COMMUNITY ASSISTANCE PLANNING REPORT NO. 341

A LAKE MANAGEMENT PLAN FOR LAKE COMUS

WALWORTH COUNTY, WISCONSIN

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Special acknowledgement is due to Dale J. Buser, PE. PH Principal Specialist; Dr. Justin Poinsatte, Senior Specialist – Biologist; Zofia Noe, Senior Specialist – Biologist; Dr. Thomas Slawski, Chief Biologist; Megan Shedivy, Planner; Aaron Owens, Senior Planner; Alexa Carzoli, Administrative Assistant; and Megan Deau, Senior Graphic Designer for their contributions to the conduct of this study and the preparation of this report.

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WALWORTH COUNTY, WISCONSIN

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December 2022

A LAKE MANAGEMENT PLAN FOR LAKE COMUS

EXECUTIVE SUMMARY

A MANAGEMENT PLAN FOR LAKE COMUS AND ITS WATERSHED

The health of a lake ecosystem usually directly reflects the use and management of land within the lake's watershed. Abundant wetlands in Lake Comus' (the Lake's) watershed helps filter pollutants and supports diverse plant and wildlife populations, including several rare species. However, high phosphorus and sediment loading rates will continue to harm the Lake if active management action is not taken. The Lake Comus Management Plan (the Plan) was developed to quantify natural resource conditions in the Lake and its watershed and provide a set of targeted, specific recommendations to improve Lake Comus, Turtle Creek (the Creek), and ecological conditions throughout the watershed. This Plan supplements and builds upon previously completed plans and recommendations (such as the 1984 Turtle Creek Priority Watershed Plan) and integrates with Lake recreational planning concepts outlined in the Downtown Delavan Strategic Plan.

CHARACTERISTICS OF LAKE COMUS AND ITS WATERSHED

Lake Comus covers 131 acres on the north side of the City of Delavan. The Lake receives runoff from a 32.8 square mile watershed located entirely within Walworth County. Agriculture and wetlands are the most common land uses within the watershed. Lake Comus, a shallow impoundment on Turtle Creek, is a significant part of the extensive primary environmental corridor stretching along the Creek. Turtle Creek is the Lake's largest tributary, supplying approximately two-thirds of the Lake's water, while precipitation, groundwater, and other tributaries supply the rest. Unlike many lakes with public access in Southeastern Wisconsin, most of the Lake's shoreline is undeveloped wetland. This allows ample opportunity for wildlife viewing, fishing, and paddle sports. The Lake supports a warmwater sport fish community and is also regularly stocked with northern pike. The adjacent Paul Lange and Ora Rice Arboretums as well as close proximity to downtown Delavan enhances the Lake's recreational values and opportunities.

The public lands and wetlands surrounding Lake Comus provide ample recreational opportunities.

JUSTIFICATION FOR PLAN

As a shallow lake with a large watershed, Lake Comus is highly susceptible to problems associated with excessive nutrient and sediment loading. Such problems include diminished water clarity, minimal aquatic plant coverage, and frequent algal blooms. Issues of concern addressed in this management plan include the following:

- Water Quality Trends
- Priority Areas and Conservation Practices for Pollutant Load Reduction
- Aquatic Plant Community
- Shoreline Erosion and Restoration
- Restoring Natural Hydrology

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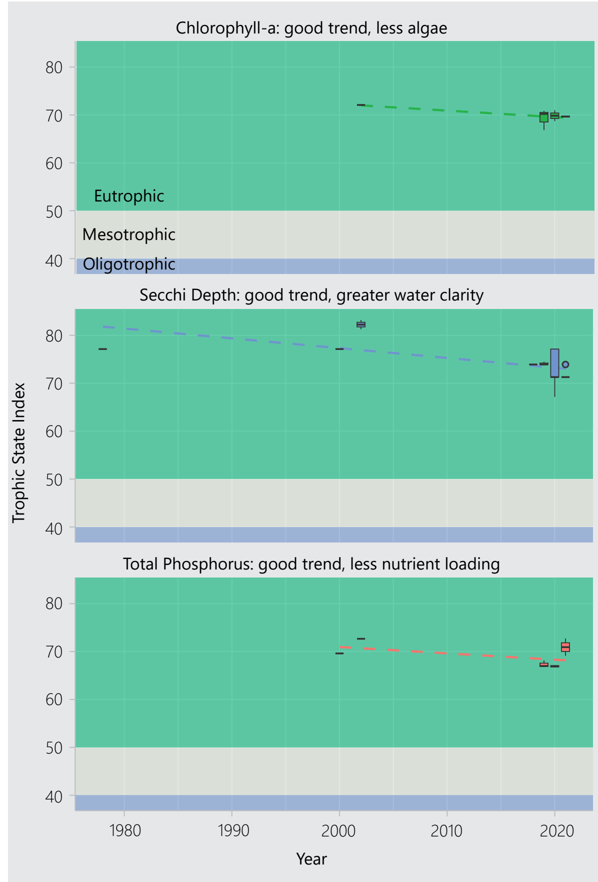
WATER QUALITY TRENDS

The limited water quality data available for Lake Comus suggests that the Lake has maintained its nutrient-rich (eutrophic) status since at least the late 1970s. Excessively high nutrient concentrations are detrimental to Lake health, resulting in low water clarity, greater frequencies of algal blooms, and reduced aquatic organism diversity - these impacts are recognized by the Lake's 2022 listing on the 303(d) impaired waters lists. Much of the ongoing sediment load delivered to the Lake accumulates on the Lake bottom. This has reduced the Lake volume by approximately 40 percent since 1963 despite a dredging project that removed 440,000 cubic yards of sediment from the Lake during the late 1980's. Nevertheless, recent water quality monitoring suggests that conditions are improving with declining total phosphorus and chlorophyll-a concentrations and increasing water clarity. These insights are only possible thanks to the renewed effort by volunteers to monitor the Lake's water quality as part of this plan. Continued monitoring of Lake water quality would help track progress towards meeting water quality goals as plan recommendations to reduce pollutant loading are implemented.



Greater water clarity and reduced algal abundance indicate improving water quality. Increasing phosphorus remains an issue of concern.

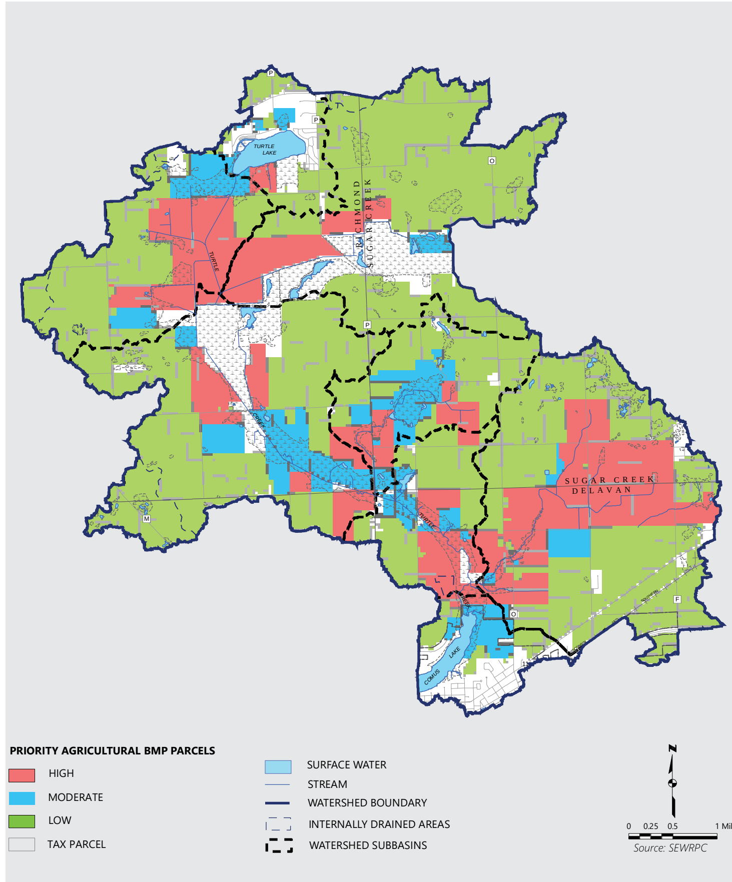
Continued monitoring is essential for tracking progress toward improving water quality.

Excessive phosphorus and sediment loads threaten environmental quality and/or recreational use within the Lake if left unaddressed. The U.S. Environmental Protection Agency (USEPA) and the Wisconsin Department of Natural Resources (WDNR) identified the Turtle Creek watershed as a significant contributor of phosphorus and sediment to the Rock River, with reaches of the River listed as impaired for low dissolved oxygen. The USEPA established a total maximum daily load (TMDL) in 2011 for the Rock River basin to address excessive phosphorus and sediment pollution. Since the Turtle Creek watershed is part of the Rock River TMDL, these state permitted allocations establish minimum phosphorus and sediment reduction goals for the Lake's watershed. The recommendations provided within this management plan will help communities reduce their pollutant loading to meet and exceed these goals.

Pollutant	Nonpoint Source Pollution Sources	Non-Permitted Urban Sources	MS4 Systems	Wastewater Treatment Plants
Total Phosphorus	49%	19%	0%	75%
Total Suspended Solids	25%	15%	0%	1%

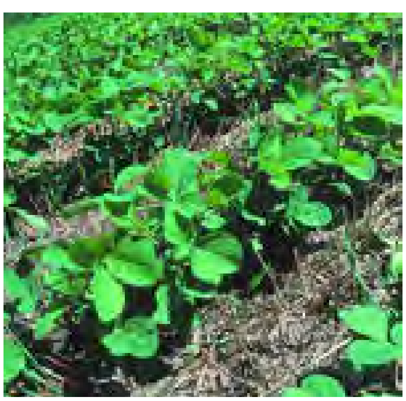
Priority Areas and Conservation Practices for Pollutant Load Reduction

This planning project identifies priority areas and conservation practices that help reduce pollutant loads delivered to the Lake. Commission staff examined previous studies and conducted pollutant load modeling exercises throughout the watershed using the Commission's 2015 land use information. Prior studies and recent modeling results indicate that rural nonpoint sources are the largest sources of phosphorus and sediment to the Lake.



Commission staff prioritized agricultural parcels by their potential for conservation practices to reduce sediment and phosphorus loading

Achieving the phosphorus and sediment reduction goals set by the TMDL will require major commitments from all watershed stakeholders to implement best management practices. Due to the extensive agricultural land use within the watershed, novel agricultural practices and conservation practices that reduce rural nonpoint source loading should be prioritized and incentivized. These practices include utilizing cover crop and conservation tillage practices, ensuring that all agricultural lands are following a nutrient management plan, retrofitting drain tile systems, restoring wetlands in farmed areas, and expanding shoreline and riparian buffers. The Plan provides estimates of the number and acreage of rural nonpoint source conservation practices required to meet TMDL pollutant loading reduction goals based on the Commission's pollutant load modeling results. An inventory of priority areas and parcels for riparian buffers and agricultural conservation practices is also provided in the Plan.

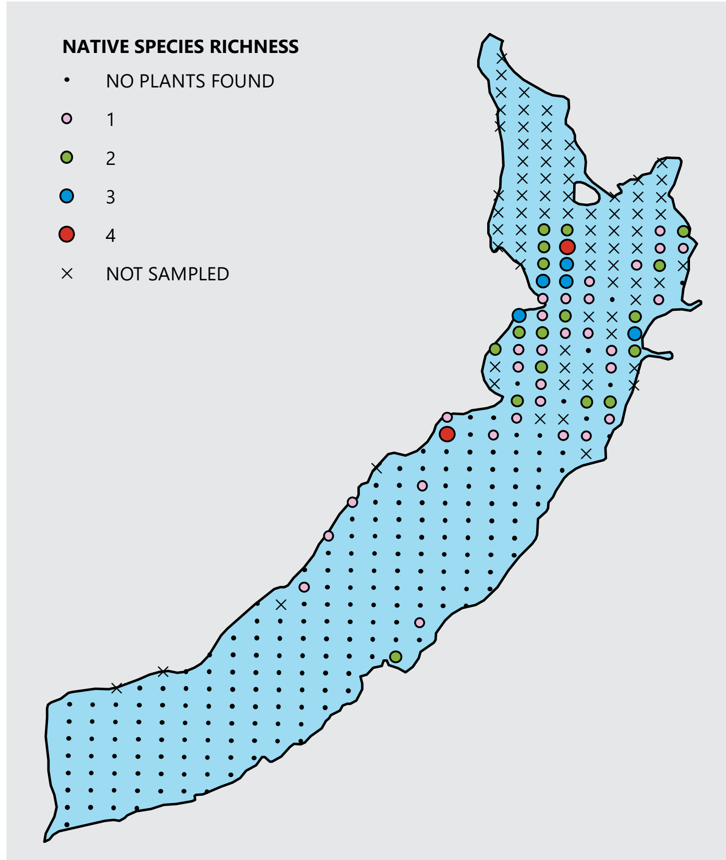


Example conservation practices recommended in the Plan: no-till cropping, riparian buffers, and cover crops planted into residue. These practices enhance soil health and reduce pollutant loading.

A LAKE MANAGEMENT PLAN FOR LAKE COMUS

AQUATIC PLANT COMMUNITY

The Lake's aquatic plant community is in generally poor condition, with low coverage by submerged vegetation, few native plant species, and a dominance of invasive species. A 2019 survey by Commission staff identified only five native aquatic plant species> Invasive Eurasian watermilfoil was the most common species observed. Submerged plants were growing no deeper than four feet. This suggests that turbid water likely does not transmit enough light for plants to grow beyond this depth. Additionally, aquatic plants were only found in half of the areas where enough light was available to sustain their growth, suggesting that other factors like disturbance and/or consumption by common carp might be reducing plant abundance in potentially suitable habitat. Enhancing the coverage and diversity of the Lake's aquatic plant community is an important component of the Plan as a healthier plant community would improve water quality, provide habitat and food for aquatic organisms, and subsequently enhance recreational activities on the Lake. As the LCPRD does not utilize intensive plant management activities like harvesting or chemical treatments, Commission staff recommend aquatic plant management strategies that enhance the Lake's native plant population. These strategies include measures that improve the Lake's water clarity and reduce the Lake's common carp population.



Lake comus is largely devoid of aquatic plants and has low native plant diversity. The highest aquatic plant coverage is in the shallow northeastern area of the Lake.

Enhancing Native Plant Community
Restoring native aquatic plant community would improve water quality, provide food and habitat for aquatic organisms, and enhance recreational opportunities

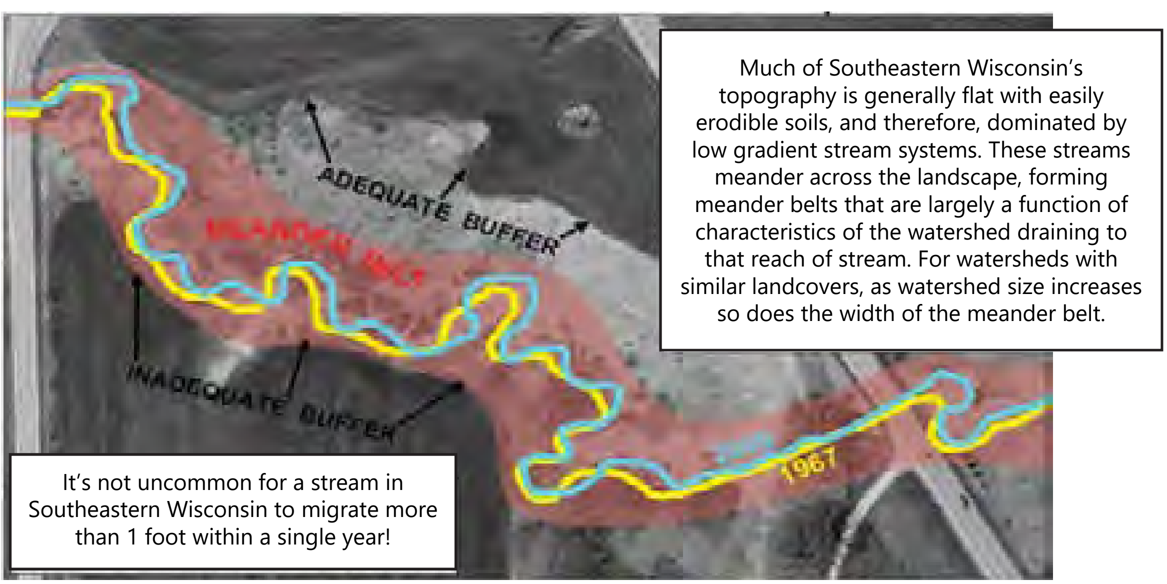
SHORELINE EROSION AND RESTORATION

Lake residents expressed concern regarding shoreline erosion. To examine this concern, Commission staff performed a field inventory of shoreline conditions during 2019 and compared historical and current aerial imagery. Most of the Lake shoreline was in good condition, with extensive vegetative buffer and little noticeable erosion, aside from apparent shoreline recession along the Paul Lange Arboretum and slight erosion on the southwestern shoreline by North Terrace Street. Due to low wave activity in Lake Comus, techniques that incorporate both vegetation and low-lying structural surfaces, such as edging and sills, may be sufficient to restore the shoreline and protect it from further deterioration. These practices can be supported through state funding following verification by a more detailed engineering study.

Apparent shoreline recession along Paul Lange Arboretum

RESTORING NATURAL HYDROLOGY

The watershed uplands have been altered from their pre-settlement coverage by oak forest and prairie into predominantly agricultural uses. While much of the pre-settlement wetland remains, the hydrology of these wetlands has been changed through ditching, drain tiles, stream channelization, and filling largely to enhance agricultural production. Comparing the current Turtle Creek mainstem channel streamline against the streamline from an 1837 plat map demonstrates that many of the natural meanders were straightened, reducing the total stream length by nearly 25 percent. These land use and hydrologic changes reduce the landscape's ability to capture, filter, and detain runoff; lower downstream flood peaks; retain nutrients and sediment in the soil; maintain streamflow during dry periods; and provide suitable habitat for many fish species. Plan recommendations help communities preserve the Lake's water supply by modulating floodwater volumes, protecting groundwater infiltration, and advocating sustainable groundwater use and management concepts.



Example of a naturally meadering stream.

A LAKE MANAGEMENT PLAN FOR LAKE COMUS

Key Management Objectives to Improve the Lake Comus Watershed

- Use existing TMDL guidance for phosphorus and sediment load reduction goals
- Prioritize implementing regenerative agricultural practices to improve soil health and reduce phosphorus and sediment loading to Lake and Creek
- Continue water quality monitoring to track progress toward meeting nonpoint source load reductions and improving water quality
- Restore native aquatic plant community and educe common carp population
- Preserve or enhance groundwater recharge to improve water quality and protect habitat for coolwater species
- Establish partnerships between municipalities, associations, and permitted entities to collaborate on water quality goals, pursue funding, and incentivize practices

The Lake's water levels have been controlled by an outlet dam for nearly two centuries. The current dam configuration, which needs major repairs and modifications, was not purposely designed to include features that help promote the Lake and watershed health. The dam is also a major barrier to fish passage and recreational use between the Lake and downstream Turtle Creek. The current dam will likely be replaced in the next few years. Dam replacement presents an important opportunity to incorporate features into dam design that help promote waterbody health and recreation. This management plan provides concepts and advice on how the dam modification can best foster the aesthetic, recreational, and ecological goals for the Lake and Turtle Creek.

FUNDING AND PARTNERSHIPS

Funding is available to implement conservation practices within the Lake Comus watershed. Several state and federal programs promote conservation practices that protect water quality. Through its Surface Water Grants and the Targeted Runoff Management programs, the WDNR offers funding for restoring surface waters and wetlands as well as implementing nonpoint source pollution reduction projects recommended in this Plan. Additionally, the LCPRD could sponsor the WDNR Healthy Lakes and Rivers program to fund in-lake and riparian projects, such as native plant buffers, rain gardens, and fish habitat structures. The U.S. Department of Agriculture administers several programs, such as the Conservation Reserve Program, the Environmental Quality Incentives Program, and the Conservation Stewardship Program, to implement conservation practices and promote land conservation in agricultural lands. The Wisconsin Department of Agriculture, Trade and Consumer Protection and the Natural Resource Conservation Service also offer grant funding for farmer-led activities to reduce nonpoint source pollution. Local land trusts work with landowners to preserve land through conservation easements, land purchases, and land donations.

The greatest potential for funding projects within the Lake's watershed may be through establishment of an adaptive management program to address permitted phosphorus point source loads. Adaptive management is a phosphorus compliance option that allows point and nonpoint sources to work together to reduce watershed phosphorus loading. As an example, the City of Oconomowoc established a program with the City of Oconomowoc Wastewater Utility and other partners to reduce pollutant loading in the Oconomowoc River watershed for the Rock River TMDL. Establishment of a similar program between the Walworth County Metropolitan (WalCoMet) wastewater treatment facility and the landowners and municipalities within the upper Turtle Creek watershed should be considered, as this would enable greater opportunities for cost-sharing and achieving TMDL compliance.

Promote best management practices by supporting farmers to purchase equipment for cover crops as well as retrofitting infrastructure.

PARTNERSHIP AND COLLABORATION NECESSARY TO ACHIEVE WATER QUALITY GOALS

The Lake Comus watershed has significant aesthetic and ecological value and has the potential to be a more diverse and resilient aquatic ecosystem. Water quality within the Lake has slightly improved since the late 1970s, but as indicated by the Lake's 303(d) listing, excessive phosphorus and sediment loads as well as the altered watershed hydrology remain major management challenges. Following the recommendations provided in this Plan will help improve water quality and quantity for human needs and will help improve the hydrological and ecological integrity of the water resources. This will also lead to a healthier and more resilient local economy.

Achieving plan goals for the Lake Comus watershed will continue to be a challenge requiring collaboration of many participating organizations adopting elements component to the unified plan. The measures presented in this Plan primarily focus on those that can be implemented through collaboration between local organizations and individuals, such as the LCPRD; Lake residents and Creek riparian owners; Walworth County; the WDNR; the Wisconsin Department of Agriculture, Trade, and Consumer Protection; the USDA Natural Resource Conservation Service; WalCoMet; the Towns of Darien, Delavan, Richmond, and Sugar Creek; and other stakeholders. The plan must be adaptable to address new or changing challenges that may arise during implementation. Watershed implementation is primarily a volunteer effort, however, this effort needs support from targeted technical and financial assistance. All communities within the watershed must commit and collaborate to reach compliance with existing regulations, which in turn helps improve the Lake's condition.

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Credit: SEWRPC Staff

PLAN PURPOSE AND GOALS 1

Lake Comus (the Lake) lies within U.S. Public Land Survey Sections 7,8, and 18, Township 2 North, Range 16 East in west-central Walworth County, Wisconsin. The Lake is located almost entirely in the City of Delavan and partially in the Town of Delavan (Map 1.1). Lake Comus, together with its associated watershed and wetlands, is an important high-quality natural resource and is a substantial asset to the local and regional community. For this reason, preserving and enhancing the Lake's health is an issue of considerable interest to resource managers, Lake residents, Lake users, and others who benefit from the Lake's recreational, ecological, and aesthetic value.

1.1 PLAN PURPOSE AND OVERVIEW

The health of a lake or stream is usually a direct reflection of land use and management within the lake's watershed (the land surrounding a lake that slopes toward the lake or a tributary stream, and that contributes runoff to the lake). In the face of human-induced change, active intervention is often necessary to stabilize, maintain, or enhance resource conditions. This management plan focuses on what can be done to *protect* critical resources from human-induced deterioration and *prevent* future water pollution or resource degradation. This management plan is the first lake management plan developed by the Southeastern Wisconsin Regional Planning Commission (the Commission) for Lake Comus. This plan complements other existing programs and ongoing management actions in the Lake Comus watershed and represents the continuing commitments of government agencies, municipalities, and citizens to diligent land use planning and natural resource protection. This plan recommends appropriate and feasible watershed management measures to help enhance and preserve the water quality, aesthetics, and ecological integrity of the Lake and its tributaries and provide the public with opportunities for safe and enjoyable recreation within the Lake and its watershed. This document's primary purpose is to review and analyze available data and provide an updated management framework with specific recommendations. Such information enables organizations to take appropriate measures to protect the health and use value of the Lake.

This plan is divided into three chapters. Chapter One briefly outlines the plan's purpose, summarizes basic Lake characteristics and assets, and describes general goals and objectives. Chapter Two presents and interprets information needed to understand Lake conditions and the factors that could imperil Lake health. Finally, Chapter Three discusses approaches to protect and enhance the Lake and its watershed. Chapter

Map 1.1
Location Comus Lake Watershed Study

Source: SEWRPC

Three recommendations aim to enhance Lake Comus' native plant community, ecology, and water quality, while allowing Lake users and watershed residents opportunities for safe and enjoyable recreation within the Lake and the Lake's watershed.

This management plan provides practical guidance for maintaining or enhancing water quality within the Lake Comus watershed and for managing lands that drain directly and indirectly to the Lake and its tributary streams. The plan is developed to assist units of government, nongovernmental organizations, businesses, and citizens in developing strategies benefiting the natural assets of Lake Comus and protecting sensitive and other high-value habitats within its watershed. By applying the strategies outlined in this plan, the natural environment will be enriched and preserved. In addition, carefully planned urban development can preserve ecological benefits that directly benefit human habitation. For example, planning can create and maintain desirable aesthetics, groundwater recharge areas, and wildlife corridors, all of which benefit Lake Comus' ecology, watershed residents and businesses, and visitors.

This planning program was funded in part by a Chapter NR 190 Lake Management Planning grant awarded to the Lake Comus Protection and Rehabilitation District (LCPRD). Examples of major grant program deliverables include the following items:

- Maps delineating the watershed and defining characteristics such as groundwater recharge potential, buffers, and existing/planned land use
- Documenting stakeholder concerns, desires, and education
- Assessing Lake Comus' water quality condition and trends
- Examining Turtle Creek's water quality and quantity
- Characterizing the Lake's shoreline condition
- Modeling watershed phosphorus and sediment sources and loads
- A field investigation of Lake sediment depths and to provide suggestions for controlling sedimentation
- An aquatic plant inventory and management plan
- Describing fish and wildlife conditions as well as recreational use on the Lake and within its watershed
- Specific recommendations for watershed management including maps and an action plan
- Establishing pollutant load reduction goals consistent with the Rock River basin Total Maximum Daily Load (TMDL) allocations
- A comprehensive written report

The inventory and aquatic plant management plan elements presented in this report conform to requirements and standards set forth in relevant *Wisconsin Administrative Codes*.[1]

[1] *This plan has been prepared pursuant to the standards and requirements set forth in the following chapters of the* Wisconsin Administrative Code*: Chapter NR 1, "*Public Access Policy for Waterways;*" Chapter NR 40, "*Invasive Species Identification, Classification and Control;*" Chapter NR 103, "*Water Quality Standards for Wetlands;*" Chapter NR 107,* "Aquatic Plant Management;*" and Chapter NR 109,* "Aquatic Plants Introduction, Manual Removal and Mechanical Control Regulations."

1.2 CHARACTERISTICS AND ASSETS OF LAKE COMUS AND ITS WATERSHED

Lake Comus is essentially a wide and deep section of Turtle Creek (the Creek) created by the Lake's outlet dam. The Creek enters the Lake on the northeastern shore and exits the Lake's southwestern shore. The Lake is in the central portion of the Turtle Creek watershed, downstream of Turtle Lake, and upstream of the confluences with Delavan Lake's outlet stream (hereafter referred to as "Swan Creek"). Turtle Creek enters the Rock River just south of Beloit, Wisconsin. From there, the Rock River enters the Mississippi River just south of Rock Island, Illinois. Water from Lake Comus and the Turtle Creek watershed ultimately discharges to the Gulf of Mexico.

Lake Comus is classified by the Wisconsin Department of Natural Resources (WDNR) as a reservoir. The reservoir was formed when Turtle Creek was dammed during the late 1830s just north of Delavan, Wisconsin. The dam originally drove milling equipment, however, the waterpower generated by the dam is no longer used. The dam is now used to maintain and control water levels in the upstream reservoir (i.e., Lake Comus). The Lake is rather shallow, with a maximum depth of six feet, and a mean depth of four feet.[2] Much of the Lake's shoreline is owned by the City of Delavan, making this lake very accessible to the public. Lake Comus has a surface area of 131 acres and receives runoff from over 33 square miles of primarily agricultural watershed (Map 1.2). This means that each acre of lake receives runoff from over 175 acres of watershed. Given that the Lake's watershed is dominated by agricultural land use, the potential for heavy sediment and nutrient loads to the Lake is high.

Lake Comus and its watershed provide numerous, widely varying, recreational assets. Prominent features include the Ora Rice Arboretum and Paul Rice Arboretum along the Lake's western shoreline, the Turtle Valley Wildlife Area in the upstream portion of the watershed, a public boat launch, and several shoreline residences. The Lake successfully supports a spectrum of recreational interests as evidenced by observations from Commission staff and Lake residents. Lake and Creek users engage in fishing, hunting, paddle sports, birdwatching, boating, and other activities.

Lake Comus supports a locally-popular warmwater fishery with a range of sport and panfish. Portions of the watershed, including the Lake's eastern shoreline and upstream groundwater springs, may also provide habitat for coolwater fish species as well as spawning grounds for northern pike (Esox lucius). The Lake's watershed also contains critical species habitat areas and a variety of wetlands, uplands, and woodlands. The watershed likely supports many resident animal species, including several species of amphibians and rare reptiles, small and large mammals, insects, and invertebrates, as well as a number of transient bird species that may be found in the area during seasonal migrations.[3]

1.3 LAKE MANAGEMENT GOALS

The purpose of this plan is to provide a framework to enable communities in the area to work together with a common mission: to protect and improve Lake Comus. This lake management plan focuses on what can be done to continue to protect existing high-quality resources from human impacts and prevent future water pollution or resource degradation from occurring by implementing the following general goals:

- Minimize the further degradation of surface water and preserve, restore, and maintain the high quality of all waterbodies within the watershed

- Identify opportunities to improve the quality of the land and water (including groundwater) resources within the watershed by reducing both nonpoint agricultural and urban runoff

- Manage and develop lands in a manner that is consistent with the protection of living resources: avoid habitat fragmentation and encourage the preservation and enhancement of wetlands and wildlife corridors including providing and preserving connections with upland habitats and through sensitive landscaping practices

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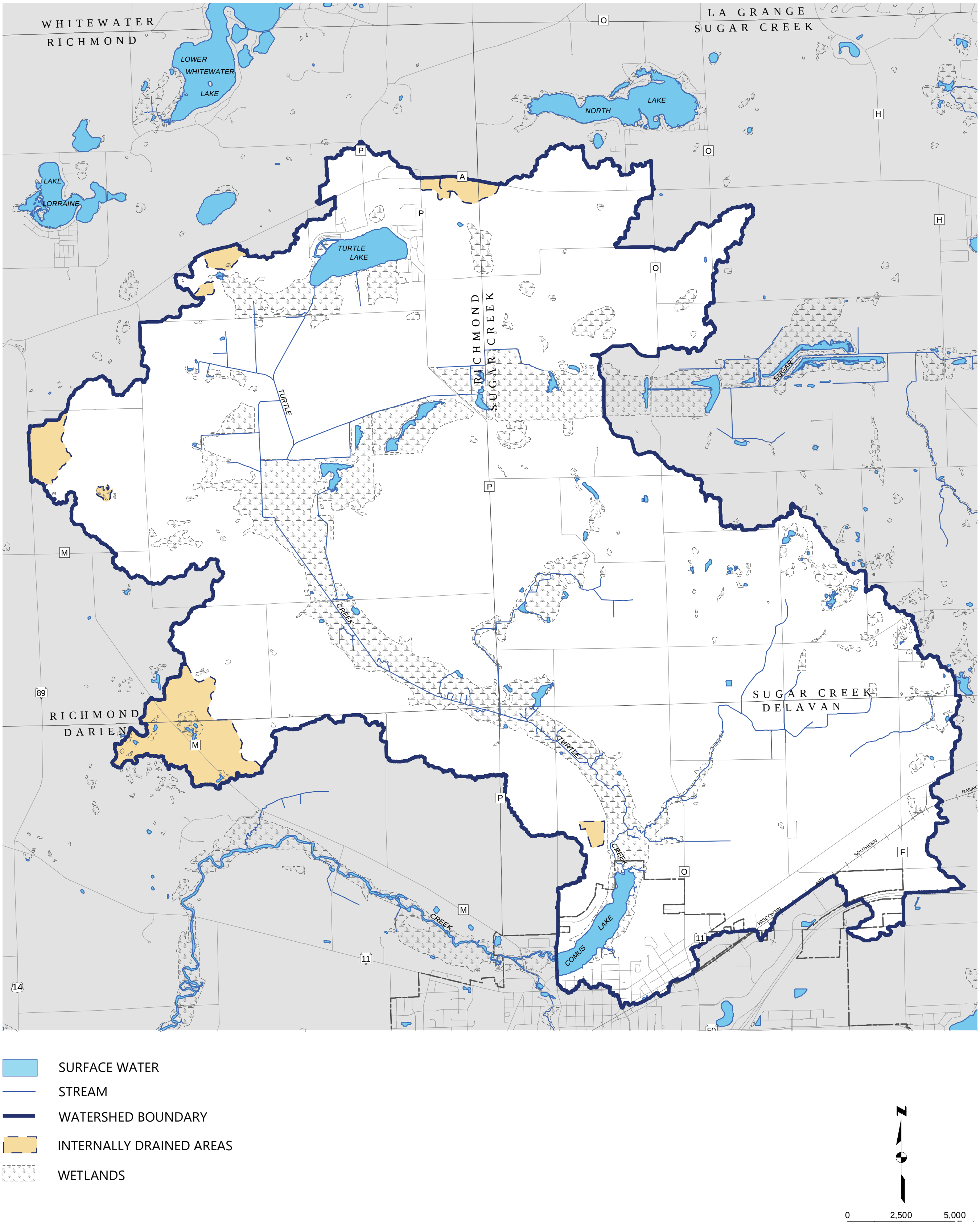
[2] *LCPRD board members report that some portions of the Lake are up to eight feet deep.*

[3] *These estimates are based on bird, amphibian, and reptile databases for the Region.*

Map 1.2
Surface Water Features and Internally Drained Areas Within the Comus Lake Watershed



Source: SEWRPC

- Enhance recreational opportunities on Lake Comus and Turtle Creek, particularly for fishing, hunting, and paddle sports

- Promote active stewardship among residents, farmers, landowners, businesses, community associations, as well as governmental and non-governmental organizations

These goals are consistent with objectives established in the Downtown Delavan Strategic Plan,[4] the Turtle Creek Priority Watershed Plan,[5] the Multi-Jurisdictional Comprehensive Plan for Walworth County,[6] the Walworth County Land and Water Resources Management Plan,[7] and the Rock River Recovery.[8]

This lake and watershed inventory represents an ongoing commitment by the LCPRD to sound environmental planning pursuant to recommendations set forth in the regional and river basin water quality management plans and forms the basis for the development of a comprehensive lake management plan for Lake Comus. This inventory was prepared by the Commission in cooperation with the LCPRD and the City of Delavan and it incorporates the data and analyses developed in the lake management related studies. This report describes the physical, chemical, and biological characteristics of the Lake and pertinent related characteristics of the tributary watershed, as a basis for assessing the feasibility of various watershed and in-lake management measures which may be applied to enhance the water quality conditions, biological communities, and recreational opportunities of the Lake. The primary objectives of this inventory are:

- Update watershed condition descriptions, with particular emphasis on the Turtle Creek watershed immediately upstream of the Lake. This includes identifying and quantifying potential point and nonpoint sources of pollution, nutrient and sediment inputs, and nutrient and contaminant balances. Also, provide conceptual examples of projects that could be undertaken to mitigate the impact of identified sediment and pollution sources.

- Identify the extent of existing and potential future water quality problems likely to be experienced in the Lake and in Turtle Creek. This includes examining the Lake's and Creek's water quality using physicochemical monitoring data collected as part of ongoing water quality monitoring programs. In addition, estimate future water quality changes and provide advice regarding appropriate future monitoring activity.

- Examine the Lake's aquatic plant community. Document the status of the Lake's aquatic plant community, with particular emphasis on the occurrence and distribution of nonnative species. Use this information to better understand the changes and dynamics of the Lake's aquatic plant community. Evaluate the impact of aquatic plants on Lake use, water quality, and habitat value.

- Survey sediment distribution, composition, chemistry, and susceptibility to compaction within the Lake and recommend strategies to reduce sediment loading to the Lake.

- Inventory Lake shoreline conditions and recommend practices to mitigate shoreline erosion.

- Assess the degree and intensity of recreational water use in and around Lake Comus.

- Compile and summarize readily available fish and wildlife information for the Lake, Turtle Creek, and the Lake's watershed.

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[4] *City of Delavan and Vandewalle & Associates, Inc.*, Downtown Delavan Strategic Plan: City of Delavan, Wisconsin, *May 2013*.

[5] *Rock County Department of Land Conservation,* Turtle Creek Priority Watershed Plan, *April 1984*.

[6] *SEWRPC Community Assistance Planning Report No. 288 (2nd edition)*, A Multi-Jurisdictional Comprehensive Plan Update for Walworth County, *June 2019*.

[7] *Walworth County Land Use and Resource Management,* Walworth County Land and Water Resource Management Plan: 2021 - 2030*, 2020*.

[8] *dnr.wisconsin.gov/topic/TMDLs/RockRiver/index.html*

- Formulate appropriate management objectives, action plans, public information and education strategies, ordinances, and other possible responses to the identified problems.

- Provide advice and concepts describing management, enhancement, and restoration measures that address identified issues of concern and could improve current and future Lake health and ecological resilience/resistance. This likely will include active measures as well as outreach and education.

Conscientiously implementing the actions recommended herein should provide an important step toward achieving the LCPRD's desired lake use/protection objectives over time.

Credit: SEWRPC Staff

INVENTORY FINDINGS AND RELEVANCE TO RESOURCE MANAGEMENT 2

Despite being a valuable resource to the community as briefly described in Chapter I, human activity around the Lake and within its watershed subjects Lake Comus to conditions that contribute to existing management challenges and could lead to future problems and concerns. To better define and understand these issues, and to help maintain water body characteristics supporting quality recreational use and the Lake's great latent ecological value, the Lake Comus Protection and Rehabilitation District (LCPRD) and the Southeastern Wisconsin Regional Planning Commission (Commission) executed an agreement to study the causes of community concern and to develop a management plan addressing these concerns.

2.1 LAKE AND WATERSHED PHYSIOGRAPHY

The condition and overall health of waterbodies are related to the natural and human-induced characteristics and features within the area draining to the waterbody. This section describes many features including the shape and arrangement of landscape features, the composition and arrangement of soil and rock, stream channel and Lake basin shapes, how water moves through the area, and how humans influence and alter the landscape.

Given the connections between the practices around a lake and lake water quality, it is important to characterize the area that drains to a lake—its watershed—to determine potential pollution sources and risks to the lake's water quality. Several items need to be examined in order to complete this characterization, including:

- **The location and extent of a lake's watershed.** Before characterizing a watershed, its extent must be quantified. The delineation process involves carefully examining land surface elevation data to delineate the area from which water draining from the land surface eventually reaches a waterbody. This analysis provides the basis for determining whether potential pollutant sources threaten a waterbody. For example, if a pollutant source is near a waterbody but outside the watershed, contaminated surface runoff from that source would not reach the waterbody. Therefore, such a pollutant source may not influence water quality within the waterbody of interest.

- **The type and location of existing land use within the watershed.** The type, extent, and location of land use practices can help predict the type and amount of pollutants reaching a waterbody. Land use conditions can be represented with models to estimate total pollutant loads entering a waterbody, evaluate the relative contribution of certain land uses or areas, and predict consequences of land use change. Once loads are estimated, management efforts can be efficiently focused on those areas generating the greatest loads. For example, if tilled agricultural fields are predicted to be the primary source of phosphorus to a water body, initial pollution reduction efforts may focus on tillage practices, soil health, buffers, and other agricultural best management practices.

- **The type and location of past land use changes within the watershed.** Being aware of past land use changes can provide context for understanding linkages between watershed activities and waterbody health. This is particularly true when considered with contemporaneous water quality monitoring data or well-documented historical issues. For example, if a long-term lake property owner remembers or recorded years of heavy aquatic plant growth, large algal blooms, or low or high-water levels, those conditions can be compared with historical land use changes to examine if something changed to cause an issue (such as an increase in impermeable surfaces or installation of stormwater infrastructure). This information can help offer insight into how a waterbody may react to similar future changes and situations.

- **The nature and location of planned land use within the watershed.** In addition to past and current land use in a watershed, planned land use changes can help estimate future waterbody conditions. This information helps target areas that may need active or pre-emptive management in the future, as well as estimate the potential type and magnitude of future pollution issues.

- **The location of known pollutant sources in the watershed.** Many human activities contribute pollutants to waterbodies. Many potential pollutant sources are stringently regulated. However, some may continue to be employed and/or are diffuse, creating significant pollution sources. One example is private onsite wastewater treatment systems (POWTS), commonly known as septic systems. POWTS can be a significant source of phosphorus when not properly maintained and are usually a source of chloride. Consequently, it is important to investigate whether POWTS exist within a watershed.

Watershed Extent and Topography

Lake Comus covers 131 acres and receives runoff from a 21,009-acre watershed draining west-central Walworth County.[9] The watershed's upstream reaches are located north of Turtle Lake in the Town of Richmond, an area over six miles to the north of the Lake. Much of the watershed is in the Turtle Valley, through which Turtle Creek flows in a largely northwest to southeast direction. Turtle Creek, which receives water from several unnamed tributaries and Turtle Lake, delivers most of the watershed's runoff to the Lake. A few other small tributaries also deliver water directly to the Lake along its eastern shoreline. Several internally draining areas, which do not contribute surface water runoff to the Lake, are located are located along the watershed's western and northern borders (Map 1.2). These internally draining areas total 661 acres in extent.

The ground-surface elevation in the Lake Comus watershed varies by roughly 165 feet, with elevations of approximately 888 feet above National Geodetic Vertical Datum, 1929 adjustment (NGVD 29) found along the Lake's shoreline to elevations of 1040 feet above NGVD 29 at the crest of prominent hills and ridges in the northern, eastern, and western portions of the watershed (Map 2.1). Approximately 60 percent of the watershed is less than 100 feet higher than the Lake water surface (Table 2.1).

Areas of significant topographic relief are prone to long and/or steep slopes. Steeply sloping areas are less likely to store or infiltrate water and are more likely to experience significant erosion, especially when actively cropped, developed, or urbanized. Eroded sediment is transported to lakes, streams, and wetlands where it settles and has the potential to cover desirable granular substrates. Furthermore, sediment often

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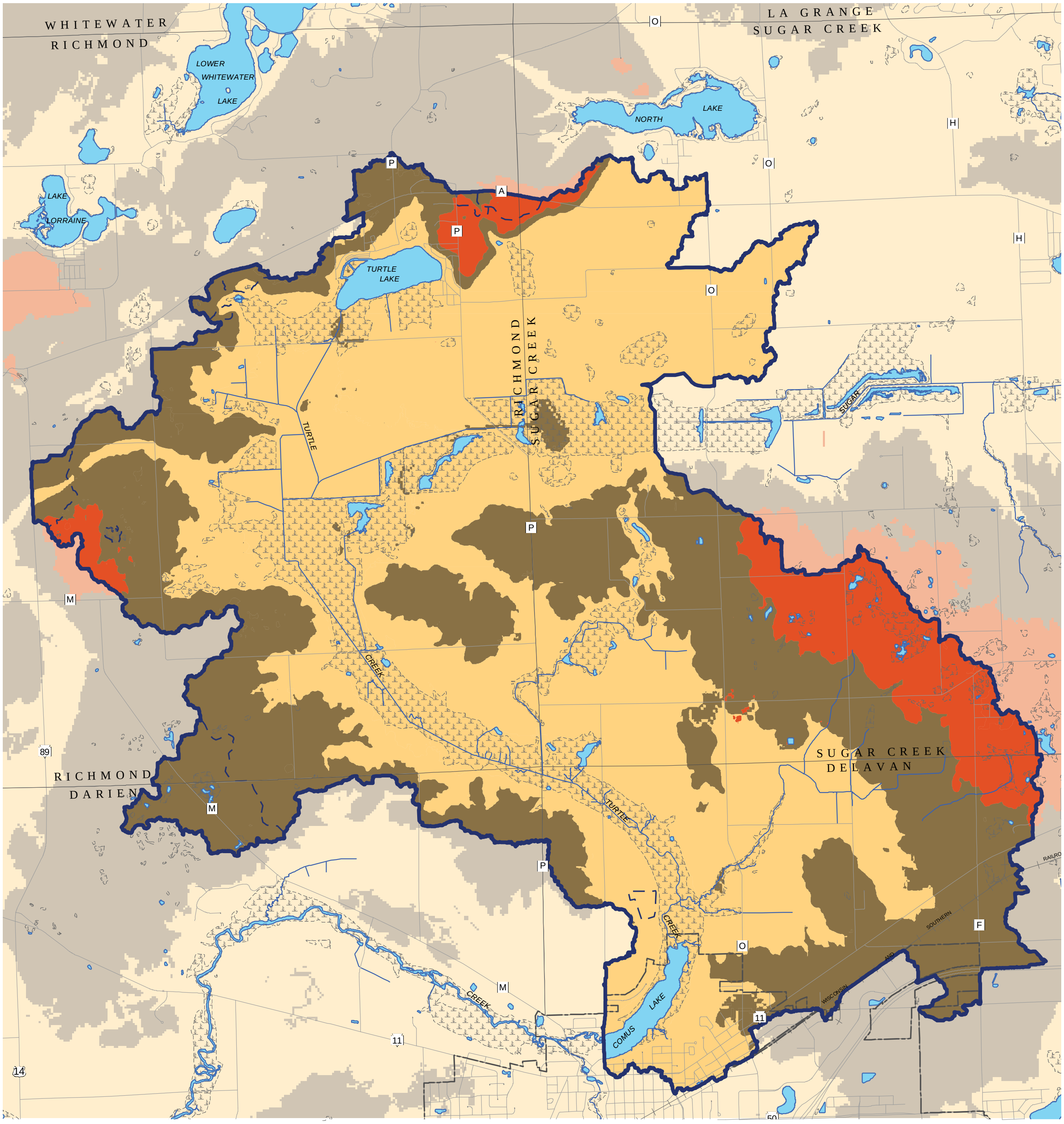
[9] *The Lake Comus watershed boundary was delineated using one-foot interval ground elevation contours derived from 2015 light detection and ranging (LiDAR) data.*

Map 2.1
Comus Lake Watershed Physiography

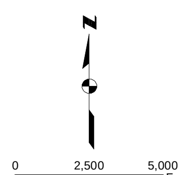


850 - 950	SURFACE WATER
975 - 1000	STREAM
1025	WATERSHED BOUNDARY
	INTERNALLY DRAINED AREAS
	WETLANDS

ELEVATION IN FEET ABOVE NATIONAL GEODETIC VERTICAL DATUM, 1929 ADJUSTMENT

Source: SEWRPC

Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.



contains significant amounts of nutrients, and can contain a variety of pollutants. Slopes in the Lake Comus watershed range from essentially flat to greater than 20 percent. As shown on Map 2.2, most areas within the Lake Comus watershed are relatively level, with 46 percent of the watershed underlain by land surfaces sloping at 2 percent or less, and 84 percent sloping at 4 percent or less (Table 2.2). The lowest slopes are generally found in lowland areas along Turtle Creek and its tributaries, with Turtle Creek only dropping 11 feet in the 5.5 miles between Turtle Lake and Lake Comus.[10] Upland areas are generally comprised of gently rolling hills with slopes between 2 to 6 percent. Nevertheless, steeply sloping land is found throughout the watershed, particularly along the margins of the Turtle Valley as well as in hilly areas along the northern and southwestern edge of the watershed. Some areas are very steep, with slopes up to 37.5 percent.

Table 2.1
Physiography of the Lake Comus Watershed

Elevation (feet)	Acres of Watershed	Percent of Watershed
<875	2,573.44	12.2
875-925	9,641.33	45.6
925-975	7,404.24	35.0
975-1025	1,520.96	7.2

Source: Wisconsin Geological and Natural History Survey and SEWRPC

The topography of land surfaces, as well as the composition and layering of underlying soil, can significantly affect the type and amount of pollutants and sediment washed into the lakes, streams, and wetlands by rainfall and snowmelt. Generally, less permeable soils and steeper slopes generate more erosive potential and a greater ability to carry pollutants and sediment to receiving waters. This situation can be exacerbated if slopes are unvegetated, paved, or relatively impermeable. Runoff volume increases rapidly as slopes increase from zero to about three percent. Further increases in slope only slightly increase runoff volume.[11] However, the same study found that soil erosion increased only gradually up to a slope of four percent. Soil erosion significantly increased when slopes were greater than four percent.

Weather and Climate

Weather and climate describe the same parameters: atmospheric temperature, precipitation, humidity, wind speed, cloud cover, and other conditions. However, weather and climate are not synonymous. The term "weather" generally refers to conditions over short periods of time (e.g., minutes, hours, days, weeks). In contrast, the term "climate" describes long term weather averages, and typically considers time periods of decades or longer. Extended periods of weather data allow climate estimates to be made and allow changes to climate to be noted.

Climate is a dynamic Earth feature and has changed many times over the Earth's history. Wisconsin climate data is based on weather observations that extend back about 180 years. For example, air temperature, precipitation, snowfall, and snow depth data has been collected at the Waukesha Water Works since 1893. The available data indicate that Wisconsin's climate is changing.[12] Many aspects of the landscape's water resource asset base respond to climate and can serve as indicators of climate change at various temporal and spatial scales. Historical data analysis demonstrates that water resources are intimately linked to local and regional climate conditions. Long-term records of lake water levels, lake-ice duration, groundwater levels, and stream baseflow are correlated with long-term trends in atmospheric temperature and precipitation.[13]

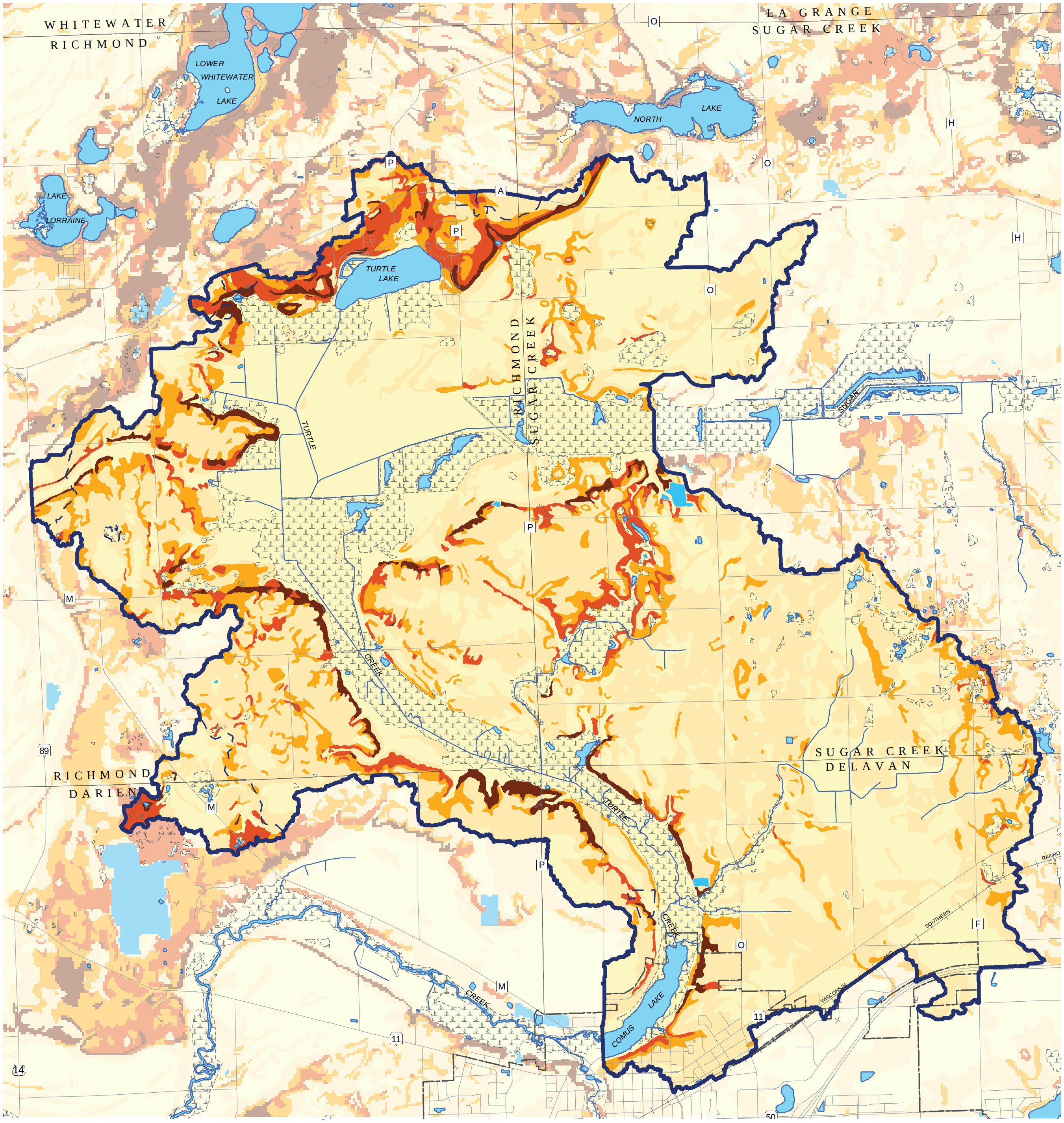
[10] Turtle Creek Priority Watershed Plan*, Department of Land Conservation, Rock County, Wisconsin, 1984.*

[11] *F.L. Duley and O.E. Hays, "The Effects of Degree of Slope on Run-off and Soil Erosion,"* Journal of Agricultural Research, *45(6): 349-360, 1982.*

[12] *C.J. Kucharik, S.P. Serbin, S. Vavrus, E.J. Hopkins, and M.M. Motew, "Patterns of Climate Change Across Wisconsin from 1950 to 2006,"* Physical Geography*, 31(1): 1-28, 2010.*

[13] *Wisconsin Initiative on Climate Change Impacts (WICCI), Wisconsin's Changing Climate: Impacts and Adaptation, Nelson Institute for Environmental Studies, University of Wisconsin-Madison, and Wisconsin Department of Natural Resources, February 2011.*

Map 2.2
Land Surface Slope Within the Comus Lake Watershed



SOILS HAVING SLOPES RANGING FROM 0 TO 2 PERCENT

SOILS HAVING SLOPES RANGING FROM 2 TO 6 PERCENT

SOILS HAVING SLOPES RANGING FROM 6 TO 12 PERCENT

SOILS HAVING SLOPES RANGING FROM 12 TO 20 PERCENT

SOILS HAVING SLOPES OF 20 PERCENT OR GREATER

SURFACE WATER

STREAM

WATERSHED BOUNDARY

INTERNALLY DRAINED AREAS

WETLANDS

Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

N

0 2,500 5,000 Feet

Source: SEWRPC and Natural Resources Conservation Service

The Wisconsin Initiative on Climate Change Impacts (WICCI) concludes that projected future climate change will affect Wisconsin's water resource quantity and quality.[14] However, WICCI also found clear evidence from analysis of past and probable future climate trends that different geographic regions of Wisconsin will respond differently to climate change (Figure 2.1). These differences reflect local variation in land use, soil type, groundwater characteristics, and runoff and seepage response to precipitation. This illustrates the importance of including existing and future conditions as part of the watershed protection plan strategy.

Table 2.2
Land Slopes of the Lake Comus Watershed

Slope (percent)	Acres of Watershed	Percent of Watershed
0.0-1.0	333.57	1.6
1.0-1.5	8,713.68	41.2
1.5-2.0	108.26	0.5
2.0-3.5	537.89	2.5
3.5-4.0	29.20	0.1
4.0-8.0	8,111.98	38.4
8.0-9.0	71.80	0.3
9.0-15.0	1,862.48	8.8
15.0-16.0	21.29	0.1
16.0-25.0	887.82	4.2
25.0-27.5	311.45	1.5
27.5-37.5	102.22	0.5
>37.5	48.35	0.2

Source: Wisconsin Geological and Natural History Survey and SEWRPC

Climate change seems to be altering water availability (volume and timing), distribution and intensity of rainfall over time, and whether precipitation falls as rain or snow, each of which affects water's movement through the water cycle. As shown in Figure 2.2, water entering the landscape arrives as precipitation (rain and snowfall) that either falls directly on waterbodies; runs off the land surface and enters streams, river, wetlands, and lakes; or percolates through the soil, recharging groundwater that flows underground and re-emerges as springs, seeps, or human well discharge, all which can feed lakes, wetlands, and streams.

Even absent climate change, when portions of the hydrologic cycle change, the surface water and groundwater system may be affected. For example, intense groundwater pumping and consumptive use can reduce or completely deplete flow in local streams (see "Groundwater Resources" later in this section). Climate change may expose the vulnerabilities of water supplies within a given natural system or human community, and this vulnerability is commonly proportional to how much humans have altered the water cycle. Water supply vulnerability is often most evident during protracted dry weather while flooding and infrastructure failure are most evident during extremely wet weather.

The WICCI Water Resources Working Group (WRWG) incorporated WICCI's 1980-2055 temperature, precipitation (including occurrence of events), and changes in snowfall projection to evaluate potential hydrologic process and resource impacts.[15] This team of experts identified and prioritized the most serious potential water resource problems related to anticipated climate change and proposed strategic adaptation strategies to address those impacts across the State of Wisconsin. The WRWG offers the following guidance to help local communities develop adaptation strategies:[16]

- **Minimize threats to public health and safety by anticipating and managing for extreme events-floods and droughts.** We cannot know when and where the next flooding event will occur or be able to forecast drought conditions beyond a few months, but we do know that these extreme events may become more frequent in Wisconsin in the face of climate change. More effective planning and preparing for extreme events is an adaptation priority.

[14] *Wisconsin Initiative on Climate Change Impacts, February 2011,* op. cit.

[15] *The Water Resources Working Group (WRWG) included 25 members representing the Federal government, State government, the University of Wisconsin System, the Great Lakes Indian Fish and Wildlife Commission, and the Wisconsin Wetlands Association. Members were considered experts in the fields of aquatic biology, hydrology, hydrogeology, limnology, engineering, and wetland ecology in Wisconsin. Over the course of a year, the group convened to discuss current climate-related water resources research, potential climate change impacts, possible adaptation strategies, and future research and monitoring needs across the entire State of Wisconsin. For more details on climate change, impacts, adaptation, and resources visit www.wicci.wisc.edu/water-resources-working-group.php.*

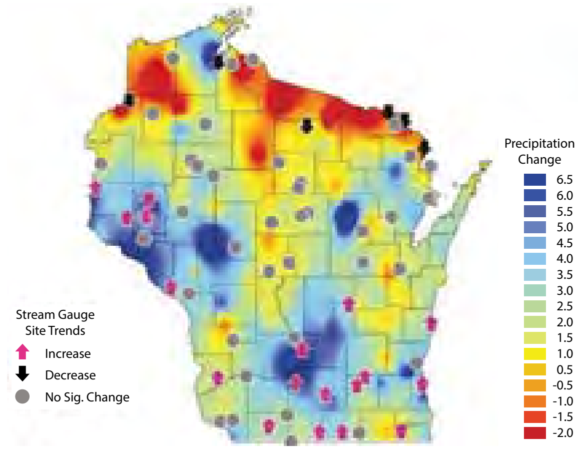
[16] *Wisconsin Initiative on Climate Change Impacts, February 2011,* op. cit.

- **Increase resiliency of aquatic ecosystems to buffer the impacts of future climate changes by restoring or simulating natural processes, ensuring adequate habitat availability, and limiting human impacts on resources.** A more extreme and variable climate (both in temperature and precipitation) may mean a shift in how we manage aquatic ecosystems. We need to try to adapt to the changes rather than try to resist them. Examples include managing water levels to mimic pre-development conditions at dams and other water level structures, limiting groundwater and surface water withdrawals, restoring or reconnecting floodplains and wetlands, and maintaining or providing migration corridors for fish and other aquatic organisms.

- **Stabilize future variations in water quantity and availability by managing water as an integrated resource, keeping water "local" and supporting sustainable and efficient water use.** Many of our water management decisions are made under separate rules, statutory authorities, administrative frameworks, and even different government entities. This can lead to conflicting and inconsistent outcomes. In the face of climate change, the more we can do to integrate these decisions at the appropriate geographic scale, the better adapted and ready for change we will be. In addition, treating our water as a finite resource and knowing that supply will not always match demand will allow for more sustainable water use in the future.

- **Maintain, improve, or restore water quality under a changing climate regime by promoting actions to reduce nutrient and sediment loading.** Water quality initiatives will need to be redoubled under a changing climate in order to minimize worse-case scenarios such as fish kills, harmful blue-green algae blooms, or mobilizing sediments and nutrients and to prevent exacerbating existing problems.

Figure 2.1
River Baseflow and Precipitation Change in Wisconsin: 1960-2006



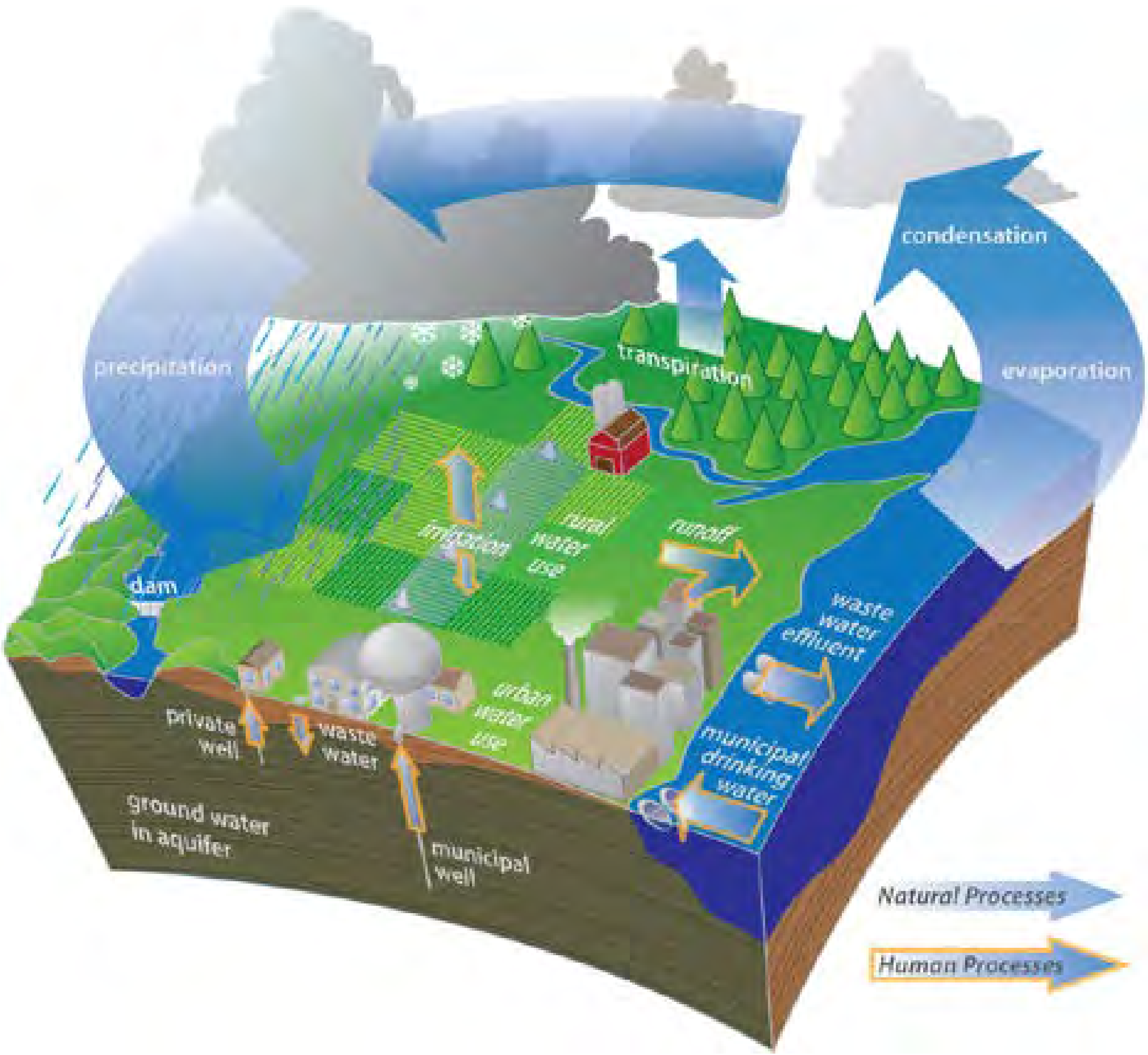
From 1950-2006, Wisconsin as a whole became wetter, with an increase in annual precipitation of 3.1 inches. This increase has primarily occurred in southern and western Wisconsin, while northern Wisconsin experienced some drying. Concomitantly, stream baseflow increased in wetter areas.

Source: Water Resources Working Group of the Wisconsin Initiative on Climate Change Impacts and SEWRPC

Overall, available data suggest that the local climate is becoming increasingly warm and wet. Most additional precipitation is falling in the fall and winter, and wetter than normal spring weather is often a harbinger of greater than normal annual precipitation. The published National Oceanic and Atmospheric Administration (NOAA) for the 1991 – 2020 and the 2006 - 2020 climate normals for the weather station at the Delavan wastewater treatment facility are presented in Table 2.3. As indicated by the difference in these climate normals, the average temperate increased by 1.4°F with nearly 3 additional inches of annual precipitation in the past 15 years. Commission staff have also compiled precipitation records from weather stations in Beloit and Union Grove illustrating the long-term increases in total annual precipitation and the increasing frequency of one-inch rainfall events (Figures 2.3 and 2.4). Records of ice thaw from Geneva Lake in Walworth County as well as Lake Mendota and Lake Monona in Dane County indicate that the length of lake ice cover is decreasing and thaw is occurring earlier in the year.[17] Climate projections developed using the Representative Concentration Pathway 4.5 and 8.5 scenarios indicate that mean annual temperatures in the Upper Rock River watershed, in which Lake Comus lies, have a 70 percent probability of increasing between 2 and 4°F by 2050 and a low but significant probability of increasing between 5 and 9°F. There is less model agreement regarding annual precipitation, which is projected to either decrease by 0.6 inches (1.5 percent probability) or increase by 0.8 inches (2 percent

[17] *Information on changes in lake ice is provided at www.epa.gov/climate-indicators/climate-change-indicators-lake-ice.*

Figure 2.2
Human Influence on Hyrologic Cycle



This schematic shows how human processes associated with land use development affect how water moves through the hydrologic cycle. Water returns to the atmosphere through evaporation (process by which water is changed from liquid to vapor), sublimation (direct evaporation by snow and ice), and transpiration (process by which plants give off water vapor through their leaves).

Source: Water Resources Working Group of the Wisconsin Initiative on Climate Change Impacts and SEWRPC

probability).[18] Changes in patterns of temperature, ice cover, and precipitation can impact soil runoff, shoreline erosion, dam operation, and the growth of aquatic plants. Such insights should be integrated into water resource management planning and water infrastructure design.

Geology and Soils

Most of Walworth County was covered by glacial ice until approximately 15,000 years ago. As part of this most recent glacial advance, the extreme northwestern corner of the County was overridden by the Green Bay Lobe of the Laurentide Ice Sheet while much of the eastern, southeastern, and central portions of the County were covered by glacial ice of the Lake Michigan Lobe. The two Lobes of glacial ice met and formed

[18] *As illustrated by the USGS National Climate Change Viewer for the Upper Rock River watershed. For more information, see www2.usgs.gov/landresources/lcs/nccv/maca2/maca2_watersheds.html.*

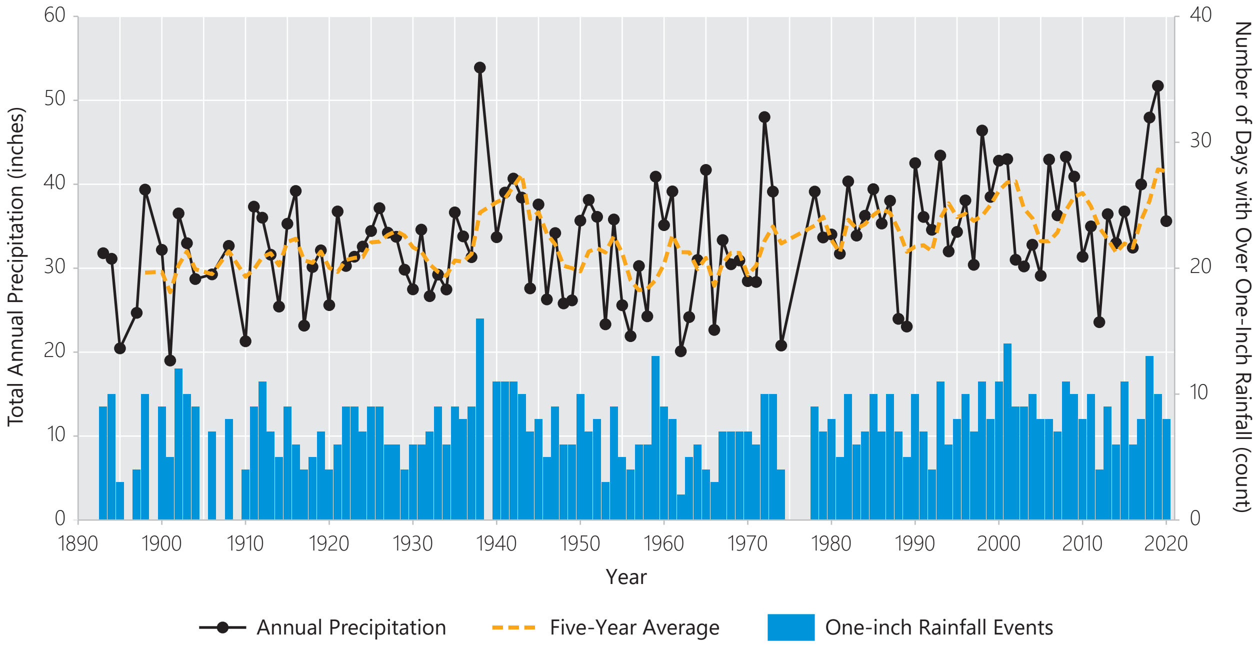
Table 2.3
Climate Normals for Delavan Wastewater Treatment Facility: 1991-2020 and 2005-2020

	1991 - 2020				2006 - 2020				Difference			
Month	Max. Temp. (°F)	Min. Temp. (°F)	Average Temp. (°F)	Precipitation (inches)	Max. Temp. (°F)	Min. Temp. (°F)	Average Temp. (°F)	Precipitation (inches)	Change in Max. Temp. (°F)	Change in Min. Temp. (°F)	Change in Average Temp. (°F)	Change in Precipitation (inches)
Jan	29.2	13.4	21.3	1.56	29.7	13.9	21.8	1.58	0.5	0.5	0.5	0.02
Feb	32.6	16	24.3	1.67	31.1	13.9	22.5	1.86	-1.5	-2.1	-1.8	0.19
Mar	43.7	24.9	34.3	1.97	44	24.9	34.5	2.31	0.3	0	0.2	0.34
Apr	57	35.7	46.4	3.66	56.8	35.7	46.3	3.87	-0.2	0	-0.1	0.21
May	68.8	46.9	57.9	4.19	69.3	47.4	58.4	4.15	0.5	0.5	0.5	-0.04
Jun	79	56.8	67.9	4.96	79	57.1	68.1	5.43	0	0.3	0.2	0.47
Jul	82.9	60.8	71.9	3.79	83.3	61.2	72.3	4.36	0.4	0.4	0.4	0.57
Aug	81.1	58.9	70	3.87	81.3	59	70.2	4.31	0.2	0.1	0.2	0.44
Sep	74.2	51.2	62.7	3.74	74.7	51.9	63.3	3.75	0.5	0.7	0.6	0.01
Oct	60.8	39.5	50.2	2.89	60.5	39.8	50.2	3.36	-0.3	0.3	0	0.47
Nov	46.2	28.9	37.6	2.61	46.9	29.1	38	2.39	0.7	0.2	0.4	-0.22
Dec	34.5	19.6	27.1	1.83	34.9	19.9	27.4	2.35	0.4	0.3	0.3	0.52

Note: The temperature and precipitation values presented in this table are the U.S. Climate Normals calculated by the National Oceanic and Atmospheric Administration using their averaging periods of 1991 – 2020 and 2006 – 2020, as accessed through the following website: www.ncei.noaa.gov/access/us-climate-normals/. The difference was calculated as the maximum temperature (max. temp.), minimum temperature (min. temp.), average temperature (average temp.), and precipitation from 2006 – 2020 subtracted from the corresponding information from 1991 – 2020.

Source: NOAA and SEWRPC

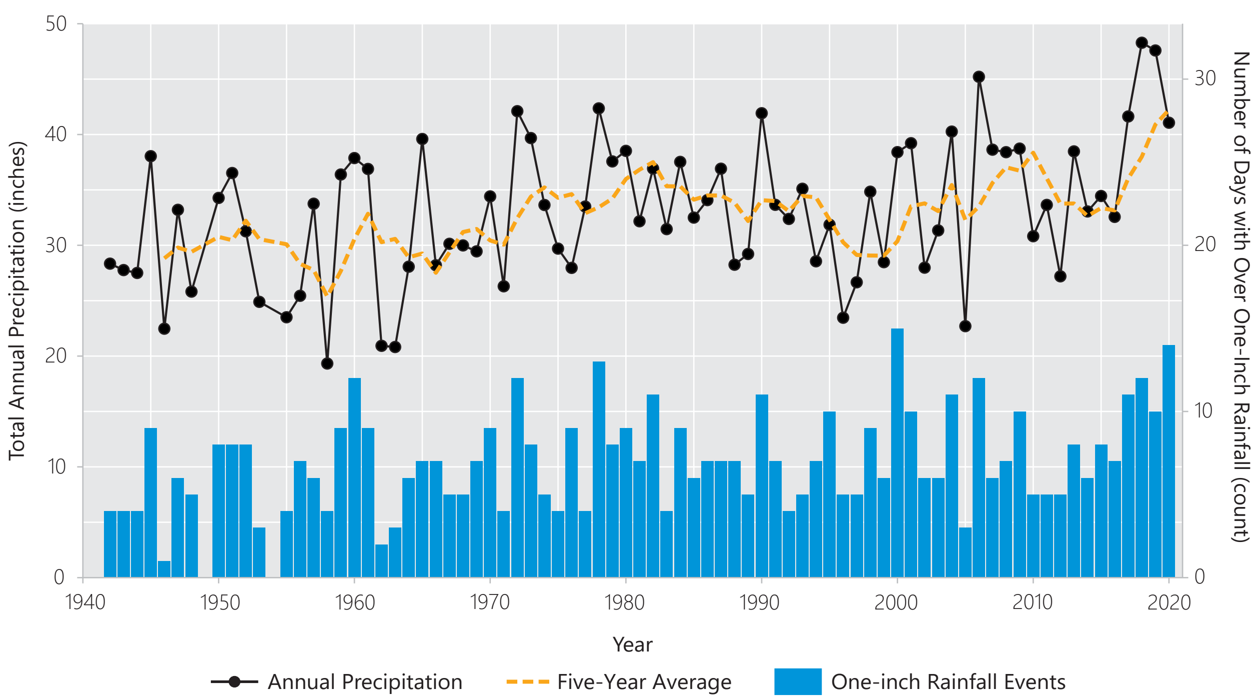
Figure 2.3
Beloit Total Annual Precipitation and One-Inch Rainfall Events: 1893-2020



Note: Daily weather data downloaded from USC00470696 in Beloit, Wisconsin. 1896, 1899, 1905, 1907, 1909, 1939, 1975, 1976, and 1997 omitted due to insufficient data.

Source: NOAA and SEWRPC

Figure 2.4
Union Grove Total Annual Precipitation and One-Inch Rainfall Events: 1942-2020



Note: Daily weather data downloaded from USC00478723 in Union Grove, Wisconsin. 1954 omitted due to insufficient data.

Source: NOAA and SEWRPC

the prominent ridges of the Kettle Interlobate Moraine (commonly referred to as the "Kettle Moraine"), which extends into the County's northwestern corner. South of the Whitewater area, the maximal extent of glacial ice is demarked by the Darien Moraine, a northwest-southeast trending ridge. The Darien Moraine extends from the Whitewater Lake area and wraps southeasterly ultimately forming the prominent ridge south of Lake Geneva. Beyond the Darien Moraine, sediments deposited by earlier glacial advance are exposed at the surface. These sediments were deposited between roughly 20,000 and 130,000 year before present.[19,20,21]

Glaciers transported vast quantities of unsorted sediment (diamicton) to the area and deposited these sediments under and at the distal end of glacial ice. When glacial diamicton is deposited directly by glacial ice, it is referred to as till. Till deposited under glacial ice is termed ground moraine while that deposited near the wasting end of a glacier forms a terminal moraine. Melting glaciers released enormous volumes of water and this water flowed away from the glacier transporting and sorting sediment. Sorted glacial sediment is commonly referred to as glaciofluvial sediment (outwash) when deposited by flowing water or glaciolacustrine sediment (glacial lake deposits) when deposited in still water. The chaotic and rapidly changing environment near melting glacial ice commonly creates complexly interlayered assemblages of till and water-lain sediment. Ice blocks separate from the main body of ice and can be buried in sediment. When the buried ice block melts, an irregular land surface marked by conspicuous steep-walled depressions ("kettles") results.

Near the active edge of melting glacial ice, meltwater forms small, diffuse, rapidly evolving channels that have a similar appearance to a river delta. Much of northwestern and southeastern Walworth County are covered by sediment deposited by flowing meltwater.[22] Small diffuse channels can coalesce to create large meltwater channels carrying vast amounts of water. Such channels can erode previously deposited sediments and can erode prominent steep-walled valleys. As finer grained sediment is winnowed away, large clasts often remain behind creating a lag deposit of boulders and cobbles. When glaciers exit the area, the primary source of water to these valleys is eliminated leaving a small stream in its place. This smaller stream is wholly incapable of forming the prominent channel that it flows through and is called a "misfit stream". The broad valley through which Turtle Creek flows upstream of Lake Comus was likely eroded by glacial meltwater and Turtle Creek is an example of a misfit stream.

Surficial sediments in the uplands draining to Lake Comus were deposited directly by glacial ice and consists of yellowish-brown, sandy glacial till and debris-flow sediment of the New Berlin Member of the Holy Hill Formation. The land surface is commonly hummocky. Sand and gravel New Berlin Member sediment typically underlies the finer-grained surficial layer. The areas occupied by marshland, waterbodies, and other low-lying areas are commonly underlain by meltwater stream sediment. As it flows south, Turtle Creek enters a more confined channel eroded by glacial meltwater. Glacial meltwater erosion likely enriched the coarse-grained fraction in Pleistocene-age sediment. Therefore, boulders and cobbles are likely common in higher gradient reaches and/or are likely buried under modern stream sediment.

The Lake Comus watershed lies just west of the Niagara Escarpment. Consequently, essentially all of Lake Comus' watershed is underlain by Ordovician-age bedrock. Modest areas in the eastern portion of the watershed are underlain by easily eroded shale of the Maquoketa Formation. The balance of the watershed is underlain to more erosion resistant dolomite of the Sinnippee Group.[23] Prominent bedrock

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[19] *R.G. Borgman,* Ground-Water Resources and Geology of Walworth County, Wisconsin, *U.S. Geological Survey and Wisconsin Geological and Natural History Survey, Information Circular No. 34, 1976.*

[20] *An excellent overview of Wisconsin's glacial geology is published by the Wisconsin Geological and Natural History Survey: Attig, John W., Michael Bricknell, Eric C. Carson, Lee Clayton, Mark D. Johnson, David M. Mickelson, and Kent M. Syverson (Contributors),* Glaciation of Wisconsin*, Wisconsin Geological and Natural History Survey Educational Series 36, Fourth Edition, 2011.*

[21] *Syverson, Kent M., Lee Clayton, John W. Attig, David M. Mickelson (Editors),* Lexicon of Pleistocene Stratigraphic Units of Wisconsin*, Wisconsin Geological and Natural History Survey Technical Report 1, 2011.*

[22] *Ham, Nelson R and John W. Attig,* Preliminary Pleistocene Geologic Map of Walworth County, Wisconsin*, Wisconsin Geological and Natural History Survey Open-File Report 2004-08, 2004.*

[23] *Massie-Ferch, K. M.,* Preliminary Bedrock Geologic Map of Walworth County, Wisconsin*, Wisconsin Geological and Natural History Survey Open-File Report 2004-11A, 2004.*

valleys are found throughout Walworth County. However, the structure and composition of underlying bedrock appears to exert little influence on surface topography and drainage patterns in Lake Comus watershed (Map 2.3).[24]

Soils are the uppermost layers of terrestrial sediment and result from weathering and biological activity. The type of soil underlying an area depends on several factors including landscape position and slope, parent material, hydrology, climate, and the types of plants and animals present. The Lake Comus watershed has a diverse array of soils, with soils of the Miami-McHenry Association, Plano-Griswold Association, and the Casco-Fox Association predominant in upland areas while soils of the Houghton-Palms Association predominate along Turtle Lake, Turtle Creek, and Lake Comus (Map 2.4 and Table 2.4). Miami-McHenry Association soils are generally well-drained soils with a subsoil of clay loam and silty clay loam. These soils are found on upland till plains where loess deposits were less than 18 inches thick over till as well as on terminal moraines.[25] These soils are found in the central portion of the watershed on uplands to the east and west of the Turtle Creek valley. Like the Miami-McHenry soils, the Plano-Griswold Association soils are also well-drained soils found on till plains, but these soils have a subsoil of silty clay loam and sandy clay loam. These soils are found on uplands in the watershed's southeastern corner. Casco-Fox Association soils are well-drained soils over a subsoil of clay loam that are moderately deep over sand and gravel from glacial outwash plains. These soils are found in the northern part of the watershed near Turtle Lake, extending into the watershed from the southern portions of the Kettle Moraine. The Houghton-Palm Association soils are generally poorly drained, highly organic soils developed in decomposing plant materials within topographic depressions and wetlands, such as those in the Turtle Valley. Just over five percent of the watershed is covered by Plano, gravely-substratum Warsaw Association soils, which are found along the eastern, northeastern, and western edges of the watershed. These soils are well-drained, have a subsoil of silty clay loam and clay loam that is moderately deep over sand and gravel, and found on glacial outwash plains and stream terraces.[26] A small area of Casco-Rodman Association soils is found at the northwestern edge of the watershed. Soils of the Casco-Rodman association are typically well drained, with subsoils often dominated by sand and gravel although clay and silt layers are found. The Casco-Rodman Association soils are typical of the Kettle Moraine and are commonly found in areas of irregular topography and great topographic relief.[27]

Hydric soils are formed when soils are saturated for extended periods of time. Hydric soils indicate groundwater near the land surface, ponding, or extended flooding, and are commonly associated with wetland areas. Approximately 17 percent of the Lake Comus watershed is underlain by soils exhibiting hydric characteristics. Most of these areas are located along in the Turtle Valley along Turtle Creek and its tributaries as well as adjacent to Lake Comus (Map 2.5). Many hydric soil areas were likely drained for human use. Hydric soil areas often are sites of physical and biological processes that protect and sustain a lake's water quality and ecology and therefore warrant protection.

Hydrologic soils groups indicate the amount of runoff from bare soil following prolonged wetting.[28] Soils with high permeability rates, such as sandy and/or gravelly soils, generally generate less runoff than soils with low permeability rates, such as soils with over 40 percent clay. High permeability soils generate less runoff because the water quickly moves to lower soil layers rather than saturating the upper layer and moving over the land surface to topographically lower areas as runoff, as occurs in low permeability soils. Soils are placed into four broad classes (A, B, C, and D) indicating the amount of runoff that can be expected from soil, with A as the lowest runoff potential and D as the greatest runoff potential. Soil permeability can also vary depending on the water table elevation. To account for this, certain soils have dual hydrologic group designations, such as A/D, that indicates the amount of runoff expected if the soil is drained or undrained.[29]

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[24] Ibid.

[25] Soil Survey of Walworth County, Wisconsin, *United States Department of Agriculture, 1971.*

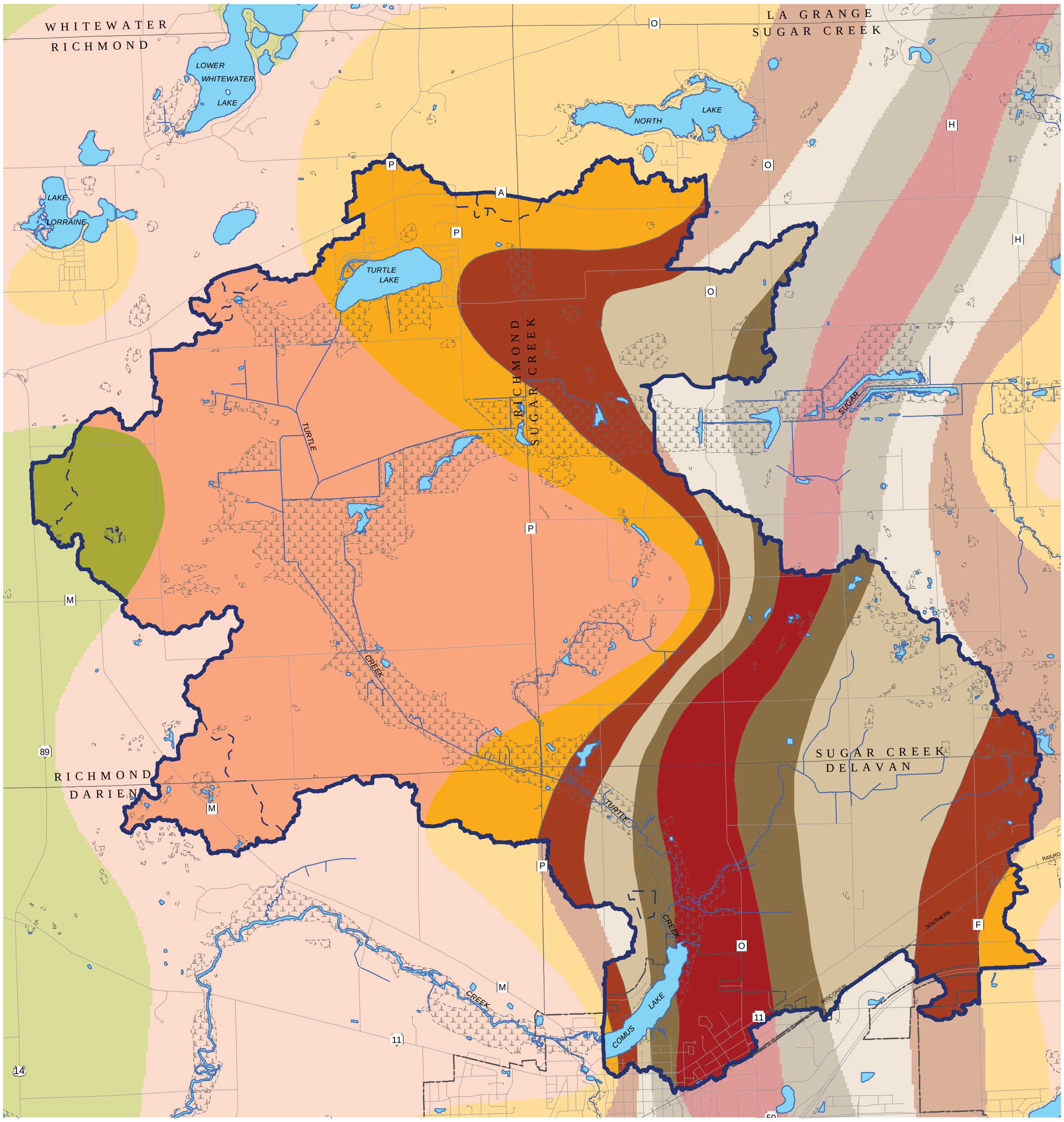
[26] Ibid.

[27] *J.A. Steingraeber and C.A. Reynolds,* Soil Survey of Waukesha County, Wisconsin*, United States Department of Agriculture, 1971.*

[28] *SEWRPC Planning Guide No. 6,* Soils Development Guide, *1969.*

[29] *National Engineering Handbook Part 630 Hydrology*, Chapter 7: Hydrologic Soil Groups, *United States Department of Agricultural Natural Resources Conservation Service, 2007.*

Map 2.3
Unconsolidated Sediment Thickness Within Comus Lake Watershed



100 - 150	300 - 350
150 - 200	350 - 400
200 - 250	400 - 450
250 - 300	

SURFACE WATER
STREAM
WATERSHED BOUNDARY
INTERNALLY DRAINED AREAS
WETLANDS

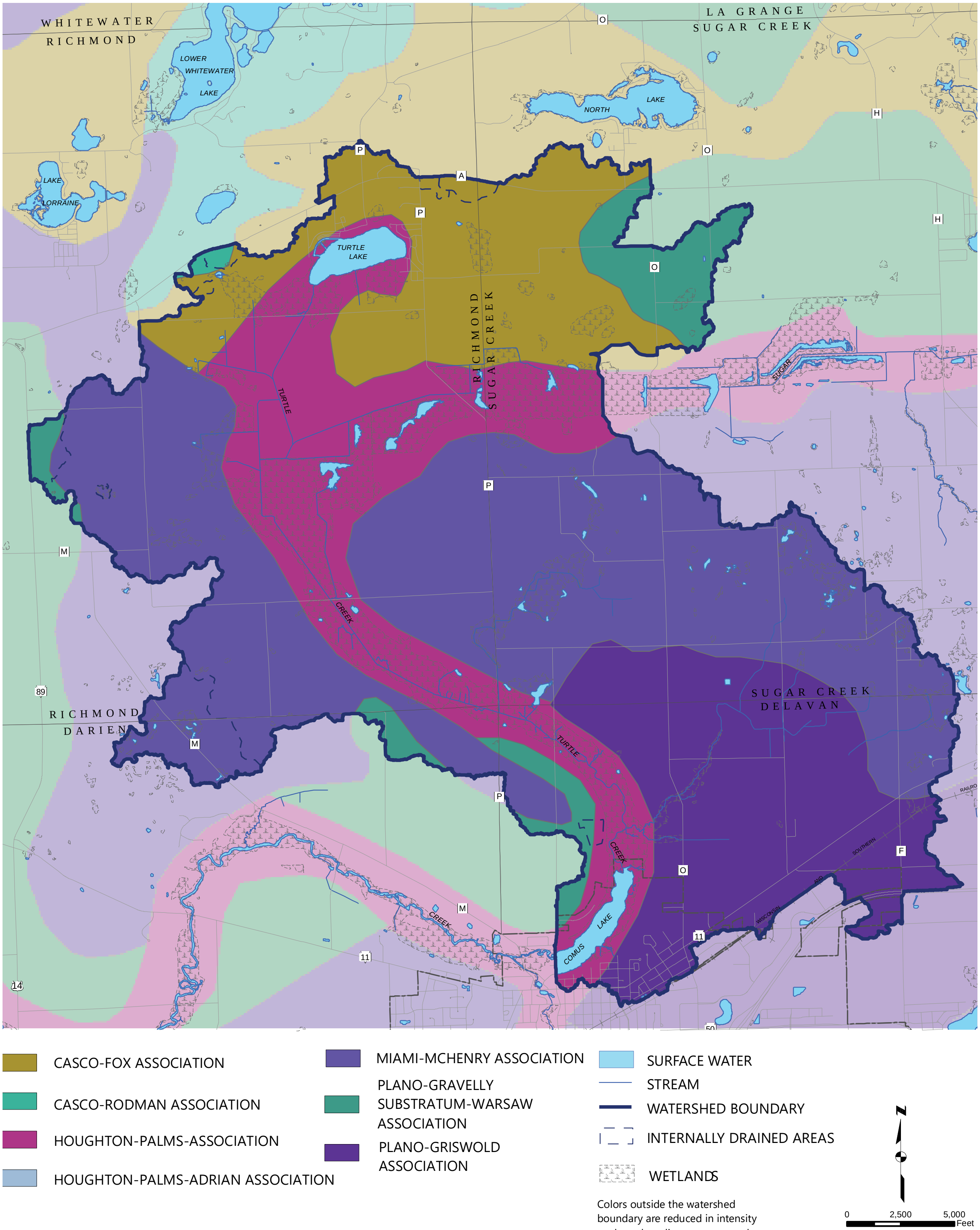
The information shown on this map is general in nature, and may not reflect localized variations.

Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

0 2,500 5,000 Feet

Source: Wisconsin Geological and Natural History Survey and SEWRPC

Map 2.4
Comus Lake Watershed Soil Association



Source: Natural Resources Conservation Service and SEWRPC

Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

Over two-thirds of the Lake Comus watershed (including most upland areas) is covered by soils in the B hydrologic soil group, indicating that these soils are generally well-drained silty or loamy soils that yield a moderate amount of runoff (Map 2.6 and Table 2.5). The areas around Turtle Creek, the Creek tributaries, and Lake Comus are generally covered by soils in the A/D and B/D groups, indicating these soils have low to moderate runoff when drained and very high runoff when undrained. Just over five percent of the watershed, scattered throughout upland areas, is covered by soils in the C and C/D groups which have moderately high to high runoff.

Table 2.4
Soil Associations of the Lake Comus Watershed

Soil Association	Acres of Watershed	Percent of Watershed
Casco-Fox Association	3,038.93	14.4
Casco-Rodman Association	44.09	0.2
Houghton-Palms Association	4,565.02	21.6
Miami-McHenry Association	8,644.33	40.9
Plano-Griswold Association	3,761.51	17.8
Plano, gravelly substratum Warsaw Association	1,086.09	5.1

Source: Wisconsin Geological and Natural History Survey and SEWRPC

Water Resources

Lake Comus receives water from precipitation falling directly upon its open water surface, from runoff in the Lake's watershed, and from groundwater. The Lake loses water via evaporation and plant transpiration, to groundwater, and through the Lake's outlet to downstream portions of Turtle Creek. This section describes principles needed to understand water resource feature dynamics, discusses management principles, examines the way water enters and leaves the Lake, provides insight into morphometry of the Lake, and describes watershed features influencing hydrology. This information is used to suggest management options in Chapter 3.

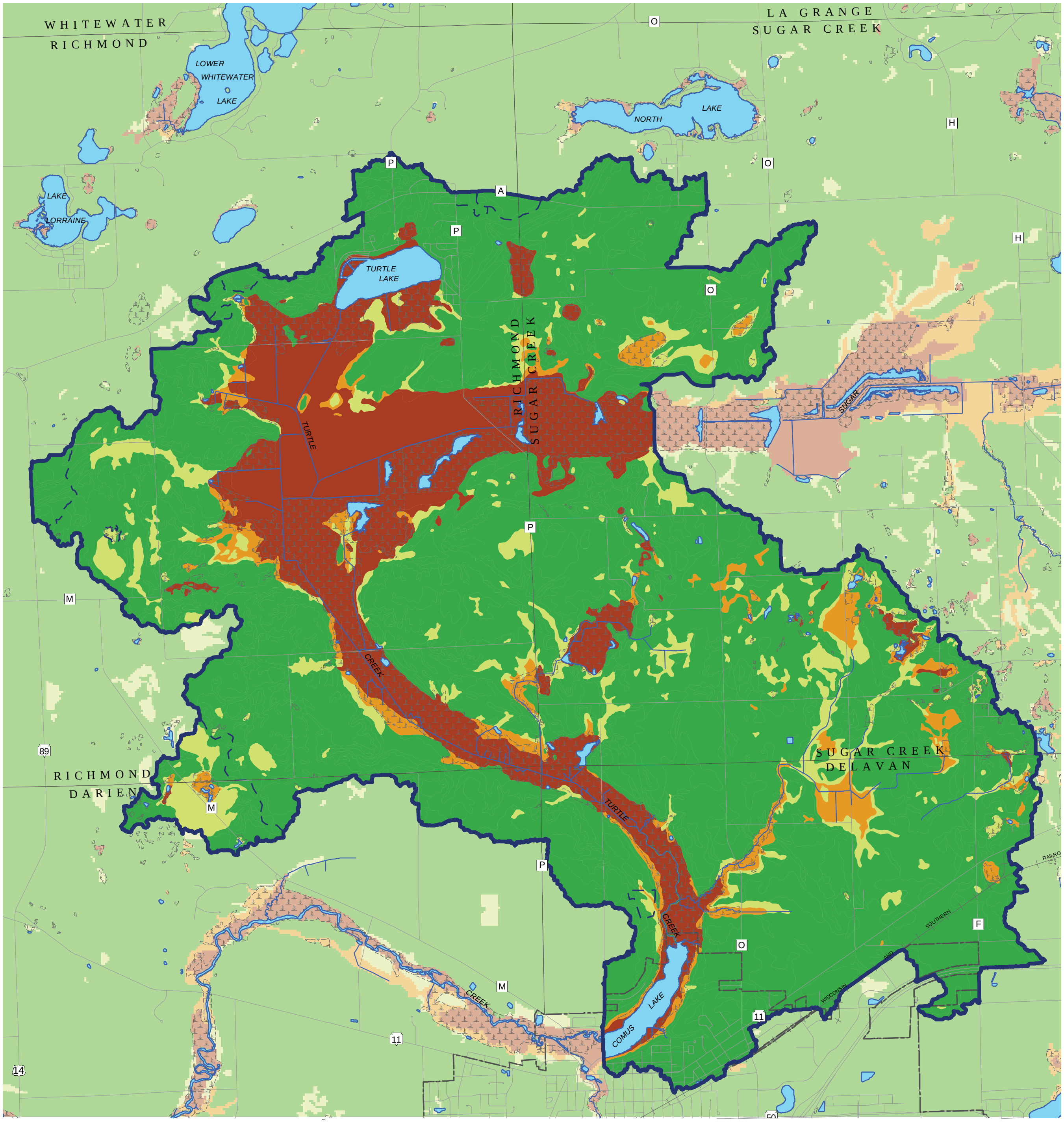
General Concepts and Management Principles

All waterbodies gain and lose water through various means. Precipitation directly or indirectly supplies all water found in the Region's waterbodies. Although some waterbodies are largely fed by runoff, tributary streams, human discharges, and/or groundwater, all these sources ultimately are derived from precipitation. Waterbodies lose water in several ways including evaporation, plant transpiration, outflow, infiltration into beds and banks, and human withdrawal. When water inflow and outflow are not balanced, water elevations and streamflow fluctuate. If water supply is less than water demand, lake elevations can fall and stream flows can be reduced or eliminated. During heavier than normal precipitation, lake and river levels may rise.

