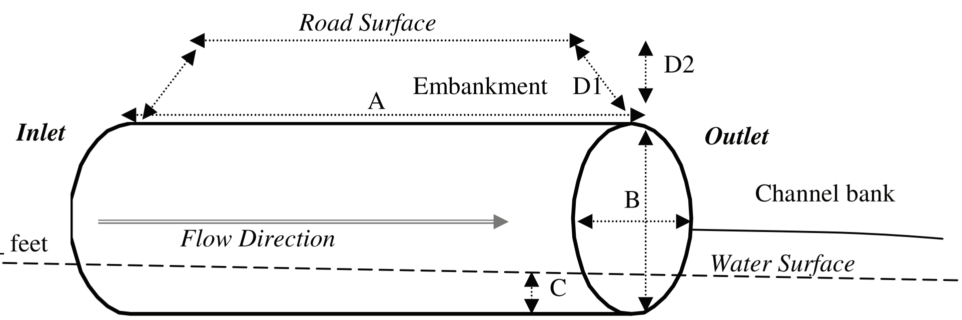
A: Culvert Length ________ feet

B: Culvert Height ________ feet

Culvert Width ________ feet

C: Depth of water in structure: _______ feet

D: Embankment:



Inlet: D1_____feet D2______feet **Outlet:** D1______feet D2______feet

Culvert Rise (top of culvert to stream bed): **Inlet Rise**: ____ft **Outlet Rise**: ______ft

Inlet/Outlet Characteristics: **Inlet Drop**: ____ft **Outlet Perch**: _____ft

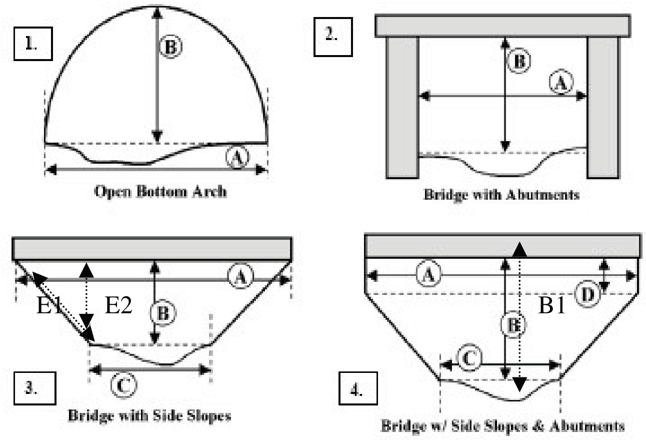
Inlet Type: Projecting Headwall Wingwalls Mitered Apron Other
Outlet Type: Projecting Headwall Wingwalls Mitered Apron Other

Substrate: Y N Match Stream? Y N

Multiple Culverts: NOTE: (*number multiple culverts from left to right facing downstream. Fill in sections above for culvert # 1 and use this table for remaining culverts)*

Culvert #	Shape/ Material	Length	Height	Width	Rise inlet/outlet	Depth of water in structure	Inlet drop	Outlet perch	Condition
2									
3									
4									

E. Bridge Characteristics (For multiple cells see below):



Bridge Type (# from diagram) _______

Bridge Surface Material:

Wood	Open decking? Y N
Concrete	Asphalt
Metal	other __________

Bridge Measurements:

A: Span ______feet Width (parallel to stream) ______feet

B: Bottom of beam to water surface _______feet

B1: Bridge Rise (bottom of beam to stream bed) _______feet

C: Stream width _______feet

D: Bottom of beam to top of embankment _______feet

E: Side Slopes (facing downstream):

Left bank: E1_______feet E2______feet **Right Bank**: E1______feet E2______feet

Present at inlet (circle all that apply): Wingwalls Apron Other _______________
Present at outlet (circle all that apply): Wingwalls Apron Other _______________

Condition of Structure: Deteriorating **Y or N**
If yes, where (check all that apply)? ☐ Abutments ☐ Decking ☐ Wingwalls ☐ Other___________________

Multiple Bridge Cells
NOTE: *(number multiple bridge cells (usually separated by abutments) from left to right facing downstream. Fill in sections above for bridge cell # 1 and use this section for remaining cells)*

Bridge Cell #	A (ft.)	B (ft.)	B1 (ft.)
2			
3			
4			

F. Erosion Properties – *(fill out all that apply, add other locations in blank rows. Other locations to note may include prominent erosion along stream banks within 50' of crossing.)*

Location of Erosion	Erosion Dimensions (feet)			Material Eroded (clay, silt, sand, gravel, loam, sandy loam, OR gravelly loam)	Erosion Reaching Stream? (Y/N)	Comments
	Length	Width	Depth			
Road approach *(left, facing downstream)*						
Road approach *(right, facing down stream)*						
Ditch(s) *(upstream side of road)*						
Ditch(s) *(downstream side of road)*						
Road over crossing (or bridge deck)						
Culvert inlet embankment						
Culvert outlet embankment						
Bridge Side slopes *(left, facing downstream)*						
Bridge Side slopes *(right, facing down stream)*						

If erosion occurs on the approaches or in the ditches, is there opportunity (room) to install road drainage measures?
Y **N**

G. Site Sketches (Identify road crossing, stream, flow direction, issues, and location and direction of photos):

↑ **N**

Comments: *(Provide additional information such as invasive plants present, spillways present, etc)*