As illustrated in Figure 2.2, groundwater and surface water systems are connected. Water sources to a water body include:

- **Precipitation** falling directly upon a water body. While this can be a significant water source to expansive features such as lakes and wetlands, it typically is not a significant contributor to a stream or river's total water budget.
- **Surface runoff** (or overland flow) that travels over the land surface to a waterbody. Surface runoff is the primary source of wet-weather stream flow in most watersheds.
- **Interflow** is that portion of infiltration that moves laterally in the unsaturated zone and returns to the land surface of enters water bodies before becoming groundwater.
- **Hyporheic flow** is stream flow occurring in or near the stream bed paralleling the general direction of stream flow. This is only important in streams and rivers. Hyporheic flow may persists even when visible stream flow ceases. Hyporheic flow initiates and sustains many important geochemical and biological processes that support stream health.
- **Groundwater** is the primary source of water to most waterbodies during dry weather. In some instances, waterbodies lose water to the groundwater flow system.

Map 2.5
Hydric Soils Within the Comus Lake Watershed



HYDRIC

NON HYDRIC

PREDOMINANTLY HYDRIC

PREDOMINANTLY NON HYDRIC

SURFACE WATER

STREAM

WATERSHED BOUNDARY

INTERNALLY DRAINED AREAS

WETLANDS

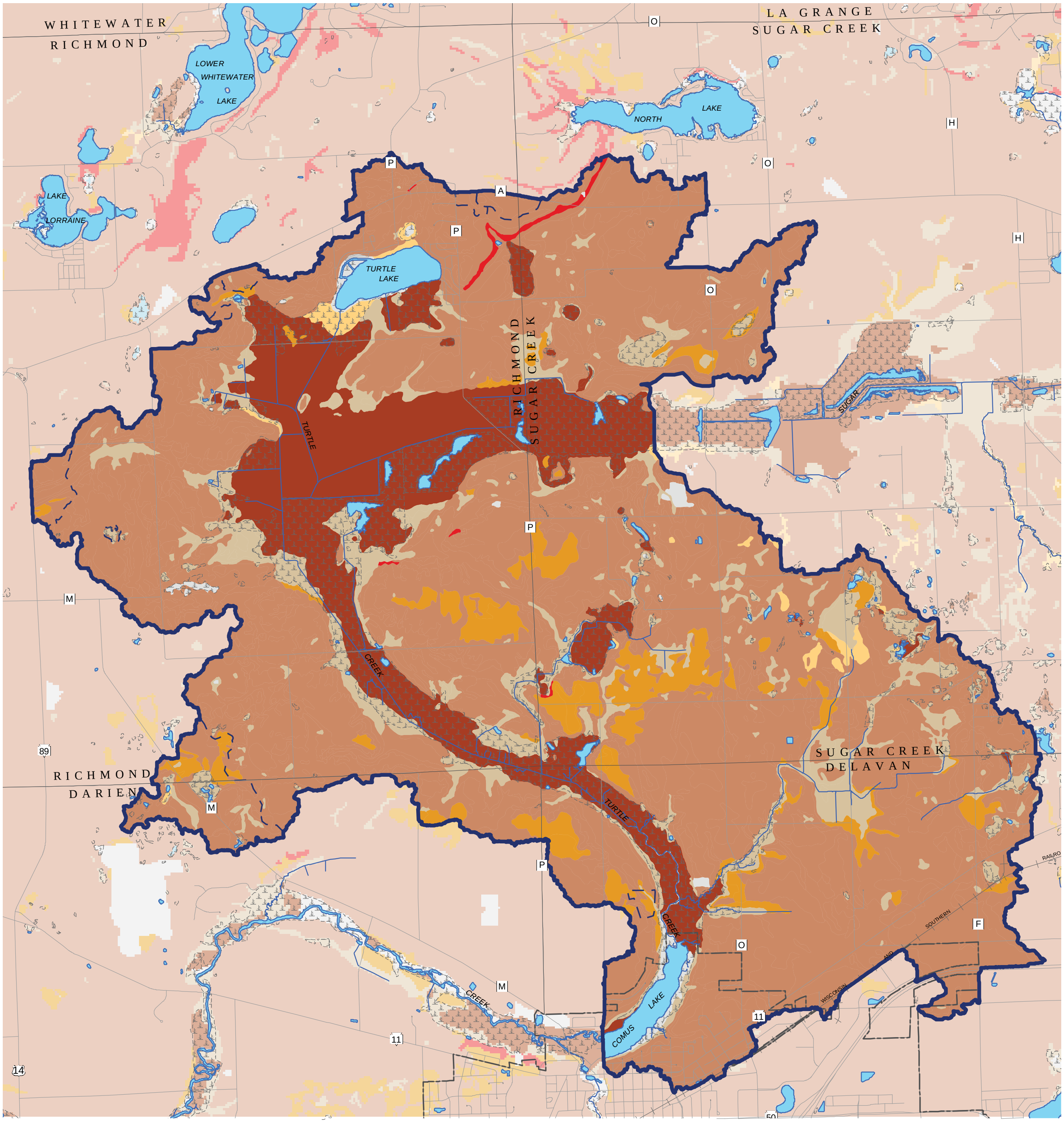
Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

N

0 2,500 5,000 Feet

Source: Natural Resources Conservation Service and SEWRPC

Map 2.6
Hydrologic Soils Within the Comus Lake Watershed



GROUP A:
WELL-DRAINED SOILS

GROUP A/D:
WELL-DRAINED SOIL/VERY POORLY DRAINED SOIL (WELL-DRAINED IF WATER TABLE IS LOWERED THROUGH PROVISION OF A DRAINAGE SYSTEM. VERY POORLY DRAINED IF WATER TABLE IS NOT LOWERED.)

GROUP B:
MODERATELY DRAINED SOILS

GROUP B/D:
MODERATELY DRAINED SOIL/VERY POORLY DRAINED SOIL (MODERATELY DRAINED IF WATER TABLE IS LOWERED THROUGH PROVISION OF A DRAINAGE SYSTEM. VERY POORLY DRAINED IF WATER TABLE IS NOT LOWERED.)

GROUP C:
MODERATELY-DRAINED SOILS

GROUP C/D:
MODERATELY-DRAINED SOILS WHEN DRAINED VERY POORLY DRAINED IF WATER TABLE IS NOT LOWERED

GROUP UND:
UNDETERMINED

SURFACE WATER

STREAM

WATERSHED BOUNDARY

INTERNALLY DRAINED AREAS

WETLANDS

Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

N

0 2,500 5,000 Feet

Source: Natural Resources Conservation Service and SEWRPC

Surface runoff and interflow are only important during storm events or snowmelt, and their contributions typically are combined into a single term called the direct runoff component of streamflow. Groundwater, on the other hand, is most important for sustaining waterbodies during periods between storms and during dry times of the year and is often a substantial component of the total annual flow through a waterbody.

Table 2.5
Hydrological Soil Groups of the Lake Comus Watershed

Hydrological Soil Group	Acres of Watershed	Percent of Watershed
A	48.35	0.2
A/D	3,143.38	14.9
B	14,295.34	67.6
B/D	2,043.37	9.7
C	1,048.52	5.0
C/D	138.62	0.7
Undefined	422.39	2.0

Source: Wisconsin Geological and Natural History Survey and SEWRPC

Human Influences on Water Resources

The potential for a natural landscape to detain stormwater runoff and contribute to groundwater recharge is influenced by many factors. Examples include landscape topography, soil composition and structure, antecedent weather, season, and vegetative cover. Runoff speed is slowed, groundwater recharge is increased, and overall runoff volumes are generally reduced by thick healthy vegetative cover, irregular topography that causes water to temporarily pond, permeable healthy soils, gentle slopes, intact wetlands, and well-connected floodplains.

Human land use commonly reduces a landscape's ability to replenish groundwater supplies, compromises natural processes that cleanse runoff, reduces the extent and/or hydraulic connectivity of natural features that temporarily store runoff, and simplifies stream channel geometry. These changes often increase runoff volumes, raise flood elevations, promote soil and streambank erosion, generate higher sediment and nutrient loads to waterbodies, and diminish waterbody ecological health. Preserving or enhancing landscape attributes and features that slow runoff, detain stormwater, and enhance infiltration benefit waterbody and watershed health and resilience in many ways, including the following interrelated examples:

- **Creating impermeable surfaces.** Constructing artificial impermeable surfaces and directing runoff to rapidly draining stormwater conveyance features. Such infrastructure hastens runoff speed, increases runoff volume, and diminishes groundwater recharge. In turn, these changes typically increase the volume of water reaching lakes and rivers through runoff during wet weather which in turn increases runoff intensity and flood elevations, taxes groundwater resources, and decreases flow to waterbodies during dry weather.

- **Groundwater pumping.** Pumping water from water-supply wells and dewatering activity alters natural groundwater flow patterns. If most extracted groundwater is returned to groundwater at or near the point of withdrawal after use, overall impact may be minimal. However, when water is either consumptively used (e.g., evaporated) or is exported from the local groundwater flow system (e.g., carried away by sewers that discharge beyond the groundwatershed boundary), groundwater elevations may fall, flow of springs and seeps feeding surface water features can be diminished, and aquifers feeding water supply wells may yield less water.

- **Diminishing soil permeability.** Until very recently, agricultural practices relied almost solely upon intensive tilling, non-crop plant suppression, artificial nutrient applications, and/or heavy applications of chemical herbicides/pesticides/fungicides so produce target commodities. These practices are expensive to employ and have been found to dramatically alter soil structure over time, reducing soil organic matter content, soil tilth, soil permeability, and dry-weather soil moisture availability. These soil health changes require ever increasing artificial input costs to maintain crop yields and often increase runoff and the potential for soil erosion. As some soil health practitioners state, "the nation is not facing a soil erosion problem, it is facing a soil permeability problem." While cropland is a major focus of this issue, it must be remembered that soil permeability can also be diminished in non-agricultural land through actions that compromise soil health and lead to mechanical compaction.

- **Altering stream morphology.** Streams are often ditched to promote drainage, usually by straightening and deepening natural channels. This generally reduces a watershed's ability to detain floodwater diminishing a stream's ability to deposit sediment and nutrients in quiescent floodplain areas. Less stormwater detention increases runoff speed, increasing wet-weather streamflow volume and velocity, in turn increasing stream power. Increased stream power allows a stream to carry more and larger sized sediment downstream, a condition promoting bank and bed erosion. Increased runoff speed also increases downstream peak flood flow volumes and flood elevations, a situation often addressed by more ditching.

- **Building dams.** Although dams effect stream morphology, most dams in Southeastern Wisconsin create "run-of-the-river" reservoirs. These features not designed or operated to detain floodwater. Most run-of-the-river reservoirs do not significantly influence stream hydrology but often dramatically affect sediment transport, water temperature, water quality, and aquatic ecology. In some instances, existing or retrofitted spillway gates can be carefully operated to beneficially influence stream and reservoir ecology. Other features can be added to dams to promote and enhance aquatic organism community health and recreational opportunities (e.g., fishways, portage routes, unique spillway configurations).

As the examples mentioned above illustrate, a wide range of human activities directly or indirectly affect water supplies feeding lakes and streams and overall waterbody health. Therefore, management actions must strive to reduce negative consequences of human-induced change on waterbodies. Natural resource management choices promoting water detention and infiltration reduce flooding, improve water quality, reduce soil erosion, and promote health aquatic ecosystems. Slowing runoff speed and reducing runoff volume are priority issues to promote waterbody health. Modern engineered stormwater detention infrastructure is designed to diminish runoff intensity. A portion of incident and detained precipitation has potential to infiltrate into soils where it can be temporarily stored and returned to the atmosphere or where it can move deeper to groundwater flow systems. Runoff that infiltrates to local and regional groundwater flow systems supplies aquifers that nourish waterbodies and water supply wells. Management strategies should identify opportunities, quantify changes, and evolve over time. Data collected by systematic monitoring helps lake managers make decisions consistent with current conditions and trends. Recommendations designed to help protect surface water and groundwater sources feeding the Lake and sustaining its ecology and overall health are presented in Chapter 3.

Turtle Creek

Lake Comus has one named tributary – Turtle Creek. Turtle Creek receives flow from many small tributaries, wetlands, groundwater, and one modest-sized lake (Turtle Lake in Walworth County).[30] Turtle Creek also serves as Lake Comus' outlet. Lake Comus is essentially a wide and deep segment of Turtle Creek formed during the 1830s when Turtle Creek was dammed.

Turtle Creek begins as a wetland stream originating at the southwest corner of Turtle Lake. From its headwaters, Turtle Creek flows predominantly southeasterly through wetlands until it enters the northern end of Lake Comus. The Turtle Creek watershed upstream of Lake Comus covers approximately 22 squares and encompasses roughly two-thirds of the area draining to Lake Comus. Turtle Creek is a third order stream when it enters the Lake. The third order reach extends upstream to the County Highway P crossing while the second order reach extends upstream to roughly a mile south of Turtle Lake. Throughout the stretch from Turtle Lake to Lake Comus, Turtle Creek is joined by several unnamed tributaries that drain wetlands and agricultural lands throughout the northern half of the Lake Comus watershed. Turtle Creek becomes a fourth-order stream just downstream of the Lake after joining with Swan Creek flowing from the outlet dam on Delavan Lake. Much of the Creek and its tributaries have been highly modified and channelized to facilitate agriculture. Plat maps from 1837 show a course of Turtle Creek with many more meanders than the current ditched stream (Figures 2.5 and 2.6). These modifications contribute to water quality problems in

[30] *Stream order refers to a stream classification concept developed by Arthur Strahler and Robert Horton during the 1940s and 1950s. Headwater perennial tributaries are assigned a stream order of one and are labeled first order streams. When two first order streams converge, a second order stream is formed, when two third order streams converge, a third order stream is formed, and so on. When a lesser order stream converges with a higher order stream, the larger stream's order remains unchanged.*

the Creek and the Lake. Section 2.5, "Stream Habitat" provides a more detailed discussion of how stream channelization affects water quality and aquatic organism habitat in the Lake Comus watershed.

No USGS gaging stations operate or have operated upstream of Lake Comus so little direct data is available regarding Turtle Creek's discharge or velocity in this reach. However, the WDNR's online Presto-Lite tool provides an estimate of typical modeled stream flows based on watershed characteristics and can be used to estimate the Creek's discharge. Where the Creek enters Lake Comus, Presto-Lite reports a median discharge of 8.11 cfs, with flows between 4.7 and 18.9 cfs 90 percent of the time.[31] Furthermore, as discussed below, downstream gaging station data can be used to estimate a watershed yield to use in the areas upstream of Lake Comus. Groundwater is likely a major source of water to Turtle Creek.

Lake Comus

Lake Comus is not a natural lake. Before European settlement, the area now occupied by the Lake was a free-flowing stretch of Turtle Creek flanked by marshland. A dam was constructed to produce waterpower during initial settlement of the Delavan area. The portion of former free-flowing stream channel now inundated by the reservoir was 17 to 26 feet wide (Figure 2.5).[32] This dam is officially named the Delavan Dam but is also known as the Comus Lake Dam.

Figure 2.5
1837 Plat Maps of Turtle Creek

Plat Map of Township 3, Range 15, East

Plat Map of Township 2, Range 16, East

Source: Wisconsin Board of Commissioners of Public Lands, University of Wisconsin Digital Hosting Center, University of Wisconsin-Madison, and SEWRPC

Dam History, Design, and Operation

Over the years, the WDNR and predecessor State agencies (e.g., Railroad Commission of Wisconsin, Public Service Commission of Wisconsin) regulated dam establishment and operation, evaluated dam condition, and recommended certain management actions. Important information used to make these decisions was preserved and includes copies of sketches, tables of values, correspondence, photographs, and other information pertinent to the dam.[33] Most of the information presented in this section was obtained from these records.

The dam presently impounding Lake Comus is not the first dam to be built at the site. An earth and timber dam built by Samuel and Henry Phoenix during 1839 impounded water to power a flour and feed mill.[34] The resultant millpond formed Lake Comus. A new dam was constructed in 1881 for the same purpose. Lake Comus is visible in an 1893 map produced by the U.S. Geological Survey (Figure 2.7). Another dam was built on Swan Creek a short distance to the southwest of Lake Comus. A canal was built sometime before 1892 from the southwest corner of Lake Comus to the Swan Creek Dam at some point (Figure 2.8). After this canal was built, water from Lake Comus was shunted to the Swan Creek millpond to supplement

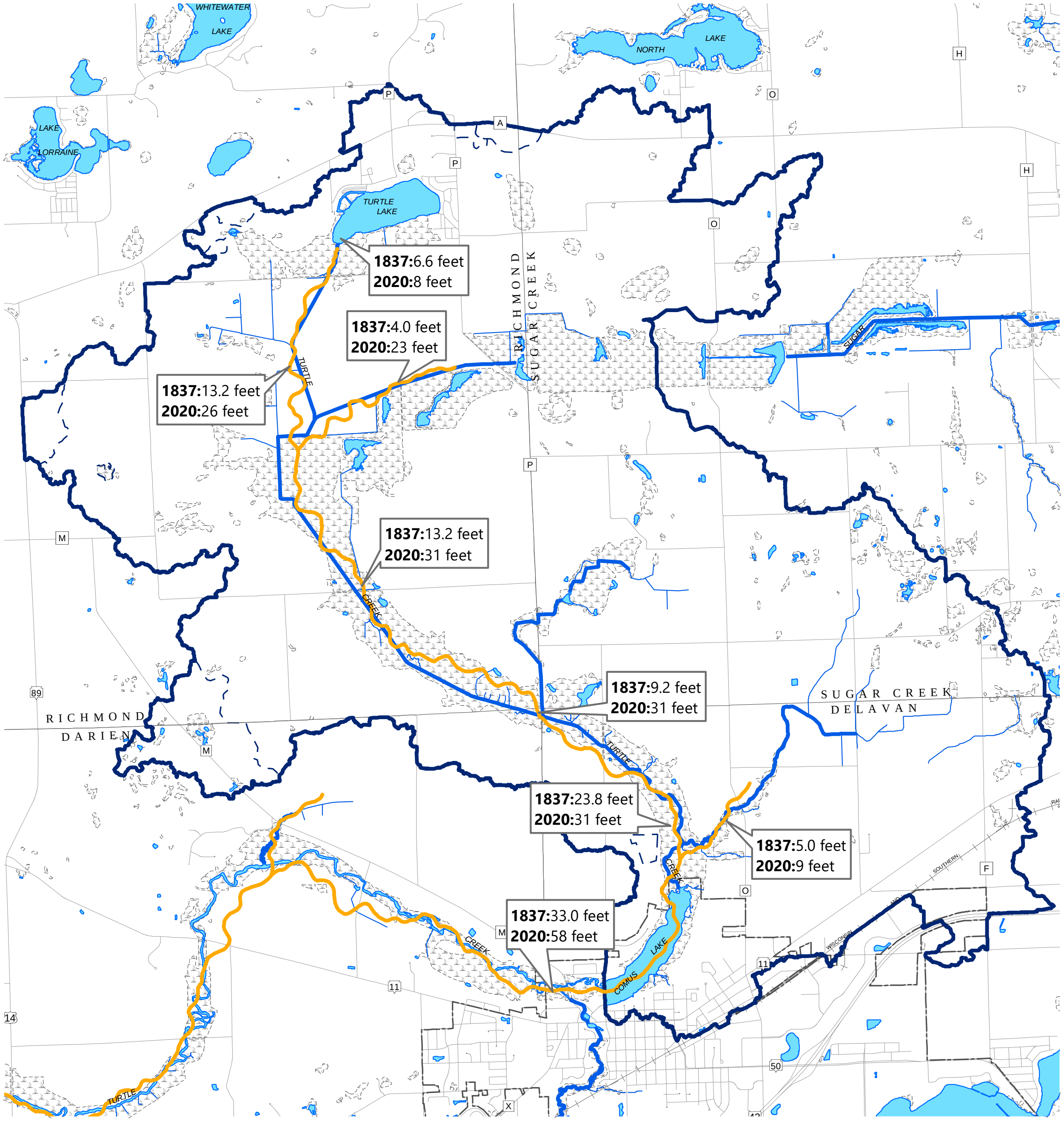
[31] *For more information on the Presto-Lite model, see dnr.wisconsin.gov/topic/SurfaceWater/PRESTO.html*

[32] *Wisconsin Board of Commissioners of Public Lands,* Wisconsin Public Land Survey Records: Original Field Notes and Plat Maps*, University of Wisconsin - Madison Libraries, Township 2 North Range 16 East, downloaded September 23, 2021.*

[33] *The information presented in this section is mainly drawn from a review of various documents found in the WDNR's file for the Delavan Dam.*

[34] *Delavan Wisconsin Historical Society,* Some History, *www.delavanhistory.org/some-history/, website accessed on November 28, 2022.*

Figure 2.6
1837 Stream Widths and Thalweg Locations Compared to 2020 Streamline



2020 THALWEG: TURTLE CREEK AND MAJOR TRIBUTARIES

1837 THALWEG: TURTLE CREEK AND MAJOR TRIBUTARIES (APPROXIMATED FROM PLAT MAP)

SURFACE WATER

WATERSHED BOUNDARY

INTERNALLY DRAINED AREAS

WETLANDS

Note: The 1837 streamlines of Turtle Creek and its major tributaries have been digitized from 1837 plat maps based on land surveying. Thus, the actual streamline between Public Land Survey System Section lines may just be a representation of the actual streamline. 1837 stream widths are converted from the widths reported as chain links on the 1837 plat maps. Each chain link is 7.92 inches.

Source: SEWRPC

Figure 2.7
1893 United States Geological Survey Topographic Map

Source: USGS and SEWRPC

Figure 2.8
Lake Comus Canal in 1941 Aerial

Source: Walworth County and SEWRPC

available waterpower the Swan Creek dam location. A dam was also built on Delavan Lake to store even more water, water that was available to power the downstream milling operation through Swan Creek. The Delavan Lake dam increased Delavan Lake's water level by 5 feet, vastly increasing water storage capacity for dry weather mill operation.

The mill continued to be powered exclusively by waterpower into the 1930s, longer than most milling operations in the area. After milling operations ceased, the City of Delavan assumed control of the dam, operating it for recreational and aesthetic purposes. The City of Delavan bought the dam and mill's water rights in 1948. The Delavan Lake Improvement Association purchased the water rights to the Delavan Lake dam in 1927. During 1968, the channel between Swan Creek and Lake Comus was blocked when the Mill Pond swimming beach berm was constructed. The remainder of the channel connecting the two millponds was filled during 1988.[35]

The dam presently impounding Lake Comus has a maker mark and date cast into a concrete wall on the dam's upstream side near the roadway reading "A. G. Blowland, Mount Horeb, 1931." Dam regulatory correspondence states that the dam was "washed out" in 1946. Apparently, the 1931 structure was not completely washed out and was instead repaired. The existing dam is a low-hazard earthen gravity dam with a controlled spillway. It has a normal storage capacity of 606 acre-feet and a maximum storage of 850 acre-feet.[36] The dam embankment crest is roughly 100 feet in length, located near the northern end of a 1,000-stretch of North Terrace Street (also known as Dam Road farther to the north) along the southwestern shoreline of the Lake.[37] The exact width of the earth fill comprising the dam as opposed to general road fill can only be speculated.

[35] *Mark Wendorf, City of Delavan, personal correspondence with Commission staff (Dale Buser and Justin Poinsatte), February 22nd, 2021.*

[36] *Wisconsin Department of Natural Resources,* Detailed Information for Dam Delavan.

[37] *Becher-Hoppe Associates, Inc.*, Delavan Dam (Comus Lake) 2011 Dam Safety Inspection Report, *2011.*

Lands upstream of Lake Comus were extensively drained to facilitate agriculture. As such, the Turtle Creek drainage board desired lower water levels for Lake Comus to promote more complete and efficient drainage of upstream cropland. However, other individuals were concerned that mill operation caused unduly low water levels in Lake Comus, exposing broad areas of Lake bottom, and injuring aquatic life. Because of such concerns, water levels were discussed and were set by the Wisconsin Public Service Commission during early 1936.

The dam's principal spillway has five vertical sluice gates that range from 3.3 to 3.7 feet wide, all of which were originally fitted with stop logs. At present, the left, right, and center gates are fitted with timber stop logs. The uppermost stop log acts as a fixed weir over which excess water exits the Lake. The number of stop logs installed into the fitments controls the capacity of the gate and the elevation of the weir. The remaining two gates were replaced with slide gates sometime between 1978 and 1986 The slide gates are fitted with independent, manually actuated, worm gear driven, gate lifting mechanisms. These two gates can be raised from an access walkway to allow water to flow under each gate. From available plans, it appears that the gates are each 55 inches tall and can be lifted to allow 62 inches of flow below each gate.

The WDNR operating order for the Lake Comus outlet dam requires that the Lake's water level be maintained between 886.74 and 888.23 feet 1929 National Geodetic Vertical Datum (NGVD 1929). These elevations are generally equivalent to the elevations specified by the 1936 Wisconsin Public Service Commission's decision. Per WDNR orders, these water levels are measured as a maximum of 38.25 inches below the top edge of the dam's catwalk and a minimum of 55.5 inches below the top edge of the catwalk.[38] The City of Delavan operates the dam and records water levels. A graph of values spanning the last six and a half years can be found as Figure 2.9. Lake Comus has been drawn down for relatively brief time periods to enable dredging or other maintenance work. However, aside of short, abrupt higher water periods likely related to episodes related to intense runoff, the available data suggest that the Lake's water level remains remarkably stable near the high range of the WDNR-ordered water level range season-by-season and year-to-year. Essentially static water levels rarely occur in natural water bodies and are generally unfavorable to regeneration and persistence of many desirable native aquatic plants.

The Lake Comus outlet dam was inspected on June 2nd, 2021 by Ayres Associates, Inc. in accordance with WDNR guidelines.[39] The dam inspection report mentioned that elements of the dam, such as the concrete wing walls and gate assemblies, were deteriorating and that the City of Delavan should plan for significant repairs and/or replacement of dam elements by December 31st, 2024. Additionally, the inspection report recommended that a portage route should be developed to facilitate recreational canoe and kayak travel between the Lake and downstream Turtle Creek.

The City of Delavan is exploring approaches to correct outlet dam deficiencies. The City has been working with the LCPRD, consultants, and the Commission to develop an approach. According to information provided by Kevin Armstrong of the LCPRD and the City of Delavan on May 25, 2022, the outlet dam project received funding from the WDNR Chapter NR 335 *Municipal Dam Grant Program* to help fund dam replacement. According to NR 335 program guidance, the City could obtain up to $400,000 from this program.

From preliminary information received by the Commission from the City of Delavan, the existing dam would be demolished and the City would build a new dam at the location of the existing dam. The Dam Road bridge crossing Turtle Creek immediately downstream of the outlet dam would also be replaced as part of the project and it is anticipated that the stream crossing would be integrated with the new dam structure. Three outlet options were presented during February 2022 as part of a feasibility study. These include options incorporating a leaf gate, a labyrinth weir with a small sluice gate, and a drop inlet with a small sluice gate. As of July 2022, the drop inlet/sluice gate design is favored. If possible, the gate access walkway will also be configured to be used as a fishing platform.

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[38] *Personal communication between Mark Wendorf, City of Delavan, and Commission staff (Dale Buser and Justin Poinsatte), February 23rd, 2021.*

[39] *Ayres Associates Inc Letter to Mark Wendorf,* Re: Dam Safety Inspection Report, Comus Lake Dam, WDNR Field File No. 64.02, Key Sequence No. 314, *June 2021.*

Figure 2.9
Water Elevations Measured at Lake Comus Outlet Dam: 2016-2020

Source: City of Delavan and SEWRPC

Lake Morphometry

A variety of morphologic and hydrologic parameters are used to judge the potential impact of human influence on a lake, including those described below.

Watershed/Lake Area Ratio contrasts the land area contributing surface water runoff to the lake to the open water area of a lake. Lakes with higher ratios are typically considered more vulnerable to human influence and more prone to water quality problems. However, watershed use can greatly influence the amount of pollutants carried to a lake. As a rule of thumb, lakes with a watershed area/lake area ratio greater than 10:1 often experience some water quality issues.[40] Lake Comus' watershed/lake area ratio is approximately 175:1 while the typical Wisconsin inland lake has a watershed/lake area ratio of 7:1.[41] Lake Comus' tributary area to lake surface area ratio is substantially higher than those of nearby Lake Delavan, with a ratio of 12.5:1,[42] or Whitewater Lake, with a ratio of 6.1:1.[43] This suggests that Lake Comus is highly susceptible to human influence and is therefore more vulnerable to land-use related water quality problems compared to typical Wisconsin inland lakes and neighboring lakes.

[40] *Uttormark, Paul D. and Mark L. Hutchins,* Input Output Models as Decision Criteria for Lake Restoration, *University of Wisconsin Water Resources Center, 1978*

[41] *R.A. Lillie and J.W. Mason,* Limnological Characteristics of Wisconsin Lakes, *Wisconsin Department of Natural Resources Bulletin No. 138, 1983.*

[42] *SEWRPC Community Assistance Planning Report No. 253,* A Lake Management Plan for Delavan Lake, *May 2002.*

[43] *SEWRPC Memorandum Report No. 177 (2nd Edition),* An Aquatic Plant Management Plan for Whitewater and Rice Lakes, *April 2017.*

Shoreline Development Factor compares the length of a lake's shoreline to the circumference of a perfect circle of identical area. Higher values result when lakes exhibit irregular shapes including such features as bays and peninsulas. Lakes with high shoreline development factors are commonly more biologically productive and have greater proportions of shallow nearshore areas (or *littoral zone*). Extensive littoral zones are conducive to aquatic plant growth which can grow to nuisance levels and may impede navigation. The littoral zone generally represents the most productive habitat for plant and animal life in a lake. All other things being equal, a lake with a large shoreline development factor would be expected to have more plant and animal life than a lake having a low development factor. Given their longer shoreline lengths per acre of surface water, lakes with high shoreline development factors also commonly have greater numbers of residential lots per lake surface-acre and therefore can be subject to heavier human use pressure.

Lake Comus has a shoreline development factor of 1.92, meaning that the Lake has nearly twice as much shoreline compared to a perfectly circular lake. The Lake's shoreline is undeveloped and bordered by wetland along the northern and northeastern shores as well as the semi-natural environments of the Paul Lange Arboretum and the Ora Rice Arboretum along much of the western shore. The more developed southern shoreline is occupied by residential lots and North Terrace Street, but this only amounts to roughly 20 percent of the Lake's shoreline. Therefore, the Lake is not likely subject to heavy human use pressure from shoreline development compared to other local lakes.

Lake-basin bathymetry and bottom sediment composition influences lake biological productivity. To illustrate, lakes with large, nearly flat, shallows covered with soft bottom sediments are generally more biologically productive than uniformly deep lakes with rocky bottoms. As shown on Figure 2.10, the open-water surface of the Lake extends roughly a mile upstream of the dam. A cattail (*Typha* spp.) marsh occupies portions of the former Lake basin that has filled with sediment over the years. Lake Comus is quite shallow, with a maximum depth of eight feet. Much of the Lake is presently less than two feet deep. Most of Lake Comus would be in the littoral zone if the Lake had average to high water clarity.

The Lake's bottom very gently slopes from northeast to southwest and soft sediment (silt and muck) deposited by Turtle Creek covers the original sand and gravel beds illustrated in the 1929 Lake bathymetry map (Figure 2.11). Coarser grained sediment delivered by Turtle Creek is likely deposited close to where the Creek enters the Lake. Given these factors, Lake Comus would be expected to have high biological productivity, nutrient-rich water, and the ability to support abundant aquatic plant growth and a productive warmwater fishery. However, excessive nutrients can create management challenges such as turbid water, algal blooms, and an imbalanced fish population.

The Lake was reported to be between eight to ten feet in the 1929 Lake bathymetry map (Figure 2.11). This map also reveals that cattail marsh has expanded into the Lake over time. In the more distant past, the Lake was undoubtedly deeper and more extensive. The earliest dam inspection report (1915) available from the WDNR describes the Lake as extending two miles upstream, covering 90 acres, and having a maximum depth of 12 feet. Curiously, the 1915 report suggests the Lake extended almost a mile further upstream but also reports less acreage than the current area. The Lake's volume reported by the Wisconsin Conservation Department (now the WDNR) in 1963 was 606 acre-feet with a maximum depth of approximately six feet.[44] A study completed during 1981 found that the Lake was two feet deep or less and suggested dredging to restore Lake use.[45] These reductions in Lake surface area and depth since the 1929 bathymetry map suggest that the Lake has been filling in with soft sediment that originates as soil runoff upstream and is transported downstream by Turtle Creek. The extensive hydrological modification and intensive agricultural uses in the watershed over the past 130 years have likely increased both runoff volume and sediment load delivered to the Lake (see Section 2.3, "Water Quality and Pollutant Loading").

Commission staff surveyed the Lake's water depth and sediment depth along a uniformly spaced grid of GPS points during 2019. At each navigable point, Commission staff used a 10-foot measuring rod to measure water depth and then pushed downward through flocculent sediment until sensing a hard bottom at which point the soft sediment depth was measured. Water was most shallow in the Lake's northeastern portion, with depths averaging slightly less than two feet. The sediment thickness in this area varied between one

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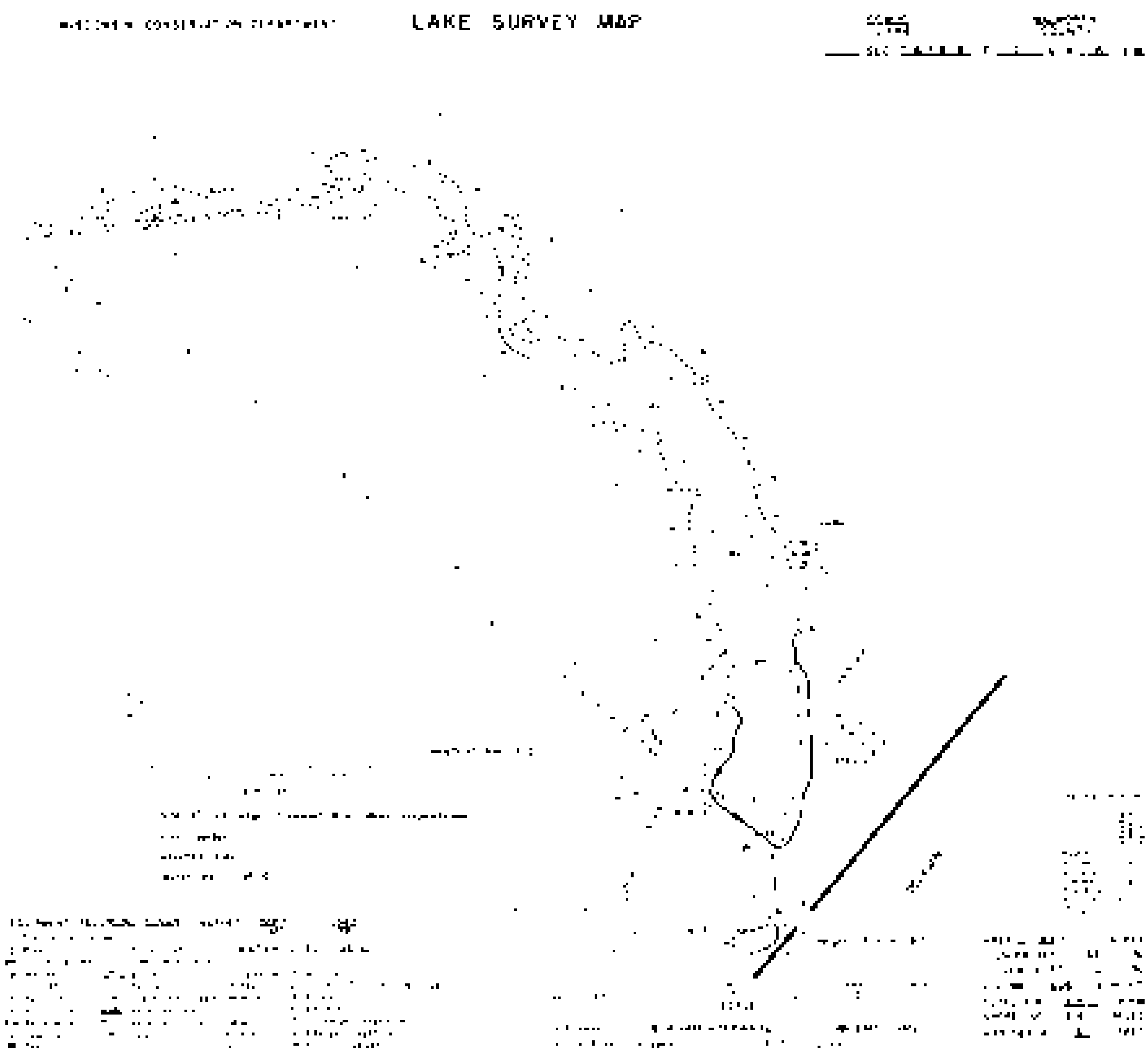
[44] *For more information, see dnr.wi.gov/lakes/maps/DNR/0794200a.pdf.*

[45] *Donohue and Associates, Incorporated*, Lake Comus Management Plan*, 1981*

Figure 2.10
1963 Bathymetric Map of Lake Comus



Source: Wisconsin Department of Natural Resources 608-266-2621 Comus Lake – Walworth County, Wisconsin DNR Lake Map Date – Sep 1963 - Historical Lake Map - Not for Navigation

foot to nearly ten feet, averaging slightly less than four feet (Figure 2.12). However, much of area where the shallowest water depth and greatest sediment thickness was expected were also too shallow to navigate with the jon boat, so these averages may overestimate water depth and underestimate sediment depth in this area. Heavy channelization of Turtle Creek facilitates sediment delivery to the Lake. This is consistent with the observation of substantial sediment deposition within the upstream, northern portion of the Lake (see Section 2.5, "Stream Habitat" for more information on stream channelization).

Measured water depths were much greater in the southern half of the Lake, ranging from 1.5 feet near the shorelines to nearly 8.5 feet in the middle of the Lake. The southern half of the Lake also had less accumulated soft sediment, with thicknesses ranging from no flocculent sediment to 5.5 feet with an average of two feet. Some stretches of the southern shoreline have firm, sandy or gravelly sediments while portions of the northwestern shoreline are armored with riprap with little to no overlying fine-grained or flocculent sediment. Sediment thickness may be underestimated in the deepest portions of the Lake since the measuring rod was ten feet long and extended through up to 8 feet of water before reaching bottom sediment. Therefore, soft sediment accumulations thicker than two feet could not be measured in greater than eight feet of water. Based upon water depth measurements made by Commission staff during 2019 as part of the on-the-water aquatic plant inventory, the Lake's volume is currently 360 acre-feet.

Dredging programs are used as lake management tools to temporarily increases water depth in key areas. Dredging also temporarily increases lake volume but continued sedimentation gradually decreases lake depth and volume over time. Approximately 440,000 cubic yards of sediment were subsequently dredged during 1987 and 1988,[46] increasing Lake volume and depth, but sediment has continued to accumulate. This sediment volume is equivalent to about 270 acre-feet of lake water volume.

Figure 2.11
1929 Bathymetric Map of Lake Comus

Source: City of Delavan, LCPRD, and SEWRPC

Water Budget

Lake Comus receives water from runoff, groundwater, storm sewers, and rainfall falling upon its surface. These water sources enter the Lake directly or via tributary flow. Runoff is derived from rainfall and snowmelt in the Lake's watershed while groundwater is derived from precipitation, snowmelt, and runoff that soaks into the ground and recharges groundwater supplies in the Lake's groundwatershed. Water leaves the Lake by evaporating from open water areas, flowing over the outlet dam, and by seeping into the Lake's bed and shorelines.

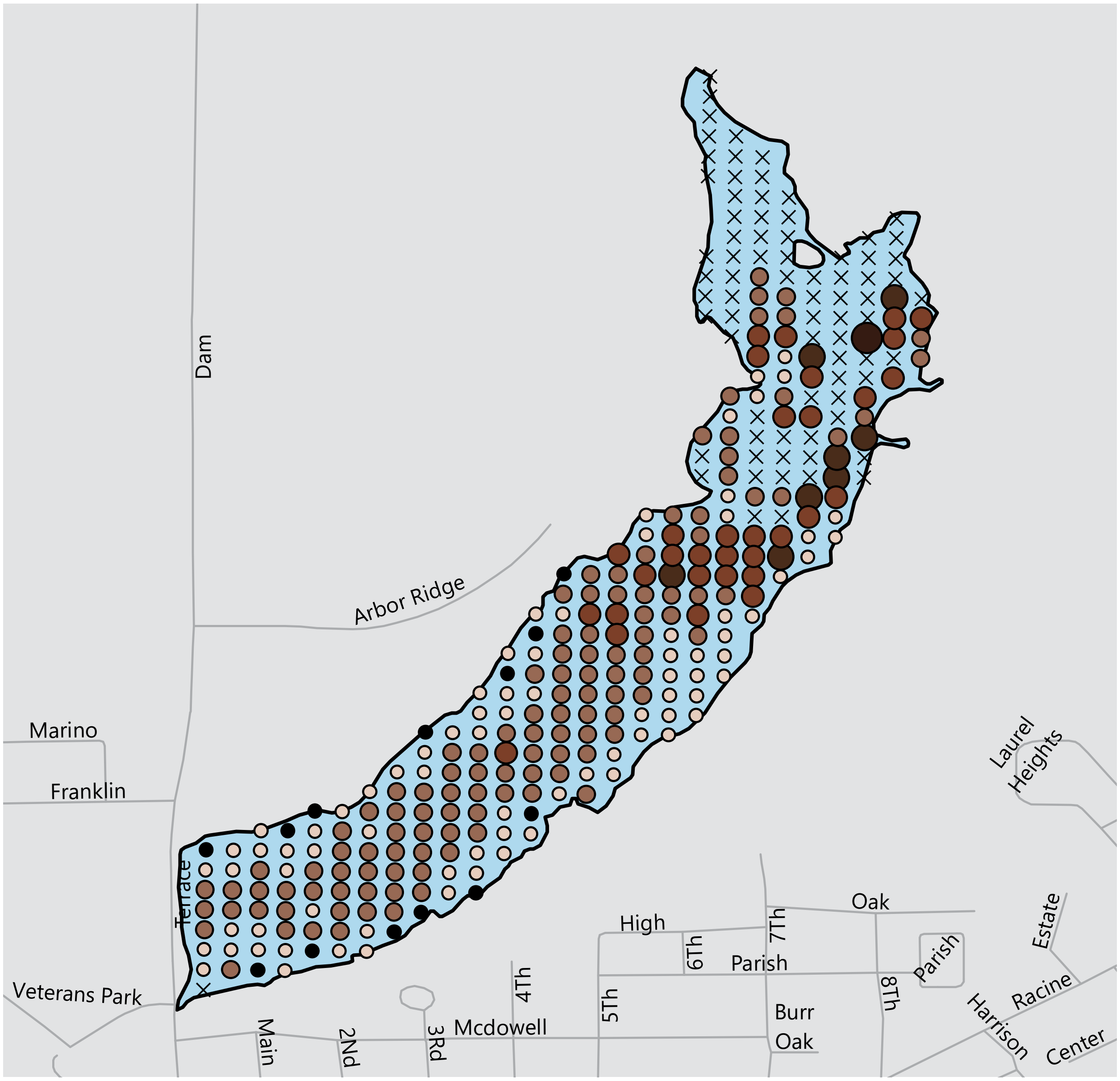
A water budget is an accounting of significant lake water inflows and outflow, assigning volumes to various water source and loss factors. Lake water budgets help managers evaluate Lake processes and sources of nonpoint source pollution. Gaged streamflow information, local weather data, groundwater monitoring wells, and seepage gages are robust data sources for accounting tributary and groundwater flows to the Lake. However, no streamflow gages exist upstream of Lake Comus and installing groundwater monitoring devices was well beyond the scope of this study. Therefore, Commission staff created a water budget using readily available precipitation and evaporation information, modeled streamflow information from the WDNR Presto-Lite tool, and extrapolation from nearby watersheds to estimate tributary inflows and lake outflow discharge (Figure 2.13).[47]

As a 131-acre lake receiving an average of 34.72 inches of precipitation annually, Lake Comus receives 379 acre-feet of water via direct precipitation upon open water areas each year during average weather. Based upon Presto-Lite models, tributaries contribute 7,366 acre-feet of water to the Lake per year during average weather years. Of this total, 5,871 acre-feet per year are delivered from Turtle Creek, 1,520 acre-feet per year are delivered by the CTH O tributary, and 65 acre-feet per year flow to the Lake from an unnamed tributary on the Lake's eastern shoreline. Substantial portions of these tributary flows are accountable to groundwater. The Presto-Lite modeled Lake discharge from the Lake other than evaporation at 8,687 acre-feet per year and losses to direct evaporation from the Lake account for 430 acre-feet per year, resulting in 9,117 acre-feet lost from the Lake per year during an average year. Assuming no change in total Lake water storage, direct contributions from groundwater and surface runoff contributes 1,372 acre-feet of water per year during an average year.

[46] *Foth and Van Dyke*, Lake Comus Dredging Project*, 1995.*

[47] *For more information on Presto-Lite, see dnr.wisconsin.gov/topic/SurfaceWater/PRESTO.html.*

Figure 2.12
Thickness of Lake Comus Soft Bottom Sediment: August 2019



Sediment Thickness (feet)

- × Not Sampled
- No Flocculent Sediment
- 0.1 to 2.0
- 2.1 to 4.0
- 4.1 to 6.0
- 6.1 to 8.0
- 8.1 to 9.7
- Roads
- Lake Comus

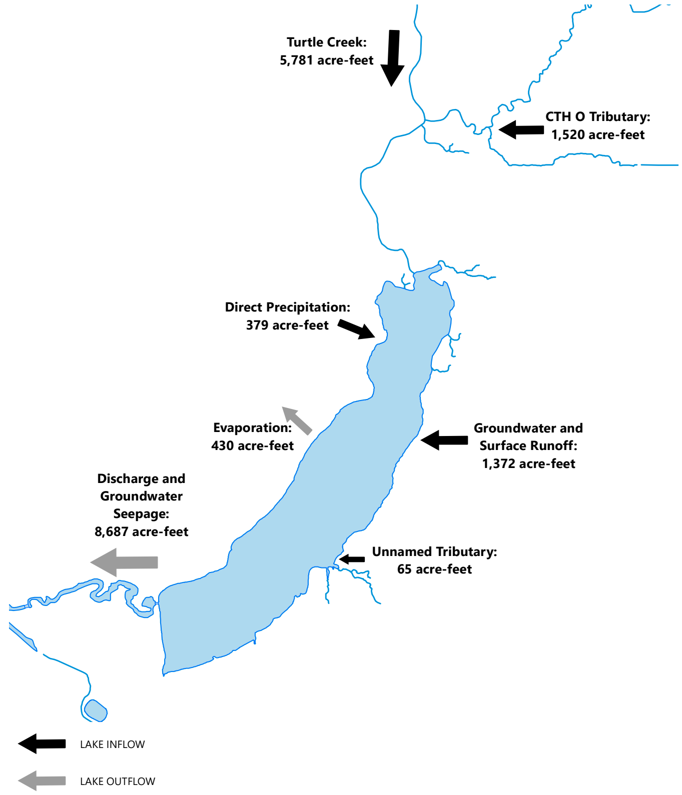
Note: Measurements taken in Lake Comus between August 23 and September 4,

Source: Wisconsin Department of Natural Resources and SEWRPC

Based upon the flow exceedances provided by the WDNR Presto-Lite tool, roughly half (nearly 4,000 acre-feet) of the water entering the Lake through tributary streams during a typical year is likely groundwater. Using this same percentage for the combined surface runoff and groundwater inflow directly entering the Lake results in nearly 700 acre-feet of water contributed directly to the Lake by groundwater during a typical year. Therefore, on an overall basis, groundwater likely provides roughly 4,700 acre-feet of water to the Lake during a typical year.

Another way to estimate the amount of runoff entering Lake Comus uses watershed-specific information gathered on Turtle Creek downstream of the Lake near Clinton. The United States Geological Survey has measured Turtle Creek's flow near Carvers Rock Road near Clinton, Wisconsin since 1939. Data from the last 35 years was used to determine Turtle Creek's watershed yield during periods of drought, fair weather, and wet weather. Drought water yield is likely mostly a result of groundwater contributions and water discharged to Turtle Creek by the WalCoMet wastewater treatment plant at Delavan.[48] The following annualized watershed-specific yield estimates were made by examining 1986 through 2021 hydrograph of Turtle Creek at Carvers Rock Road and deducting the average contribution made by the WalCoMet wastewater treatment plant:

Figure 2.13
Generalized Annual Hydrologic Budget for Lake Comus



Source: WDNR, and SEWRPC

- Extremely long periods of dry weather: 2.6 inches per year
- Average weather: 6.5 inches per year
- Long periods of wet weather: 26 inches per year

These values represent averages over a large watershed, not all of which may be representative of the Turtle Creek watershed upstream of Lake Comus. Nevertheless, using these values, the amount of water contributed to the Lake over a year during various weather patterns can be estimated:

- Long periods of extremely dry weather: 4,700 acre-feet per year
- Average weather: 11,000 acre-feet per year
- Long periods of extremely wet weather: 47,000 acre-feet per year

Since groundwater supplies most of Turtle Creek's flow to the Lake during long periods of dry weather, groundwater contributions to the Lake are likely 4,700 acre-feet per year.

[48] *According to WalCoMet's website, the wastewater treatment plant's average daily flow is 7.00 million gallons per day which equates to roughly 7,800 acre-feet per year.*

Contrasting the two approaches demonstrates good agreement between the two methods. The Presto-Lite model predicts that roughly 9,000 acre-feet of water enter the Lake during an average weather year while water yield estimates based on downstream hydrographs predicts 11,000 acre-feet per year. Whatever the case, groundwater discharging to the Lake's tributaries and the Lake itself contribute roughly 40 to 50 percent of the Lake's overall water supply during average weather. Groundwater is vital to maintaining flow to and through the Lake during dry weather. Similarly, discharge over the dam is by far the dominant way water leaves the Lake. Evaporation from the Lake's surface, infiltration into the Lake's bed and banks, and seepage around the dam likely become significant components of total Lake outflow during extremely dry weather.

Human activity has radically altered the watershed upstream of Lake Comus. Primarily agricultural and some urban land uses replaced natural vegetation and landscapes. These changes decrease the ability of landscapes to detain surface water and typically decrease groundwater recharge. Furthermore, the meandering channel that formerly crossed broad riparian wetlands was channelized to lower water tables and limit flooding, allowing wet areas to be used for agriculture. Collectively these changes increase the volume of water leaving the landscape as runoff. Furthermore, these changes speed runoff, a situation that works together with increased runoff volume to increase high-runoff period flow rates and flood elevations. The corollary to increased wet-weather runoff and flood elevation increases is decreased flow during fair and dry weather. Decreased fair and dry weather flow was already observed over 90 years ago in Turtle Creek by the operators of the waterpower facility at the foot of Lake Comus.[49]

Retention Time refers to the average length of time needed to replace a lake's entire water volume.[50] In general, lakes with larger watershed/lake area ratios have shorter retention times. Retention time can help determine how quickly transient pollutant loads can be flushed from a lake. For example, if retention times are short, pollutants are quickly flushed out of a lake. In such cases, management efforts can likely focus on pollutant and nutrient loads contributed to the lake from the watershed. In contrast, lakes with long retention times tend to accumulate nutrients and pollutants. These can eventually become concentrated in bottom sediments as opposed to flushed downstream. In this case, in addition to preventing external pollution from entering a lake, it also may be necessary to employ in-lake water quality management efforts to address pollutants not readily flushed from the lake.

Lake Comus, as a shallow impoundment of Turtle Creek, currently has a modest total volume of 360 acre-feet according to recent Commission estimates. Using this volume and the annual water inputs derived in the previous section, Lake Comus' retention time during periods of typical weather is 12 days. During extremely dry weather, the retention time increases to 28 days. During extended periods of wet weather, the Lake's retention time is 2.8 days. With a lake-wide retention time averaging 12 days, Lake Comus' flushing rate is orders of magnitude faster than Wisconsin statewide averages. As such, apparent water quality may improve quickly if nutrient inputs to the Lake decrease. Whatever the case, when it comes to maintaining or improving water quality, the importance of management actions that protect groundwater contributions and limit nutrient inflow from the watershed into the Lake cannot be over emphasized.

[49] *Public Service Commission of Wisconsin,* In the Matter of S. C. Wadmond and 34 Other Persons for a Determination for the Minimum and Maximum Levels of Lake Comus, Walworth County, Wisconsin*, 1936*.

[50] *The terms "flushing rate" and "hydraulic residence time" are also commonly used to describe the amount of time runoff takes to replace one lake volume. Flushing rate is the mathematic reciprocal of retention time, while hydraulic residence time is the same value as retention time. Therefore, while residence and retention time are expressed in years and have units of time, flushing rate is typically expressed as the number of times lake water is completely replaced by runoff in one year, and is therefore a rate (units/time).*

Other Lakes and Streams

The only other significant lake within the Lake Comus watershed is 141-acre Turtle Lake. Turtle Lake attains a maximum depth of 30 feet and has a predominantly mucky bottom.[51] The Lake is classified as a spring lake due to its groundwater springs and seeps, its perennial outlet, and lack of inlet streams. Other lentic waterbodies of note are several open-water shallow marshes located in the wetland complex that comprises much of the northern half of the watershed. The hydrology of these marshes is managed to promote waterfowl production as part of the Turtle Valley Wildlife Area.[52]

Several unnamed tributaries contribute to Turtle Creek before it enters Lake Comus. Most notable among these are the tributary draining the watershed's northeastern wetlands before joining Turtle Creek as well as the tributary that joins the Creek from the east about a half-mile before it enters Lake Comus (hereafter referred to as the CTH O tributary). Additionally, several small, unnamed, groundwater-fed tributaries enter the Lake directly along its eastern shore. These tributaries may provide refuge habitat for coolwater fish species by sustaining baseflow during dry periods and by lowering water temperatures in Turtle Creek and areas along the eastern shore of the Lake (see Section 2.6, "Fisheries," for more information on this topic).

Groundwater Resources

General Principles and Importance

Groundwater includes water that has percolated into the ground surface and has reached saturated sediment zones below the Earth's surface. The free-water elevation of the shallowest saturated subsurface water-bearing media is commonly referred to as the "water table." Groundwater is not visible to casual observation except where it discharges to surface water (e.g., springs and seeps). Water in unsaturated soil above the water table can either return to the atmosphere via evapotranspiration or may move to aquifers if soil moisture increases through additional percolation from the surface.

In Southeastern Wisconsin, local precipitation is the source of most groundwater and essentially all groundwater is stored and moves in the natural pore spaces and fractures found in unconsolidated sediment and bedrock.[53] Sediment and rock units with significant porosity or fracturing can supply usable amounts of water over prolonged periods and are referred to as "aquifers." Three aquifers underlie the Lake Comus watershed, as summarized below in order of increasing depth from the land surface.[54]

- **Sand and gravel aquifer**. This aquifer is found in porous, coarse-grained sand and gravel deposited primarily by glacial activity. Much of the water feeding this aquifer infiltrates the land surface in the local area. Its thickness and properties vary widely, but it is an important water supply for nearly all of Walworth County. It is commonly highly vulnerable to contamination and over exploitation. Water quality and quantity can be significantly influenced by local land use change. The sand and gravel aquifer is commonly in good hydraulic communication with the underlying Galena-Platteville aquifer.

- **Galena-Platteville aquifer**. Water in this aquifer is stored and moves primarily in fractures. This generally unconfined aquifer is the uppermost bedrock aquifer for the entirety of the Lake Comus watershed. Although only providing small to moderate water yields, it is an important source of domestic water supplies. A layer of low permeability Maquoketa shale overlies the aquifer in the eastern portions the Lake Comus watershed.

- **Sandstone aquifer.** The sandstone aquifer is commonly deeply buried and is found at depths well below the sand and gravel and Galena-Platteville dolomite aquifers. Water is stored and moves through fractures and the rock's innate porosity. This aquifer is very thick, but the water bearing characteristics vary widely with depth. Water recharging the sandstone aquifer infiltrates

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[51] *For more information, see dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=795100.*

[52] *For more information, see dnr.wisconsin.gov/topic/Lands/WildlifeAreas/turtlevalley.html.*

[53] *A common local myth suggests that water flows in underground rivers from the far north (e.g., Lake Superior). Although a few small caves are found in Southeastern Wisconsin, they are not significant contributors to overall groundwater flow and do not extend appreciable distances.*

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

through the shallow sand and gravel and dolomite aquifer extending through the rest of the watershed. Because it is deeply buried, the sandstone aquifer is less vulnerable to local pollution sources in the watershed. The sandstone aquifer is an important public and industrial water supply, but because of the cost of establishing deep wells, is not commonly used for residential water supplies in the Walworth County.

The amount, recharge, movement, and discharge of groundwater are controlled by several factors including precipitation, topography, soil permeability and structure, land use, and the lithology and water-bearing properties of rock units.

All residential, municipal, and industrial water supplies in the Lake Comus watershed depend upon groundwater, making it a natural resource critical to human habitation of the watershed. In general, groundwater supplies in the Region are adequate to support a growing population, agricultural demands, commerce, and viable and diverse industrial uses. However, overexploitation and attendant water shortages could occur in areas of concentrated development, nonconductive geology, and/or intensive water demand. In addition to supplying human needs, groundwater is important to the health, vitality, and overall ecology of natural systems. Groundwater sustains water levels and flow during dry weather in lakes, wetlands, and perennial streams. Groundwater systems also modulate flood flows by detaining water during wet weather. Groundwater that reaches surface waterbodies is commonly referred to as "baseflow." Baseflow can either directly enter large waterbodies, or it can enter small streams, ponds, and seeps tributary to larger waterbodies. Groundwater resources must be wisely developed and managed so as to balance human water demands with ecosystem function and needs.

Baseflow sustains dry-weather Lake elevation and the flow of the Lake's perennial tributary streams. Groundwater typically contains little to no sediment or phosphorus, has a more stable temperature regimen, and commonly contains a lower overall pollutant load when compared to surface water runoff—all of which are favorable to aquatic life and the ecology of waterbodies. Groundwater-derived baseflow sustains water elevations and/or flow in many lakes, wetlands, and streams during drier weather periods. Reliable water elevations and flow regimens enables groundwater-fed waterbodies to maintain a diverse assemblage of plants and animals. Groundwater is critical to these waterbodies' ability to provide unique ecological functions. Consequently, maintaining baseflow from the aquifers that supply the Lake and the streams and wetlands that drain to the Lake is an important Lake management concern.

Groundwater supplies are naturally replenished by precipitation or runoff soaking into the ground and entering aquifers. Water that infiltrates the land surface and enters aquifers is often referred to as "groundwater recharge." Precipitation is the ultimate source of all groundwater recharge, but recharge does not necessarily occur uniformly throughout the landscape, at the point where precipitation initially strikes the Earth, or uniformly throughout the year. Relatively flat undeveloped areas underlain by thick layers of granular permeable mineral soil typically contribute more water to groundwater recharge and are identified as having high or very high groundwater recharge potential. On the other hand, hilly areas underlain with low permeability (e.g., clay) soils would be likely be classified as having low recharge potential. Nevertheless, it must be remembered that water running off from areas less conducive to groundwater recharge can still flow to areas more conducive to groundwater recharge and infiltrate there, becoming a component of groundwater flow. Most groundwater recharge occurs during periods of low natural water demand (i.e., when plants are dormant and temperatures are cool) and/or abundant precipitation or runoff. Little groundwater recharge occurs from small summer rains, even on the best sites, because plants and higher evaporation rates associated with higher temperatures consume the incident precipitation, returning it to the atmosphere. Evaluating groundwater recharge potential helps identify areas most important to sustainable groundwater supplies. The Commission evaluated groundwater recharge potential for all Southeastern Wisconsin.[55] Such data can help planners decide which areas should not be covered with impervious surfaces and/or where infiltration basins would be most effective.

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

In most instances, the water table elevation is a subdued reflection of surface topography. The Commission has estimated water table elevation throughout the Region.[56] Topographically higher areas are commonly recharge areas, while lakes, wetlands, and streams are commonly groundwater discharge areas. Groundwater recharge/discharge systems occur on many spatial scales: long regional recharge/discharge relationships and short localized flow paths, both of which can be important contributors to a water body's overall water budget. While localized groundwater flow systems are commonly confined within a lake's surface watershed, regional groundwater flow paths may trace directions and distances out of phase with surface water feeding a lake. Therefore, some groundwater feeding a lake may originate in areas distant from the lake and/or outside the lake's surface watershed boundary. The relationship between short- and long-distance flow paths is illustrated in Figure 2.14.

Smaller-scale local groundwater flow paths commonly approximate surface water flow paths. However, to estimate the direction of more regionally extensive flow systems, groundwater elevation contours derived from measurements collected in water supply or monitoring wells need to be consulted. Since water normally moves perpendicular to elevation contours, groundwater flow directions can be predicted. When performing such analyses, it is necessary to consider the locations and elevations of streams, ponds, and lakes. This relationship can be used to predict if a surface water body is fed by groundwater, recharges groundwater, or has little interaction with groundwater. By combining these data, maps can be prepared identifying those land areas that likely contribute recharge and are, therefore, sources of baseflow to a surface water feature and those areas that convey groundwater directly to a lake.

As shown in Figure 2.15, a waterbody gains water when groundwater elevations are higher than the adjacent waterbody (Figure 2.15, "Gaining Stream"). Conversely, a perennial waterbody loses water wherever water table elevation is lower than the waterbody's elevation. In such instances, water seeps into the underlying groundwater system (Figure 2.15, "Losing Stream"). In some instances (e.g., ephemeral streams), the water table may not be in contact with the surface water feature. The rate at which water flows between a stream and its adjoining aquifer depends on the hydraulic gradient between the two waterbodies and on the hydraulic conductivity of geologic materials that may be located at the groundwater/surface-water interface. For example, a clayey streambed will reduce the rate of flow between a stream and aquifer compared to a sandy or gravelly streambed. In the absence of surface water contributions, streamflow volume increases along gaining reaches and decreases along losing reaches. Streams can have both gaining and losing reaches and the extent of these reaches may change based upon prevailing conditions. Since precipitation rates, evapotranspiration, water table elevations, and human-induced hydrologic stressors vary with time, a particular stream reach can switch from a gaining to a losing condition or from a losing to a gaining condition from one period to the next.

Groundwater is a dynamic, vital, yet often poorly understood resource. Water discharging to water bodies is replaced with water received from infiltrating precipitation, much of it in the local area. By combining data regarding groundwater recharge potential, groundwater flow direction, and the water body elevations, a broad understanding of the interconnected nature of surface water and groundwater resources can be surmised. Maps can be prepared identifying land areas that more likely contribute to recharge and are, therefore, sources of baseflow to a waterbody. These maps also can help illustrate the routes groundwater takes in the subsurface and whether a waterbody gains or loses water to the groundwater flow system. Such information helps resource managers plan where work management and protection actions should focus. For example, this information can help resource managers identify parcels where action should be taken to maintain or enhance the landscape's ability to provide groundwater recharge or where features purposely designed to detain and infiltrate stormwater should be located.

Human Influences on Groundwater

Humans deplete groundwater in two primary ways: 1) by actively pumping water from aquifers, which reduces, or in extreme cases eliminates, natural groundwater discharge through springs and seeps, and 2) by reducing groundwater recharge through land use changes that increase impervious cover and/or hasten runoff.

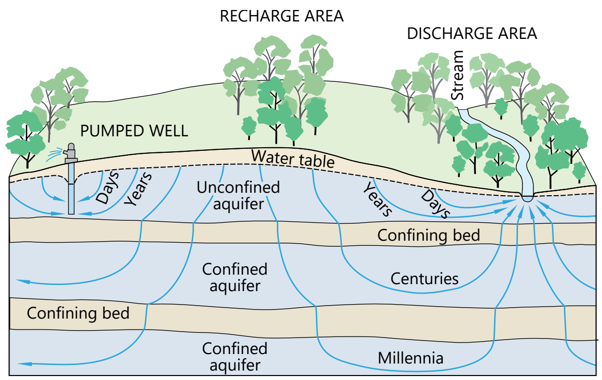
[56] *SEWRPC Technical Report No. 37, 2002,* op. cit.

Land use can profoundly alter the ability for an area to absorb water and contribute to groundwater recharge. Urban development decreases groundwater recharge potential. Most areas developed greater than 30 years ago route stormwater runoff directly to surface waters, discouraging groundwater recharge. Despite requirements of Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* calling to detain/infiltrate runoff from new developments, where practicable, such developments still have the cumulative effect of reducing groundwater recharge compared to pre-development conditions. In addition to reducing groundwater recharge, urban development places additional demand on groundwater supplies as water is extracted for various uses. Removing water from natural groundwater flowpaths often reduces groundwater elevations and the volume of natural groundwater discharge to surface waterbodies.

Depletion through artificial groundwater abstraction most commonly occurs when high-capacity wells, numerous smaller wells, or dewatering systems are operated without considering the effect pumping may have on naturally occurring groundwater discharge areas. Wells developed in the shallow aquifers often provide sufficient yield, but can negatively impact nearby surface water resources, and are generally more vulnerable to contamination than deeper bedrock wells. Communities tapping the shallow aquifer also face choices between using individual low-capacity household wells or developing a municipal water system with homeowners connecting to high-capacity municipal wells. In some cases, some watersheds have an overall negative groundwater balance because water pumped from watershed aquifers is piped to wastewater treatment plants that discharge to waterbodies outside of the watershed. In cases where development of high-capacity wells in the shallow aquifer could negatively affect surface water resources, the Commission's regional water supply plan recommends conducting studies to evaluate potential negative effects.[57] This plan also calls for installing systems to enhance infiltration in areas where studies indicate a potential significant reduction in baseflow to surface waters.

Groundwater recharge can be reduced in many ways. Examples include hastening stormwater runoff, eliminating native vegetative cover, reducing soil's ability to absorb water (e.g., compaction, disrupted structure), ditching, tiling and otherwise draining wet areas, disconnecting floodplains from streams, and increasing the amount of impervious land cover. Such factors all contribute to reduced stormwater infiltration, increased runoff, and reduced groundwater recharge. Similarly, if sanitary sewers are installed in areas now served by private onsite wastewater treatment systems, much of the water that currently re-enters the shallow aquifer is often

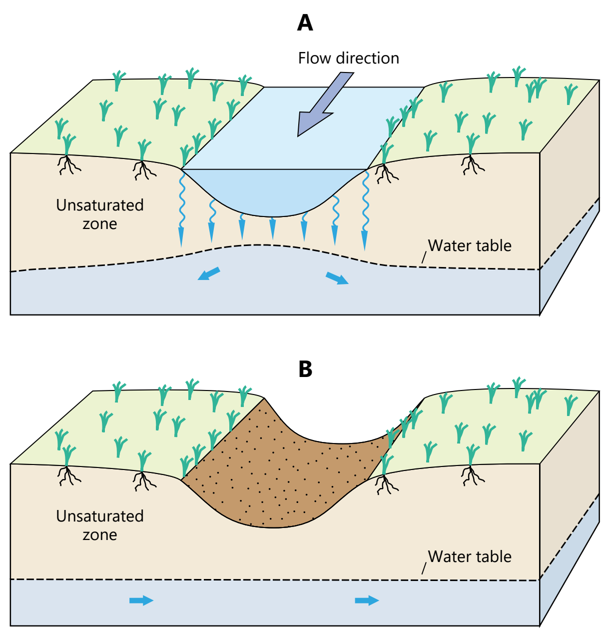
Figure 2.14
Regional vs. Local Groundwater Flow Paths



Groundwater flows from recharge areas at the water table to discharge locations at the stream and well. The residence time of groundwater can range from days to centuries to millennia.

Source: U.S. Geological Survey and SEWRPC

Figure 2.15
Groundwater and Streamflow Interactions: Hydraulically Disconnected Stream Reaches



Disconnected stream reaches are separated from the groundwater system by an unsaturated zone. In other words, the water table is lower than the streambed. In A, streamflow is a source of recharge to the underlying groundwater system, but in B, streamflow and groundwater recharge have ceased and the streambed is dry.

Source: U.S. Geological Survey and SEWRPC

[57] *SEWRPC Planning Report No. 52,* A Regional Water Supply Plan for Southeastern Wisconsin*, December 2010.*

conveyed to downstream discharge points outside of the watershed, a condition that could reduce the volume of groundwater entering a lake or stream. Development and land management activities need to consider groundwater recharge, and actions to protect and enhance recharge should be a priority. Some communities have passed groundwater ordinances to protect precious resource elements and help assure groundwater supplies are sustainable in the long term.[58]

Waterbody Depletion

Although groundwater generally provides a safe and reliable source of potable water, excessive groundwater extraction can seriously and adversely affect desirable, life-cycle critical, aquatic habitat. One of the most visible effects is reduced dry-weather streamflow and lower water levels in hydraulically connected lakes and streams—a process called depletion. Depletion stems from reduced discharge to springs and seeps feeding these waterbodies and has the potential to impact lakes, ponds, streams, rivers, and wetlands. The complex interconnection and interaction between surface and groundwater makes managing depletion challenging, particularly because significant delays may occur from the time when extraction begins to the time when the effects of that extraction are discerned in affected waterbodies. Other complicating factors may confound analysis and influence the timing, rate, and location of depletion. Nonetheless, managers should keep in mind several crucial factors when studying the relationship between surface water features and groundwater pumping, including the following:

- An individual low-capacity well may not produce noticeable change. However, well clusters, high-capacity wells, and/or unfavorable aquifer properties can combine to significantly decrease groundwater discharge to surface water features.

- Basin-wide groundwater development typically occurs over a period of several decades. Therefore, resulting cumulative depletion effects may not manifest themselves for decades.

- Depletion may persist for extended periods of time after groundwater withdrawal ends. Aquifers take time to recover from long-term extraction stress. In some aquifers, maximum surface water depletion may occur after pumping stops, and full recovery of the groundwater system may take decades to centuries.

- Depletion can affect water quality in surface water features and/or aquifer. For example, in many streams, groundwater discharge sustains year-round habitat for fish and other aquatic organisms by moderating seasonal temperature fluctuations, cooling stream temperatures in summer and warming stream temperatures in winter. Reduced groundwater discharge can degrade such moderating influences.

- Major factors affecting depletion timing and intensity are distance from a well to the waterbodies, local geology, and stream and aquifer properties.

- Decreased discharge may be more isolated to certain waterbodies or waterbody segments or may be pervasive throughout the watershed.

Sustainable groundwater utilization does not solely depend on the rates at which groundwater systems are naturally replenished (recharged). Instead, sustainable pumping rates must consider myriad factors including aquifer properties, groundwater elevations, surface water features, biologically acceptable minimum stream flows, and the wishes of the general public and regulatory agencies. These considerations underscore the need to employ an interdisciplinary approach that simultaneously considers both surface water features and groundwater supplies.

[58] *The Village of Richfield in Washington County passed a groundwater protection ordinance over 15 years ago and uses the ordinance as a tool to encourage development that is consistent with long-term sustainability. More information about Richfield's groundwater ordinance can be found at the following website: www.richfieldwi.gov/index.aspx?NID=300.*

An example of unsustainable groundwater use is extraction from the deep sandstone aquifer. Water levels in the deep sandstone aquifer were once above the ground surface meaning that water in a well drawing water from the sandstone aquifer rose to above the ground without pumping.[59] The quality and abundance of this resource made it a prime target for large volume wells. On account of heavy withdrawals throughout the region, this aquifer's water levels have declined hundreds of feet since the 1800s, as shown in Figure 2.16. Whereas the sandstone aquifer formerly provided recharge to the dolomite and sand and gravel aquifers, flow is reversed, and the shallow aquifers now contribute water to the sandstone aquifer. In much of the Region, water movement from the shallow sand and gravel and dolomite aquifer into the deep sandstone aquifer is limited by the low permeability Maquoketa shale aquitard, a rock layer which forms a relatively impermeable barrier between the two aquifers and direct surface recharge. As a result, the rates of local groundwater recharge to the deep aquifer are much less than the rates that water is being extracted by pumping. The drawdowns of the deep aquifer are indicative of a water budget deficit and are the combined result of pumping primarily in Southeastern Wisconsin and Northeastern Illinois. In contrast, drawdowns in the shallow aquifer throughout the Region are much smaller even though nearly twice the amount of water is being extracted from it compared to the deep aquifer. The reason for the lower drawdowns is that the shallow aquifer is unconfined in most places. It receives direct recharge from precipitation and is also linked directly to surface waterbodies.

Management Tools – Plans and Models

The Commission developed a water supply system plan for the Southeastern Wisconsin Region.[60] This plan considers existing water demands, future development, sustainability, and protection of natural resource features. This plan is the third component of the Commission's regional water supply planning program. The other two elements were a groundwater resource inventory and a regional groundwater model.[61,62] The regional aquifer simulation model allows water levels in the deep and shallow aquifers under historical, current, and planned conditions to be predicted and allows the effects of different groundwater management alternatives on surface water resources to be simulated. Additionally, the model provides a framework within which more-detailed "inset" models may be developed to investigate site-specific groundwater-related questions, including the possible effects of high-capacity wells on surface water resources. In summary, the model provides the capability of addressing the following questions:

- What is the sustainable capacity of an aquifer to supply human needs?
- How much have humans altered the groundwater system?
- What effect does human groundwater system alteration have on surface waters?

It is important to note that while the resolution of the regional groundwater models was considered sufficient and valid to compare differences in alternative plans, it may not be sufficiently fine to predict site-specific impacts, or may not be able to resolve differences in impacts between surface water or groundwater features that are in close proximity to one another.[63] Simulating conditions over a relatively small area such as the Lake Comus watershed would likely require a refined model that includes more detailed site-specific hydrogeological data and smaller model cell size. As noted previously, in cases where development of high-capacity wells in the shallow aquifer could negatively affect surface water resources, the Commission regional water supply plan recommends conducting detailed site-specific studies to evaluate potential negative effects and installing enhanced rainfall infiltration systems in areas where such studies indicate a potential significant reduction in baseflow to surface waters.

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[59] *When the elevations of water within a well are above the adjacent land surface, the well will freely flow and is considered an artesian well.*

[60] *SEWRPC Planning Report No. 52, 2010*, op. cit.

[61] *SEWRPC No. 37, June 2002,* op. cit.

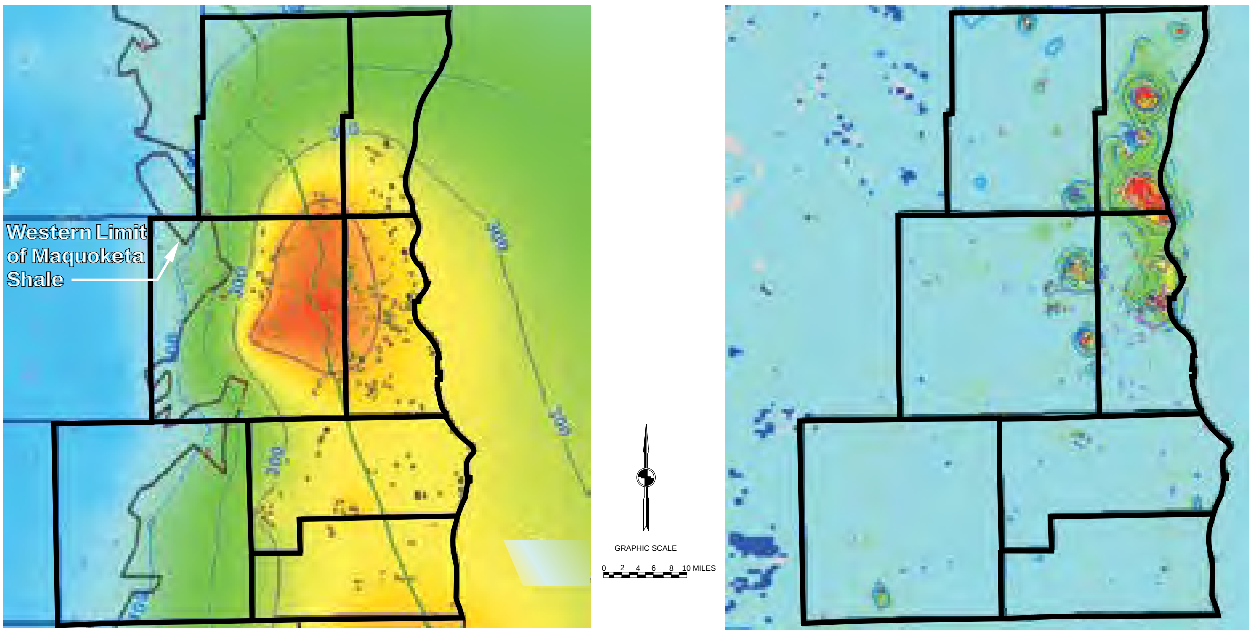
[62] *SEWRPC Technical Report No. 41,* A Regional Aquifer Simulation Model for Southeastern Wisconsin*, June 2005.*

[63] *Since the average grid cell size of the groundwater simulation model is over one-quarter square mile (about 2,500 feet on a side), the results from this regional modeling effort are not sufficiently detailed to estimate the impact of groundwater withdrawal on a site-specific basis. In other words, this regional model cannot specifically be used for local level groundwater supply planning purposes for the Lake Comus watershed, because this area is too small.*

Figure 2.16
Simulated Gorundwater Drawdowns for Southeastern Wisconsin Region

Figure A: Deep Aquifer – the red zones shows areas where pumping has depressed natural groundwater pressure head by more than 400 feet. In many areas, the deep aquifer naturally had pressure sufficient to produce artesian conditions.

Figure B: Shallow Aquifer – the red zones are areas where pumping has depressed the water table by more than 50 feet.



Source: U.S. Geological Survey, Wisconsin Geological and Natural History Survey, and SEWRPC Technical Report No. 46, Groundwater Budget Indices and Their Use in Assessing Water Supply Plans for Southeastern Wisconsin, *February 2010*

One of the most accessible and effective tools developed as part of the water supply planning effort is the groundwater recharge potential map derived from a soil-water balance recharge model developed for the Southeastern Wisconsin Region. Understanding groundwater recharge potential and its distribution on the landscape are key to making informed land use decisions that jointly consider human and environmental groundwater needs. Unlike the regional model discussed above, groundwater recharge potential maps are plotted at a significantly smaller grid size (about one hundred feet on a side) and can therefore be directly employed for local level groundwater planning purposes. Therefore, these groundwater recharge potential maps are generally applicable to the Lake Comus watershed for identifying and protecting recharge areas that contribute most to baseflow of the lakes, streams, springs, and wetlands in the watershed, which is important to the goals of sustainable groundwater use and a healthy natural environment.

In summary, sustainable groundwater supplies provide reliable, high-quality water that supports both short-term and long-term needs and desires. Reliable water supplies support existing and new development, avoid undue influence on existing wells and natural groundwater discharge areas, and avoid reduced groundwater discharge or adulterated quality that could affect treasured and sensitive natural resource features.

<u>Groundwater Conditions in the Lake Comus Watershed</u>

To help determine where management efforts could best protect groundwater recharge to aquifers feeding Lake Comus, Commission staff analyzed water table elevation contours and groundwater recharge potential in the areas surrounding the Lake.[64,65] This inventory was not confined to the surface watershed (as was the case for the other inventories completed in this report) because the groundwater flow paths may extend outside of the surface water watershed. The results of these inventories are described below.

[64] *SEWRPC Technical Report Number 37,* Groundwater Resources of Southeastern Wisconsin*, June 2002.*

[65] *SEWRPC Planning Report No. 52, December 2010,* op. cit.

Water table elevation contours for the Lake Comus area are shown in Map 2.7. Depth to groundwater varies considerably across the landscape. In and near waterbodies and wetlands, the water table is near or at the land surface whereas it can be over one hundred feet or more below the land's surface in upland areas near the periphery of the watershed.[66] The Commission used water table elevations to estimate the area where water infiltrating into the land surface ultimately reaches Lake Comus. This area, the Lakes groundwatershed, is the source for water issuing as springs and seeps to the Lakes, its tributaries, and associated wetlands.

Map 2.7 also illustrates the extent of the Lake's 18,995-acre groundwatershed. The groundwatershed overlaps much of the eastern portion of the surface water watershed and extends beyond to the shores of Delavan Lake in the southeast and across CTH A near Lake Lorraine in the northwest. Based upon groundwater contour lines, springs and seeps are likely especially prevalent along the eastern portions of the Lake and Turtle Creek. A 1929 Lake bathymetry map maintained by the City of Delavan indicates the location of several of these springs along the eastern and northern shorelines of the Lake (Figure 2.11). These springs are partially fed by water infiltrating into the bed and shoreline of Delavan Lake and the bed of Swan Creek immediately downstream of the dam impounding Delavan Lake.[67] In the headwater portion of Turtle Creek, springs and seeps are fed by extensive high to moderate groundwater recharge potential areas in the eastern uplands. All groundwater recharge feeding Lake Comus originates east of Turtle Creek.

The western shoreline of Lake Comus and Turtle Creek for about two miles upstream of the Lake do not contribute groundwater to the Lake. Instead, water from the Creek and Lake infiltrates into the bed and banks where it contributes to groundwater flow. This water moves in shallow aquifers under the highlands to the northwest of the Lake ultimately re-entering Turtle Creek as seeps and springs in areas up to three miles downstream of Lake Comus.

Evaluating groundwater recharge potential helps identify portions of a groundwatershed most important to sustaining a waterbody's seeps and springs. The Commission evaluated groundwater recharge potential for all Southeastern Wisconsin.[68] Such data can help planners decide which areas should not be covered with impervious surfaces and/or where infiltration basins would be most effective. The distribution of various groundwater recharge potential categories for Lake Comus' groundwatershed are illustrated in Map 2.7 and tabulated in Table 2.6.

The Lake's tributary streams receive a sizable percentage of their flow from groundwater. Therefore, a large proportion of the water delivered to the Lake from its tributaries is also derived from groundwater. The Commission's water budget suggests that tributary streams indirectly contribute roughly 7,456 acre-feet of water to the Lake each year. Based upon the flow exceedances provided by the WDNR Presto-Lite tool, roughly half (nearly 4,000 acre-feet) of the water entering the Lake through tributary streams during a typical year is likely groundwater. Using this same percentage for the combined surface runoff and groundwater inflow directly entering the Lake results in nearly 700 acre-feet of water contributed directly to the Lake by groundwater during a typical year. Therefore, on an overall basis, groundwater likely provides roughly 4,700 acre-feet of water to the Lake during a typical year.

Preserving and enhancing recharge potential within the groundwatershed, especially in the areas identified as having high and very high recharge potential, is essential to protecting the groundwater feeding the Lake and its tributaries. High and very high recharge potential sites should remain substantially open and may provide ideal sites to position stormwater infrastructure designed to infiltrate detained stormwater.[69] Infiltrating stormwater helps reduce peak flows and increases cool, high quality baseflow to waterbodies during dry periods, conditions that generally improve waterbody health.

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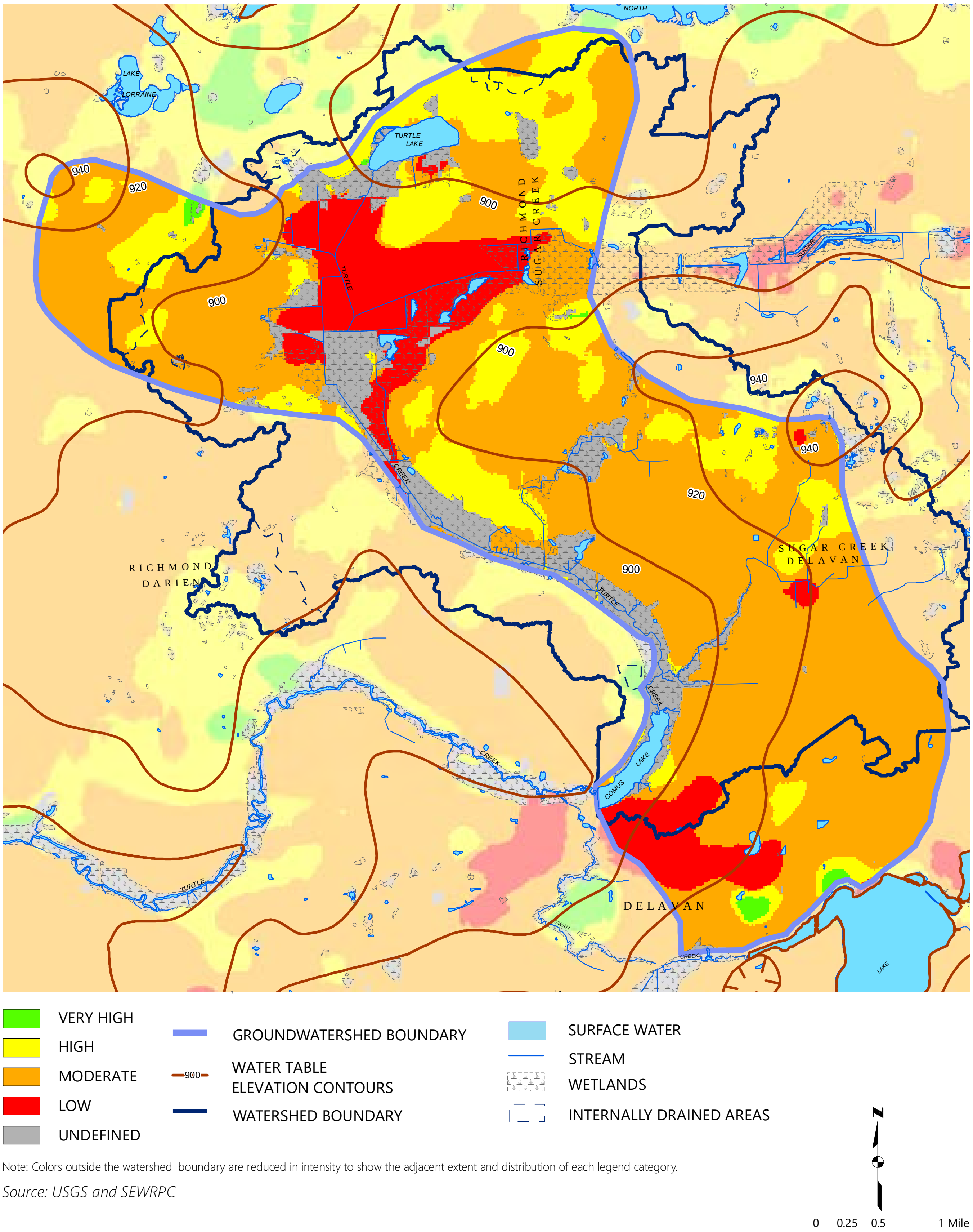
[66] *The depth to groundwater for a particular location can be estimated by subtracting groundwater elevation values from surface topography values.*

[67] *Delavan Lake's water surface elevation is almost 10 feet higher than Lake Comus' water surface elevation.*

[68] *SEWRPC Technical Report No. 47,* op. cit.

[69] *Care needs to be taken to infiltrate water that does not degrade the quality of groundwater resources. More information regarding stormwater infiltration is available from many sources, including the following website: learningstore.uwex.edu/assets/pdfs/g3691-3.pdf.*

Map 2.7
Groundwater Elevation Contours and Recharge Potential Within the Comus Lake Watershed



Note: Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

Source: USGS and SEWRPC

In the Lake Comus groundwatershed, there is no confining unit between the shallow aquifers and the deep sandstone aquifer, so the sandstone aquifer has experienced less drawdown that other parts of the Region. Additionally, the shallow sand and gravel aquifer in the watershed has high hydraulic conductivity and recharge rates with comparatively low water use and consumption.

Table 2.6
Groundwater Recharge Areas in the Lake Comus Watershed

Groundwater Recharge	Acres	Percent
Low	1,793.5	8.5
Moderate	12,719.6	60.2
High	4,483.8	21.2
Very High	66.4	0.3
Undefined	2,076.8	9.8

Source: Wisconsin Geologic and Natural History Survey and SEWRPC

Numerous wells are found throughout the watershed, with the largest cluster in the City of Delavan. All wells, as well as other human-induced groundwater abstraction such as quarry dewatering, diverts groundwater from natural discharge points and can reduce the flow of springs, seeps, and streams. Therefore, human demands placed on groundwater supplies should be considered as part of lake management planning. Only a small portion of the Lake Comus watershed is either served or is planned to be served by public sewers (Map 2.8). Additionally, much of the watershed has moderate to high susceptibility to groundwater contamination due to its highly permeable soils, its permeable sand and gravel aquifer, and the shallow water table.[70,71] According to well data published by the University of Wisconsin Stevens Point, there have been observations that exceed the 10 mg/l standard for nitrate in private wells within the Lake Comus watershed.[72] Walworth County has published an interactive dashboard that illustrates well water results for arsenic, coliform, *E. coli*, lead, and nitrate within the County.[73] Those served by private wells should be aware of the potential for groundwater contamination in the watershed, have their well water tested, and/or utilize private water treatment such as reverse osmosis to reduce nitrate exposure.

All wastewater discharged to public sanitary sewers within the Lake Comus watershed is exported from the watershed to the WalCoMet treatment facility downstream along Turtle Creek. Since the water discharged to sanitary sewers originates as groundwater drawn from within the watershed, household water use in areas served by public wastewater collection systems represents a small net artificial demand placed upon the groundwater flow system feeding waterbodies in the Lake Comus watershed. This slightly decreases the volume of groundwater discharging to the watershed's waterbodies.

Groundwater is the water supply for all the residences, agriculture, and industry within the Lake Comus watershed. Additionally, it is a critical source of cool, clean water to the Lake and Turtle Creek, maintaining surface water elevations and stream baseflow during dry periods. However, human activities can imperil groundwater resources, particularly by depleting groundwater through excessive abstraction, constructing impervious surfaces on important groundwater recharge areas, and contaminating groundwater with pollutants.[74] Protecting high recharge areas from coverage by impervious surface and reducing nonpoint source pollution will preserve the quality and supply of groundwater within the watershed. Discussion of these problems and associated management recommendations are provided in Section 3.2, "Hydrology/ Water Quantity."

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[70] *Wisconsin Department of Natural Resources and the Wisconsin Geologic and Natural History Survey,* Groundwater Contamination Susceptibility in Wisconsin, *1989. For more information, see dnr.wi.gov/education/documents/ groundwater/susceptibilityMap.pdf.*

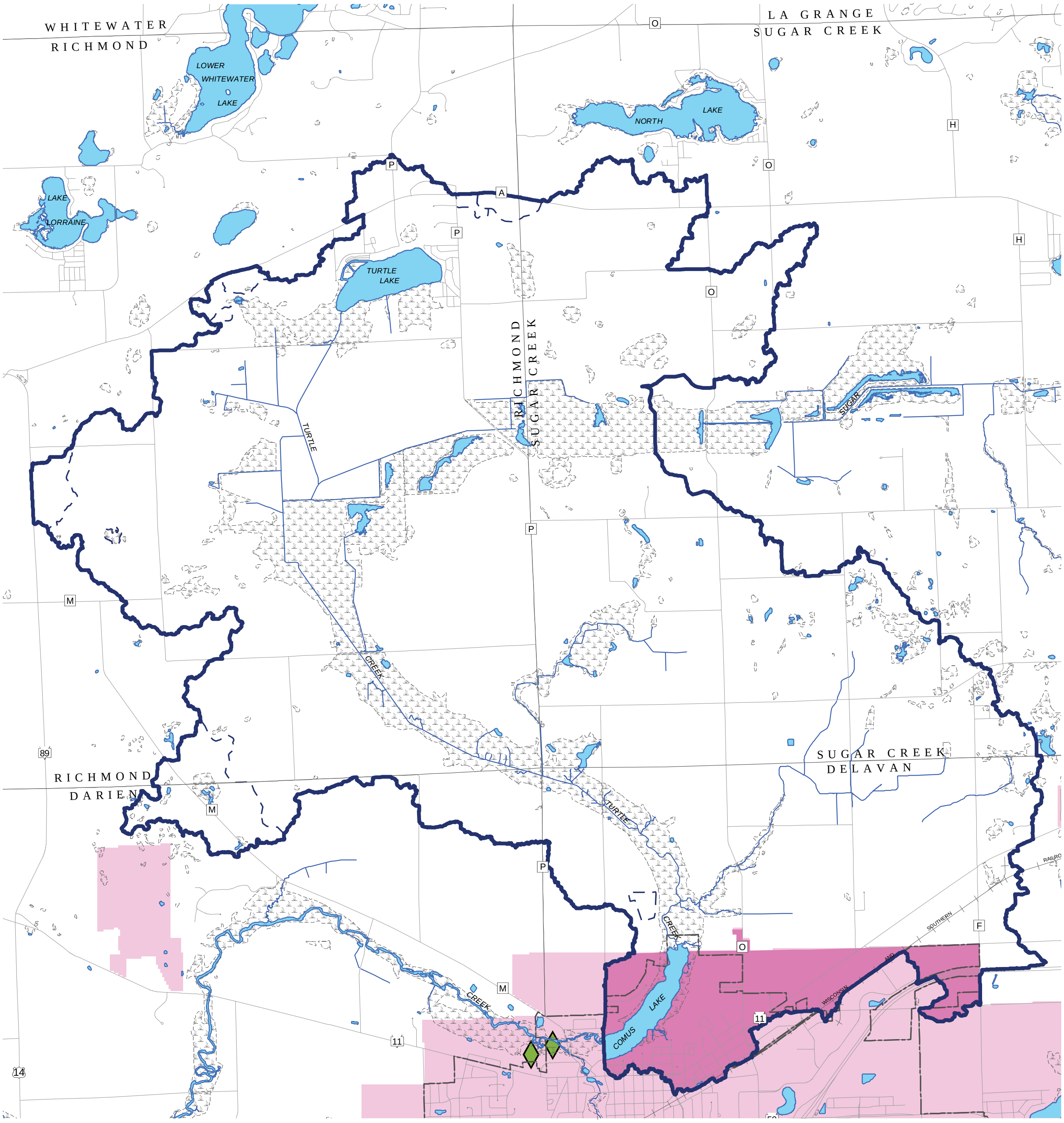
[71] *University of Wisconsin – Whitewater,* Assessing Nitrate Pollution Potential in Walworth County through GIS, *2017. For more information, see www.co.walworth.wi.us/DocumentCenter/View/4199/UW-Whitewater-Assessing-Nitrate-Pollution-Potential-in-Walworth-County-through-GIS-PDF.*

[72] *The University of Wisconsin Stevens Point hosts an interactive map of groundwater quality from private wells at: www. gissrv3.uwsp.edu/webapps/gwc/pri_wells/.*

[73] *To view the Walworth County well water viewer dashboard, visit www.walco.maps.arcgis.com/apps/opsdashboard/index. html#/a0be5495d249437b8a5443ce036558e4.*

[74] *It should be remembered that pollutants can include seemingly innocuous substances such as sodium chloride (the same as simple table salt). In some parts of the region, groundwater now contains concentrations of salt in excess of drinking water quality standards.*

Map 2.8
Adopted Sanitary Sewer Service Areas Within the Comus Lake Watershed



DELAVAN/DELAVAN LAKE

EXISTING TREATMENT PLANTS - OCTOBER 2016

SURFACE WATER

STREAM

WATERSHED BOUNDARY

INTERNALLY DRAINED AREAS

WETLANDS

Source: SEWRPC

Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

Vegetation

Before European settlement, the Lake Comus watershed was dominated by oak savanna, oak forest, and prairie in the upland areas by wetland in the Turtle Valley (Map 2.9 and Table 2.7). Prairie was predominant in the southeastern corner of the watershed while oak forest and oak savannah were spread uniformly throughout the remaining upland. The watershed was also home to small pockets of conifer swamp, lowland hardwood forest, and maple – basswood forest.

Native vegetation was largely removed throughout the watershed as part of European settlement. European settlers, cleared much of the original vegetation to make room for farming and to provide raw materials to support initial settlement. Native vegetation was largely supplanted by vegetation associated with agricultural or urban land uses, although some pockets of native vegetation remain. Much of the land in the watershed is extremely well suited for agriculture, with 73 percent of the land area identified as farmland of statewide importance, prime farmland areas, or potential prime farmland areas (Map 2.10).

Today's vegetation has been manipulated to support human needs and desires. Most of the watershed are devoted to agricultural and residential uses. Wetlands, environmental corridors, floodplains, and undeveloped upland areas host vegetation supporting wildlife and natural resource functions. Only about 12.5 percent of the watershed's upland areas presently host woodlands, brush, unmanaged grass, or admixtures of these elements (Map 2.11). Deciduous woodlands account for well over a half of this total. Such areas and remaining wetlands and floodplains are further discussed in subsequent sections of this chapter.

2.2 HUMAN LAND USE AND OCCUPATION

Cultural History

Humans first occupied Southeastern Wisconsin a few thousand years after glaciers retreated from the area. Several Native American cultures rose and declined over the millennia. While some Native American cultures were subsistence hunter-gatherer cultures and modified the natural landscape to a limited degree, others practiced agriculture and modified the native vegetation using fire to promote agricultural and favorable game conditions. Mound Builders of the Woodland Culture settled the Lake Comus area between 500 to 1000, constructing effigy mounds along the shores of nearby Delavan Lake. In the late 18th century, the Potawatomi people also settled near Delavan Lake and erected burial mounds that remain to this day.[75]

Although a few European adventurers, missionaries, trappers, and traders visited the area since the 1600s, the 1800s witnessed the first great influx of European settlers to the Lake Comus area. These settlers brought sweeping changes to the natural environment. The first Europeans settled in the vicinity of Lake Comus during 1836 when Allen Perkins built a family cabin in what is now the City of Delavan. Two brothers, Samuel and Henry Phoenix also arrived the same year with the intention of establishing a temperance colony. Samuel Phoenix filed the name "Delavan" with the Wisconsin Territory legislature after a New York temperance leader as well as the name "Walworth" for Walworth County. The newly founded temperance colony attracted settlers from New England who began farming the area, converting native forests and prairies for agricultural uses. As mentioned in Section 2.1, "Lake and Watershed Physiography," the Phoenix brothers constructed the first gristmill in 1839, forming Lake Comus behind the gristmill dam. This gristmill would become the core business in Delavan for over a century.[76]

Infrastructure was developed as more people settled the area in the mid-1800s, converting native forests and prairies for agricultural, industrial, and residential use. The Mabie brothers assisted with development of the plank road between Delavan and Racine and a section of Racine-Mississippi railroad running through Delavan. The Wisconsin School for the Deaf was founded in 1852 and a manufacturing plant to develop windmills and wooden pumps was built in 1861. The U.S. Olympic Circus established their winter quarters in Delavan in 1847, begetting a trend that led to twenty-six circuses quartering in the late 1800s, including the P.T. Barnum Circus, "The Greatest Show on Earth." The final traveling circus left Delavan in 1894.

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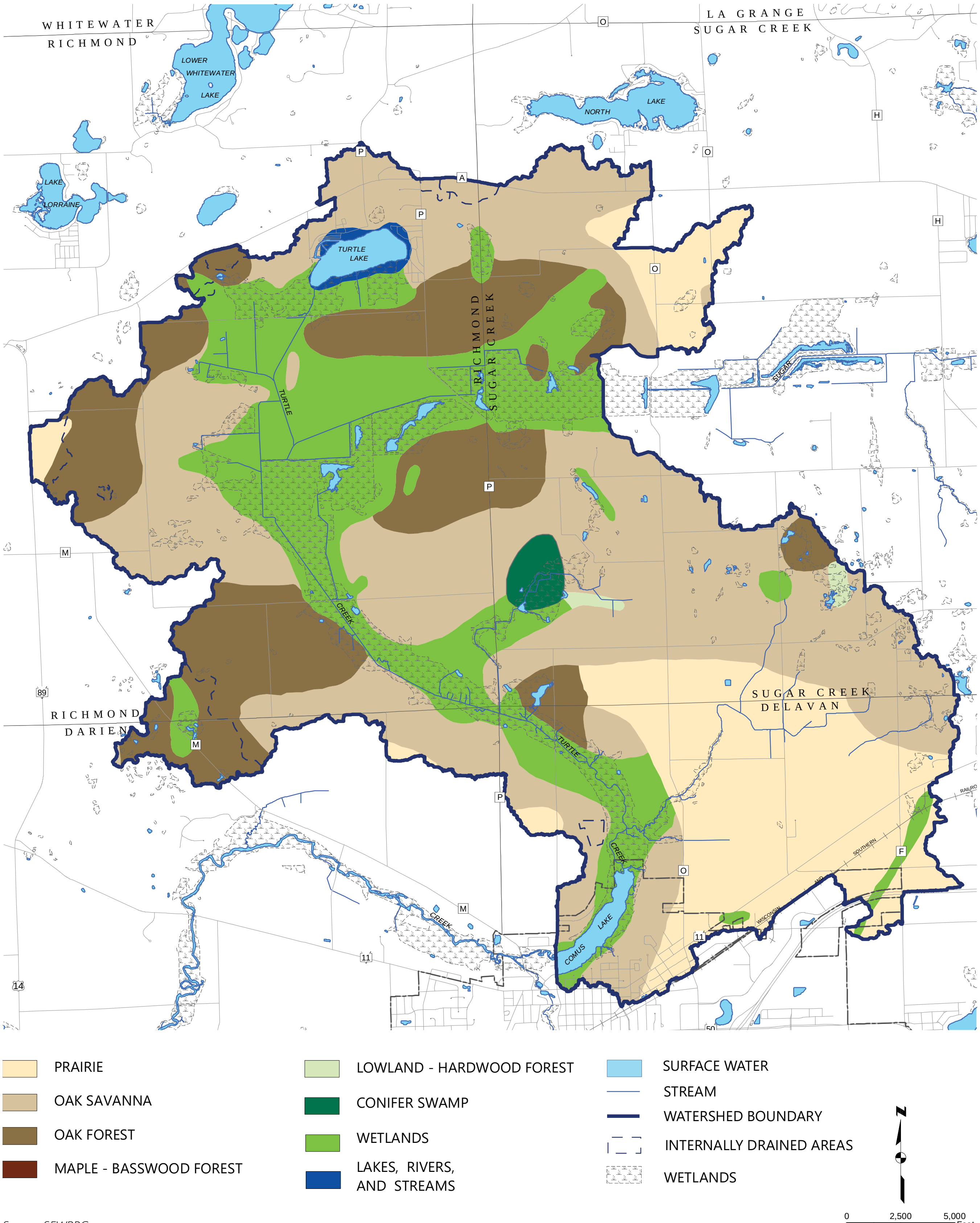
[75] *Delavan Wisconsin Historical Society,* op. cit.

[76] Ibid.

Map 2.9
Presettlement Vegetation Within the Comus Lake Watershed



Source: SEWRPC

The 1890s and early 1900s saw increased urban development as Delavan became a city with electricity, paved streets, and the establishment of its first major manufacturer, the Bradley Knitting Company. During the Great Depression and World War II, Delavan's economy was kept afloat by its manufacturer of electrical and timing devices as well as many government contracts. Establishment of additional industrial firms drove City growth through the 1940s and 1950s. In the 1960s, the Lange Memorial Arboretum was established and much of the wetlands along the northern shore of Lake Comus were donated to the City of Delavan as a botanical and wildlife refuge. From the 1970s onward, increased commercial, industrial, and residential growth has occurred in the eastern portion of the City as the former State Highway 15 became Interstate Highway 43.[77]

Table 2.7
Pre-Settlement Vegetation of the Lake Comus Watershed

Pre-settlement Vegetation	Acres of Watershed	Percent of Watershed
Prairie	3,820.23	18.1
Oak Savanna	8,207.68	38.8
Oak Forest	3,744.48	17.7
Lowland Hardwoods	74.47	0.4
Conifer Swamp/Bog	170.36	0.8
Wetland	4,894.17	23.2
Lakes, Rivers, and Streams	228.58	1.1

Source: Wisconsin Geological and Natural History Survey and SEWRPC

Today the City remains a local manufacturing and retail hub while its proximity to IH-43 and STH-50 attracts travelers between Beloit and Milwaukee as well as visitors to nearby lakes. The City also has a growing Hispanic community with several business and restaurants started by Hispanic entrepreneurs.[78] The City's strategic plan indicates a desire for greater interaction between the downtown area and the Lake. The City plans to achieve this by increasing Lake public access points, making the Lake a destination for paddle sports, and developing a walking trail that encompasses the Lake.[79]

Historical Land Use

As discussed in Section 2.1, "Lake and Watershed Physiography," before European settlement, the Lake Comus watershed's uplands were dominated by oak savanna, oak forest, and prairie. Wetlands occupied extensive areas in the Turtle Creek valley. Following European settlement, sizable portions of the landscape were converted to agricultural use. Natural vegetation was cleared to make way for crops. Efforts were made to drain wetlands to facilitate cropping. Steeply sloped, non-arable lands were often grazed by livestock. This land conversion significantly influenced water quality, water quantity, and wildlife habitat. For example, water quality has been compromised through increased erosion leading to siltation of surface waters. In addition, natural waterways were dredged and straightened to facilitate rapid runoff, bypassing natural systems such as floodplains and wetlands, features that detain runoff and retain sediment. By 1941, agriculture was the most dominant land use in the watershed, and it remains the most dominant within the watershed to this day. Although agriculture remains a dominant land use, it has decreased in area since the 1940s. Some areas previously used for agriculture have reverted to woodland and wetland, particularly along the northeastern unnamed tributary to Turtle Creek and along the Creek itself. Expanding woods and wetlands have reduced fragmentation of environmental corridors, highlighting the capacity to shift the landscape from a "disturbed" to a more "natural" condition.

Historical records of urban growth and development help illustrate land use history within a watershed. Urban growth within the Lake Comus watershed is summarized on Map 2.12 and Table 2.8. There has been little urban development within the watershed and 97 percent of the watershed presently remains non-urban. The largest expansions of urban growth came during 1900 to 1950 with the growth of Delavan's downtown area and development along the eastern shore of Turtle Lake, and 1951 to 1970 with continued growth along the perimeter of these urban areas. Table 2.8 shows the growth of the population and the number of households in the Lake Comus watershed between 1960 and 2010. Those periods of greatest urban growth shown in Table 2.9 are reflected in similar increases in population and households: population increased 16

[77] Ibid.

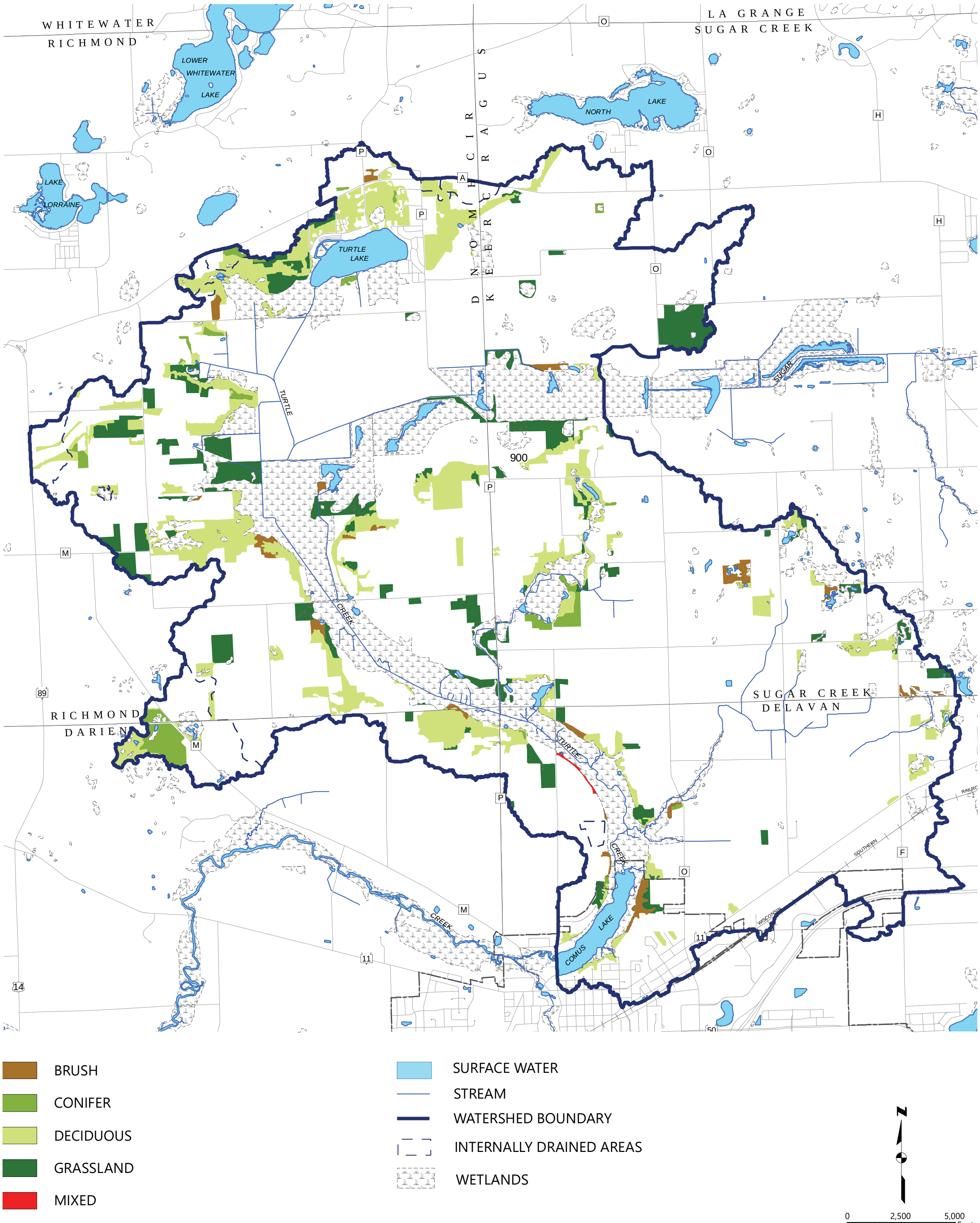
[78] *City of Delavan and Vandewalle & Associates, Inc.*, Downtown Delavan Strategic Plan: City of Delavan, Wisconsin, *May 2013.*

[79] Ibid.

Map 2.10
Federal and State Soil Classifications for Agricultural and Open Lands Within the Comus Lake Watershed

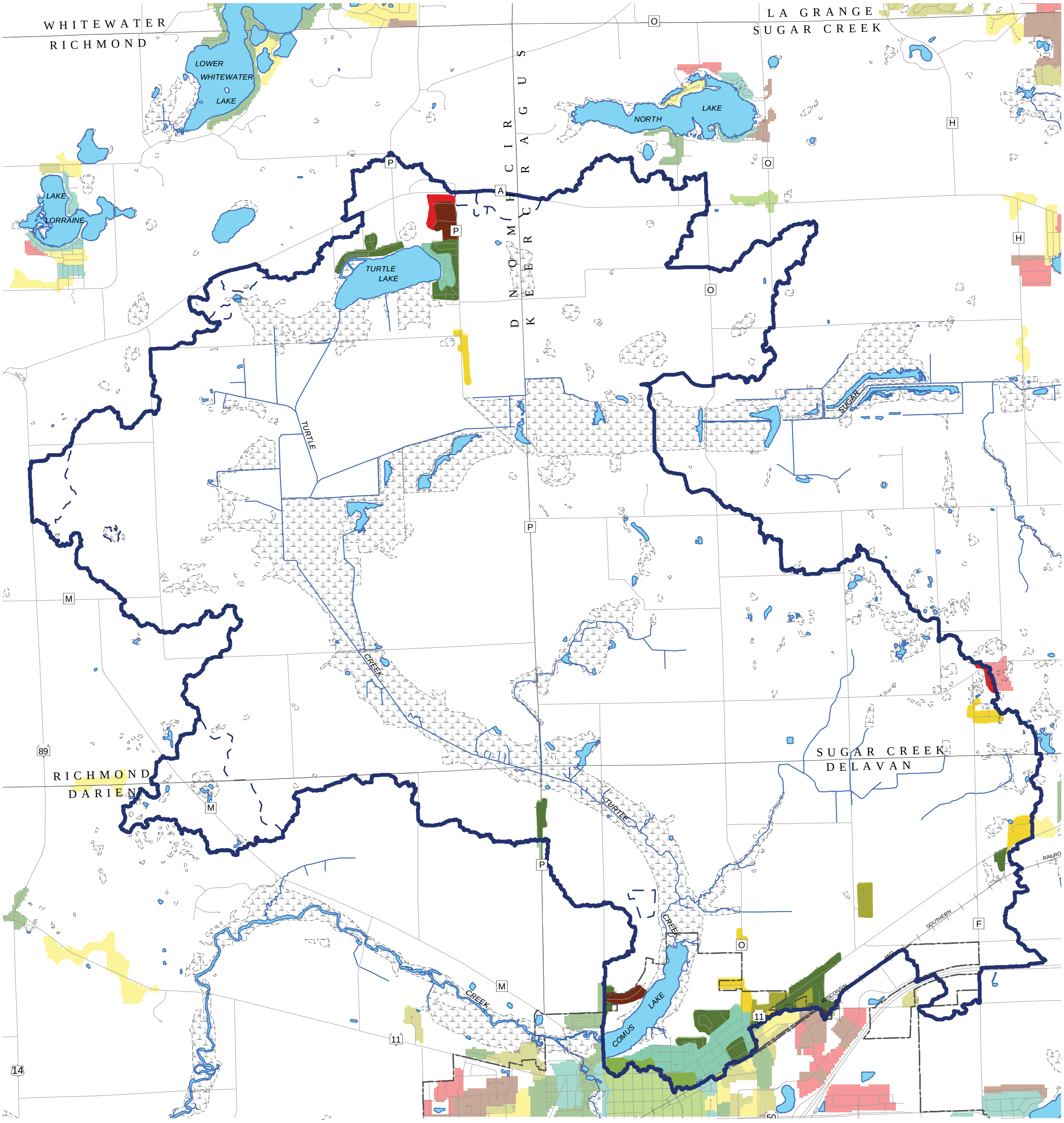
Source: Natural Resources Conservation Service and SEWRPC

Map 2.11
Upland Cover Types Within the Comus Lake Watershed



Source: SEWRPC

Map 2.12
Historic Urban Growth Within the Comus Lake Watershed: 1850-2010



	PRE 1900		1981 - 1990		SURFACE WATER
	1900 - 1950		1991 - 2000		STREAM
	1951 - 1970		2001 - 2010		WATERSHED BOUNDARY
	1971 - 1980				INTERNALLY DRAINED AREAS
					WETLANDS

Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

N

0 2,500 5,000 Feet

Source: SEWRPC

percent from 1963 to 1970 with a 25 percent increase in the number of households.

Current and Planned Land Use

The Commission periodically quantifies the ways humans use land in Southeastern Wisconsin and projects how land use will change over the near term. Existing land uses in the Lake Comus watershed were last evaluated in 2015. As shown in Table 2.10 and Map 2.13, as of 2015, the watershed is predominantly rural, with agricultural uses constituting 67 percent of the watershed and combined surface water, wetlands, and woodlands at 22 percent. Nearly 88 percent of the agricultural uses were cultivated cropland, with another 6 percent in pasture, and the remaining 6 percent split amongst orchards, farm buildings, and other uses. Agricultural lands are mostly found on upland area while wetlands and woodlands are located adjacent to Turtle Creek and its tributaries in the low-lying portions of the watershed. The urban lands, which are almost entirely in the City of Delavan and along the northern and eastern shores of Turtle Lake, are largely split between residential, transportation, communication, and utility land uses.

No major changes are anticipated for the watershed with planned land use (Map 2.14). Agricultural uses are expected to decrease by 287 acres (roughly one percent of the watershed) while commercial, industrial, and low-density residential uses will all slightly increase, occupying these formerly agricultural areas. Most urban development is planned to occur in the corridor between State Hwy 11 and Interstate 43 along the southeastern edge of the watershed. Some low-density residential development is also planned in areas north of Turtle Lake as well as just east and west of Lake Comus' northern shoreline.

Table 2.8
Historic Urban Growth in the Lake Comus Watershed: 1850-2010

Year	Acres of Watershed	Percent of Watershed	Cumulative Percent of Watershed
<1850	0.98	0.00	0.00
1850-1880	39.26	0.19	0.19
1880-1920	84.26	0.40	0.59
1920-1940	4.81	0.02	0.61
1940-1950	84.60	0.40	1.01
1950-1963	167.95	0.79	1.80
1963-1970	38.05	0.18	1.98
1970-1975	29.71	0.14	2.12
1975-1980	68.89	0.33	2.45
1980-1985	37.57	0.18	2.63
1985-1990	15.53	0.07	2.70
1990-2000	50.72	0.24	2.94
2000-2010	26.09	0.12	3.04

Source: SEWRPC

Table 2.9
Populations and Households in the Lake Comus Watershed: 1963-2010 and Planned

Year	Population	Households
1963	2,624	753
1970	3,042	943
1980	2,986	1,072
1990	3,068	1,171
2000	3,368	1,248
2010	3,373	1,293
Planned	3,824	1,584

Source: SEWRPC

Political Jurisdictions

The Lake Comus watershed lies entirely within Walworth County (Map 1.1). Lake Comus' open water area and shoreline are almost entirely within the City of Delavan, aside from a small northwest section within the Town of Delavan (Map 2.15). Despite comprising nearly the entire Lake and Lake-adjacent area, the City comprises only 4 percent of the entire watershed (Table 2.11). The rest of the watershed is in the Towns of Darien (4 percent), Delavan (19 percent), Richmond (42 percent), and Sugar Creek (32 percent). The City also only comprises a small fraction of the lands bordering Turtle Creek. The Creek's headwaters are in the Town of Richmond and the Creek subsequently flows through the Town of Delavan before entering the Lake.

Sewer Service Area

Adopted sanitary sewer service areas are shown on Map 2.8. Sewer service areas are delineated through a local sewer service area planning process. As part of this process, communities, assisted by the Commission, define a public sewer service area boundary that is 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 plan adoption by the designated management agency for the wastewater treatment plant, the Commission considers local sewer service area plans for adoption. Once adopted by the Commission,

Table 2.10
Land Use in the Lake Comus Watershed: 2015 and Planned

Land Use Categories[a]	2015 Acres	2015 Percent of Total	Planned Acres	Planned Percent of Total
Urban				
Residential				
Single-Family - Rural Density	215	1.0	215	1.0
Single-Family - Suburban Density	44	0.2	47	0.2
Single-Family - Low Density	301	1.4	358	1.7
Single-Family - Medium Density	202	1.0	235	1.1
Single-Family - High Density	0	0.0	0	0.0
Multi-Family	20	0.1	26	0.1
Commercial	39	0.2	107	0.5
Industrial	62	0.3	134	0.6
Governmental and Institutional	55	0.3	62	0.3
Transportation, Communication, and Utilities	611	2.9	652	3.1
Recreational	33	0.2	33	0.2
Urban Subtotal	1582	7.6	1869	8.8
Rural				
Agricultural	14,074	66.5	13,802	65.4
Other Open Lands	869	4.1	799	3.8
Wetlands	2,941	13.9	2,941	13.9
Woodlands	1,335	6.3	1,331	6.3
Water	326	1.5	326	1.5
Extractive	13	0.1	72	0.3
Landfill	0	0.0	0	0.0
Rural Subtotal	19,558	92.4	19,271	91.2
Total	21,140	100.0	21,140	100.0

[a] *Parking included in associated use.*

Source: SEWRPC

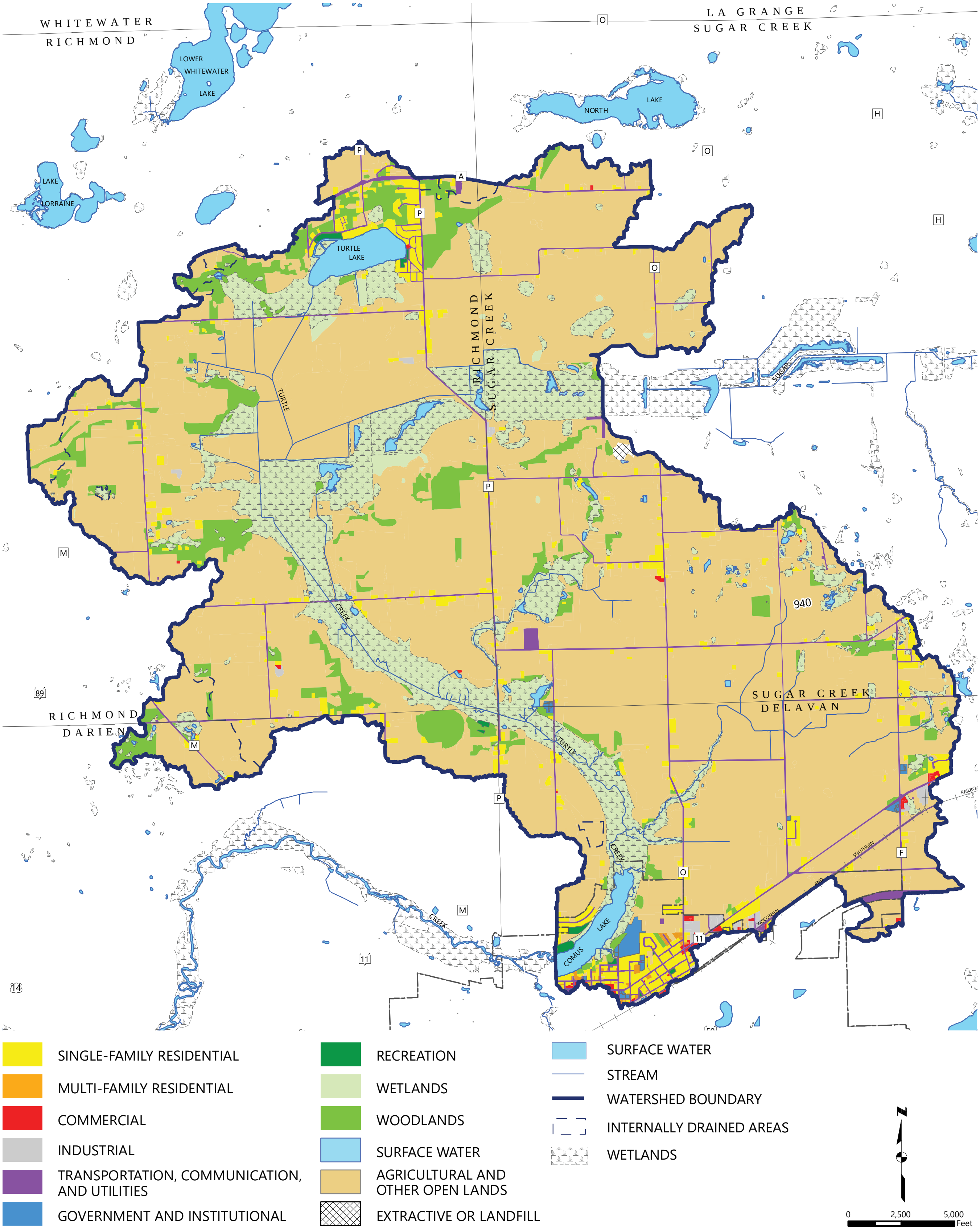
the plans become a formal amendment to the regional water quality management plan and the Commission forwards the plans to the Wisconsin Department of Natural Resources for approval.

Only one 1,233-acre sewer service area has been adopted in a southern portion of the watershed in the City of Delavan and part of the Town of Delavan. There are no wastewater treatment plants within the Lake Comus watershed. Sewage is pumped to the Walworth County Metropolitan Sewerage District located near the confluence of Turtle Creek with Swan Creek downstream of the dam. Treated effluent is discharged to Turtle Creek downstream of Lake Comus.

Natural Resource Elements

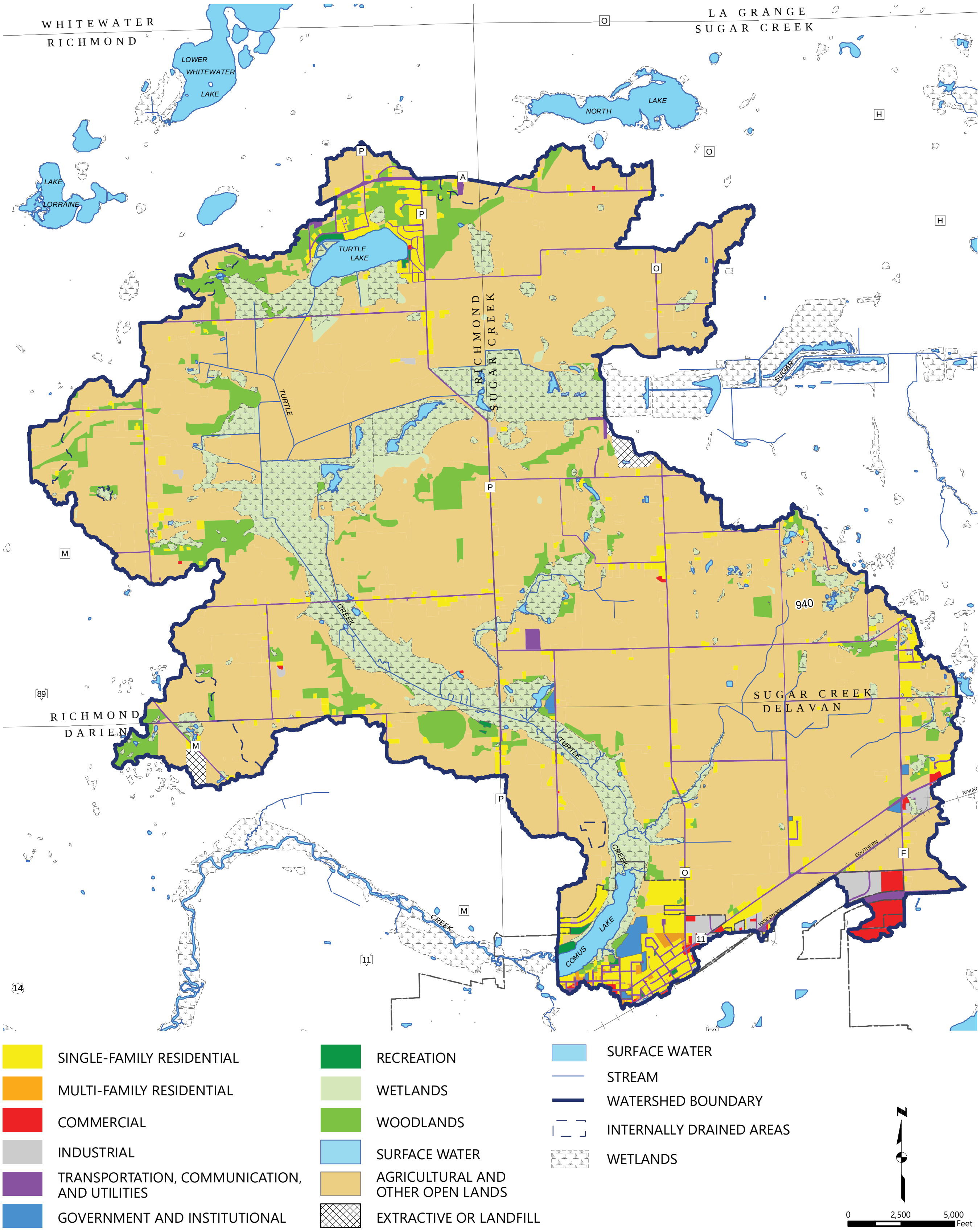
Natural resources elements are features that remain integral parts of the Southeastern Wisconsin landscape provisioning many human needs and desires. Natural resource elements are vital to continued environmental health. The ability of natural resource elements to provision human needs and desires and support ecology is built upon a complex network of abiotic and biotic relationships. Deterioration or removal of one important relationship may damage the entire network. For example, draining a wetland can eliminate the area's ability to supply important fish reproduction, nursery, and refuge functions, may compromise upland wildlife habitat value, can interrupt important groundwater recharge/discharge relationships, and can inhibit natural runoff filtration and floodwater storage. This loss in ecosystem function may further affect groundwater supply for domestic, municipal, and industrial uses or its contribution to maintain dry-weather flows in streams and rivers. Preserving natural resource elements not only improves local environmental quality, but it can also sustain and possibly enhance aquatic, avian, and terrestrial wildlife populations across the Region.

Map 2.13
2015 Land Use Within the Lake Comus Watershed



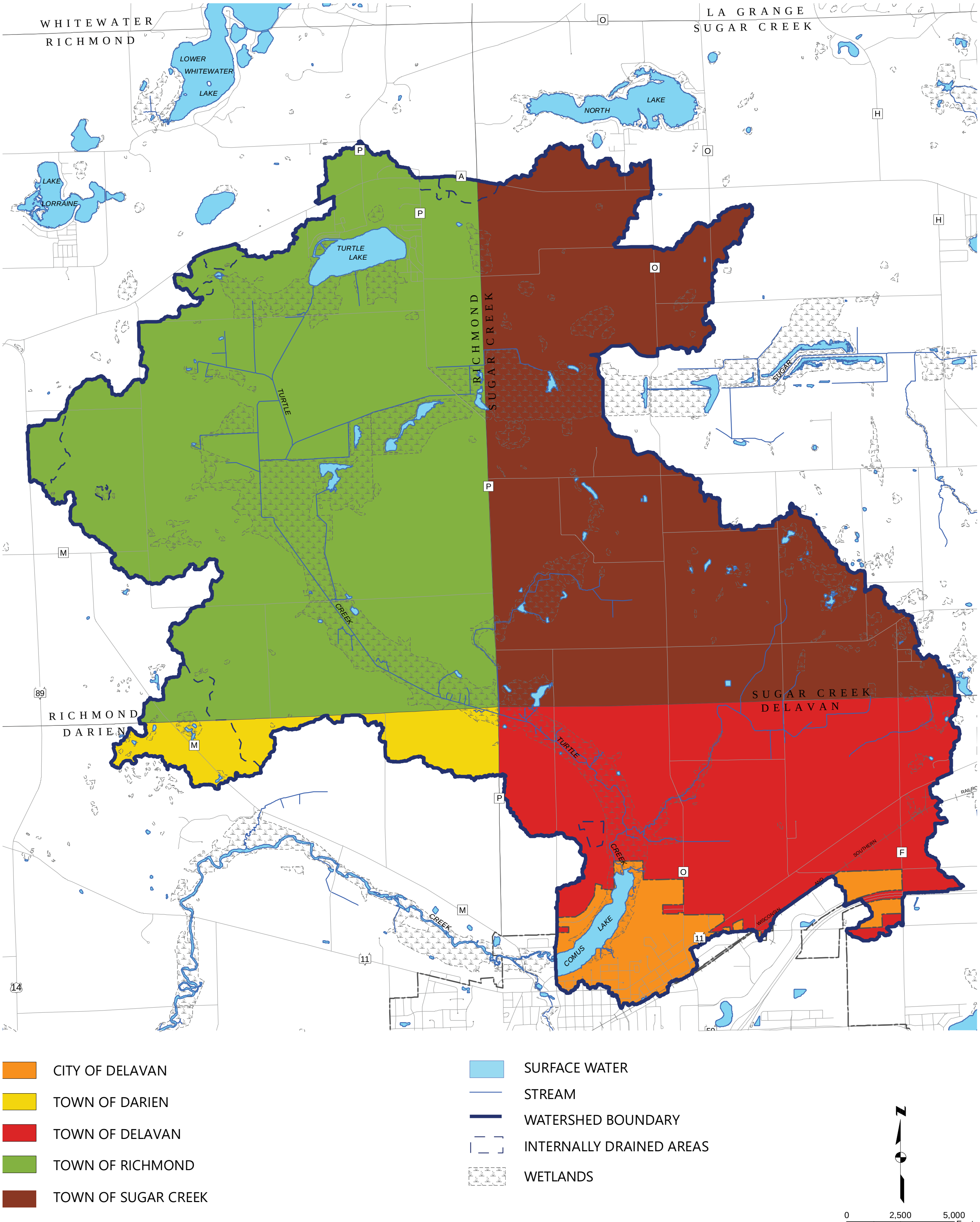
Source: SEWRPC

Map 2.14
Planned Land Use Within the Lake Comus Watershed



Source: SEWRPC

Map 2.15
Comus Lake Watershed Civil Divisions: 2015



Source: SEWRPC

Floodplains

Section 87.30 of the *Wisconsin Statutes* requires that counties, cities, and villages adopt floodplain zoning to preserve floodwater conveyance and storage capacity and prevent new flood-damage-prone development in flood hazard areas. The minimum standards that 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 that has a 1-percent-annual-probability of being inundated. The 1-percent-annual-probability (100-year recurrence interval) floodplains within the Lake Comus watershed are shown on Map 2.1. As required under Chapter NR 116, local floodland zoning regulations must prohibit nearly all development within the floodway which is that portion of the floodplain actively conveying flowing water during the 1-percent-annual-probability flood flow. Local regulations must also restrict filling and development within the flood fringe, which is that portion of the floodplain located beyond the floodway that is inundated during the one-percent-annual-probability flood, detaining floodwater for later release. Filling within the flood fringe reduces floodwater storage capacity and may increase downstream flood flows and flood depths/elevations. Approximately 1,351 acres of floodplain are present within the Lake Comus watershed.

Table 2.11
Civil Divisions in the Lake Comus Watershed: 2020

Municipality	Acres	Percent
City of Delavan	825.6	3.9
Town of Darien	731.8	3.5
Town of Delavan	3,988.0	18.9
Town of Richmond	8,885.0	42.0
Town of Sugar Creek	6,709.6	31.7

Source: SEWRPC

Ordinances related to floodplain zoning recognize existing uses and structures and regulate them in accordance with sound floodplain management practices. These ordinances are intended to: 1) regulate and diminish 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 public responsibilities generated by continued and expanded development of land and structures inherently incompatible with natural floodplains; and 3) lessen potential danger to life, safety, health, and welfare of persons whose lands are subject to the hazards of floods.

Wetlands

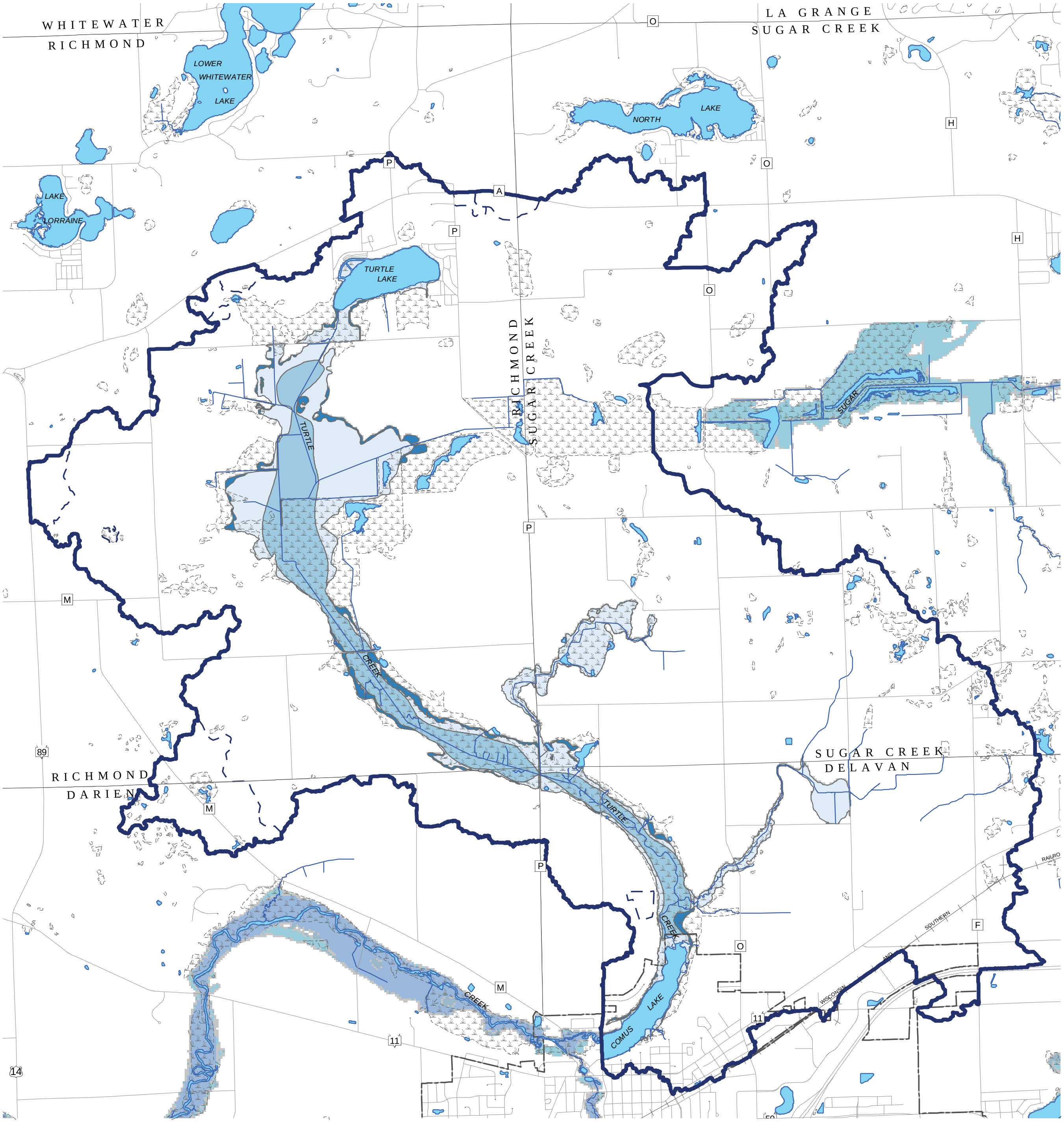
Historically, wetlands were largely viewed as wastelands, lands presenting obstacles to agricultural production and development. Private interests as well as governmental institutions supported the transformation of wetlands through large-scale draining and filling. Wetland habitat was aggressively removed until scientific research revealed their value as incredibly productive and biologically diverse ecosystems.[80] Wetlands are most known for their variety of plant life, with communities composed of a mixture of submergent pondweeds (*Potamogeton* spp.), floating-leaf plants, emergent cattails, bulrush (*Schoenoplectus* spp. and *Scirpus* spp.), woody shrubs, and tamaracks (*Larix lacarina*), as just a few examples. Wildlife species that rely on, or are associated with, wetlands for at least part of their lives include crustaceans, mollusks, and other aquatic insect larvae and adults; fishes, including forage fish and important gamefish species like trout, northern pike, and largemouth bass; amphibians; reptiles; mammals including deer; resident bird species like turkey as well as migrants like sandhill or whooping cranes. Thus, wetlands help maintain biologically diverse communities of ecological and economic value.

In addition to maintaining biodiversity, wetlands also store runoff and floodwater; filter pollutants; improve water quality; sustain groundwater aquifers; serve as sinks, sources, or transformers of materials; and provide recreation sites for boating and fishing. Recognition of the value and importance of wetlands led to creation of rules and regulations protecting wetlands globally, nationally (i.e., the Federal Clean Water Act of 1972), statewide, and locally. These efforts are designed to protect or conserve wetlands and the ecosystem services they provide. The term "ecosystem services" refers to any of the benefits that ecosystems—both natural and semi-natural—provide to humans.[81] In other words, ecosystem functions are classified by their

[80] *J.A. Cherry, "Ecology of Wetland Ecosystems: Water, Substrate, and Life,"* Nature Education Knowledge*, 3(10): 16, 2012, www.nature.com/scitable/knowledge/library/ecology-of-wetland-ecosystems-water-substrate-and-17059765.*

[81] *Millennium Ecosystem Assessment,* Ecosystem Services and Human Well-Being: Wetlands and Water*, Synthesis. Report to the Ramsar Convention. Washington, DC: World Resources Institute, 2005, www.millenniumassessment.org/en/Global.html.*

Map 2.16
Mapped Floodways and Floodplains Within the Comus Lake Watershed



1 PERCENT ANNUAL PROBABLITY (100 - YEAR RECURRANCE INTERVAL) FLOODPLAIN

1 PERCENT ANNUAL PROBABLITY FLOODPLAINS ZONE AE FLOODWAY

0.2 PERCENT ANNUAL PROBABLITY FLOODPLAIN BEYOND ONE-PERCENT ANNUAL FLOODPLAINS (500 YEAR OCCURANCE INTERVAL)

SURFACE WATER

STREAM

WATERSHED BOUNDARY

INTERNALLY DRAINED AREAS

WETLANDS

Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

0 2,500 5,000 Feet

Source: SEWRPC

abilities to provide goods and services that satisfy human needs,[82] either directly or indirectly. Examples of ecosystem services provided by wetland ecosystems are illustrated in Figure 2.17. The economic value of the ecosystem services provided by wetlands exceeds those provided by lakes, streams, forests, and grasslands and is second only to the value provided by coastal estuaries.[83] Society gains a great deal from wetland conservation. Therefore, it is essential to incorporate wetland conservation and restoration targets as part of this plan.

Wetlands are transitional areas often possessing characteristics of both aquatic and terrestrial ecosystems while at the same time possessing features unique on to themselves. For regulatory purposes, the State of Wisconsin defines wetlands as areas where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation and which has soils indicative of wet conditions. Three specific characteristics of wetlands are evaluated when a wetland determination is made including:

- Hydrology that results in wet or flooded soils
- Soils that are dominated by anaerobic (without oxygen) processes
- Rooted vascular plants that are adapted to life in flooded, anaerobic environments

These characteristics pose severe limitations for urban development. Wetlands have shallow water tables as well as soils that are highly compressible, are unstable, have high shrink-swell potential, and have low bearing capacity. Thus, development in wetlands may result in flooding, wet basements, unstable foundations, failing pavement, and failing sanitary sewer and water lines. Furthermore, significant and costly onsite preparation and maintenance costs associated with developing wetland soils, particularly in regard to roads, foundations, and public utilities.

Within the Lake Comus watershed, wetlands total approximately 3,224 acres, or about 15 percent of the total watershed area, as illustrated on Map 2.17 and tabulated in Table 2.12. The wetlands vary by ecological community type and include aquatic beds, emergent/wet meadows, scrub/shrub, and forested wetlands. Each wetland community type has unique sets of flora and fauna and provides distinct ecosystem services.

Uplands

Upland/woodland habitat is comprised of non-wetland natural areas. These areas are higher in elevation and farther from open water than wetlands, and thus are generally not as moist. However, there are many exceptions in this broad generalization of uplands, examples of which can be seen within the Lake Comus watershed. Upland versus wetland habitat can sometimes be difficult to distinguish because these features form broad and complex mosaics or combinations across the landscape. It is precisely these combinations and the linkages between these unique community types that provides habitat critical to sustaining healthy and diverse aquatic and terrestrial wildlife.

As discussed in the "Historical Land Use" subsection, natural vegetation on most uplands in the Lake Comus watershed was replaced by plants associated with agricultural land use. The remaining upland habitat, which comprises approximately 25 percent of the watershed (Map 2.11 and Table 2.13), is dominated by deciduous woodlands, with substantial areas of grassland and some areas of conifer forest, mixed forest, and brush.[84] Like wetlands ecosystems, upland habitats also provide a variety of ecosystem services. Although the economic value of their ecosystem services is not as large as wetland ecosystems, these areas provide important services worth protecting.[85] Uplands produce food, livestock, and crops for human use. Uplands also support groundwater recharge and water quality and can help modulate flood risk. Furthermore,

[82] *R.D.S. de Groot, M.A. Wilson, and R.A.M. Bauman, "A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services,"* Ecological Economics*, 41: 393-408, 2000, www.sciencedirect.com/science/article/pii/S0921800902000897.*

[83] *R.W. Costanza, R. d'Arge, R. de Groot, et al., "The Value of the World's Ecosystem Services and Natural Capital,"* Nature*, 387(6630): 253–260, 1997.*

[84] *SEWRPC Planning Report No. 42,* op. cit.

[85] *R.W. Costanza et al., 1997,* op. cit.

Figure 2.17
Natural and Created Wetland Ecosystem Services

Service	Examples of Goods and Services Derived	Estimated value (1994 US \$/ac^{-1} yr^{-1})[a]
REGULATION SERVICES		
Water quality		
Erosion control and sediment retention	Sediment filtration and storage capabilities that prevent downstream migration of sediment and improve downstream water quality.	NA
Waste treatment	Reduction of excess nutrient, organic, and metal loadings reduced through microbial degradation and/or sorption to improve water quality. Reduction of runoff temperature via shading and water's heat capacity.	1,690
Nutrient cycling	Reduction of nitrogen and phosphorus concentrations through denitrification and biological uptake.	NA
Hydrologic regulation	Moderation of the rate, volume, and frequency of surface runoff to provide flood and storm surge protection.	1,860
Climate regulation		
Greenhouse gas regulation	Maintenance of air quality and CO_2/CH_4 balance (through C sequestration); regulation of gases also influences climate effects.	54
Microclimate regulation	Maintenance of a favorable climate (such as temperature, precipitation) for human habitation, health, and cultivation.	NA
Soil formation	Building of land surface through the accumulation of organic material in wetlands.	NA
HABITAT SERVICES		
Refugia	Maintenance of biological and genetic diversity through provision of suitable habitat for resident or migratory plant and animal species. Includes the maintenance of populations of commercially harvested species and biological pest control services. This diversity forms the basis of many other ecosystem services.	123
PRODUCTION SERVICES		
Food production	Production of fish, game, fruits for small-scale hunting/gathering or aquaculture.	104
Raw materials	Production of trees, peat, and other biomass appropriate for lumber, fuel, or fodder.	43
INFORMATION SERVICES		
Recreation	Provision of opportunities for hunting, bird-watching, hiking, or other recreational uses.	232
Cultural	Provision of opportunities for noncommercial uses, including the use of wetlands for school excursions/education and for scientific research. Aesthetic, artistic, and spiritual values are also included.	357

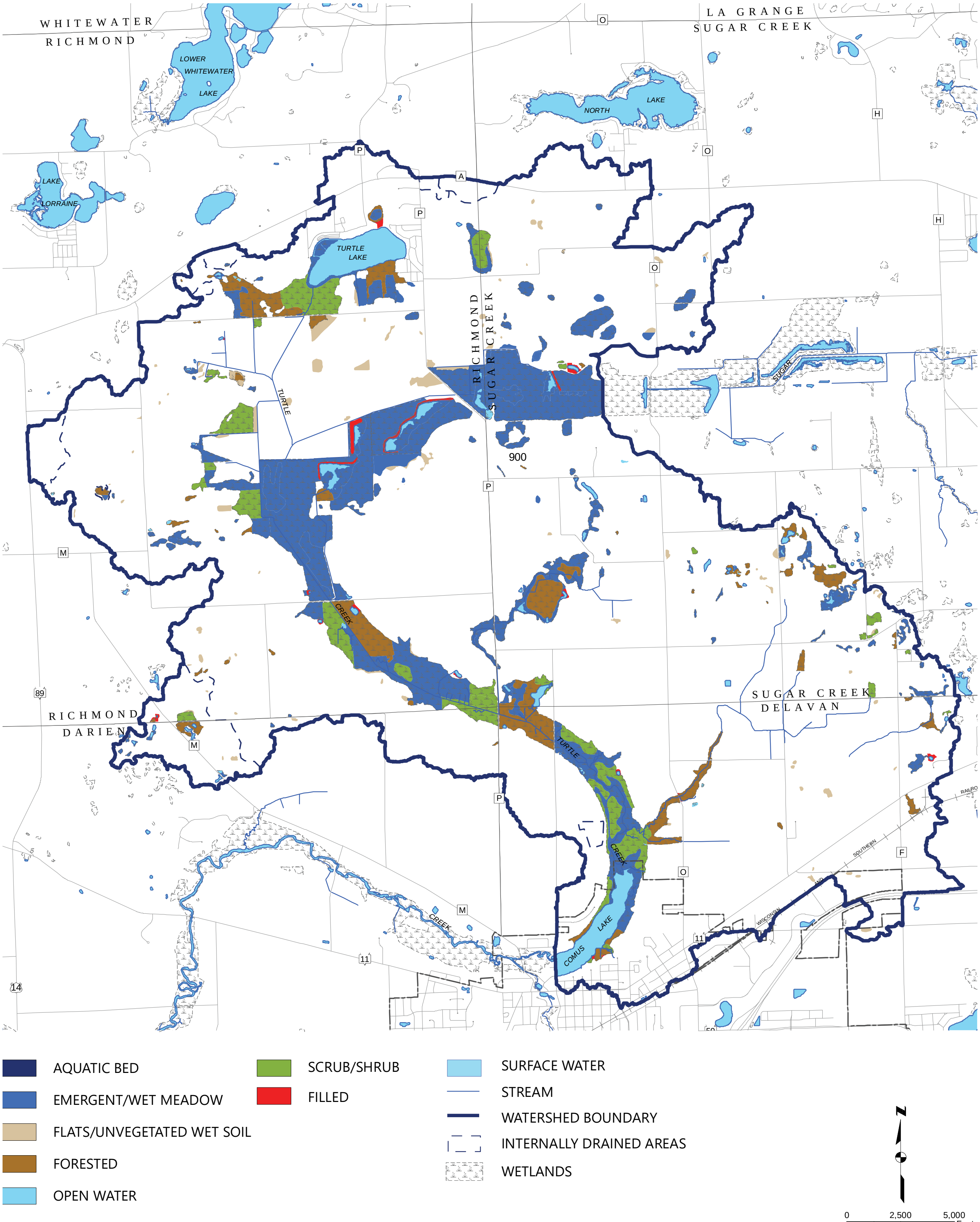
[1]Adapted from Costanza et al., 1997, and de Groot, 2006)

[2] Value estimates for each service taken from Costanza et al. (1997). A listing of NA for individual services indicates that a formal valuation of this service had not yet been conducted.

uplands can foster air quality protection and soil conservation, can promote wildlife through provision of critical breeding, refuge, nesting, resting, and feeding grounds, and are vital for recreation, tourism, and educational opportunities.

Another important contrast between uplands and wetlands is that the upland soils generally pose fewer limitations for urban development. In general, uplands have soils with a deeper water table, lower compressibility and greater soil stability, greater bearing capacity, and lower shrink-swell potential compared to wetland soils. These conditions usually result in less flooding, dry basements, more stable foundations, more stable pavements, and less failure of sanitary sewer and water lines. Therefore, costs associated with onsite preparation and maintenance with the development of upland soils, particularly in connection with roads, foundations, and public utilities are much lower, making these areas targets for urban development. Therefore, upland conservation and restoration targets should be integral to this plan.

Map 2.17
Wetland Cover Types Within the Comus Lake Watershed



Source: SEWRPC

Natural Resource Planning Features

Living organisms rely on an intertwined network of relationships with the environment. The destruction or deterioration of any single element may lead to a chain reaction of undesirable and damaging consequences. Draining wetlands, for example, may have far-reaching effects. For example, wetland drainage may compromise fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural water filtration and floodwater storage areas. The quality of surface water and groundwater may be compromised, flood flows can increase, dry-weather streamflow may decrease, and the amount of water suitable for domestic, municipal, and industrial water supply needs can be diminished. Another example involves destroying woodland habitat and other upland cover types. Such activity may increase erosion, may smother streambeds with fine sediment, may generate more rapid runoff and increase flooding, and may eliminate unique and important wildlife habitat. Although the effects of any single environmental changes in isolation may not be pronounced, the overall effects of such change may cause the underlying and supporting natural resource base and habitat value to deteriorate. This, in turn, diminishes the landscape's ability to support human needs and desires. Therefore, the importance of protecting and preserving environmental corridors and their associated complexes of wetland, upland, and critical species habitats becomes readily apparent.

Table 2.12
Wetland Cover Types in the Lake Comus Watershed

Wetland Cover Type	Acres of Watershed	Percent of Watershed
Aquatic bed	7.6	0.0
Emergent/wet meadow	1,954.1	9.2
Flats/unvegetated wet soil	130.8	0.6
Forested	503.6	2.4
Open water	161.7	0.8
Scrub/shrub	465.9	2.2
Total	3,223.7	15.2

Source: Wisconsin Geologic and Natural History Survey and SEWRPC

Table 2.13
Upland Cover Types in the Lake Comus Watershed

Upland Cover Type	Acres of Watershed	Percent of Watershed
Brush	125.0	0.6
Conifer	177.9	0.8
Deciduous	1,544.7	7.3
Grassland	809.0	3.8
Mixed	5.1	0.0
Total	2,661.7	12.5

Source: Wisconsin Geologic and Natural History Survey and SEWRPC

Primary Environmental Corridors

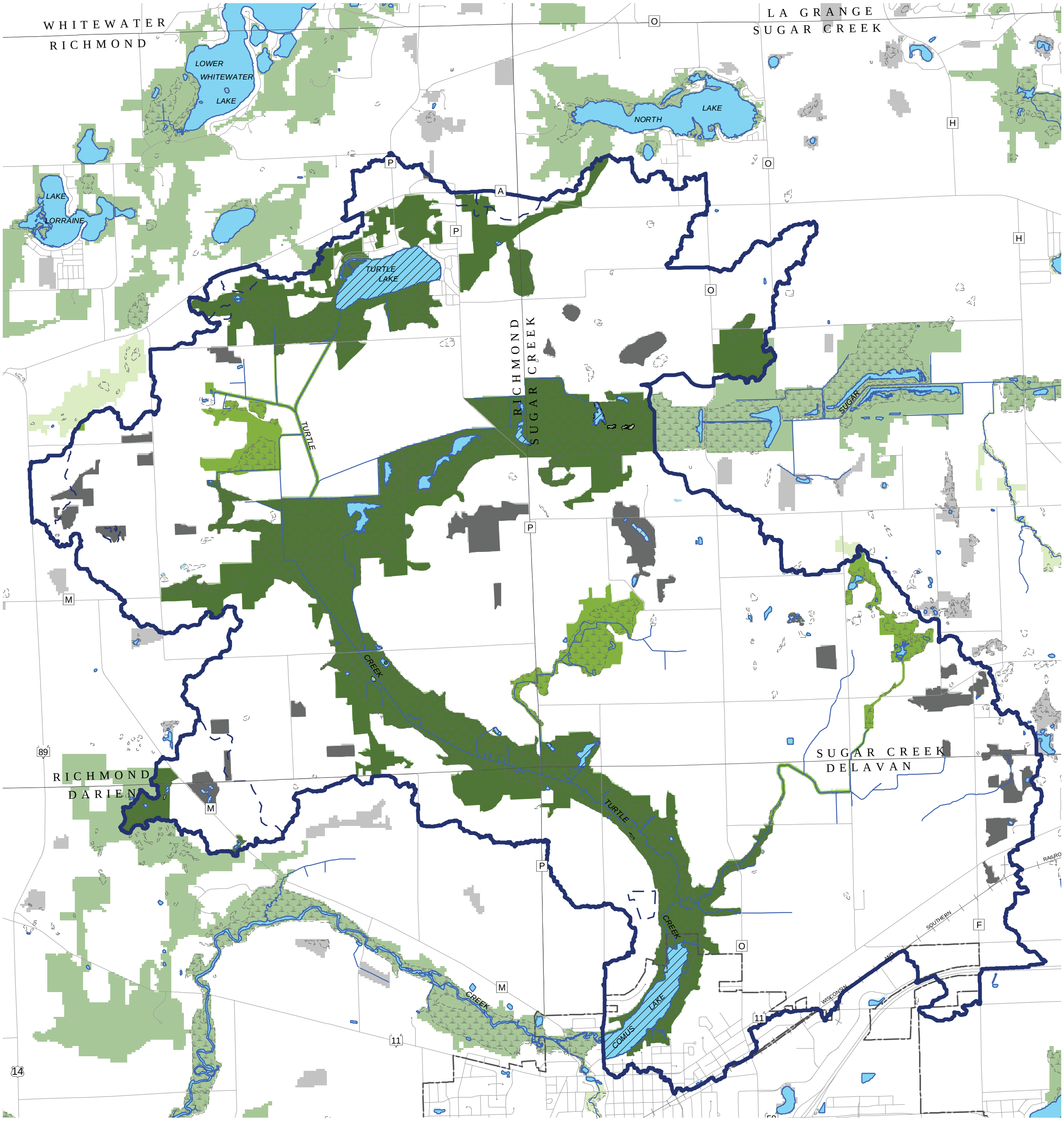
Primary environmental corridors (PECs) encompass a wide variety of important resources and resource-related elements. PECs are at least 400 acres in size, two miles in length, and 200 feet in width.[86] During 2015, PECs covered about 3,980 acres, or about 19 percent, of the Lake Comus watershed. Much of this acreage is adjacent to Lake Comus, Turtle Creek, and Turtle Lake (Map 2.18). PECs represent a composite of the best remaining elements of the watershed's natural resource base. PECs cover almost all the best remaining woodlands, wetlands, and wildlife habitat areas in the watershed. Although typically displayed as open water, lakes, rivers, streams, and associated shorelands are aquatic life PECs. Thus, Lake Comus and its associated shorelands are part of the highest quality natural resources within the watershed, highlighting the importance of managing nearshore areas to protect quality and integrity.

Secondary Environmental Corridors

Secondary environmental corridors (SECs) generally connect with the primary environmental corridors and are at least 100 acres in size and one-mile long. In 2015, secondary environmental corridors encompassed about 551 acres, or just under three percent, of the watershed (Map 2.18). Secondary environmental corridors are remnant resources that have been reduced in size compared to the larger PECs as described above due to land developed for intensive urban or agriculture land uses. However, secondary environmental corridors preserve ecosystem function by facilitating surface water drainage, maintaining pockets of natural resource features, providing corridors for the movement of wildlife and dispersal of vegetation seeds, as well as oftentimes providing a protective buffer for PECs.

[86] *SEWRPC Planning Report No. 42,* op. cit.

Map 2.18
Environmental Corridors and Isolated Natural Resources Areas Within the Comus Lake Watershed: 2015



PRIMARY ENVIRONMENTAL CORRIDOR

SECONDARY ENVIRONMENTAL CORRIDOR

ISOLATED NATURAL RESOURCE AREA

WATERBODIES IN ENVIRONMENTAL CORRIDOR

SURFACE WATER

STREAM

WATERSHED BOUNDARY

INTERNALLY DRAINED AREAS

WETLANDS

Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

N

0 2,500 5,000 Feet

Source: SEWRPC

Isolated Natural Resource Areas

Smaller concentrations of natural resource features that have been separated physically from environmental corridors by intensive urban or agricultural land uses. These natural resource areas, which are at least five acres in size, are referred to as isolated natural resource areas (INRAs). Widely scattered throughout the watershed, isolated natural resource areas included about 552 acres, or just under three percent of the watershed in 2015, as shown in Map 2.18. Connecting SECs and multiple INRAs throughout the Lake Comus watershed to the larger PEC areas, as well as building and expanding upon the existing protected lands (Map 2.19), represent sound approaches to enhancing the corridor system and wildlife areas within the watershed.

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 (Map 2.20). Natural areas are generally comprised of wetland or upland vegetation communities and/or complex combinations of both these fundamental ecosystem units. In fact, some of the highest quality natural areas within Southeastern Wisconsin are wetland complexes that have maintained adequate or undisturbed linkages (i.e., landscape connectivity) between the upland-wetland habitats, which is consistent with research findings in other areas of the Midwest.[87]

Natural areas have been identified for the seven-county Southeastern Wisconsin Region in SEWRPC Planning Report Number 42, "*A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*," published in September 1997 and amended in 2008. This plan was developed to assist Federal, State, and local agencies and governmental units as well as nongovernmental organizations make environmentally sound land use decisions. This includes prioritizing conservation program funding and property acquisition, managing public lands, and developing land in a fashion that helps protect and preserve the natural resource base of the Region. Walworth County uses SEWRPC Planning Report Number 42 to guide land use decisions.

Planning Report Number 42 classifies natural areas 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)

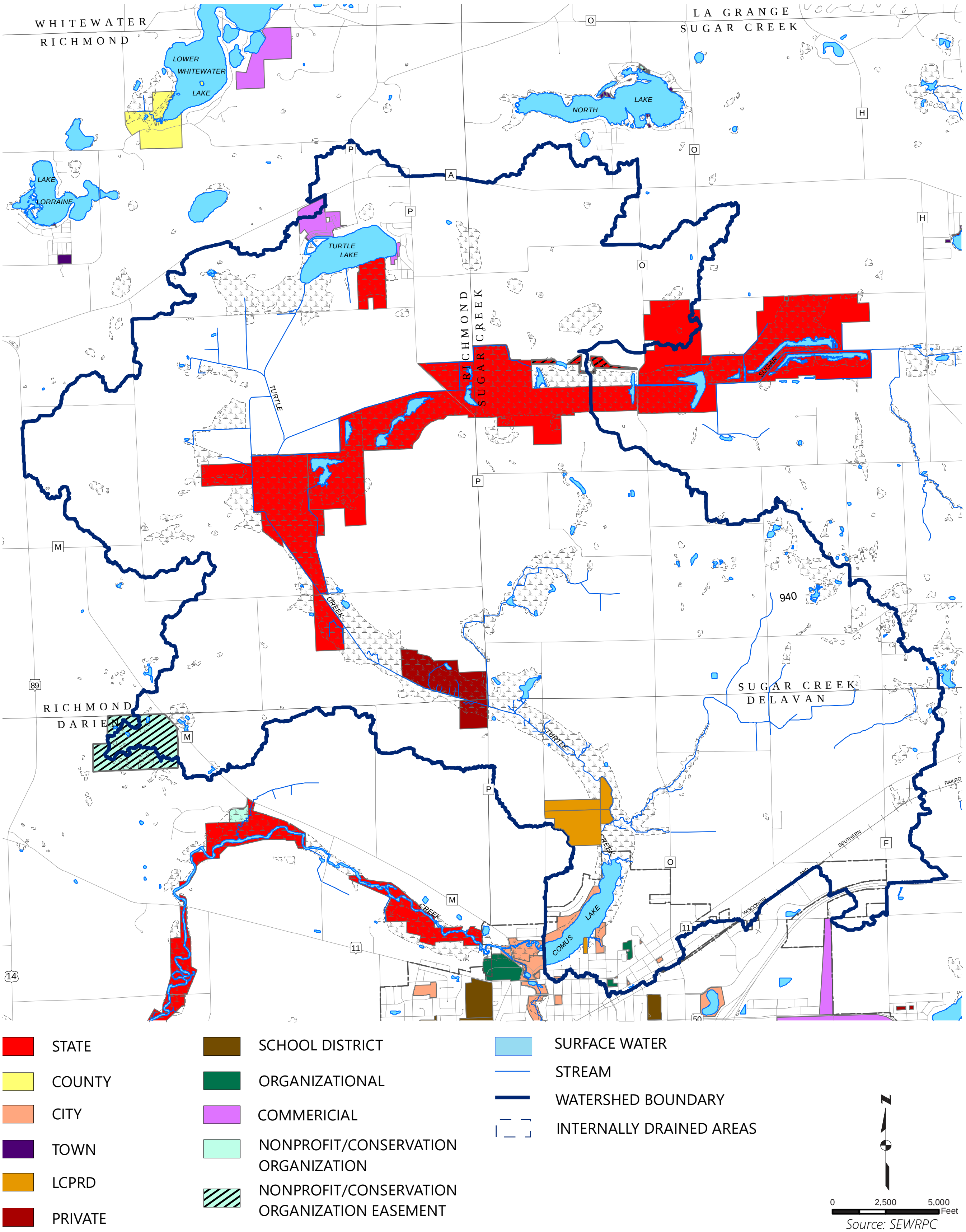
3. Natural area of local significance (NA-3)

Assigning a particular area into one of these three categories was based upon several factors, including considering 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. The Lake Comus watershed contains one natural area of countywide or regional significance (the 292-acre Comus Lake Wetland Complex) and three natural areas of local significance (18-acre CTH P Sedge Meadow, 5.5-acre Marsh Road Railroad Prairie, and the 21-acre Turtle Lake Fen). The Comus Lake Wetland Complex is located just north of Lake Comus and is of particular interest due to its size and its close association with the Lake and Turtle Creek (number 9 on Map 2.20).

Within or immediately adjacent to bodies of water, the WDNR, pursuant to authority granted under Chapter 30 of the *Wisconsin State Statutes* and Chapter NR 107 of the *Wisconsin Administrative Code,* designates environmentally sensitive areas on lakes. These areas have special biological, geological, ecological, or archaeological significance "offering critical or unique fish and wildlife habitat, including seasonal or life-stage requirements, or offering water quality or erosion control benefits of the body of water." Wisconsin law mandates special protections for these "sensitive areas," or "Critical Habitat Designation" areas, which are

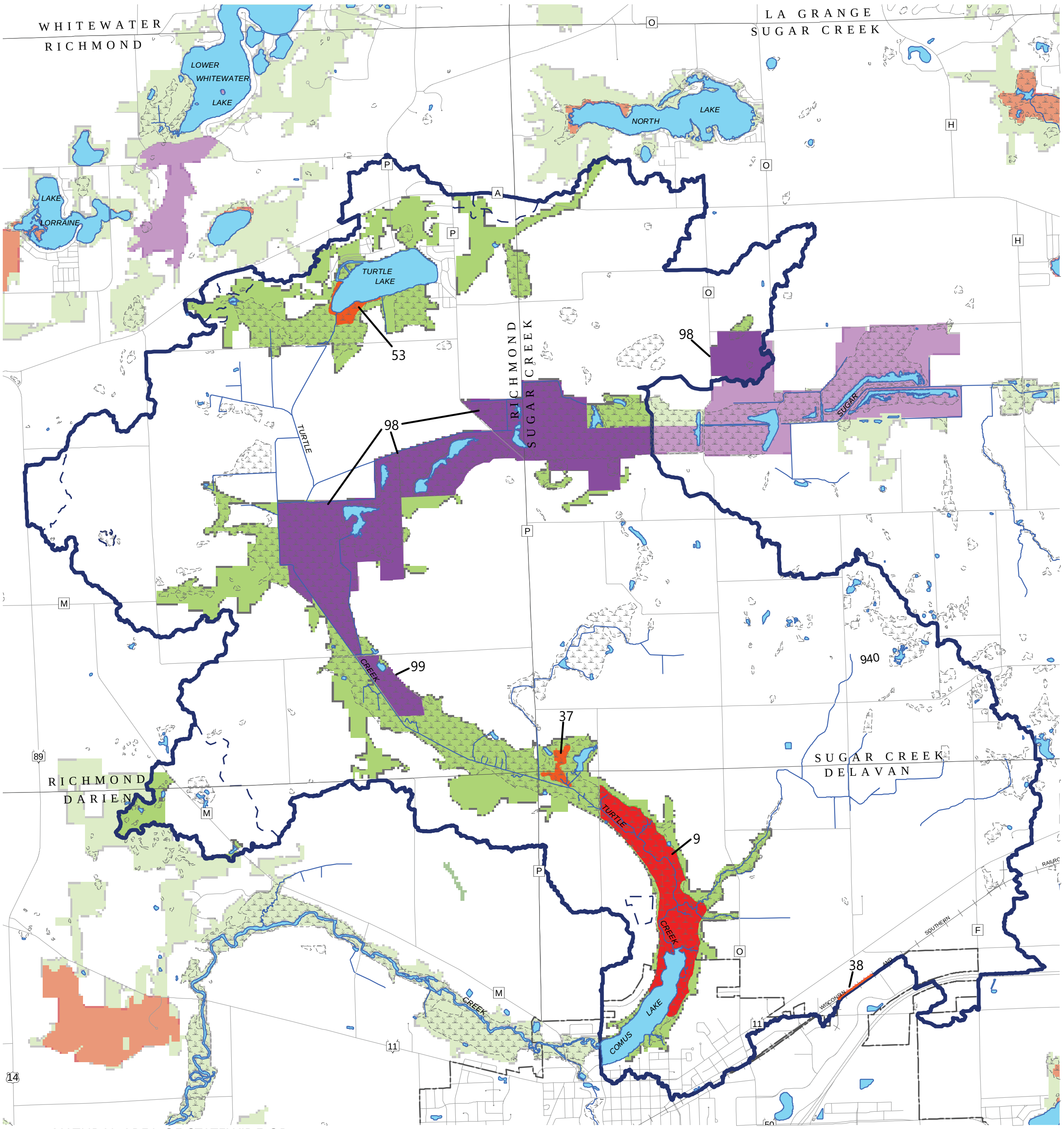
[87] *O. Attum, Y.M. Lee, J.H. Roe, and B.A. Kingsbury, "Wetland Complexes and Upland-Wetland Linkages: Landscape Effects on the Distribution of Rare and Common Wetland Reptiles,"* Journal of Zoology*, 275: 245-251, 2008.*

Map 2.19
Lands in Public and Private Protection Within the Comus Lake Watershed



Source: SEWRPC

Map 2.20
Natural Areas and Critical Species Habitat Within the Comus Lake Watershed: 2010



NATURAL AREA OF STATEWIDE OR GREATER SIGNIFICANCE (NA-1) ((NONE))
NATURAL AREA OF COUNTYWIDE OR REGIONAL SIGNIFICANCE (NA-2)
NATURAL AREA OF LOCAL SIGNIFICANCE (NA-3)
CRITICAL SPECIES HABITAT SITE
PRIMARY ENVIRONMENTAL CORRIDOR
WETLANDS

SURFACE WATER
STREAM
WATERSHED BOUNDARY
INTERNALLY DRAINED AREAS

9 COMUS LAKE WETLAND COMPLEX
37 CTH P SEDGE MEADOW
38 MARSH ROAD RAILROAD PRAIRIE
53 TURTLE LAKE FEN
99 TURTLE VALLEY WILDLIFE AREA

Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

home to approximately eighty percent of the plants and animals on the state's endangered and threatened species list. A significant part of the critical habitat designation lies in the fact that it assists waterfront owners recognize these areas so that they can design their waterfront projects to protect habitat and ensure the long-term health of the lake where they live. If a project is proposed in a designated Critical Habitat area, the permit process allows WDNR to ensure that proposed projects will not harm sensitive resources. Critical habitat areas in the Lake Comus watershed are located on Map 2.20. The "Turtle Valley Wildlife Area," which constitutes 95 percent of the watershed's critical species habitat area, is of particular interest due to its size and its connection with Turtle Creek and its tributaries.

Critical species are those plants, animals, or other organisms, considered by the Federal or State governments to be rare, threatened, or endangered, or of special concern. Nine such species known to occur in the watershed and include mussels, fish, reptiles, amphibians, birds, and plant species (Table 2.14). Photos of each of these critical species and links to life history information are included in Figure 2.18. Of note is the State-endangered and Federally threatened Eastern Massasauga rattlesnake (*Sistrurus catenatus*), which has been observed in wetlands along Turtle Creek north of Lake Comus.[88] The US Fish and Wildlife Service and WDNR have developed best management practices for minimizing incidental mortality and habitat loss for this species during routine land management activities, which are described in greater detail in Section 2.7, "Other Wildlife," and Section 3.6, "Fish and Wildlife."

2.3 WATER QUALITY AND POLLUTANT LOADING

Actual and perceived water quality are generally high priority concerns to lake and stream resource managers, residents, and Lake users. Concern is often expressed that pollutants entering a lake from various sources has degraded lake water quality over time. The water quality information presented in this section can help interested parties better understand the current and historical conditions, trends, and dynamics of Lake Comus and Turtle Creek. By interpreting and applying this information, management strategies can target issues having the best chance of protecting long-term waterbody health.

When discussing water quality, it is important to consider what "water quality" means since individuals have varying perceptions, experiences, and levels of understanding. To the casual observer, water quality is commonly described using visual cues. For example, algae, cloudy water, and heavy growth of aquatic plants leads some to conclude a lake is "unclean." To judge if such a conclusion is merited and/or to quantify water quality, lake managers and residents must carefully examine specific chemical, physical, and biological parameters that influence or indicate water quality. Common metrics used to assess water quality include water clarity, water temperature, and the concentrations of chloride, phosphorus, chlorophyll-*a*, and dissolved oxygen (DO) (Table 2.15 for more information regarding the meaning and significance of these parameters).

Water quality metrics generally respond to water quality changes. For example, nutrients from excessively eroded topsoil and inappropriate use of common fertilizers can cause a lake's phosphorus concentrations to increase. In turn, Increased phosphorus concentrations fuel algal growth. Increased algal abundance causes lake water to become cloudier, diminishing water clarity. Finally, chlorophyll-*a* concentrations (a measure of algae content) increase. In addition to water clarity, phosphorus, chlorophyll-*a*, and DO values, several other parameters can also help determine the "general health" of a lake. For example, the abundance of the bacteria *Escherichia coli*, commonly known as *E. coli*, is often measured as an indicator if lake water is safe for swimming while chloride concentrations are an indicator of overall human-induced pollution entering a lake.[89] Key water-quality indices must be regularly measured over long periods of time to allow lake managers to establish baselines, identify trends, and develop water quality maintenance and improvement initiatives.

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[88] *Turtle Creek Priority Watershed Plan, 1984,* op. cit.

[89] *Chloride is used as an indicator of human-induced pollution because natural chloride concentrations are low in Southeastern Wisconsin. Chloride is a "conservative pollutant" meaning that it remains in the environment once released and is not attenuated by natural processes other than dilution. High chloride concentrations may result from road salt transported in runoff, fertilizer application, private onsite wastewater treatment systems that discharge to the groundwater that provides baseflow for streams and lakes, and a multitude of other sources.*

Table 2.14
Endangered, Threatened, and Special Concern Species in the Lake Comus Watershed: 2021

Common Name	Scientific Name	Status Under the U.S. Endangered Species Act	Wisconsin Status
Fish			
Lake Chubsucker	*Erimyzon sucetta*	Not listed	Special concern
Reptiles and Amphibians			
Blanding's Turtle	*Emydoidea blandingii*	Not listed	Special concern
Eastern Massasauga Rattlesnake	*Sisturus catenus*	Federally threatened	Endangered
Queensnake	*Regina septemvittata*	Not listed	Endangered
Birds			
Black Tern	*Chilidonias niger*	Species of Concern	Endangered
Upland Sandpiper	*Bartramia longicauda*	Not listed	Threatened
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	Not listed	Special concern/migrant[a]
Plants			
Small White Lady's Slipper	*Cypripedium candidum*	Not listed	Threatened
Slender Bog Arrow-grass	*Triglochin palustris*	Not listed	Special concern

[a] *Migrant (i.e., fully protected by Federal and State laws under the Migratory Bird Act).*

Source: Wisconsin Department of Natural Resources, Wisconsin State Herbarium, United States Fish and Wildlife Service and SEWRPC

Lake Characteristics Influencing Water Quality

Water quality fluctuates over short- and long-term time periods. Therefore, thorough lake water quality evaluation relies upon regular monitoring of various chemical and physical properties, ideally at the same depths and locations, over protracted time periods. Monitoring data are used to evaluate the concentration and nature of pollutants within a lake, the risks associated with that pollution, the lake's ability to support various fish and recreational uses, and overall lake health. When examining water quality, it is important to understand certain lake characteristics that provide context and meaning to the data. These lake characteristics include:

1. **A lake's residence time.** Residence time refers to the amount of time needed to circulate a lake's entire volume. It helps determine how quickly certain pollution problems can be resolved.

2. **Whether the lake stratifies and, if it does, when the lake mixes.** Stratification refers to a condition when the temperature difference (and associated density difference) between a lake's surface waters (the *epilimnion*) and the deep waters (the *hypolimnion*) is great enough to form thermal layers that can impede mixing of gases and dissolved substances between the two layers (Figure 2.19).

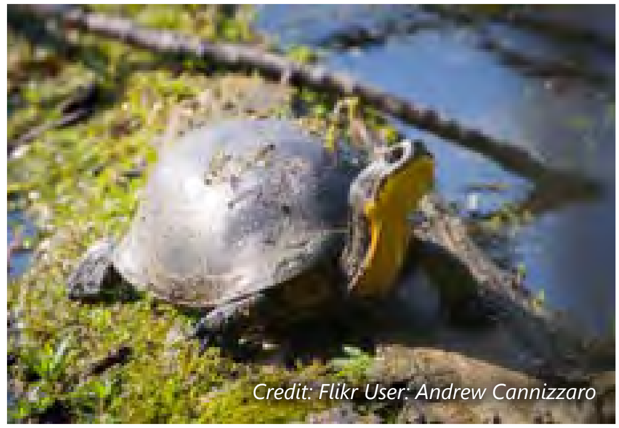
3. **Whether internal loading is occurring.** *Internal loading* refers to release of phosphorus stored in a lake's bottom sediment under certain water quality conditions associated with stratification. Additional phosphorus loading can lead to increased plant and algal growth. If this is occurring, a water quality management plan may focus on in-lake phosphorus management efforts in addition to preventing polluted runoff from entering the lake.

4. **The lake's current and past trophic state.** Lakes are commonly classified according to their degree of nutrient enrichment, or *trophic state*. The ability of lakes to support a variety of recreational activities and healthy fish and other aquatic life communities is often correlated with the lake's degree of nutrient enrichment. Three terms are generally used to describe the trophic state of a lake: *oligotrophic* (nutrient poor), *mesotrophic* (moderately fertile), and *eutrophic* (nutrient rich) (Figure 2.20). Each of these states can happen naturally. Lakes tend to naturally shift to a more nutrient-rich state, a progression sometimes referred to as "aging" (Figure 2.21). However, if a lake rapidly shifts to a more eutrophic state, human-induced pollution may be responsible for this change. An indicator of severe human pollution is when a lake displays "hyper-eutrophic" nutrient levels, a condition indicating highly enriched water (Figure 2.22). Hyper-eutrophic conditions do not commonly occur under natural conditions and are nearly always related to human pollutant sources.

Figure 2.18
Special Concern, Threatened, and Endangered Species Known to Occur in Lake Comus Watershed

BLACK TERN
Childonias niger

BLANDING'S TURTLE
Emydoidea blandingii



LAKE CHUBSUCKER
Erimyzon sucetta

EASTERN MASSASAUGA RATTLE SNAKE
Sisturus catenus

QUEENSNAKE
Regina septemvittata

SLENDER BOG ARROW-GRASS
Triglochin palustris

Figure 2.18 (Continued)

SMALL WITE LADY'S SLIPPER
Cypripedium candidum

UPLAND SANDPIPER
Bartramia longicauda

YELLOW-HEADED BLACKBIRD
Xanthocephalus xanthocephalus

Source: SEWRPC

5. **Lake tributary area/type.** Lakes with large tributary streams commonly receive larger sediment and nutrient loads than lakes that are fed primarily by precipitation or groundwater. The type of land use in the watershed greatly effects the pollutant loads carried by tributary streams. Lakes that are fed primarily by tributary streams are labeled drainage lakes.

Lake Comus Water Quality

Water quality data was only sporadically measured before this lake management planning project was initiated. Nevertheless, Commission staff endeavored to provide as much insight as possible on the Lake's historical water quality using the available data with the context of the lake characteristics. More frequent measurements have been made as part of this study.

Temperature and Dissolved Oxygen

During summer, many Wisconsin lakes (especially those with water depths greater than 20 feet) experience a distinct layering of their waters known as "stratification" (Figure 2.19, "summer stratification"). As summer progresses and surface waters warm, a difference in water temperature and density forms a barrier between the shallow and deep waters. This barrier includes a zone of rapidly cooling water temperature known as the *thermocline* (sometimes called the "metalimnion"). The thermocline is characterized by approximately 0.5°F of change per foot of water depth. The thermocline separates the warmer, less dense, upper layer

Table 2.15
Lake Water Quality Parameter Descriptions, Typical Values, and Regulatory Limits/Guidelines

Parameter	Description	Southeastern Wisconsin Values[a]		Regulatory Limit or Guideline	Lake Comus Values	
		Median	Range		Median	Range
Chloride (mg/L)	Low concentrations (e.g., < 5 mg/L) naturally occur in lakes due to natural weathering of bedrock and soils. Human activities increase concentrations (e.g., road salts, wastewater, water softener regeneration) and can affect certain plants and animals. Chloride remains in solution once in the environment and can serve as an excellent indicator of other pollutants.	41	18-260	Acute toxicity[b,c] 757 Chronic toxicity[b,c] 395	Unknown	Unknown
Chlorophyll-*a* (µg/L)	The major photosynthetic "green" pigment in algae. The amount of chlorophyll-*a* present in the water is an indicator of the biomass, or amount of algae, in the water. Chlorophyll-*a* levels above 10 µg/L generally result in a green-colored water that may be severe enough to impair recreational activities such as swimming or waterskiing and are commonly associated with eutrophic lake conditions.	9.9	1.8-706.1	2.6[d]	110[f]	72-145[e]
Dissolved Oxygen (mg/L)	Dissolved oxygen levels are one of the most critical factors affecting the living organisms of a lake ecosystem. Generally, dissolved oxygen levels are higher at the surface of a lake, where there is an interchange between the water and atmosphere, stirring by wind action, and production of oxygen by plant photosynthesis. Dissolved oxygen levels are usually lowest near the bottom of a lake where decomposer organisms and chemical oxidation processes deplete oxygen during the decay process. A concentration of 5.0 mg/L is considered the minimum level below which many oxygen-consuming organisms, such as fish, become stressed. Many species of fish are unlikely to survive when dissolved oxygen concentrations drop below 2.0 mg/L.	--	--	≥5.0[d]	9.4[g]	0.5-22.3
Growing Season Epilimnetic Total Phosphorus (µg/L)	Phosphorus enters a lake from natural and human-derived sources and is a fundamental building block for plant growth. Excessive phosphorus can lead to nuisance levels of plant growth, unsightly algal blooms, decreased water clarity, and oxygen depletion, all of which can stress or kill fish and other aquatic life. A concentration of less than 40 µg/L is the concentration considered necessary in a drainage lake such as Lake Comus to limit algal and aquatic plant growth to levels consistent with recreational water use objectives. Phosphorus concentration exceeding 40 µg/L are considered to be indicative of eutrophic lake conditions.	30	8-720	40[d]	171[e]	141-308[e]

Table continued on next page.

Table 2.15 (Continued)

Parameter	Description	Southeastern Wisconsin Values[a]		Regulatory Limit or Guideline	Lake Comus Values	
		Median	Range		Median	Range
Water Clarity (feet)	Measured with a Secchi disk (a ballasted black-and-white, eight-inch-diameter plate), which is lowered into the water until a depth is reached at which the disk is no longer visible. It can be affected by physical factors, such as suspended particles or water color, and by various biologic factors, including seasonal variations in planktonic algal populations living in a lake. Measurements less than five feet are considered indicative of poor water clarity and eutrophic lake conditions.	4.6	3-12	10.9[g]	1.5	0.7-3[e]
Water Temperature (°F)	Temperature increases above seasonal ranges are dangerous to fish and other aquatic life. Higher temperatures depress dissolved oxygen concentrations and often correlate with increases of other pollutants.	--	--	Ambient[d] 35-77 Sub-lethal[d] 49-80 Acute[d] 77-87	--[f]	32-91.3

[a] *Wisconsin Department of Natural Resources Technical Bulletin No. 138,* Limnological Characteristics of Wisconsin Lakes, *Richard A. Lillie and John W. Mason*, 1983.

[b] Wisconsin Administration Code *Chapter NR 105, Surface Water Quality Criteria and Secondary Values for Toxic Substances. July, 2010.*

[c] *Pollutants that will kill or adversely affect aquatic organisms after a short-term exposure are termed acutely toxic. Chronic toxicity relates to concentrations of pollutants that will kill or adversely affect aquatic organisms over long time periods (time periods that are a substantial portion of the natural life expectancy of an organism).*

[d] Wisconsin Administrative Code *Chapter NR 102, Water Quality Standards for Wisconsin Surface Waters, November 2010.*

[e] *Values collected, during growing season (June 1 through August 31) 2000-2021.*

[f] *Oxygen concentrations and temperatures vary with depth and season. Median values provide little insight to understand lake conditions.*

[g] *U.S. Environmental Protection Agency,* Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria: Lakes and Reservoirs in Nutrient Ecoregion VII, *EPA 822-B-00-009, December 2000.*

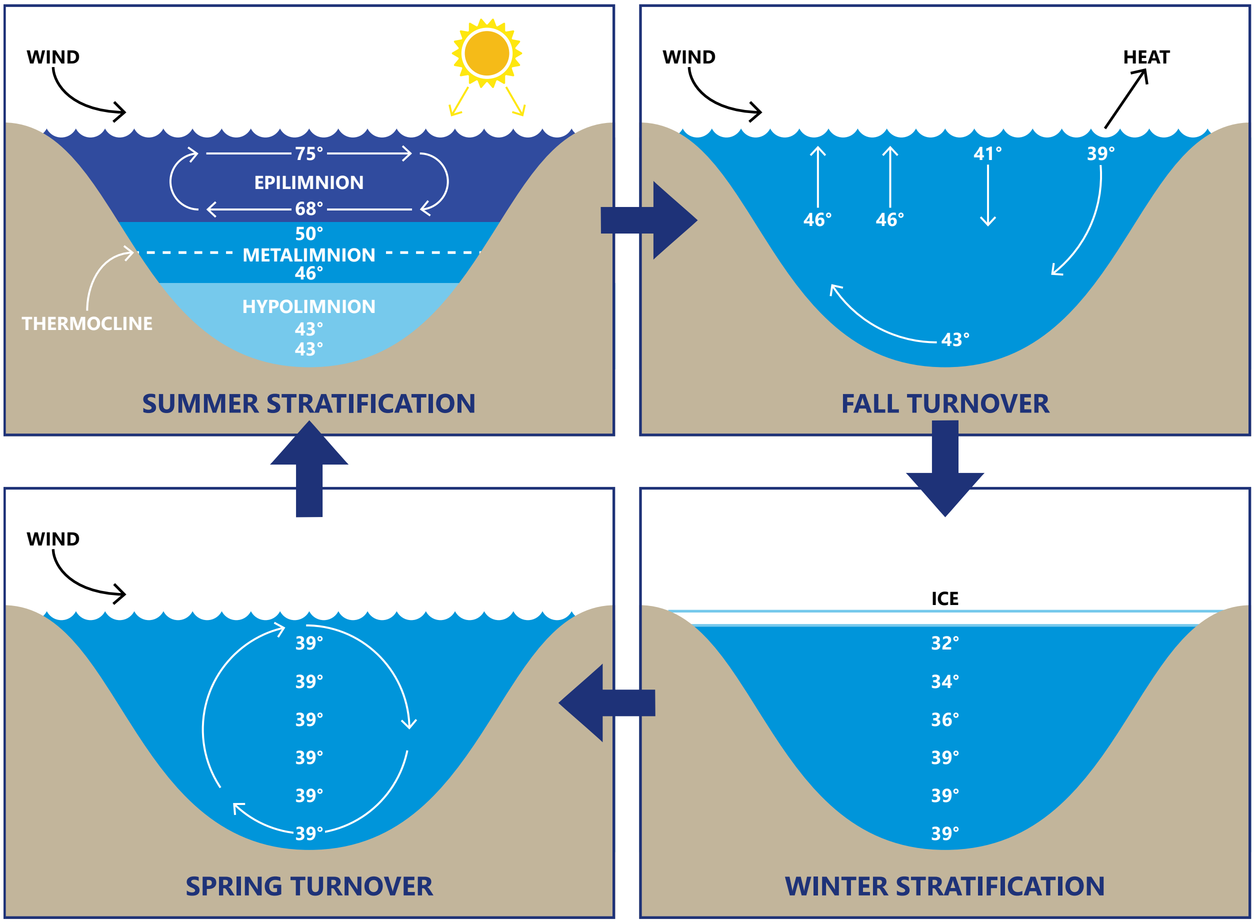
Source: Wisconsin Department of Natural Resources, Wisconsin

of water (called the *epilimnion*) from the cooler, more dense, lower layer (called the *hypolimnion*). The thermocline is generally found somewhere between 10 and 30 feet below the surface, with depth varying by lake, month, and year.

As air temperatures go through seasonal warming and cooling cycles, lake waters experience resultant warming and cooling trends, leading to alternating periods of seasonal stratifications. Although stratification is more typical in summer, it does occur (albeit usually weakly) in winter as well. In between these seasonal stratifications, the lake undergoes de-stratification or “mixing,” which typically occurs during spring and fall. During the spring and fall turnover, the lake has a generally uniform temperature throughout all depths. The degree to which a lake “stratifies” has a major impact on both the chemical and biological activity in a lake, as well as the lake’s water quality.

Temperature and dissolved oxygen (DO) profiles for Lake Comus were developed from data collected during 1978, 1980, 2000, 2018, 2019, 2020, and 2022. Temperatures profiles are presented in Figure 2.23 and DO profiles in Figure 2.24. As a shallow reservoir, Lake Comus does not exhibit a pattern of stratification. Instead, it experiences constant mixing of waters throughout the summer. This insight is evident by examining the Lake’s water temperature profiles. Stratified lakes will exhibit a shift in temperature between the upper epilimnion and the lower hypolimnion. Lake Comus exhibits nearly uniform temperatures throughout the entire profile for every sampling event. Summer (June through September) temperatures in the Lake ranged between 70°F to 85°F throughout the measured profiles.

Figure 2.19
Typical Seasonal Thermal Stratification Within Deeper Lakes



Source: Modified from B. Shaw, C. Mechenich, and L. Klessig, Understanding Lake Data, *University of Wisconsin-Extension, p. 3, 2004 and SEWRPC*

In addition to the temperature profiles measured by WDNR staff and volunteers, Commission staff used automated temperature loggers to measure hourly temperatures in Lake Comus from September 2019 to August 2021 as well as in groundwater springs contributing to the Lake from October 2020 to August 2021. As illustrated in Figure 2.25, hourly temperatures in the main body of Lake Comus ranged from 32.5°F in winter to 91.3°F in summer. Monthly summer (June through September) temperatures averaged 65.8 to 81.8°F while average winter temperatures were just above freezing at 34.1 to 38.9°F. The groundwater springs along the Lake's eastern shore had warmer winter temperatures, averaging between 42.7 to 46.4°F, and cooler summer temperatures, averaging between 54.8 to 59.3°F, than the main body of the Lake. Portions of the Lake with temperature extremes moderated by these springs may act as refugia for fish and other aquatic life.

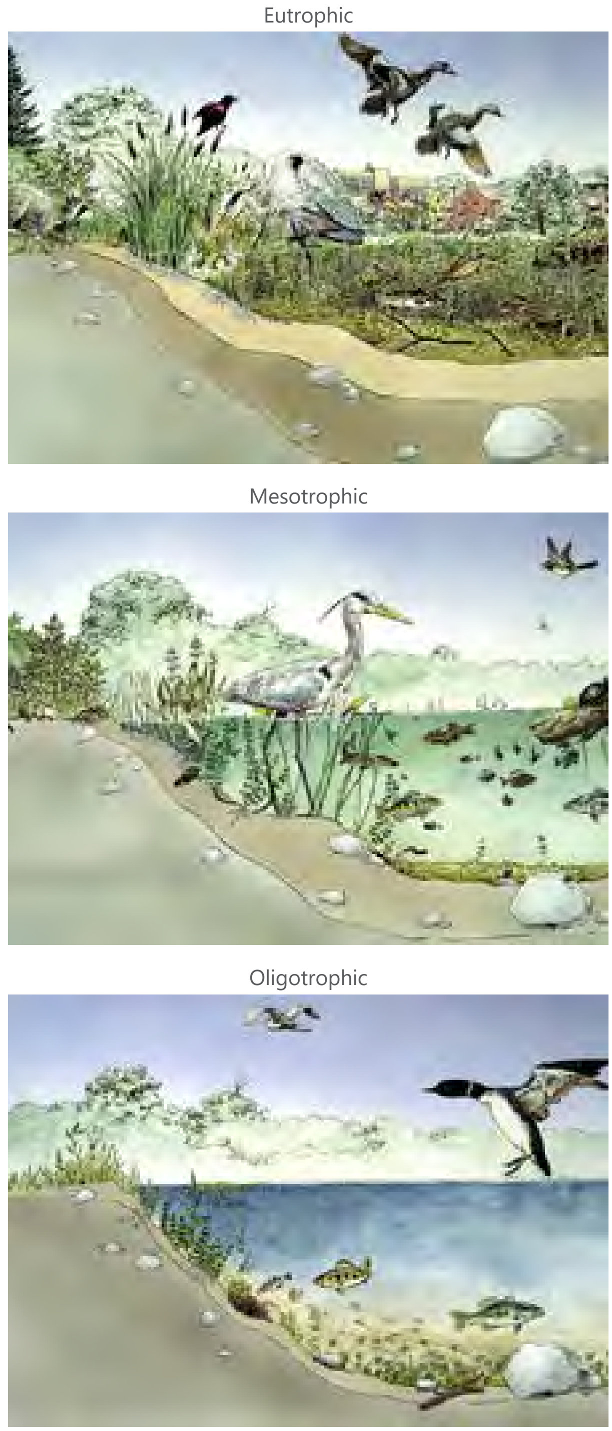
Dissolved oxygen (DO) concentrations are one of the most critical factors affecting the living organisms of a lake ecosystem. DO concentrations are generally higher at the surface of a lake where there is an interchange between the water and atmosphere, stirring by wind action (which aids in atmospheric oxygen diffusion into the surface waters at the air-water interface), and oxygen production by plant photosynthesis. However, if a lake thermally stratifies during summer, the thermocline prevents oxygen-rich surface (epilimnion) waters from freely mixing with water in deeper portions (hypolimnion) of the lake. Meanwhile, metabolic processes that consume oxygen continue to occur in the hypolimnion throughout the summer. If oxygen demands in the hypolimnion during this time are high (such as in a nutrient-rich lake), or if the volume of isolated hypolimnetic water is small (limiting oxygen storage potential), oxygen levels in the deep portions of lakes generally begin to decline as summer wears on. A minimum DO concentration of 5 mg/l is considered necessary for survival of many desirable fish species. In many Southeastern Wisconsin lakes, as summer progresses, oxygen concentration in water below the thermocline may be reduced to less than 2 to 3 mg/l—a condition known as *hypoxia*. In some situations, oxygen concentration can approach zero, a condition known as *anoxia*. Fortunately for fish and other oxygen-dependent organisms in stratified lakes, oxygenated surface waters mix throughout all depths when the thermocline breaks down during the fall and spring overturns.

Dissolved oxygen profiles indicate high dissolved oxygen concentrations (Figure 2.24). While there does appear to be low oxygen concentrations in September 2018 and May 2019, these concentrations are more likely due to extremely high biological oxygen demand from decomposition than due to any stratification effect, particularly since there is no corresponding change in water temperature.

Up to this point, the discussion of oxygen in lakes has focused on the DO concentration, as measured in mg/l. However, there is another important measure involving oxygen in water: oxygen *saturation*, expressed as a percent. Oxygen saturation refers to the oxygen concentration measured in water compared to the oxygen concentration in equilibrium with the atmosphere at a given temperature; simply put, it is a ratio of the amount of oxygen dissolved in water to the total amount of oxygen that is possible to be held in that water at a given temperature and pressure. For example, if a sample of water at a given temperature is holding 5 mg/l of oxygen but can hold 10 mg/l of oxygen at that temperature, the water is said to be at 50 percent oxygen saturation – it is holding only half of what it can hold at that temperature and pressure.

Warm water holds less oxygen than cold water; consequently, warm water becomes oxygen-saturated at lower concentrations of DO than cold water. For example, at 90 percent saturation, water at 70°F will hold about 8 mg/l of DO while water at 50°F will hold over 10 mg/l of DO at the same saturation level of 90 percent.[90] During summer months, the warm waters at the surface of a lake may become saturated at relatively low DO concentrations. Thus, completely oxygen saturated warm waters can still have too little DO for fish, particularly cold-water species like trout. Additionally, oxygen saturation has its own consequences for aquatic life. Oxygen saturation values between 90 and 110 percent are generally considered desirable for aquatic life. However, supersaturation levels above 115 percent can be detrimental to aquatic life. Fish exposed to oxygen saturations greater than 115 percent can develop bubbles in their tissues (a condition similar to "the bends" experienced by deep-

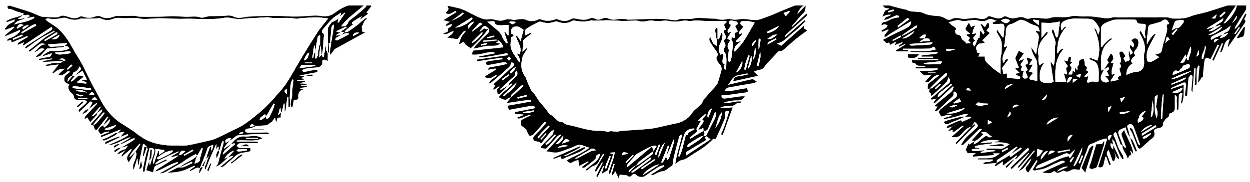
Figure 2.20
Comparison of Trophic Lake Status



Source: UW-Extension Lakes Program and SEWRPC

[90] *USGS DOTABLES at www.water.usgs.gov/software/DOTABLES.*

Figure 2.21
Lake Aging's Effect on Trophic Status



OLIGOTROPHIC
- Clear water, low productivity
- Very desirable fishery of large game fish

MESOTROPHIC
- Increased production
- Accumulated organic matter
- Occasional algal bloom
- Good fishery

EUTROPHIC
- Very productive
- May experience oxygen depletion
- Rough fish common

Source: Modified from B. Shaw, C. Mechenich, and L. Klessig, Understanding Lake Data*, University of Wisconsin-Extension, p. 5, 2004 and SEWRPC*

water divers).[91] Thus, under conditions of abnormally high surface temperatures in a lake, fish can become "squeezed" into an increasingly narrow range of depths between supersaturated surface waters above and an anoxic hypolimnion below. In addition, oxygen saturation can also fluctuate diurnally. Many waterbodies that experience oxygen supersaturation during the day can also experience low oxygen saturation levels at night, as oxygen-consuming activities such as respiration and decomposition occur at night without oxygen-producing photosynthesis. Such conditions are stressful to aquatic organisms and can also lead to fish kills in summer.

Dissolved oxygen saturation profiles in Lake Comus indicate that the Lake is likely experiencing supersaturation during late summer with oxygen saturation frequently over 115 percent in August and September (Figure 2.26). These high oxygen saturation values are likely the byproduct of photosynthesis by the Lake's overly abundant algal community. Oxygen supersaturation values such as those measured in the Lake are detrimental to the Lake's fish community and may result in more sensitive species seeking refugia at deeper depths or in cooler waters near the groundwater spring inputs to the Lake. Excessive algal growth is likely fueled by excessive phosphorus loads delivered to the Lake with runoff.

pH and Acidity

The acidity of water is measured using the pH scale. The pH scale is a logarithmic measure of hydrogen ion (H+) concentration on a scale of 0 to 14 Standard Units (stu, or SU) with 7.0 indicating neutrality. Water with pH values lower than 7.0 stu has higher hydrogen ions concentrations and is more acidic, while water with pH values higher than 7.0 stu has lower hydrogen ion concentrations and is less acidic. Since the scale is logarithmic, each 1.0 pH change reflects a tenfold change in hydrogen ion concentration, e.g., a pH of 4 is *ten* times more acidic than a pH of 5 and a *hundred* times more acidic that a pH of 6. In Wisconsin lakes, pH can range anywhere from 4.5 in some acid-bog lakes to 8.4 in hard water, marl lakes.[92]

Many chemical and biological processes are affected by pH, as are the solubility and availability of many substances. Different organisms can tolerate different ranges of pH, with most preferring ranges between about 6.5 and 8.0 stu. Although moderately acidic water (slightly below a pH of 7) does not usually harm fish, as pH drops to 6.5 or lower, some species can be adversely affected, especially during spawning. For example, at a pH of 6.5, walleye spawning can be inhibited; at a pH of 5.8, lake trout spawning is inhibited; and at a pH of 5.5, smallmouth bass disappear.[93] As pH continues lower, walleye, northern pike and other

[91] *Supersaturation refers to a condition when the amount of dissolved substance exceeds the substance's maximum solubility in the solvent under normal circumstances. Such conditions are typically unstable. Dissolved gas comes out of water as bubbles.*

[92] *Wisconsin Department of Natural Resources, Byron Shaw, Christine Mechenich, and Lowell Klessig,* Understanding Lake Data*: www.uwsp.edu/cnr-ap/UWEXLakes/Documents/ecology/shoreland/background/understanding%20lake%20data.pdf.*

[93] Ibid.

popular sport fishes gradually disappear. A pH of 3.0 is toxic to all fish.[94] In addition, many metals are more soluble in water with low pH than they are in water with high pH. Thus, toxicity of many substances for fish and other aquatic organisms can be affected by pH. Under low pH conditions, toxic metals, such as aluminum, zinc, and mercury, can be released from lake sediment if present. At a pH of 5.0, aluminum is at its most poisonous, precipitating onto the gills of the fish in the form of aluminum hydroxide.[95]

Figure 2.22
Potential Appearance of a Hyper-Eutrophic Lake

Source: University of Wisconsin-Stout and SEWRPC

Lakes have natural and anthropogenic sources of acidity. Peat-bog lakes are naturally acidic due to the natural release of organic acids during decomposition. Many such lakes are without fish.[96] Because of carbon dioxide diffusion into water and associated chemical reactions, rainfall (in areas that are not impacted by air pollution) has a pH of about 5.6 stu; the pH of rainfall in areas where air quality is affected by oxides of nitrogen or sulfur tends to be lower. The mineral content of the soil and bedrock underlying a waterbody also has a strong influence on the waterbody's pH. Pollutants contained in discharges from point sources and in stormwater runoff can also affect a waterbody's pH. Further, photosynthesis by aquatic plants, phytoplankton, and algae can cause pH variations both on a daily and seasonal basis.

The pH of Lake Comus ranges from 8.5 to 9, as determined measurements conducted in the summers of 1978, 2000, and 2002. Like most lakes in Southeastern Wisconsin (mean pH of 8.1), Lake Comus is a slightly basic waterbody.[97] Since carbonate bedrock, such as dolomite, underlies much of the Lake Comus watershed, the pH in the Lake tends to be in the alkaline range. Not enough pH data has been collected to discern whether seasonal variations from photosynthesis are affecting the Lake.

Alkalinity and Hardness

Alkalinity is a measure of the capacity of a lake to absorb and neutralize acids, known as "buffering." The alkalinity of a lake depends on the levels of bicarbonate, carbonate, and hydroxide ions present in the water. Lakes in Southeastern Wisconsin typically have a high alkalinity because of the types of soils and underlying bedrock in the Region's watersheds. In contrast, water *hardness* is a measure of the multivalent metallic ion concentrations, such as those of calcium and magnesium, present in a lake. Hardness is usually reported as an equivalent concentration of calcium carbonate ($CaCO_3$), measured in mg/l. If a lake receives groundwater through rock layers containing calcite and dolomite, the lake's alkalinity and hardness will be high. Such rocks are common in the Lake Comus watershed. Soft water lakes have calcium carbonate levels less than 60 mg/l; hard water lakes contain levels over 120 mg/l.

Lake Comus may be classified as a hard-water alkaline lake, with recorded alkalinity measurements of 228 mg/l in 2000 and 213 mg/l in 2002. These alkalinities are within the normal range of lakes in Southeastern Wisconsin.[98] Total hardness has not been measured within Lake Comus. Since Lake Comus has a high alkalinity or buffering capacity, and because the pH does not fall below 7, the Lake is not considered susceptible to the harmful effects of acid rain.

[94] Ibid.

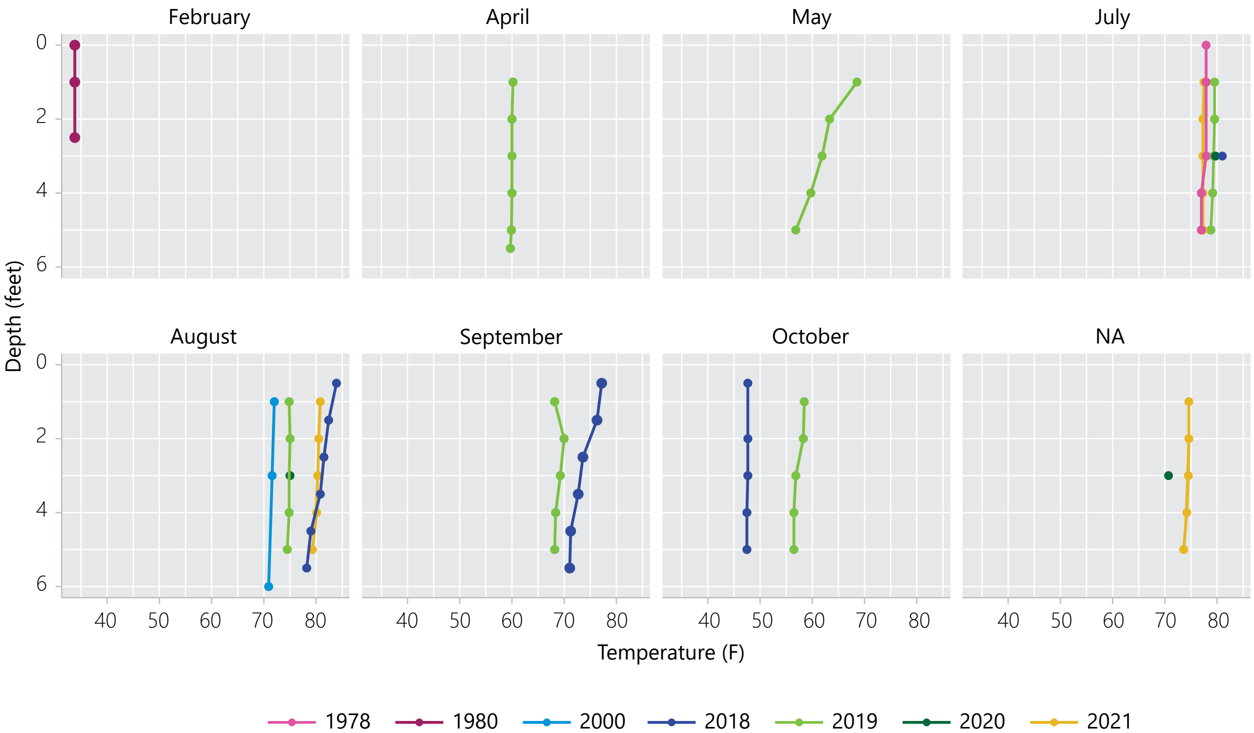
[95] *www.air-quality.org.uk/13.php.*

[96] *T. Hellström, "Acidification in Lakes," In L. Bengtsson, R.W. Herschy, R.W. Fairbridge (eds.)* Encyclopedia of Lakes and Reservoirs*, 2012.*

[97] *Lillie and Mason, 1983,* op. cit.

[98] Ibid.

Figure 2.23
Temperature Profiles in Lake Comus: 1978-2021



Source: Wisconsin Department of Natural Resources and SEWRPC

Specific Conductance and Chloride

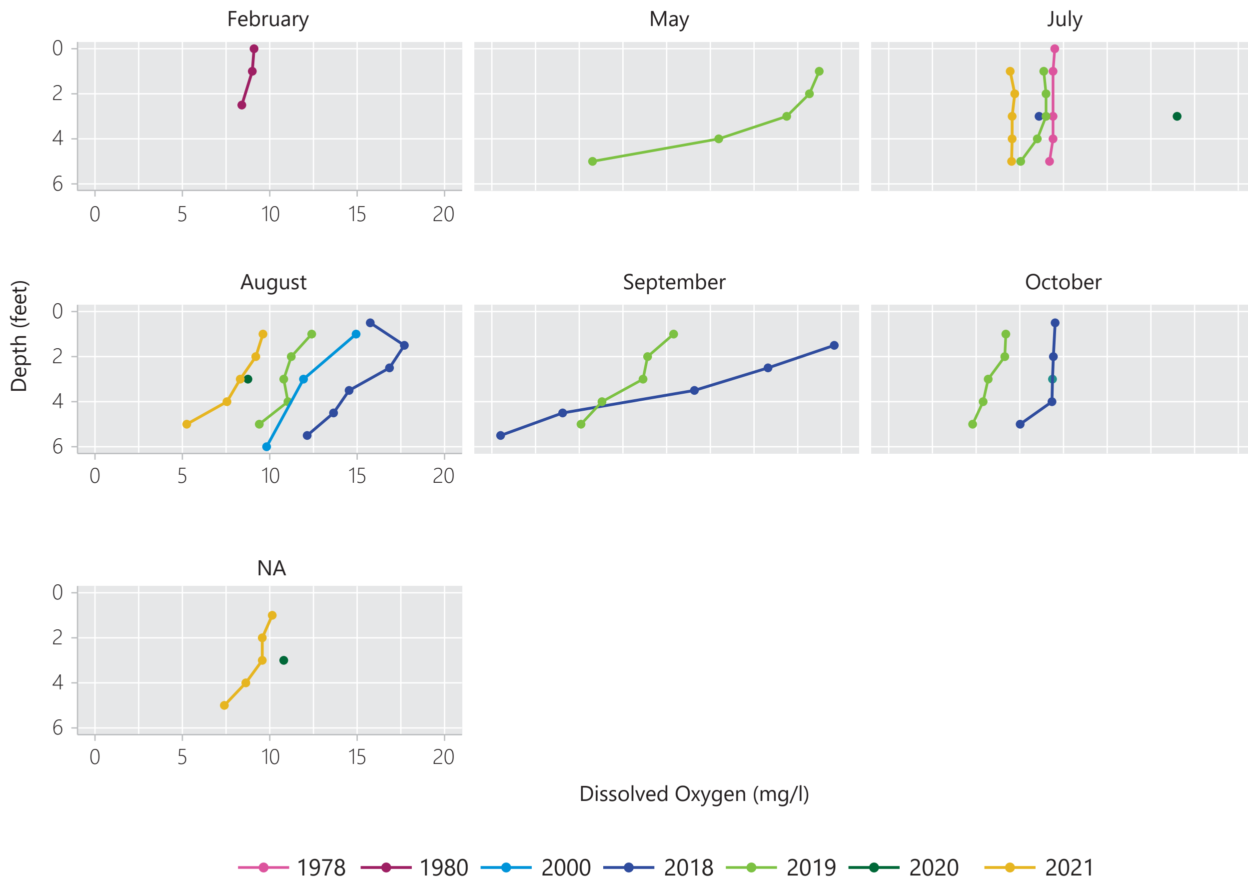
Specific conductance is a measure of the ability of a liquid, such as lake water, to conduct electricity, standardized at a specific temperature (25°C). Water's specific conductance relates to dissolved solids concentration: as dissolved solids increase, specific conductance increases. While many of dissolved solids are minerals leaching from soil and bedrock (e.g., calcium, magnesium), compounds released to the environment such as sodium chloride can contribute to higher specific conductance values as well. Humans use compounds containing chloride for a multitude of purposes. Road deicing, water softening, industrial processes, agricultural fertility and tilth enhancement procedures, pesticides applications, and pharmaceutical use are examples of human activities that can be sources of chloride to the environment. Since chloride is a prevalent substance used by modern society and is a *conservative pollutant*,[99] chloride concentrations often increase in watersheds with pronounced human activity. Therefore, chloride concentrations are a good indicator of the overall level of human activity/potential impact and the overall health of a water body.

Under natural conditions, surface water in Southeastern Wisconsin contains little chloride. Studies completed in Waukesha County lakes during the early 1900s reported concentrations of three to four mg/l of chloride. In fact, lakes in Southeastern Wisconsin had the lowest levels of chlorides statewide.[100] Most Wisconsin lakes saw little increase in chloride concentrations until the 1960s and a rapid increase thereafter. Elevated chloride concentrations are associated with high specific conductance values, as the abundance of chloride ions increases water conductance. Chloride concentrations have never been measured in Lake Comus as far as Commission staff are aware.

[99] *Conservative pollutants tend to remain dissolved in water after they are introduced. Conservative pollutant concentrations in waterbodies are not significantly moderated by biological or most natural physical processes.*

[100] *Lillie and Mason, 1983,* op. cit.

Figure 2.24
Dissolved Oxygen Profiles in Lake Comus: 1978-2021



Source: Wisconsin Department of Natural Resources and SEWRPC

Specific conductance has been recorded only a handful of times within Lake Comus, with measurements in 1978, 2000, and 2002. These measurements have ranged from 400 to 600 µS/cm with no discernible trend over time. Chloride has not been measured within Lake Comus, so its influence on specific conductance cannot be ascertained. However, due to the modest specific conductance values, the high alkalinity of water in the area, and the low proportion of impervious surfaces in the watershed, it is unlikely that chloride is substantially contributing to specific conductance values.[101]

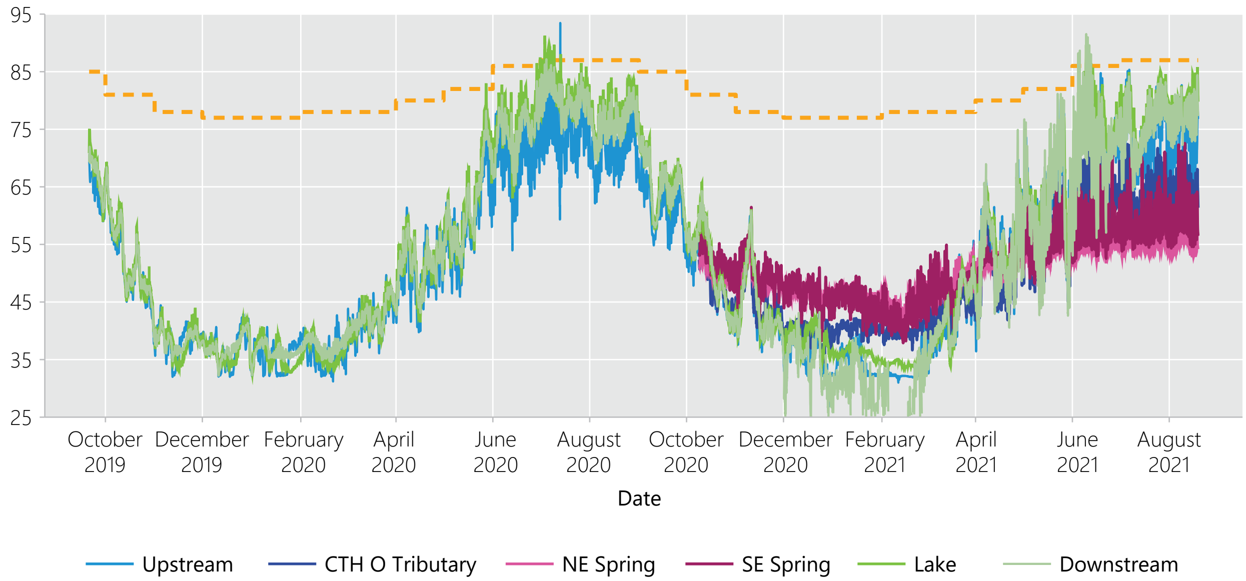
Nutrients and Trophic State

Nutrients are elements and compounds that plants and algae need to grow. They are often found in a variety of chemical forms, both inorganic and organic, which may vary their availability to plants and algae. Typically, growth and biomass of plants and algae in a waterbody are limited by the availability of the nutrient present in the lowest amount relative to the organisms' needs. This nutrient is referred to as the *limiting nutrient*, where additions of this nutrient will increase organism growth and biomass. Phosphorus is usually, though not always, the limiting nutrient in Wisconsin's freshwater systems. Under unique, usually human activity related circumstances, nitrogen can act as the limiting nutrient.

Lake biological productivity is referred to in terms of "trophic state." Low productivity lakes with few nutrients, algae, and plants are in an *oligotrophic* state; lakes with moderate nutrients and productivity are in a *mesotrophic* state; and lakes with excessive nutrients and productivity are in a *eutrophic* state. Wisconsin trophic state index (WTSI) equations are used to convert summer water clarity, chlorophyll-*a* concentrations, and phosphorus concentrations to a common unit used to assess and compare lake

[101] *WDNR, Understanding Lake Data,* op. cit.

Figure 2.25
Water Temperature of Lake Comus, Turtle Creek, and Groundwater Springs: 09/20/2019-08/19/2021



Note: Dashed orange line indicates acute temperature standard for inland lakes and impoundments. Upstream temperature logger may have been exposed to air on 07/14/2020, resulting in anomalously high temperatures.

Source: SEWRPC

trophic state throughout Wisconsin.[102] WTSI values based upon chlorophyll-*a* are considered the most reliable estimators of lake trophic state as this is the most direct measurement of algal abundance.

Figure 2.27 shows the trophic state of Lake Comus, as determined by summer surface measurements of these three parameters. Lake Comus is a very eutrophic lake with an average WTSI of 71 over the past two years. Although thresholds are not determined for impounded flowing waters, such as Lake Comus, these WTSI values would be considered “fair” to “poor” lake conditions if the Lake were classified as a shallow lowland lake, the closest approximation.[103] The Lake’s WTSI values have remained essentially constant since the earliest measurements in 1978. At such high WTSI values, the Lake has excessive nutrients that can cause algal blooms on the water surface and limit light penetration supporting aquatic plant growth.[104] If the WTSI values were to approach 80, algal blooms could be frequent with little to no aquatic plants and summer fish kills caused due to low dissolved oxygen concentrations.

Water Clarity

One of the three determinants of trophic state is water clarity. Water clarity, or transparency, provides an indication of overall water quality. In many cases, greater clarity is associated with better the water quality. Clarity may decrease because of turbidity caused by:

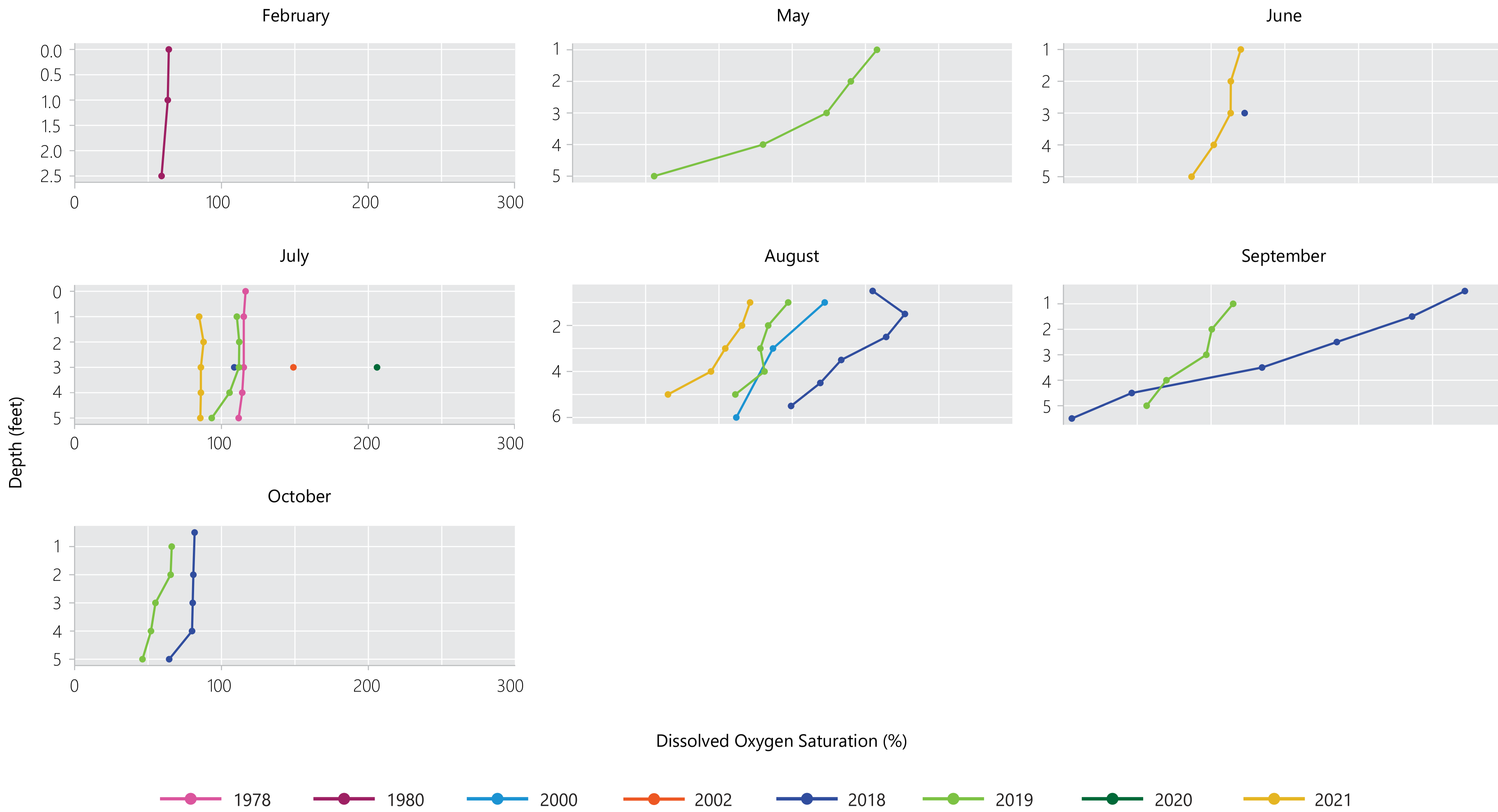
- high concentrations of small, aquatic organisms, such as algae and zooplankton
- suspended sediment and/or inorganic particles

[102] *R.A. Lillie, S. Graham, and P. Rasmussen,* Trophic State Index Equations and Regional Predictive Equations for Wisconsin Lakes, Research Management Findings, Number 35, *Bureau of Research – Wisconsin Department of Natural Resources, May 1993.*

[103] *Wisconsin Department of Natural Resources,* Wisconsin Consolidated Assessment and Listing Methodology (WisCALM) 2022, *January 2021.*

[104] *A WDNR figure showing TSI values for Lake Comus can be viewed at dnr.wi.gov/lakes/clmn/reports/tsigraph.aspx?stationid=653286. It should be noted that the WDNR utilizes different equations for calculating TSI than the Commission, potentially resulting in slightly different TSI values for the Lake.*

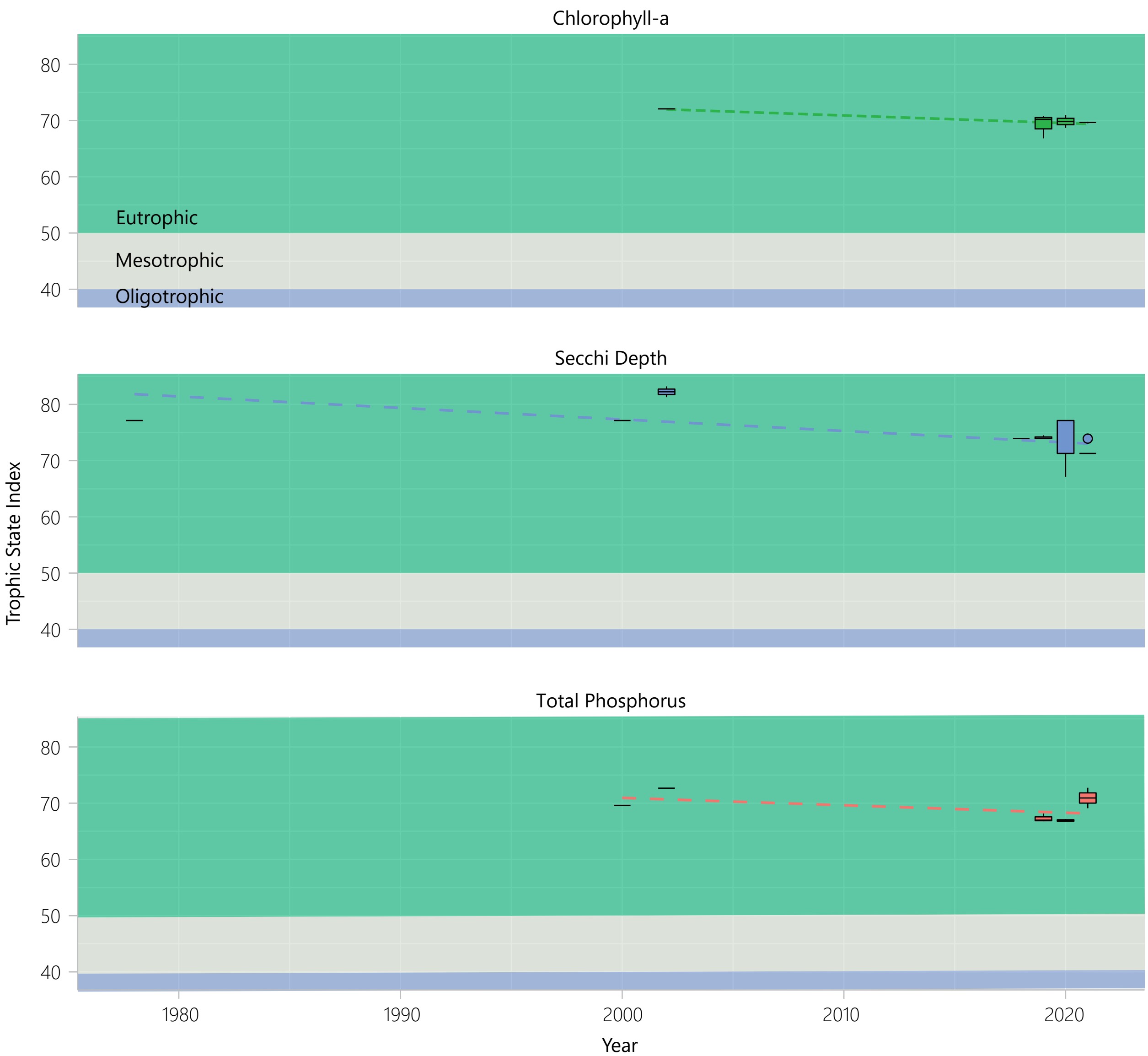
Figure 2.26
Dissolved Oxygen Saturation in Lake Comus: 1978-2021



Note: Meter calibration was not confirmed for dissolved oxygen profiles measured in 2018.

Source: Wisconsin Department of Natural Resources and SEWRPC

Figure 2.27
Lake Comus Trophic State Index Trends: 1978-2021



Source: Wisconsin Department of Naural Resources and SEWRPC

- color caused by high concentrations of dissolved organic substances (e.g., tannin stained water of bog lakes)

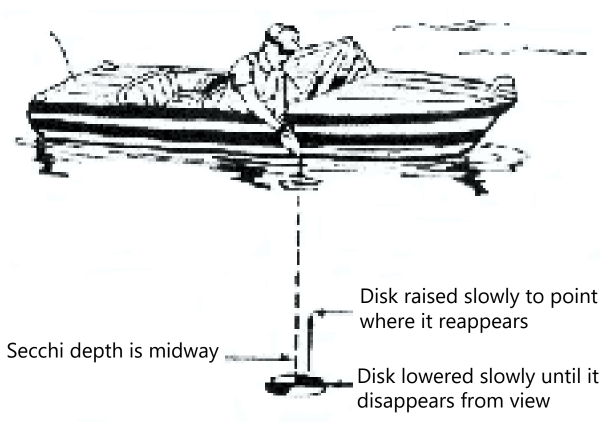
In most Southeastern Wisconsin lakes, water clarity is influenced by the abundance of algae and suspended sediment. Water clarity varies throughout the year as algal populations increase and decrease in response to changes in lake temperature, sunlight, and nutrient availability. Large rainfall events can also influence water clarity with sediment-induced clarity declines caused by heavy turbid runoff.

Clarity is measured using a Secchi disk, a black-and-white, eight-inch-diameter disk. This disk is lowered into the water until it is no longer visible, at which point the depth is recorded, and then it is raised until visible again, when depth is recorded again (Figure 2.28). The average of these depths is called the "secchi depth." Using these measurements, we can determine that Lake Comus has very poor water clarity with the secchi depth rarely more than one foot. Low clarity may hinder growth of a substantial aquatic plant population in the Lake as plants growing more than a few feet deep may be light-limited.

Chlorophyll-*a* and Algae

Chlorophyll-*a,* a photosynthetic pigment used to indicate algal abundance, is the most reliable metric of a lake's trophic state. Algae is an important and healthy part of lake ecosystems. Algae is a foundational component of lake food chains and produces oxygen in the same way as rooted plants. Many kinds of algae exist ranging from single-cell, colonial, and filamentous algae to cyanobacteria (Figure 2.29). Most algae strains benefit lakes when present in moderate levels. However, the presence of toxic strains (Figure 2.30), as well as excessive growth patterns, should be considered issues of concern. As with aquatic plants, algae grow faster in the presence of abundant phosphorus (particularly in stagnant areas). Consequently, when toxic or high volumes of algae begin to grow in a lake, it often is a sign of phosphorus enrichment or pollution.

Figure 2.28
Measuring Water Clarity with a Secchi Disk



Source: lakes.chebucto.org and SEWRPC

Algae populations are quantified by abundance and composition and can be examined to determine if the algae present are toxin-forming. Suspended algal abundance is estimated by measuring the chlorophyll-*a* concentration in the water column, with high concentrations associated with green-colored water. Mean summer chlorophyll-*a* measurements for Lake Comus during 2019 and 2020 were 118 and 109 µg /l, respectively. These concentrations are far above the 27 µg/l threshold at which aquatic life impairment can occur and algae blooms are more prevalent. Surficial algae blooms along the shallow, northern portion of the Lake were noted by Commission staff in summer 2019 (Figure 2.31). A WDNR algal expert identified that this algae bloom was likely of *Oscillatoria*, a type of blue-green algae, via these photographs.[105] Regular monitoring for algae should be considered, as blue-green algae blooms can produce toxins in concentrations that are harmful to humans and pets.

Phosphorus

The third determinant of a lake's trophic state is the lake's total phosphorus concentration. Phosphorus is a key nutrient for aquatic plants and algae, with the availability of phosphorus often limiting their growth and abundance. Sources of phosphorus can vary across a watershed, with agricultural fertilizers and animal manure as the predominant phosphorus sources in rural areas while stormwater discharge and onsite wastewater treatment systems contribute phosphorus in urban areas.

Two forms of phosphorus are commonly sampled in surface waters: total phosphorus and dissolved phosphorus. Total phosphorus consists of all phosphorus dissolved or suspended in water. Dissolved phosphorus consists only of the phosphorus dissolved in water and does not consider phosphorus suspended in particulate material. In both, phosphorus may be present in a variety of chemical forms. However, as the degree of eutrophication in freshwater systems correlates more strongly with total phosphorus concentration than with dissolved phosphorus concentration, the State's water quality criteria are expressed in terms of total phosphorus. Thus, water quality sampling tends to focus on assessing total phosphorus concentrations rather than dissolved phosphorus concentrations.

Total phosphorus concentrations have only been measured regularly in Lake Comus within the past few years. The earliest measurements were conducted in 2000 and 2002 by WDNR, with concentrations of 0.206 and 0.305 mg/l, respectively. Since 2019, surface summer phosphorus concentrations measured at the Lake's "deep hole" site have averaged 0.15 mg/l and ranged from 0.12 to 0.17 mg/l. These concentrations are substantially higher than the 0.040 mg/l limit mandated by *administrative code*[106] for non-stratified reservoirs, which is the closest analogue to Comus' lake type. These elevated phosphorus concentrations are likely stimulating the heavy algae growth within the Lake, diminishing water clarity.

[105] *Personal communication via email, Justin Poinsatte, SEWRPC, with Gina LaLiberte, WDNR, 2019.*

[106] Wisconsin Administrative Code *Chapter NR 102,* op. cit.

Nitrogen

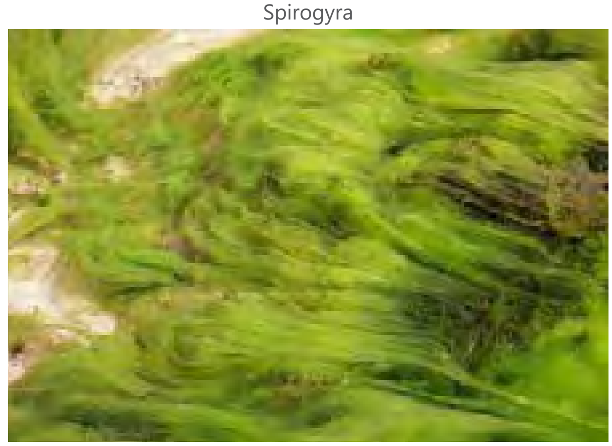
Surface waters contain a variety of nitrogen compounds that are nutrients for plants and algae. Typically, only a small number of forms of nitrogen are examined and reported in water quality sampling. Total nitrogen includes all the nitrogen in dissolved or particulate form in the water, excluding all gaseous forms of nitrogen. Total nitrogen is a composite of several different compounds that vary in their availability to algae and aquatic plants and in their toxicity to aquatic organisms. Many nitrogen-containing organic compounds, such as amino acids, nucleic acids, and proteins that commonly occur in natural and polluted waters are included in total nitrogen. Common inorganic constituents of total nitrogen include ammonia, nitrate, and nitrite. These are the forms that most commonly support algal and plant growth. Total Kjeldahl nitrogen has been measured in Lake Comus at concentrations 2.44 mg/l in 2000 and 3.58 mg/l in 2002. Median total nitrogen concentration in 61 Southeastern Wisconsin lakes was 1.18 1.43 mg/l, with values ranging from 0.4 mg/l to 6.5 mg/l.[107] The higher than typical total nitrogen concentrations in Lake Comus suggest that nitrogen the Lake's receives nutrient-enriched runoff. While nitrate can be harmful to humans at high concentrations (the WDNR drinking water limit is 10 mg/l), combined nitrate and nitrite concentrations in the Lake were measured at 0.474 mg/l in 2000 and 0.011 in 2002, far below the drinking water standards.

A variety of point and nonpoint sources contribute nitrogen compounds to surface waters. In urban settings, nitrogen compounds from lawn fertilizers and other sources may discharge through storm sewer systems to lakes and streams. Cross-connections between sanitary and storm sewer systems, illicit connections to storm sewer systems, and decaying sanitary and storm sewer infrastructure may be a phantom contributor of sanitary wastewater to waterbodies. In rural settings, nitrogen compounds from chemical fertilizers and animal manure may be discharge from drain tiles or may directly runoff into waterbodies. Poorly maintained or failing onsite wastewater treatment systems can also contribute nitrogen compounds. In addition, some species of lake cyanobacteria "fix" nitrogen by converting otherwise inert gaseous nitrogen into ammonia or another compound usable by algae and plants.

Figure 2.29
Common Types of Non-Toxic Algae

Hydrodictyon

Spirogyra



Chlamydomonas

Source: (1) Lewis Lab (2) University of New Mexico (3) Taranaki Regional Council & Landcare Research

Occasionally, nitrogen acts as the limiting nutrient for algal and plant growth in freshwater systems, typically when phosphorus concentrations are very high. In general, when the ratio of total nitrogen (N) to total phosphorus (P) concentrations is 15:1 or greater, the availability of phosphorus limits algal growth. Conversely, when this proportion is less than 10:1, nitrogen concentrations limit plant growth. Ratios

[107] *Lillie and Mason, 1983,* op. cit.

between 15:1 and 10:1 are considered transitional.[108] The 2000 and 2002 N/P ratios were both 12:1 indicating a transition between phosphorus and nitrogen being the main limiting factors for plant and algae growth.

Bacteria

The concentration of certain bacteria in water is measured to assess the quality of the water for drinking water supply and recreational uses. A variety of disease-causing organisms can be transmitted through water contaminated with fecal material. These organisms include bacteria, such as those causing cholera and typhoid fever; viruses, such as those causing poliomyelitis and infectious hepatitis; and protozoa, such as *Giardia* and *Cryptosporidium*. It is not practical to test surface waters for all these diseasecausing organisms as rapid and inexpensive tests do not currently exist for many of these organisms. Instead, the sanitary quality of surface water is assessed by examining samples for the presence and concentrations of organisms indicating fecal contamination. Two groups of bacteria are commonly examined in surface waters: fecal coliform bacteria and *Escherichia coli* (*E. coli*). All warm-blooded animals have these bacteria in their feces so the presence of high concentrations of fecal coliform bacteria or *E. coli* in water indicates a high probability of fecal contamination. While most strains of these two bacterial groups have a low probability of causing illness, they can indicate the possible presence of other pathogenic agents in water, particularly when present in high concentrations.

Figure 2.30
Appearance of Toxic Algae Blooms

Microcystis

Cylindrospermopsis

Source: (1) National Oceanic and Atmospheric Administration
(2) St. John's River Water Management District

Fecal coliform bacteria are currently used to indicate the suitability of inland waters in Wisconsin for recreational uses.[109] The State requires that counts of fecal coliform bacteria in waters of the State not exceed 200 colony-forming-units (a measure of living cells abbreviated as cfu) per 100 milliliters (cfu per 100 ml) as a geometric mean based on not less than five samples per month, nor exceed 400 cfu per 100 ml in more than 10 percent of all samples during any month. There are no records of fecal coliform testing on Lake Comus in the WDNR water quality database.

E. coli is a species of fecal coliform bacteria. The U.S. Environmental Protection Agency (USEPA) recommends using either *E. coli* or enterococci as indicators of fecal pollution in recreational waters for freshwater systems. Agencies participating in the monitoring of beaches in the Wisconsin Beach Monitoring program use *E. coli* as the indicator of sanitary quality of the associated waters. Water quality advisories are issued for beaches whenever the *E. coli* concentration in a sample exceeds 235 cfu per 100 ml or whenever the geometric mean of at least five samples taken over a 30-day period exceeds 126 cfu per 100 ml. Beaches are closed whenever the concentration of *E. coli* exceeds 1,000 cfu per 100 ml. Since no public beaches are found on Lake Comus, *E. coli* monitoring is not routinely conducted on the Lake's water.

[108] Ibid.

[109] *Wisconsin Department of Natural Resources,* Wisconsin Consolidated Assessment and Listing Methodology (WisCALM) 2022, *January 2021.*

Aquatic Life Designated Use

All surface waters in Wisconsin are considered to have appropriate designed uses for the protection of fish and aquatic life (Aquatic Life), recreational use (Recreation), incidental human contact and fish consumption (Public Health and Welfare), and the protection of wildlife that depends on the waterbody (Wildlife). Each designated use has its own set of water quality standards. The water quality standards for temperature, dissolved oxygen, total phosphorus, chlorophyll-*a*, and chloride are for the Aquatic Life designated use. As of the 2022 listing cycle, Lake Comus is currently classified as not supporting its Aquatic Life designated use and the Lake has been listed on the State of Wisconsin's Clean Water Act 303(d) Impaired Waters list. The WDNR has identified the Lake to be impaired by excessive concentrations of total phosphorus in its waters, a condition leading to excessive algal growth, comprised biological integrity, and eutrophication. The phosphorus is identified to be related to non-point sources.

Figure 2.31
Algal Bloom Observed on Lake Comus: August 2019

Source: SEWRPC

Turtle Creek Water Quality and Designated Uses

Lakes and streams have strikingly different environments. This presents special challenges when dealing with water quality issues. This subsection will present data collected from Turtle Creek and a subset of its unnamed tributaries. An analysis of these data will provide context to the water quality characteristics of Lake Comus since a lake's tributaries play a vital role in the overall health of the lake into which they flow. An understanding of these data should aid in developing management strategies for both the Lake and its tributaries.

Temperature and Dissolved Oxygen

The interplay between temperature and oxygen in streams differs from lakes in several ways. For example, without stratification, streams avoid many of the complexities (hypolimnetic anoxia, internal loading, etc.) imposed on lakes that stratify. In addition, the continual movement of water in streams makes for a constant mixing of waters at the surface and below and helps reinforce oxygen levels. The WDNR has designated Turtle Creek's mainstem from Turtle Lake to Lake Comus with an attainable Aquatic Life use of a warmwater sport fish community (Table 2.16), indicating that the stream should have warm to cool temperatures and DO above 5.0 mg/l to support this aquatic life community. The other tributaries in the watershed have been designated with attainable default Fish and Aquatic Life uses and are assumed to support either warmwater or coldwater communities depending on water temperatures and habitat in these streams.

Volunteers have monitored water temperatures along the Turtle Creek mainstem at Dam Road during summer from 2019 to 2021 while volunteers and WDNR staff have monitored temperatures of the CTH O tributary at CTH O during summer between 2017 to 2021. Summer temperatures at Dam Road ranged from 60 to 74°F while summer temperatures of the CTH O tributary ranged from 56 to 71°F (Figure 2.32).

Commission staff also measured hourly temperatures in Turtle Creek upstream of the Lake at Dam Road and downstream of the Lake at Richmond Road from September 2019 to August 2021 using temperature loggers (Figure 2.25). Water temperatures of the CTH O tributary were also measured approximately 750 feet upstream of its confluence with Turtle Creek from October 2020 to August 2021. Summer Lake water temperatures were between three to six degrees Fahrenheit higher than those recorded upstream of

Table 2.16
Water Quality Criteria for Streams in the Lake Comus Watershed

Water Quality Parameter	Designated Use Category[a]						Source
	Coldwater Community	Warmwater Fish and Aquatic Life	Limited Forage Fish Community (variance category)	Special Variance Category A[b]	Special Variance Category B[c]	Limited Aquatic Life (variance category)	
Temperature (°F)	--[d]	--[d]	--[d]	--[d]	--[d]	86.0	NR 102 Subchapter II
Dissolved Oxygen (mg/l)	6.0 minimum 7.0 minimum during spawning	5.0 minimum	3.0 minimum	2.0 minimum	2.0 minimum	1.0 minimum	NR 102.04(4) NR 104.04(3) NR 104.06(2)
pH Range (S.U.)	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	NR 102.04(4)[e] NR 104.04(3)
Fecal Coliform Bacteria (MFFCC)							NR 102.04(5)
Geometric Mean	200	200	200	1,000	1,000	200	NR 102.04(6)
Maximum	400	400	400	2,000	--	400	NR 102.06(2)
Total Phosphorus (mg/l)							NR 102.06(3) NR 102.06(4)
Designated Streams[f]	0.100	0.100	0.100	0.100	0.100	0.100	NR 102.06(5)
Other Streams	0.075	0.075	0.075	0.075	0.075	--	NR 102.06(6)
Chloride (mg/l)							
Acute Toxicity[g]	757	757	757	757	757	757	NR 105.05(2)
Chronic Toxicity[h]	395	395	395	395	395	395	NR 105.06(5)

[a] *NR 102.04(1) All surface waters shall meet the following conditions 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 materials producing color, odor, taste or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the State. Substance in concentrations or combinations which are toxic or harmful to humans shall not be present in amounts found to be of public health significance, nor shall substances be present in amounts which are acutely harmful to animal, plant, or aquatic life.*

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

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

[d] *See Table 2.16.*

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

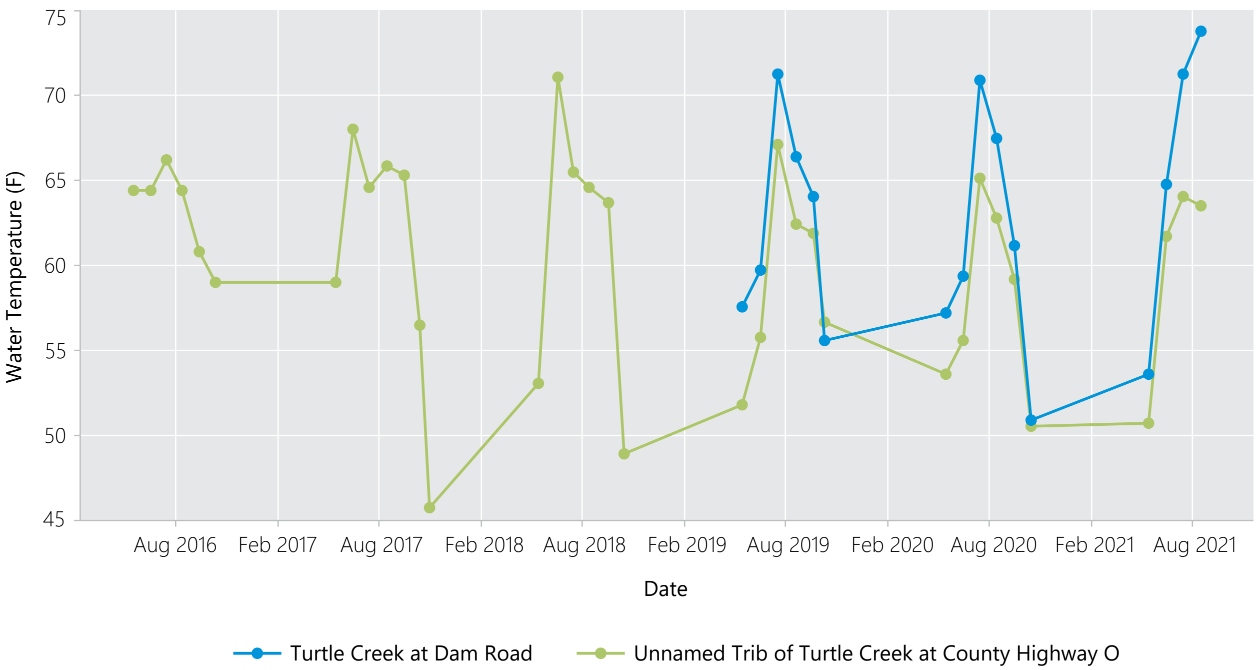
[f] *Designated in Chapter NR 102.06(3)(a) of the* Wisconsin Administrative Code. *There are no designated streams in the Pewaukee Lake watershed*

[g] *The acute toxicity criterion is the maximum daily concentration of a substance that ensures adequate protection of sensitive species of aquatic life from the acute toxicity of that substance and will adequately protect the designated fish and aquatic life use of the surface water if not exceeded more than once every three years.*

[h] *The chronic toxicity criterion is the maximum four-day concentration of a substance that ensures adequate protection of sensitive species of aquatic life from the chronic toxicity of that substance and will adequately protect the designated fish and aquatic life use of the surface water if not exceeded more than once every three years.*

Source: Wisconsin Department of Natural Resources and SEWRPC

Figure 2.32
Water Temperatures of Turtle Creek and CTH Tributary



Source: Wisconsin Department of Natural Resources and SEWRPC

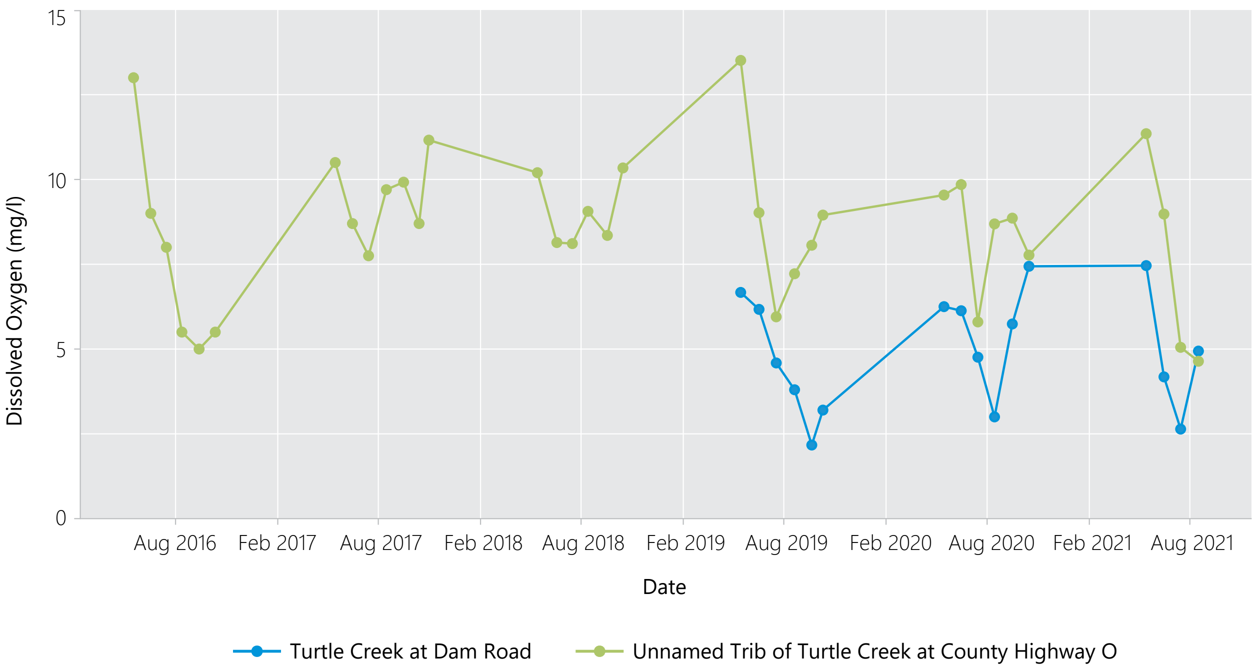
the Lake at the Dam Road. The Lake was also between two and five degrees Fahrenheit warmer than the downstream Richmond Road site. However, the downstream site generally had slightly higher summer temperatures than the Upstream site. The CTH O tributary temperatures were generally 10°F lower than Turtle Creek upstream of the Lake, indicating that significant volumes of groundwater enter this tributary, a situation likely providing a coolwater refuge during summer. During the winter, the CTH O tributary maintained temperatures above 35 degrees Fahrenheit while the sites located upstream, within, and downstream of the Lake were near or below freezing temperatures.

Water temperature influences the types of species living in rivers (each aquatic species has a preferred range). Water temperature also controls the amount of oxygen that can be held in water (warmer water holds less oxygen than cool water[110]). The minimum DO standards for coldwater (e.g., 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. Streams classified as coldwater habitat must also maintain dissolved oxygen concentrations of 7.0 mg/l or greater during trout spawning season. If water in a stream, or other waterbody, becomes too warm, DO levels may be suboptimal (e.g., less than 5.0 mg/l) for many species of fishes and other aquatic organisms. However, streams can also become supersaturated with oxygen, generally above 15 mg/l, which can also injure to fish and other aquatic life. Because the warmest water temperatures occur in the summer, summer is the most important season for determining physiological limitations for aquatic organisms based on DO concentrations.

Along with water temperatures, volunteers have monitored dissolved oxygen concentrations along the Turtle Creek mainstem at Dam Road during summer from 2019 to 2021 while volunteers and WDNR staff have monitored temperatures of the CTH O tributary at CTH O during summer from 2016 to 2021. Dissolved oxygen concentrations of the CTH O tributary ranged between 4.6 to 13.5 mg/l, with a median of 8.7 mg/l, while concentrations of Turtle Creek ranged between 2.2 and 7.5 mg/l, with a median of 4.9 mg/l (Figure 2.33). These measurements indicate that the CTH O tributary concentrations are supportive of a healthy fish population while concentrations for Turtle Creek at Dam Road were suboptimal (below 5.0 mg/l) in most observations.

[110] *A key cause of increased stream temperatures is impervious surfaces (roadways, parking lots, buildings), which restrict infiltration of water.*

Figure 2.33
Dissolved Oxygen Concentrations of Turtle Creek and CTH Tributary



Source: Wisconsin Department of Natural Resources and SEWRPC

Specific Conductance and Chloride

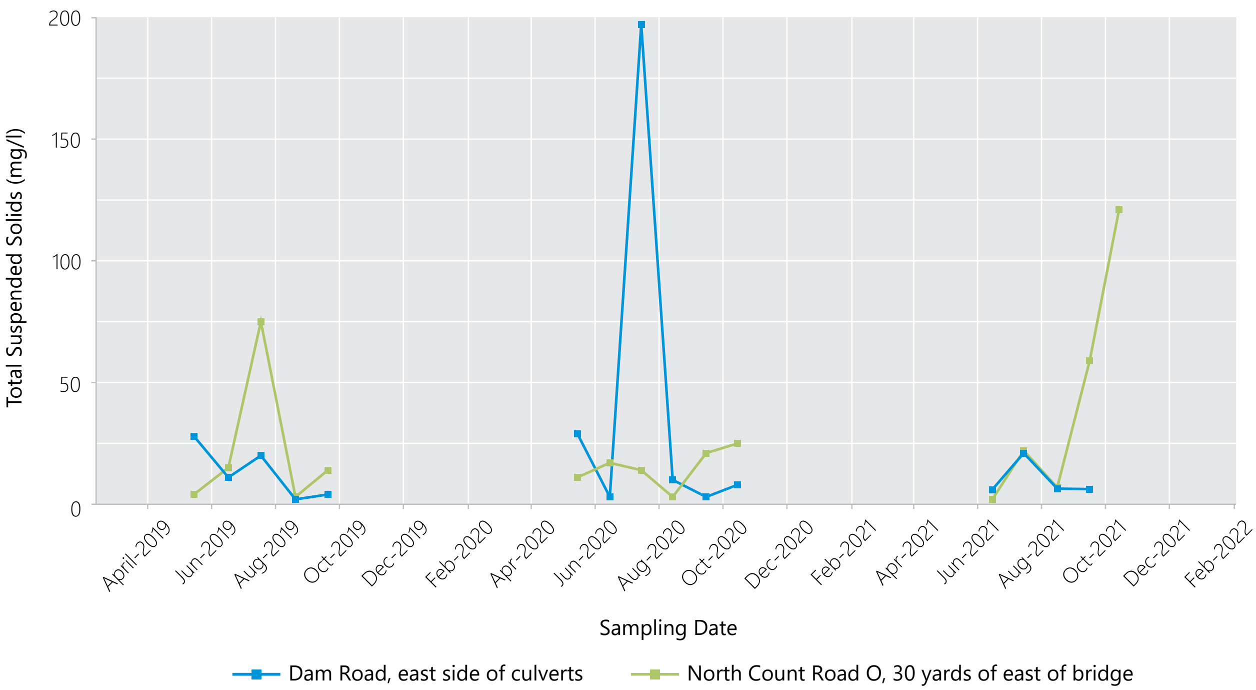
As with lakes, high specific conductance values and chloride concentrations may indicate human influence upon stream water quality. As was discussed in the Lake Comus water quality section, humans release a variety of substances into the environment that increase water conductance and chloride concentrations. Streams are particularly vulnerable to high chloride concentrations in winter related to road deicers. Winter concentrations can greatly exceed acute biological chloride standards for a brief period of time, potentially damaging biological communities in these streams.

Specific conductance or chloride concentrations have not been measured upstream in Turtle Creek or any other tributary upstream of Lake Comus. However, the Commission maintained a continuous monitoring site downstream of the Lake where Turtle Creek passes under US Highway 14 which measured water specific conductance in 15-minute intervals since between 2018 and 2021. Although Turtle Creek receives treated wastewater and water from Delavan Lake at this downstream location, this conductivity record could emulate conditions upstream of Lake Comus. Specific conductivity at this site ranges between 300 and 900 µS/cm, with the lowest values during the winter months which is the opposite pattern of what is typically seen in road salt-affected areas. This may be attributable to flows diminished in summer by dry weather and evapotranspiration demands, making the wastewater contribution a higher proportion of summer flow. Treated municipal wastewater usually contains significant concentration of salt that most commonly enters the wastewater stream through water conditioning (softening) and industrial processes. Since wastewater enters Turtle Creek downstream of Lake Comus, stream water conductance and chloride concentrations in the Lake and Turtle Creek upstream of the Lake are likely lower and may not have the same seasonal trends.

Sediment

Volunteers from the LCPRD monitored total suspended sediment concentrations in water collected from the CTH O tributary and on Turtle Creek at Dam Road between 2019 and 2021 (Figure 2.34). Total suspended sediment concentrations at the CTH O tributary ranged from 3 to 75 mg/l, with an average of 18.4 mg/l, while concentrations at Dam Road ranged from 2 to 197 mg/l, with an average of 28.6 mg/l. Monitoring events with high sediment concentrations also had high concentrations of total phosphorus (see below) indicating that much of the total phosphorus transported by Turtle Creek and its tributaries may be bound

Figure 2.34
Total Suspended Solids Monitoring on Turtle Creek and CTH O Tributary: 2019-2021



Source: LCPRD, WalCoMet, and SEWRPC

to sediment particles. Thus, intense precipitation events that erodes sediment from uplands and delivers it via flowing water to waterbodies is likely a significant contributor to sediment and total phosphorus loading to water bodies in the Lake Comus watershed.

Phosphorus

Total phosphorus concentrations were monitored on the CTH O tributary in 2016-2017 as part of the Targeted Watershed Assessment for Turtle Creek as well as on the CTH O tributary and on Turtle Creek at Dam Road in 2019-2021 (Figure 2.35). Phosphorus concentrations in the CTH O tributary and Turtle Creek at Dam Road averaged 0.165 and 0.267 mg/L, respectively. Both concentrations are substantially higher than the 0.075 mg/L phosphorus limit for streams and small rivers established by *Wisconsin Administrative Code* NR 102.06.

In the summers of 2020 and 2021, LCPRD volunteers collected and analyzed water samples for phosphorus from the upstream portions of the watershed (Map 2.21). All these samples, aside from a 0.06 mg/l sample collected on June 30th, 2020 at the culvert under Turtle Lake Road, contained total phosphorus concentrations far exceeding the 0.075 mg/L phosphorus limit. Turtle Lake, the source of Turtle Creek, has averaged total phosphorus concentrations of 0.020 mg/L in its surface waters at its "deep hole" site from monitoring conducted between 1996 and 2020.[111] This indicates that Turtle Lake is not a major source of total phosphorus to the Creek, as this concentration is far lower than the total phosphorus concentrations measured further downstream.

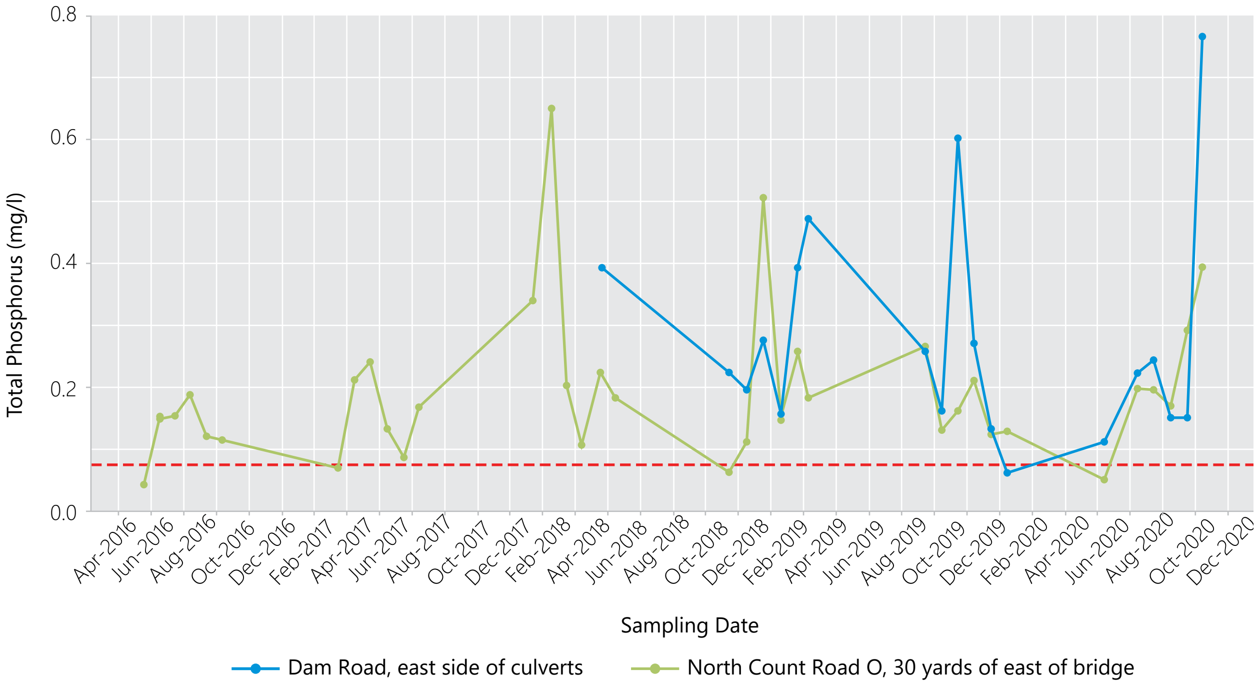
As part of 2020-2021 sampling effort, total phosphorus concentrations were measured in agricultural drain tile effluent.[112] Drain tiles have been shown to export multiple forms of phosphorus and can be a substantial portion of total phosphorus loss from agricultural systems.[113] Drain tile effluent total phosphorus

[111] *dnrx.wisconsin.gov/swims/viewStationResults.do?id=12406*

[112] *Agricultural drain tiles are perforated conduits buried to more rapidly drain water and lower high water table elevations. Drain tiles are intended to increase agricultural productivity in soils that are excessively wet during potions of the year.*

[113] *For a thorough literature review on phosphorus dynamics with drain tiles, see J. Moore,* Literature Review: Tile Drainage and Phosphorus Losses from Agricultural Land, *Lake Champlain Basin Program*, 2016.

Figure 2.35
Total Phosphorus Monitoring on Turtle Creek and CTH O Tributary: 2016-2021



Note: The dashed red line indicates the 0.075 mg/l total phosphorus impairment threshold for Wisconsin streams.

Source: SEWRPC

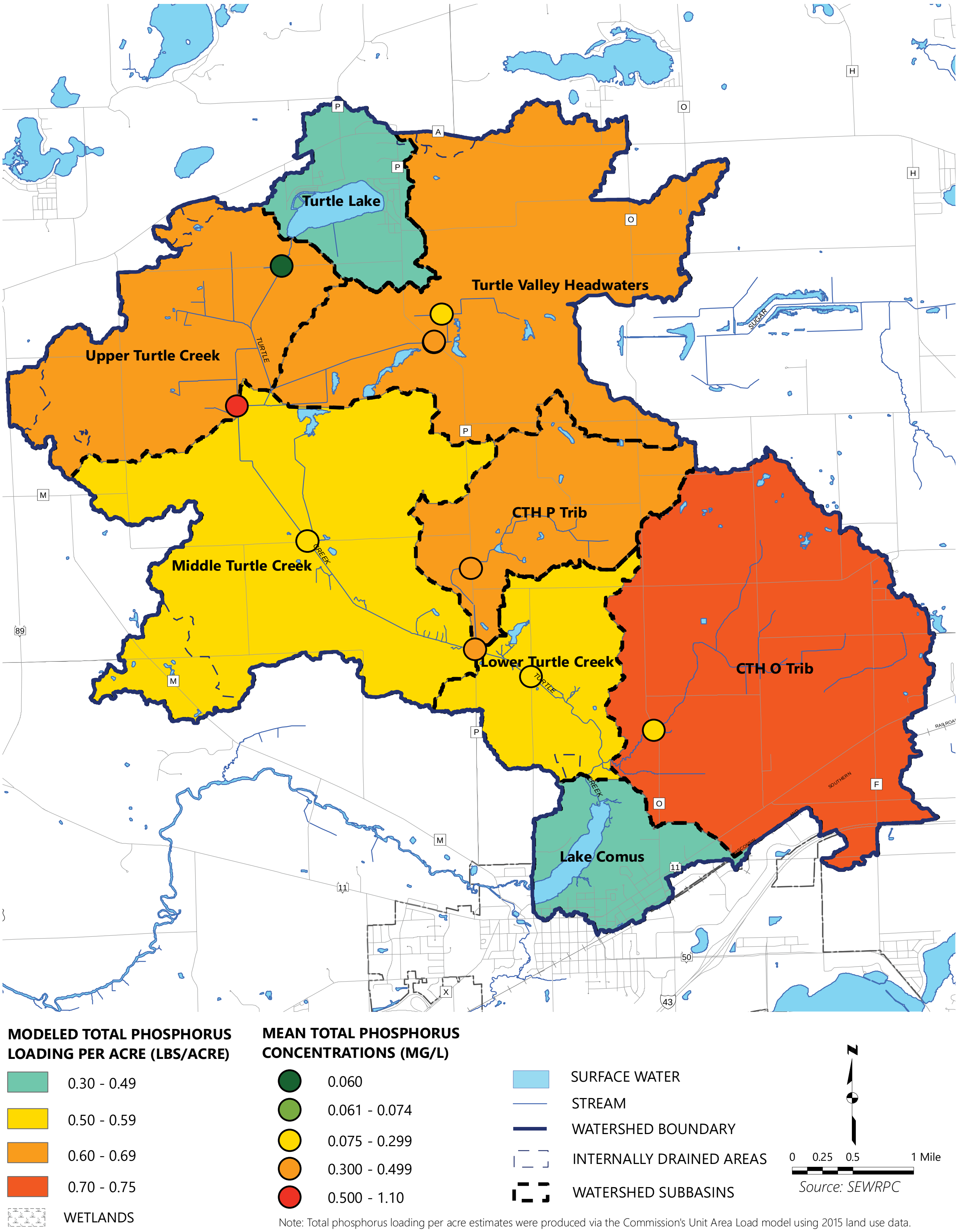
concentrations ranged from non-detectable to 0.63 mg/l in the 2020-2021 monitoring. Of the six drain tile samples collected, four were higher than the 0.075 mg/l total phosphorus standard for streams and small rivers. Several of these samples were collected after heavy rainfall and thus may not represent average phosphorus concentrations of the drain tile effluent. Furthermore, some drain tiles are also used to convey surface runoff and may not be completely representative of tile infiltrate after storms. Additionally, flow measurements were not collected for the drain tile effluent and thus a measure of the total phosphorus load from these tiles could not be calculated. However, these observations demonstrate that drain tiles are contributing water exceeding total phosphorus standards and thus further study into their total phosphorus loading to Turtle Creek and its tributaries is warranted.

Peaks in total phosphorus concentrations at the Dam Road and CTH O tributary sites were associated with periods of elevated rainfall. This suggests that Turtle Creek becomes a more significant sources of phosphorus and sediment to Lake Comus during periods of heavy precipitation and runoff. Phosphorus is tightly bound to soil particles. Therefore, as the soil is eroded during heavy precipitation events, the Creek becomes turbid and phosphorus transport rates greatly increase. This phenomenon has been studied by the United States Geological Survey in the Bark River in Waukesha County where half of the total phosphorus load of the Bark River was transported on about 10 percent of the days during their monitoring period.[114] Nearby Jackson Creek, which flows into the northern inlet of Delavan Lake, shows a similar effect with the highest streamflow events (streamflow exceeded less than 10 percent of the time) transporting magnitudes larger total phosphorus loads than typical or lowflow events.[115]

[114] *H. S. Garn, D. M. Robertson, W. J. Rose, G. L. Goddard, and J. A. Horwatich.,* Water Quality, Hydrology, and Response to Changes in Phosphorus Loading of Nagawicka Lake, a Calcareous Lake in Waukesha County, Wisconsin*, U. S. Geological Survey, Scientific Investigations Report 2005-5273, 2006, pubs.usgs.gov/sir/2006/5273/.*

[115] *SEWRPC Community Assistance Planning Report No. 320,* Jackson Creek Watershed Protection Plan, *June 2017.*

Map 2.21
Mean Total Phosphorus Concentrations and Modeled Total Phosphorus Loading Per Acre by Subbasin



Source: SEWRPC

Note: Total phosphorus loading per acre estimates were produced via the Commission's Unit Area Load model using 2015 land use data.

As discussed in Section 2.1, total annual precipitation has been increasing over the past century as have the number and intensity of large rainfall events occurring each year based on records at nearby weather stations (Figures 2.3 and 2.4). This is evident through the increasing frequency of historically "wet" years with summer precipitation in the top 25 percent of all years as well as the higher number of days with over one inches of rainfall each year over time. Thus, we can expect that runoff events have and will continue to profoundly affect phosphorus and sediment loads reaching Lake Comus.

Aquatic Life Designated Use

Rivers and streams receive a separate classification from the lakes for their Aquatic Life designated use under *Wisconsin Administrative Code*. Turtle Creek's mainstem is classified as a warmwater sportfish community, which requires warm or cool waters with dissolved oxygen concentrations above 5.0 mg/L. Tributaries to Turtle Creek, including the CTH O tributary, are not considered in *Wisconsin Administrative Code* and thus are classified as default Aquatic Life waters. As of the 2022 listing cycle, Turtle Creek's mainstem upstream of the Lake Comus outlet dam was classified as not supporting its warmwater sportfish community classification. Aquatic Life designated use while the Creek downstream of the dam was classified as not supporting its default Aquatic Life designated use.[116] The CTH O tributary was also classified as not supporting its default Aquatic Life designated use.

Watershed Pollutant Loading

At the present time, most pollutants delivered to the Lake and its tributary streams are carried by runoff and wind. No pollutants are known to be deliberately discharged to the Lake and its tributaries through wastewater discharge points. In-Lake processes are another significant contributor to overall phosphorus loads in many lakes and human activity can intensify their contribution.

The Commission estimated probable pollutant loads, in-lake phosphorous concentrations, and the pollutant reduction from conservation practice implementation using a series of pollutant loading models. Model output can help identify pollutants that could impinge upon the Lake health, land uses and land areas responsible for elevated pollutant loads, and suites of conservation practices that help reduce pollutant loads.

Watershed Pollutants and Pollutant Sources

The most common pollutants entering most lakes are excessive sediment and nutrients. Both occur naturally and are important to lake ecology, but both commonly can be related to human activity. Sediment and nutrients contribute to lake aging. Sediment and nutrient loads can greatly increase when humans disturb land cover and runoff patterns through activities such as tilling and construction, both of which typically loosen soil, increase runoff and in turn allow soil to more easily erode and eventually enter streams and lakes. Drain tiles in agricultural fields have also been shown to export nitrogen and phosphorus from the soil subsurface. In contrast, other pollutants such as detergents, oils, and fertilizers, and certain heavy metals were absent in the environment under natural conditions in Southeastern Wisconsin and are \completely attributable to human activity.

Different human land uses contribute differing pollutants to water bodies. For example, phosphorus in rural areas may be correlated with agricultural fertilizers and animal waste delivered to waterbodies through overland runoff. In contrast, in urban areas, phosphorus from lawn fertilizers, lawn clippings, leaves from ornamental plantings, and cleaning agents are often quickly conveyed to water bodies with little opportunity for attenuation. In 2010, the State of Wisconsin placed restrictions on the sale of some phosphorus-containing cleaning agents.[117] The State has also adopted a turf management standard limiting

[116] *A description of the WDNR's designated water conditions as well as the 2022 water condition list can be viewed at dnr.wisconsin.gov/topic/SurfaceWater/ConditionLists.html.*

[117] *Section 100.28 of the* Wisconsin Statutes *bans the sale of cleaning agents for non-household dishwashing machines and medical and surgical equipment that contain more than 8.7 percent phosphorus by weight. This statute also bans the sale of other cleaning agents containing more than 0.5 percent phosphorus by weight. Cleaning agents for industrial processes and cleansing dairy equipment are specifically exempted from these restrictions.*

the application of lawn fertilizers containing phosphorus within the State,[118] potentially helping reduce the amount of phosphorus released from lawns. In both rural and urban areas, poorly maintained or failing onsite wastewater treatment systems have been found to contribute phosphorus to surface water features.

Urban leaf litter and pollen can be a substantial source of phosphorus pollution, particularly in highly developed areas. A study conducted in the Lake Wingra watershed in Dane County found that 55 percent of the total annual residential phosphorus loading occurs during autumn, largely attributable to curbside and street-area leaf litter.[119] Rain falling upon leaves crushed by vehicular traffic leach greater amounts of phosphorus. Runoff then washes the leached phosphorus into the stormwater drainage system that often discharge directly into surface waters. Effectively managing leaves on residential streets can significantly reduce urban phosphorus loading. Preventing leaves from accumulating on the roadway for long periods of time through prompt leaf collection, and especially the timing of that collection from the streets, is a critical part of reducing external phosphorus loading from residential areas. Curbside leaf litter pick up is provided by the City of Delavan to City residents.

Tributary Nutrient Loading

Monitoring and reducing phosphorus and sediment loads to Lake Comus is a major goal of this management plan. Load reduction will eventually improve Lake water quality, reduce nutrient availability for algae and aquatic plants, and increase the effective lifespan of dredging projects. The Commission used water quality monitoring data as well as model output from several sources to estimate phosphorus and sediment loads to Lake Comus as well as sediment accumulation within the Lake.

<u>Sediment</u>

As part of the natural aging process, lake basins gradually fill with sediment. This sediment is primarily derived from the following processes.

- **Sediment carried to a lake by actively flowing water**. Erosion over broad expanses of upland areas is typically the primary sediment source to most lakes. This sediment is generally funneled to lakes through tributary streams. In some cases, general overland flow around a lake and shoreline erosion can also be significant contributors to overall sediment load. Much of the sediment carried to lake basins by moving water is comprised of inorganic gravel, sand, silt, and clay. Lakes with large watersheds, significant land and shoreline disturbance, and large expanses of quiescent water can accumulate copious amounts of sediment each year. Coarser-grained sediments (i.e., silt, sand, and gravel) commonly accumulate near the point where moving water enters a lake. In contrast, portions of a lakes well offshore or otherwise distant from moving water accumulate clay-size sediment. The actual amount of sediment entering lake basins is highly dependent on lake- and watershed-specific factors and weather conditions. Therefore, the amount of sediment carried to a lake by flowing water varies greatly day-to-day and from lake-to lake.

  Lake sediment loads are most often estimated using models. If quantitative sediment information exists, it often is based upon sporadic sampling and may not adequately represent overall sediment load since the amount of sediment carried by flowing water is highly dependent on flow conditions, seasons, and other factors. Furthermore, in most cases, samples quantify only suspended sediment load. Rivers and streams also transport sediment as *bedload*. Bedload is sediment that is too heavy for flowing water to suspend and instead rolls, hops, or otherwise moves at or near the streambed in response to flowing water. Very few studies quantify bedload. However, studies in Wisconsin and nearby states generally suggest that bedload commonly transports a mass of sediment equal to

[118] *On April 14, 2009, 2009 Wisconsin Act 9 created Section 94.643 of the* Wisconsin Statutes *relating to restrictions on the use and sale of fertilizer containing phosphorus in urban areas throughout the State of Wisconsin.*

[119] *Roger Bannerman of the USGS has described the findings of the Lake Wingra study in his presentation entitled* "Urban Phosphorus Loads: Identifying Sources and Evaluating Controls."

between 25 percent and 400 percent of the mass transported as suspended load.[120,121] Therefore, if lake managers are interested in the *total* mass of sediment transported by flowing water to lakes, bedload must be considered.

- **Sediment carried to lakes by wind**. The atmosphere deposits significant amounts of sediment to lakes. Southeastern Wisconsin lakes commonly receive nearly 200 pounds of sediment per acre per year from atmospheric fallout.

- **Sediment formed by geochemical processes within a lake**. In most Southeastern Wisconsin lakes, groundwater entering the lake is "hard" and therefore rich in dissolved carbonate minerals. Some carbonate minerals may come out of solution once in a lake, a process promoted by biochemical processes associated with photosynthesis. The carbonate minerals precipitated from lake water often co-precipitate phosphorus. The mixture of carbonate and phosphate minerals settles to the lake bottom is often termed "marl." Marl deposits are common in Southeastern Wisconsin lakes receiving abundant groundwater discharge. The amount of marl deposited in lakes and marl deposition patterns within lakes vary widely.

- **Sediment originating in a lake comprised of dead plants and animals**. All aquatic plants, algae, diatoms, fish, and other aquatic life eventually die and settle to the lake bottom. When the supply of such material exceeds the ability for material to be decomposed and removed from the lake bottom, organic deposits form. These deposits are commonly termed muck or peat. Muck is deposited throughout lake basins while peat is general confined to riparian wetlands. The amount of these materials deposited within lakes varies widely and is highly dependent upon the level of lake nutrient enrichment.

No USGS gages exist on Turtle Creek upstream of Lake Comus. Therefore, Commission staff were unable to use total phosphorus concentrations with concurrent streamflow measurements to calculate total sediment loads from the Creek to Lake Comus. However, Commission staff were able to gather information on streamflow estimates to provide estimated average summer sediment loads from the Creek to the Lake. The June through September mean streamflow for the portion of Turtle Creek at the Dam Rd monitoring site is 9.4 cfs while the mean streamflow for the CTH O tributary is 2.8 cfs. Using the average sediment concentration of 28.6 mg/L for Turtle Creek at Dam Rd, Turtle Creek contributes an estimated 86 tons of sediment to the Lake between June and September. With the average sediment of concentration of 18.4 mg/L, the CTH O tributary contributes an estimated 16.5 tons of sediment to the Lake between June and September.

<u>Phosphorus</u>

Turtle Creek and its tributaries are major sources of total phosphorus to Lake Comus, as indicated by the watershed water quality monitoring described earlier in this section and the pollutant load modeling described below under the "Simulated Nonpoint Source Loading" subsection. Using the approach described above for sediment, Commission staff estimated average June through September total phosphorus loads to the Lake from Turtle Creek and the CTH O tributary. Estimated total phosphorus loads from Turtle Creek were 1,605 pounds between June and September while loads from the CTH O tributary were 296 pounds.

Legacy Phosphorus and Sediment

Efforts to address pollutant loading within the Lake Comus watershed may be complicated by the presence of legacy phosphorus and sediment. Legacy phosphorus consists of phosphorus that is detained and transported within the watershed. Such phosphorus may be detained in several ways including as particulate phosphorus deposited in sediments on the beds of waterbodies, dissolved phosphorus adsorbed to sediments on the beds of waterbodies, phosphorus contained within the bodies of plants and algae growing within waterbodies, particulate and dissolved phosphorus stored in sediments that are deposited

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[120] *Ladewig, Matthew David,* Sediment Transport Rates in the Lower Muskegon River and Tributaries*, Master of Science Thesis: Department of Natural Resources and Environment, University of Michigan, August 2006.*

[121] *Williams, Garnett P. and David L. Rosgen,* Measured Total Sediment Loads (Suspended Loads and Bedloads) for 93 United States Streams*, United States Geological Survey Open-File Report 89-67, 1989.*

on seasonally inundated floodplains and are subsequently eroded, and phosphorus that has accumulated in soils and groundwater. A major source of legacy phosphorus consists of phosphorus from nutrient or fertilizer applications that is not taken up or used by plants.

Accumulated sediment and legacy phosphorus can reduce a system's capacity to store phosphorus. Legacy phosphorus can be detained and may then be released back into the water through several processes. Examples of these processes include high instream flows returning stored particulate phosphorus to the water column through resuspension of sediment, degradation of organic material in sediment or water releasing stored phosphorus, or changes in chemical conditions in the water column or sediment allowing chemically-bound phosphorus in sediment to enter solution and diffuse into the water. Some release processes may take place over years to centuries. For example, it may take years to decades for concentrations of excess phosphorus stored in agricultural soils to decrease to minimum levels needed to support crops.[122] Because groundwater tends to move slowly, dissolved phosphorus stored or transported in groundwater may take a long time to enter waterbodies in baseflow. Similarly, sediment-bound phosphorus deposited in floodplains might not be remobilized until streambank erosion and channel migration occurs.

When present, legacy phosphorus may obscure measurable benefits yielded by conservation practices.[123] When inputs of phosphorus to a waterbody are reduced, legacy phosphorus released from storage can continue to supply large amounts of phosphorus to the waterbody. This can create a significant time lag between implementation of conservation measures reducing phosphorus loading and the response of the stream. This may result in time lags between reduced phosphorus loading and ecological responses to such reductions. The length of such time lags depends on several factors including the amount, location, and forms of phosphorus and the mechanisms through which legacy phosphorus is released back into waterbodies.

An example of legacy phosphorus issues can be seen in the Yahara watershed which includes the Yahara River and a chain of four lakes near Madison, including Lakes Mendota and Monona, along the River. Several studies show that phosphorus inputs to this watershed are greater than outputs and that the levels of phosphorus in soils are greater than those required by plants and needed to sustain crop yields.[124] One study in the late 1990s estimated it could take decades to centuries for crops to draw soil phosphorus concentrations down to 1974 levels.[125] A more recent phosphorus budget for the Lake Mendota watershed reports that phosphorus inputs to the watershed have likely declined since the mid-1990s but still exceed outputs.[126] Despite considerable nutrient reduction efforts over the past three decades, phosphorus loads to Lake Mendota have not changed.[127] The persistence of loads has been attributed, in part, to the presence of legacy phosphorus.[128]

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[122] *A. Sharpley, H.P. Jarvey, A. Buda, L. May, B. Spears, and P. Kleinman, "Phosphorus Legacy: Overcoming the Effects of Past Management Practices to Mitigate Future Water Quality Impairment,"* Journal of Environmental Quality *42: 1308-1326, 2013.*

[123] *Wisconsin Department of Natural Resources,* Wisconsin's Nonpoint Source Program Management Plan – FFY 2021-2025, *2021.*

[124] *E.M. Bennett, T. Reed-Anderson, J.N. Houser, J.R. Gabriel, and S.R. Carpenter, "A Phosphorus Budget for the Lake Mendota Watershed,"* Ecosystems *2: 69-75, 1999; T. Reed-Anderson, S.R. Carpenter, and R.C. Lathrop, "Phosphorus Flow in a Watershed-Lake Ecosystem,"* Ecosystems *3: 561-573, 2000; E.L. Kara, C. Heimerl, T. Killpack, M.C. Van de Bogert, H. Yoshida, and S.R. Carpenter, "Assessing a Decade of Phosphorus Management in Lake Mendota, Wisconsin Watershed and Scenarios for Enhanced Phosphorus Management,"* Aquatic Sciences *74: 241-253, 2012.*

[125] *Bennett and others, 1999,* op. cit.

[126] *Kara and others, 2011,* op. cit.

[127] *R.C. Lathrop and S.R. Carpenter, "Water Quality Implications from Three Decades of Phosphorus Loads and Trophic Dynamics in the Yahara Chain of Lakes,"* Inland Waters *4: 1-14, 2013.*

[128] *A.R. Rissman and S.R. Carpenter, "Progress on Nonpoint Pollution: Barriers & Opportunities,"* Daedalus *144: 34-47, 2015; S. Gillon, E.B. Booth, and A.R. Rissman, "Shifting Drivers and Static Baseline in Environmental Governance: Challenges for Improving and Proving Water Quality Outcomes,"* Regional Environmental Change *16: 759-775, 2016.*

The phosphorus content of sediment in Turtle Creek and Lake Comus has rarely been assessed. As part of the preparation for dredging, sediment samples were collected from six sites in Lake Comus with chemical analyses discussed in the 1980 Lake Comus Management Plan.[129] Phosphorus concentrations in the sediment ranged from 43.4 to 817 mg/kg dry weight, indicating that the lake-bottom sediment was quite organic and phosphorus-rich. A sediment settling analysis conducted as part of this plan showed that it took eight days for enough sediment to settle to produce "clear" supernatant water, and that even in the "clear" water that concentrations of total phosphorus (0.18 to 0.29 mg/L) still exceeded water quality standards. If the current sediment and soils within the watershed are similarly rich in phosphorus, the substantial amount of sediment stored along Turtle Creek's streambed and bed of the Lake Comus suggest that a considerable amount of legacy phosphorus and sediment may affect conditions in the Creek and Lake. If this is the case, it is likely that there will be a significant time delay between reduced phosphorus loading to waterbodies of the watershed and response of the Lake's trophic state. While the lengths of these time lags are not certain, it is possible that they may be on the order of several decades.

Simulated Nonpoint Source Loading

<u>Historic Estimates of Soil Loss</u>

Using the Universal Soil Loss Equation (USLE), the WNDR estimated 18,319 tons of soil erosion per year within the Lake Comus watershed.[130] Approximately 98 percent of this soil erosion was estimated to come from cropland, while pasture and woodlands made up the balance. Croplands were estimated to lose 6.7 tons per acre per year. It is important to note that the USLE does not estimate soil loss from commercial, residential, or wetland land uses, so the estimated soil loss does not include these acreages. Muck farming, which was a common practice within the watershed, is particularly susceptible to wind erosion if the fine organic soils dry out. The Turtle Watershed Priority Plan indicated that wind erosion control practices should be installed with the Lake Comus watershed, as it is particularly susceptible to wind erosion problems.

<u>Current Pollutant Loading Estimates</u>

Phosphorus and total suspended sediment loads to the Upper Turtle Creek watershed were estimated as part of the 2011 Rock River Total Maximum Daily Load (TMDL). As part of the TMDL, nonpoint source phosphorus and sediment loads from agricultural and natural areas were modeled using the Soil & Water Assessment Tool (SWAT). The SWAT model used climatic information, topography, streamflow, soil types, land use, cropping and tillage practices, and crop yields to estimate pollutant loads. The Upper Turtle Creek watershed, which includes the Lake Comus watershed as well as lands tributary to Swan Creek and Turtle Creek downstream to the Rock-Walworth County border, has an estimated baseline total phosphorus load of between 2,000 to 4,000 pounds per year and a total suspended sediment load of between 300 to 600 tons per year. On a per-acre basis, the estimates were between 0.03 to 0.10 pounds of total phosphorus per acre per year and less than or equal to 0.02 tons of total suspended sediment per acre per year. If these per-acre estimates are extrapolated to the 21,009-acre Lake Comus watershed, the total loading to Lake Comus would be between 630 and 2,101 pounds of total phosphorus per year and between 21 and 420 tons of total suspended sediment per year.

The Commission simulated nonpoint source pollutant loads for suspended solids (sediment) and total phosphorus to the Lake using two land-use based models. One simulation used the Wisconsin Lake Model Spreadsheet (WiLMS version 3.3.18) while the other used the Commission's unit area load-based (UAL) model developed for the Southeastern Wisconsin Region. These two models assume that a given land use type emits a set rate of pollutants on an annual basis.

The Commission's 2015 land use data was used with a unit area load-based (UAL) model to estimate historical and present-day phosphorus and sediment loads across the Lake's watershed. The UAL model estimates that 3,283 tons of suspended sediment and 12,870 pounds of total phosphorus are currently delivered the Lake each year from surface runoff using year 2015 land use conditions (Table 2.17). These values represent a 45-fold increase in phosphorus loading and 10-fold increase in sediment delivered to the Lake compared to natural conditions. Agricultural land uses are the major sediment and phosphorus sources, contributing 98 percent of the sediment and 94 percent of the phosphorus reaching the Lake.

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[129] *Donohue & Associates, 1980,* op. cit.

[130] *Turtle Creek Priority Watershed Plan, 1984,* op. cit.

Table 2.17
Estimated Annual Land Use Pollutant Loads in the Lake Comus Watershed: Pre-settlement and 2015 Land Use

Land Use Category	Pollutant Loads: Pre-settlement		Pollutant Loads: 2015 Land Use	
	Sediment (tons)	Phosphorus (pounds)	Sediment (tons)	Phosphorus (pounds)
Urban				
Residential	0	0	18.0	183.8
Commercial	0	0	15.3	47.0
Industrial	0	0	23.3	72.4
Governmental	0	0	14.0	74.0
Transportation	0	0	2.9	67.2
Recreational	0	0	0.4	8.9
Urban Subtotal	0	0	73.9	453.2
Rural				
Agricultural	0	0	3,166.8	12,104.1
Open Lands	18.1	420.2	4.1	95.6
Wetlands	9.4	202.6	5.4	117.6
Woodlands	22.2	481.1	2.5	53.4
Water	21.5	29.7	30.6	25.3
Rural Subtotal	71.3	1,133.6	3,209.4	12,413.1
Total	71.3	1,133.6	3,283.3	12,866.3

Source: SEWRPC

To help identify areas of the watershed with higher pollutant loading, Commission staff subdivided the watershed into subbasins using topographical and hydrological information and then calculated the total phosphorus loading per acre in each subbasin from the UAL model output. The CTH O Tributary had highest total phosphorus loading per acre, followed by the Upper Turtle Creek, Turtle Valley Headwaters, and CTH P Tributary subbasins (Map 2.21). The lake-direct subbasins of Turtle Lake and Lake Comus had the lowest total phosphorus loading per acre.

Commission staff also estimated phosphorus loading to the Lake using WiLMS, which incorporates land use, hydrologic, and watershed area information to simulate the total flux of phosphorus during a typical year.[131] Load estimates from WiLMS were then used to predict water quality in the receiving lake using several regression equations. The regression equations have been designed to fit a variety of lake types. For example, some are designed for reservoirs, some for deep lakes, while others are general lake models. The Vollenweider Shallow Lake and Reservoir model was utilized to model Lake Comus total phosphorus concentrations based on the WiLMS-derived total phosphorus loading. For 2015 land use conditions, the WiLMS model predicts 13,993 pounds of phosphorus are delivered to the Lake per year, a value similar to that estimated by the Commission's UAL model. Cultivated crop lands contribute approximately 84 percent of the total phosphorus load. With these loading estimates, the modeled total phosphorus concentration of the Lake is 0.155 mg/l, which is three percent higher than the observed mean growing season total phosphorus concentration of 0.150 mg/l from 2015 to 2021. This suggests that the Vollenweider model may be a useful tool to estimate the affect of phosphorus load reduction programs on Lake water quality.

Pollutant Load Reduction via Best Management Practices

To estimate how much pollutant loads could be reduced via best management practices (BMPs) within the Lake Comus watershed, a separate USEPA Spreadsheet Tool for Estimating Pollutant Load (STEPL) model was applied under this study.[132] STEPL employs simple algorithms to calculate nutrient and sediment loads from different land uses and the load reductions that would result from the implementation of various BMPs. STEPL provides a user-friendly Visual Basic interface to create a customized spreadsheet-based

[131] *These models do not account for groundwater influx and exit from the lake. Models can be manipulated to include this variable if sufficient interest is expressed by lake users and managers as part of a future study. Including groundwater in future models may not necessarily improve the accuracy of the models but will account for and potentially eliminate a currently untested variable from the simulation process.*

[132] *For more information on STEPL, see www.epa.gov/nps/spreadsheet-tool-estimating-pollutant-loads-stepl.*

model in Microsoft Excel. It computes watershed surface runoff; nutrient loads, including total nitrogen, phosphorus, and 5-day biological oxygen demand; and sediment delivery based on various land uses and management practices. The annual nutrient loading was calculated based on the runoff volume and runoff water pollutant concentrations as influenced by factors such as land use distribution and management practices. The annual sediment load (sheet and rill erosion only) is calculated based on the Universal Soil Loss Equation and the sediment delivery ratio. The sediment and pollutant load reductions resulting from the implementation of BMPs are computed using generalized BMP efficiencies.

Commission staff initialized the STEPL model using US EPA parameters defined for the Headwaters Turtle Creek watershed. Present-day watershed BMP coverage estimates of 75 percent conservation tillage, 50 percent nutrient management plans, 10 percent no tillage, and 5 percent cover crops were provided by Walworth County Land Use & Resource Management (LURM) staff.[133] For the purposes of the STEPL modeling exercise, any agricultural lands utilizing no tillage practices or cover crops were also assumed to be under a nutrient management plan. The remainder of the lands under nutrient management plans were assumed to be using conservation tillage. Additionally, LURM staff provided the numbers of animal operations within the watershed as well as the number of animals and housing type for each of these operations. These numbers were also used as input for the total loading in the STEPL model.

Without any BMPs implemented, Commission staff estimate an annual load of 32,423 pounds of phosphorus, 87,689 pounds of nitrogen, and 8,221 tons of sediment to Lake Comus from its watershed. Under the current estimated BMP coverage, the model outputs an estimated annual load of 22,034 pounds of phosphorus, 70,737 pounds of nitrogen, and 5,435 tons of sediment. Thus, the BMPs already implemented in the watershed are reducing nonpoint source pollutant loads by 32 percent for phosphorus, 19 percent for nitrogen, and 34 percent for sediment compared to modeled conditions without any BMPs implemented. With the BMPs implemented, cultivated croplands account for 79.9 percent of the phosphorus loads, 65.8 percent of the nitrogen loads, and 95.5 percent of the sediment loads to the Lake. Urban lands account for 7.4 percent of the phosphorus loads, 14.0 of the nitrogen loads, and 4.4 of the sediment loads. Animal operations account for 11.2 percent of the phosphorus loads, 17.5 percent of the nitrogen loads, and zero percent of the sediment loads. All other sources (pastures, forest, and septic systems) combined account for the remaining 1.5 percent of the phosphorus loads, 10.0 percent of the nitrogen loads, and 2.7 percent of the sediment loads.

Pollution Mitigation Strategies

Properly implemented pollution mitigation strategies, such as employing appropriate agricultural conservation practices, restoring wetlands, minimizing shoreline erosion, and creating riparian buffers, reduce pollutant loading into lakes and streams. This subsection discusses these strategies and implementation concepts for the Lake Comus watershed.

Modeled Load Reduction via Conservation Practices

Using the STEPL model described above, Commission staff simulated several scenarios in which conservation practices were employed that further reduce pollutant loading were applied to the Lake's watershed. The goal of these scenarios was to estimate the acreage of conservation practices necessary to achieve the 49 percent total phosphorus reduction for nonpoint source loading set by the Rock River TMDL. The practices with the highest modeled phosphorus reduction that can be implemented on the greatest number of acres are nutrient management plans, no-till, and cover crops. Other practices with high phosphorus reduction potential, such are buffer strips, terracing, and contour farming, can only be applied in limited areas such as along streambanks, the edge of fields, and on highly sloped fields. Conservation practices are more effective in series (e.g., a field with no-till surrounded by a 35 foot grass buffer) than in parallel (e.g., a no-till field with no buffer next to a tilled field with a buffer). Combining multiple BMPs on cultivated fields throughout the watershed was the most effective strategy for reducing total phosphorus loads to the Creek and the Lake in the Commission's STEPL modeling exercises.

Since 75 percent of the watershed's agricultural lands are already estimated to be utilizing conservation tillage, incorporating additional conservation practices on these agricultural fields such as nutrient management plans, cover crops, and/or grass buffers along the field edges would most effectively reduce nonpoint

[133] *Personal communication between Brian Smetana, Walworth County Land Use & Resource Management, and Commission staff (Justin Poinsatte), on May 4th, 2021.*

source loading in the watershed. For example, implementing cover crop programs on approximately 80 percent of the watershed's cultivated farmlands that are currently using conservation tillage practices would meet the phosphorus reduction goal. Implementing no-till practices in agricultural fields that are currently using conventional or conservation tillage would also greatly reduce the total phosphorus and sediment loading to surface waters as well as promoting soil health in these fields. Ensuring that all agricultural lands are under a nutrient management plan would reduce operator input costs while minimizing surplus nutrient loss to surface and ground waters. While many combinations of BMP application would achieve the phosphorus reduction goals for the watershed set by the Rock River TMDL, a simple approach to achieve TMDL compliance involves enrolling all the watershed's agricultural lands under nutrient management plans while maintaining conservation tillage, no till, and cover crops where already implemented. Any further increase in the use of these other practices would exceed the Rock River TMDL phosphorus reduction goal and further benefit water quality in the Creek and Lake. Another concept that could achieve TMDL goals would be to retire select agricultural production areas and naturalize vegetation and hydrology in these areas. These two examples could be used alone or together. Opportunities for the LCPRD and other entities in the watershed to support adoption of these practices are discussed in Chapter 3.

Reducing Erosion Through Shoreline Protection

Some property owners abutting Lake Comus are concerned with jointly maintaining the Lake's shorelines, promoting recreational use, and furthering aesthetic appeal without jeopardizing Lake health. This issue of concern is further emphasized by the fact that water quality, sedimentation, and aquatic plant growth can all be affected by shoreline maintenance practices.

Before discussing shoreline characteristics, it is important to understand the difference between two terms: *shoreline protection* and *buffers.*

- *Shoreline protection* encompasses various measures—engineered or natural—that shield the immediate shoreline (water-land interface) from the erosive forces of wave action

- *Buffers* are areas of plant growth—engineered or natural—in the riparian zone (lands immediately back from the shoreline) that trap sediment and nutrients emanating from upland and nearshore erosion

"Hard" engineered seawalls of stone, riprap, concrete, timbers, and steel, once considered "state-of-the-art" shoreline protection, are not the sole way to protect to protect a shoreline from excessive erosion and often do little to promote lake water quality, wildlife, recreational opportunities, and scenic beauty. Indeed, the inability of hard shorelines to absorb wave energy can reflect that energy back into a lake, increasing wave energy in other portions of a lake. Manmade "hard" options available to homeowners include: "bulkheads," where a solid *vertical* wall of erosion-resistant material (e.g., poured concrete, steel, or timber) is erected; "revetments," where a solid, *sloping* wall (usually asphalt, as in the case of a roadway, or poured concrete) is installed; "riprap," where loose stone material is placed along the shoreline. These options are only available with a WDNR permit.

"Soft" shoreline protection techniques, such as vegetated shoreline protection, are increasingly required pursuant to *Wisconsin Administrative Code* Chapter NR 328, "Shore Erosion Control Structures In Navigable Waterways." These techniques include natural shoreline, native planting, promoting aquatic plants along shorelines, and "fish sticks" (Figure 2.36). Vegetative shoreline protection is becoming more popular as people living along lakes and streams become increasingly aware of the value of protecting their shorelines, improving overall aesthetic appeal of their shoreline, and promoting natural and nature-like habitat for both terrestrial and aquatic wildlife. Additionally, shorelines protected with vegetation help shield a lake from both land-based and shoreline pollution and sediment deposition**.** These "soft" techniques can be incorporated with "hard" shoreline protection in order to reduce erosion, mitigate pollutant loading, and improve aquatic habitat. Examples of techniques that incorporate "hard" and "soft" techniques into "living" shorelines are presented in Appendix A.[134]

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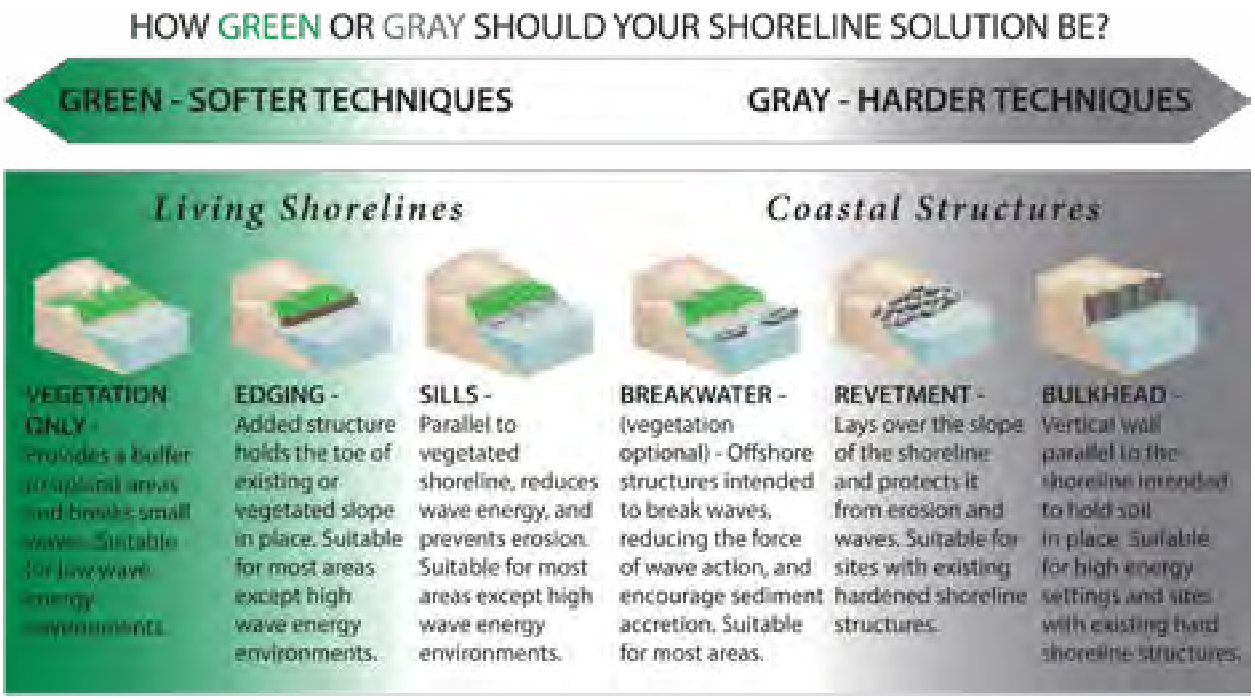
[134] *For more information on "living" shorelines, see www.habitatblueprint.noaa.gov/wp-content/uploads/2018/01/NOAA-Guidance-for-Considering-the-Use-of-Living-Shorelines_2015.pdf.*

Figure 2.36
"Green" vs. "Gray" Shoreline Protection Techniques



Given the broad benefits of "soft" shoreline protection measures, the WDNR no longer grants permits for construction of new "hard" structures in lakes that do not have intensive wave action threatening the shoreline, although existing structures may be repaired. Consequently, the recommendations in this plan related to shoreline restoration focus on "soft," vegetative shoreline protection measures. Beach areas, which by law need to be made from pea gravel,[135] are considered as a separate category. Placing pea gravel may be permitted; however, this must be evaluated by WDNR on a case-by-case basis.

It should be emphasized that shoreline protection need not always rely on manufactured, engineered structures. Many types of natural shoreline offer substantial protection against erosive force. For example, the boulders and rock cliffs found along Lake Superior function as natural riprap or bulkheads checking excessive shoreline erosion. Additionally, marshlands containing areas of exposed cattail stalks and lily pads effectively mitigate shoreline erosive forces as exposed marshland plant stalks disperse and dampen waves and dissipate energy.

Lake Shoreline Survey

Lake residents, the LCPRD, and the City of Delavan have expressed concern over eroding shorelines, particularly along the southern shore of the Lake and along the Paul Lange Arboretum.[136,137] In 2018, concerned lake residents contacted the City of Delavan regarding shoreline erosion that was thought to potentially threaten an existing sewer line. In response, the City of Delavan instructed Baxter & Woodman, a private consulting firm, to review shoreline conditions and review the 1968 sewer engineering plans. The firm established that while there was some evidence of erosion but there was no threat to the sanitary sewer from shoreline erosion at that time.[138] The Paul Lange Arboretum is sited atop the former City of Delavan dump from the 1930s, causing concern that the Arboretum shoreline erosion could expose the

[135] *WDNR does not permit the use of sand because these materials quickly flow into a waterbody and contribute to the "fill-in" of the Lake.*

[136] *Mark Wendorf,* Sanitary Sewer Along the South Shoreline of Lake Comus, *City of Delavan Memorandum, June 2018.*

[137] *Mark Wendorf and Tom Klug,* Options for Arboretum Shoreline Erosion Control, *City of Delavan Memorandum, February 2021.*

[138] *Gary E Vogel, P.E., and Thomas Ganfield,* Comus Lake Shoreline Assessment, *Baxter and Woodman, Consulting Engineers, September 2018.*

Lake to materials buried within the former dump.[139] In the 1990s, the City of Delavan received a WDNR grant to place bio-logs in the nearshore area to protect the Arboretum's shorelines from erosion. As of 2021, the bio-log installation had become worn down and erosion of up to six feet was noted since bio-log installation.[140]

Commission staff surveyed Lake shoreline conditions during 2019 (Map 2.22). Compared to the average lake in Southeastern Wisconsin, Lake Comus' shoreline has relatively little development and is very well-buffered by natural vegetation. Over three-quarters of Lake Comus' shoreline is protected by undeveloped wetland that extends along much of the western, northern, and eastern shores. Several fallen trees remain in the near-shore areas of the Lake. These trees are benefit the Lake by protecting shorelines from wave erosion and also provide woody habitat for aquatic organisms. The most developed shorelines are along the residential lots on the southern shore, the western shore along North Terrace Street, and portions of the Paul Lange Arboretum. Riprap has been placed along much of these developed shorelines with some cattails growing in the Lake providing additional protection from wave erosion. However, approximately 2,200 linear feet across all three areas have little to no shoreline protection, with mowed grass down to the water's edge. These more developed areas also had more evident signs of erosion in the Commission's 2019 survey than did the shorelines along the northern three-quarters of the Lake. Commission staff also observed localized erosion during an August 2021 visit at the southeastern corner of the Lake along North Terrace Street, with vegetation and soil sliding into the Lake.

In addition to the on-the-water shoreline survey, Commission staff also investigated whether shoreline recession was visible through aerial imagery by comparing 2005 and 2020 aerial photos of the Lake as well visual observation during field visits (Figure 2.37). The northern shoreline along the Paul Lange Arboretum appeared to show substantial shoreline recession, particularly in the wetlands just northeast of the eastern extent of the Arboretum path. In contrast, the southern shoreline did not show substantial shoreline recession or erosion and maintained relatively consistent shorelines since the earliest aerial imagery in 1940. Recommendations to enhance shoreline protection efforts are presented in Section 3.7, "Recreational Use and Facilities."

Riparian Corridor Conditions

Healthy riparian corridors help protect water quality, groundwater, fisheries and wildlife, and ecological resilience to invasive species, and can reduce potential flooding of structures and harmful effects of climate change.[141] The health of riparian corridors is largely dependent upon width, connectivity, and continuity. Therefore, efforts to protect and expand remaining riparian corridor width, connect them to waterbodies, and promote habitat continuity are foundational to protecting and improving Lake Comus' fishery, wildlife, and recreational value.

Riparian buffers are areas of plant growth – constructed or natural – in the *riparian zone* (those lands immediately back from the shoreline) that trap sediment and nutrients emanating from upland and nearshore erosion. Providing buffer strips along waterways represents an important intervention that addresses anthropogenic sources of contaminants. Even relatively small buffer strips provide a degree of environmental benefit, as suggested in Table 2.18 and Figure 2.38.[142,143]

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[139] *Mark Wendorf and Tom Klug, 2021,* op cit.

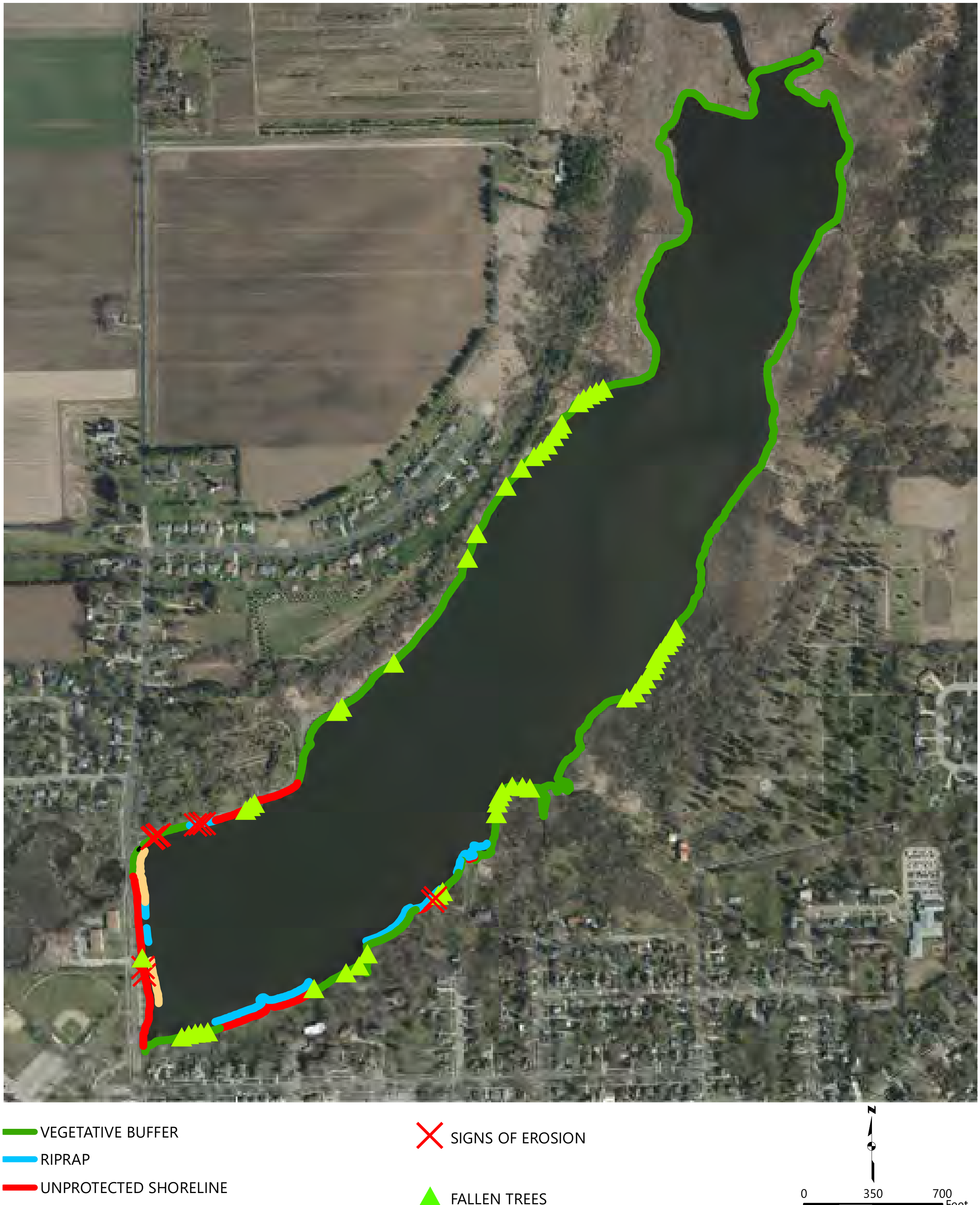
[140] Ibid.

[141] *N.E. Seavy, et al., "Why Climate Change Makes Riparian Restoration More Important than Ever: Recommendations for Practice and Research,"* Ecological Restoration*, 27(3): 330-338, 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.*

[142] *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.*

[143] *See www.sewrpc.org/SEWRPCFiles/Publications/ppr/rbmg-001-managing-the-waters-edge.pdf.*

Map 2.22
Shoreline Characteristics and Existing Buffers Along Comus Lake: 2019



Source: SEWRPC
Date of Photography: April 2015

Figure 2.37
Shoreline Recession along the Paul Lange Arboretum

Source: SEWRPC

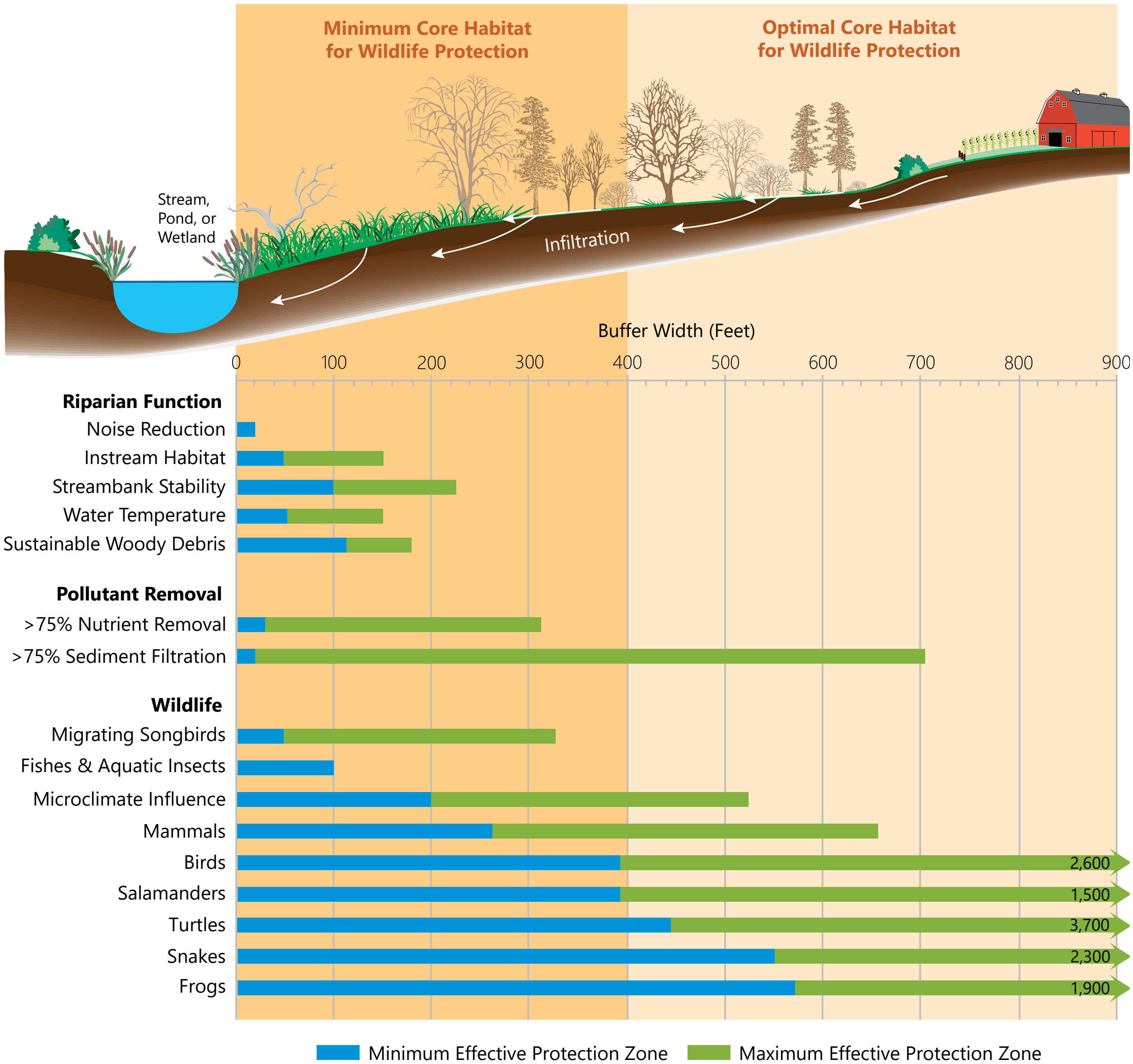
Table 2.18
Effect of Buffer Width on Contaminant Removal

Buffer Width Categories (feet)	Contaminant Removal Efficiency (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] *Removal efficiency measured in surface runoff.*

Source: University of Rhode Island Sea Grant Program

Figure 2.38
Buffer Widths Providing Specific Conservation Functions



Source: SEWRPC

The Wisconsin Buffer Initiative (WBI) further developed two key concepts 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.[144] However, it is important to note that the WBI limited its assessment and recommendations solely to protecting water quality and did not consider the additional values and benefits provided by riparian buffers. Research clearly shows that riparian buffers can have many potential benefits, such as mitigating floods, preventing channel erosion, providing fish and wildlife habitat, enhancing environmental corridors, and moderating water temperature. However, the nature of the benefits and the extent to which the benefits are achieved is site-specific. Consequently, the ranges in buffer width for each of the buffer functions shown in Figure 2.38 are large. Buffer widths should be based on desired functions, as well as site conditions. For example, based upon several sediment removal studies, buffer widths ranging from about 25 to nearly 200 feet achieved removal efficiencies between 33 and 92 percent, depending upon local site differences such as soil type, slope, vegetation, contributing area, and

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

influent concentrations. Figure 2.38 shows that for any particular buffer width (for example 75 feet), the buffer can provide multiple benefits, ranging from moderating water temperature to enhancing wildlife species diversity. Benefits not shown in the figure include bank stabilization, which is an important concept in utilizing buffers for habitat protection.

While it is clear from 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 protecting and preserving groundwater recharge or wildlife species. Riparian buffer strips greater than 75 feet in width provide significant additional physical protection of streams, owing to their function in intercepting sediment and other contaminants mobilized from the land surface as a result of natural and anthropogenic activities. These wider buffers help sustain groundwater recharge and discharge relationships and attendant ecological benefits as a result of the habitat available within the shoreline and littoral areas associated with streams and lakes.[145]

Healthy and sustained aquatic and terrestrial wildlife diversity depends upon adequate riparian buffer width and habitat diversity. Specifically, recent research found that wildlife species protection is determined by the preservation or protection of core habitat within riparian buffers with widths ranging from a minimum of 400 feet to an optimal 900 feet or greater. These buffer areas are essential for supporting healthy populations of multiple groups of organisms, including birds, amphibians, mammals, reptiles, and insects and their various life stages. For example, some species of birds, amphibians, turtles, snakes, and frogs have been found to need buffer widths as great as 2,300 feet, 1,500 feet, 3,700 feet, 2,300 feet, and 1,900 feet, respectively, for at least part of their life histories. Hence, preserving riparian buffers to widths of up to 1,000 feet or greater represents the optimal condition for protecting wildlife in the Lake Comus watershed.[146]

Maps 2.11 and 2.17 show the major natural upland and wetland cover types, respectively, both within and outside of the existing riparian buffers distributed throughout the Lake Comus watershed. This inventory shows that the riparian buffers are comprised of a variety of wetland (emergent/wet meadow, flats, forested, and scrub/shrub) and upland (brush, grassland, upland conifer, and deciduous) vegetative communities. Each of these habitats is necessary to support the life history requirements of multiple wildlife species. For example, amphibians and reptiles utilize numerous habitat types that include seasonal (ephemeral) wetlands, permanent wetlands (lakes, ponds, and marshes), wet meadows, bogs, fens, small and large streams, springs and seeps, hardwood forest, coniferous forest, woodlands, savannahs, grasslands, and prairies.[147] Hence, this mosaic of habitats and the ability of organisms to travel between them at the correct times in their lives allows them to survive, grow, and reproduce, which is essential to support an abundant and diverse wildlife community throughout this watershed.

Development patterns and infrastructure that humans create on the landscape often creates obstacles that limit both the availability of wildlife habitat as well as the ability for organisms to travel between habitats. These obstacles are created by roadways, railways, and buildings that fragment the natural landscape. Therefore, an effective management strategy to protect wildlife abundance and diversity in the Lake Comus watershed would be to maximize critical linkages between landscape habitat areas ensuring the ability of species to access a variety of areas. Examples of critical linkages include the following:

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[145] *See, for example, B.M. Weigel, E.E. Emmons, J.S. Stewart, and R. 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*.

[146] *The 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 this concept and to avoid confusion, the optimum buffer width for wildlife protection is defined as extending 1,000 feet from the ordinary high water mark on both sides of the lakes, ponds, and navigable streams in the watershed.*

[147] *B.A. Kingsbury and J. Gibson (eds.),* Habitat Management Guidelines for Amphibians and Reptiles of the Midwestern United States, *Partners in Amphibian and Reptile Conservation Technical Publication HMG-1, 2nd Edition, 2012.*

- Water's edge (lake, pond, river, wetland) to terrestrial landscapes (i.e., riparian buffer width)
- Water's edge to water's edge (e.g., river to ephemeral pond, lake to ephemeral pond, permanent pond to ephemeral pond)
- Habitat complexes or embedded habitats-wetland to upland (e.g., seep to prairie) and upland to upland (e.g., grassland to woodland)

In addition, connecting the secondary environmental corridor lands and multiple isolated natural resource areas throughout the Lake Comus watershed to the larger primary environmental corridor areas, as well as building and expanding upon the existing protected lands, represent sound approaches to enhancing the corridor system and wildlife areas within the watershed.

Potential Restorable Wetlands

Wetlands benefit water quality, provide important wildlife habitat, help mitigate floods, are often important groundwater recharge or discharge areas, and provide a multitude of other functions critical to ecological integrity and human wellbeing. According to the USEPA, a typical one-acre wetland can store about one million gallons of water.[148] Restoring wetlands can increase a watershed's floodwater detention capacity and can reduce sediment and phosphorus loading to surface water. Establishing restored wetlands, particularly as riparian buffers, can help reduce pollution loads from drain tile outlets, barnyards, and upland runoff. Restored wetlands are commonly established in areas where excessively wet soils and/or flooding diminishes crop yields and complicates crop establishment and harvesting. Although modeling load reductions associated with wetland restorations was beyond the scope of this study, constructed wetlands have been reported to reduce median pollutant loads by 73 percent for total suspended solids, 38 percent for total phosphorus, 69 percent for particulate phosphorus, 30 percent for total nitrogen, 70 percent for metals (zinc and copper), 60 percent for bacteria, and 80 percent for hydrocarbons.[149]

Hydric soils are a type of soil that is considered to be characteristic of wetlands. Hydric soils form under settings where sediment is saturated for long enough periods of time to change in the soil properties. These unique soils and growing conditions foster a suite of plant species that thrive in wet, oxygen-deprived soil. Most wetlands remaining in the Lake Comus watershed lie adjacent to Turtle Creek and its tributaries. Wetlands currently cover roughly 15 percent of the Lake Comus watershed. This is above the standard of 10 percent established by Environment Canada for the minimum recommended level of wetland area needed to provide protection to major watersheds. Despite being above this minimum wetland standard, Turtle Creek and Lake Comus are still exceeding surface water quality standards for total phosphorus concentrations due to high nonpoint source loading rates, as described earlier in this section. Restoring additional wetland areas may help address nonpoint source soil erosion and associated pollutant load reductions.

Map 2.23 illustrates the location of the 1,287 acres of potentially restorable wetlands within the Lake Comus watershed. Most of these potentially restorable wetlands are located adjacent to the channelized upper reaches of Turtle Creek as well as in the headwater areas of the CTH O tributary of Turtle Creek. Potentially restorable wetland areas are also suitable candidate sites for constructed floodplain benches associated with re-meandering ditched reaches within the Lake tributary network and/or opportunities to modify tile drainage to reduce pollution loads. Therefore, any potential restorable wetland areas located within the existing floodplain boundary would be a high priority for conversion to wetland because their location facilitates multiple benefits and yields a higher level of protection to reduce the pollutant load entering Lake Comus. Onsite evaluation of potential wetland restoration sites will be necessary prior to design and implementation.

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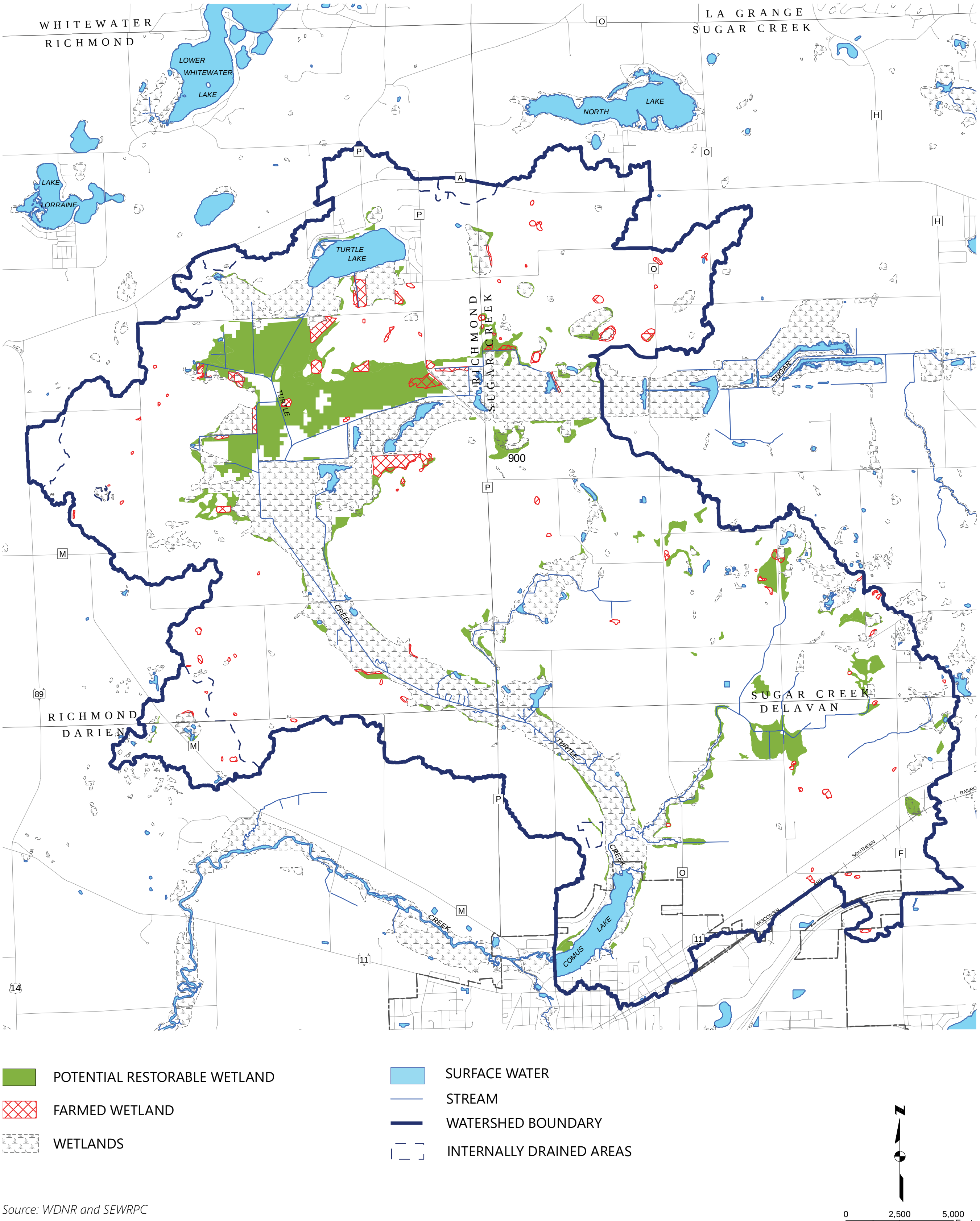
[148] *U.S. Environmental Protection Agency (USEPA),* Wetlands: Protecting Life and Property from Flooding*, May 2006, USEPA843-F-06-001, Website: water.epa.gov/type/wetlands/outreach/upload/Flooding.pdf.*

[149] *Minnesota Pollution Control Agency, Minnesota Stormwater Manual website, stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs.*

Map 2.23
Potentially Restorable and Farmed Wetlands Within the Comus Lake Watershed



Source: WDNR and SEWRPC

Wetlands by Design is a planning tool designed collaboratively by the WDNR and The Nature Conservancy that can be used to help prioritize decisions regarding wetland conservation and restoration. This tool provides information on ecosystem services provided by wetlands.[150,151] Individual wetland areas, as delineated using multiple statewide datasets, are ranked according to their capacity to provide flood abatement, fish and aquatic habitat, phosphorus and sediment retention, nitrogen reduction, surface water supply, shoreline protection, carbon storage, and floristic integrity. Additionally, potentially restorable wetlands are also ranked for their potential to provide these services as well as the feasibility of restoring these areas back into wetlands based on current land use and invasive species presence. Finally, this tool also indicates the type of wildlife habitat that existing wetlands currently provide. Within the Lake Comus watershed, the wetlands adjacent to Turtle Creek extending from Island Road to Lake Comus as well as within the Turtle Valley Wildlife Area ranked highly for flood abatement, fish and aquatic habitat, sediment retention, and nitrogen reduction. The wetlands upstream of CTH P rank highly for phosphorus reduction while the wetlands near and adjacent to Lake Comus rank very high for shoreline protection. This wetland corridor ranks high or moderate for floristic integrity, presumably due to the extensive cattail marsh present in this area.

Existing and Potential Riparian Buffers

Map 2.24 shows the current status of existing and potential riparian buffers at the 75-foot, 400-foot, and 1,000-foot widths along Lake Comus, Turtle Creek, and their tributary streams. Buffers were primarily developed from 2020 digital orthophotographs and the 2015 WDNR Wisconsin Wetland Inventory, and from Commission inventories of PECs, SECs, and INRAs. Polygons were created using geographic information system (GIS) techniques to delineate contiguous natural lands (i.e., non-urban and non-agricultural lands) comprised of wetland, woodland, and other open lands adjacent to waterbodies. Those lands comprise a total of about 4,084 acres, or 20 percent, of the total land area (not including water area) within the Lake Comus watershed.

The most extensive existing buffers were found along the eastern shore of Lake Comus as well as riparian areas adjacent to the Turtle Creek mainstem and the Creek tributary draining the Turtle Valley Wildlife Area. Existing riparian buffer extends to 1,000 feet and beyond throughout much of these areas, providing the comprehensive protection to waterways. The highest quality environmental corridors, natural areas, and vegetation communities are located within and adjacent to the riparian buffer network throughout the Lake Comus watershed (Map 2.18). Riparian buffers are a vital conservation tool providing connectivity among landscapes improving viability of wildlife populations within the habitats comprising the primary and secondary environmental corridors and isolated natural resource areas.[152]

The western and southern shorelines of Lake Comus, the upper reaches of Turtle Creek, and much of the CTH O tributary have rather limited and narrow existing buffers. These narrow buffers likely provide insufficient protection to these waterways (Map 2.24). Some of these areas have the potential to expand riparian buffers to 1,000 feet based on existing land use but current buffers in these areas do not even extend 75 feet from waterways. There are 179 acres, 1,304 acres, and 2,597 acres of potential buffer within 75 feet, 400 feet, and 1,000 feet of waterways, respectively, within the Lake Comus watershed. These areas present the best opportunities to enhance the riparian buffer network to protect water quality and wildlife while reducing pollutant loading in the watershed, particularly since several of the areas are suspected of contributing to higher total phosphorus concentrations in the Creek and its tributaries. Even extending riparian buffers to 75 feet in these areas can help reduce phosphorus and sediment loading and enhance habitat for aquatic organisms and migrating songbirds (Figure 2.38).

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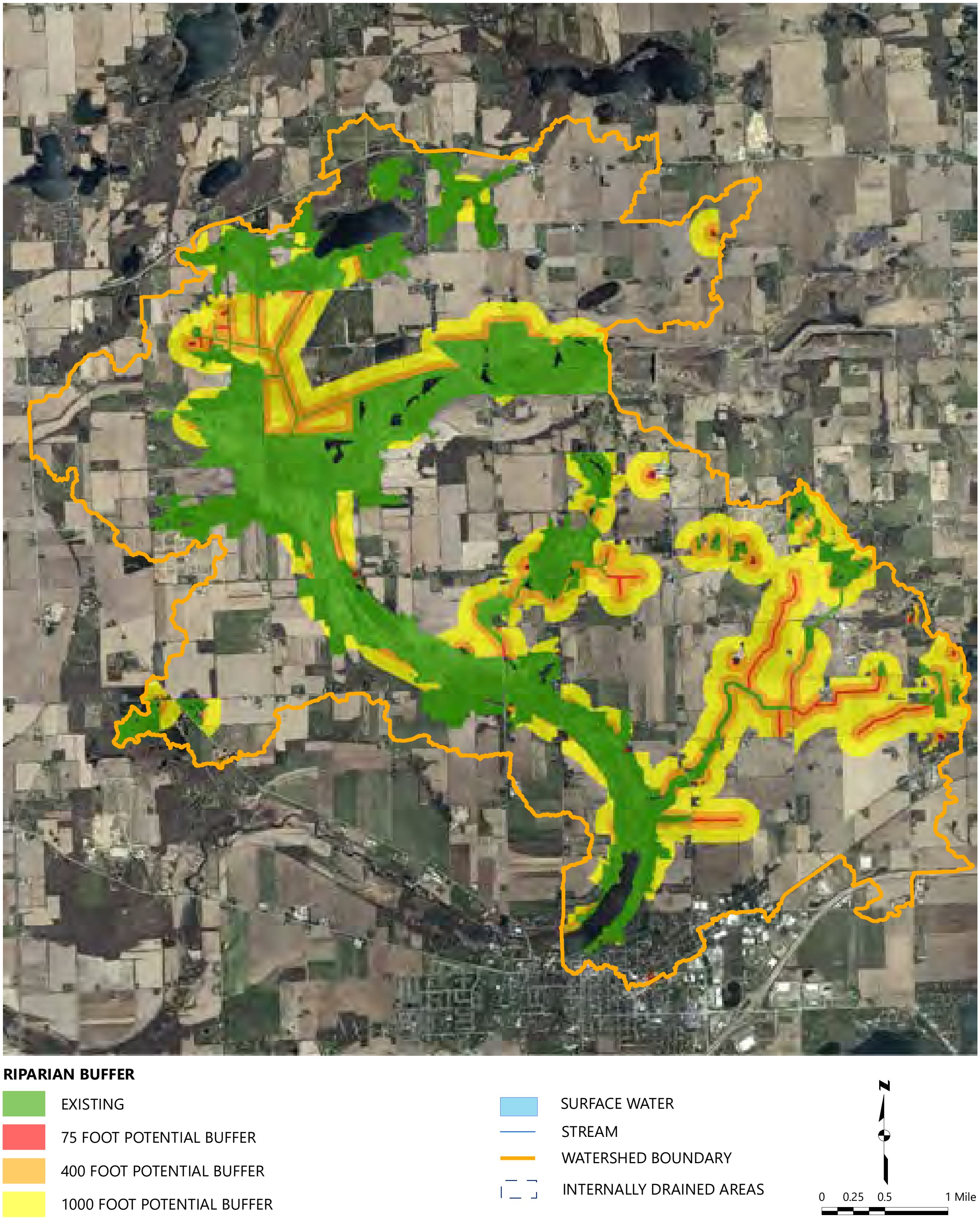
[150] *Miller, N., J. Kline, T. Bernthal, J. Wagner, C. Smith, M. Axler, M. Matrise, M. Kille, M. Silveira, P. Moran, S. Gallagher Jarosz, and J. Brown,* Wetlands by Design: A Watershed Approach for Wisconsin, *Wisconsin Department of Natural Resources and The Nature Conservancy, 2017.*

[151] *The results of the Wetlands by Design process can be viewed using the Nature Conservancy's Wetlands and Watershed Explorer: maps.freshwaternetwork.org/wisconsin/#.*

[152] *P. Beier and R.F. Noss, "Do Habitat Corridors Provide Connectivity?,"* Conservation Biology, *12(6): 1241-1252, 1998.*

Map 2.24
Existing and Potential Riparian Buffer Within the Lake Comus Watershed



Source: SEWRPC

2.4 AQUATIC PLANTS

This section presents data from a 2019 aquatic plant survey of Lake Comus and can be used to better understand of the Lake's plant community, evaluate changes in the Lake's plant communities over time, and guide aquatic plant management, particularly as it relates to invasive species.

All healthy lakes have aquatic plants and algae. Native aquatic plants and algae are the foundation of lake ecosystems. Through photosynthesis, plants and algae utilize nutrients from lake sediment and/or lake water and energy from sunlight to produce carbohydrates and oxygen. Oxygen is a byproduct of this process which is released in the water and is used by many other aquatic life forms into the water. Aquatic plants and algae convert inorganic compounds into organic substances directly available as food to other aquatic organisms. Aquatic plants also serve several other valuable functions in a lake ecosystem, including:

- Improving water quality by filtering excess nutrients from the water
- Providing habitat for invertebrates and fish
- Stabilizing lake bottom substrates
- Supplying food for waterfowl and various lake-dwelling animals

It is also important to note that even though aquatic plants may hinder human use and/or access to a lake, aquatic plants should not be eliminated or even significantly reduced in abundance because they often support many other beneficial functions. For example, white water lily plays a key role in providing shade, habitat, and food for fish and other important aquatic organisms. Water lilies also help prevent wave damage to shorelines by dampening wave power that could otherwise erode the shoreline. Additionally, the shade that this plant provides helps reduce the growth of undesirable plants (e.g., invasive EWM) because it limits the amount of sunlight reaching the lake bottom. Given these benefits, large-scale removal of native plants that may be perceived as a nuisance (such as white water lilies) should be avoided when developing plans for aquatic plant management.

Phytoplankton and Macrophytes

Aquatic plants include microscopic algae ("phytoplankton") and larger multicellular plants ("macrophytes"). Macrophytes are often described using the terms *submerged, floating-leaf, free-floating,* and *emergent,* terms describing where the plant grows in the lake ecosystem. *Submerged* plants are found in the main lake basin. Although most are rooted in bottom substrate, some species, such as coontail (*Ceratophyllum demersum*) can become free-floating. *Floating-leaf* plants, such as water lilies, generally have large, floating leaves and are usually found in shallow water areas a few feet in depth or less that contain loose bottom sediments. *Free-floating* plants, such as duckweed (*Lemna* spp.), have small leaves, are not rooted to the sediment, and are often wind-blown around the waterbody. *Emergent* plants, which have leaves that extend above water, are commonly found along the lake shorelines. Two examples of emergent plants are bulrushes and cattails. All four aquatic plant types have significant roles to play in the overall lake ecology. Maintaining a rich and diverse community of native species is important for every lake ecosystem as this:

- Helps sustain and increase the robustness of the existing ecosystem
- Increases the ability of an ecosystem to adapt to environmental changes
- Provides a spectrum of options for future decisions regarding the management of that system

Many factors, including lake configuration, depth, water clarity, nutrient availability, bottom substrate, wave action, and type and size of fish populations, influence the distribution and abundance of aquatic macrophytes in lakes Most waterbodies within Southeastern Wisconsin naturally support abundant and diverse aquatic plant communities.

Depending on their types, distribution, and abundance, aquatic macrophytes can be either beneficial or a nuisance. Plants growing in the proper locations and in reasonable densities help maintain lake fisheries, wildlife populations, and provide habitat for a variety of aquatic organisms. Aquatic plants also may remove nutrients from the water that otherwise would contribute to excessive algal growth and low water clarity. Aquatic plants become a nuisance when their densities become so great as to interfere with swimming and boating activities, when their growth forms limit habitat diversity, or when the plants reduce the aesthetic appeal of the resource.

Phytoplankton

Phytoplankton is the term for a group of aquatic microscopic organisms that includes bacteria, protists, and algae. These organisms all actively photosynthesize. Maintaining a healthy phytoplankton community is essential for lake health, as these species form the foundation of the lake's food web and create oxygen required by other organisms, such as zooplankton and fish. However, overabundant phytoplankton, generally caused by excessive nutrient loads, can impair lake health by decreasing water clarity and reducing hypolimnetic oxygen. Phytoplankton have never seen surveyed in Lake Comus.

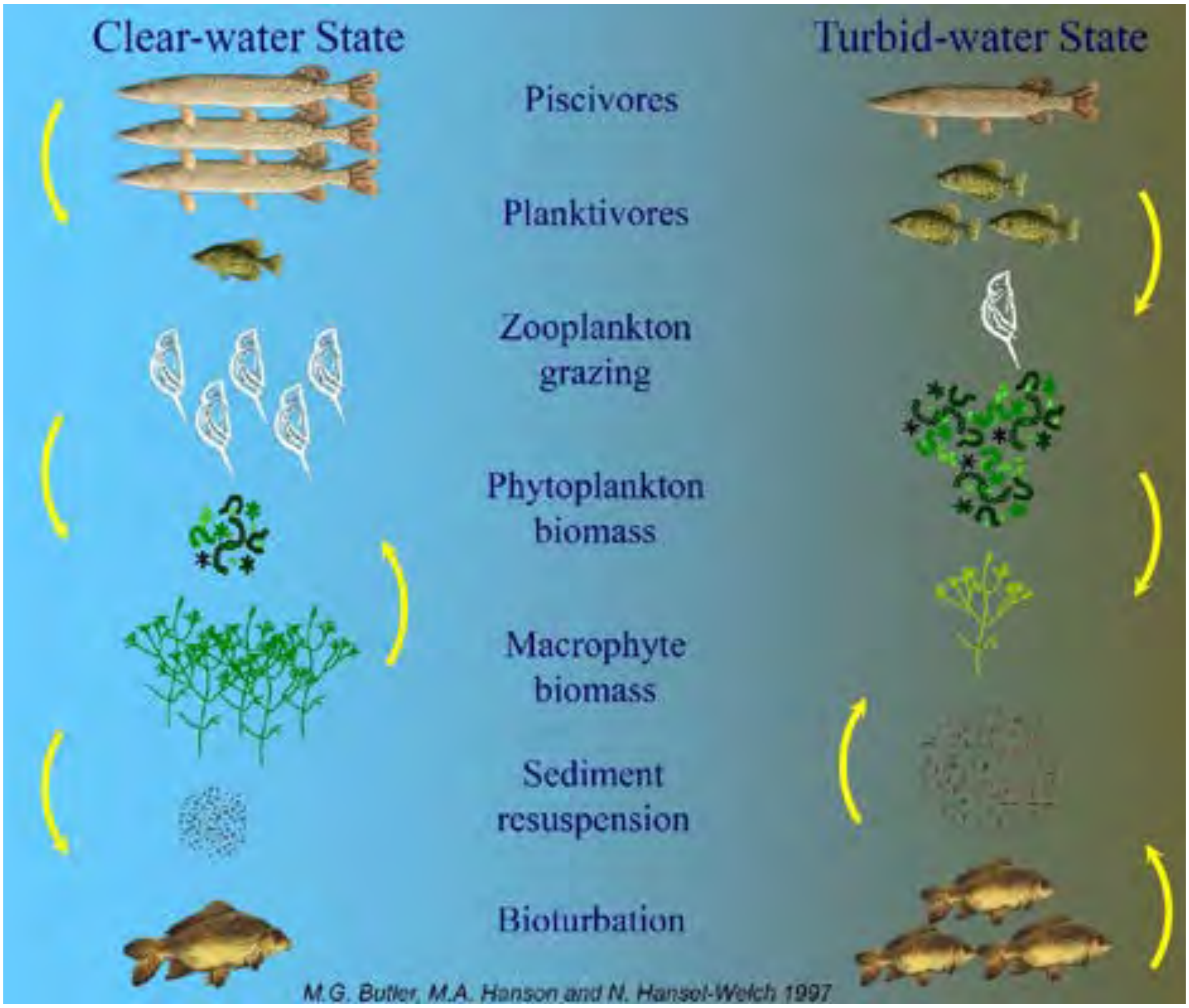
Since phytoplankton and rooted plants compete for nutrients, an abundance of rooted aquatic plants means fewer nutrients (usually phosphorus) available to phytoplankton, in turn reducing the abundance of free-floating algae and increasing water clarity. Conversely, when rooted aquatic plants senesce or die, the subsequent return of nutrients to the water column can increase algal populations and decrease water clarity; algae blooms often occur during large aquatic plant die-offs. This is particularly evident in shallow, nutrient-rich lakes like Lake Comus, where researchers propose that two alternative "stable states" exist: an algae-dominated state and a macrophyte-dominated state (Figure 2.39). The algae-dominated state is characterized by high algae abundance, low water clarity, low macrophyte biomass, few predatory sport fish, and can be exacerbated by sediment resuspension due to wind, poorly managed boating, and rough fish activity. In contrast, the macrophyte-dominated state has low algal abundance, high water clarity, high macrophyte biomass, a larger population of predatory sport fish, and less sediment resuspension due to vegetation covering the bottom sediment. Examples of Walworth County lakes likely exhibiting the algae-dominated state include Rice Lake and Lake Comus while Lake Wandawega and Turtle Lake are likely exhibiting the macrophyte-dominated state. Thus, it is important to appreciate the balance that exists between rooted aquatic plants and algae in a Lake; the over-suppression of one can often lead to an over-abundance of the other. For example, eliminating too many rooted plants while attempting to achieve a "weed-free lake" can result in chronic algae blooms, supersaturated oxygen levels in nighttime surface waters, and summer fish kills.

Native Plants

Healthy aquatic plant communities usually include a variety of plant types that take advantage of unique ecological niches and provide unique value to lake health. These aquatic plants communities are dynamic assemblages with complex interdependencies. Native aquatic plant species are specifically adapted to local aquatic environments and many kinds of wildlife depend on the presence of specific native plant species for survival. For example, the seeds and tubers of Sago pondweed (*Stuckenia pectinata*) are an important food source for migratory waterfowl. In Wisconsin, the presence of native pondweeds is generally considered to a sign of a healthy lake with good habitat for fish and aquatic life. In southern Wisconsin, white-stem pondweed (*Potamogeton praelongus*) is considered a species particularly sensitive to water pollution; thus, its presence in a waterbody indicates healthy conditions.

Each aquatic plant species has certain habitat in which that species thrives as well as conditions that limit or completely inhibit its growth. For example, water conditions (e.g., depth, clarity, source, alkalinity, and nutrient concentrations), substrate composition, the presence or absence of water movement, and pressure from herbivory and/or competition can influence the type of aquatic plants found in a water body. All other factors being equal, water bodies with diverse habitat variables are more likely to host a diverse aquatic plant community. For similar reasons, some areas of a particular lake may contain plant communities with little diversity while other areas of the same lake may exhibit good diversity. Historically, human manipulation has often favored certain plants and has reduced biological diversity. Thoughtful aquatic plant management can help maintain or even enhance aquatic plant community biodiversity.

Figure 2.39
Alternative Stable States in Shallow Lakes



Source: M.G. Butler, M.A. Hanson, and N. Hansel-Welch.

Aquatic Nonnative and Invasive Plant Species

The terms "nonnative" and "invasive" are often confused and incorrectly assumed to be synonymous. *Nonnative* is an overarching term used to label living organisms introduced to new areas beyond their native range with intentional or unintentional human help. Nonnative species may not necessarily harm ecological function or human use values in their new environments. *Invasive* species, on the other hand, are the subset of nonnative species that have damaging impacts on the ecological health of their new environments and/ or are considered a nuisance to human use values. In summary, invasive species are non-native but not all non-native species are invasive.

Introducing invasive species, either plants or animals, can severely disrupt both terrestrial and aquatic natural systems. Since invasive species often have no natural predators to control their growth, they are often able to reproduce prolifically and outcompete native species for space and other necessary resources. This can have devastating effects on native species that have well developed interdependencies with other native plants and animals.

The most common and destructive invasive species in Wisconsin lakes are Eurasian watermilfoil (EWM) (*Myriophyllum spicatum*) and curly-leaf pondweed (CLP) (*Potamogeton crispus*); both are declared nuisance species identified in Chapters NR 40 and NR 109 of the *Wisconsin Administrative Code*. Both species were observed by Commission staff in Lake Comus during a plant survey in 2019.

Invasive species of high concern are continuously changing due to new introductions and successful management of past invasions. Starry stonewort (*Nitellopsis obtusa*), a newly introduced invasive species in Wisconsin, has been observed in nearby Geneva Lake but has not been observed in Lake Comus. Hybrid Eurasian/northern watermilfoil, which has been observed in Turtle Lake, may also be present in Lake Comus but the WDNR does not currently list it as verified in the Lake.[153] Hybrid strains can only be distinguished from pure strains of EWM through genetic testing.

Eurasian Watermilfoil

While eight milfoil species are found in Wisconsin, EWM is the only nonnative, or *exotic*. As an exotic species, EMW has few natural enemies that can inhibit its growth. Thus, EWM grow profusely in suitable conditions, particularly in mesotrophic or eutrophic hard-water lakes, especially where the lake bottom has been disturbed, such as following dredging. Unless its growth is well defined and controlled, EWM populations can displace native plant species and interfere with the aesthetic and recreational use of waterbodies. EWM is a severe ecological and recreational problem in many Southeastern Wisconsin lakes.

EWM can quickly reproduce through rooting plant fragments which often are unintentionally created during lake recreational activities. For example, boat propellers can fragment EWM plants, and these fragments generate new root systems causing the plant to become more widespread. Additionally, these fragments allow EWM to disperse to new lakes as they cling to boats, trailers, motors, and/or bait buckets and can stay alive for weeks. EWM can become a dominant plant species within two years of arriving in a new waterbody. Therefore, it is important to remove all vegetation from boats, trailers, and other equipment after removing them from the water and prior to launching in other waterbodies.

Curly-leaf Pondweed

Curly-leaf pondweed is the only non-native pondweed found within Wisconsin. This species is predominantly found in disturbed, eutrophic lakes, where it exhibits a peculiar split-season growth cycle that provides a competitive advantage over native plants and makes management of this species difficult. This species reproduces using turions, a type of plant bud found in some aquatic plants. Turions are produced in late summer, lie dormant in lake sediment, and germinate during cooler weather in fall. Over the winter, the turions produce winter foliage that thrives under the ice. In spring, when water temperatures begin to rise again, the plant has a head start on the growth of native plants and quickly grows to full size, shading the lake bottom and producing flowers and fruit earlier than its native competitors. CLP begins to senesce in midsummer, increasing lake water phosphorus concentrations during warm weather. This can cause excessive growth of other plants and algae and can reduce lake water quality. CLP can grow in more turbid waters than many native plants. Therefore, protecting or improving water quality is an effective method of control of this species, as clearer waters in a Lake can help native plants compete more effectively.

Community Changes Over Time

Aquatic plant communities undergo cyclical and periodic changes that reflect community responses to interannual climatic conditions as well as long-term changes in a lake's "hydroclimate." Interannual changes, occurring between three to seven years, can include surface water elevations, water temperature, as well as ice-off and ice-on dates. These factors can promote the short-term growth of certain species, such as CLP being more abundant in years with earlier ice-off. Long-term factors affecting plant communities—those which occur over a decade or longer—can include nutrient loading, sedimentation rates, recreational use patterns, and natural stressors. Natural stressors can include biological stressors, such as herbivory and disease, as well as climatic and limnological factors, such as insolation, water temperature, and lake circulation patterns. For example, EWM populations have been observed to increase rapidly upon

[153] *See dnr.wi.gov/lakes/invasives/AISLists.aspx?species=MILFOIL_HYBRID&location=68.*

introduction but decline following this explosive initial growth period,[154] a situation that may be partly attributed to herbivory by native milfoil weevils. Additionally, aquatic plant management can reduce the abundance of nonnative species over time although total eradication from the community is unlikely in many cases. Examining changes in aquatic plant communities over time can reveal factors promoting or inhibiting the growth of specific species. This knowledge that can be used to design management options to control invasive species abundance.

Macrophyte Community of Lake Comus

The earliest description of the Lake Comus macrophyte community known to Commission staff was a 1961 WDNR report that reported concern over "weeds that choke the entire lake".[155] The Commission's 2019 aquatic plant survey is the only known comprehensive aquatic plant survey of Lake Comus. The Commission utilized the point-intercept method, which was adopted by WDNR in 2010 for conducting aquatic plant surveys in Wisconsin lakes.[156] In this method, sampling sites are based on predetermined global positioning system (GPS) location points that are arranged in a grid pattern across the entire surface of a lake (Figure 2.40). At each grid point sampling site, a single rake haul is taken and a qualitative assessment of the rake fullness, on a scale of zero to three, is made for each species identified.

Several metrics are useful to describe aquatic plant community condition and design management strategies. These metrics include maximum depth of colonization, species richness, biodiversity, relative species abundance, and sensitive species. Maximum depth of colonization (MDC) is a useful indicator of water quality, as turbid and/or eutrophic (nutrient-rich) lakes generally have shallower MDC than lakes with clear water.[157] The number of different types of aquatic plants present in a lake is referred to as the *species richness* of the lake. Larger lakes with diverse lake basin morphology, less human disturbance, and/or healthier, more resilient lake ecosystems generally have greater species richness. Species richness is often incorrectly used as a synonym for biodiversity. Biodiversity is based on the number of species present in a habitat along with the abundance of each species. Aquatic plant biodiversity can be measured with the Simpson Diversity Index.[158] Using this measure, a community dominated by one or two species would be considered less diverse than one in which several different species have similar abundance. Native "sensitive" species are species that are intolerant of ecological disturbance and thus indicate healthy water conditions. Wisconsin species have been ranked on a conservatism (C) scale from 0 to 10, with 0 indicating invasive species and 10 indicating species only found in undisturbed habitats. The Floristic Quality Index of a Lake, calculated as the average Lake species' C value divided by the square root of species richness, is an assessment metric used to evaluate how closely a lake's aquatic plant community matches that of undisturbed, pre-settlement conditions.[159]

Results from the 2019 survey indicated that Lake Comus has a poor aquatic plant community with low overall aquatic plant cover, a shallow MDC, low species richness and diversity, and a high proportion of invasive species. Of the 253 points visited during the 2019 survey, only 60 points (24 percent) had vegetation present. This low percent cover can be partially attributed to the Lake having an MDC of four feet. As MDC is often related to water clarity, this extremely shallow MDC indicates that plant growth is likely limited by light availability at depths greater than four feet in the Lake.[160] Many shallower areas in the Lake also had low plant cover, with only 51 percent of points shallower or equal to four feet in depth having vegetation present compared to an

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[154] *S.R. Carpenter, "The Decline of* Myriophyllum spicatum *in a Eutrophic Wisconsin (USA) Lake,"* Canadian Journal of Botany, *58(5): 527-535, 1980.*

[155] *Wisconsin Department of Natural Resources,* Surface Water Resources of Walworth County*, 1961.*

[156] *Wisconsin Department of Natural Resources, Publication No. PUB-SS-1068 2010,* Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry and Analysis, and Applications*, 2010.*

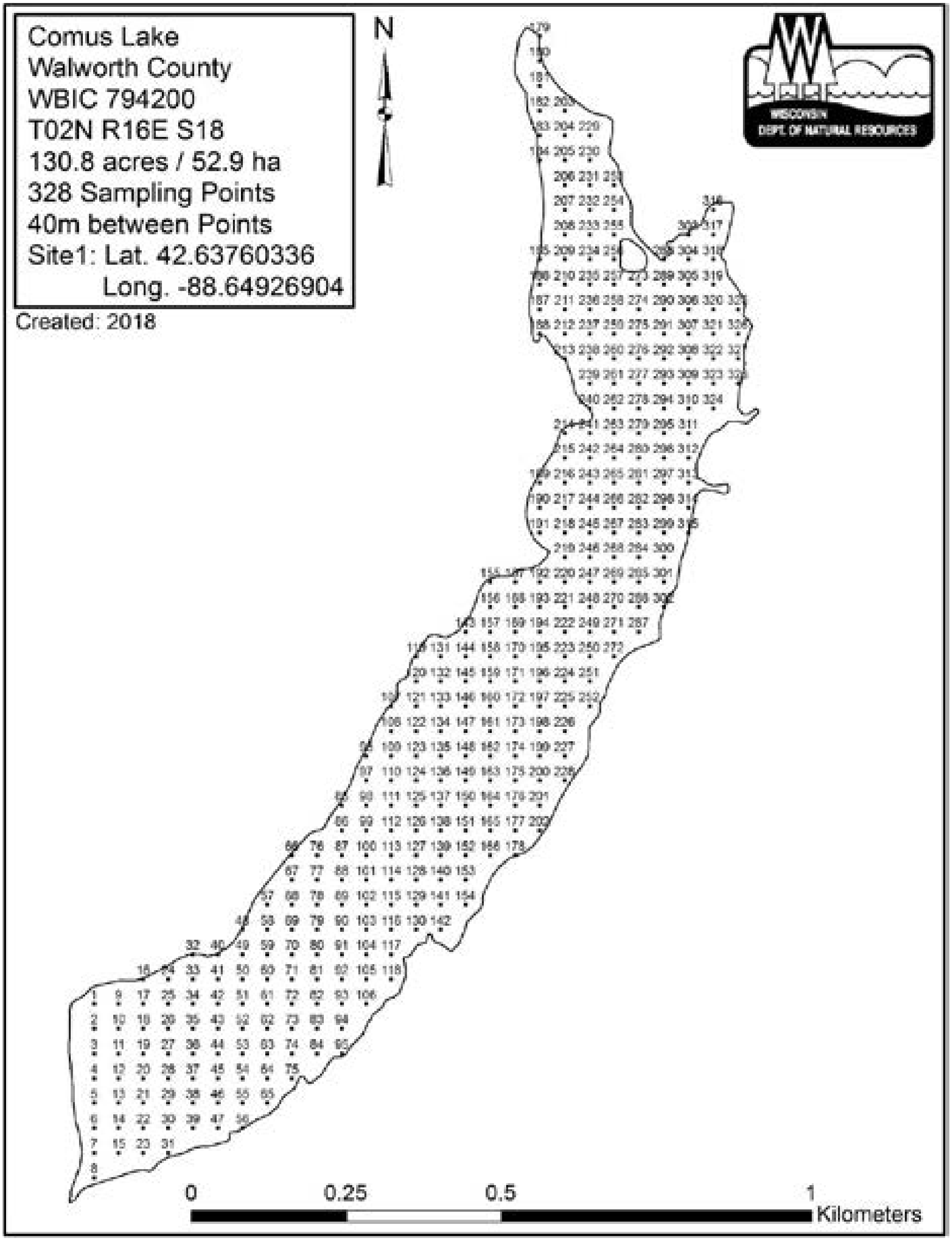
[157] *Canfield Jr, D.E., Langeland, L., and Haller, W.T. "Relations between water transparency and maximum depth of macrophyte colonization in lakes." Journal of Aquatic Plant Management 23, 1985.*

[158] *The SDI expresses values on a zero to one scale where 0 equates to no diversity and 1 equates to infinite diversity.*

[159] *Nichols, S. "Floristic quality assessment of Wisconsin lake plant communities with example applications."* Lake and Reservoir Management *15 (2), 1999.*

[160] *The average MDC for similar lakes in the Region is 10.6 feet, while the average across all lake types is 14.3 feet.*

Figure 2.40
Aquatic Plant Sampling Map for Lake Comus



Source: WDNR and SEWRPC

average of 79 percent for similar lakes in the Region. This detail indicates that low light availability is not the only factor limiting plant growth within the Lake, suggesting that factors such as habitat disturbance may also be affecting the plant community. The Lake's sizable common carp population is likely contributing to reduced water clarity and habitat disturbance. Common carp disturb lake-bottom sediment through their feeding and spawning habitats and consume aquatic vegetation; both factors can contribute to reduced water clarity by increasing phosphorus and sediment concentrations in the water column.

The species composition is also indicative of disturbed conditions within the Lake. Only seven species were observed during the survey, compared to a Regional average of 14 species for similar lakes. The Lake had a Simpson Diversity Index of 0.56, suggesting that the community is dominated by very few species, and the Lake only averaged 1.5 species per point with vegetation present.[161] The most dominant species in the Lake by far was EWM which was observed at 92 percent of points with any vegetation present (Figure 2.41 and Table 2.19). Coontail, the next most dominant species in the Lake, was only observed at 30 percent of vegetated points. The remainder of the species, in order of decreasing dominance, were small duckweed (*Lemna minor*), white water lily (*Nymphaea odorata*), Sago pondweed, CLP (Figure 2.42), and elodea (*Elodea canadensis*). Although several of these species provide other values in the Lake, such as food and/or habitat, none of these species is considered a "sensitive" species with a C value of 7 or greater suggestive of pristine conditions. Figure 2.43 presents the locations where native species were observed during the survey. The Floristic Quality Index of the Lake is 8, which is substantially lower than the regional averages of 18 for similar lakes and 23 for all lakes. This low FQI indicates that the species present in the Lake are all generally tolerant of disturbed conditions.

Although not a quantitative survey, Commission staff did notice a marked increase in the abundance and coverage of white water lily and spatterdock (*Nuphar variegata*) during a field visit in August 2021 to retrieve temperature loggers from the Lake, Turtle Creek, and the CTH O tributary. Lilies were particularly common in the shallow, northeastern area of the Lake as well as along the edges of Turtle Creek (Figure 2.44). Within the CTH O tributary, duckweeds covered nearly the entire water surface. This rapid change in vegetation coverage within the Lake indicates the potential for aquatic plant communities to shift in response to changing environmental conditions, as the summer of 2021 was marked by drought through June and July followed by intense rainfall in early August. The lilies may have been able to colonize larger swathes of the Lake with lower water levels and reduced water velocity in the Creek during the drought. This brief drought period may indicate that these species would be able to utilize a slight lake drawdown in late spring and early summer to cover a larger portion of the shallow northern Lake area.

Aquatic Plant Management

Since Lake Comus does not have nuisance levels of aquatic plants, large-scale aquatic plant management techniques such as mechanical harvesting and/or widespread chemical treatment are not needed or widely desired. As previously discussed, the Lake has a depauperate aquatic plant community with sparse growth, potentially due to low water clarity and the destructive habitats of its common carp population. Consequently, the following description will focus on techniques, both direct and indirect, that foster a healthy aquatic plant community with less focus on removal of invasive and/or nuisance plant populations.

Aquatic plant management control techniques can be classified into six groups:

- *Physical measures* – including lake bottom coverings.
- *Biological measures* – which include using living organisms, including herbivorous insects.
- *Manual measures* – physical removal of plants by individuals using hand-held rakes or by hand.
- *Mechanical measures* – including harvesting and removing aquatic plants with a machine known as a harvester or by suction harvesting.
- *Chemical measures* – including using aquatic herbicides to kill nuisance and nonnative aquatic plants.

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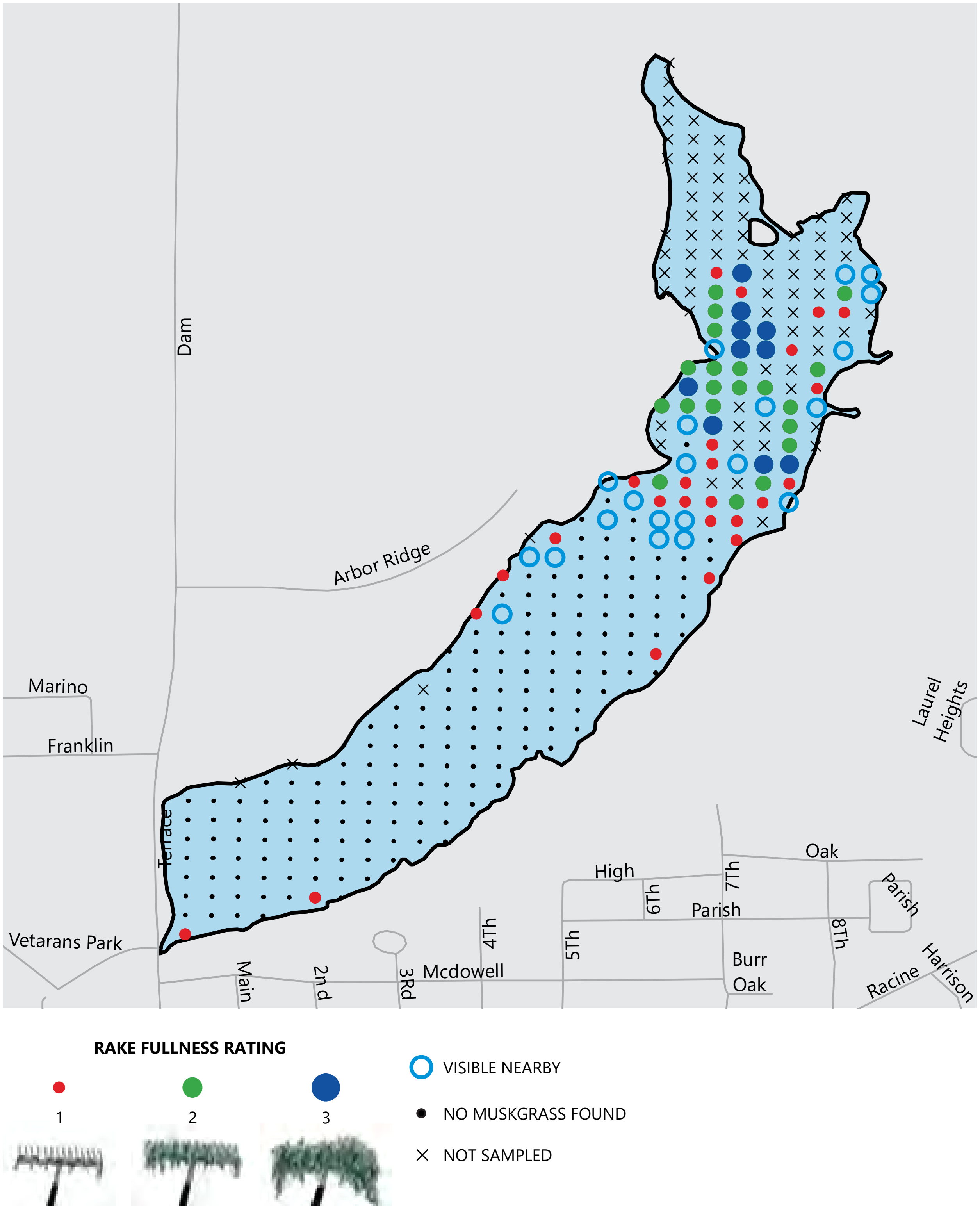
[161] *The Simpson Diversity Index expresses values on a zero to one scale where 0 equates to no diversity and 1 equates to infinite diversity.*

Figure 2.41
Eurasian Watermilfoil Occurrence in Lake Comus: August 2019



Note: Samples were collected in Comus Lake between August 23 and September 4, 2019.

Source: Wisconsin Department of Natural Resources and SEWRPC

Table 2.19
Frequency of Occurrence of Aquatic Vegetation in Lake Comus: 2019

Species	Number of Sites	Frequency of Occurrence Within Vegetated Areas (%)[a]	Relative Frequency[b]	Average Rake Fullness (max = 3.0)	Visual Sightings
Myriophyllum spicatum, Eurasian watermilfoil	55	91.2	61.1	1.73	21
Ceratophyllum demersum, Coontail	18	30	20	1.22	3
Elodea canadensis, Elodea	--	--	--	--	1
Lemna minor, Small duckweed	13	21.7	14.4	1	29
Nymphaea odorata, White water lily	1	1.7	1.1	1	15
Stuckenia pectinata, Sago pondweed	3	5	3.3	1	5
Filamentous algae	--	--	--	--	2

Note: NR 109.07 *Wisconsin Administrative Code* designated nonnative and/or invasive species above are listed in red print; all other species are native. NR 107.08 *Wisconsin Administrative Code* high-value species are printed in green print.

[a] *Frequency of Occurrence is the number of occurrences of a species divided by the number of samplings with vegetation, expressed as a percentage. It is the percentage of times a particular species occurred when there was aquatic vegetation present.*

[b] *Relative Frequency is the frequency of that particular species compared to the frequencies of all species present.*

Source: WDNR and SEWRPC

- *Water level manipulation* – varying water levels during critical time periods to influence aquatic plant community composition. This often includes freezing and/or desiccation.

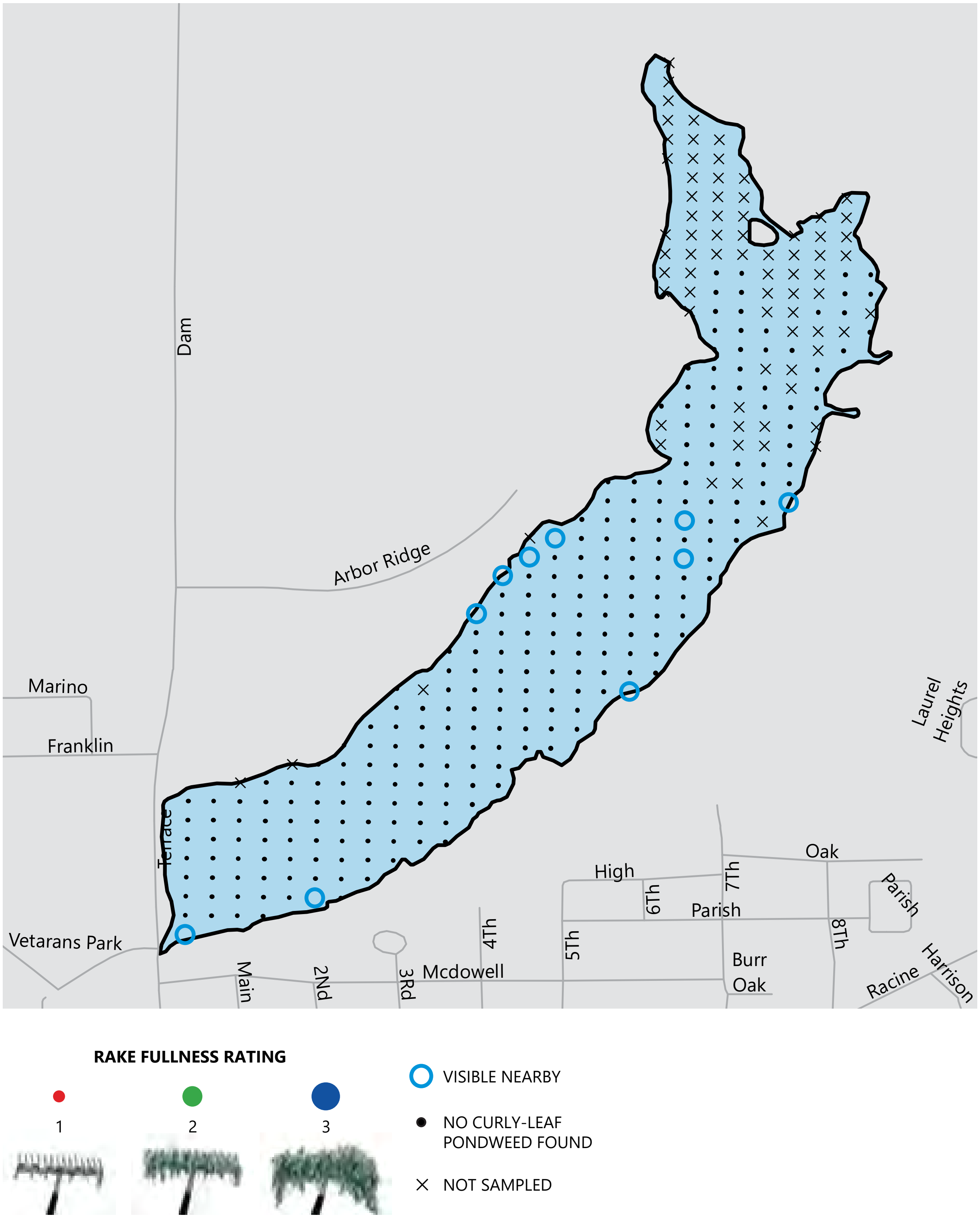
More information regarding these alternatives is provided below. All control measures are stringently regulated and most require a State of Wisconsin permit. Chemical controls, for example, require a permit and are regulated under Chapter NR 107, "Aquatic Plant Management," of the *Wisconsin Administrative Code*, while placing bottom covers (a physical measure) requires a WDNR permit under Chapter 30 of the *Wisconsin Statutes*. All other aquatic plant management practices are regulated under Chapter NR 109, "Aquatic Plants: Introduction, Manual Removal and Mechanical Control Regulations," of the *Wisconsin Administrative Code*.

The aquatic plant management elements described below consider alternative management measures consistent with the provisions of Chapters NR 103, "Water Quality Standards for Wetlands," NR 107, and NR 109 of the *Wisconsin Administrative Code*. Furthermore, the alternative aquatic plant management measures are consistent with the requirements of Chapter NR 7, "Recreational Boating Facilities Program," and with the public recreational boating access requirements relating to eligibility under the State cost-share grant programs set forth in Chapter NR 1, "Natural Resources Board Policies," of the *Wisconsin Administrative Code*.

Physical Measures

Lake-bottom covers and light screens provide limited control of rooted plants by creating a physical barrier that reduces or eliminates plant-available sunlight. Various materials such as pea gravel or synthetics like polyethylene, polypropylene, fiberglass, and nylon can be used as covers. The longevity, effectiveness, and overall value of some physical measures is questionable. Whatever the case, the WDNR does not permit these kinds of controls. Consequently, lake-bottom covers are not a viable aquatic plant control strategy for Lake Comus.

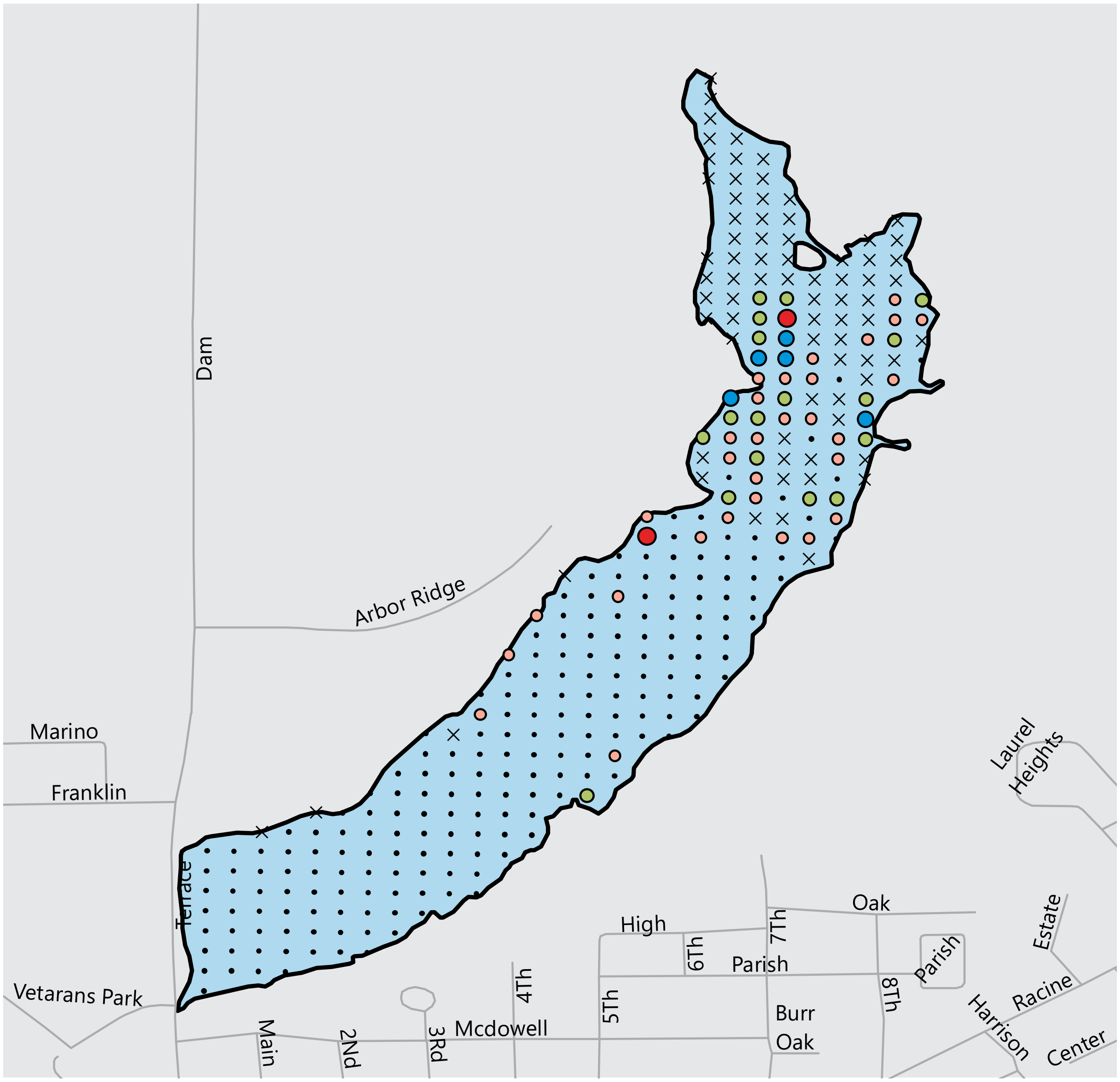
Figure 2.42
Curly Leaf Pondweed Occurrence in Lake Comus: August 2019



Note: Samples were collected in Comus Lake between August 23 and September 4, 2019.

Source: Wisconsin Department of Natural Resources and SEWRPC

Figure 2.43
Occurrence of Native Species in Lake Comus: August 2019



NATIVE SPECIES RICHNESS

- • NO PLANTS FOUND
- 1
- 2
- 3
- 4
- × NOT SAMPLED

Note: Samples were collected in Comus Lake between August 23 and September 4, 2019.

Source: Wisconsin Department of Natural Resources and SEWRPC

Biological Measures

Biological controls offer an alternative approach to control nuisance or exotic plants. Biological control techniques traditionally use herbivorous insects that feed upon nuisance plants. This approach has been effective in some Southeastern Wisconsin lakes.[162] Milfoil weevils (*Eurhychiopsis lecontei)* do best in waterbodies with balanced panfish populations,[163] and under conditions that include dense EWM beds where the plants reach the surface and are close to shore, natural shoreline areas where leaf litter provides habitat for over-wintering, and little boat traffic. Lake Comus does not have a dense population of EWM that would be necessary to sustain a weevil population. For these reasons, milfoil weevils are not likely well suited for application on the Lake.

Mechanical Measures

Two methods of mechanical harvesting are currently permitted and employed in Wisconsin. These methods include use of an aquatic plant harvester (mechanical harvesting) and suction harvesting. More details about each are presented below.

Mechanical Harvesting

Modern harvesters are sophisticated machines that cut, gather, and transport aquatic plant material. Harvesters consist of an adjustable depth cutting apparatus that can be adjusted to shear plants from the surface down to about five feet below the water surface. The cut plants are then gathered with a collection system (e.g., a conveyor and a basket) that picks up most cut plant material. Mechanical harvesting can be a practical and efficient means of controlling nuisance plant growth as well as help reducing in-lake nutrient recycling, sedimentation, and target plant reproductive potential. In other words, harvesting removes plant biomass, which would otherwise decompose and release nutrients, sediment, and seeds or other reproductive structures (e.g., turions, bulbils, plant fragments) into a lake. Mechanical harvesting is particularly effective for large-scale projects. The aquatic plant community on Lake Comus does not warrant such an intensive management technique. Thus, mechanical harvesting is not well-suited for the current ecology and use of the Lake.

Figure 2.44
Aquatic Vegetation Observed in Lake Comus,Turtle Creek and the CTH O Tributary: August 2021

Duckweeds Covering Surface of CTH O Tributary

Spatterdock and White Water Lily Flank Turtle Creek

White Water Lily in Lake Comus

Source: SEWRPC

Suction Harvesting (DASH)

An alternative aquatic plant harvesting method has emerged called Diver Assisted Suction Harvesting (DASH). First permitted in 2014, DASH (also known as suction harvesting) is a mechanical process where divers identify and pull select aquatic plants by their roots from the lakebed and then insert the entire plant into a suction hose that transports the plant to the lake surface for collection and disposal. The process is

[162] *B. Moorman, "A Battle with Purple Loosestrife: A Beginner's Experience with Biological Control,"* LakeLine*, 17(3): 20-37, 1997; see also, C.B. Huffacker, D.L. Dahlsen, D.H. Janzen, and G.G. Kennedy,* Insect Influences in the Regulation of Plant Population and Communities, *pp. 659-696, 1984; and C.B. Huffacker and R.L. Rabb (eds.),* Ecological Entomology*, John Wiley, New York, New York, USA.*

[163] *Panfish such as bluegill and pumpkinseed are predators of herbivorous insects. High populations of panfish lead to excess predation of milfoil weevils.*

essentially a more efficient and wide-ranging method for hand-pulling aquatic plants. Such labor-intensive work by skilled professional divers is, at present, a costly undertaking and long-term monitoring will need to evaluate the efficacy of the technique. Nevertheless, many apparent advantages are associated with this method, including: 1) lower potential to release plant fragments when compared to mechanical harvesting, raking, and hand-pulling, thereby reducing spread and regrowth of invasive plants like EWM; 2) increased selectivity in terms of plant removal when compared to mechanical and hand harvesting, thereby reducing the loss of native plants; and 3) lower potential for disturbing fish habitat.

Both mechanical harvesting and suction harvesting are regulated by WDNR and require a permit.[164] Non-compliance with permit requirements is an enforceable violation of Wisconsin law and may lead to fines and/or complete permit revocation. The information and recommendations provided in this report will help frame permit requirements. Permits can cover up to a five-year period.[165] At the end of that period, it would be necessary to develop a new plant management plan. The updated plan must consider the results of a new aquatic plant survey and should evaluate the success, failure, and effects of earlier plant management activities that occurred in the lake.[166] These plans and plan execution are overseen by the WDNR coordinator for the region.[167]

Chemical Measures

Using chemical herbicides in aquatic environments is stringently regulated and requires a WDNR permit and WDNR staff oversight during application. Chemical herbicide treatment is a short-term method to control heavy growth of nuisance aquatic plants. Chemicals are applied to growing plants in either liquid or granular form. The advantages of using chemical herbicides to control aquatic plant growth include relatively low cost as well as the ease, speed, and convenience of application. Disadvantages associated with chemical control include:

1. **Unknown and/or conflicting evidence about long-term effects of chemicals on fish, fish food sources, and humans**—Chemicals approved by the U.S. Environmental Protection Agency as aquatic plant herbicides have been studied to rule out short-term (acute) effects on humans and wildlife. Additionally, some studies also examine long-term (chronic) effects of the chemical on animals (e.g., the effects of being exposed to these herbicides for many years). However, it is often impossible to conclusively state that no long-term effects exist due to the animal testing protocol, time constraints, and other issues. Additionally, long-term studies have not addressed all potentially affected species.[168] For example, conflicting studies/opinions exist regarding the role of the chemical 2,4-D as a human carcinogen.[169] Some lake property owners judge the risk of using chemicals as being too great, despite legality of use. Consequently, the concerns of lakefront owners should be considered whenever chemical treatments are proposed. Additionally, if chemicals are used, they should be applied as early in the season as practical and possible. This helps assure that applied chemical herbicides decompose before swimmers and other lake users begin to actively use the lake.[170]

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[164] *Permits for mechanical harvesting can be dependent on the type of harvesters utilized.*

[165] *Five-year permits allow a consistent aquatic plant management plan to be implemented over a significant length of time. This process allows the selected aquatic plant management measures to be evaluated at the end of the permit cycle.*

[166] *Aquatic plant harvesters must document harvesting activities as one of the permit requirements.*

[167] *Information on the current coordinator is found on the WDNR website.*

[168] *U.S. Environmental Protection Agency, EPA-738-F-05-002, 2,4-D* RED Facts, *June 2005.*

[169] *M.A. Ibrahim, et al., "Weight of the Evidence on the Human Carcinogenicity of 2,4-D,"* Environmental Health Perspectives*, 96: 213-222, 1991.*

[170] *Though the manufacturers indicate that swimming in 2,4-D-treated lakes is allowable after 24 hours, it is possible that some swimmers may want more time following application to ensure that they receive less exposure to the chemical. Consequently, allowing for extra time is recommended, so that residents and lake users can feel comfortable that they are not being unduly exposed.*

2. **An increased risk of algal blooms**—Waterborne nutrients promote growth of aquatic plants and algae. If rooted aquatic plants are not the primary user of waterborne nutrients, algae use these nutrients and tend to be more abundant. Action should be taken to avoid both loss of native plants and excessive chemical use, a situation that can compromise the health of a lake's native plant community and reduce the ability of rooted aquatic plants to compete with algae for limiting nutrients. Balance must be maintained between rooted aquatic plants and algae—when the population of one declines, the other may increase in abundance to nuisance levels. In addition to decreasing competition for water-borne nutrients, the death and decomposition of aquatic plants can increase nutrient levels in lake water. Higher nutrient concentrations fuel aquatic plant and algal growth.

3. **A potential increase in organic sediments, and associated anoxic conditions, can stress aquatic life and cause fish kills**—When chemicals are used to control large mats of aquatic plants, the dead plant material generally settles to the bottom of a lake and subsequently decomposes. This process leads to an accumulation of organic-rich sediment and can deplete oxygen from the water column as bacteria decompose plant remains. Excessive oxygen loss can inhibit a lake's ability to support certain fish and can trigger chemical processes that release phosphorus from bottom sediment, further increasing lake nutrient levels. These concerns emphasize the need to limit chemical control to early spring, when EWM has not yet formed dense mats.

4. **Adverse effects on desirable aquatic organisms due to loss of native species**—Native plants, such as pondweeds, provide critical food and spawning habitat for fish and other wildlife. A robust and diverse native plant community is a foundational element to the overall conditions a lake needs to provide and host desirable gamefish populations since fish, and the organisms fish eat, require aquatic plants for food, shelter, and oxygen. If native plants are unintentionally lost due to inappropriate herbicide application, fish and wildlife populations often suffer. Consequently, if chemical herbicides are applied to the Lake, these chemicals must preferentially target EWM or CLP. Such chemicals should be applied in early spring when native plants have not yet emerged.

5. **A need for repeated treatments due to re-emergence of target plants from existing seed banks and/or plant fragments**—Chemical treatment is not a one-time solution. The fact that the treated plants such as EWM are not actively removed from the Lake increases the potential for viable seeds/fragments to remain after treatment, allowing for resurgence of the target species later in the season and/or the next year. For example, underwater monitoring of auxin herbicide (Triclopyr or 2,4-D) treated EWM and hybrid EWM infested areas within Gun Lake, Michigan revealed recovery and survival of severely injured plants in the forms of shoot formation, root crowns, and rooting of settled vegetative fragments within four weeks after treatment.[171] Additionally, leaving large areas void of plants (both native and invasive) creates a disturbed area without an established plant community. EWM flourishes in disturbed areas. In summary, applying chemical herbicides to large areas can provide opportunities for reinfestation, which in turn necessitates repeated herbicide applications.

6. **Hybrid water milfoil's resistance to chemical treatments**—Hybrid water milfoil[172] complicates management since research suggests that certain strains may have higher tolerance to commonly utilized aquatic herbicides such as 2,4-D and Endothall and those differences may be heritable among different genotypes.[173] Consequently, further research on the efficacy and impacts of

[171] *R.A. Thum, S. Parks, J.N. McNair, P. Tyning, P. Hausler, L. Chadderton, A. Tucker, and A. Monfils, "Survival and vegetative regrowth of Eurasian and hybrid watermilfoil following operational treatment with auxinic herbicides in Gun Lake, Michigan,"* Journal of Aquatic Plant Management*, 55: 103-107, 2017.*

[172] *In recent years, it has become evident that EWM and native (or northern) water milfoil have begun to hybridize; the resultant hybrid strains – and they are many – cannot be reliably identified based on physical appearance alone, thus making identification and selection of the appropriate control method problematic.*

[173] *L.L. Taylor, J.N. McNair, P. Guastello, J. Pashnick, and R.A. Thum, "Heritable variation for vegetative growth rate in tem distinct genotypes of hybrid watermilfoil",* Journal of Aquatic Plant Management*, 55: 51-57, 2017; E.A. LaRue, et al., "Hybrid Watermilfoil Lineages are More Invasive and Less Sensitive to a Commonly Used Herbicide than Their Exotic Parent (Eurasian Watermilfoil)",* Evolutionary Applications*, 6: 462-471, 2013; and, L.M. Glomski, M.D. Netherland, "Response of Eurasian and Hybrid Watermilfoil to Low Use Rates and Extended Exposures of 2,4-D and Triclopyr",* Journal of Aquatic Plant Management*, 48: 12-14, 2010.*

herbicides on hybrid water milfoil is needed to better understand the appropriate dosing applied within lakes which increases lead time and cost. Hybrid water milfoil has not been observed and verified in Lake Comus.

7. **Effectiveness of small-scale chemical treatments**—Small-scale treatments of 2,4-D on EWM have highly variable results. A study completed in 2015 concluded that less than 50 percent of the 98 treatment areas were effective or had more than a 50 percent reduction in EWM.[174] In order for a treatment to be effective it must meet a certain exposure time while maintaining a target concentration; however, due to the dissipation of chemicals (e.g., wind and wave action) target concentrations are often not met. Therefore, when deciding to implement small-scale chemical treatments the variability in results together with the cost of treatment must be considered.

Water Level Manipulation

Manipulating water levels can also be an effective method for controlling aquatic plant growth and restoring native aquatic plant species, particularly emergent species such as bulrush and wild rice.[175] Water level manipulation has also been used to drive shallow lakes from an algae-dominated state to a macrophyte-dominated state.[176] In Wisconsin, overwinter lake drawdown is generally considered to be the most effect water level manipulation technique to reduce invasive submergent plant abundance. Overwinter drawdown exposes lake sediment to freezing temperatures while avoiding conflict with summer recreational uses. One to two months of lake sediment exposure can damage or kill aquatic plant roots, seeds, and turions through freezing and/or desiccation. As large areas of lake sediment need to remain exposed for long time periods, water level manipulation is most cost effective in lakes with operable dam gates that can sustain fine levels of water elevation control. In lakes without dams, high-capacity water pumping can be used to reduce lake levels at generally much greater cost.

While water level manipulation affects all aquatic plants within the drawdown zone, however, not all plants are equally susceptible to drawdown effects. Abundance of water lilies (*Nymphaea* spp. and *Nuphar* spp.) and milfoils (*Myriophyllum* spp.) can be greatly reduced by winter drawdowns while other species, such as duckweeds (*Lemna* spp.), may increase in abundance.[177] Two studies from Price County, Wisconsin show reduced abundance of invasive EWM and CLP and increased abundance of native plant species following winter drawdowns.[178,179] Many native emergent species rely upon the natural fluctuations of water levels within a lake. Conducting summer and early fall drawdowns have effectively been used to stimulate growth of desired emergent vegetation species, such as bulrush, burreeds, and wild rice in exposed lake-bottom sediment, all of which subsequently provide food and habitat for fish and wildlife. However, undesired emergent species, such as invasive cattails and phragmites (*Phragmites* spp., also known as common reed grass), can also colonize exposed sediment so measures should be taken to curtail their growth after drawdown.[180] A combination of measures, such as mowing while the water levels are drawn down and then flooding the cut cattail stems when the water levels are raised, are reported to be more effective in reducing cattail expansion than any single treatment alone.[181] Prescribed burning

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[174] *M. Nault, S. Knight, S.V. Egeren, et al., "Control of Invasive Aquatic Plants on a Small Scale,"* LakeLine, 35(1): *35-39, 2015.*

[175] *For detailed literature reviews on water level manipulation as an aquatic plant control measure, see C. Blanke, A. Mikulyuk, M. Nault, et al.,* Strategic Analysis of Aquatic Plant Management in Wisconsin*, Wisconsin Department of Natural Resources, pp. 167-171, 2019 as well as J.R. Carmignani and A.H. Roy, "Ecological Impacts of Winter Water Level Drawdowns on Lake Littoral Zones: A Review,"* Aquatic Sciences, *79, 803-824, 2017.*

[176] *www.dnr.state.mn.us/mcvmagazine/issues/2014/jul-aug/shallow-lake-restoration.html*

[177] *G.D. Cooke, "Lake Level Drawdown as a Macrophyte Control Technique,"* Water Resources Bulletin*, 16(2): 317-322, 1980*

[178] *Onterra, LLC, Lac Sault Dore, Price County, Wisconsin: Comprehensive Management Plan, 2013.*

[179] *Onterra, LLC, Musser Lake Drawdown Monitoring Report, Price County, Wisconsin, 2016.*

[180] *WDNR, 2017,* op. cit.

[181] *D. Svedarsky, J. Bruggman, S. Ellis-Felege, et al.,* Cattail Management in the Northern Great Plains: Implications for Wetland Wildlife and Bioenergy Harvest, *University of Minnesota Northwest Research and Outreach Center, 2016. www.crk.umn.edu/sites/crk.umn.edu/files/cattail-management-northern-great-plains.pdf*

during mid-summer when soils and rhizomes are dry are a recommended control strategy for curtailing phragmites growth.[182]

Water level manipulation can also have unintended impacts on water chemistry and lake fauna.[183,184] Decreased water clarity and dissolved oxygen concentrations as well as increased nutrient concentrations and algal abundance have all been reported following lake drawdowns. Rapid drawdowns can leave lake macroinvertebrates and mussels stranded in exposed lake sediment increasing mortality and subsequently reducing prey availability for fish and waterfowl. Similarly, drawdowns can disrupt the habitat and food sources of mammals, birds, and herptiles, particularly when nests are flooded as water levels are raised in the spring (see Section 2.7, "Other Wildlife" and Section 3.6, "Fish and Wildlife" for more information on how water level manipulation may affect rare reptiles in the watershed). Therefore, thoughtful consideration of drawdown timing, rates, and elevation as well as the life history of aquatic plants and fauna within the lake is highly recommended. Mimicking the natural water level regimen of a lake as closely as possible may be the best approach to achieve the desired drawdown effects and minimize unintended and detrimental consequences.

Fostering a Healthy Aquatic Plant Community

The control measures described above effectively manage healthy plant communities by reducing and/or removal invasive and nuisance plant growth. However, most of these measures are not effective for fostering native macrophyte growth in lakes with low diversity and limited plant coverage, such as Lake Comus. Enhancing the aquatic plant community in Lake Comus will require increased water clarity, reduced sedimentation, reduced nutrient (particularly phosphorus) loads (see Section 2.3, "Water Quality and Pollutant Loading"), and reducing the common carp population (see Section 2.6, "Fisheries"), All may be facilitated through water level drawdowns and aquatic plant plantings. The goal would be to transform the Lake from its current turbid condition, dominated by suspended algae, to a clear-water condition dominated by macrophytes. This clear-water state better aligns with the goals of the LCPRD and Lake residents, fosters a healthy aquatic plant community to provide food and habitat to aquatic organisms and waterfowl, and improves the water quality of the Lake and Turtle Creek downstream of the dam.

As discussed above, water level manipulation can dramatically affect aquatic plant community species composition and coverage of aquatic vegetation in a lake by reducing EWM and CLP populations, encouraging the spread of desirable emergent species such as bulrush, and promoting growth of native plant species like muskgrass, naiads (*Najas* spp.), and pondweeds. Furthermore, water level drawdowns can consolidate and decrease the organic matter content of lake-bottom sediment as well as facilitate a larger winterkill of common carp. All these efforts could help reduce sediment resuspension that cause turbid water in the Lake, subsequently improving water clarity that would facilitate greater coverage of the lake-bottom sediment by rooted aquatic plants. However, any lake drawdown efforts would need to consider potential impacts to the state-Endangered and federally Threatened Eastern Massasauga rattlesnake, as discussed in greater detail in Section 2.7, "Other Wildlife" and Section 3.6, "Fish and Wildlife." Recommendations and strategies to enhance native plant coverage are discussed in Section 3.5, "Aquatic Plants."

2.5 STREAM HABITAT

This section discusses ecosystem services that streams provide, environmental factors that influence streams including human manipulation, and the current conditions of stream habitat in the Lake Comus watershed.

Stream Function, Form, and Process

Streams actively transport water *and* sediment. Streams continually erode, transport, and deposit sediment causing stream channels to change over time. When the amount of sediment load delivered to a stream is equal to what is being transported downstream, and when stream widths, depths, and length remain consistent over time, it is common to refer to such a stream as being in a state of "dynamic equilibrium."

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[182] *A.L. Thompson and C.S. Luthin,* Wetland Restoration Handbook for Wisconsin Landowners, *Wisconsin Department of Natural Resources Bureau of Science Services, SS-989, 2004. dnr.wisconsin.gov/topic/Wetlands/handbook.html*

[183] Ibid.

[184] *Cooke, 1980,* op. cit.

In other words, the stream retains its overall physical dimensions, but those physical features may shift or migrate over the landscape with time. It is not uncommon for low-gradient streams in Southeastern Wisconsin to migrate more than one foot within a single year.

Stream channel characteristics, such as slope, length, and sinuosity are the product of many disparate factors including geology (e.g., soil gradation and permeability, topography); flora, fauna, and their interplay; weather; and human manipulation (e.g., ditching, impoundments, changed hydrology). Many healthy streams naturally meander and migrate across a landscape over time. Sinuosity is a measure of how much a stream meanders and is defined as the ratio of channel length between two points on a channel to the straight-line distance between the same two points. Sections of streams that have been artificially straightened typically have low sinuosity values (a value closer to one).

To better understand stream systems and what influences their conditions, it is important to understand the effects of both spatial and temporal scales. Streams can theoretically be subdivided into a spectrum of habitat disturbance sensitivity and recovery time (Figure 2.45).[185] Microhabitats, such as a small patch of gravel or the cover provided by a particular tree, are most susceptible to disturbance, while entire 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 both large- and smaller-scale features of streams. For example, sediment deposition may occur simultaneously with scour at another nearby site, but the overall characteristics of the reach do not significantly change. In contrast, a large-scale disturbance, such as results from an extremely large flood event, is initiated at the segment level, and reflected at all lower hierarchal levels (reach, habitat, and 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.[186]

The two most important stream system fundamentals are listed below.

- A fluvial system is an integrated series of physical gradients. Downstream areas are longitudinally linked to and dependent upon upstream segments.

- Streams are intimately connected to their adjacent terrestrial setting. Land-stream interaction is crucial to healthy stream ecosystem processes and this connectivity does not diminish in importance with stream size. In this regard, human land use and manipulation significantly influence stream channel condition and associated biological integrity.[187] Human manipulation often isolates streams from their floodplains and riparian habitat areas.

Physical Stream Habitat

Physical stream habitat includes streambed substrates, water temperature, and large woody structure from streamside vegetation. Streambed substrates include bedrock, boulders, cobbles, gravel, silt, clay, and a wide range of organic materials ranging from muck to submerged trees. Streambed sediment composition varies on account of stream gradient, channel form, vegetation type and abundance, hydrology, and local geology. Streambed substrates provide living space for many stream organisms. Stable substrates, such as cobbles and boulders, shelter organisms from the stream's current and protect organisms from being washed downstream during high flows. Streams with abundant cobbles and boulders commonly support greater biological diversity than do streams dominated by less stable substrates (e.g., muck, sand, and silt).

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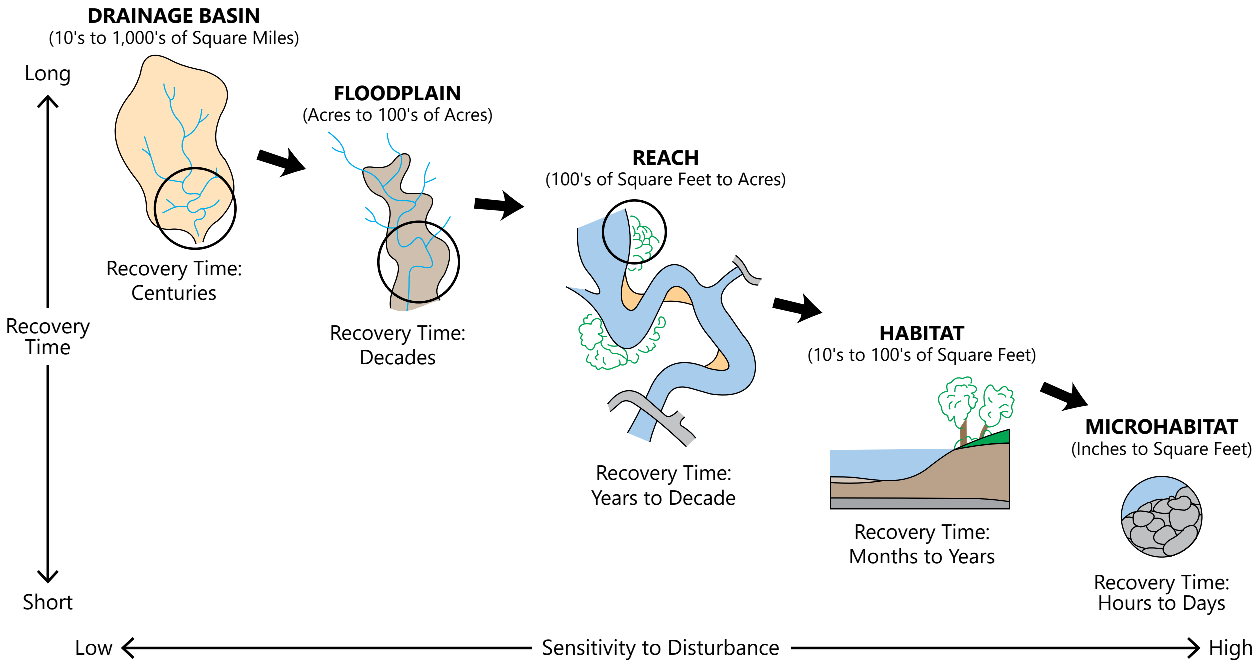
[185] *C.A. Frissell, W.J. Liss, C.E. Warren, and M.D. Hurley, "A Hierarchical Framework for Stream Classification: Viewing Streams in a Watershed Context,"* Journal of Environmental Management*, 10: 199-214, 1986.*

[186] *G.J. Niemi, P. DeVore, N. Detenbeck, et al., "An Overview of Case Studies on Recovery of Aquatic Systems From Disturbance,"* Journal of Environmental Management*, 14: 571-587, 1990.*

[187] *L. Wang, J. Lyons, P. Kanehl, and R. Gatti., "Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams,"* Fisheries*, 22(6): 6-12, 1997; J.S. Stewart, L. Wang, J. Lyons, et al., "Influences of Watershed, Riparian-Corridor, and Reach-Scale Characteristics on Aquatic Biota in Agricultural Watersheds,"* Journal of the American Water Resources Association*, 37(6): 1475-1487, 2001; F.A. Fitzpatrick, B.C. Scudder, B.N. Lenz, and D.J. Sullivan, "Effects of Multi-Scale Environmental Characteristics on Agricultural Stream Biota in Eastern Wisconsin,"* Journal of the American Water Resources Association*, 37(6): 1489-1507, 2001.*

Figure 2.45
Relationship Between Recovery Time and Sensitivity to Disturbance for Different Hierarchical Spatial Scales Associated with Stream Systems



Source: Adapted from C.A. Frissell, W.J. Liss, C.E. Warren, and M.D. Hurley, "A Hierarchical Framework for Stream Habitat Classification: Viewing Streams in a Watershed Context," Environmental Management 10: 199-214, *1986, and SEWRPC*

Water temperature directly influences aquatic organism metabolism, respiration, feeding rate, growth, and reproduction. Most aquatic species have a unique and specific optimal temperature range for growth and reproduction. Therefore, the spatial and temporal distributions of aquatic organisms are largely dictated by temperature differences created by regional differences in climate and elevation along with more local effects from riparian (stream corridor) shading and groundwater influence. Water temperature also influences many chemical processes, such as the solubility of oxygen in water. Cold water holds more oxygen than warm water.

The riparian zone is land directly adjacent to and abutting streams. Plant and animal communities in riparian zones commonly rely on moisture and nutrients delivered by streams. The size and character of riparian zones influence the amount of shelter and food available to aquatic organisms and the amount of sunlight reaching the stream through the tree canopy, which influences water temperature and the amount of energy available for photosynthesis. Riparian zones also influence the amount and quality of runoff reaching streams.

Human Manipulation

Scientists have found that stream health suffers throughout the nation in both agricultural and urban settings.[188] Of three aquatic biological communities (algae, macroinvertebrates, and fish), at least one was altered at least 80 percent of the time. Nevertheless, almost 20 percent of streams found in agricultural and urban areas were relatively healthy. Ecological health of a stream system was found to be related to the degree of human-induced change to streamflow characteristics and water quality (nutrients, sediments, and other human-sourced pollutants). Major findings and important implications of this study include:

[188] *D.M. Carlisle, M.R. Meador, T.M. Short, et al.,* The Quality of Our Nation's Waters—Ecological Health in the Nation's Streams, 1993-2005, *U.S. Geological Survey Circular 1391, 2013, pubs.usgs.gov/circ/1391/.*

- The presence of healthy streams in watersheds with substantial human influence suggests that it is possible to maintain and restore healthy stream ecosystems in landscapes occupied and modified by humans.

- Water quality is not independent of water quantity. Flow volumes are a fundamental part of stream health. Because flow regimens are manipulated in so many streams and rivers, many water-quantity based management and protection strategies commonly enhance stream health.

- Efforts to understand the causes of reduced stream health should consider the possible effect of nutrients, sediment, chloride, heavy metals, organic pollutants, and pesticides, particularly in agricultural and urbanized settings.

<u>Changes in Land Use</u>

The land- and water-use activities associated with agricultural and urban land uses have been demonstrated to influence the hydrological and chemical factors of streams. The effects manifested in streams are often carried to and manifested within connected lakes. These factors are summarized below and are illustrated in Figure 2.46.[189]

Hydrologic Factors

The timing, variability, and volume of water flowing in a stream influence, and even control, many key physical, chemical, and biological characteristics, and processes of stream systems. For example, recurring high flows from seasonal rainfall or snowmelt organize and shape the basic structure of a river's channel shape, structure, and its physical habitats, which in turn influence the types of aquatic organisms that can thrive. For many aquatic organisms, low flows impose basic constraints on the availability and suitability of habitat, such as water depth and the amount of wetted streambed. The life cycles of many aquatic organisms are synchronized with the variation and timing of stream flows. For example, the reproductive period of some common fish species (e.g., northern pike and white sucker *(Catostomus commersoni*)) is triggered by the onset of heavy, cold runoff created by early spring snowmelt and associated rainfall.

In general, human activities in Southeastern Wisconsin's agricultural settings alter the natural flow regimen of streams and rivers in several ways, including the following examples.

- **Vegetation and soil changes.** Clearing natural vegetation and intensive cropping typically reduces soil's ability to absorb runoff. This in turn can increase runoff volume and speed, lower water tables, reduce the landscape's ability to detain water, reduce groundwater recharge, and lessen the landscape's ability to sustain water features during extended dry weather periods.

- **Enhanced and artificial drainage.** This includes features such as drain tiles, French drains, artificial ditches, straightened and/or deepened streams, and storm sewers. As with vegetation and soil changes, these changes can increase runoff volume and speed, lower water tables, reduce the landscape's ability to detain water, reduce groundwater recharge, and lessen the landscape's ability to sustain water features during extended dry weather periods.

- **Groundwater pumping,** which can deplete groundwater systems feeding lakes, streams, springs, and wetlands. Water exported from a watershed has the greatest impact to local groundwater flow systems. Export can include supplying a use outside the local watershed or water consumptively used or not returned to the local groundwater system.

- **Irrigation.** Irrigation can supplement natural soil moisture and increase groundwater recharge. If irrigation water is sourced beyond the local watershed or draws upon groundwater not normally discharging to waterbodies in the watershed, irrigation can increase the supply of groundwater to local water bodies.

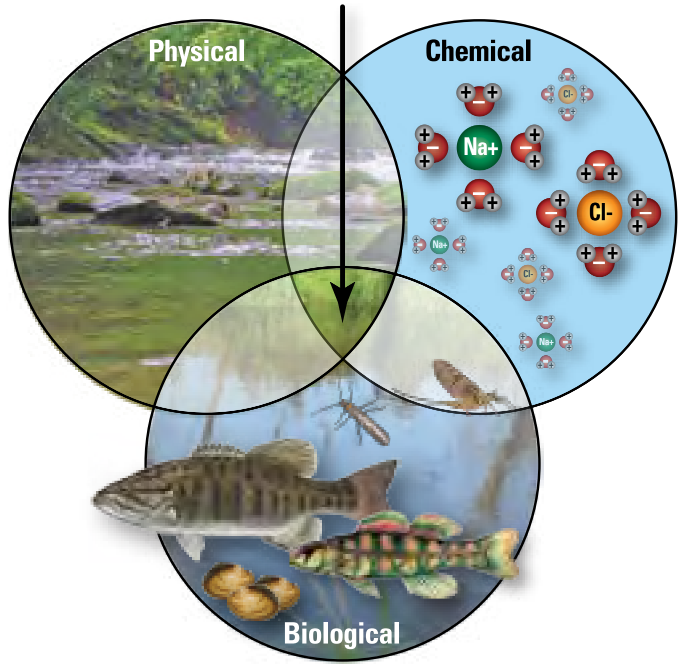
Since agricultural practices and stream system characteristics are diverse (Figure 2.47 "Agricultural Stream"), the net effect of agriculture upon stream ecosystems can be highly variable.

[189] Ibid.

One of the most profound changes humans make in urban settings is greatly increasing the amount of impervious land cover (e.g., rooftops and pavement). Impervious surfaces restrict precipitation from infiltrating into the soil, decreasing groundwater recharge and increasing the volume of water reaching streams as stormwater runoff. Engineered stormwater conveyance systems are often installed to manage increased runoff volumes. These systems rapidly convey runoff to lakes and streams, and, if unmitigated by careful design, compromise a watershed's ability to store runoff and remove sediment and pollutants entrained in runoff. This situation also increases storm runoff rates and speed, decreases stormwater retention, and leads to higher and more variable peak stream flows, generating "flashy" streams that convey large volumes of water immediately after rainfall or snowmelt occurs, but which exhibit very low flow during dry periods. High peak flows scour the bed and banks of stream and degrade channel morphology. More nutrients, sediment, and pollutants reach stream channels, reducing water quality.

Figure 2.46

Illustrations of the Dynamic Components of Natural, Agricultural, and Urban Stream Ecosystems



This simple diagram shows that a stream's ecological health (or "stream health") is the result of the interaction of its biological, physical, and chemical components. Stream health is intact if (1) its biological communities (such as algae, macroinvertebrates, and fish) are similar to what is expected in streams under minimal human influence and (2) the stream's physical attributes (such as streamflow) and chemical attributes (such as salinity or dissolved oxygen) are within the bounds of natural variation.

Source: Modified from Carlisle, D.M., Meador, M.R., Short, T.M., Tate, C.M., Gurtz, M.E., Bryant, W.L., Falcone, J.A., and Woodside, M.D., 2013, The Quality of our Nation's Waters—Ecological Health in the Nation's Streams, 1993–2005, *U.S. Geological Survey Circular 1391, p. 2, pubs.usgs.gov/circ/1391, and SEWRPC*

Reduced infiltration to groundwater reduces stream flow during dry weather. This issue is particularly pronounced in headwater streams where groundwater supplies most dry-weather streamflow. In addition, larger human populations, industry, and commercial endeavors commonly increase overall water demand in urbanized areas. Many urbanized areas in Southeastern Wisconsin draw their water supply from aquifers underlying watersheds, excluding those with access to Lake Michigan's surface water. Increased groundwater withdrawal reduces the volume of water emitted by natural discharge points (e.g., springs and seeps), which in turn affects natural stream flow regimens, water quality, and stream ecology.

Recent research has shown that average flow volume, high flow volume, high flow event frequency, high flow duration, and rate of change of stream cross-sectional area were the hydrologic variables most consistently associated with changes in algal, invertebrate, and fish communities.[190] While the Lake Comus watershed overall has low urban development, the largest urban area is in the immediate proximity of the Lake and thus may negatively affect water quality and quantity.

To some degree, the negative effects of impervious surface can be mitigated with traditional storm water management practices and emerging green infrastructure technologies, such as pervious pavement, green roofs, rain gardens, bioretention, and infiltration facilities. Modern stormwater management practices manage runoff using a variety of techniques, including those focused on detention, retention, and conveyance. Emerging technologies, in contrast, differ from traditional modern stormwater practices in that they seek to mimic the behavior of precipitation on an undisturbed landscape by retaining and infiltrating stormwater onsite. Several non-traditional, emerging low-impact development technologies that have been implemented

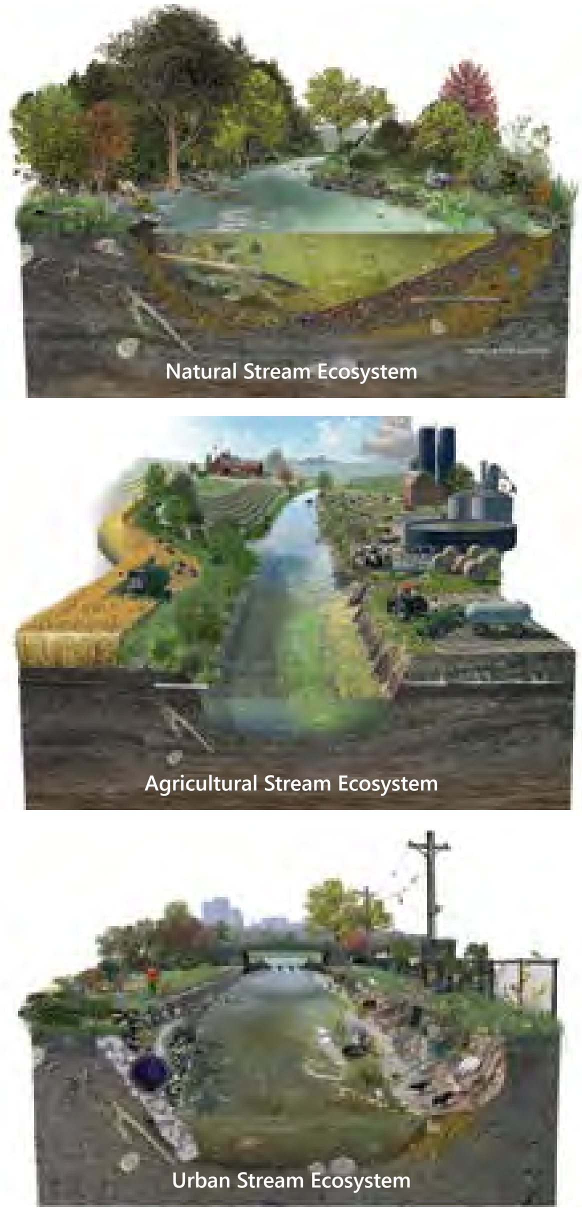
[190] *Personal Communication, Dr. Jeffrey J. Steuer, U.S. Geological Survey.*

throughout the Region, including disconnecting downspouts; installing rain barrels, green roofs, and rain gardens; improving water infiltration under lawns; and constructing biofiltration swales in parking lots and along roadways. Experience has shown that these emerging technologies can be effective. For example, recent research demonstrated that bioretention systems can work in clayey soils with proper sizing, remain effective in the winter, and can contribute significantly to groundwater recharge especially when such facilities utilize native prairie plants.[191]

The location of impervious surfaces also determines the degree of direct impact they will have upon a stream. For example, impervious surfaces located close to a stream are more damaging than those more distant since less time and distance is available to attenuate runoff volume and pollutant loads. 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 farther from the stream.[192]

Since urban lands located adjacent to streams have a greater impact on the biological community, an assumption could be made that riparian buffer strips located along streams could be instrumental in attenuating 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 piped storm sewers or engineered channels and therefore enter streams without first passing through riparian buffers. Riparian buffers need to be combined with other management practices, such as detention basins, grass swales, and infiltration facilities 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 and runoff volume management.

Figure 2.47
Example Illustrations of
How Land Use Affects Water Bodies



Source: Illustration by Frank Ippolito, www.productionpost.com Modified from Carlisle, D.M., Meador, M.R., Short, T.M., Tate, C.M., Gurtz, M.E., Bryant, W.L., Falcone, J.A., and Woodside, M.D., 2013, The Quality of our Nation's Waters—Ecological Health in the Nation's Streams, 1993–2005, *U.S. Geological Survey Circular 1391, p. 28, pubs.usgs.gov/circ/1391, and SEWRPC*

[191] *R. 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; W.R. Selbig and N. 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.*

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

Chemical Factors
The unique water chemistry requirements and tolerances of each aquatic plant and animal species defines their natural abundance and distribution in streams. Many naturally occurring chemical substances are vital to normal growth, development, and reproduction. For example, sufficient DO is necessary for normal respiration. DO concentration in streams and rivers is determined, in part, by physical aeration processes that are influenced by the slope and depth of the stream, the amount of oxygen used in the stream to support respiration and decomposition of organic matter, as well as the water temperature. Similarly, nominal amounts of nutrients and minerals (e.g., nitrogen, phosphorus, calcium, and silica) must be available to sustain stream ecological health.

Human activities often contribute additional amounts of naturally occurring substances as well as other synthetic (artificial) chemicals to streams from point and nonpoint sources. Runoff from agricultural lands (see "Agricultural Stream Ecosystem" in Figure 2.47) may contain 1) eroded soil; 2) nutrients and organic matter adhering to the soil or from applying fertilizer or manure; 3) chloride and other salts from soil amendments; 4) pesticides used to control insects, weeds, rodents, bacteria, fungi, or other unwanted organisms; and 5) other synthetic compounds used for varying purposes. Runoff from urban lands (see "Urban Stream Ecosystem" in Figure 2.47) may contain 1) sediment from construction and other activities; 2) organic matter from trees, lawns, urban animals, and pets; 3) nutrients and pesticides applied to lawns and recreational areas; and 4) petroleum compounds, organic toxins, and deicing salts from roads and parking lots. Point sources include municipal and industrial wastewater effluent that, depending on the sources of wastewater and level of treatment, may contain various amounts of nutrients and other contaminants.

Stream Channelization
Straightening meandering stream channels (sometimes referred to as "ditching" or "channelization") was once widely practiced to speed runoff. Many streams (especially smaller first and second order streams) draining intensely farmed or highly developed areas were ditched. The United States Department of Agriculture National Resources Conservation Service (NRCS) cost-shared such activities until the early 1970s in Southeastern Wisconsin.[193] The objectives of channelization included the following goals:

- Reduce local flooding by conveying stormwater runoff more rapidly downstream
- Drain low-lying land thereby increasing the value of land to agriculture and development
- Relocate streams to allow more efficient farming in rectangular fields and simplify site drainage in developing areas

Channelization shortens overall stream channel length between two points. As such, the distance water travels to descend a set amount is decreased, the resultant channel slope increases, and water velocity increases. Streams with higher slopes and faster moving water have greater ability to move sediment, both in terms of sediment volume and particle size. Artificially increasing stream slope commonly destabilizes natural bed substrate and channel forms that have equilibrated to a lower slope channel. Channelized stream segments commonly erode their beds and/or banks, and, through sediment erosion or deposition, can propagate instability in adjacent unaltered stream segments.

In many cases, drain tiles and supplemental drainage ditches were installed to complement and facilitate water movement off fields and reduce the incidence of shallow saturated soil. To facilitate drainage, many channelized stream reaches were commonly dredged much deeper and wider than the pre-existing stream channel provide a discharge point for drainage ditches and tiles. Such modification tends to produce slow moving, essentially stagnant, waterways during modest flow. Many channelized reaches became long straight pools or areas of sediment deposition and accumulation, as velocities within these reaches are too low to carry suspended materials. Therefore, many channelized reaches frequently contain uniformly deep, fine-grained, organic-rich sediments as their predominant substrate type. These accumulated sediments are regularly removed through expensive ditch maintenance programs.

[193] *Personal communication, Gene Nimmer, NRCS engineer.*

Channelizing streams often leads to a long series of unintentional negative changes in stream form and function. Channelized streams experience instream hydraulic changes that compromise the stream's ability to access floodplain areas during high runoff periods. This break in stream and floodplain connectivity has numerous detrimental impacts, including the following examples:

- Reduced capacity of the stream and riparian area to filter sediment and pollutant from floodwater
- Reduced floodwater storage, increasing downstream flood volumes and elevations
- Increased erosive and sediment carrying capacity of water flowing through the ditched segment
- Destabilized stream channels at the point of modification as well as in unaltered stream segments upstream and downstream of the modified reach

Channelization often destroys shade-providing riparian vegetation, increasing summer water temperatures. Furthermore, channelization can alter instream sedimentation rates and paths of sediment erosion, transport, and deposition.

In addition to the loss of stream channel length, channel straightening significantly reduces the number of pool and riffle features within a stream system. Pool-riffle sequences are often found in meandering streams, where pools occur at meander bends and riffles at crossover stretches.[194] Pools and riffles are important refuge, reproduction, feeding, and nursery areas for a wide variety of aquatic life, and encourage hyporheic flow,[195] which benefits in-stream habitat and overall water quality. Therefore, channelization, as traditionally accomplished without mitigating features, generally creates an unraveling effect on stream form, can exacerbate flooding and water quality problems in downstream reaches, and diminishes suitability of instream and riparian habitat for fish and wildlife.

Current Stream Conditions

While comprehensive on-the-water stream surveys of Turtle Creek and other Lake tributaries were beyond the scope of this study, Commission staff were able to provide the following assessment of stream conditions using historic aerial imagery, U.S. Geological Survey maps, casual field observations, and geographic information system (GIS) inventory.

Turtle Creek upstream of Lake Comus is a low-gradient stream system, characterized by a gradient of about 0.005 feet/foot or less. High-quality low-gradient streams tend to lack riffles and have relatively slow currents, small substrate particle sizes, and well-developed meandering (i.e., high sinuosity) channel morphology. Such systems often flow through wetlands and may have soft, unconsolidated (i.e., organic) substrates and poorly defined channels in some cases. These characteristics were noted by Commission staff while traveling upstream on Turtle Creek from the Lake to the confluence with the CTH O tributary in October 2020 and in August 2021. This lower portion of the Creek slightly meanders through a wetland dominated by cattail (*Typha* spp.) with the stream bottom largely appearing to consist of soft sediment (Figure 2.44).

The organic sediment surrounding low-gradient streams makes them desirable candidates for modification to enhance agricultural development, resulting in stream channelization and tile installation to improve field drainage. As discussed in Section 2.2, "Human Use and Occupation," the Lake's watershed was converted for agricultural uses in the mid-1800s and agricultural use is still the predominant land use in the watershed. Runoff from agricultural land use is a major contributor to the watershed's pollutant loading and the elevated total phosphorus concentrations in Turtle Creek and the CTH O tributary, as discussed in Section 2.3, "Water Quality and Pollutant Loading." These organic pollutants are likely contributing to the low dissolved oxygen concentrations observed in Turtle Creek at Dam Road. Thus, hydrological changes associated with agricultural development continues to strongly influence the conditions of Turtle Creek and its tributaries.

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

[195] *Hyporheic flow is water moving into, out of, and within sediment below and alongside a stream bed that frequently enters and exits the stream's main flow channel. Hyporheic flow stimulates favorable geochemical reactions, supports life in the stream bed, and helps stabilize stream temperatures.*

As mentioned in Section 2.1, "Lake and Watershed Physiography," Turtle Creek and its tributaries were substantially channelized over the last two centuries leading to loss of instream habitat, stream length, and over-widening of streams. Comparing 2020 aerial imagery to an 1837 PLSS plat map indicates that while the modern-day Turtle Creek does generally follow its original path through the watershed, many of the meanders that existed in 1837 have been straightened, particularly in the reaches between Turtle Lake Road and Dam Road (Figures 2.5, 2.6, and 2.48). In addition to the channelization, the streams have become overly widened since 1837, likely due to channelization. The 1837 plat maps report the stream width in chain links (7.92 inches per link) where Turtle Creek and its larger tributaries cross PLSS lines. As shown in Figure 2.6, Commission staff estimated stream width using aerial imagery at these same locations to compare stream widths between pre-disturbance and current conditions. Turtle Creek is currently estimated to be over three times as wide in some reaches compared to 1837, while the CTH O tributary is double its 1837 width and the tributary draining the Turtle Valley Wildlife Area is nearly six times its 1837 width. Over-widening of streams can cause problems with sediment transport, loss of instream habitat, and lead to increased stream temperatures. Furthermore, when streams are ditched, the spoil material generated by excavation is commonly cast along the banks of the ditch. This can isolate the ditched stream from its floodplain.

Compounded with the ditching of former wetlands, the low-gradient Turtle Creek has likely become unable to transport the substantial loads of sediment it receives via runoff, leading to deposition of flocculent sediment along the stream bottom as observed by Commission staff in 2020 and 2021. These flocculent sediment deposits can increase stream turbidity during baseflow and cause excessive turbidity during significant rainfall events as this sediment is resuspended with higher streamflow. Increased turbidity reduces water quality and clarity as well as habitat suitability for sensitive fish and macroinvertebrate species (see following subsection, "Macroinvertebrates as Indicators of Stream Conditions" for more information).

An 1893 quad map from the U.S. Geological Survey shows that while some modification may have begun, many meanders still existed at this time (Figure 2.7). The early 1900s saw the formation of the Turtle Creek Drainage District which facilitated construction of drainage ditches, lateral lines, and tile lines along Turtle Creek to improve viability for farming operations.[196] By 1941, the streamlines of Turtle Creek and several of its tributaries have been straightened and the stream widths nearly match their current dimensions (Figure 2.49). Loss of stream meander has likely greatly shortened the overall length of the Creek. For example, the length of the historic stream channel in Figure 2.49 is approximately 2,400 feet while the length of the current channel is only 370 feet, a stream length loss of nearly 85 percent. The sinuous historic stream channel is still visible in some sections in the 1941 imagery, providing a stark contrast to straightened stream channel. The 1941 aerial imagery also reveals that much of the wetlands that currently flank the Creek had previously been farmed, with little to no natural vegetative buffer between the Creek and the surrounding farmland (Figures 2.49 and 2.50).

Despite having more than 70 to 100 years to recover from channelization, these reaches have not been able to redevelop more natural or appropriate sinuosities. Similarly, these channels are nearly the same widths in 2020 as in the 1940 aerial imagery. Therefore, the only reasonable way to restore stream function within these systems is to physically naturalize them through reconstruction. Reconstructing meanders restoring more natural sinuosity, particularly in low gradient systems, is one of the most effective ways to restore instream habitat as well as restore the ability of this system to transport sediment and to function more like a healthy stream system. Good locations to restore stream function are where natural channel lengths cut off during channel straightening still exist. Several extensive reaches exist within Turtle Creek where the natural channel is visible but is separated from the current channel, as shown on Figures 2.49 and 2.50. Even if a natural stream channel has been buried or cannot be located, many opportunities remain to rehabilitate or increase stream sinuosity, floodplain connectivity, and associated habitat and stream function within channelized stream reaches.

[196] *Donohue & Associates,* Lake Comus Management Plan, *1980*.

Macroinvertebrates as Indicators of Stream Conditions and Health

Macroinvertebrates are organisms without backbones inhabiting substrates such as sediments, debris, logs, and plant vegetation in the bottom of a stream or creek for at least part of their life cycle. Macroinvertebrates are visible to the naked eye, are abundant in freshwater systems, and include insect larvae, leeches, worms, crayfish, shrimp, clams, mussels, and snails. Since macroinvertebrates develop and grow within the water, they are affected by changes in local water quality.

Most macroinvertebrates tend to be found within shallow, fast flowing riffle habitats of streams compared to deeper and slower flowing pool or run habitats. Riffles can range from uneven bedrock or large boulders to sand substrates. However, the optimum riffle substrates for macroinvertebrates are characterized by particle diameters ranging from gravels (one inch) to cobbles (ten inches). Water flowing through these areas provides plentiful oxygen and food particles. Riffle-dwelling communities are made up of macroinvertebrates that generally require high dissolved oxygen levels and clean water, and most are intolerant of pollution. For example, mayflies (Ephemeroptera), stonefly larvae (Plecoptera), and caddisfly larvae (Trichoptera) tend to be found in cold, clear flowing water with a gravel or stone bottom and high dissolved oxygen concentrations. Caddisfly larvae are particularly sensitive to pollution and oxygen depletion.[197]

Macroinvertebrate Biotic Indices

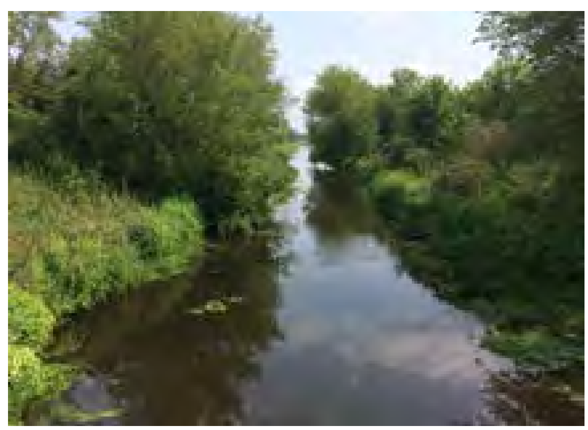
Macroinvertebrates are useful water quality indicators because they spend much of their life in the waterbody, they are not mobile, they are easily sampled, and the references needed to identify them to a useful degree of taxonomic resolution are readily available. In addition, the differences among macroinvertebrate species in habitat preferences, feeding ecology, and environmental tolerances allow the quality of water and habitat in a waterbody to be evaluated based upon the identity of the groups that are present and their relative abundances. The differences among macroinvertebrate species in feeding ecology are often represented through the classification of species into functional feeding groups based upon the organisms' principal feeding mechanisms.[198] Several groups have been described. Scrapers include herbivores and detritivores that graze on microflora, microfauna, and detritus attached to mineral, organic, or plant surfaces. Shredders include detritivores and herbivores that feed primarily on coarse particulate organic matter. Collectors feed on fine particulate organic matter.

Figure 2.48
Straightened Channels of Turtle Creek: August 2021

Turtle Creek South of Turtle Lake Road

Turtle Creek Upstream of Island Road

Turtle Creek Downstream of Island Road



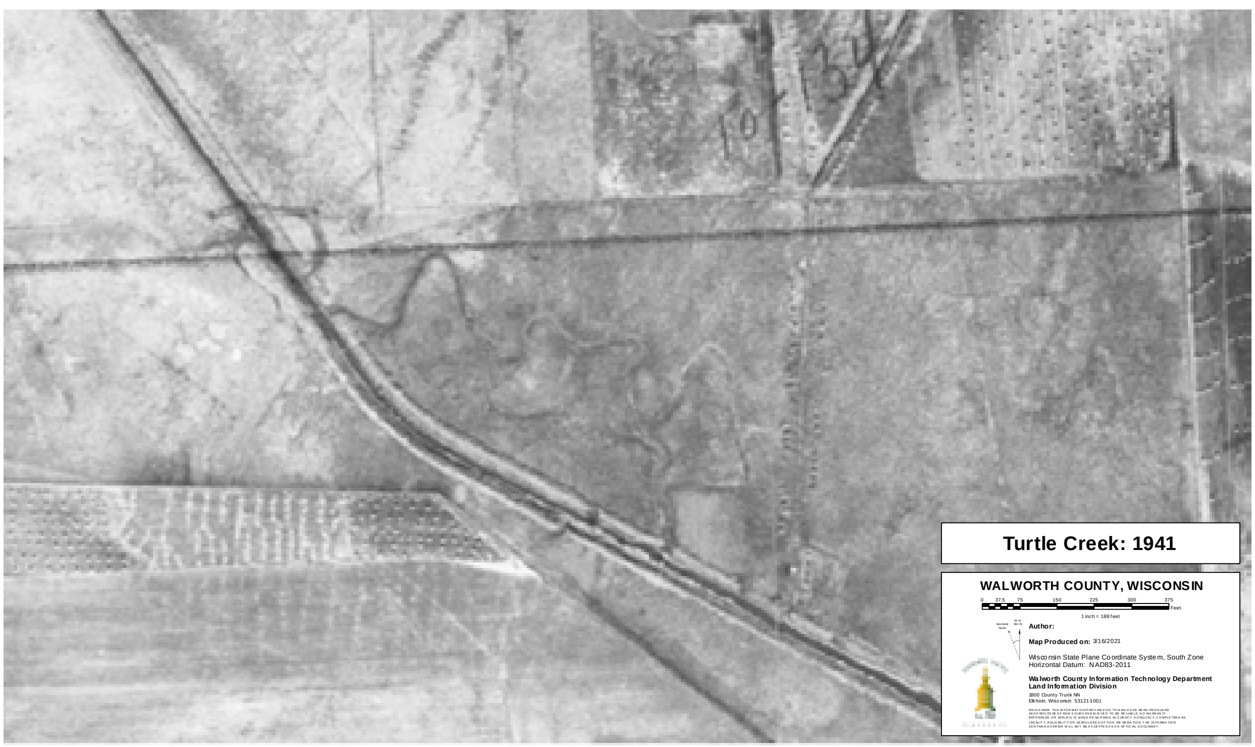
Source: SEWRPC

[197] *D.L. Osmond, D.E. Line, J.A. Gale, et al.,* WATERSHEDSS: Water, Soil and Hydro-Environmental Decision Support System*h2osparc.wq.ncsu.edu, North Carolina State University Water Quality Group, 1995, see website at www.water.ncsu.edu/watershedss/info/macroinv.html.*

[198] *K.W. Cummins, "Trophic Relations of Aquatic Insects,"* Annual Review of Entomology, *18: 183-206, 1973; K.W. Cummins and M.J. Klug, "Feeding Ecology of Stream Invertebrates,"* Annual Review of Ecology and Systematics*, 10: 147-172, 1979.*

Figure 2.49
1941 Aerial of Turtle Creek Channel: Upstream

Figure 2.50
1941 Aerial of Turtle Creek Channel: Downstream



This group includes filterers that remove suspended material from the water column and gatherers that utilize material deposited on the substrate.

A variety of metrics have been developed and used for evaluating water quality based upon macroinvertebrate assemblages.[199] These include metrics based on taxa richness, trophic function, relative abundance of the dominant taxa, and diversity, as well as more complicated metrics. Most of these metrics have been developed for stream systems, though some macroinvertebrate metrics are being developed for other aquatic environments, such as wetlands.[200] The Hilsenhoff Biotic Index (HBI), and the percent of individuals detected consisting of members of the insect orders Ephemeroptera, Plecoptera, and Trichoptera (percent EPT) were used to classify existing macroinvertebrate data and evaluate environmental quality of the Lake's tributaries.[201]

The HBI represents the average weighted pollution tolerance values of all arthropods present in a sample. It is based upon the macroinvertebrate community's response to high loading of organic pollutants and reductions in dissolved oxygen concentrations. The HBI is designed for use with samples collected from riffles and runs and thus may not be reliable for interpreting data collected from other stream environments. For example, macroinvertebrate data from samples collected from snags tend to be more variable and give higher HBI values than data from samples collected in riffles.[202] Lower HBI values indicate better water quality while higher values indicate worse water quality conditions.

The percent EPT consists of the percentage of individuals detected in a sample that are members of the insect orders Ephemeroptera, Plecoptera, and Trichoptera. These taxa represent the organisms in streams and rivers that are less tolerant of organic pollution. Higher values of percent EPT indicate better water quality. Lower values indicate worse water quality. Low values of percent EPT may result from a variety of stressors including high loadings of organic pollution, low concentrations of dissolved oxygen, biologically active concentrations of toxic substances, stream flow regime disruptions, and water temperature increases.

Tributary Macroinvertebrate Conditions

Only one recorded macroinvertebrate survey in the Lake Comus watershed, which occurred on October 31st, 2017 where CTH O crosses over an unnamed tributary to Turtle Creek. As noted above, the number and type of macroinvertebrates present in a stream can provide an indicator of water quality. Hence, the HBI, species richness and percent EPT were used to classify macroinvertebrate and environmental quality in the CTH O tributary. This survey indicated fair macroinvertebrate community conditions with a HBI score of fair (5.9), a low percent EPT (10.8 percent), and a fairly high species richness (36 species). Less than three percent of the species identified are known to be pollution-intolerant, indicating that this macroinvertebrate community is tolerant of organic water pollution such as total suspended sediment. This survey was conducted in a relatively flat, meandering reach of the CTH O tributary with dissolved oxygen concentrations between 5 to 10 mg/l but fair to low transparency tube measurements, corroborating evidence that the macroinvertebrate survey is being affected by organic pollutants.

No recorded macroinvertebrate surveys have been conducted by WDNR in Turtle Creek upstream of the Lake. However, LCPRD volunteers conducted qualitative macroinvertebrate surveys on Turtle Creek at Island Road and at Dam Road in August through October of 2020. These surveys only observed amphipods and pouch snail shells at Dam Road while no macroinvertebrates were observed at Island Road.[203] The high concentrations of suspended sediment and heavily channelized stream are likely detrimental to the macroinvertebrate communities of the Creek. As described above, high concentrations of organic pollutants

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[199] *R.A. Lillie, S.W. Szczytko, and M.A. Miller,* Macroinvertebrate Data Interpretation Manual*, Wisconsin Department of Natural Resources, PUB-SS-965 2003, Madison, Wisconsin, 2003.*

[200] *R.A. Lillie, "Macroinvertebrate Community Structure as a Predictor of Water Duration in Wisconsin Wetlands,"* Journal of the American Water Resources Association*, 39: 389-400, 2003.*

[201] *W.L. Hilsenhoff, "Rapid Field Assessment of Organic Pollution With a Family-Level Biotic Index,"* Journal of the North American Benthological Society, *7(1): 65-68, 1988.*

[202] *Lillie, Szczytko, and Miller, 2003,* op. cit.

[203] *Notes from Larry Meyer, LCPRD volunteer, on Lake Comus and Turtle Creek water quality observations and recommendations, October 2020.*

can reduce dissolved oxygen concentrations and species sensitive to low dissolved oxygen concentrations cannot persist in these waters. Channelizing reaches removes the natural meander of the stream as well as the riffle and pool habitats created by that meander. Riffle habitats produce the highest abundance and diversity of macroinvertebrate food, such as Ephemeroptera, Trichoptera, and Diptera, for insectivorous fish species compared to other instream habitats. Reducing pollutant loading and restoring the historic meandering channel patterns present immense potential to improve the quality of the macroinvertebrate and fish communities of the Creek.

2.6 FISHERIES

This section describes the historical and current conditions and management of fish populations in the Lake Comus watershed, including a history of fish stocking and management in Lake Comus followed by a description of the current fishery. The fisheries and conditions of Turtle Creek are also described.

Lake Comus

Lake Comus has long supported a warmwater fish population with some sport fish. A 1961 WDNR report indicates that the Lake was managed for largemouth bass and panfish but also has populations of northern pike, yellow perch, bullheads, and rough fish.[204] The 1984 Turtle Creek Priority Watershed Plan stated that the Lake's fishery had deteriorated over the previous 25 years and had several winterkill events during this period, leaving a community dominated by rough fish and only a remnant of its sport fish population.[205] Today, Lake Comus contains a small variety of naturally reproducing warmwater fish species as well as northern pike, the populations of which are supported by stocking. The WDNR lists northern pike, largemouth bass, and panfish as "present" in Lake Comus.[206] The fishery classification approach developed for Wisconsin lakes by Rypel, et. al. describes Lake Comus' fishery as a simple, warm, dark system indicating a fishery with three or fewer sportfish, no walleye present, warm water temperatures, low water clarity, and the capacity to develop high abundance of black crappie.[207] This system is the most common in Southeastern Wisconsin and also describes nearby Walworth County lakes such as Como, Lorraine, North, Rice, and Wandawega. One deviation from the Lake's classification is that simple, warm, dark systems are not predicted to support the coolwater white sucker, which have been observed in Lake Comus. Their presence in an otherwise warmwater system may indicate the presence of coolwater refugia provided by abundant groundwater springs.

Wisconsin's high-quality warmwater fisheries are characterized as having many native species. Cyprinids, darters, suckers, sunfish, and percids typically dominate the fish assemblage. Pollution intolerant species (species that are particularly sensitive to water pollution and habitat degradation) are also common in such high-quality warmwater systems.[208] Pollution tolerant fish species (species that can persist 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.

Stocking

Fish stocking records in Lake Comus are presented in Table 2.20. The WDNR stocked approximately 34,700 fingerling largemouth bass in 1984, 1989, and 1990. The WDNR began stocking northern pike into the Lake in 1983 and continued sporadic stocking until 2012, when it began stocking nearly every year. In

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204 *WDNR, 1961,* op. cit.

205 Ibid.

206 *Wisconsin Department of Natural Resources publication PUB-FH-800*, Wisconsin Lakes, *2005*.

207 *A.L. Rypel, T.D. Simonson, D.L. Oele, et al.,* Flexible Classification of Wisconsin Lakes for Improved Fisheries Conservation and Management, *Fisheries 44:5 225-238, 2019*.

208 *J. 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*.

Table 2.20
WDNR Fish Stocking in Lake Comus: 1983-2018

Year	Species	Age Class	Number	Average Fish Length (inches)
1983	Northern Pike	Fingerling	800	9
1984	Largemouth Bass	Fingerling	10,800	3
1989	Largemouth Bass	Fingerling	7,900	2
1989	Northern Pike	Fingerling	328	10
1990	Largemouth Bass	Fingerling	16,000	1
1990	Northern Pike	Fingerling	900	8
2006	Northern Pike	Large Fingerling	492	9.2
2008	Northern Pike	Large Fingerling	487	10
2012	Northern Pike	Large Fingerling	262	8
2014	Northern Pike	Large Fingerling	328	9.1
2015	Northern Pike	Small Fingerling	3,275	3.6
2016	Northern Pike	Small Fingerling	4,498	4
2017	Northern Pike	Large Fingerling	252	7.9
2018	Northern Pike	Large Fingerling	576	9

Source: WDNR and SEWRPC

total, the WDNR has stocked 12,198 small and large fingerling northern pike into the Lake. Additionally, one private stocking event released 517 fingerling northern pike into the Lake in 2001. A previous report has noted that northern pike migrate upstream from the Lake to spawn in the wetland complex adjacent to Turtle Creek.[209] These observations indicate how good connections between the Lake and the Creek can facilitate northern pike production in this system. Refer to Chapter 3 for management recommendations geared towards safeguarding these spawning stocks to protect and enhance the natural reproduction of these populations.

Fishery Surveys

The WDNR has completed numerous fish surveys in Lake Comus dating back at least to 1956 using a combination of boom shockers, fyke nets, trap nets, and seines. Across all these surveys, the WDNR has observed a warmwater assemblage of 11 fish species and a transitional or coolwater assemblage of 3 species (northern pike, walleye, and white sucker) in the Lake (Table 2.21). However, smallmouth bass and walleye have not been observed since 1957, while bowfin and bullheads have not been observed since 1973 and 1966, respectively. The most observed species in Lake Comus across all surveys are bluegill, black crappie, common carp, largemouth bass, pumpkinseed, and yellow perch. Many of these species are tolerant of degraded water conditions and low dissolved oxygen conditions, indicating that Lake Comus may experience occasional winterkill events. Common carp was the most commonly observed species in the most recent WDNR fishery survey in 2015, with bluegill, black crappie, largemouth bass, and yellow perch all constituting similar proportions of the observed fish population (Figure 2.51).

Carp Management

Carp have been referred to as "ecological engineers" because they can modify the habitat and biology of water bodies they colonize. When carp are overly abundant, water quality and the types of algae, plants, and animals in a lake may change to a state less desirable to human use. Abundant carp are often associated with turbid water, fewer rooted aquatic plants, more free-floating algae, and fewer desirable fish.[210] Carp populations can generally persist in a wider range of water quality conditions than native fish species. For example, carp are tolerant of dissolved oxygen concentrations below 2.0 mg/l and can survive at concentrations below 1.0 mg/l[211] while bluegill require dissolved oxygen concentrations above 5.0 mg/l.[212] Additionally, carp can tolerate a wide range of water pH, from 6.0 to 9.0 stu while native sunfish can only

[209] *Turtle Creek Priority Watershed Plan, 1984*, op. cit.

[210] Ibid.

[211] *U.S. Fish and Wildlife Service,* Habitat Suitability Index Models: Common Carp, *1982*

[212] *U.S. Fish and Wildlife Service,* Habitat Suitability Index Models: Bluegill, *1982*

Table 2.21
Fish Species Physiological Tolerance in Lake Comus Watershed: 1954-2015

Fish Species According to Their Relative Tolerance to Pollution	Lake Comus					CTH O Tributary
	1954-1959	1963-1967	1973-1979	1999-2003	2015	2017
Transitional						
Sensitive						
Northern Pike[a]	X	X	X	X	--	--
Intermediate						
Johnny Darter	--	--	--	--	--	X
Walleye	X	--	--	--	--	--
Yellow Perch	X	X	X	X	X	--
Tolerant						
Brook Stickleback	--	--	--	--	--	X
Central Mudminnow	--	--	--	--	--	X
White Sucker	X	--	X	X	--	X
Warmwater						
Sensitive						
Rock Bass	X	--	X	--	--	--
Smallmouth Bass	X	--	--	--	--	--
Intermediate						
Black Crappie	X	X	X	X	X	--
Bluegill	X	X	X	X	X	--
Bowfin	X	X	--	--	--	--
Largemouth Bass[a]	X	X	X	X	X	--
Pumpkinseed	X	X	X	X	--	--
White Bass	--	--	--	X	--	--
Tolerant						
Channel Catfish	X	--	--	--	--	--
Common Carp	X	--	X	X	X	--
Fathead Minnow	--	--	--	--	--	X
Green Sunfish	--	--	--	--	--	X
Unspecified Groups						
Unspecified						
Bullheads	--	--	--	X	X	--
Minnows and Carps	--	--	X	--	--	--
Suckers	X	X	--	--	--	--
Sunfishes	--	--	X	--	--	--
Total Number of Species	14	7	10	9	5	6

[a] *This species has been stocked in Lake Comus by Wisconsin Department of Natural Resources fisheries management staff.*

Source: Wisconsin Department of Natural Resources and SEWRPC

tolerate a more narrow range of 7.0 to 8.5.[213] Carp can negatively affect a fishery by destroying habitat, reducing water quality by stirring up sediment, competing for food with native fish species, and disrupting spawning areas by dislodging aquatic plants.[214] Studies have suggested that these detrimental effects are the cause of lower sport fish abundance in lakes with high common carp density.

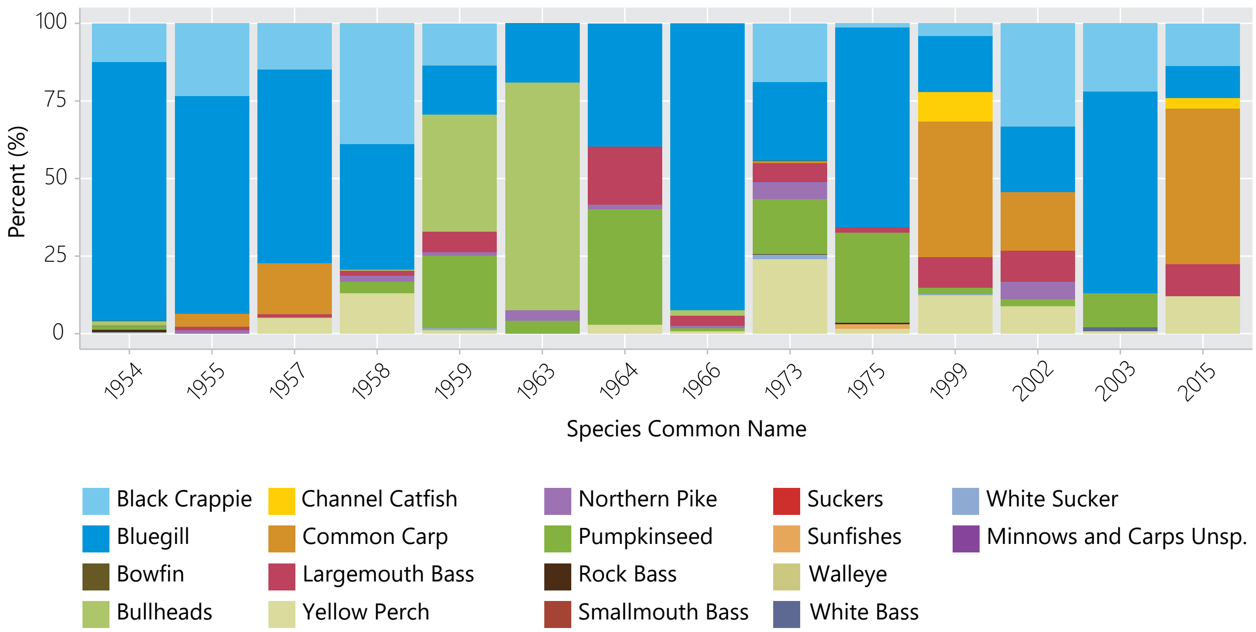
The high common carp populations from WDNR fishery surveys are a concern of the LCPRD and previous measures have been taken to reduce the carp population in the Lake. A Lake drawdown was conducted in 1937 to reduce the population of rough fish but was considered generally unsuccessful.[215] Large amounts of

[213] *J.E. McKee and H.W. Wolf,* Water Quality Criteria (second edition), *California State Water Quality Control Board, Publication No. 3-A, 1963.*

[214] *Joe Pfeiffer and Bonnie Duncan,* A Review of the Impacts, Effects of Common Carp on Freshwater Lake Systems through Nutrient Contributions and Ecological Thresholds, *KCI Associates of Ohio, PA, 2016.*

[215] *Donohue & Associates, 1980,* op. cit.

Figure 2.51
Comus Lake Fish Survey Data: 1954-2015



Note: This figure excludes surveys that caught fewer than 50 fish.

Source: Wisconsin Department of Natural Resources and SEWRPC

carp were removed from the Lake in a 1957 seining operation.[216] In 1983, another lake drawdown that reduced the water depth to between 2 and 2.5 feet was conducted to enhance rough fish removal by commercial fishermen.[217] The Lake has also experienced several winterkill events over the decades that could have eliminated some carp but also may have favored increased carp populations. Despite these efforts, the carp population in the Lake persists and may be causing detrimental impacts to the Lake's ecology.

Carp populations in shallow lakes with abundant breeding habitat can sustain extremely high (e.g., 90 per cent) harvest rates with little reduction of the mass of carp present per acre. Managers believe that removing adult carp fosters recruitment of young carp, a situation offsetting harvest. Some lakes have deployed barriers to reduce reproduction potential by preventing carp from using key breeding areas. When reproduction potential is reduced, commercial harvest can have a meaningful long-term impact on lake carp populations. Unfortunately, carp barriers also restrict movement of desirable aquatic species, and are therefore complicated to employ or inadvisable.

In many inland lakes, the carp population is not large enough to support an attractive, profitable harvest, decreasing the ability of for-profit fishing enterprises to manage carp populations. On account of this, some inland lakes groups pay a bounty on carp, encouraging commercial fishermen to pursue harvest. These subsidies typically pay a per pound premium for an initial mass of fish, with progressively lower subsidies for higher catch targets. Additionally, a premium may be set for achieving a particular harvest mass. Some lakes have deployed transponder-containing carp (sometimes called "Judas fish") to identify winter carp congregation sites, allowing targeted under the ice netting when carp are concentrated in smaller areas. This can be coupled with a bounty system to improve carp harvest rates. Up to 90 percent of carp have been removed from lakes with such an approach.[218] See the following websites for additional information:

[216] Ibid.

[217] *Wisconsin of Department of Natural Resources,* Environmental Assessment: Lake Comus Rehabilitation Project, *1983.*

[218] *Lechelt, Joseph (WDNR),* Common Carp Recruitment Dynamics and Mechanical Removal; A Modeling Approach, *Presentation at the 2017 Training Workshop on the Ecology and Management of Shallow Lakes, Horicon, Wisconin, February 7 and 8, 2017.*

- www.uwsp.edu/cnr-ap/UWEXLakes/Documents/resources/newsletter/vol36-vol40/vol36-1.pdf

- www.startribune.com/2-tons-of-carp-removed-from-silver-lake-to-improve-water-quality/248401671/

- maisrc.umn.edu/about-commoncarp

Predator populations help limit recruitment of young carp and hence are a tool to limit adult carp populations. To support carp control, the WDNR has switched to stocking small northern pike fingerlings since these fish fare better in turbid waters such as those of Lake Comus and can be stocked at higher rates. The aim of this measure is to provide long-term carp population control by encouraging a healthy population of predatory size northern pike, as pike eat juvenile carp. As discussed above, WDNR has frequently stocked northern pike fingerlings into Lake Comus and the wetlands north of Lake Comus have been identified as spawning areas for northern pike.[219] Bluegill have also been shown to prey heavily on young carp, with some lakes reporting up to a 95 percent reduction in young carp accountable to bluegill predation.[220] Recommendations to manage carp populations in Lake Comus are provided in Chapter 3.

Turtle Creek and Other Tributary Streams

Wisconsin streams are classified as coldwater, warmwater, and coolwater by summer maximum water temperatures, which is an important environmental determinant influencing the occurrence and abundance of fishes.[221] Streams with relatively cold summer maximum water temperatures are usually dominated by a small number of ''coldwater'' species in the salmonid (i.e., trout) and cottid (e.g., sculpin) families that are not able to tolerate warmer temperatures while streams with relatively warm temperatures contain a greater richness of ''warmwater'' species in the minnow and carp, sucker, bullhead, sunfish, and perch families. These species, while able to survive as individuals at colder temperatures, require warmer temperatures to complete their life cycle and persist as populations.[222,223] However, it is now also recognized that coolwater streams, which are generally intermediate in species richness and fish abundance between coldwater versus warmwater streams, are the most widespread and abundant thermal class comprising as much as 65 percent of the total stream lengths in Wisconsin.[224] It is important to recognize these stream community distinctions, because they help inform fisheries management goals and development of appropriate environmental protections or strategies.

Based on a combination of detailed temperature data,[225] fish species occurrence and abundance observations, and WDNR's stream natural community classification, reaches of mainstem Turtle as well as tributaries to Turtle Creek and Lake Comus were classified into their appropriate biotic community and ecological conditions (i.e., streamflow and water temperature).[226] These natural community designations were used to assign the appropriate IBI to assess fishery health (Table 2.22). Due to the fundamental differences among warmwater, coolwater, and coldwater headwater and mainstem streams, separate fish

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219 *Turtle Creek Priority Watershed Plan, 1984*, op. cit.

220 *Lechelt, Joey,* op cit.

221 *John J. Magnuson, "Temperature as an Ecological Resource,"* American Zoologist *19(1): 331-343, 1979.*

222 *John Lyons, "Patterns in the Species Composition of Fish Assemblages Among Wisconsin Streams,"* Environmental Biology of Fishes *45: 329-341, 1996.*

223 *John Lyons, "Influence of Winter Starvation on the Distribution of Smallmouth Bass Among Wisconsin Streams: a Bioenergetics Modeling Assessment*," American Fisheries Society *126(1)*: 157-162, 1997.

224 *John Lyons et al., "Defining and Characterizing Coolwater Streams and Their Fish Assemblages in Michigan and Wisconsin, USA*," North American Journal of Fisheries Management*. 29: 1130-1151, 2009.*

225 *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 *139: 365-374, 2007.*

226 *John Lyons, "Development and Validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin,"* North American Journal of Fisheries Management *16, 1996; John Lyons, "Proposed Temperature and Flow Criteria for Natural Communities for Flowing Waters," February 2008, updated October 2012; and, John Lyons,* An Overview of the Wisconsin Stream Model*, Wisconsin Department of Natural Resources, 2007.*

Table 2.22
Water Temperature and Flow Criteria Defining
Natural Stream Community Type and Biotic Integrity

Natural Community	Maximum Daily Mean Water Temperature (°F)	Annual 90 Percent Exceedance Flow (cfs)	Primary Index of Biotic Integrity
Ephemeral	Any	0.0	N/A
Macroinvertebrate	Any	0.0-0.03	Macroinvertebrate
Cold Headwater	<69.3	0.03 -1.0	Coldwater Fish
Cold Mainstem	<69.3	>1.0	Coldwater Fish
Cool (Cold-Transition) Headwater	69.3-72.5	0.03-3.0	Headwater Fish
Cool (Cold-Transition) Mainstem	69.3-72.5	>3.0	Cool-Cold Transition Fish
Cool (Warm-Transition) Headwater	72.6-76.3	0.03-3.0	Headwater Fish
Cool (Warm-Transition) Mainstem	72.6-76.3	>3.0	Cool-Warm Transition Fish
Warm Headwater	>76.3	0.03-3.0	Headwater Fish
Warm Mainstem	>76.3	3.0-110.0	Warmwater Fish
Warm River	>76.3	>110.0	River Fish

Note: for further information on stream natural community types, visit the WDNR's webpage explaining stream natural communities: dnr.wi.gov/topic/rivers/naturalcommunities.html.

Source: References for IBIs: Macroinvertebrate–Weigel 2003; Coldwater Fish–Lyons et al. 1996; Headwater Fish–Lyons 2006; Coolwater Fish–Lyons, in preparation; Warmwater Fish–Lyons 1992; River Fish–Lyons et al. 2001

IBIs have been developed to assess the health of each of these types of streams.[227] Through calculation of the IBI, fish population data can provide insight into the overall health of the stream ecosystem. The Lake Comus watershed contains a variety of stream natural communities, with warmwater headwaters, cool-warm headwaters, cool-cold headwaters, coldwater, and macroinvertebrate reaches all featured (Map 2.25). Much of the channelized headwater reaches located are classified as warm headwater streams. The middle and lower reaches of Turtle Creek are classified as a cool-cold mainstem presumably due to the cooling influence of cool-cold headwater tributaries sourced from groundwater springs in the eastern portion of the watershed. Coldwater and macroinvertebrate reaches are also present as tributaries to the Creek and at the headwaters of cool-cold tributaries.

No fishery surveys have been conducted by WDNR in the reaches of Turtle Creek upstream of Lake Comus. Qualitative surveys conducted by LCPRD volunteers on Turtle Creek at Island Road and at Dam Road during August through October 2020 indicated that there was little to no fish activity in the Creek.[228] WDNR conducted a fishery survey in a coolwater transitional reach of the CTH O tributary of Turtle Creek on June 1st, 2017 (Map 2.25 and Table 2.21). This survey attained a Good rating and observed six species: central mudminnow, brook stickleback, fathead minnow, johnny darter, green sunfish, and white sucker. The species assemblage indicates that the fish community is largely tolerant of polluted waters and has an even mix of coolwater and warmwater species.

Projected Effects of Climate Change

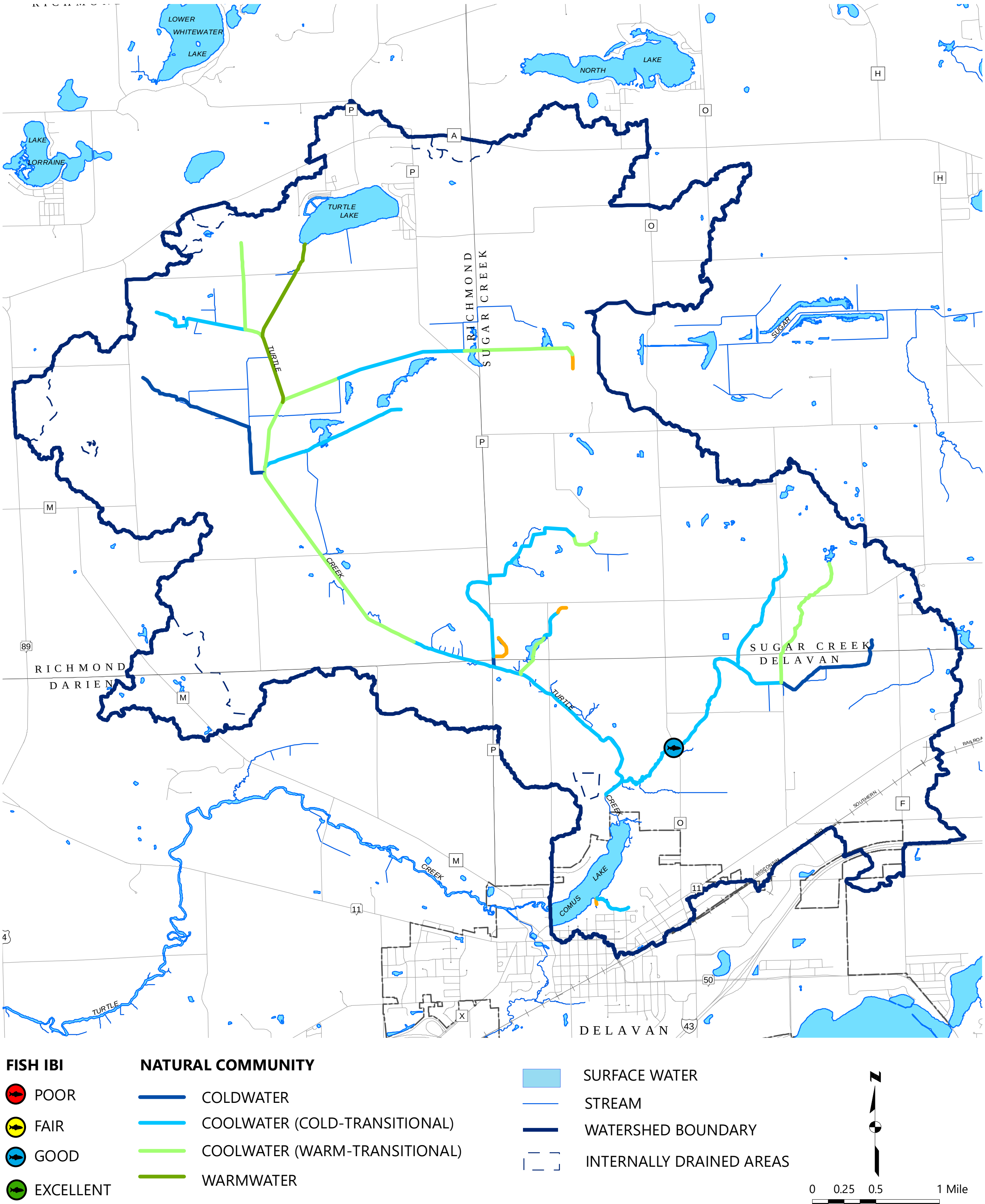
The USGS has developed the "FishVis" decision support tool to display model projections of changes in stream temperature, streamflow, and fish species occurrence throughout the 21st century for watersheds within the Great Lakes Region, including the Lake Comus watershed.[229] The model was developed using historical information on stream temperatures and flow, as well as projections from thirteen downscaled climate models, to model stream temperatures and streamflow for the presentday, mid (2046 – 2065), and late (2081 – 2100) 21st century. With this modeled temperature and streamflow information, as well as a suite of environmental variables, the model then predicts the occurrence of four coldwater, five coolwater, and four warmwater species across these time periods (presentday, mid, and late 21st century) within individual reaches of each watershed. Of these thirteen modeled species, four species (common carp, green

[227] *John Lyons, 1996,* op. cit.

[228] *Notes from Larry Meyer, LCPRD volunteer, October 2020.*

[229] *J.S. Stewart et al., "FishVis, A Regional Decision Support Tool for Identifying Vulnerabilities of Riverine Habitat and Fishes to Climate Change in the Great Lakes Region,"* U.S. Geological Survey Scientific Investigations Report 20165124*, 2006.*

Map 2.25
Stream Natural Community and Fish Biotic Indices Within the Lake Comus Watershed: 1990-2019



Source: SEWRPC

sunfish, northern pike, and white sucker) have been observed within the Lake Comus watershed. While the exact distribution of fish species within the Lake Comus watershed has not been studied, it is likely that the model is underrepresenting some populations. For example, the model predicts that common carp is only present in two small reaches of Turtle Creek and northern pike are only found in Turtle Creek downstream of the dam, although northern pike has been observed in the Lake and spawning in the Creek upstream of the Lake. The model predicts that green sunfish are found throughout the entire watershed and that white suckers are found in the larger channels of Turtle Creek and the CTH O tributary.

The FishVis model predicts a substantial range in currently observed stream temperatures within the watershed with predicted July mean temperatures ranging from 57.9°F (14.4°C) in headwater tributary streams to 74.7°F (23.7°C) in the Turtle Creek mainstem exiting Turtle Lake. Mainstem temperatures decrease as the Creek approaches Lake Comus due to the influx of colder water from the tributary streams. Projected stream temperatures will increase by up to 4.1°F (2.3°C) by the late 21st century with concurrent streamflow increases in all modeled reaches of the Lake Comus watershed as the model incorporated the projections of increased precipitation in southeastern Wisconsin with climate change. Despite these projected increases in temperature and streamflow, the projected change in modeled species distribution within the watershed is minimal. Green sunfish and common carp are still projected to exist where currently observed in the watershed, while northern pike are still not projected to be found upstream of Lake Comus. White sucker distribution is projected to slightly decrease as they are not projected to occur in the upstream channels of the Turtle Creek mainstem by the late 21st century. As white sucker is a coolwater species, these changes are indicative of stream conditions that are more favorable to warmwater species by the late 21st century but with mainstem temperatures that are still buffered by cool groundwater contributions from tributary streams.

2.7 OTHER WILDLIFE

A healthy wildlife population (e.g., whitetail deer, amphibians, birds, small mammals, etc.) is the ultimate indicator of a healthy watershed. Although the quality of lakes, streams, and rivers is often assessed based on measures of the chemical or physical properties of water, a more comprehensive perspective is obtained if resident biological communities (including wildlife) are also assessed. Guidelines to protect human health and aquatic life have been established for specific physical and chemical properties of water and have become useful yardsticks with which to assess water quality. Biological communities provide additional crucial information because they live within the watershed for weeks to years and therefore time-integrate the effects of change within their chemical or physical environment.[230]

In addition, biological communities are a direct measure of waterbody health—an indicator of the ability of a waterbody to support aquatic life. Thus, the condition of biological communities, integrated with key physical and chemical properties, provides a comprehensive assessment of waterbody health. The presence and abundance of species in a biological community are a function of the inherent requirements of each species for specific ranges of physical and chemical conditions. Therefore, when changes in land and water use in a waterbody cause physical or chemical properties to exceed their natural ranges, vulnerable aquatic species are eliminated, which ultimately impairs the biological condition and waterbody health.[231]

Aquatic and terrestrial wildlife communities have educational and aesthetic values, perform essential 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 Lake Comus watershed.

Aquatic Animals
Aquatic animals include microscopic zooplankton; benthic, or bottom-dwelling, invertebrates; fish; reptiles and amphibians; mammals; and waterfowl and other birds that inhabit the Lake and its shorelands. These make up the primary and secondary consumers of the food web.

[230] *Carlisle et al., 2013,* op. cit.

[231] Ibid.

Zooplankton

Zooplankton are animals that eat phytoplankton, the microscopic plants and algae that are the base of the freshwater lake food web. While generally microscopic, some lake-dwelling zooplankton are visible to the naked eye. Common zooplankton in freshwater lakes include cladocerans, copepods, protozoans, and rotifers. An important link in the aquatic food web, zooplankton feed mostly on algae and, in turn, are preferred fish food. A healthy zooplankton population can reduce lake algal abundance, improve water clarity, and support populations of planktivorous fish. Zooplankton populations have never been surveyed in Lake Comus to the knowledge of Commission staff.

Benthic Invertebrates

The benthic, or bottom dwelling, faunal communities of lakes include such organisms as sludge worms, midges, and caddisfly larvae. These organisms are an important part of the food chain, acting as processors of organic material that accumulates on the lake bottom. Some benthic fauna are opportunistic in their feeding habits, while others are predaceous. The diversity of benthic faunal communities can be used as an indicator of lake trophic state. In general, a reduced or limited diversity of organisms present is indicative of a eutrophic lake; however, there is no single "indicator organism." Rather, the entire community must be assessed to determine trophic state as populations can fluctuate widely through the year and between years because of season, climatic variability, and localized water quality changes. Benthic invertebrates have never been surveyed in Lake Comus to the knowledge of Commission staff.

Mussels

Freshwater mussels are bivalve (two-shelled) mollusks that live in sediments of rivers, streams, lakes, and ponds. These soft-bodied animals are enclosed by two shells made mostly of calcium carbonate that are connected by a hinge. Mussels are typically found anchored in the substrate with only their siphons occasionally exposed. They typically favor sand, gravel, and cobble substrates. Mussels play a significant role in aquatic communities by helping stabilize river bottoms; serving as natural water filters; and serving as food for fish, birds, and some mammals. Live mussels and relict shells provide a relatively stable substrate in dynamic riverine environments for a variety of other macroinvertebrates such as caddisflies and mayflies and for algae.

Mussels are 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. All mussel species are susceptible to pollution, including pesticides, heavy metals, ammonia, and algal toxins. Mussels are wholly dependent on fishes to complete their life history, particularly for early larval stages. Hence, loss of a particular fish species from an environment may result in the eventual decline and loss of certain mussel species as well. Many mussel species grow slowly and have long life spans, with some individuals in some species able to survive for up to 100 years. For this reason, mussels can be used to document changes in water quality over prolonged periods of time. Shells accumulate metals from both water and sediment, so testing heavy metal concentrations in shells can provide information on contamination history. 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 mean good water quality.

Currently, the WDNR Bureau of Natural Heritage Conservation[232] is working with citizen scientists on a mussel monitoring program that aims to update information on statewide mussel distributions. Researchers are enlisting 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 Wisconsin Mussel Monitoring Program. Volunteers wade in 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.[233]

[232] *This was formerly the Bureau of Endangered Resources.*

[233] *For more information, visit the Wisconsin Mussel Monitoring Program website at wiatri.net/inventory/mussels/ as well as their iNaturalist project at www.inaturalist.org/projects/wisconsin-mussel-monitoring-program.*

Mussels have never been thoroughly sampled in the Lake Comus watershed, so their abundance and diversity within this system is unknown. The Mussel Monitoring Program has identified fifteen mussel species between the headwaters of Turtle Creek and the crossing of County Hwy C downstream of Lake Comus (Table 2.23).[234]

Nonnative and Invasive Aquatic Animals

Introducing nonnative aquatic animals to a waterbody can disturb food webs, ultimately impacting water quality, habitat, and potentially recreational use. However, not all nonnative animals are invasive or cause severe negative impacts to lake ecosystems. Aside from the common carp, no nonnative or invasive aquatic animals were observed during field surveys on Lake Comus or have been reported by WDNR. However, several species, such as zebra mussels (*Dreissena polymorpha*), banded mystery snails (*Viviparus georgianus*), and Chinese mystery snails (*Cipangopaludina chinensis*) are common throughout Southeastern Wisconsin lakes, including in upstream Turtle Lake and nearby Delavan Lake. All three species are listed in the Restricted category of NR 40.[235] The LCPRD and Lake users should vigilantly monitor for introductions of these species as well as other invasive species into the Lake. Recommendations for monitoring and management of nonnative and invasive aquatic animals are presented in Chapter 3.

Zebra Mussels

Zebra mussels are small fingernail-size clams with D-shaped shells. Adults typically range from one-quarter to one and one-half inch in size. The shells commonly have yellow and brownish stripes. This invasive species reproduces rapidly (females can produce up to a half million eggs per year) forming colonies on nearly any clean, hard, flat underwater surface. This behavior has caused the zebra mussel to become a costly nuisance to humans as massive populations of the mollusk have clogged municipal water intake pipes and fouled underwater equipment. Zebra mussels feed by filtering small plants, animals, and particles from the water column, an action that deprives native zooplankton (small aquatic animals that form an important food source for many larger organisms), native mussels, juvenile and larval fish, and many other organisms of key food sources. [236]

The filter feeding proclivity of zebra mussels has led to improved water clarity in many lakes. Improved water clarity has sometimes, in turn, increased growth of rooted aquatic plants, including EWM. A curious interplay between zebra mussels, water clarity, EWM, and native aquatic plants has been observed within Southeastern Wisconsin. Zebra mussels have been observed to attach themselves to stems of the EWM plants (Figure 2.52). The increased weight of the shells and live mussels drags the plant deeper below the surface and partially out of the *photic zone* (the depth to which sufficient sunlight penetrates lake water to support photosynthesis). This interferes with the competitive strategy of the EWM plants and has sometimes contributed to regrowth of beneficial native aquatic plants. In other instances, decreased EWM has led to nuisance growths of filamentous algae (which is too large to be ingested by the zebra mussels). Regardless of the seemingly beneficial impact of zebra mussels on water clarity, the overall environmental, aesthetic, and economic tolls of invasive aquatic animals on lake ecosystems and recreational resource values generally outweigh positive factors.

Banded Mystery Snail

Banded mystery snails are predominantly native to the southern United States although their native distribution extends north to Illinois along the Illinois River drainage. First observed in Wisconsin in 1906, this species is now found in waterbodies throughout the state. Not much is known about detrimental environmental impacts caused by banded mystery snails. However, some studies have shown that banded mystery snails can establish quite dense colonies where present, and their populations have been linked to declines in largemouth bass and bird populations.[237]

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[234] *For more information, see wiatri.net/inventory/mussels/About/musselWaters.cfm.*

[235] *For the complete list of species in NR 40, see dnr.wi.gov/topic/Invasives/documents/nr40lists.pdf.*

[236] *For more information on zebra mussels, see dnr.wisconsin.gov/topic/Invasives/fact/Zebra.html.*

[237] *For more information on banded mystery snails, see nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=1047.*

Table 2.23
Characteristics of Mussels Species Observed in the Upper Turtle Creek Watershed

Species	Maximum Size	Habitat	Potential Host Fish Species	
			Observed in Turtle Creek Upstream of Dam	Not Observed Upstream of Dam
Black sandshell	10 inches	Rivers, lakes, and large streams usually in riffles with firm mud, sand, and gravel	Bluegill, pumpkinseed, rock bass, largemouth bass, walleye, yellow perch, green sunfish	White crappie, banded killifish, white perch, central stoneroller, redfin shiner, rosyface shiner, redbreast sunfish, long ear sunfish, orange spotted sunfish
Creeper[b]	4 inches	Creeks, small streams, and occasionally large rivers in mud, sand, and gravel	Rock bass, yellow bullhead, black bullhead, pumpkinseed, bluegill, yellow perch, largemouth bass, smallmouth bass, walleye, channel catfish, black crappie, green sunfish	Northern redbelly dace, burbot, central stoneroller, brook stickleback, fantail darter, Iowa darter, blackside darter, logperch, longear sunfish, white crappie, spotfin shiner, sand shiner, fathead minnow, fathead minnow, rainbow darter, johnny darter, creek chub, common shiner, bluntnose minnow, central mudminnow
Cylindrical Papershell	3.5 inches	Creeks and small streams, in sand and mud; common headwater species	White sucker, bluegill, largemouth bass, black crappie	Sea lamprey, mottled sculpin, spotfin shiner brook stickleback, Iowa darter, blacknose shiner, fathead minnow, common shiner, bluntnose minnow
Deertoe	2 inches	Lakes and medium to large rivers in mud, sand, and gravel	N/A	Freshwater drum, sauger
Elktoe	5 inches	Small streams to large rivers in sand, rock, and gravel	White sucker, rock bass	Warmouth, redhorse
Fatmucket	5 inches	Small streams to large rivers, lakes, and ponds in silt, sand, and gravel	Bluegill, largemouth bass, pumpkin seed, rock bass[a], smallmouth bass, white sucker, yellow perch, black crappie, green sunfish	Common shiner, tadpole madtom, warmouth, silver shiner, bluntnose minnow , sand shiner, white crappie
Fawnsfoot	2 inches	Large rivers or lower reaches of medium streams in sand and gravel	N/A	Freshwater drum, sauger
Fragile Papershell	6 inches	Small streams to large rivers and lakes in mud, gravel, and occasionally sand	N/A	Freshwater drum
Giant Floater	10 inches	Small streams to large rivers, ponds to lakes; silt, sand, and gravel	Bullhead	Darters, freshwater drum, gar, gizzard shad, and skipjack herring
Mucket	6 inches	Medium to large rivers in sand or gravel	Smallmouth bass, largemouth bass, yellow perch, black crappie, rock bass, green sunfish	White crappie, sauger, white bass, banded killifish, central stoneroller, silverjaw minnow, orange spotted sunfish
Plain Pocketbook[b]	7 inches	Small streams to large rivers in stable, compacted mud, through stable sand or gravel	Bluegill, smallmouth bass, largemouth bass, yellow perch, walleye, green sunfish	White crappie, tiger salamander, sauger
Round Pigtoe[b,e]	4 inches	Small to large streams in mud, sand, and gravel	Bluegill	Northern redbelly dace, southern redbelly dace, spotfin shiner, central stoneroller, bluntnose minnow

Table continued on next page.

Table 2.23 (Continued)

Species	Maximum Size	Habitat	Potential Host Fish Species	
			Observed in Turtle Creek Upstream of Dam	Not Observed Upstream of Dam
Spike	5.5 inches	Small stream to large rivers and occasionally in lakes; silt, sand, and gravel	Black crappie, smallmouth bass, largemouth bass, yellow perch	Gizzard shad, flathead catfish, white crappie, sauger, sculpins
Threeridge	8 inches	Compacted mud, sandy or gravel areas of smaller streams to large rivers	Rock bass, northern pike, green sunfish, pumpkinseed, bluegill, largemouth bass, yellow perch, black crappie	Shortnose gar, sauger, white bass, flathead catfish, warmouth, white crappie
Wabash Pigtoe	4 inches	Creeks, small streams, and large rivers in mud, sand, and gravel	Bluegill, black crappie	Silver shiner, white crappie, creek chub

Source: D.C. Allen, B.E. Sietman, D.E. Kelner, M.C, Hove, J.E. Kurth, J.M. Davis, and D.J. Hornbach, "Early Life-History and Conservation Status of Venustaconcha ellipsiformis (Bivalia, Unionidae), in Minnesota," American Midland Naturalist, Volume 157, pages 74-91, 2007; K. Hillegass and M. Hove, "Suitable Fish Hosts for Glochidia of Three Freshwater Mussels: Strange Floater, Ellipse, and Snuffbox," Triannual Unionie Report, Volume 13, page 25, 1997; M. Hove, "Suitable Fish Hosts of the Lilliput, Toxolasma parvus," Triannual Unionid Report, Volume 8, page 9, 1995; M. Hove, R. Engelking, M. Peteler, E.M. Peterson, A.R. Kapuscinski, L.A. Sovell, and E.R. Evers, "Suitable Fish Hosts for Glochidia of Four Freshwater Mussels," Conservation and Management of Freshwater Mussels II: Proceedings of a UMRCC Symposium, 1997; M. Hove and A.R. Kapuscinski, "Ecological Relationships Between Six Rare Minnesota Mussels and Their Host Fishes," Final Report to the Minnesota Department of Natural Resources, 1998; R. Howells, "New Fish Hosts for Nine Freshwater Mussels (Bivalvia: Unionidae) in Texas," Texas Journal of Science, Volume 49, pages 255-258, 1997; R. Klocek, J. Bland, and L. Barghusen, A Field Guide to the Freshwater Mussels of Chicago Wilderness, Chicago Wilderness, 2008; R. Mulcrone, Incorporating Habitat Characteristics and Fish Hosts to Predict Freshwater Mussel (Bivalvia: Unionidae) Distributions in the Lake Erie Drainage, Southeastern Michigan, Ph.D. Dissertation, University of Michigan, 2004; S. O'Dee and G. Watters, "New or Confirmed Host Identifications for Ten Freshwater Mussels," Proceedings of the Conservation, Captive Care ,and Propagation of Freshwater Mussels Symposium, pages 77-82, 2000; F.A. Riusech and M.C. Barnhart, "Host Suitability and Utilization in Venustaconcha ellipsiformis and Venustaconcha pleasii (Bivalvia: Unionidae) from the Ozark Plateaus, Proceedings of the Conservation, Captive Care ,and Propagation of Freshwater Mussels Symposium, pages 83-91, 2000; R. Trdan, "Reproductive Biology of Lampsilis radiate siliquoidea (Pelecypoda: Unionidae)," American Midland Naturalist, Volume 106, pages 243-248, 1982; R. Trdan and W. Hoeh, "Eurytopic Host Use by Two Congeneric Species of Freshwater Mussel (Pelecypoda: Unionidae: Anodonta)," American Midland Naturalist, Volume 108, pages 381-388, 1982; E. van Snik Gray, W. Lellis, J. Cole, and C. Johnson, "Hosts of Pyganodon cataracta (Easter Floater) and Strophitus undulates (Squawfoot) from the Upper Susquehanna River Basin, Pennsylvania," Triannual Unionid Report, Volume 18, page 6, 1999; G. T. Watters, "An Annotated Bibliography of the Reproduction and Propagation of the Unionoidea (Primarily of North America)." Ohio Biological Survey Miscellaneous Contributions No. 1, 1994; G.T. Watters, A Guide to the Freshwater Mussels of Ohio, Ohio Department of Natural Resources, 1995; G.T. Watters, S. O'Dee, and S. Chordas, "New Potential hosts for: Strophitus undulatus-Ohio River Drainage; Strophitus undulates-Susquehanna River Drainage; Alasimidonta undulate- Susquehanna River Drainage; Actinonaias ligamentina-Ohio River Drainage; and Lasmigona costata-Ohio River Drainage," Triannual Unionid Report, Volume 15, pages 27-29, 1998; and J.L. Weiss and J.B. Layzer, "Infestations of Glochidia on Fishes in the Barren River, Kentucky," American Malacological Bulletin, Volume 11, pages 153-159, 1995.

Chinese Mystery Snail

Native to eastern Asia, Chinese mystery snails have been found in many Wisconsin waterbodies following their introduction to the Great Lakes area in the 1930s or 1940s. Like banded mystery snails, not much is known about the impacts of Chinese mystery snails to lake ecosystems, except that they may have a negative effect on native snail populations.[238] These animals prefer soft sediment, which they scrape and consume from the lake bottom.

Figure 2.52
Zebra Mussels Attached to Eurasian Watermilfoil

Source: SEWRPC

Other Wildlife

Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of the current Lake Comus study, a list of species observed during Commission staff field visits in the area of the Lake Comus watershed includes common carp, turtles, great blue heron, osprey, and various songbirds. Also, it is possible, by polling naturalists and wildlife managers familiar with the area, to complete a list of amphibians, reptiles, birds, and mammals that may be expected to be found in the area under existing conditions. The technique used in compiling the wildlife data involved obtaining lists of those amphibians, reptiles, birds, and mammals known to exist, or known to have existed, in the Lake Comus area, associating these lists with the historic and remaining habitat areas in the Lake Comus area as inventoried, and projecting the appropriate amphibian, reptile, bird, and mammal species into the Lake Comus area. Applying this technique provides a list of species that were probably once present in the drainage area, those species that may be expected to still be present under currently prevailing conditions, and those species that may be expected to be lost or gained as a result of urbanization within the area.

Amphibians and Reptiles

Amphibians and reptiles are vital components of ecosystems within the Lake Comus watershed. Table 2.24 lists those amphibian and reptile species normally expected to be present in the watershed under present conditions and identifies those species most sensitive to urbanization. Of particular note are rare reptiles that have been observed in the watershed, including the Eastern Massasauga rattlesnake (a state Endangered species), Blanding's turtle (*Emydoidea blandingii,* a state Special Concern species) and the Queensnake (*Regina septemvittata*, a state Endangered species). The website iNaturalist, used by citizen scientists to post and identify flora and fauna observations, also has Research Grade observations of seven amphibian and reptile species in the Turtle Creek watershed: American toad, common water snake, green frog, gray tree frog species complex, painted turtle, common snapping turtle, and spiny softshell turtle.[239]

Most amphibians and reptiles have definite habitat requirements that are adversely affected by advancing urban development as well as by certain agricultural land management practices. The major detrimental factors affecting the maintenance of amphibians in a changing environment is destruction of breeding ponds, urban development occurring in migration routes, and changes in food sources brought about by urbanization.

As a federally Threatened species, the U.S. Fish and Wildlife has developed a recovery plan for the Eastern Massasauga rattlesnake that it intends to implement over the next 25 years.[240] Land managers of the wetlands north of Lake Comus should consider the best management practices developed for minimizing

[238] *For more information on Chinese mystery snails, see nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=1044 and dnr.wi.gov/topic/Invasives/documents/classification/LR_Cipangopaludina_chinensis.pdf.*

[239] *See citizen science reptile and amphibian observations in the Turtle Creek watershed at inaturalist.org/observations?place_id=116676&quality_grade=research&subview=grid&view=species&iconic_taxa=Amphibia,Reptilia.*

[240] *www.fws.gov/midwest/endangered/reptiles/eama/index.html*

Table 2.24
Amphibians and Reptiles of the Lake Comus Watershed Grouped by Scientific Family

Common Name	Scientific Name	Species Reduced or Dispersed with Complete Urbanization	Species Lost with Complete Urbanization
Amphibians			
Proteidae Family			
Mudpuppy	*Necturus maculosus*	X	--
Ambystomatidae Family			
Blue-Spotted Salamander	*Ambystoma laterale*	--	X
Spotted Salamander	*Ambystoma maculatum*	X	--
Eastern Tiger Salamander	*Ambystoma tigrinum*	X	--
Salamandridae Family			
Central Newt	*Notophthalmus viridescens*	X	--
Bufonidae Family			
American Toad	*Bufo americanus americanus*	X	--
Hylidae Family			
Western Chorus Frog	*Pseudacris triseriata*	X	--
Boreal Chorus Frog	*Pseudacris maculata*	X	--
Blanchard's Cricket Frog[a,b]	*Acris blanchardi*	X	--
Northern Spring Peeper	*Pseudacris crucifer*	--	X
Cope's Gray Tree Frog	*Hyla chrysoscelis*	X	--
Gray Tree Frog	*Hyla versicolor*	--	X
Ranidae Family			
American Bullfrog[c]	*Lithobates catesbeianus*	--	X
Green Frog	*Lithobates clamitans*	X	--
Northern Leopard Frog	*Lithobates pipiens*	--	X
Pickerel Frog[c]	*Lithobates palustris*	--	X
Wood Frog	*Lithobates sylvaticus*	X	--
Reptiles			
Chelydridae Family			
Common Snapping Turtle	*Chelydra serpentina*	X	--
Kinosternidae Family			
Musk Turtle (stinkpot)	*Sternotherus odoratus*	X	--
Emydidae Family			
Western Painted Turtle	*Chrysemys picta belli*	X	--
Midland Painted Turtle	*Chrysemys picta marginata*	X	--
Blanding's Turtle[d]	*Emydoidea blandingii*	X	--
Trionychidea Family			
Eastern Spiny Softshell	*Trionyx spiniferus spiniferus*	X	--
Colubridae Family			
Common Water Snake	*Nerodia sipedon sipedon*	X	--
DeKay's Brown Snake	*Storeria dekayi wrightorum*	X	--
Northern Red-Bellied Snake	*Storeria occipitomaculata*	X	--
Eastern Garter Snake	*Thamnophis sirtalis sirtalis*	X	--
Butler's Garter Snake[d]	*Thamnophis butleri*	X	--
Eastern Hognose Snake	*Heterodon platirhinos*	--	X
Smooth Green Snake	*Opheodrys vernalis vernalis*	--	X
Queensnake[b]	*Regina septemvittata*	X	--
Eastern Milk Snake	*Lampropeltis triangulum*	--	X
Viperidae Family			
Eastern Massasauga[b]	*Sisturus catenatus*	X	--

[a] *Likely to be extirpated from the watershed.*

[b] *State-designated endangered species.*

[c] *State-designated special concern species.*

[d] *State-designated threatened species.*

Source: Gary S. Casper, Geographical Distribution of the Amphibians and Reptiles of Wisconsin, 1996, Wisconsin Department of Natural Resources, Kettle Moraine State Forest, Lapham Peak Unit; and SEWRPC disturbance to Eastern Massasauga rattlesnakes and their habitat.[241] These practices include mowing and prescribed burning in cooler months when the rattlesnake is dormant, with a final burn date of March 25th; minimizing use of herbicides, mowing, disking, and earthmoving in rattlesnake habitat; and limiting water level fluctuations during the rattlesnake's inactive season. Recommendations to tailor land management activities to minimize incidental harm to the Eastern Massasauga, Blanding's turtle, and the Queensnake are provided in Section 3.6, "Fish and Wildlife."

Birds and Mammals

Many birds, ranging in size from large game birds to small songbirds, are found in the Lake Comus area. Table 2.25 lists those birds that expected to occur in the watershed. Each bird is classified as to whether it breeds within the area, visits the area only during the annual migration periods, or visits the area only on rare occasions. Because of the mixture of natural lands still present in the area, along with the favorable summer climate, the area supports many other species of birds. Hawks, owls, swallows, whippoorwills, woodpeckers, nuthatches, flycatchers, robins, red-winged blackbirds, orioles, cardinals, kingfishers, and mourning doves provide valuable ecological roles and many serve as subjects for bird watchers and photographers. The Turtle Valley Wildlife Area is maintained by WDNR in part to support its significant waterfowl and shorebird population, including mallard, teal, ruddy duck, wood duck, redhead, hooded merganser, lesser yellowlegs, sandpipers, American bittern, and Wilson's phalarope.[242] Larger numbers of birds move through the drainage area during migrations when most of the regional species may also be present; ospreys and loons are notable migratory visitors.

A variety of mammals, ranging in size from large animals like the northern white-tailed deer to small animals like the least shrew, can be expected to be found in the Lake Comus area. Table 2.26 lists those mammal species whose ranges are known to extend into the Lake Comus area. The website iNaturalist records 41 Research Grade observations of 13 mammal species within the Turtle Creek watershed: American mink, American red squirrel, common raccoon, coyote, eastern cottontail, eastern chipmunk, eastern gray squirrel, fox squirrel, groundhog, muskrat, red fox, Virginia opossum, and white-tailed deer.[243]

Species of Concern

While Southeastern Wisconsin has historically supported a wide variety of plant communities and attendant wildlife species, increased pressure from urban development and agriculture have had significant and adverse impacts on local biota. Many habitat types were virtually eliminated and most have been seriously degraded. As habitat is lost, so, typically, are the species dependent on that habitat. The result for many species has been local and regional elimination, and for some, even extirpation or extinction. Table 2.27 lists those species of vertebrate animals documented as having existed at the time of initial European settlement but have since disappeared from the Region.

The vertebrate animal (mammal, bird, reptile, amphibian, and fish) and vascular plant species found in Southeastern Wisconsin officially listed by the WDNR, Bureau of Endangered Resources, on the "Wisconsin Natural Heritage Working List" were identified in SEWRPC Planning Report Number 42. Within the Region, the List identified 20 plant and 19 vertebrate animal species as Endangered, 25 plant and 17 animal species as Threatened, and 69 plant and 61 animal species as Special Concern. This species compilation is intended to be dynamic, reflecting the most updated ecological information regarding these species. Since preparing SEWRPC Planning Report No. 42, the Bureau of Endangered Resources has updated its list periodically, adding or removing species and changing the status of other species as more knowledge is obtained about native species, as species become more or less rare, and as the degree of endangerment increases or decreases. Accordingly, the regional list should be updated to reflect these changes. Currently, 18 vertebrate animal species of the Region are listed as endangered; 20 are listed as threatened; and 59 are listed as special concern. Table 2.28 lists the revisions that have been made in the status of the Region's critical vertebrate animal species.

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[241] *For a description of these best management practices, see www.fws.gov/midwest/endangered/section7/bo/2018_Rangewide_EMRLandManagementByUSFWS06282018.pdf*

[242] Turtle Valley Wildlife Area*, Wetland Gems Workhorse Wetland, Wisconsin Wetland Association.*

[243] *www.inaturalist.org/observations?place_id=116676&quality_grade=research&subview=grid&view=species&iconic_taxa=Mammalia*

Table 2.25
Birds Known to Likely Occur Within the Lake Comus Watershed Grouped by Scientific Family

Common Name	Breeding	Wintering	Migrant
Gaviidae Family			
Common Loon[a]	--	--	X
Podicipedidae Family			
Pied-Billed Grebe	X	--	X
Horned Grebe	--	--	X
Phalacrocoracidae Family			
Double-Crested Cormorant	--	--	X
Pelicanidae Family			
American White Pelican	--	--	X
Ardeidae Family			
American Bittern[a]	X	--	X
Least Bittern[a]	X	--	X
Great Blue Heron[a]	X	R	X
Great Egret[b]	--	--	X
Cattle Egret[a,c]	--	--	R
Green Heron	X	--	X
Black-Crowned Night Heron[a]	--	--	X
Anatidae Family			
Tundra Swan	--	--	X
Mute Swan[c]	X	X	X
Snow Goose	--	- -	X
Canada Goose	X	X	X
Wood Duck	X	- -	X
Green-Winged Teal	--	- -	X
American Black Duck[a]	--	X	X
Mallard	X	X	X
Northern Pintail[a]	--	--	X
Blue-Winged Teal	X	--	X
Northern Shoveler	--	--	X
Gadwall	--	--	X
American Wigeon[a]	--	--	X
Canvasback[a]	--	--	X
Redhead[a]	--	--	X
Ring-Necked Duck	--	--	X
Lesser Scaup[a]	--	--	X
Greater Scaup	--	--	R
Common Goldeneye[a]	--	X	X
Bufflehead	--	--	X
Red-Breasted Merganser	--	--	X
Hooded Merganser[a]	R	--	X
Common Merganser[a]	--	--	X
Ruddy Duck	--	--	X
Cathartidae Family			
Turkey Vulture	X	--	X
Accipitridae Family			
Osprey[a]	--	--	X
Bald Eagle[a,d]	--	--	R
Northern Harrier[a]	X	R	X
Sharp-Shinned Hawk	X	X	X
Cooper's Hawk[a]	X	X	X
Northern Goshawk[a]	--	R	X
Red-Shouldered Hawk[b]	R	--	X

Table continued on next page.

Table 2.25 (Continued)

Common Name	Breeding	Wintering	Migrant
	Accipitridae Family (Continued)		
Broad-Winged Hawk	R	--	X
Red-Tailed Hawk	X	X	X
Rough-Legged Hawk	--	X	X
American Kestrel	X	X	X
Merlin[a]	--	--	X
	Phasianidae Family		
Grey Partridge[c]	R	R	--
Ring-Necked Pheasant[c]	X	X	--
Wild Turkey	X	X	--
	Rallidae Family		
Virginia Rail	X	--	X
Sora	X	--	X
Common Moorhen	X	--	X
American Coot	X	R	X
	Gruidae Family		
Sandhill Crane	X	--	X
	Charadriidae Family		
Black-Bellied Plover	--	--	X
Semi-Palmated Plover	--	--	X
Killdeer	X	--	X
	Scolopacidae Family		
Greater Yellowlegs	--	--	X
Lesser Yellowlegs	--	--	X
Solitary Sandpiper	--	--	X
Spotted Sandpiper	X	--	X
Upland Sandpiper[a]	R	--	X
Semi-Palmated Sandpiper	--	--	X
Pectoral Sandpiper	--	--	X
Dunlin	--	--	X
Common Snipe	R	--	X
American Woodcock	X	--	X
Wilson's Phalarope	--	--	X
	Laridae Family		
Ring-Billed Gull	--	--	X
Herring Gull	--	X	X
Common Tern[e]	--	--	R
Caspian Tern[e]	--	--	R
Forster's Tern[e]	--	--	R
Black Tern[a]	X	--	X
	Columbidae Family		
Rock Dove[c]	X	X	--
Mourning Dove	X	X	X
	Cuculidae Family		
Black-Billed Cuckoo	X	--	X
Yellow-Billed Cuckoo[a]	X	--	X
	Strigidae Family		
Eastern Screech Owl	X	X	--
Great Horned Owl	X	X	--
Snowy Owl	--	R	--
Barred Owl	X	X	--
Long-Eared Owl[a]	--	X	X
Short-Eared Owl[a]	--	R	X
Northern Saw-Whet Owl	--	--	X

Table continued on next page.

Table 2.25 (Continued)

Common Name	Breeding	Wintering	Migrant
Caprimulgidae Family			
Common Nighthawk	X	--	X
Whippoorwill	--	--	X
Apodidae Family			
Chimney Swift	X	--	X
Trochilidae Family			
Ruby-Throated Hummingbird	X	--	X
Alcedinidae Family			
Belted Kingfisher	X	X	X
Picidae Family			
Red-Headed Woodpecker[a]	X	R	X
Red-Bellied Woodpecker	X	X	--
Yellow-Bellied Sapsucker	--	R	X
Downy Woodpecker	X	X	--
Hairy Woodpecker	X	X	--
Northern Flicker	X	R	X
Tyrannidae Family			
Olive-Sided Flycatcher	--	--	X
Eastern Wood Pewee	X	--	X
Yellow-Bellied Flycatcher[a]	--	--	X
Acadian Flycatcher[b]	R	--	X
Alder Flycatcher	R	--	X
Willow Flycatcher	X	--	X
Least Flycatcher	R	--	X
Eastern Phoebe	X	--	X
Great Crested Flycatcher	X	--	X
Eastern Kingbird	X	--	X
Alaudidae Family			
Horned Lark	X	X	X
Hirundinidae Family			
Purple Martin[a]	X	--	X
Tree Swallow	X	--	X
Northern Rough-Winged Swallow	X	--	X
Bank Swallow	X	--	X
Cliff Swallow	X	--	X
Barn Swallow	X	--	X
Corvidae Family			
Blue Jay	X	X	X
American Crow	X	X	X
Paridae Family			
Tufted Titmouse	R	R	--
Black-Capped Chickadee	X	X	X
Sittidae Family			
Red-Breasted Nuthatch	R	X	X
White-Breasted Nuthatch	X	X	--
Certhiidae Family			
Brown Creeper	--	X	X
Troglodytidae Family			
Carolina Wren	--	--	R
House Wren	X	--	X
Winter Wren	--	--	X
Sedge Wren[a]	X	--	X
Marsh Wren	X	--	X

Table continued on next page.

Table 2.25 (Continued)

Common Name	Breeding	Wintering	Migrant
Regulidae Family			
Golden-Crowned Kinglet	--	X	X
Ruby-Crowned Kinglet[a]	--	--	X
Blue-Gray Gnatcatcher	X	--	X
Eastern Bluebird	X	--	X
Veery[a]	X	--	X
Gray-Cheeked Thrush	--	--	X
Swainson's Thrush	--	--	X
Hermit Thrush	--	--	X
Wood Thrush[a]	X	--	X
American Robin	X	X	X
Mimidae Family			
Gray Catbird	X	--	X
Brown Thrasher	X	--	X
Bombycillidae Family			
Bohemian Waxwing	--	R	--
Cedar Waxwing	X	X	X
Laniidae Family			
Northern Shrike	--	--	X
Loggerhead Shrike[e]	--	--	R
Sturnidae Family			
European Starling[c]	X	X	X
Vireonidae			
Bell's Vireo	--	--	R
Solitary Vireo	--	--	X
Yellow-Throated Vireo	X	--	X
Warbling Vireo	X	--	X
Philadelphia Vireo	--	--	X
Red-Eyed Vireo	X	--	X
Parulidae Family			
Blue-Winged Warbler	X	--	X
Golden-Winged Warbler[a]	R	--	X
Tennessee Warbler[a]	--	--	X
Orange-Crowned Warbler	--	--	X
Nashville Warbler[a]	--	--	X
Northern Parula	--	--	X
Yellow Warbler	X	--	X
Chestnut-Sided Warbler	--	--	X
Magnolia Warbler	--	--	X
Cape May Warbler[a]	--	--	X
Black-Throated Blue Warbler	--	--	X
Yellow-Rumped Warbler	--	R	X
Black-Throated Green Warbler	--	--	X
Cerulean Warbler[b]	R	--	R
Blackburnian Warbler	--	--	X
Palm Warbler	--	--	X
Bay-Breasted Warbler	--	--	X
Blackpoll Warbler	--	--	X
Black-and-White Warbler	--	--	X
Prothonotary Warbler[a]	--	--	R
American Redstart	X	--	X
Ovenbird	X	--	X
Northern Waterthrush	--	--	X
Connecticut Warbler[a]	--	--	X
Mourning Warbler	R	--	X

Table continued on next page.

Table 2.25 (Continued)

Common Name	Breeding	Wintering	Migrant
Parulidae Family (Continued)			
Common Yellowthroat	X	--	X
Wilson's Warbler	--	--	X
Kentucky Warbler[b]	--	--	R
Canada Warbler	R	--	X
Hooded Warbler[b]	R	--	R
Thraupidae Family			
Scarlet Tanager	X	--	X
Cardinalidae Family			
Northern Cardinal	X	X	--
Rose-Breasted Grosbeak	X	--	X
Indigo Bunting	X	--	X
Emberizidae Family			
Dickcissel[a]	R	--	X
Eastern Towhee	X	--	X
American Tree Sparrow	--	X	X
Chipping Sparrow	X	--	X
Clay-Colored Sparrow	R	--	X
Field Sparrow	X	--	X
Vesper Sparrow[a]	X	--	X
Savannah Sparrow	X	--	X
Grasshopper Sparrow[a]	X	--	X
Henslow's Sparrow[b]	R	--	X
Fox Sparrow	--	R	X
Song Sparrow	X	X	X
Lincoln's Sparrow	--	--	X
Swamp Sparrow	X	X	X
White-Throated Sparrow	--	R	X
White-Crowned Sparrow	--	--	X
Dark-Eyed Junco	--	X	X
Lapland Longspur	--	R	X
Snow Bunting	--	R	X
Icteridae Family			
Bobolink[a]	X	--	X
Red-Winged Blackbird	X	X	X
Eastern Meadowlark[a]	X	R	X
Western Meadowlark[a]	R	--	X
Yellow-Headed Blackbird	X	--	X
Rusty Blackbird	--	R	X
Common Grackle	X	X	X
Brown-Headed Cowbird	X	R	X
Orchard Oriole[a]	R	--	R
Baltimore Oriole	X	--	X
Fringillidae Family			
Purple Finch	--	X	X
Common Redpoll	--	X	X
Pine Siskin[a]	--	X	X
American Goldfinch	X	X	X
House Finch	X	X	X
Evening Grosbeak	--	X	X
Passeridae Family			
House Sparrow[c]	X	X	--

Table continued on next page.

Table 2.25 (Continued)

Note: Total number of bird species: 220
Number of alien, or nonnative, bird species: 7 (3 percent)
Breeding: Nesting species
Wintering: Present January through February
Migrant: Spring and/or fall transient
X – Present, not rare; R – Rare

[a] *State-designated species of special concern. Fully protected by Federal and State laws under the Migratory Bird Act.*

[b] *State-designated threatened species.*

[c] *Alien, or nonnative, bird species.*

[d] *Federally designated threatened species.*

[e] *State-designated endangered species.*

Source: Samuel D. Robbins, Jr., Wisconsin Bird Life, Population & Distribution, Past and Present, *1991; John E. Bielefeldt, Racine County Naturalist; Zoological Society of Milwaukee County and Birds Without Borders-Aves Sin Fronteras, Wisconsin Department of Natural Resources; Wisconsin Society for Ornithology,* Wisconsin Bird Breeding Atlas II; *and SEWRPC*

2.8 RECREATION

Essentially all Lake residents and users want to ensure that Lake Comus continues to support conditions favoring recreation and, relatedly, property value. This issue of concern relates to many of the topics discussed in this chapter (e.g., aquatic plants, water quality, algal blooms, water quantity, and wildlife) because each can affect different recreational uses.

Lake Shorelines

Maintaining Lake Comus' aesthetic appeal, recreational use, and overall health is a shared responsibility of riparian landowners, those who live within the Lake watershed, and those who visit and use the Lake. Water quality, sedimentation, aquatic plant growth, and aquatic habitat are all affected by shoreline conditions and maintenance practices.

Most of the Lake's northern shoreline is undeveloped wetland, while the western shore is largely recreational land use (e.g., Paul Lange Arboretum) and the southeastern shore is devoted to residential land use. The large expanses of wetland shoreline are a unique feature of the Lake that residents have expressed interested in protecting as it provides aesthetic appeal and enhances the Lake's recreational value. A public boat launch is located at the southwestern end of the Lake in the vicinity of the outlet. Much of the western shoreline affords public access to the Lake, particularly by walking in the Paul Lange Arboretum or fishing from the shore along North Terrace Street. Recreational facilities development, including lakeshore paths, at the southern end of the Lake are envisioned as part of the City of Delavan's downtown strategic planning.[244] Land has recently been dedicated to extending the nature trail along the shoreline as part of this strategic plan.

Public Access

Public access to Lake Comus includes several parks, a fishing pier, and a boat launch site. The public launch is located on the western edge of the Lake near the outlet dam while the public pier is in the southwestern corner of the Lake. There is no boat launch fee required to launch on Lake Comus. The 24.6-acre Paul Lange and 6.1-acre Ora Rice Arboretums border the Lake on its northwestern shore while the 3-acre Robert Miller Park and the 9-acre Ned Hollister Wetland Conservancy border the eastern shore.[245,246] The 25-acre Veterans Memorial Park is located just west of Lake Comus across North Terrace Street. Public access to the Lake will be enhanced through the planned lakeshore trails along the western and southern shores.[247]

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[244] *City of Delavan and Vandewalle & Associates, 2013,* op. cit.

[245] *ci.delavan.wi.us/departments/parks-recreation/city-parks/*

[246] *visitdelavan.com/to-do/index.cfm?catID=All&navID=82*

[247] *City of Delavan and Vandewalle & Associates, 2013,* op. cit.

Lake User Survey

Commission staff collaborated with the LCPRD to design and promote a survey to gauge opinions of Lake users, City of Delavan residents, and shoreline residents regarding Lake Comus. The LCPRD prepared a press release and distributed the survey in the summer of 2019, but the survey received a lackluster response and thus did not provide as useful of information as had been anticipated. While plans were discussed to conduct another survey in the summer of 2020, the onset of the Covid-19 pandemic hampered those plans.

Recreational Activities

Commission staff have anecdotally noted recreational use of Lake Comus and Turtle Creek during surveys to the area in 2019 through 2021, including boating, fishing, and passive enjoyment of the Lake. While several lake residents do have boats and docks, the LCPRD boat being used by Commission staff was typically the only boat on the Lake during these surveys. Thus, Lake Comus does not appear to be a large draw for recreational boating such as pleasure cruising or water-skiing. Indeed, the Mutual Lake District Regulations in the City of Delavan municipal code states that the entire Lake is a slow-no-wake zone, limiting the capacity to recreate in these fashions.[248] Fishing appears to be a popular activity on Lake Comus, as several people were often observed fishing from the dock at the boat launch, along North Terrace Street, and along Turtle Creek just downstream of the Lake's outlet dam. The most frequently observed recreational activity by Commission staff was passive enjoyment of the Lake by people walking along the shoreline in the Paul Lange Arboretum or sitting on the Arboretum's benches enjoying the Lake views. Commission staff did not observe anyone swimming in Lake Comus during their visits and there is no designated swim area within the Lake.[249]

The LCPRD conducted a survey of recreational use on Lake Comus during August 2021 (Table 2.29). The survey spanned eleven days, with nine morning observational periods and two afternoon observational periods. Walking along the shoreline trails was the most popular activity by a wide margin, followed by fishing from the shoreline and then paddle sports. These survey results are consistent with the anecdotal observations noted by Commission staff described above.

Table 2.26
Mammals Likely Present Within the Lake Comus Watershed

Common Name	Scientific Name
Didelphidae Family	
Virginia Opossum	*Didelphis virginiana*
Soricidae Family	
Cinereous Shrew	*Sorex cinereus*
Short-Tailed Shrew	*Blarina brevicauda*
Least Shrew	*Cryptotis parva*
Vespertilionidae Family	
Little Brown Bat	*Myotis lucifugus*
Silver-Haired Bat	*Lasisoncteris octivagans*
Big Brown Bat	*Eptesicus fuscus*
Red Bat	*Lasiurus borealus*
Hoary Bat	*Lasiurus cinereus*
Leporidae Family	
Cottontail Rabbit	*Sylvilgus floridanus*
Sciuridae Family	
Groundhog	*Marmota monax*
Thirteen-Lined Ground Squirrel (gopher)	*Spermophilus tridencemilineatus*
Eastern Chipmunk	*Tamias striatus*
Grey Squirrel	*Sciurus carolinensis*
Western Fox Squirrel	*Sciurus niger*
Red Squirrel	*Tamiasciurus hudsonicus*
Southern Flying Squirrel	*Glaucomys volans*
Castoridae Family	
American Beaver	*Castor canadensis*
Cricetidae Family	
Woodland Deer Mouse	*Peromyscus maniculatus*
Prairie Deer Mouse	*Peromyscus leucopus bairdii*
White-Footed Mouse	*Peromyscus leucopus*
Meadow Vole	*Microtus pennsylvanicus*
Common Muskrat	*Ondatra zibethicus*
Muridae Family	
Norway Rat (introduced)	*Rattus norvegicus*
House Mouse (introduced)	*Mus musculus*
Zapodidae Family	
Meadow Jumping Mouse	*Zapus hudsonius*
Canidae Family	
Coyote	*Canis latrans*
Eastern Red Fox	*Vulpes vulpes*
Gray Fox	*Urocyon cinereoargenteus*
Procyonidae Family	
Raccoon	*Procyon lotor*
Mustelidae Family	
Least Weasel	*Mustela nivalis*
Short-Tailed Weasel	*Mustela erminea*
Long-Tailed Weasel	*Mustela frenata*

Table continued on next page.

[248] *City of Delavan Municipal Code, Section 12-2-6, Speed Restrictions, ci.delavan.wi.us/government/municipal-code/*

[249] *ci.delavan.wi.us/wp-content/uploads/2013/09/Delavan_Park_System_Map2008.pdf*

The City of Delavan has envisioned that the Lake become a regional hub for non-motorized boating activities, such as paddle sports and fishing, which are already popular activities on the Lake.[250] To that end, the Downtown Delavan Strategic Plan calls for creating a recreation area in Veterans Memorial park where canoes, kayaks, fishing gear, and ice skates can be rented for use on the Lake.[251] This recreational area is part of a larger vision of connecting downtown Delavan with the Lake, which also includes establishing a lakeside trail along North Terrace Street to connect downtown with the Paul Arboretum as well as acquiring easements and developing a lakeside trail along the southern shore of the Lake. Additionally, the City worked with the school district to establish the Delavan Paddle Sports Program in 2014 which allows the City to access the school district's kayaks during the summer. The City purchased eight additional paddleboards to supplement their fleet in 2014. This program, which is operated out of the Delavan Mill Pond facility, has had between 53 and 154 rentals each year since 2015.[252]

In the upstream portions of the watershed, the WDNR manages the Turtle Valley Wildlife Area, a 2,300-acre expanse of restored woodland, prairie, and open wetland habitats.[253] The Wildlife Area was created in 2000 through collaboration between the United States Department of Agriculture Natural Resources Conservation Service and the WDNR and is the largest Wetland Reserve Program site enrollment in Wisconsin's history. The Wildlife Area has been supported and expanded with the help of private landowners, the US Fish and Wildlife Service, Walworth County Land Use & Resource Management Department, and Pheasants Forever. Home to abundant waterfowl and ring-necked pheasant populations, this Wildlife Area is popular with birdwatchers, hikers, hunters, and trappers. Snowmobiling and cross-country skiing are available on the property in winter.

Table 2.26 (Continued)

Common Name	Scientific Name
Mustelidae Family (Continued)	
Mink	*Mustela vison*
Badger (occasional visitor)	*Taxidea taxus*
Striped Skunk	*Mephitis mephitis*
Otter (occasional visitor)	*Lontra canadensis*
Cervidae Family	
White-Tailed Deer	*Odocoileus virginianus*

Source: H.T. Jackson, Mammals of Wisconsin, *1961, U.S. Department of Agriculture Integrated Taxonomic Information System, National Museum of Natural History, Smithsonian Institute, and SEWRPC*

Table 2.27
Animals Extirpated from Southeastern Wisconsin

Common Name	Scientific Name
Mammals	
Bison	*Bison bison*
Gray Wolf	*Canis lupus*
Elk	*Cervus canadensis*
Cougar	*Felis concolor*
Lynx	*Lynx canadensis*
Fisher	*Pekania pennanti*
Indiana Bat	*Myotis sodalist*
Black Bear	*Ursus americanus*
Birds	
Carolina Parakeet (extinct)	*Conuropsis carolinensis*
Passenger Pigeon (extinct)	*Ectopistes migratorius*
Swallow-Tail Kite	*Elanoides forficatus*
Long-Billed Curlew	*Numenius americanus*
Bewick's Wren	*Thyromanes bewickii*
Fish	
Longjaw Cisco (extinct)	*Coregonus alpenae*
Deepwater Cisco (extinct)	*Coregonus johannae*
Blackfin Cisco	*Coregonus nigripinnis*
Creek Chubsucker	*Erimyzon oblongus*
Black Redhorse	*Moxostoma duguesnei*

Source: Wisconsin Natural Heritage Inventory Working List; Wisconsin Department of Natural Resources, 1990, and SEWRPC

Paddle sports are a locally popular activity on Turtle Creek further downstream of Lake Comus from School Section Road to the confluence with the Rock River in South Beloit, Illinois.[254] In particular, the sections of the Creek running through the Turtle Creek Wildlife Area the Creek are noted for their excellent wildlife viewing opportunities, natural stream meanders, abundant groundwater springs, high water clarity, and abundant aquatic plants.[255,256]

[250] *City of Delavan and Vandewalle & Associates, 2013,* op. cit.

[251] Ibid.

[252] *Not including 2020 as the program was not operational due to the Covid-19 pandemic.*

[253] *dnr.wisconsin.gov/topic/Lands/WildlifeAreas/turtlevalley.html*

[254] *www.friendsofturtlecreek.com/paddle/*

[255] *milespaddled.com/turtle-creek-paddle-guide/*

[256] *www.wisconsinrivertrips.com/segments/turtle-creek*

Table 2.28
Status of the State of Wisconsin-Designated Rare Animals

Common Name	Scientific Name	Status as Listed in PR-42	Current Status
		Mammals	
Red-Backed Vole	*Clethrionomys gapperi*	Special Concern	Not listed
Bobcat	*Lynx rufus*	Special Concern	Not listed
Thompson's Pigmy Shrew	*Sorex thompsonii*	Special Concern	Not listed
Southern Bog Lemming	*Synaptomys cooperi*	Special Concern	Not listed
		Birds	
Bewick's Wren	*Thryomanes bewickii*	Endangered	Not listed
Bald Eagle	*Haliaeetus leucocephalus*	Threatened	Special Concern
Henslow's Sarrow	*Ammodramus henslowii*	Special Concern	Threatened
Pine Siskin	*Carduelis pinus*	Special Concern	Not listed
Evening Grosbeak	*Coccothraustes vespertinus*	Special Concern	Not listed
Yellow Rail	*Coturnicops noveboracensis*	Special Concern	Threatened
Blackburnian Warbler	*Dendroica fusca*	Special Concern	Not listed
Orchard Oriole	*Icterus spurius*	Special Concern	Not listed
Common Merganser	*Mergus merganser*	Special Concern	Not listed
Red-Breasted Merganser	*Mergus serrator*	Special Concern	Not listed
Tennessee Warbler	*Vermivora peregrina*	Special Concern	Not listed
Canada Warbler	*Wilsonia canadensis*	Uncommon	Special Concern
Blue-Winged Warbler	*Vermvora pinus*	Uncommon	Special Concern
Nashville Warbler	*Vermivora ruficapilla*	Uncommon	Special Concern
Wood Thrush	*Hylocichia mustelina*	Uncommon	Special Concern
Red Crossbill	*Loxia curvirostra*	Uncommon	Special Concern
White-Eyed Vireo	*Vireo griseus*	Uncommon	Special Concern
Great Blue Heron	*Ardea herodias*	Uncommon	Special Concern
Whip-Poor-Will	*Caprimulgus vociferous*	Uncommon	Special Concern
Least Flycatcher	*Empidonax minimus*	Uncommon	Special Concern
Willow Flycatcher	*Empidonax traillii*	Uncommon	Special Concern
Veery	*Catharus fuscescens*	Uncommon	Special Concern
American Woodcock	*Scolopax minor*	Uncommon	Special Concern
Golden-Winged Warbler	*Vermivora chrysoptera*	Uncommon	Special Concern
		Reptiles And Amphibians	
Four-Toed Salamander	*Hemidactylium scutatum*	Uncommon	Special Concern
Butler's Garter Snake	*Thamnophis butleri*	Uncommon	Threatened
		Fish	
Lake Herring	*Coregonus artedii*	Special Concern	Not listed

Source: Wisconsin Natural Heritage Inventory Working List; Wisconsin Department of Natural Resources, 2007, and SEWRPC

Table 2.29
Lake Comus Recreational Survey: August 2021

Date	Time	Paddling	Shore Fishing	Lake Fishing	Shoreline Trail	Other
1-Aug	Morning	3	4	1	14	0
5-Aug	Morning	2	2	0	8	0
7-Aug	Morning	8	7	2	23	0
8-Aug	Afternoon	4	3	1	9	0
13-Aug	Morning	0	5	1	16	0
15-Aug	Morning	5	3	0	12	0
18-Aug	Morning	1	6	0	6	0
21-Aug	Morning	6	9	2	18	0
28-Aug	Morning	5	6	3	26	0
29-Aug	Afternoon	3	7	2	11	0
30-Aug	Morning	4	3	0	7	1[a]
	Total	41	55	12	150	1

[a] The "Other" tally was a gas-powered boat traveling to a blind.

Source: LCPRD and SEWRPC

Credit: SEWRPC Staff

MANAGEMENT RECOMMENDATIONS AND PLAN IMPLEMENTATION 3

3.1 INTRODUCTION

Lake Comus is a valuable resource to lake residents and visitors, contributes to the local economy and quality of life, and is an important feature to the overall hydrology and ecology of the Turtle Creek watershed. Because of the Lake's value to the community, the Lake Comus Protection and Rehabilitation District (LCPRD) requested, and was subsequently awarded, a grant to inventory the Lake's resource base and conditions, study issues perceived to harm or threaten the Lake, and suggest solutions to help maintain or enhance the Lake's overall community value. Unmitigated human-induced change is generally detrimental to waterbody health. Therefore, management actions should be taken to counter negative effects of human activity. This chapter provides actionable suggestions that help maintain and enhance the health of the Lake and support its continued enjoyment.

Major Challenges and Goals

Lake Comus and its watershed possess many unique and valuable features including substantial lengths of undeveloped shoreline, extensive riparian wetlands, numerous opportunities for public access and recreation, large and growing areas of publicly owned land managed to support wildlife, and the presence of several rare and threatened species. Nevertheless, the Lake and the Creek face major challenges as revealed by its 2022 assignment to the Clean Water Act 303(d) impaired waters list. For example, as detailed in Chapter 2, the Lake receives heavy sediment and nutrient loads and is highly eutrophic (nutrient-rich). This causes the Lake to have very limited water clarity, large shoals of nutrient-rich sediment, a depauperate aquatic plant community, and experience occasional algae blooms. Such factors limit the Lake's ecological potential and its overall recreational use value. These conditions are exacerbated by abundant invasive common carp that hinder aquatic plant growth and agitate phosphorus-laden soft Lake-bottom sediment.

The Lake's eutrophic state is driven by excessive nutrient and sediment loads delivered to the Lake primarily from the upper Turtle Creek watershed. Extensive historical ditching and channelizing of Turtle Creek and its tributaries combined with intensive agricultural use have dramatically changed watershed hydrology and increased nutrient and sediment delivery to the Lake. Even with implementation of conservation practices that help reduce ongoing pollutant loading, legacy phosphorus and sediment are still delivered to the Lake via Turtle Creek and are deposited at the Lake's shallow northern end. Continuing efforts are required to decrease nonpoint pollutant loading within the watershed which, in turn, reduces the transport of excessive amounts of sediment and nutrients to the Lake. Similarly, the Lake's water supply must also be protected. Many of the management actions taken to manage nonpoint pollutant loading also benefit and protect the Lake's surface-water and groundwater supplies.

As stated in Chapter 1, this management plan strives to protect existing high-quality resources, prevent resource degradation, and enhance resource function by implementing tasks consistent with the following goals:

- Minimize further degradation of surface-water features and preserve, maintain, or enhance the quality of all waterbodies within the watershed.

- Identify opportunities to improve the quality of land and water (including groundwater) resources within the watershed by reducing both nonpoint agricultural and urban runoff.

- Manage and develop lands in a manner protecting natural resources features. This includes avoiding habitat fragmentation, encouraging preservation and enhancement of wetlands and wildlife corridors, providing and preserving connections with upland habitats, and encouraging thoughtful, sensitive landscaping practices.

- Enhance recreational opportunities on Lake Comus and Turtle Creek, particularly for fishing, hunting, paddle sports, and hiking on Lake shoreline trails.

- Promote active stewardship among residents, farmers, landowners, businesses, community associations, as well as governmental and non-governmental organizations.

Successful plan implementation depends upon strong community leadership and coordination, community outreach, and stakeholder collaboration. Examples of this include effective partnering arrangements amongst stakeholders, developing innovative watershed-based tactics that contribute to multiple strategic goals, developing institutional capacity to carry tactics through to completion, and actively monitoring progress and adjusting tactics as needed to reach strategic goals.

Management Recommendations

Management recommendations for Lake Comus are based upon the interests and priorities of lake users, analysis of available data, practicality, and the potential for successful implementation (Table 3.1). Select recommendation concepts, and the general areas of the watershed where these concepts are applicable, are shown in Map 3.1. Implementing these recommendations helps maintain and enhance the health of the Lake and its tributaries, helps the watershed better achieve its latent ecological potential, and improves the watershed's ability to provide short- and long-term sustainable benefits to the overall community.

The recommendations made in this chapter cover a wide range of programs and seek to address a broad array of factors and conditions that significantly influence the health, aesthetics, and recreational use of Lake Comus. Many initiatives share similar strategies and implementation tactics. Therefore, implementing certain tactics often benefits several goals. Since the plan addresses many issues, it is not be feasible to implement every recommendation immediately. To promote efficient plan implementation, the relative time sensitivity/significance of each recommendation is noted to help Lake managers prioritize plan elements. Nevertheless, all recommendations are important and should eventually be addressed, subject to possible revision based on analysis of yet-to-be collected data (e.g., future aquatic plant surveys and water quality monitoring results), project logistics, and/or changing/unforeseen conditions.

Several recommendations constitute major management actions that may provide multiple water quality, recreational use, and aquatic life benefits. However, major management actions may also require careful planning and permitting, community engagement, regulatory approval, and/or significant expense. Examples of such actions include water level manipulation, sediment dredging, and carp removal. Guidance regarding the effects, benefits, and considerations of these lake management actions are summarized in Table 3.2.

Table 3.1
Summary of Recommendation Grouped by Issues

Recommendation Number	Recommendation	Priority
	Hydrology/water quantity	
	Surface Water Monitoring and Management	
1.1	Continue to monitor Lake Comus' water surface elevation	High
1.2	Quantify surface water outflow	High
1.3	Monitor and quantify the volume of water delivered to the Lake from Turtle Creek	High
	Groundwater Monitoring and Protection	
1.4	Institute groundwater monitoring	Medium
1.5	Maintain of enhancing conditions slowing stormwater runoff	Low-High[a]
1.6	Curb growth of groundwater demand	Low-High[a]
1.7	Preserve or enhance water supplies to groundwater	Low-High[a]
1.8	Protect groundwater quality	High
	Lake Outlet Dam Operation and Configuration	
1.9	Dam design opportunities	High
1.10	Dam operation opportunities	High
	Water quality	
	Lake Monitoring	
2.1	Continue and enhance comprehensive water quality monitoring within Lake Comus	High
	Tributary Monitoring	
2.2	Continue to conduct level 1 Water Action Volunteer (WAV) monitoring in Turtle Creek and the CTH O Tributary	High
2.3	Consider expanding up to Level 2 WAV monitoring to install programmable water temperature logging devices in Turtle Creek and the CTH O tributary	Medium
2.4	Consider implementing a continuous turbidity monitoring program in Turtle Creek	Low
2.5	Supplemental water quality monitoring	Medium
	Phosphorus Management	
2.6	Reduce nonpoint source external phosphorus loads	High
2.7	Manage factors that stimulate in-Lake phosphorus recycling	High
	Cyanobacteria and Floating Algae	
2.8	Reduce Lake phosphorus concentrations	High
2.9	Monitor algal abundance and sample for algal toxins during suspected algal bloom conditions	High
2.10	Warn residents not to enter water in event of an algal bloom	High
2.11	Encourage healthy aquatic plant community to compete with algal growth	High
2.12	Reduce carp populations within Lake	High
	Pollutant and sediment sources and loads	
	Agricultural Best Management Practices	
3.1	Incentivize use of no-till and conservation tillage practices	High
3.2	Encourage increase in cover crop acres	High
3.3	Ensure that all lands are under nutrient management plans	High
3.4	Install additional grassed waterways	High
	Drain Tiles	
3.5	Reduce and retrofit drain tile systems	High
3.6	Implement saturated buffers and/or bioreactors to treat tile drainage	Medium
3.7	Manage fertilizer application to minimize losses via drain tile	High
	Animal Operations	
3.8	Ensure that animal operation performance standards are met	High
	Ditching and Channelizing	
3.9	Restore natural landscape elements to detain runoff	High
	Urban Best Management Practices	
3.10	Encourage pollution source reduction efforts through BMPs	Medium
3.11	Promote native plantings in and around existing and new stormwater detention basins	Medium
3.12	Retrofit existing and enhance planned stormwater management infrastructure	Medium

Table c ontinued on next page.

Table 3.1 (Continued)

Recommendation Number	Recommendation	Priority
	Urban Best Management Practices (Continued)	
3.13	Combine riparian buffers with other structures and practices	Low
3.14	Stringently enforce construction site erosion control and stormwater management ordinances and creative employment of these practices	Low
3.15	Maintain stormwater detention basins	Low
3.16	Promote urban nonpoint source abatement	Low
3.17	Collect leaves in urbanized areas	Low
	Riparian Buffer Protection and Prioritization Strategies	
3.18	Increase coverage of riparian buffers	High
	Aquatic plants	
4.1	Protect native aquatic plants to the highest degree feasible through careful implementation of aquatic plant management and water quality recommendations	Medium
4.2	Avoid disrupting bottom sediment or leaving large areas of bottom sediment devoid of vegetation	Low
4.3	Reduce the Lake's carp population	High
4.4	Prevent the introduction of new invasive species	Low
4.5	Consider manipulating water levels to encourage native plant growth	Medium
	Fish and wildlife	
	Habitat Quality	
5.1	Preserve and expand wetland and terrestrial wildlife habitat, while making efforts to ensure connectivity between such areas	High
5.2	Preserve and enhance instream features that provide important fish spawning and rearing habitats	High
5.3	Restore natural meanders and improve floodplain connectivity to Turtle Creek and its tributaries	Medium/High [a]
5.4	Preserve natural areas of countywide and local significance, as those of critical species habitat	High
5.5	Incorporate upland conservation and restoration targets into management and policy decisions	Medium
5.6	Improve aquatic habitat in Lake Comus by maintaining and adding large woody debris and/or vegetative buffers along the Lake's edge	Low/Medium[a]
5.7	Mitigate water quality stress on aquatic life and maximize areas habitable to desirable fish	Medium/High[a]
5.8	Mitigate streambank erosion	Low
	Population Management	
5.9	Reduce and control the Lake's carp population	High
5.10	Improve wildlife populations by encouraging best management practice adoption	Medium
5.11	Continue to monitor fish and wildlife populations	Medium
	Eastern Massasauga Rattlesnake and Other Rare Reptiles	
5.12	Follow WDNR and US Fish and Wildlife guidance on land management BMPs in potential rare reptile habitat	High
5.13	Consider impacts to Eastern Massasauga rattlesnake and Blanding's turtle if conducting water level manipulation for lake management	High
	Recreational use and facilities	
6.1	Maintain and enhance fishing by protecting and improving aquatic habitat and water quality	High
6.2	Maintain public boat launch sites	Medium
6.3	Maintain natural shorelines in planned development	High
6.4	Incorporate the City of Delavan's planned recreational facilities	High
6.5	Enhance public access with walkway as part of dam replacement project	High
6.6	Develop and improve walkway and parkway along western shoreline	High
6.7	Collaborate with City of Delavan to develop planned lakeshore trail	Medium
6.8	Consider a designated portage route as part of outlet dam replacement	Medium/High
6.9	Enhance shoreline erosion protection, particularly along Paul Lange Arboretum	High
	Plan implementation	
7.1	Integrate lake users and residents in management efforts	High
7.2	Encourage key players to attend meetings, conferences, and/or training programs to build their lake management knowledge	Medium

Table continued on next page.

Table 3.1 (Continued)

Recommendation Number	Recommendation	Priority
	Plan implementation (Continued)	
7.3	Continue to ensure inclusivity and transparency with respect to all Lake management activities	High
7.4	Foster and monitor management efforts to communicate actions and achievements to future lake managers	Medium
7.5	Consider installing "This is Our Watershed" and "Adopt a Highway" signage throughout the watershed	Medium
7.6	Increase visibility of Lake Comus on City of Delavan website	Medium
7.7	Actively share this plan and work with municipalities to adopt it by maintaining and enhancing relationships with County, municipal zoning administrators, directors of public works/municipal engineers, and law enforcement officers	High
7.8	Keep abreast of activities within the watershed that can affect the Lake	Low/High
7.9	Educate watershed residents about relevant ordinances. Update ordinances as necessary to face evolving use problems and threats.	Medium
7.10	Encourage formation and growth of producer-led group within the watershed	High
7.11	Consider inter-governmental agreements with neighboring municipalities	Medium
7.12	Foster open relationships with potential project partners	High
7.13	Apply for grants when available to support implementing recommended programs	High

Note: This summary of recommendations is a compiled list of items the Lake Comus Protection and Rehabilitation District; the City of Delavan; the Towns of Delavan, Richmond, Sugar Creek; the residents of the Lake Comus watershed; and riparian owners, working together with volunteers and other nonprofit organizations, could implement to improve Lake Comus and its watershed.

[a] *The priority is based on the sub recommendations.*

Source: SEWRPC

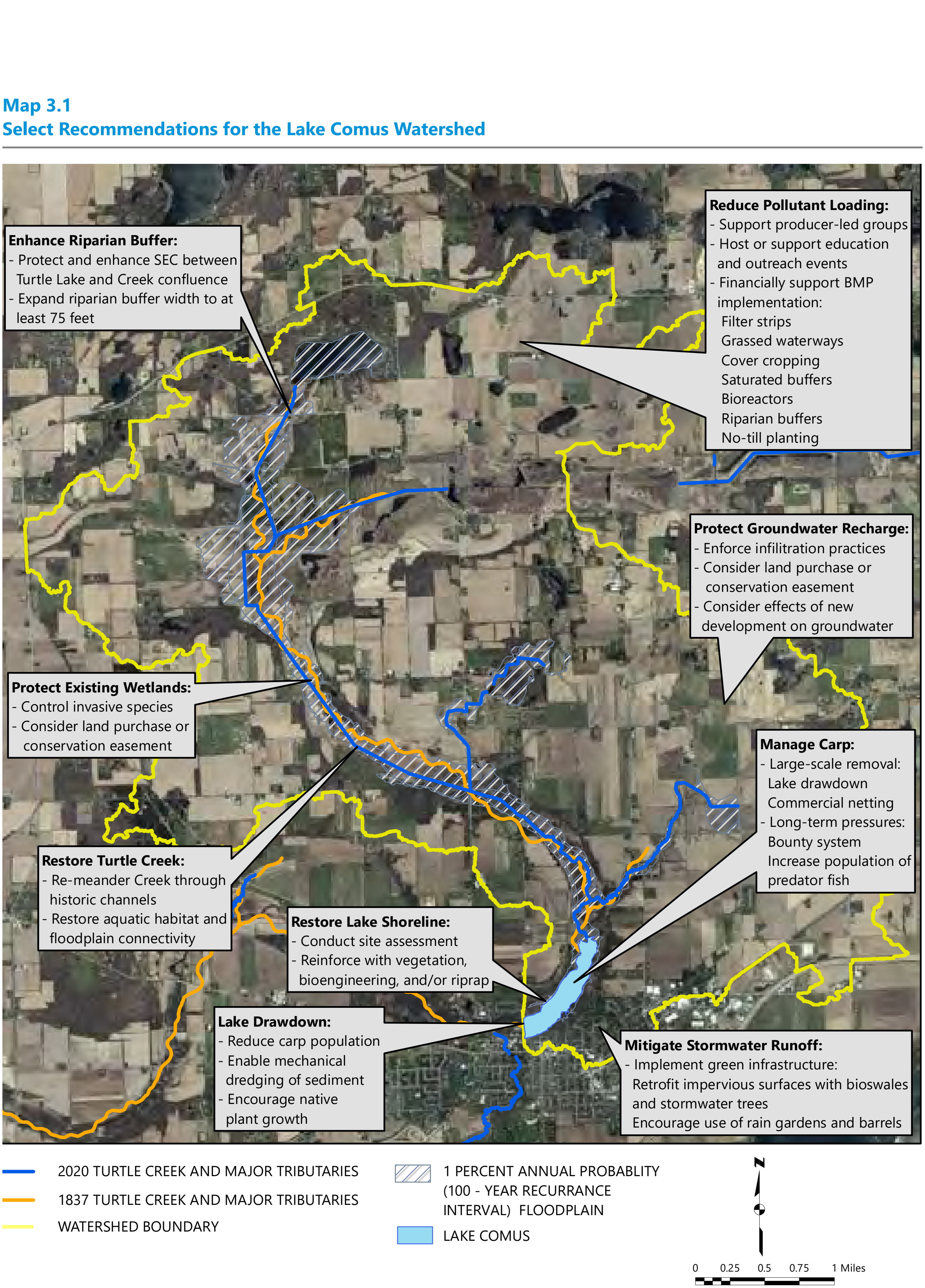
Those responsible for Lake planning and management should actively conceptualize, seek, and promote projects and partnerships that enable plan recommendations to be implemented. The measures presented in this chapter focus primarily on those that can be implemented through collaboration between local organizations, watershed property owners, and others who have a vested interest in the long-term health of Lake Comus, Turtle Creek, and the watershed. Examples include watershed property owners (riparian property owners in particular), the LCPRD, the City of Delavan, Walworth County, the Wisconsin Department of Natural Resources (WDNR), and the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS). Collaborative partnerships formed among other potential stakeholders, such as agricultural producers, non-governmental organizations (e.g., Rock River Coalition, Kettle Moraine Land Trust, Friends of Turtle Creek, producer-led groups, the Michael Fields Agricultural Institute), developers, wastewater treatment plants (e.g., the Walworth County Metropolitan Sewerage District), and other watershed municipalities (i.e., Towns of Darien, Delavan, Richmond, and Sugar Creek), can help promote efficient, affordable, and sustainable actions promoting the long-term ecological health of Lake Comus.

As a planning document, this chapter provides concept-level descriptions of activities that may be undertaken to help protect and enhance Lake Comus and its watershed. It is important to note that plan recommendations provide stakeholders and implementing entities with guidance regarding the type and nature of projects to pursue to meet plan goals. These recommendations and project suggestions do not constitute detailed technical specifications. The full logistical and design details needed to implement many recommendations must be more fully developed in the future when individual recommendations are implemented. Grants are often available to develop concept plans into actionable design drawings and programs.

In summary, this chapter provides those implementing the plan the ability to:

- Better understand plan element context and what needs to be done
- Judge the relative importance of plan recommendations
- Better comprehend plan intent
- Envision the appearance of executed plan elements

Map 3.1
Select Recommendations for the Lake Comus Watershed



Source: SEWRPC

Table 3.2
Effects, Benefits, and Considerations of Major Lake Management Actions

Major Management Actions	Effects	Benefits	Considerations
	Lake Level Manipulation		
Water Quality	Little to no water in lake during drawdown. Drawdown compacts sediment and exposure to air decomposes sediment organic matter.	Reduced nutrient resuspension upon water level rise. Potential for increased clarity and reduced algal abundance.	Potential for lower dissolved oxygen and higher temperatures in remaining pool of water during drawdown.
Aquatic Plants	Fluctuations in water level encourage other native submerged and emergent plants to establish.	Increased coverage by plants. More habitat for aquatic organisms. Greater phosphorus uptake and reduced sediment resuspension.	Potential expansion of cattail marsh and/or other unwanted species into current open water.
Fisheries	Reduced water levels during drawdown would concentrate fish into small areas of Lake.	Facilitates invasive common carp removal operations.	Higher potential for lake-wide fish kill, including desired species.
Recreation and Aesthetics	Lake drawdowns leave sediment exposed for long periods of time. Frequent fluctuations may leave piers and docks stranded and/or underwater.	Long-term benefits via potential for reduced algal blooms, greater water clarity, and improved fishery.	Community may find exposed sediment to be unsightly and/or produce odors. Lake will be unusable during drawdown.
	Lake Sediment Dredging		
Water Quality	Dredging would remove phosphorus-laden sediment from lake bottom.	Reduced nutrient resuspension through wind and/or disturbance by carp. Potentially improved water clarity.	Increase in phosphorus resuspension during dredging operations, unless conducted during drawdown.
Aquatic Plants	Dredging removes rooted aquatic plants as well as plant turions and seeds in sediment.	Long-term benefits via enhanced aquatic plant growth and coverage if dredging improves water clarity.	Removal of much of the aquatic plant biomass within the lake, as it is concentrated in shallow northern area.
Fisheries	Dredging may remove some spawning habitat.	Minimal direct effects.	Minimal direct effects.
Recreation and Aesthetics	Dredging increases lake depth. Recreational use may be limited while dredging operations underway.	Greater water depth would facilitate boat passage in shallow northern area.	Community may find noise, smell, and/or sight of dredging to be undesirable.
	Carp Removal Program		
Water Quality	Carp disturb lake sediment, reducing water clarity and increasing algae and phosphorus abundance.	Improved water clarity and lower lake phosphorus concentrations.	Use of chemical treatments would affect short-term water quality.
Aquatic Plants	Carp consume and disturb aquatic plants. Decreased water clarity could affect colonization depth.	Greater aquatic plant coverage and at deeper depths in the Lake.	Plant coverage reduced if a lake drawdown is used to facilitate removal efforts.
Fisheries	Carp destroy aquatic plants that act as habitat and food sources for native fish. Native species sometimes consume carp eggs as food source.	More abundant habitat via increased plant coverage. Less competition for food sources.	Other native species may be affected by removal efforts. Native species may be reduced with loss of eggs as food source.
Recreation and Aesthetics	Recreational use may be limited while removal operations underway. Removal will affect lake fishery, potentially including sport and panfish populations.	Enhanced fishery for native species. Improved water clarity.	Lower carp population for bow-fishing. Community may oppose removal methods and/or find method to be unsightly.

Source: SEWRPC

Such concepts can be invaluable for building coalitions and partnerships, writing competitive and meaningful grant requests, and initiating project design work.

3.2 HYDROLOGY, WATER QUANTITY, AND WATER RESOURCE INFRASTRUCTURE

Management plans that call upon practices that preserve, enhance, or naturalize watershed runoff, consider natural resource features and limitations, and promote thoughtfully engineered water resource infrastructure can benefit waterbody and watershed health and resilience in many ways. Such plans help managers choose alternative courses of action that slow runoff, detain stormwater, promote stormwater infiltration, sustain groundwater supplies, protect and enhance habitat value, and benefit recreational pursuits A few examples of benefits accruing from such practices are listed below.

- Stormwater runoff intensity is reduced. This can reduce watercourse bed and bank erosion, lower sediment/nutrient loads, preserve topsoil integrity, foster soil water storage and groundwater recharge, protect infrastructure, and improve aquatic habitat value.

- Favorable soil moisture conditions are prolonged. This positively affects plant health and crop yields, especially during drier summers. Furthermore, less stormwater leaves the landscape as runoff, reducing downstream flooding and soil erosion.

- Groundwater recharge potential is maintained helping assure groundwater continues to flow at natural groundwater discharge points such as springs and seeps. Furthermore, maintaining groundwater recharge potential helps maintain aquifer water levels that assure reliable potable water supplies for human needs.

- Stream flow volumes are modulated and water quality is improved. Peak runoff volumes and flood elevations are reduced, dry-weather flows are increased, summer water temperatures are cooler, and winter water temperatures are sometimes slightly higher.

- Waterbody ecology is benefitted. Aquatic habitat health is promoted by the factors listed above allowing the waterbody to better reach its latent ecological potential.

- Recreational opportunities are maintained or increased. Healthy aquatic habitat supports more abundant, more diverse, and more desirable plants and animals.

Management strategies addressing the Lake's water supply and water elevation/storage volume should identify opportunities, quantify changes, and evolve over time. Data collected by systematic monitoring helps lake managers make decisions consistent with current conditions and trends. The following recommendations suggest practical strategies to protect and enhance the Lake's water supply and generate data needed to gage ongoing conditions.

➤ **Recommendation 1.1: Continue to monitor Lake Comus' water-surface elevation**

The Lake's water surface elevation is influenced by several factors including precipitation, evaporation, wind, and various other weather conditions; the elevation and condition of the outlet dam weir; obstructions in the outlet weir; and the volume of water entering the Lake from its watershed and groundwater. Variations in these factors cause Lake water levels fluctuate. Recording Lake-specific information relating these factors helps monitor human and environmental stressors on the Lake's water supply. Detailed knowledge of Lake elevation allows the Lake's hydrology to be better understood and changes noted. The availability of information collected consistently over long periods of time may be useful for future ordinance and technical guidance development, may help gage the impact of continued development and management activity, and can help with design and operation of water management infrastructure such as dam gates.

At a minimum, the LCPRD or the City of Delavan should continue to manually measure and record daily precipitation and Lake water levels whenever the monitoring point is not frozen. The measuring point elevation must be related to a known datum (e.g., NGVD 1929) to allow comparison to data collected in the past and the future as well as at other locations. This recommendation should be assigned a high priority.

Consideration should also be given to installing automated water level recording equipment to reduce labor demands and increase data collection frequency. Furthermore, automated water-level recording equipment could allow the LCPRD or the City to post Lake water surface elevation to a website in real time. Such information allows staff to react more quickly to rapid water elevation changes caused by blockage, heavy runoff, equipment failure, or other reasons. Electronic water level monitoring equipment is widely available with the hardware associated with simpler devices costing around $1,000. Monitoring additional weather conditions and noting lake appearance would also be beneficial (e.g., record wind speed, wind direction, water and air temperature, ice conditions, wave action). The measuring location used to monitor lake water elevation need not be directly at the dam outlet. Instead, it could be installed at any convenient location throughout the reservoir if the reference point and sensor remain static. Given the relatively low cost and great value of resultant data, automated sensor installation is also assigned a high priority.

- **Recommendation 1.2: Quantify Surface Water Outflow**

  The amount of water leaving the Lake through the dam outlet works provides valuable information about Lake and watershed hydrology. Quantifying outlet flow over extended periods of time will help with future management decisions and may be valuable to future management actions such as aquatic plant management. The amount of water leaving through the dam outlet works can be easily estimated using water elevation data collected as part of Recommendation 1.1, noting the position of operable gates, and applying relatively simple published empirical relationships. Automated water level data collection would enrich this data set and could be used to post real-time outlet flow graphs. This recommendation should be considered a high priority.

- **Recommendation 1.3: Quantify the volume of water delivered to the Lake from Turtle Creek**

  No stream gaging stations exist on Turtle Creek upstream of Lake Comus. Nearly all Creek discharge estimates are derived from models. Measuring Creek discharge would help validate modelled discharge projections and the Creek's contributions to the Lake's water budget estimated by the Commission using model values. At a minimum, stream flow should be occasionally measured when water quality samples are collected. Additional measurements should be made to help quantify flow during fair weather, periods of heavy runoff, and dry weather. Rough estimates of flow can be made by measuring water velocities at locations where stream cross sectional area is easily quantified (e.g., culverts, bridges). Velocity multiplied by cross sectional area yields a flow rate. The level of detail used to quantify flow and cross-sectional area improves estimate validity.[257] After sufficient data is collected, a rough rating curve for the particular site in question can be developed. A rating curve allows flow to be estimated from water depth or elevation alone, simplifying data collection. This recommendation is a high priority.

- **Recommendation 1.4: Institute groundwater monitoring**

  Groundwater recharge within the Lake Comus watershed supplies water to the shallow aquifers, which, in turn, provides baseflow to the Lake, Turtle Creek, and their tributaries. Baseflow is essential to maintaining the hydrology, instream habitat, and overall health of the Creek, particularly during dry weather.[258] Groundwater discharge points, such as seeps and springs, are important sources of cool, unadulterated water to Lake Comus. Groundwater discharge points may help sustain coolwater fish species and bolsters the Lake's water quality. Therefore, maintaining or enhancing groundwater recharge is a crucial part of any plan that hopes to maintain or improve water quality and instream habitat conditions within the watershed. Methods to accomplish this are discussed in a subsequent subsection.

[257] *A summary of methods suggested by the Wisconsin Water Action Volunteers program to measure streamflow can by found at the following website: StreamFlowMethods_2015.pdf (wateractionvolunteers.org). Many alternate suitable methods exist.*

[258] *Atypically dry weather may occur more frequently as climate change occurs.*

Groundwater is not visible to casual observation and changes often go unnoticed until critical thresholds are reached (e.g., a well goes dry, a stream or pond dries up). Changes to groundwater flow systems are often subtle and may occur over decades. To ascertain subtle change, the LCPRD should consider initiating a groundwater monitoring program in the Lake's groundwatershed. Groundwater elevations can be monitored in appropriately selected water supply wells and/or in purpose-built shallow monitoring wells. Ideally, measurements would be collected at least once a month into perpetuity. Relatively inexpensive automated measuring devices are also commercially available. Groundwater elevation data should be permanently recorded and a brief annual "water year" summary should be made discussing thoughts regarding measured water levels.[259] This initiative should be assigned a medium priority.

➤ Recommendation 1.5: Maintain or enhance conditions slowing stormwater runoff

Human activity modifies drainage basin hydrology and profoundly affects the amount and timing of water reaching waterbodies. In general, human activity decreases a landscape's ability to detain and absorb precipitation, hastens runoff speed, increases peak and total runoff volume, and discourages water infiltration into soils. These changes increase surface runoff intensity and the overall volume of stormwater runoff reaching lakes and rivers during wet weather and decrease flow to waterbodies during dry weather. Increased wet-weather runoff intensity and volumes increase soil erosion, destabilize natural stream channels, increase downstream flood elevations, and increase sediment and nutrient loads to waterbodies. A few common examples of human activities promoting these consequences include creating impermeable or less permeable surfaces (e.g., roofs, parking lots, roadways, compacted soil areas), ditching natural streams, conveying stormwater over or through smooth impermeable surfaces or pipes, filling low areas, artificially draining closed depressions and wet areas, and eliminating native vegetative cover in favor of crops, lawns, and other manicured landscaping features.

Actions increasing runoff volume generally decrease the amount of water absorbed by soils, decrease water available to plants over dry portions of the growing season, and decrease the volume of water contributed to groundwater systems. Consequently, human activity often disrupts natural soil moisture regimens as well as groundwater flow directions and discharge patterns. Groundwater is the sole source of potable water in Walworth County. If most pumped groundwater is returned to groundwater after use (e.g., soil absorption fields associated with septic systems), overall impact to groundwater flow systems may be minimal. However, when water is either consumptively used (e.g., evaporated) or exported from the local groundwater flow system (e.g., carried by sanitary sewers to discharge points outside of the groundwatershed), groundwater elevations may fall and discharge to, and flow in, surface-water features can be reduced or eliminated. Protecting groundwater resources is discussed in more detail as part of recommendation 1.6.

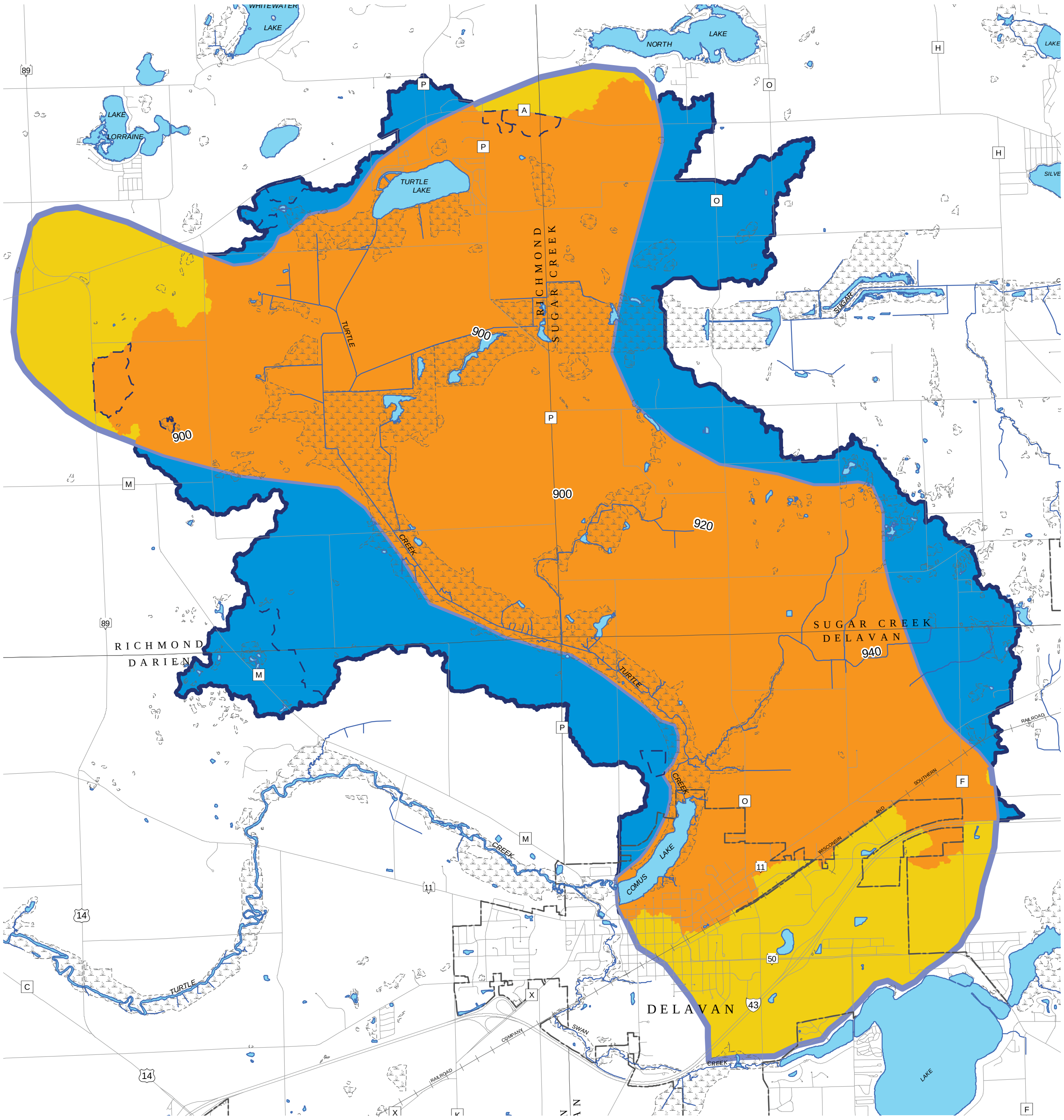
Strategies promoting the quantity, timing, and quality of water reaching surface water features are most efficiently applied to specific areas. The complex interplay of surface water and groundwater flow systems creates a situation where different geographic areas have differing potential to protect and enhance the Lake's water supply and water quality. These areas are described below and are illustrated in Map 3.2.

- Areas within the Lake's surface-watershed, but outside of the area replenishing the shallow groundwater flow systems feeding Lake Comus, upper Turtle Creek, and their tributaries, are best suited to strategies that detain stormwater runoff and enhance runoff water quality. Projects in this area do not influence groundwater supplies feeding the Lake and its tributaries. Well-conceived projects within this area focusing on detaining stormwater runoff should be assigned a medium priority.

- Areas outside of the surface watershed, but within the recharge area of the shallow groundwater flow systems feeding Lake Comus, upper Turtle Creek, and their tributaries are best suited to strategies that aim to increase stormwater infiltration and control net groundwater demand. Surface-water detention projects in this area do not influence runoff reaching the Lake or its tributaries. Well-conceived projects within this area focusing on infiltration and control of net groundwater demand should be assigned a medium priority.

[259] *An example of a recent biannual groundwater report for the Village of Richfield in Washington County can be found at the following URL: wi-richfield2.civicplus.com/DocumentCenter/View/2539/Village-of-Richfield-Board-Presentation-2021.*

Map 3.2
Areas Affecting the Lake Comus Watershed and Groundwatershed



AREAS AFFECTING WATERSHED AND GROUNDWATERSHED

AREAS AFFECTING THE GROUNDWATERSHED ONLY

AREAS AFFECTING THE WATERSHED ONLY

GROUNDWATERSHED BOUNDARY

WATERSHED BOUNDARY

SURFACE WATER

STREAM

WETLANDS

INTERNALLY DRAINED AREAS

N

0 0.25 0.5 1 Mile

Source: USGS and SEWRPC

- Projects executed in the area within both the Lake's watershed and groundwatershed can benefit both the Lake's surface-water and groundwater supply. Projects completed within this area can use a combination of detention, infiltration, and net groundwater demand control to benefit the Lake. Because of the manifold benefit of projects completed in this area of overlap, all well-conceived projects in this area affiliated with runoff detention, groundwater recharge, and controlling net groundwater demand should be assigned a high priority.

Detaining Runoff and Enhancing Infiltration

Much of the Lake Comus watershed is intensively cropped or used for other agricultural purposes. Cropped areas are most often managed to quickly shed precipitation and snowmelt, a situation reducing the landscape's ability to temporarily detain runoff and recharge groundwater. Turtle Creek upstream of the Lake was extensively ditched and straightened, reducing the ability of floodwater to spread over the landscape and be temporarily detained in ponded areas. Reduced recharge and high human water demand stresses the watershed's surface water and groundwater resources, and the situation will likely intensify as the area continues to develop.

Human-induced change to watershed hydrology is most often detrimental to waterbody health and sustainability. Therefore, management actions in the area contributing water to Lake Comus should attempt to reduce the impact of human-induced change on waterbody hydrology. To maintain waterbody health and provide sustainable potable water sources, action should be taken to counteract human activity that compromise sustainable, high quality, water supplies. In general, management actions should aim to slow and detain runoff, maintain or increase groundwater recharge, and control the volume of groundwater extracted from systems feeding Lake Comus, Turtle Creek, and their tributaries. Examples of such approaches are described in the following paragraphs.

Detaining Runoff

Agricultural pursuits and urban development involve manipulating the natural landscape in ways that usually increase runoff volume and speed and decrease groundwater infiltration. Actions can be taken to detain and more slowly release surface runoff to better approximate natural rainfall/runoff patterns. When water is detained, runoff intensity and downstream flood elevations are reduced, natural streams are less likely to excessively erode their beds and banks, and physical and biological processes reduce pollutant and sediment loads. Examples of methods to protect or increase stormwater detention follow.

- Protect remaining landscape features that detain storm water. Many natural landscape features detain runoff. Examples of such features include wetlands, floodplains, and closed depressions. Efforts should focus on protecting and enhancing natural stormwater detention areas. Such features should be protected throughout the watershed. This activity should be assigned a high priority.

- In areas where human activity has diminished natural floodplain capacity (e.g., through ditching and berming natural streams), projects should be pursued to naturalize floodplain hydrology. A particularly good opportunity to restore floodplain function exists along ditched portions of Turtle Creek upstream of the Lake abutting public lands devoted to wildlife management. Remeandering the Creek and restoring hydraulic conductivity with the adjacent riparian wetlands would allow floodwaters to spread, be detained, be cleansed by natural processes, and benefit the ecology of the area and watershed. Restoring stream floodplain connectivity and naturalizing stream form is an excellent way to restore floodplain function. This recommendation should be pursued throughout the watershed and should be assigned a high priority.

- Retire marginally productive cropland and/or restore features that detain runoff. Historically, cropland was expanded into areas where soil moisture regimens were not naturally conducive to agricultural production. To facilitate agriculture, these areas were ditched, graded, and subsurface drainage tiles were installed. In many instances, the practices were successful with the drained cropland now providing additional productive and profitable agricultural land. In other instances, the newly drained land was not successfully converted to good cropland and was either abandoned or provides marginal crop yields and economic returns. These less-than-successful drainage projects should be scrutinized for restoration of natural hydrology and habitat. This can include disrupting drain tile networks, completing ditch plugs and fills, and enhancing landscape features that naturally hold runoff (e.g., closed depressions, wetlands). Because of the large acreage of public land already withdrawn from agricultural production available for restoration projects, this recommendation should be assigned a medium priority.

- Replace rural detention capacity lost on account of human activity with engineered infrastructure. If the capacity of existing and restored natural features remains insufficient to achieve desired goals, stormwater can be detained in purpose-built artificial structures (e.g., agricultural sedimentation basins, stormwater detention basins, ditch checks, swales). Given the amount of publicly and privately held land restoration opportunities available in the watershed, this recommendation should be assigned a low priority.

- Expand urban stormwater detention infrastructure. Artificial stormwater detention features should be installed to service new developments or retrofitted to infrastructure in developed areas. With careful and holistic planning, it can sometimes be feasible to build detention features as part of new development that also serve existing development. The recommendation should be assigned a medium priority as part of greenfield development or planned infrastructure replacement projects in legacy development. Homeowner-scale projects that help detain stormwater (e.g., downspout disconnection from storm sewers, rain gardens, promoting soil health in turfgrass areas) should also be assigned a low priority. In most instances, large stand-alone projects in existing high-value development areas should be assigned a low priority.

Enhancing Infiltration

Traditional urban development increases impervious surface area and decreases overall landscape permeability. Without deliberate engineering to promote infiltration of stormwater and meltwater runoff, development reduces the volume of water infiltrating into soils and feeding shallow aquifers. Reduced infiltration reduces groundwater supplies which in turn decreases stream baseflow. Decreased baseflow reduces dry weather flow that can lead to substantial loss in stream depth, increased water temperatures, loss of critical fish and other aquatic organism habitat, increased potential for summer fish kills caused by low dissolved oxygen concentrations, and loss or degradation of desirable fish species.

As inferred in the preceding paragraph, infiltration is component to both reducing stormwater runoff volume and recharging groundwater flow systems. Therefore, protecting and enhancing stormwater infiltration is integral to protecting both surface water and groundwater resources. Examples of concepts seeking to use stormwater infiltration to reduce runoff volume and intensity are provided below.

- Protect natural infiltration capacity. A basic way to promote stormwater infiltration is to protect natural infiltration in areas with conducive land use, soils, and topography. In rural and less urbanized areas, the best candidate sites are within moderate, high, and very high groundwater recharge potential areas (Map 2.7). Infiltration is promoted when areas exhibit naturally diffuse runoff paths, abundant vegetation, irregular topography with closed depressions, and features that detain or slow runoff promote infiltration (e.g., floodplains, wetlands). Protecting such areas by encouraging appropriate land use, land management, and enlightened land development, as well as adoption of thoughtful ordinances, should be given a high priority.

- Enhance landscape infiltration potential in areas modified by human activity. Historically, infiltration potential was commonly reduced when humans altered the landscape. Examples of such alterations include constructing impermeable surfaces (e.g., roadways, roofs), installing piped runoff conveyance features, grading and filling low areas to encourage rapid and complete drainage, reducing soil infiltration capacity through soil structure degradation, and reducing vegetative density. In such instances, many landscape practices can help increase stormwater infiltration and help naturalize hydrology. Some examples include restoring wetlands, reconnecting floodplains, disabling or modifying drainage tile networks, improving soil health, and restoring abundant perennial vegetation. Projects planned for areas with moderate, high, or very high groundwater recharge potential should be assigned a high priority. Projects in other areas should be assigned a medium priority.

- In some areas, land use has been extensively modified in a way that inexorably reduces landscape infiltration capacity. An example would be constructing a shopping mall upon a former meadow. In such instances, engineered stormwater infrastructure (e.g., detention ponds employing infiltration, vegetated swales) should be used to increase landscape infiltration potential. Larger-scale projects manage urban stormwater from entire developments. Considering that most of the Lake's watershed is rural in nature, engineered infiltration capacity restoration projects planned for areas with moderate, high, or very high groundwater recharge potential should be assigned a medium priority. Projects in other areas should be assigned a low priority.

- Smaller-scale practices installed across the watershed by many landowners can increase overall landscape infiltration capacity. This can help decrease runoff volume and intensity and improve runoff water quality. Examples of homeowner-scale practices include managing turf and other areas to decrease soil compaction and increase soil permeability, directing stormwater runoff to areas of permeable soil and favorable topography instead of piping water directly to storm sewers, minimizing, and if possible, reducing the extent of impermeable surfaces, and redirecting downspouts and other runoff away from storm sewers and into raingardens. Such initiatives can be promoted by active educational outreach, providing instructions and supplies to property owners, and/or through financial subsidies. Supporting efforts to attract landowners to such programs should be given a low priority.

- Given their relatively great importance of outreach programs associated with this recommendation, the LCPRD could consider providing financial incentives to owners of parcels that drain directly to the Lake, its major tributaries, and storm sewers leading directly to the Lake and its tributaries. Some practices and projects, especially those completed on publicly owned property, may also qualify for cost sharing through the WDNR's Healthy Lakes initiative. Again, these actions are particularly effective when applied to areas with moderate, high, or very high groundwater recharge potential (Map 2.7).

- Promote practices that bolster soil health. Since agricultural land uses dominate the Lake's watershed, actions increasing stormwater infiltration in cultivated areas are very important to Lake Comus' overall health. Research has shown that healthy soil has much higher infiltration capacities compared to soils subjected to conventional tillage. Higher infiltrations typically correlate with lower soil erosion rates. As former USDA soil health practitioner states, "we don't have a soil erosion problem, we have an infiltration problem." Recent government programs and a rapidly growing corps of agricultural producers are refining and successfully employing cropping systems that shift producer focus from "yield per acre" to "profit per acre."

- The LCPRD should promote soil health initiatives throughout the rural area contributing surface and/or groundwater to the Lake Comus. Healthy soils are more porous, are less prone to erosion, and, therefore, help reduce runoff volume and intensity and improve baseflow and water quality.[260] Actively promoting and financially supporting soil health initiatives across the entire watershed should be assigned a high priority. Although agricultural lands throughout the Lake's watershed are amenable to this approach, parcels abutting Lake Comus tributaries should be targeted first.

- Complement soil health initiatives. Other infiltration preservation and enhancement practices complementing soil health initiatives should be promoted throughout the entire rural portion of the watershed. For example, the landscape should not be further altered to cause water to rapidly leave the land surface, especially in dry upland cropland mapped to have moderate, high, or very high groundwater recharge potential. Therefore, intensive farmstead development, drainage ditches, tiling and other soil drainage schemes, runoff enhancing grading and filling, piped storm sewers, and soil compaction should be avoided, or the impact of such modifications should be carefully mitigated by restoring or enhancing natural detention features with good connection

[260] *More information regarding soil health can be obtained from many sources including the following website: www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health/*

to groundwater flow systems.[261] This recommendation should be assigned a high priority in high and very high groundwater recharge potential areas, a medium priority in moderate groundwater recharge potential areas, and a low priority in areas with low groundwater recharge potential.

- Promote stormwater infiltration throughout the Lake's surface-watershed. Although stormwater infiltration occurring outside of the Lake Comus groundwatershed does not support baseflow to the Lake or its tributary streams, it still benefits the Lake. Stormwater infiltration within the surface-watershed decreases stormwater runoff intensity and volume, decreasing the tributaries' ability to erode their beds and banks and carry sediment and nutrients to the Lake. Furthermore, groundwater recharge beyond the Lake's groundwatershed supports baseflow in neighboring lakes and streams, some of which are ecologically significant and may contribute to the Lake's fish and wildlife populations. For example, water infiltrating from natural sources and detention features in the western portion of the City of Delavan does not contribute flow to the Lake but does nourish groundwater systems discharging to Swan Creek.

Protecting Groundwater Supplies

The Lake and many of its tributaries receive significant amounts of groundwater, a situation benefiting waterbody health. For example, groundwater discharge sustains dry-weather stream flow, moderates stream temperatures in winter and summer, and maintains water levels in the Lake during dry weather. To help protect the quantity and quality of groundwater discharging to the Lake and its tributaries, management action must focus on the Lake's groundwatershed, an area lying mostly to the east of the Lake and Turtle Creek (Map 3.2). Appropriate management action in this area helps maintain groundwater recharge, avoids unsustainable groundwater extraction and export, and maintains high groundwater quality. Even if groundwater resources are carefully managed within the Lake's groundwatershed, large-scale groundwater extraction beyond the groundwatershed can also influence the amount of groundwater entering and/or leaving the Lake. Therefore, activities already occurring or planned to occur near the Lake's groundwatershed should also be scrutinized. Actions helping protect the Lake's groundwater supply include the following examples.

➤ Recommendation 1.6: Curb growth of groundwater demand

Groundwater supplies all residential, commercial, and industrial potable water demands in the City of Delavan, the Lake Comus watershed, and greater Walworth County. Additionally, much of the human population of the Lake Comus groundwatershed is served by public sanitary sewers which export wastewater to other watersheds. Therefore, some of the water pumped from local aquifers is exported from the local groundwatershed and no longer can supply baseflow to Lake Comus or its tributaries. This is a vexing problem that often increases over time and has few easy solutions. However, action can be taken to reduce current and future net demand placed on local aquifers. Examples of such concepts are provided below.

- Evaluate if any clean-water discharges now directed to sanitary sewers, or discharge points outside the watershed, can be redirected to discharge points within the area contributing surface water and groundwater to Lake Comus. An example would be redirecting clean non-contact cooling water drawn from wells located in the Lake's groundwatershed to surface water within the Lake's watershed. Since few opportunities likely exist in the Lake Comus watershed, this recommendation is assigned a low priority.

- Carefully vet the impact of new development, especially those using new high-capacity wells, on groundwater withdrawals in the Lake Comus groundwatershed. The Village of Richfield in Washington County requires a professional analysis of development's impact on local groundwater elevations as a caveat to granting construction permits.[262] This should be assigned a high priority for projects within the Lake's groundwatershed.

[261] *Detention features can be built that encourage infiltration of stored water and contribute to groundwater recharge. Such systems are one of only a few artificial methods that meaningfully reduce overall runoff volume. They are best situated in areas of high and very high groundwater recharge potential.*

[262] *More information of the Village of Richfield's groundwater protection program may be found at the following URL: www.richfieldwi.gov/300/Groundwater-Protection.*

- Critically examine new commercial or industrial development proposals that use water consumptively or export water from the groundwatershed. Since most of the Lake's watershed is rural in nature and is anticipated to remain so in the next decades, this recommendation is assigned a low priority.

- Discourage new residential water supply systems in the groundwatershed that rely on private on-site water supply wells yet discharge wastewater to wastewater treatment plants outside of the Lake Comus watershed. This should be assigned a medium priority.

- Carefully evaluate activities within the Lake's groundwatershed that require long-term dewatering (e.g., quarry operations), especially if effluent water discharges to surface-water features draining to areas beyond the Lake's watershed. This should be assigned a high priority.

- Evaluate increased groundwater demands in nearby areas. Examples include new high-capacity wells or increased withdrawals from existing wells, clusters of small wells, or quarry dewatering. Such activities can influence groundwater flow directions and velocities and can change the amount of groundwater entering or leaving the Lake. This should be assigned a medium priority.

- Advocate actions that cause water providers to institute a potable water conservation campaign. This activity should focus on water now discharged to sanitary sewers in the City of Delavan. This should be assigned a low priority.

➤ Recommendation 1.7: Preserve or enhance water supplies to groundwater

Given the significant quantity of groundwater recharge lost through human landscape manipulation, maintaining, or more desirably increasing, stormwater infiltration is very important. This action not only protects surface-water features, encourages stable stream channels, reduces soil erosion, and promotes ecological health, it also helps safeguard groundwater supplying the needs of the area's human population and businesses. Several examples of tactics that help preserve or enhance groundwater recharge follow.

- As discussed earlier in this Section, the LCPRD should undertake actions promoting soil health. Healthy soils allow more stormwater to infiltrate and retain more nutrients and water benefitting crop growth. Healthy soils are characterized by greater aggregation, abundant soil macroinvertebrates like earthworms, higher root density, and higher concentrations of organic matter.[263] Promoting good soil health is most widely applicable to tilled agricultural lands within the watershed but the principles can also be applied to other lands such as parks and lawns. The LCPRD should encourage establishment of a producer-led watershed protection group covering the Lake Comus watershed. Grants are available to establish and maintain producer-led watershed protection groups.[264] The LCPRD should consider lending advice and, possibly, renting equipment and offering financial incentives to soil health practitioners. Although agricultural lands throughout the Lake's watershed are amenable to this approach, parcels abutting Lake Comus tributaries should be targeted first. Soil health promotion should be assigned a high priority.

- Preserve or enhance natural landscape features promoting groundwater recharge throughout the groundwatershed. Examples of such features include topographically closed depressions, natural areas, and well-vegetated open land. Such areas identified as having moderate, high, or very high groundwater recharge potential should be assigned high priority. The balance of such areas should be assigned a medium priority (Maps 2.7 and 3.2).

[263] *See Wisconsin Natural Resource Conservation Service, Testing for Soil Health, October 2017 for more information on testing soil health: www.efotg.sc.egov.usda.gov/references/public/WI/NRCS-Soil_Testing-508.pdf.*

[264] *For more information on producer-led watershed protection grants, please consult the Wisconsin Department of Agriculture, Trade, and Consumer Protection. An example of information available can be found at the following URL: datcp.wi.gov/Pages/Programs_Services/ProducerLedProjects.aspx.*

- Discourage widespread use of artificial drainage enhancement infrastructure (e.g., field tiles, piped storm sewers, drainage ditches, straightened streams) in areas within the groundwatershed with moderate, high, or very high groundwater recharge potential. Encourage naturalizing hydrology in such areas where such infrastructure already exists (e.g., wetland restoration, stream remeandering, drainage swales substituted for buried pipes). Given the importance of agriculture in the area contributing groundwater to Lake Comus, this should be assigned a high priority.

- Promote careful control of new development in the watershed's best groundwater recharge potential areas (Map 2.7). This helps assure water supplying local and sometimes regional aquifers is protected. Control can include excluding certain types of development, maintaining recharge potential through thoughtful design, and minimizing impervious surface area. This should be assigned a high priority in areas with moderate, high, and very high groundwater recharge potential and a medium priority in low and moderate groundwater recharge potential areas.

- Promote policies that protect or enhance infiltration on public and protected lands. High priority should be given to areas identified as having high and very high groundwater recharge potential within the groundwatershed feeding Lake Comus. Medium priority should be given to low groundwater recharge potential areas.

- Encourage local regulators to require developers to infiltrate high quality stormwater as an integral part of new development proposals. Water containing high concentrations of road deicers or other contaminants should not be infiltrated. Such stormwater management infrastructure is best located on area of moderate, high, and very high recharge potential, where this recommendation should be assigned a high priority. Areas of low groundwater recharge potential should be assigned a medium priority.

- Encourage actions that retrofit existing stormwater conveyance systems in urbanized portions of the Lake's groundwatershed to promote high-quality stormwater infiltration. Good locations for retrofitted infiltration infrastructure are pockets of moderate, high and very high groundwater recharge potential within the City of Delavan (Map 2.7). Activities consistent with this recommendation would be modifying existing municipal infrastructure or promoting actions that enhance infrastructure on existing properties. Examples of the latter would be disconnecting rooftop drains from piped stormwater conveyance systems and allowing stormwater to discharge to well-vegetated soil areas.[265] This should be assigned a high priority.

- Advocate for ordinances discouraging excessively broad expanses of impermeable surfaces in any area contributing water to the Lake and/or that consider lost infiltration potential created by development and offset this loss with high-quality runoff infiltration infrastructure located on the site or elsewhere within the Lake Comus groundwatershed. This activity should be assigned a medium priority.

- Purchase land or conservation easements on natural, agricultural, and open lands within Lake Comus' watershed identified as having very high or high groundwater recharge potential and that are desirable for protection for other purposes. Given the potentially high expense of this initiative, it is assigned a low priority.

- Continue to protect wetlands and uplands with an emphasis on preserving groundwater recharge to the Lake by enforcing town, village, and city zoning ordinances (high priority).

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[265] *Rain gardens are depressions that retain water, are vegetated with native plants, and help water infiltrate into the ground. Rain gardens can help reduce erosion and the volume of unfiltered pollution entering a waterbody and can also help augment baseflow to waterbodies. Visit the Healthy Lakes program website for more information on best practices: healthylakeswi.com/.*

- **Recommendation 1.8: Protect groundwater quality**
  Groundwater quantity is only one aspect of sustaining water feeding waterbodies and supplying human needs in the Lake Comus area. Human activity commonly introduces substances that reduce the suitability of groundwater for various purposes. Therefore, the LCPRD should endeavor to promote actions that protect groundwater quality. For example, the LCPRD should promote guidelines, ordinances, and actions that help minimize use of sodium chloride-reliant roadway deicers and water softening agents as well as encourage action to expeditiously remediate identified groundwater contamination issues within the Lake's groundwatershed. This recommendation should be assigned a high priority.

Any unanticipated, long-term, or large future changes in the tributaries' flow or the Lake's water elevation would spur the need for re-evaluating these recommendations. Consequently, as mentioned earlier, tributary flow and Lake water elevation data should be collected, periodically examined, and the suitability of water quantity recommendations should be re-evaluated.

Lake Outlet Dam Configuration and Operation

Lake Comus is an artificial impoundment with water levels raised and controlled by human activity. The Lake would not exist without the dam. The way a dam is designed and operated can profoundly influence the resulting lake's overall health, its ecology, recreational opportunities, and the amount of labor and cost needed to operate and maintain the dam and its impoundment. For these reasons, dam management and operation considerations must be integral to a lake management plan addressing an impoundment. Although dam removal options are technically feasible, dam removal was not considered as part of this lake management plan given the goals of the LCPRD.

The original dam impounding Lake Comus was built almost two centuries ago to produce power for local industry. The current dam, constructed in 1931,[266] was designed to maintain the function of earlier dams, that is, provide power for ongoing milling operations. When milling operations ceased during the 1930s, the dam's residual purpose was maintaining water levels in Lake Comus to benefit aesthetics and recreation, a role for which the existing dam was not purposely designed. Mill dams are designed to store and release water at reliable and predictable rates while maximizing head drop, maximizing usable power production. In essentially all cases, mill dams were not designed to achieve broad goals such as maintaining or improving water quality, sustaining desirable fisheries, supporting recreation, promoting desirable waterfowl and wildlife, and fostering waterbody health and aesthetics. As discussed in Section 2.1, "Lake and Watershed Physiography," the existing dam reportedly has deteriorated to a point that it now has serious maintenance needs.[267,268] For this reason, significant repairs, modifications, or complete replacement are currently being considered for as early as 2024.

Dam design and construction are thoroughly regulated by government and influenced by many technical design standards and protocol. However, some dam design attributes and choices are not mandated by regulations or technical guidance and are instead tailored to meet dam owner and local needs and expectations. The contemplated Lake Comus dam refurbishment project presents an ideal opportunity to integrate Lake management goals into the dam design and engineering process. With knowledge, forethought, and sensitivity to present-day community desires and needs, the new or revised dam and its appurtenant structures can be designed and operated to better achieve community aspirations, address stakeholder concerns, and further many lake management plan strategies and tactics.

The LCPRD and City of Delavan requested that Commission staff develop examples of dam-related concepts and options that foster lake management goals. This subsection provides dam concepts and recommendations that should be considered during design and as part of operation of a new or revised dam.

[266] *A maker's mark, stamped into concrete on the dam's upstream side, reads: "A.G. Bloland Mt. Horeb, Wis., 1931".*

[267] *Ayres Associates Inc Letter to Mark Wendorf,* Re: Dam Safety Inspection Report, Comus Lake Dam, WDNR Field File No. 64.02, Key Sequence No. 314, *June 2021.*

[268] *Ayres Associates Inc Letter to Mark Wendorf,* Re: Delavan Dam Feasibility Study, *August 2021.*

➤ Recommendation 1.9: Dam design opportunities

The dam impounding Lake Comus was recently inspected by the City of Delavan's consultant and was found to be in poor overall condition. For this reason, a feasibility study is underway that evaluates dam management alternatives. Given the dam's poor condition, complete replacement of the present dam with a new structure is a favored alternative. Dam replacement, or even an extensive retrofit, provides an opportunity for the LCPRD and City of Delavan to integrate dam design details that could help enhance the health and ecological potential of both the Lake and the Creek. Thoughtful design will maximize the value derived from dam revision/replacement and will increase the ultimate aesthetic appeal and the overall recreational value of the Lake and Creek.

Engineers must achieve certain technical and regulatory goals when designing a dam. A few examples are listed below:

- The dam structure must resist the pressure of impounded water so as not to overturn or otherwise fail during all flows, including water levels associated with rare large runoff events
- The dam outlet must have sufficient engineered spillway capacity to pass extreme runoff events without overtopping or endangering the dam
- The dam must not produce undo safety concerns to those operating the dam, to those near and downstream of the dam, and to those navigating the waterway
- In the case of Lake Comus, the current dam operation order stipulates that Lake water levels must remain between 886.74 and 888.23 feet NGVD 1929

Even though dam the dam design process is strictly regulated and has high technical standards, many design aspects are not explicitly specified and are instead left to the discretion of the dam owner and the owner's engineering team. To help illustrate the concept, these non-mandated elements could be thought as similar to "options" selected as part of an automotive purchase – features that are not mandatory for safe operation but instead help the owner achieve greater overall satisfaction with the final delivered product. Such features may increase the final cost but also increase the overall value perceived by the consumer. A few examples of dam design goals not necessarily mandated by regulations and technical design standards include the following.

- Ease of operation and reasonable operation and maintenance labor costs
- Structure aesthetics and longevity
- Ability to enhance aquatic life within the reservoir or downstream areas
- Elements that promote human enjoyment of the adjacent waterbodies and nearby upland areas

Given what is known about goals for the Lake itself, aspirations for the areas near and affiliated with the Lake, and Commission staff experience with other lake outlet dam projects, we recommend that the LCPRD and the City of Delavan consider dam design options that go beyond simple regulatory compliance and basic dam technical standards. These unmandated and optional design elements should be considered simultaneously with basic dam designs. Suggestions were relayed to the LCPRD and the City of Delavan earlier this year. Some of the broader suggestions are listed below. Consideration of all these recommendations, and other not-yet-identified ideas generated by other stakeholders, should be considered a high priority recommendation.

- Top-draw gates are often more capable of passing debris without fouling. Given the extensive marshy areas upstream of the dam, and the potential for mats of aquatic vegetation to float downstream, any gate design must strive to be self-cleaning to the degree practicable.

- Because of limited labor resources, many dam owners are better served by simpler top-draw gate designs. Such gates do not require frequent fine adjustment to contend with day-to-day stream flow variation. Instead, flow capacity significantly increases as reservoir water levels rise. For this reason, gates that draw from the reservoir surface are often better suited to small, shallow reservoirs as opposed to bottom-draw designs. From comments provided by the City, it does not appear that bottom-draw designs are being considered for the primary spillway, an approach with which the Commission agrees.

- Winter ice can make it difficult or impossible to modify operable gate position. This has proven problematic to some Southeastern Wisconsin communities who must operate dam gates during certain winter weather events. For example, a cold spell punctuated by rain on snow, a situation producing intense runoff and freezing temperatures. This produces need for additional spillway capacity, but the gates are frozen into the ice and are immobile, creating a serious problem. Care must be taken to produce designs that prevent ice from locking gates in a fixed position. This can be done in several ways including avoiding designs susceptible to ice locking or including ice disrupting bubblers, heat, or using active water flow or other means to avoid icing of sensitive and critical control components.

- Both the drop and labyrinth designs incorporate a sluice gate, assumedly for reservoir dewatering. In many designs, this gate is sized only to allow brief drawdown during low flow for dam inspection and simple maintenance. To allow for more reliable longer term reservoir water level control and/or dewatering, a situation potentially needed for various reservoir sediment and vegetation management practices, the sluice gate should strive to be sized to pass, at a minimum, the two-year flow event.

- Bottom-hinged crest gates have been used in some Wisconsin dams to retain the top draw configuration and reduce the problem with ice-locked vertical slide gates. An example is the hydraulically actuated Obermeyer gate on the Milwaukee River in Grafton, Wisconsin. For illustration, a schematic of a small pneumatic Obermeyer gate installed in Saint Cloud, Minnesota is included as Figure 3.1.

- The potential for seepage through the earthen embankment must be evaluated as part of dam rehabilitation. Brief inspection by Commission staff during late summer 2021 suggested that water may be seeping through the dam, particularly on its northern end. Seepage through earthen dams can contribute to embankment failure. Seepage can be arrested and/or captured through various remedies appropriate for use at the Lake Comus dam.

- Traditional dams are composed of a single vertical berm or structure that raises upstream water level to the desired level. Such single-structure systems are commonly barriers to fish migration, can be public safety hazards, and impede navigation. Alternatives to traditional dams exist. For example, a dam may be partially or wholly substituted by what amounts to an “engineered rapids.” In such an instance, the single vertical water drop at the dam is supplanted by a stretch of high-gradient channel, a situation that is both navigable and passable to fish if engineered correctly. Many examples exist. A general concept sketch is included in Figure 3.2.[269] Ideally, the slope of the engineered rapids should be less than 2 percent although it can vary. Given that the Lake Comus dam has a hydraulic height of seven feet, an engineered rapids measuring 350 feet long would produce a 2 percent gradient. The engineered rapids could extend upstream and/or downstream of the current dam. Furthermore, dam substitution need not be a “all or nothing” alternative. A bypass channel supplementing spillway capacity could be incorporated into a traditional dam design, and to retain control over reservoir water levels, a gated outlet would need to be incorporated into the design.

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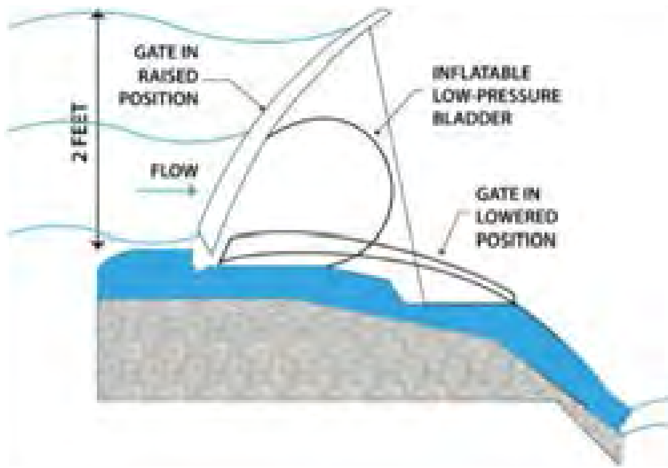
[269] *More information can be obtained from many state and federal agencies. Additional information regarding the illustrated concept can be found at the following website: files.dnr.state.mn.us/eco/streamhab/reconnecting_rivers_chap2.pdf.*

- The existing dam serves a supplemental purpose beyond impounding Lake Comus. The earthen berm is used as a road embankment traversed by North Terrace Street, connecting the City of Delavan with the City's Arboretum property and continuing north as Dam Road. A project proposing change to the dam presents an opportunity to improve roadway stability and capacity, pedestrian access, Lake access, portage routes, and a host of other factors that could influence the positioning, elevation, and configuration of the Dam embankments and outlet gates. For example, the bridge over the Lake's outlet could be widened to permit dedicated pedestrian and bicycle access to the Arboretum from the urbanized areas south of the Lake.

Figure 3.1
Obermeyer Gate Configuration



Source: City of St. Cloud, Minnesota

The LCPRD and the City of Delavan should strive to collaboratively identify opportunities to use the dam construction dewatering process to benefit the Lake's morphology, vegetation, recreational potential, aquatic life, and fishery. For example, the Lake may likely be drawn down to facilitate dam replacement work. This drawdown could be timed and extended over a time period so as to help reduce and/or consolidate flocculent lake-bottom sediment, help reduce invasive aquatic plant populations, and help promote control of common carp. The actual techniques used to accomplish these goals are described in subsequent sections – Lake drawdown is integral to many alternatives.

Under natural conditions, water elevations in most waterbodies fluctuate in response to weather patterns and seasons. Changing water levels are important to the ecology of many desirable aquatic plants – several problematic and undesirable invasive aquatic plants favor static water elevations. Drawdowns must also consider hibernating herptiles and the needs of animals that use aquatic habitat or wetlands during critical portions of their life cycle. When considering construction drawdown, the LCPRD and the City should examine these relationships, should promote protocols fostering desirable native plants and animals while hindering populations of undesirable invasive species, and should manage water levels to help encourage sediment consolidation/consumption/erosion in portions of the Lake and Creek most favored for navigation.

➤ **Recommendation 1.10: Dam operation opportunities**

If the Lake Comus dam is replaced, new opportunities may become available in the future to enhance Lake management practices and recreational opportunities. This could be facilitated by increased ability to manipulate Lake Comus' water levels and the flow of Turtle Creek downstream of the dam. For example, the ability to change and control water levels can be useful for sediment compaction, facilitating dredging, shifting the Lake's aquatic plant community to a more desirable state, reducing populations of undesirable fish species, and creating habitat for rare species. Assuming that the proposed new dam is fitted with gates that allow well-regulated and sustained reservoir drawdown, the LCPRD and the City of Delavan could consider incorporating fluctuating Lake water elevations and variable flow rates in the downstream portion of Turtle Creek into long-term Lake management plans. This should be considered a high priority recommendation.

Although the goals of fluctuating water levels would be similar to those described in the preceding paragraphs regarding construction drawdown, recurrent Lake water level fluctuation would likely require a revised dam operating order. The extant dam operating order was set using water elevations chosen almost a century ago to facilitate waterpower production and agriculture with limited consideration

Figure 3.2
Engineered Rapids Diagram

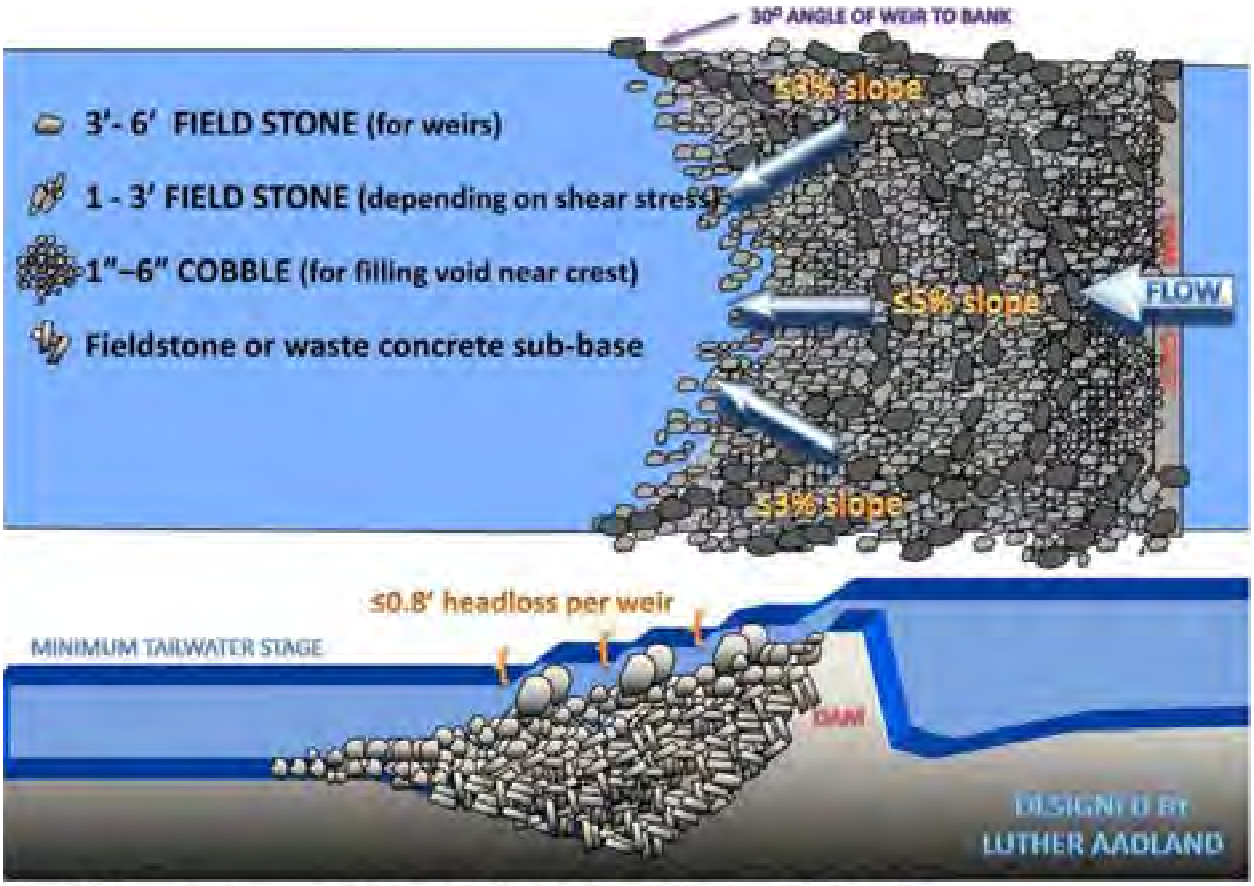


Figure 54. Generalized conceptual design of the Rock Arch Rapids developed by the author.

Note: Illustration drawn from the Minnesota Department of Natural Resource publication *Reconnecting Rivers: Natural Channel Design in Dam Removal and Fish Passage*

Source: Minnesota Department of Natural Resources

of Lake ecology and recreation. The water level operating range needed to make reservoir water level fluctuation an effective Lake management tool need to incorporate minimum elevations much lower than the minimum Lake level stipulated by the present-day dam operating order. Therefore, before such management actions are implemented, the dam owner would need to prepare and submit a petition to the WDNR to revise the water level operating order. The Commission has helped other communities with petition for revised lake level operating levels for various reasons and could provide advice and limited assistance. Although the present dam does not facilitate this initiative, it is important to set strategies and tactics related to water level manipulation now so that the dam design can support these future endeavors. This should be assigned a high priority to give the LCPRD and the City future operational flexibility to manage the Lake.

3.3 WATER QUALITY

Water quality is one of the key parameters used to determine the overall waterbody health. The importance of good water quality can hardly be overestimated. It affects or controls not only various recreational uses of a lake, but also nearly every facet of the natural balances and relationships between myriad abiotic and biotic processes. Because of the importance water quality plays in the functioning of a lake ecosystem, careful water quality monitoring represents a fundamental management tool. The fact that Lake residents are concerned with various water-quality-related issues (e.g., sources of pollution in the watershed, lack of aquatic plant growth, algal growth) suggests that water quality management is warranted on Lake Comus.

Lake Comus Water Quality Monitoring

Water quality monitoring is an important tool that helps quantify the Lake's current condition, understand long-term change, and provides insight into why changes occur. Prior to the onset of this management planning process, Lake Comus lacked consistent water quality monitoring necessary to assess Lake conditions and trends. Through the efforts of the LCPRD, WDNR, and others, a regular monitoring program has been established to measure Lake temperature, dissolved oxygen, and trophic state conditions. Recommendations to continue and enhancing these monitoring efforts are described below:

➤ **Recommendation 2.1: Continue and enhance comprehensive water quality monitoring within Lake Comus**

Water quality monitoring is an important tool that helps quantify the Lake's current condition, helps lake managers decipher longer term change, and allows the factors responsible for change to be identified. Monitoring is integral to management efforts aiming to maintain and improve Lake health. Therefore, monitoring water quality should be a <u>high priority</u>.

Through the efforts of the LCPRD in preparing this management plan, regular water quality monitoring has been initiated in the "deep hole" site in the middle of the Lake. To allow historical data to be contrasted to current conditions, and, thereby, allow trends to be identified, field measurements and water quality samples should continue to be collected at this "deep hole" site at least once during mid-summer and ideally at least monthly during the growing season. At a minimum, water quality should be analyzed for the following parameters:

- Field measurements
  - Water clarity (i.e., Secchi depth)
  - Temperature (profiled over the entire water depth range at the deepest portion of the Lake)
  - Dissolved oxygen (profiled over the entire water depth range at the deepest portion of the Lake)
  - Specific conductance (near-surface sample)
  - pH (near-surface sample)
- Laboratory samples
  - Total phosphorus (near-surface sample)
  - Total nitrogen (near-surface sample)
  - Chlorophyll-a (near-surface sample)
  - Total suspended solids (near-surface sample)
  - Chloride (near-surface sample)

Laboratory tests quantify the amount of a substance within a sample under a specific condition at a particular moment in time and provide valuable benchmarks and trend-defining values. Phosphorus, nitrogen, and chlorophyll-*a* analyses are the basic suite of parameters used to determine and track overall lake health and trophic state. These parameters are tested in many Southeastern Wisconsin lakes and are useful to contrast the Lake's health to other waterbodies of interest.

Field measurements are often reasonable surrogates for common laboratory tests. For example, water clarity decreases when total suspended solids and/or chlorophyll-*a* concentrations are high, samples with high concentrations of total suspended solids commonly contain more phosphorus, and water with higher specific conductance commonly contains more salt and, therefore, more chloride. Periodically sampling water and running a targeted array of laboratory and field tests not only provides data for individual points in time but can also allow laboratory results to be correlated with field test results. Once a relationship is established between laboratory and field values, field data can sometimes be used as an inexpensive means to estimate the concentrations of key water quality indicators normally quantified using laboratory data.

Supplemental temperature/oxygen profiles collected at other times of the year (e.g., other summer dates, nighttime summer, fall, winter) can be helpful. For example, temperature/oxygen profiles collected during midsummer nights, just before sunrise, help evaluate diurnal oxygen saturation swings.

Regular water quality monitoring helps Lake managers identify variations in the Lake's water quality, improves the ability to understand problems and propose solutions, and the capacity to track progress toward Lake water quality goals. The LCPRD should review the water quality monitoring regimen and recommendations regularly and implement revisions to address changing conditions or new threats.

Turtle Creek Monitoring

Since tributaries can play a significant role in determining a lake's water quality, it is recommended that water quality measurements continue to be taken on Turtle Creek upstream and downstream of the Lake. Recommendations for monitoring Turtle Creek are as follows:

➤ **Recommendation 2.2: Continue to conduct level 1 Water Action Volunteer (WAV) monitoring in Turtle Creek and the CTH O tributary**

UWEX maintains WAV, a stream monitoring program that is the analogue of Citizen Lake Monitoring Network for lakes. Volunteers in the Lake Comus watershed should continue to actively monitor Turtle Creek and the CTH O tributary through the WAV program. Monitoring water temperature, dissolved oxygen, as well as total phosphorus, transparency, conductivity, and pH should be included. Water chemistry monitoring in the tributaries should occur concurrently with stream flow estimation when possible. This recommendation is a high priority.

➤ **Recommendation 2.3: Consider expanding to Level 2 WAV monitoring to install programmable water temperature logging devices in Turtle Creek and the CTH O tributary**

The continuous monitoring provided by temperature logging devices provides substantially more information about stream conditions and suitability for fish species. However, participating in this program requires greater time commitment, including training, equipment calibration, and data entry. This recommendation is a medium priority.

➤ **Recommendation 2.4: Consider implementing continuous turbidity monitoring on Turtle Creek**

The LCPRD should consider installing a continuous reading turbidity monitoring device to estimate the amount of suspended sediment contributed to the Lake by Turtle Creek. Turbidity values may be able to be correlated with total suspended solids and phosphorus loads if appropriate calibration sampling is completed. Monitoring turbidity along the Creek's course should be considered by the LCPRD and assigned a low priority due to the higher training, equipment, and maintenance requirements.

➤ **Recommendation 2.5: Supplemental water quality monitoring**

Grab samples should be collected for to represent a cross section of flow events (i.e., low, medium, and high). The sampler should record the current and recent weather conditions, a qualitative description of flow and water quality (e.g., "creek is very high and muddy"), and the exact location, date, and time where the sample was collected. Sampling parameters should include the following:

- Stream flow
- Water clarity (transparency tubes)
- Total phosphorus
- Total nitrogen
- Temperature
- Dissolved oxygen

Flow rate information allows the actual mass load of phosphorus contributed from the tributaries and the areas they drain to be quantified and compared. Stream flow rates can be estimated using a variety of methods (see Recommendation 1.3). The total amount of water delivered from each tributary can also be estimated using empirical formulae (e.g., the Rational Method) and models (e.g., TR 55, SWMM, Presto-Lite). These flow estimates can be combined with water quality information collected in the tributary streams to estimate mass loadings from each stream. This information can then be used to target priority tributaries, seasons, and events for water quality analyses. This recommendation can prove very valuable to helping develop management solutions and tracking progress but requires significant volunteer commitment. Therefore, this recommendation is assigned a medium priority.

Parameters and sampling frequency may be adjusted as necessary to focus resources on the sub-basins identified to have the greatest impact to the Lake's water quality. Depending upon the sub-basin and sample results, action should be taken to help reduce pollutant loadings. For example, if phosphorus was detected in high concentrations in a tributary draining residential areas, efforts to communicate best practices to homeowners should be reinforced, stormwater management infrastructure inspected, actions to protect and expand wetlands and buffers increased, and other factors considered. Intensified and/or expanded monitoring may help pinpoint source areas for particular attention.

Phosphorus Management

As discussed in Section 2.3, "Water Quality and Pollutant Loading", Lake Comus' high total phosphorus concentrations drive high algal abundance and subsequently low water clarity. Consequently, managing phosphorus concentrations in the Lake as well as reducing phosphorus loading to the Lake are important for enhancing the Lake's water quality, aquatic life, and recreational use.

➤ **Recommendation 2.6: Reduce nonpoint source external phosphorus loads**

Lake Comus has a very large watershed in relation to the Lake's surface area, and, therefore, can receive significant sediment and pollutant loads from Turtle Creek and tributaries discharging directly to the Lake. The largest external mass load of phosphorus enters the Lake via Turtle Creek. Pollutant loading models indicate that nonpoint source loading from agricultural land uses is the predominant source of total phosphorus and sediment to surface waters. Nonpoint phosphorus loads should be reduced in accordance with the goals of the Rock River Total Maximum Daily Load (TMDL), and reduction strategies should be assigned high priority. This issue is discussed in more detail and with strategies to reduce loads in Section 3.4, "Pollutant and Sediment Sources and Loads."

➤ **Recommendation 2.7: Manage factors that stimulate in-Lake phosphorus recycling**

Available evidence suggests that phosphorus recycling and resuspension contributes substantial amounts of phosphorus to the Lake's water column. Several processes affect resuspension of phosphorus from lake sediment back into the water column including wind, common carp, boating, and the lack of aquatic vegetation on the lake-bottom sediment. Wind, boating, and common carp disturb bottom sediments while the lack of aquatic plants to act as sediment "groundcover" makes the sediment more susceptible to disturbance. Reducing in-lake phosphorus recycling through long-term watershed phosphorus load reduction measures and considering using in-lake measures should be considered a high priority.

While the most effective tool to reduce phosphorus recycling within the Lake over the long-term is reducing incoming phosphorus loads, several short-term management options may provide some temporary relief. However, these options are generally more expensive and will be rendered ineffective over time if ongoing phosphorus loading is not addressed.

- **Alum treatments** – Alum treatment involves dispersing a chemical (alum: hydrated potassium aluminum sulfate) throughout a lake. This chemical forms a flocculent solid that sinks, carrying solids to the lake bottom, allowing water to clear and rooted aquatic plants to grow at greater depth. Additional rooted aquatic plants uptake greater amounts of phosphorus and can help clear lake water in the longer term. Alum-bound phosphorus precipitated to the lake bottom does not become soluble under anoxic water conditions and can help form a cap to reduce internal phosphorus loading. These effects can help temporarily lower lake water phosphorus concentrations. Lake Comus' shallow depth and short residence time make effectiveness of alum application to maintain lower phosphorus levels very doubtful. Therefore, alum treatment is not a feasible option for long-term phosphorus reduction on Lake Comus.

- **Dredging** – Internal loading and resuspension of phosphorus depends on the availability phosphorus-rich lake bottom sediment. Dredging physically removes phosphorus-rich sediment from the waterbody and thus can reduce internal loading and recycling of phosphorus, particularly when the bottom sediment is continuously disturbed by common carp. Additionally, dredging could increase the lake volume and thus greater amounts of phosphorus would be required to attain the same concentrations as prior to dredging. However, dredging is very expensive, with estimated costs ranging from $5 to $25 per cubic yard. Dredging can also negatively affect lake ecology by removing aquatic vegetation and disrupting the habitat of aquatic organisms. If dredging is pursued as a lake management option, costs may be reduced through usage of the dredging spoil containment area already built and owned by the LCPRD. Additionally, the neighboring Town of Delavan occasionally sediment retention ponds along Jackson Creek north of Mound Road. The LCPRD could coordinate dredging at Lake Comus with the Town's Jackson Creek dredging in an attempt to lower project costs for both the LCPRD and the Town (see Section 3.8, "Plan Implementation").

- **Water Level Manipulation** – Drawing down water levels can affect phosphorus levels within a lake via several pathways. Most directly, drawdowns can cause the exposed lake bottom sediment to consolidate and enhance decomposition of organic matter, reducing the fertility of the sediment once the water level is raised again. Reduced water levels can also enhance carp winterkill and control methods. Carp stir up lake sediment and consume aquatic vegetation. Manipulating water levels to mimic natural fluctuations can also encourage the growth of native submerged aquatic plant species, such as naiads and muskgrass, and enhance the expansion of emergent plant species like cattails and bulrush (see Section 3.5, "Aquatic Plants"). Lake managers need to carefully plan and monitor the frequency, intensity, and timing of water level drawdowns to reap the greatest benefits while also minimizing unintended harm (see Recommendation 1.7). For Lake Comus in particular, any drawdown strategy should consider potential impacts protected reptile species (see Section 3.6, "Fish and Wildlife" for more information).

Cyanobacteria and Floating Algae

Algae are a naturally occurring and healthy component of all aquatic ecosystem. Algae are primary building blocks of aquatic food chains and produce oxygen in the same way as rooted plants. Many forms of algae exist, from filamentous algae to cyanobacteria to muskgrass. Most algae strains benefit waterbodies when present in moderate abundance. However, excessive algal growth or the presence of toxic algal strains should be considered an issue of concern. As with aquatic plants, algae generally grow in greater abundance in the presence of abundant dissolved phosphorus (particularly in stagnant areas). Consequently, when toxic algal strains or highly abundant algae begin to grow in a waterbody, it often indicates a problem with phosphorus enrichment or pollution. As discussed in Chapter 2, algal blooms appear to be a reoccurring problem on Lake Comus due to excessive nutrient pollution from its watershed. The following recommendations are provided to help reduce algal blooms as well as minimize illness to Lake users and their pets from algal toxin exposure.

Preventative Recommendations

To maintain desirable algal populations, this section recommends monitoring algal growth, helping Lake residents recognize and respond to excessive and/or toxic algae, and taking management actions that help prevent undesirable algal growth in the future.

➤ **Recommendation 2.8: Reduce Lake water phosphorus concentrations**

Algal growth in the Lake is limited by available phosphorus. Several techniques, discussed in Section 3.3, "Water Quality," can be used to help maintain or lower phosphorus concentrations in the Lake. Related issues are discussed in Section 3.4, "Pollutant and Sediment Sources and Loads", Section 3.5, "Aquatic Plants", and Section 3.6, "Fish and Wildlife". Lower phosphorus concentrations generally decrease potential for algal blooms. Implementing these recommendations is critical to maintaining healthy algal populations and thus is assigned a high priority.

- **Recommendation 2.9: Monitor algal abundance and sample for algae toxins during suspected algal bloom conditions**
  This effort should focus on monitoring chlorophyll-a, as was described in water quality monitoring recommendations. If large amounts of suspended or floating algae are observed (e.g., "pea soup" green water), algal samples should be collected to allow algal types, particularly toxic strains, to be identified and better inform healthy use of the Lake. Given that there have been several observations of algal blooms, including potential cyanobacterial blooms, on the Lake within the past few years, this recommendation should be assigned a high priority.

- **Recommendation 2.10: Warn residents not to enter the water in the event of an algal bloom**
  Methods to rapidly communicate unhealthful water conditions not conducive to body contact should be developed. The LCPRD could consider installing advisory signage at the boat launch to inform Lake users of the possibility of algal blooms.[270] Significant suspected blue-green algal blooms can be reported to the WDNR at DNRHABS@wisconsin.gov. This recommendation should be assigned a high priority.

- **Recommendation 2.11: Encourage a healthy aquatic plant community to compete with algal growth**
  Aquatic plants utilize phosphorus in the water column, limiting its availability for algae and subsequently limiting algal abundance. Thus, a healthy aquatic plant community is an essential component of improving water quality and reducing undesirable algae in the Lake. This can be promoted by implementing recommendations provided in Section 3.5, "Aquatic Plants." This recommendation should be assigned a high priority.

- **Recommendation 2.12: Reduce carp population within the Lake**
  Carp feeding habitats resuspend sediment and can change aquatic plant growth patterns, increasing phosphorus availability to lake algae. In-lake carp management options are more discussed in Sections 2.6, "Fisheries" and 3.6, "Fish and Wildlife." This recommendation should be assigned a high priority.

Implementing the above recommendations will help prevent excessive algal growth in Lake Comus and should not preclude or significantly inhibit Lake use. If future monitoring reveals excessive or greatly increased algal growth, or should toxic algae be identified, these recommendations should be reevaluated (high priority). Reevaluation should include rethinking all relevant Lake management efforts.

Potential Corrective Measures

In-lake measures and manual removal methods can also be implemented to correct algal populations in the Lake. Use of these methods should be considered; particularly as cyanobacterial algal blooms are a chronic problem and may threaten the health of Lake recreational users and their pets.

- **In-lake treatments** – Suspended and floating algae use dissolved or suspended nutrients to fuel growth. If water-column nutrient levels are reduced, the abundance of algae can be controlled. Water quality enhancement recommendations presented as feasible in Section 3.3, "Water Quality," should be the primary measures implemented to help control algal abundance. Supplemental activities not recommended for general water quality management, but which may provide short-term relief for severe algae problems are described below.

  - **Alum treatments** – As mentioned above in "Phosphorus Management," alum forms a flocculent solid that can carry algae to the lake bottom, providing increased light availability for aquatic plants that compete with algae for nutrients. Short term reductions in phosphorus concentrations from alum treatments also reduce the risk of algal blooms. However, the short residence time and shallow depth of Lake Comus limits the long-term effectiveness of alum treatments for algae control. Furthermore, permitting and logistical lead times to execute an alum treatment are lengthy. Therefore, alum treatment is not considered a feasible option for algae control on Lake Comus.

[270] *The WDNR blue-green algae webpage has example signage: www.dnr.wisconsin.gov/topic/lakes/bluegreenalgae.*

- **Hypolimnetic withdrawal** – Phosphorus released from the Lake's nutrient-rich bottom sediment is likely facilitating dense algal growth. Hypolimnetic withdrawal would switch the dam outlet withdrawal from the surface to a pipe drawing water from deep within the Lake. However, this technique is only significantly effective in lakes that thermally stratify in summer. Since Lake Comus remains fully mixed in summer, this option is not a feasible option and is therefore not recommended.

- **Aeration** – This process involves pumping air to the bottom of a lake to disrupt stratification and limit the extent of anoxic conditions forming in the deep portion of the Lake. This in turn reduces internal loading (i.e., the release of phosphorus from deep sediments) and may reduce the severity of algal blooms during mixing periods. This method has produced mixed results in various lakes throughout Wisconsin and appears to be most successful in smaller water bodies such as ponds. If not properly designed or operated, aeration can increase nutrient levels and intensify and/or prolong algal blooms. This technique is effective in lakes that thermally stratify in summer. Since Lake Comus remains fully mixed in summer, this option is not likely to be effective and is not recommended.

- **Manual removal** – Manual removal of algae using suction devices has recently been tested within the Region. This measure, though legal, is currently in the early stages of development and application. Additionally, algal "skimming" has been tried by lake managers with little success. Consequently, such measures should be further investigated and tested before investing significant time or funds into implementation.

All the above measures are commonly only implemented when algal blooms become so profuse that recreational use is impaired. This is often because each method is only temporarily effective, and repeated implementation of these measures can be cost prohibitive. The more permanent methods of algal control discussed above (i.e., pollution control, carp population management, and plant community maintenance) are considered most viable for Lake Comus.

3.4 POLLUTANT AND SEDIMENT SOURCES AND LOADS

Lake Comus' low water clarity, high nutrient concentrations, and significant amounts of nonpoint pollutant loading stem predominantly from rural land uses across its watershed. Turtle Creek is the main contributor of phosphorus and sediment to the Lake. As rural nonpoint runoff is the greatest source of pollutant loads, and potential load reductions, within the watershed, most of the targeted management measures are focused on cropland best management practices (BMPs). Specifically, targeted cropland BMPs recommended in this watershed include use of cover crops and no till practices, increased implementation of nutrient management plans, and expansion of potentially restorable wetlands and riparian buffers. The most effective approach for implementing BMPs across the watershed will likely require outreach about the need for, and benefits of, such practices, cost-sharing or financial incentives to reduce risk to agricultural producers, as well as meeting and exceeding existing agricultural performance standards. The examples recommendations presented below are intended to enhance ongoing efforts to reduce phosphorus and sediment loading at different scales: specific projects along the Lake's shoreline and its tributaries as well as programmatic approaches to reduce nonpoint source loading across the watershed. The overall strategy to reduce pollutant loading with the Lake Comus watershed follow.

- Utilize pollutant load reduction goals set by the Rock River Total Maximum Daily Load (TMDL)

- Prioritize implementing BMPs in areas with highest potential for pollutant loads to affect surface waters, as delineated in this plan

- Strive to implement the amount BMPs required to meet the TMDL goals, as provided in this plan

- Preserve and expand riparian wetlands adjacent to Turtle Creek to maintain and improve current phosphorus and sediment retention

- Remeander Turtle Creek and enhance its floodplain connectivity to mitigate and slow pollutant load transport downstream to Lake Comus

- Implement BMPs and restore the hydrology of Turtle Creek through a combination of outreach, cost-sharing and other financial incentives, and enforcement of existing agricultural performance standards

Table 3.3 provides a summary of the management recommendations most focused on nonpoint source pollutant load reduction, This summary includes performance indicators and quantities to implement these recommendations, their estimated costs and total phosphorus reductions, as well as the funding programs and entities responsible for their implementation.

Pollutant Load Reduction Goals from the Rock River Total Maximum Daily Load (TMDL)

Excessive sediment and nutrient loading to the Rock River has led to increased algal blooms, oxygen depletion, water clarity issues, and degraded habitat. Algal blooms can be toxic to humans and costly to the local economy. Annual economic losses associated with eutrophication in the United States have been estimated to be 2.2 billion dollars per year. The largest losses are related to losses in recreational expenditures (0.37 to 1.16 billion dollars per year) and loss of lakefront property value (0.3 to 2.8 billion dollars per year).[271] Other sources correlate a 15.6% decrease in property value with each 1.0-meter loss of secchi-depth based water clarity.[272] Additional economic costs relate directly to eutrophication beyond the examples listed previously. For example, over 44 million dollars are spent each year on plans alone to recover imperiled species, a situation related to habitat change and eutrophication. The need for potable water treatment is correlated with eutrophication. Billions are spent each year on potable water treatment, a common consequence of the need to remove sediment, tastes, and odors commonly related to eutrophication. Finally, nuisance aquatic plant growth often correlates to eutrophic conditions, a cost that some estimate to be over one billion dollars per year.[273]

Due to known waterbody impairments in the Rock River Basin, a TMDL study for phosphorus and sediment was developed for the Rock River basin and its tributaries. The TMDL study was approved in 2011 establishing phosphorus and sediment load reduction goals for the upper Turtle Creek watershed as a reach of the larger Rock River basin (see Map 3.3).[274] This watershed comprises all lands contributing to Turtle Creek upstream of State Hwy C, an area including the Delavan Lake and the Jackson Creek watersheds as well as Lake Comus and its watershed. Achieving the targeted instream concentrations in Turtle Creek will require annual total phosphorus reductions from baseline loads of 75 percent for wastewater treatment facilities (WWTFs) and 49 percent for non-point sources. It will also require baseline sediment loads reductions of 1 percent from WWTFs and 25 percent from non-point sources. Of these nonpoint source loads, non-permitted urban sources contributed 19 percent of the total phosphorus and 15 percent of the sediment.

This lake management plan envisions that restoration techniques be applied as a management action within the context of the Rock River TMDL pollutant load reduction goals as implemented through traditional regulatory actions (such as point source permits) and through voluntary programs (such as implementation of nonpoint source BMPs). Implementation of stream restoration techniques along with regulatory and voluntary actions would contribute to addressing the numeric or narrative water quality criteria and designated water use objectives for Lake Comus and Turtle Creek. In the context of the TMDL, stream restoration can also address nonattainment of a designated use or a narrative criterion that refers explicitly to habitat quality or biological diversity. The recommended management strategy would be to combine point and nonpoint source load reductions and instream ecological restoration techniques. It is important to note that stream restoration is an important and vital pollution reduction strategy to meet TMDL goals for phosphorus and sediment, but stream restoration should not be implemented for the sole purpose of nutrient or sediment reduction in this watershed.

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[271] *Dodds, Walter K, Wes W. Bouska, Jeffrey L. Eitzmann, Tyler J. Pilger, Kristen L. Pitts, Alyssa J. Riley, Joshua T. Schloesser, and Darren J. Thornbrugh, "Eutrophication of U.S. Freshwaters: Analysis of Potential Economic Damages,"* Environmental Science and Technology, *43(1): 12-19, 2009.*

[272] *C. Krysel.; E. M. Boyer, C. Parson, and P. Welle,* Lakeshore Property Values and Water Quality: Evidence from Property Sales in the Mississippi Headwaters Region*; Submitted to the Legislative Commission on Minnesota Resources: St. Paul, MN, 2003; p 59.*

[273] *Dodds, 2009,* op. cit.

[274] *USEPA and WDNR,* Total Maximum Daily Loads for Total Phosphorus and Total Suspended Solids in the Rock River Basin Columbia, Dane, Dodge, Fond du Lac, Green, Green Lake, Jefferson, Rock, Walworth, Washington, and Waukesha Counties, Wisconsin*, prepared by the CADMUS Group, July 2011.*

Table 3.3
Targeted Management Measures, Estimated Cost, and Estimated Phosphorus Reduction for the Lake Comus Watershed: 2021

Recommendations	Indicators	Quantity	Estimated Cost ($)[a]	Phosphorus Reduction[b]	Funding Programs[c]	Implementation
Agricultural BMPs						
Increase use of no-till and conservation tillage in watershed	Number of acres cropland with conservation practice applied	2,510 acres	49,267	3,665 pounds	EQIP, TRM, SWG	NRCS, Walworth County, WDNR, Local Partners
Increase use of cover crops	Number of acres cropland with conservation practice applied	2,510 acres	150,977	803 pounds	EQIP, TRM, SWG	NRCS, Walworth County, WDNR, Local Partners
Increase implementation of lands under nutrient management plans	Number of acres cropland with conservation practice applied	6,080 acres	243,200	7,236 pounds	EQIP, TRM, SWG	NRCS, Walworth County, WDNR, Local Partners
Install grassed waterways	Number of linear feet of grassed waterways installed	40,910 feet	204,550	2,624 pounds	EQIP, TRM, SWG	NRCS, Walworth County, WDNR, Local Partners
Riparian Buffers and Wetland Restoration						
Install minimum 75-foot wide riparian buffer strips	Number of acres of riparian buffer installed	179 acres	78,760	469 pounds	CREP/CRP, EQIP, TRM	NRCS, Walworth County, WDNR, Local Partners
Convert farmed Potentially Restorable Wetland into wetland	Number of acres of restored wetland	1,287 acres	5,148,000	2,214 pounds	CREP/CRP, EQIP, TRM	NRCS, Walworth County, WDNR, Local Partners
Turtle Creek Remeander						
Implement remeander projects, such as toe wood-sod mats	Number of linear feet with remeander projects installed	28,776 feet	2,877,600	N/A	TRM, SWG	NRCS, WDNR, Walworth County, Local Partners
Shoreline Protection						
Reinforce shoreline with vegetative buffer and low-lying structures	Number of linear feet with shoreline protections installed	2,200 feet	49,764	N/A	SWG	LCPRD, WDNR, Local Partners

Note: A combination of the listed practices will be applied to agricultural fields to get the desired reductions required by the Rock River TMDL. Not all practices listed will be applied to each field. The combinations of practices applied will vary by field. In most cases just applying one practice to a field will not get desired reductions and a combination of two to three practices will be necessary to get desired reductions.

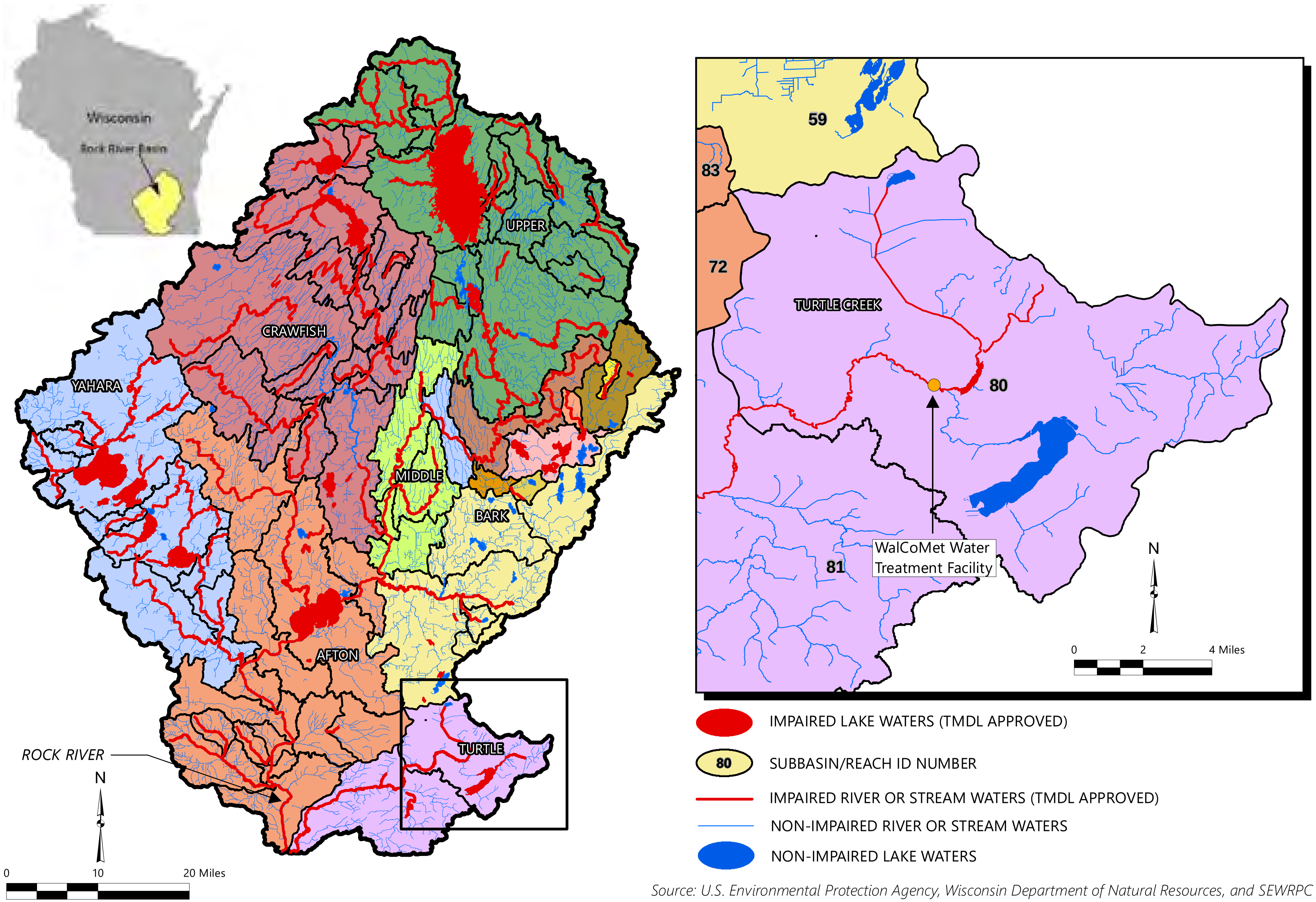
[a] Estimated per unit costs are as follows: 19.64 per acre for no-till, 60.15 per acre for cover crops, 40.00 per acre for nutrient management plans, 5.00 per linear foot for grassed waterways, 440 per acre for riparian buffer, 4,000 per acre for land conversion, 100 per linear foot for stream remeandering, and 22.62 per linear foot for shoreline protection.

[b] Estimated phosphorus reductions per acre were sourced from the STEPL pollutant loading model for each conservation practice individually applied to one acre of cultivated cropland.

[c] See "Funding Sources" in Section 3.8, "Plan Implementation" for a more detailed description of the Environmental Quality Incentives Program (EQIP), Total Runoff Management (TRM), Conservation Reserve Enhancement Program (CREP), Conservation Reserve Program (CRP), and the Surface Water Grants (SWG) programs.

Source: NRCS and SEWRPC

Map 3.3
Subbasins and Impaired Reaches of Wisconsin's Rock River Watershed: 2021



Source: U.S. Environmental Protection Agency, Wisconsin Department of Natural Resources, and SEWRPC

Choosing a management strategy is critical to meeting the water quality goals established by the TMDL. As an example, the City of Oconomowoc, also within the Rock River TMDL, has identified adaptive management as the preferred compliance alternative to meet its Wisconsin Pollutant Discharge Elimination System (WPDES) permit requirements.[275] This adaptive management plan spans three WPDES permit terms (15 years) with the understanding that progress can be demonstrated by the beginning of the third term. In order to achieve water quality goals, the City has developed the Oconomowoc Watershed Protection Program (OWPP) to build capacity and develop collaborative projects within the watershed. As of 2021, the OWPP has improved 157 acres through stormwater projects, 567 acres through long-term agricultural projects, 2029 acres through annual cover crop installation, and removed 356 pounds of phosphorus per year through wastewater treatment.[276] The OWPP has also increased water quality monitoring throughout the watershed to track compliance with the Rock River TMDL pollutant reduction goals. In addition to these efforts, the OWPP hosts informational meetings and events, such as the Nutrient Management Training workshops, and it produces and distributes the "Streamings" newsletter to provide updates on the program.[277] Through its support of the agricultural producer-led Farmers for Lake Country organization, the OWPP assists with agricultural producer education and conservation cost-share programs aimed to maximize crop profitability, improve soil health, and protect lake and stream water quality. Programs coordinated through Farmers for Lake Country include farmer education events, such as the Soil Health training day, the Water Friendly Farm Program, and an aerial cover crop seeding program.[278] Collaborating with local municipalities and WWTFs to create a similar program for the Turtle Creek watershed would greatly enhance the capacity for conservation education and implementation and help meet long-term water quality goals for Turtle Creek, Lake Comus, and other lakes in the watershed. Actions taken by the LCPRD and the City of Delavan to promote similar collaboration in the Lake Comus watershed should be assigned a high priority.

Prioritizing Parcels to Reduce Non-Point Source Pollutant Loads

Reducing nonpoint sources of phosphorus and sediment from agricultural land uses in the Lake Comus watershed is a major priority for the LCPRD, the City of Delavan, and other organizations committed to improving water quality in Lake Comus and Turtle Creek. Understanding where BMPs should be applied within a watershed is critical to ensure that land, financial, and time resources are effectively spent on projects with the greatest potential pollutant load reduction. To that end, Commission staff prioritized parcels for effectiveness of implemented conservation practices within the watershed using 2015 land use, soil, and floodplain information. Generally, the effectiveness of agricultural BMPs to improve water quality decreases with distance from a waterbody. Therefore, parcels adjacent to the Lake and its tributaries would receive high priority. Based upon this principle, a general parcel level agricultural priority map for BMP implementation was developed. Implementation priority for each parcel was assigned to one of the following three categories:

- **High priority** – Parcels with over 50 percent of land devoted to agriculture that abut or are intersected by waterways including Lake Comus, the mainstem of Turtle Creek, drainage ditches and tributaries, and/or floodways designated by the Federal Emergency Management Agency (FEMA)

- **Moderate priority** – Parcels with less than 50 percent of land devoted to agriculture that intersect waterways as well as parcels with any agricultural lands intersected by FEMA-designated floodplains

- **Low priority** – Agricultural lands that are not directly connected to a waterway and are outside of FEMA-designated floodplain

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[275] *As defined by the WDNR, "Adaptive management (AM) is a compliance option that allows owners of point and nonpoint sources of phosphorus to work together to improve water quality and to meet water quality standards. Adaptive management recognizes that excess phosphorus in lakes and rivers is the result of a variety of activities and sources; both point and nonpoint source reductions are often needed to achieve water quality standards". More information regarding AM can be found at the WDNR's website: www.dnr.wisconsin.gov/topic/Wastewater/AdaptiveManagement.html.*

[276] *For more information on OWPP projects, see oconomowocwatershed.com.*

[277] *Oconomowoc Watershed Protection Program,* Streamings*, 1(1), 2020.*

[278] *For more information on Farmers for Lake Country, see www.farmersforlakecountry.org.*

This scheme prioritizes sites where pollutant loads are most easily delivered to waterbodies and where pollutant loads can be most cost-effectively reduced. Based upon this analysis, approximately 5,622 acres of high priority, 2,000 acres of moderate priority, and 12,389 acres of low priority agricultural lands are found within the watershed (Map 3.4). Judiciously applying BMPs in higher priority parcels will help tangibly reduce pollutant loading to Lake Comus.

Recommended Non-Point Source Reduction Practices for the Lake Comus Watershed

Implementing BMPs that reduce non-point source pollutant loading throughout the watershed, educational programming, and broadening/deepening public support have the greatest potential for improving the health of Turtle Creek and Lake Comus. Reducing pollutant loads will take coordination at regional, County, municipality, and local scales. Strong partnerships that adopt programmatic approaches, such County land and water conservation plans, meaningfully contribute to long-lasting pollutant reduction. However, it is also essential to promote education and outreach programs regarding pollutant loading, particularly non-point source loading. The recommendations in this subsection are intended to improve soil health, enhance water quality, and support biological diversity.

Agricultural BMPs

Pollutant load modeling presented in this plan, the Turtle Creek Priority Watershed Plan, and the Rock River TMDL have identified rural nonpoint sources as the major contributors to total phosphorus and sediment pollution in Lake Comus and Turtle Creek.[279,280] Consequently, utilizing agricultural BMPs and regenerative agriculture techniques are the most effective measures to reduce nonpoint source pollutants and improve the water quality of the Lake and Creek. Walworth County Land Use & Resource Management staff supplied the estimated number of acres within the watershed where agricultural BMPs have already been applied.[281] Agricultural parcels where conservation practices and nutrient management plans have already been applied in the Lake Comus watershed are shown in Map 3.5.

The Commission's STEPL modeling effort indicates the number and amount of these practices required within the watershed to meet the pollutant load reduction goals set by the Rock River TMDL. A combination of enforcement to meet existing agricultural performance standards as well as outreach and financial incentives to implement additional BMPs that exceed these standards will be required to meet these goals.

Existing runoff management standards have been established by the State of Wisconsin and are administered by the WDNR and the Department of Agriculture, Trade, and Consumer Protection (DATCP). Chapter NR 151, "Runoff Management," of the *Wisconsin Administrative Code* provides runoff management standards and prohibitions for agriculture, including the soil phosphorus index, manure storage and management, nutrient management, soil erosion, tillage setback, as well as implementation and enforcement procedures for the regulations. Chapter ATCP 50, "Soil and Water Resource Management Program," of the *Wisconsin Administrative Code* prescribes farm conservation practices that can be used to implement these standards.[282] *Wisconsin Statutes* 91.80 states that landowners claiming farmland preservation tax credits must comply with soil and water conservation standards while *Wisconsin Statutes* 91.82 provides the Counties with the responsibility and protocols for monitoring compliance with these standards.[283]

Since all cultivated land within the Lake Comus watershed is within a Farmland Preservation Zoning District, agricultural landowners may be eligible to receive a $7.50 per acre tax credit if they participate in the Farmland Preservation program and are certifiably complying with NR 151.[284,285] As per the aforementioned

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[279] *Rock County Department of Land Conservation,* Turtle Creek Priority Watershed Plan, *April 1984*.

[280] *USEPA and WDNR, 2011*, op. cit.

[281] *Personal communication between Brian Smetana, Senior Conservation Technician, Walworth County Land Use & Resource Management and Commission staff.*

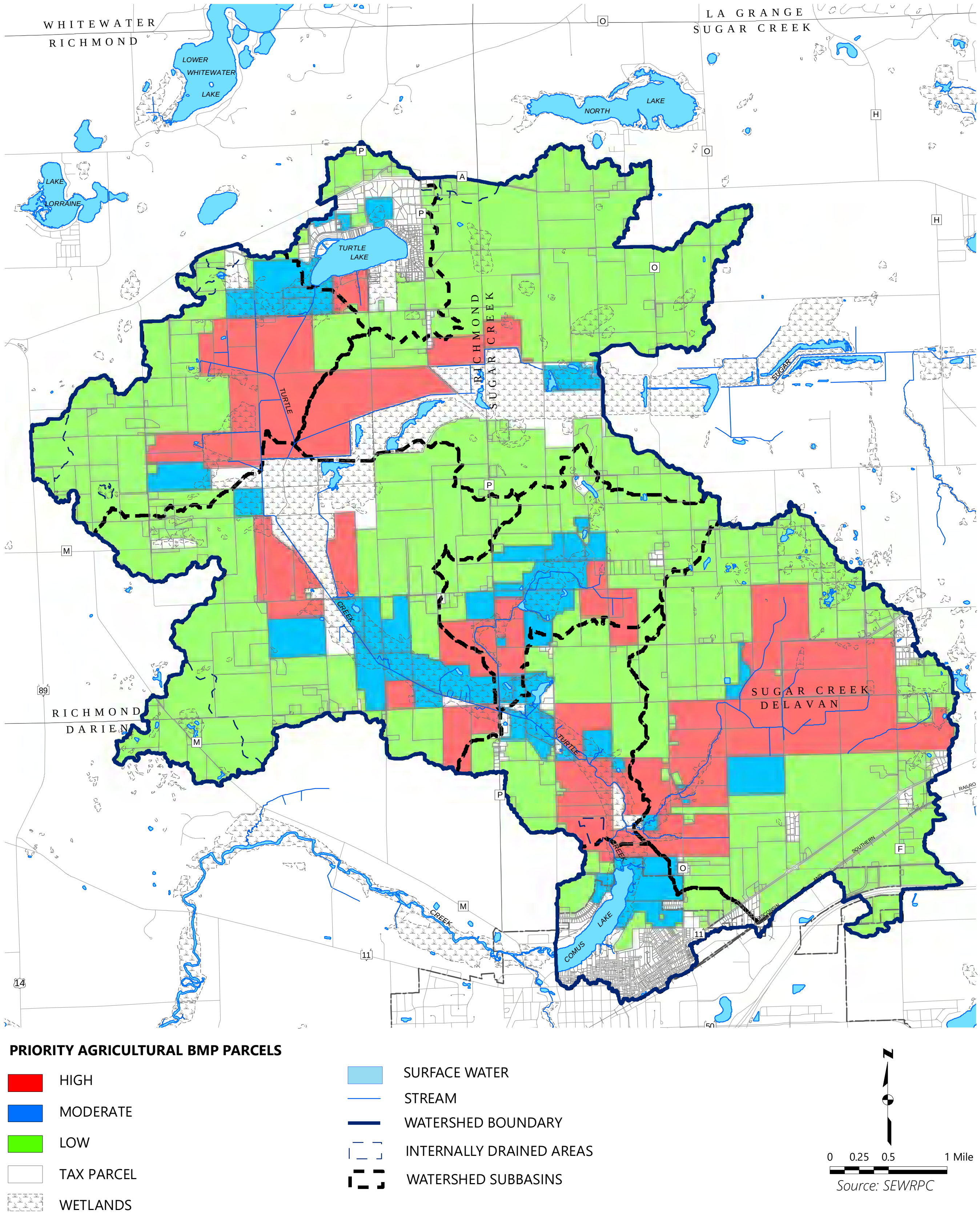
[282] *For a summary of the interaction between NR 151 and ATCP 50, see Wisconsin DATCP,* ATCP 50 Farm Conservation Standards, *ARM Pub 242, March 2014*. datcp.wi.gov/Pages/Programs_Services/NutrientManagement.aspx

[283] *For more information, see docs.legis.wisconsin.gov/statutes/statutes/91/v/80.*

[284] *To view a map of lands within Farmland Preservation Zoning Districts, see datcpgis.wi.gov/maps/?viewer=fpp.*

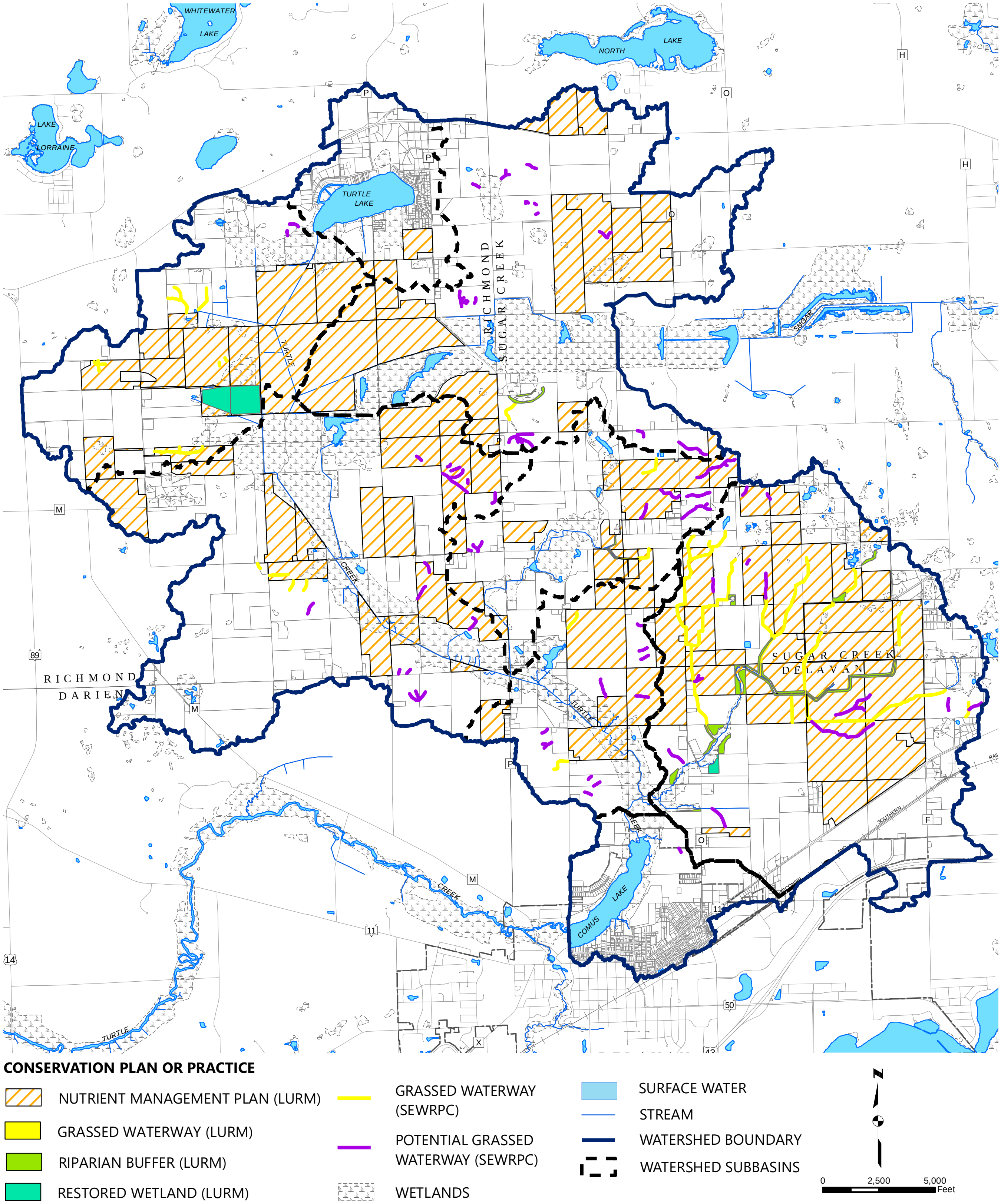
[285] *For more information on Farmland Preservation Zoning, see datcp.wi.gov/Pages/Programs_Services/FPZoning.aspx.*

Map 3.4
Prioritization Among Parcels for Implementation of Agricultural BMPs Within the Comus Lake Watershed



Source: SEWRPC

Map 3.5
Conservation Plans and Practices within the Lake Comus Watershed: 2021



Source: Walworth County LURM and SEWRPC

Note: *Information regarding conservation practices in the left column were provided by Walworth County Land Use & Resource Management (LURM). The existing and potential grassed waterway lines were estimated by Commission staff using aerial imagery and topographical contours.*

statutes and Walworth County ordinances, agricultural landowners participating in the Farmland Preservation program not in compliance will be issued a notification of non-compliance detailing the violation, a deadline to cure the violation, the process to contest the violation, and that the landowner may not claim the aforementioned tax credit until the violation is corrected.[286] Experience in the State has indicated that a combination of regulation and informed local decision making by landowners/operators is needed to achieve water quality improvements consistent with the attainment of water quality standards and criteria.[287]

Although this plan recognizes the importance of continued funding and staff to ensure adherence to State, County, and local standards, it goes beyond reliance on regulation and enforcement. This plan's strategy is to rely on empowered local decision makers creating unique solutions that work for the Lake Comus watershed to ultimately exceed compliance standards. This strategy is designed to augment the work of Walworth County staff who work with landowners and operators to implement innovative and effective conservation practices continued through collaboration amongst the County, State, and Federal agencies.

Aside from the agricultural land that they own, the LCPRD, City of Delavan, Town of Delavan, and other municipalities have little capacity to directly implement agricultural BMPs. However, these entities can play a role in encouraging, educating, and incentivizing the adoption of these practices within the watershed. The Surface Water Restoration and Management Plan Implementation subprograms of the WDNR Surface Water Grant program are two avenues by which the LCPRD and others can help fund watershed BMPs that reduce nonpoint source loading (Table 3.3). As several of these practices may require specialized equipment and training as well as a major shift in how these farms have previously been operated, the local agricultural industry, including retailers, crop advisors, cooperatives and other local markets, should be prepared to assist farmers in changing practices. Due to the importance of reducing rural nonpoint source phosphorus and sediment pollution to the water quality and general ecosystem health of Lake Comus and Turtle Creek, the following recommendations should be considered a <u>high priority</u>.

- **Recommendation 3.1: Incentivize use of no-till and conservation tillage practices**

  Removing crop residue and disrupting soil through tillage often enables soil erosion. When soil is tilled, soil structure resisting erosion is weakened and more soil is exposed to erosive forces, leading to nutrient and sediment laden surface runoff. No-till farming is the practice where soil is undisturbed except for where the seed is placed in the soil. No-till planters disturb less than 15 percent of the row width. The combination of minimal ground disturbance and minimal removal of crop residue contribute to a more stable soil surface that is less susceptible to erosion and the accompanying runoff of nonpoint source pollutants.

  No-till benefits are recognized in several areas. By not turning soil over to prepare a seed bed, soil structure, including pores and channels formed throughout the soil surface layers, remains intact. Furthermore, soil does not become compacted, allowing precipitation to better infiltrate. These changes result in less surface runoff and enable agricultural producers to enter fields in wetter conditions. The residue left behind after crop harvest is left to breakdown naturally, increasing the amount of organic matter in the soil. Decaying residue cycles nutrients back into the soil, decreasing reliance on artificial fertilizer. Soil with higher organic matter and better structure generally has more capacity to absorb and hold water, releasing it to crops during the growing season. Some soils are better suited to no till than others. Soil warming and drying may be slower in the spring especially on poorly drained soils causing plants to germinate more slowly. Since the soil is not turned over, undesirable weeds may be harder to control and herbicide use could increase or alternative weed control practices used (e.g., cover crops coupled with mechanical termination). The benefits of no-till are not fully realized until the practice has been in place for several consecutive years.

  To be effective, no-till must be done as part of a system of crop rotation, nutrient management, and integrated pest management. Managing weeds and the residue resulting from no-till requires the farmer to be committed to changing additional seemingly interdependent farming practices as well

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[286] *Walworth County Code of Ordinances Chapter 26 Article IV, "Conservation". library.municode.com/wi/walworth_county/codes/code_of_ordinances?nodeId=WACOCOOR_CH26EN_ARTIVCO_DIV2SOWACOSTFAPRPR*

[287] *The Minnesota Pollution Control, Wisconsin Department of Natural Resources, and The St. Croix Basin Water Resources Planning Team*, Implementation Plan for the Lake St. Croix Nutrient Total Maximum Daily Load*, prepared by LimnoTech, February 2013.*

as renting or purchasing new equipment or modifying existing equipment. These changes are not only a financial risk to farmers but also require that agricultural retailers, crop advisors, and local markets provide necessary training, equipment, and products to assist farmers transition to no-till.

As discussed in Chapter 2, Commission staff modeled pollutant load reduction scenarios using the Spreadsheet Tool for Estimating Pollutant Loads (STEPL) developed by the US Environmental Protection Agency. In order to achieve the nonpoint source total phosphorus reduction goal of 49 percent for the Turtle Creek Headwaters watershed established by the Rock River TMDL, the percent of acres on which no-till agriculture is currently practiced should be increased from an estimated 10 percent to at least 30 percent within the next ten years. This increase in no-till coverage, in combination with other agricultural BMPs described below, would be necessary to meet the goals set by the TMDL.

➤ Recommendation 3.2: Promote increased cover crop acreage

Establishing cover crops includes planting grasses, legumes, forbs or other herbaceous plants for seasonal cover and conservation purposes. Common cover crops used in Wisconsin include winter hardy plants such as barley, rye and wheat as well as less common crops like oats, spring wheat, hairy vetch, red clover, turnips, canola, radishes, and triticale.[288,289] Cover crops help reduce phosphorus and sediment loads to waterbodies by reducing erosion and improving infiltration, Cover crops grow during months when cultivated fields would otherwise be bare. This allows such fields to capture solar energy during fallow periods, a situation helping nourish soil biota, hold nutrients that otherwise be carried away in water, and hold soil protecting it from erosion. When used properly for erosion control, cover crops produce a near continuous vegetative ground cover protecting soil against raindrop impact as well as sheet and rill erosion. Continuous plant cover increases infiltration, reduces runoff speed, promotes diffuse flow and runoff across the soil surface, causes soils particles to aggregate promoting desirable soil structure, and binds soil particles to plant roots. Decreased soil loss and runoff translates to reduced transport from farmland of nutrients, pesticides, herbicides, and harmful pathogens associated with manure that degrade the quality of surface waters and could pose a threat to human health. Over time, a cover crop regimen increases soil organic matter leading to further improvements in soil structure, stability, increased moisture and nutrient holding capacity for plant growth, and greater soil carbon storage.

Recent findings of the USDA Sustainable Agriculture Research and Education program recommend that a variety of strategies be employed to encourage agricultural producers to plant cover crops. Education, sharing new research results, appropriate technical assistance, low-cost seed, and in some cases, financial incentives will be necessary to encourage more farmers to adopt cover crops.[290] To achieve targeted total phosphorus load reduction of 49 percent, the number of acres planted to cover crops in watershed area should increase from 5 to 25 percent in combination with other agricultural BMPs as per the Commission's STEPL modeling. The LCPRD should promote activities that encourage producers to experiment with and hopefully employ cover crops in the longer term. This could include sponsoring producer-led educational events that focus on cover crop application. Furthermore, the LCPRD could consider cooperating with Walworth County, the City of Delavan, and/or WalCoMet to make specialized equipment needed for cover crop application available to producers at low cost. Other counties have acquired such equipment and rent it producers at nominal cost.[291]

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[288] *USDA NRCS Wisconsin,* Cover Crops Factsheet, *2014*.

[289] *See UW-Extension website for more information at www.fyi.uwex.edu/covercrop*

[290] *Download USDA report at website www.sare.org/Learning-Center/From-the-Field/North-Central-SAREFrom-the-Field/2015-Cover-Crop-Survey-Analysis*

[291] *As an example, Ozaukee County and the Milwaukee River Clean Farm Families producer-led group offer a variety of incentives to encourage farmers to experiment with cover crops. Some of these programs are summarized at the following website: www.cleanfarmfamilies.com/cover-crop-program.*

➤ Recommendation 3.3: Ensure all agricultural lands employ nutrient management plans

The goal of a nutrient management plan is to avert excess nutrient applications to cropland and to thereby reduce nutrient runoff to lakes, streams, and groundwater.[292] Nutrient management plans consider the amounts, types, and timing of nutrient applications needed to obtain desired yields and minimize risk of surface water and groundwater contamination. In Wisconsin, nutrient management plans are based on the NRCS 590 standard.[293] Plans must be prepared by a qualified planner, which may be the farmer or a certified crop advisor. Soil testing is done on each field to help producers identify where nutrients are needed and where they are not and considers tillage, manure application, and residue management practices. Plans help farmers allocate nutrients economically (i.e., right source, rate, time, and place) while also helping to ensure they are not over-applying nutrients which could cause water quality impacts.[294] Ensuring that all agricultural fields in the watershed operate under a nutrient management plan would be a substantial step forward in achieving the 49 percent total phosphorus load reduction goal.

➤ Recommendation 3.4: Install additional grassed waterways

Grassed waterway carry runoff water off fields in a way that limits soil loss. Grassed waterways are constructed in natural drainage ways by grading a wide, shallow channel and planting the area to sod-forming grasses. When needed to help or keep vegetation established on sites having prolonged flows, high water tables or seepage problems, subsurface drains, underground outlets or other hard engineered components may be installed. Effective grassed waterways convey runoff water from fields and the sod helps capture entrained sediment and prevents runoff from eroding a channel and forming a gulley. The vegetation may also absorb some chemicals and nutrients in the runoff water and provide cover for small birds and animals. Grassed waterways fill with sediment over time and need to be rejuvenated by removing sediments, regrading, and replanting. Based on Commission staff estimates, the Lake Comus watershed already contains over 60,500 linear feet of grassed waterways, most of which are along ditches contributing water to the CTH O tributary (see Map 3.5). Installing additional grassed waterways, particularly within steeply sloped cultivated fields where gully erosion is already evident, can further reduce phosphorus and sediment loading to surface waters. Potential areas where grass waterways may be particularly useful due to steep slopes as well as signs of erosion and/or moisture identified via aerial imagery are illustrated on Map 3.5. Nearly 40,900 linear feet of potential new grassed waterways could be warranted in the Lake Comus watershed.

Drain Tiles

Extensive subsurface drain tile networks have been installed over large areas of agricultural land to help lower seasonally high-water tables, allowing these areas to be more amenable to profitable agricultural use. In some situations, drain tiles include surface inlets to drain closed depressions that fill with runoff (e.g., Hickenbottom inlets). Drain tiles often discharge directly into streams or into ditches that discharge into streams. Because they provide a direct drainage pathway from fields to surface waterbodies, drain tiles can allow water and pollutants to bypass agricultural BMPs and natural features that modulate flow and remove contaminants from runoff. Research conducted at the University of Wisconsin Discovery Farms illustrates this bypass effect.[295] Drain tiles can export a substantial portion of the total phosphorus lost from agricultural systems in a variety of phosphorus forms, although dissolved P tends to be more common than particulate forms.[296] In fields with intact drain tile, between 15 to 34 percent of the total phosphorus, 78 to 87 percent of the nitrogen, and about 25 percent of the sediment leaving the field moved through the drain tile system. In fields with damaged drain

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[292] *For more information on nutrient management and planning, see datcp.wi.gov/Pages/Programs_Services/NutrientManagement.aspx.*

[293] *Wisconsin Natural Resources Conservation Service,* Conservation Practice Standard: Nutrient Management Code 590, *CPS 590-1, 2015. datcp.wi.gov/Documents/NM590Standard2015.pdf*

[294] *As an example of tool to help farmers apply at the "right time", DATCP produced the Runoff Risk Advisory Forecast which uses soil moisture, temperature, landscape characteristic, and precipitation data to determine the risk of runoff in the present and near future. This tool can prevent inadvertent nutrient loss by warning producers of unsuitable nutrient application conditions. For more information, see www.manureadvisorysystem.wi.gov/runoffrisk/index.*

[295] *Eric Cooley,* Nutrients Discharging from Drain Tiles in Eastern Wisconsin*, Presentation at the Eighth Annual Clean Rivers, Clean Lake Conference, Milwaukee, Wisconsin, April 30, 2012.*

[296] *For a thorough literature review on phosphorus dynamics with drain tiles, see J. Moore,* Literature Review: Tile Drainage and Phosphorus Losses from Agricultural Land, *Lake Champlain Basin Program*, 2016.

tile (i.e., tile blow outs), about 65 percent of the total phosphorus and most of the sediment leaving the fields traveled through drain tile. These results show that drain tiles can constitute a major pathway through which sediment and nutrients travel from agricultural fields to surface waters.

Within the Lake Comus watershed, the LCPRD, local volunteers, and Walworth County staff have noted locations where drain tiles discharge to Turtle Creek and its tributaries, particularly in the Turtle Valley Headwaters subbasin (Figure 3.3). As discussed in Section 2.3, "Water Quality and Pollutant Loading", some drain tiles in the watershed are contributing waters with high concentrations of total phosphorus to surface waters although the total phosphorus loading by these drain tiles could not be calculated due to lack of simultaneous flow measurements. Consequently, action should be taken to reduce phosphorus export from these drain tiles to help protect surface water quality. The following recommendations are intended to mitigate the impacts of drain tile on the surface water hydrology and quality:

➤ **Recommendation 3.5: Repair, reduce, or retrofit drain tile systems**

At a very minimum, damaged drain tile systems should be repaired to eliminate unintentional connections with surface water (e.g., blow outs, suck holes). As stated previously, these features dramatically increase the amount of soil and nutrients carried by drain tile networks to surface water. Natural surface hydrology should be restored by reducing, to the extent feasible, ineffective or unnecessary drain tile systems and/or retrofitting systems when needed. This recommendation should be considered a high priority. Specific measures that can be taken to accomplish this recommendation include:

- Encourage producers to identify and expeditiously repair drain tile network breaches. The most obvious locations are where water carried by drain tiles erupts to the surface or where surface runoff disappears into the Earth at unplanned locations.
- Discourage the use of surface inlets. Consider the profitability of closed depression areas drained by surface inlets and evaluate alternative water management or land use options.
- Investigate drainage patterns and available drain tile system maps to determine whether certain operational systems are no longer necessary. Remove or disconnect unneeded tile systems. If drain tile network maps are not available, drain tiles may often be identified using aerial imagery or unmanned aerial vehicles looking for lines of frost heave or reduced soil moisture in spring. Additionally, visual inspection along streams and ditches, especially in early spring when vegetation is low and runoff is generally greater, can reveal the drain tile outlets.
- Measure drain tile effluent total phosphorus concentrations and flow using a regular monitoring schedule (e.g., monthly or biweekly) to determine average total phosphorus loading and estimate proportion of total field phosphorus export. Whenever possible, measure tile discharge rates.
- Integrate in-line water level control devices into drain tile systems. Lower water levels would be used to encourage drainage during spring and other stretches of excessively wet weather. Conversely, higher water levels can benefit crop yields during dry weather through subirrigation. These control structures can reduce phosphorus and nitrogen loads by reducing tile flow volume as well as by promoting denitrification.[297] An example of an inline water level control device installed in a field tile network is illustrated in Figure 3.4.

➤ **Recommendation 3.6: Implement saturated buffers and/or bioreactors to treat tile drainage**

Saturated buffers, unlike ordinary riparian buffers, capture and treat water from tile drainage. A saturated buffer has a control structure that redirects flow from a main tile line through a lateral distribution line into the buffer. Once within the buffer soils, the water redirected from the tile percolates deeper into the soil or gets taken up by vegetation. In its study at Bear Creek in Iowa, the Leopold Center for Sustainable Agriculture at Iowa State University found that the use of a saturated buffer reduced annual nitrate loads by about 55 percent. However, the evidence for phosphorus removal through saturated buffers is not well established.[298]

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[297] Ibid.

[298] Ibid.

Bioreactors are another method for capturing and treating tile drainage water. Unlike saturated buffers, which redirect nutrients deeper into soil or into vegetation, bioreactors remove nitrates by promoting a process called denitrification, by which nitrate is predominantly converted to inert nitrogen gas. Bioreactors provide a carbon source, such as wood chips, for the bacteria to fuel this conversion. As with saturated buffers, there is less consensus that bioreactors are effective for reducing phosphorus loads.[299] Implementing saturated buffers and bioreactors to reduce nitrogen from tile drainage water should be considered a medium priority.

➤ **Recommendation 3.7: Manage fertilizer application to minimize losses via drain tile**

Applying fertilizer and manure at the appropriate rates and timing has been shown to minimize phosphorus export from farm fields to drain tiles.[300] Over-application of fertilizer and manure results in excess nitrogen and phosphorus quantities in the soil that are not utilized by crops and subsequently can be exported via drain tiles. UW-Extension fertilizer application guidance suggests appropriate phosphorus and nitrogen application rates for crops and conducting soil tests for nitrogen and phosphorus to avoid over-application.[301] Avoiding application when soils are saturated can help to reduce transport of fertilizer and manure through the soil profile into the drain tile. Furthermore, since the excess nutrients are not needed by crops, excessive application diminishes producer profitability. The LCPRD, Walworth County, DATCP, and NRCS should continue to work with agricultural producers in the watershed to manage fertilizer applications and reduce nutrient loading into waterways. This recommendation should be considered a high priority.

Figure 3.3
Drain Tiles in the Lake Comus Watershed

Source: Larry Meyer, LCPRD, and SEWRPC

Animal Operations

In Wisconsin, an animal feeding operation with 1,000 or more animal units is defined as a Concentrated Animal Feeding Operation (CAFO).[302] Under state and federal law, CAFOs must have a WDNR-issued Wisconsin Pollutant Discharge Elimination System (WPDES) permit to protect surface and ground waters from excessive runoff and animal waste. Consequently, CAFOs are more stringently monitored and regulated than smaller animal feeding operations. Among the requirements are that CAFOs have a nutrient management plan developed as part of the permit process; that response plans are developed for manure and non-manure spills; that manure spreading limits and setbacks are specified; and that additional inspection, monitoring,

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[299] Ibid.

[300] Ibid.

[301] *C.A.M. Laboski and J.B. Peters,* Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin*, University of Wisconsin Cooperative Extension A2809, 2018. walworth.extension.wisc.edu/files/2018/11/Nutrient-Application-Guidelines-for-Field-Vegetable-Fruit-Crops-in-WI-A2809.pdf*

[302] Wisconsin Administrative Code *NR 243* Animal Feeding Operations *relates an animal unit to the impact of one beef steer or cow. Therefore, 1000 beef cattle are equivalent to 1000 animal units. Other animals have differing ratios. For example, the following numbers of animals are equivalent to 1000 animal units: 500 horses, 715 dairy cattle, 5,000 calves, 5,500 turkeys, 10,000 sheep.*

Figure 3.4
Inline Water Control Diagram

Source: Purdue University

and reporting requirements are adhered to[303] No CAFOs are located within the Lake Comus watershed at the time of this writing; however, at least one dairy operation within the watershed has submitted a preliminary application to expand their operation into a CAFO.[304] Walworth County staff are working with local volunteers to conduct water quality monitoring near this operation and are aware of the requirements that would go into effect if the operation becomes a CAFO.[305] In addition to this operation, there are multiple other animal operations within the watershed that do not meet the number of animal units to be defined as a CAFO (Map 3.6). The LCPRD, Walworth County staff, and local residents should continue to work with the WDNR to address any concerns about water quality impacts from animal operations in the watershed.

➤ **Recommendation 3.8: Ensure that animal operation performance standards are met**
The provision for barnyard runoff control systems and six months of manure storage are recommended for all livestock operations in the watershed as well as maintaining exclusion of livestock from waterbodies and adjacent riparian areas. Animal waste storage, management, and utilization must comply with Walworth County ordinances.[306] To assist with enforcement, citizens and volunteers can report suspected violations to County or State authorities. Furthermore, it is recommended that WDNR and DATCP consider increasing levels of cost-share funding to enable a higher level of BMP implementation needed to meet the NR 151 performance standards. This recommendation should be considered a high priority.

Ditching and Channelizing

Ditching or channelizing streams can have important implications for acute and chronic sediment source and transport within a watershed. For example, ditching reaches through wetland organic soils and/or converting highly meandering stream channels into straight line ditches can create an almost limitless source of highly erodible sediments and associated nutrient loads with a great capacity to convey sediment and nutrient loads downstream. Most notably, ditching increases channel slope and confines floodwater to small channel areas. These factors work together to increase the ability of a stream to transport sediment. However, ditches are usually dug too deep and/or wide to provide reasonable flow velocities during fair and dry weather. Therefore, sediment accumulates along the ditch during lower flows and fill with soft sediment. These accumulated sediments are readily transported downstream during the next high flow event. Ditching usually disconnects the stream from its floodplain. This results in increased downstream flooding and bank erosion because high flows are not allowed to spill out over the floodplain. Lastly, ditching also causes significant damage to instream habitats and has many negative consequences on both water quality and associated fish and wildlife communities.

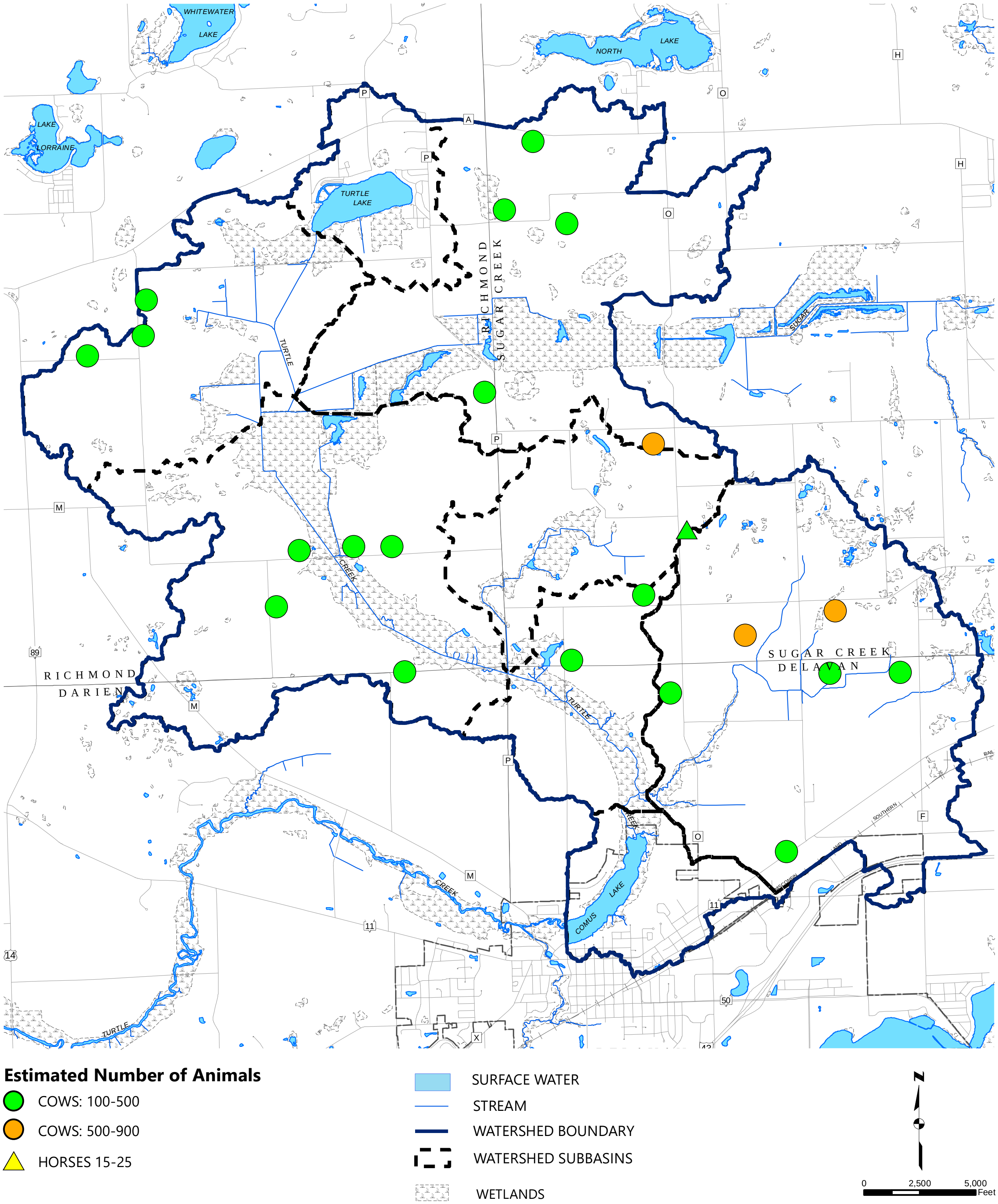
[303] *For more information, see dnr.wisconsin.gov/topic/CAFO/WPDESNR243.html.*

[304] *Letter to Marc Nelson from Anthony Salituro, WDNR,* CAFO WPDES Preliminary Permit Application- Acknowledgement of Receipt, *May 5th, 2021.*

[305] *Personal communication between Kevin Armstrong, LCPRD Chairman, and Commission staff, April 20th, 2021.*

[306] *Walworth County Code of Ordinances Chapter 6 Article IV, "Animal Waste Storage". library.municode.com/wi/walworth_county/codes/code_of_ordinances?nodeId=WACOCOOR_CH6AN_ARTIVANWAST*

Map 3.6
Animal Operations Within the Lake Comus Watershed



Source: SEWRPC

The extensive ditching and channelization of Turtle Creek and its tributaries upstream of the Lake has likely impaired desirable hydrologic and ecologic functions of Turtle Creek. A potential solution is to restore the Creek's mainstem back to its original path and profile to the extent practicable as shown in Figure 3.5, to decrease slope by remeandering, improving floodplain function, and mitigating streambank erosion. Figure 3.6 indicates areas for potential projects to restore hydrologic function in the Lake Comus watershed through the recommendations below. Further study beyond the scope of this plan would be required to determine appropriate exact reaches for installation of such features.[307]

➤ **Recommendation 3.9: Protect, enhance, or restore natural landscape elements to detain runoff**
Natural landscape elements should be restored to detain stormwater and reduce the speed that runoff leaves the landscape, contributes to stream flashiness, and its negative effects on aquatic habitat quality. This recommendation should be considered a high priority. Specific measures that can be taken to accomplish this recommendation include the following examples.

- Improve Turtle Creek's floodplain connectivity by adjusting stream morphology and channel profiles. This goal is integral with all stream realignment, remeandering, or restoration projects undertaken within the watershed. Stream morphology and profile can be adjusted to better resemble natural systems in many ways, including the following examples:
    - Relocate spoil piles that were deposited adjacent to ditched stream sections
    - Lessen stream slope by lengthening channel length as part of stream remeandering
    - Modify the stream bed or bed material to increase flood elevations (e.g., install riffles, ditch plugs, stream roughness enhancing features and/or vegetation)[308]
    - Less desirably, lower floodplain elevations in areas parallel to the creek
    - Implement sod toe restoration in straightened reaches of Turtle Creek to facilitate stream remeandering (also see Section 3.6, "Fish and Wildlife")[309]
- Divert intense runoff from impermeable surfaces away from direct discharge to surface water. Install check dams and ditch turnouts along roadside ditches to detain stormwater, encourage diffuse overland flow, encourage infiltration, and capture sediment and nutrients.
- When drained land no longer produces commodities at a profit, or when drained land is abandoned and left fallow, or when the landowner simply desires to introduce restoration practices, restore wetland hydrology and naturalize vegetation. These types of projects are particularly important in riparian areas. Implementing such projects commonly involves employing drain tile removal, ditch plugs, and ditch fills.[310]
- Consider installing saturated buffers and/or utilizing water control structures in tile-drained agricultural areas of the watershed. Alternatively, drain tiles outlets could be modified to discharge water into constructed wetlands rather than directly into surface waters.

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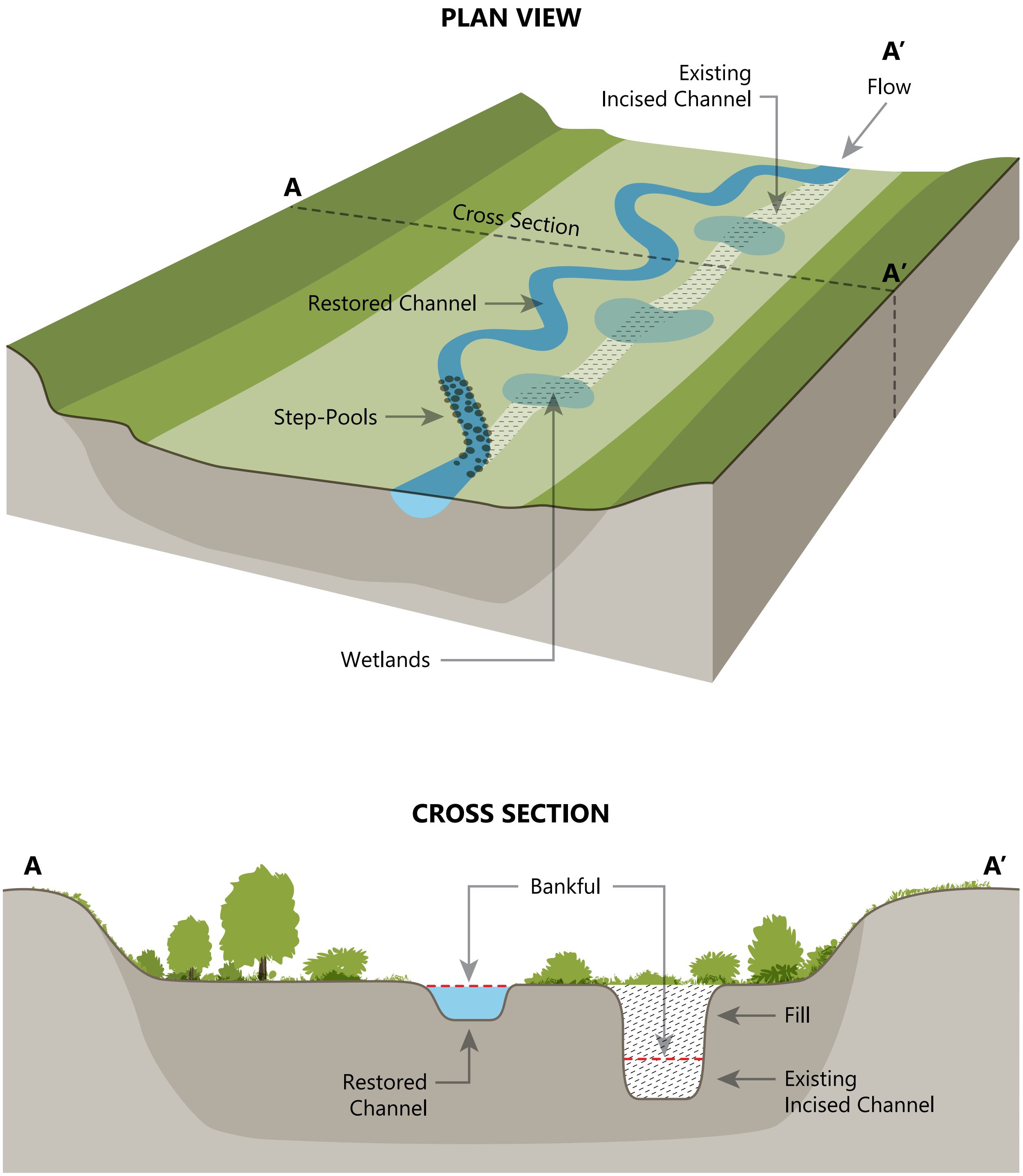
[307] *The Commission has completed plans focusing upon watershed protection. An example is Mason Creek, a tributary of North Lake in Waukesha County. This plan, entitled* Mason Creek Watershed Protection Plan*, is SEWRPC's Community Assistance Planning Report Number 321 and was published in 2018. A link to this report follows: www.sewrpc.org/SEWRPCFiles/Publications/CAPR/capr-321-mason-creek-protection-plan.pdf. The reader may find this report useful to envision future work benefiting the project.*

[308] *With careful planning, opportunities commonly exist to increase floodplain connectivity without expanding the extent of the modelled 100-year flood elevation.*

[309] *For more information on sod toe restoration, see Minnesota Department of Natural Resources,* Toe Wood-Sod Mat Factsheet*, 2010: www.files.dnr.state.mn.us/publications/waters/toe_woodsod_mat_dec2010.pdf.*

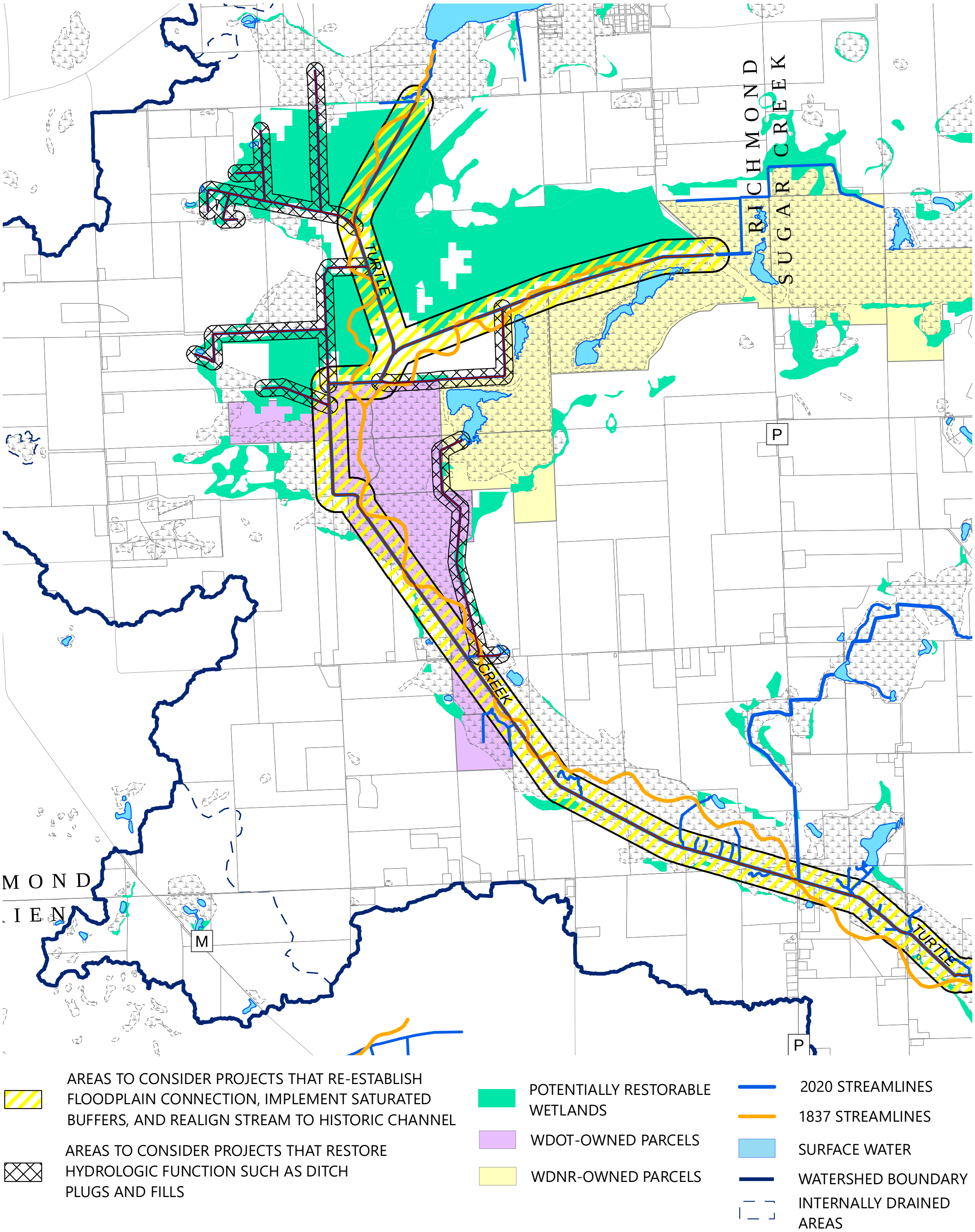
[310] *For more information on installing ditch plugs and ditch fills, see Chapter 4 of A.L. Thompson and C.S. Luthin,* Wetland Restoration Handbook for Wisconsin Landowners*, Wisconsin Department of Natural Resources Bureau of Science Services SS-989, 2004: www.dnr.wisconsin.gov/topic/Wetlands/handbook.html.*

Figure 3.5
Potential Stream Restoration Design Example to Improve Stream Function



Source: Modified from W. Harman, R. Starr, M. Carter, et al., A Function-Based Framework for Stream Assessments and Restoration Projects, *US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC, EPA 843-K-12-006, p. 36, 2012 and SEWRPC*

Figure 3.6
Potential Areas for Hydrologic Restoration Projects in the Lake Comus Watershed



Note: This figure indicates potential areas for hydrologic restoration. Further study would be required before designing and implementing any specific practice.

Source: SEWRPC

- Convert some of the watershed's potentially restorable wetlands (PRW) into wetlands (Map 2.17). The large PRW areas located south of Turtle Lake and near the intersection of Cobblestone Road and Goose Pond Road have been identified using the Wetlands by Design approach as particularly suitable for flood abatement.[311]

As many of these specific recommendations are intended to affect the Creek's hydrology, care should be taken to site these projects appropriately to avoid undesired effects on neighboring properties. The least controversial projects are likely to occur on publicly owned lands, such as the parcels owned by the Wisconsin Department of Transportation and WDNR in the Turtle Valley Wildlife Area (Figure 3.6). Owners of neighboring parcels should be informed of any potential restoration work and should ideally asked to collaborate on any proposed projects to expand the scope of restoration. Any wetland conservation or stream realignment work will likely require a permit from the WDNR and floodplain modeling.[312] Project that raise 100-year flood elevations require additional steps to execute. However, hydrologic restoration opportunities typically exist that do not raise 100-year flood elevations. For example, ditch-fill projects that fill a ditch crossing a broad floodplain oftentimes have negligible affect on 100-year flood elevations.

Urban BMPs

Historically, the approach to manage increases in rates and volumes of runoff within urbanized areas often involved constructing storm sewer and/or open channel systems to quickly convey stormwater to streams or lakes. In recent years, flooding, water quality impairment, and environmental degradation demonstrate the need for an alternative approach to urban stormwater management. Consequently, present-day stormwater management approaches seek to manage runoff using a variety of measures, including detention, retention, infiltration, and filtration, better mimicking the behavior and disposition of precipitation on a more natural landscape.

While urban nonpoint sources are not known to be and are not anticipated to be a major contributors of pollutants to the Lake, the proximity of urban development to the Lake may enable urban sources to have an outsized effect considering the low acreage of these sources within the watershed. The following recommendation address reducing urban nonpoint pollutant loads in the watershed:

➤ **Recommendation 3.10: Encourage urban pollution source reduction efforts through BMPs**
Reduce lawn fertilizer use, create rain gardens, and properly store and judiciously apply deicers and other chemicals to prevent them from washing into the Lake. Additional BMP examples are provided in the recommendations below. This recommendation should be considered a medium priority.

➤ **Recommendation 3.11: Promote native plantings in and around existing and new stormwater detention basins**
Planting native plants in these situations improves detention water filtration, reduces pollutant loading, and provides wildlife habitat. In addition, detention basin management practices should aim to reduce or eliminate fertilizing basin slopes and limit herbicide application and cutting to invasive species only. This should be considered a medium priority.

➤ **Recommendation 3.12: Retrofit existing and enhance planned stormwater management infrastructure to benefit water quality**
Water quality can benefit by extending detention times, spreading floodwater, and using features such as grassed swales to convey stormwater. Implementing such works requires close coordination with the municipalities within the Lake Comus watershed. This recommendation should be considered a medium priority.

[311] *Miller, N., J. Kline, T. Bernthal, J. Wagner, C. Smith, M. Axler, M. Matrise, M. Kille, M. Silveira, P. Moran, S. Gallagher Jarosz, and J. Brown,* Wetlands by Design: A Watershed Approach for Wisconsin*, Wisconsin Department of Natural Resources and The Nature Conservancy, 2017.*

[312] *More information on general and individual permits and required documents can be found at the following location: dnr.wisconsin.gov/permits/water.*

➤ **Recommendation 3.13: Combine riparian buffers with other structures and practices**
A much higher level of pollution removal can be achieved with "treatment trains" combining riparian buffers with better-managed detention basins or new practices such as floating island treatments (Figure 3.7), grassed swales, and infiltration facilities. This layering of overlapping practices and structures is a more effective way to mitigate the effects of urban stormwater runoff than such practices being used in isolation. This action should be assigned a low priority.

➤ **Recommendation 3.14: Stringently enforce construction site erosion control and stormwater management ordinances and creatively employ these practices**
Ordinances must be enforced by responsible regulatory entities in a manner consistent with current practices; however, local citizens can help by reporting potential violations to the appropriate authorities. This recommendation should be considered a low priority.

➤ **Recommendation 3.15: Maintain stormwater detention basins**
This should be considered a low priority due to the few basins located in the watershed. Maintaining stormwater basins includes managing aquatic plants, removing and disposing of flotsam or jetsam, ensuring adequate water depth to settle and store pollutants, inspecting and repairing outlet structures, and actively and aggressively managing excess sediment. Specifications associated with the design of stormwater detention basins and maintenance requirements ensure that basins are functioning properly.[313] It is important to remember that stormwater detention basins occasionally require dredging to maintain characteristics that protect the Lake. The frequency of dredging is highly variable and depends upon the design of the basin and the characteristics of the contributing watershed. Regulatory entities should complete basin inspection in a manner consistent with current practices; however, ensuring that the owners of these basins know the importance of meeting these requirements through educational outreach can help ensure continued proper functioning of the ponds. Coordinating with municipalities and neighborhood associations can play an important role.

➤ **Recommendation 3.16: Promote urban nonpoint source abatement**
In addition to local stormwater ordinances and stormwater management planning, another way to promote cost-effective nonpoint source pollution abatement is for Walworth County to work toward satisfying all conditions required by the Wisconsin Pollutant Discharge Elimination System municipal separate storm sewer system (MS4) discharge permitting process. This should be considered a low priority issue.

➤ **Recommendation 3.17: Collect leaves in urbanized areas**
Because of the modest amount of the Lake's watershed found in urban areas, this recommendation should be assigned a low priority. Leaves have been shown to be a very large contributor to total external phosphorus loading to lakes in urban settings. Stockpiling leaves in the street where they may be crushed and washed into the Lake or burning leaves in shoreline and ditch areas can create situations where a strong pulse of phosphorus is delivered to the Lake by late autumn rains. Residents should be encouraged to use leaf litter within their own yards as a nutrient source or much or should take advantage of the yard waste collection and leaf disposal programs in existence in those municipalities in the watershed that conduct such programs, such as the City of Delavan.

Communication, Education, and Outreach

Identifying, communicating with, and supporting willing partners in the watershed is necessary to implement the BMPs listed above. The following suggestions are provided to enhance communication, education, and outreach regarding nonpoint source BMPs. All are assigned a high priority.

- Host or sponsor educational workshops and tours, demonstration projects, and information exchange forums focusing on emerging BMPs. The LCPRD could potentially host such events on its parcels on Dam Road leased for farming.

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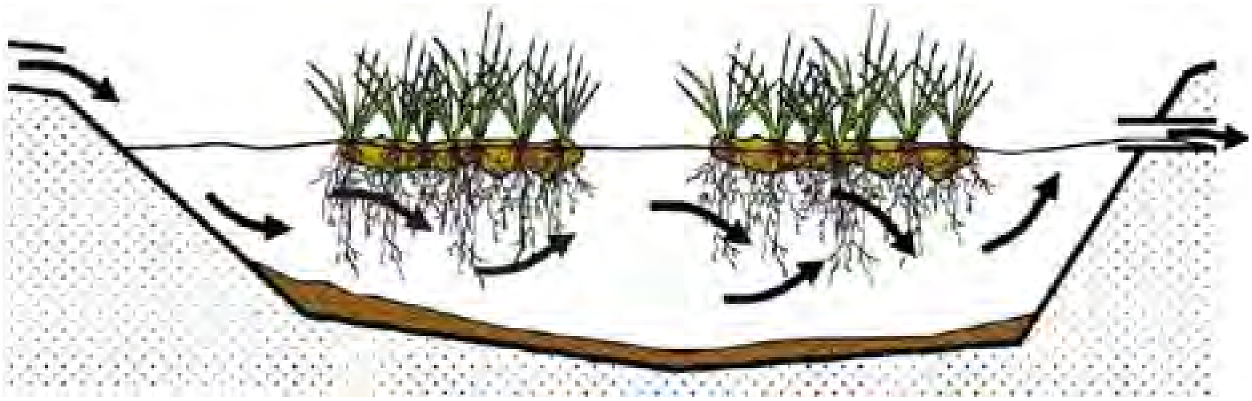
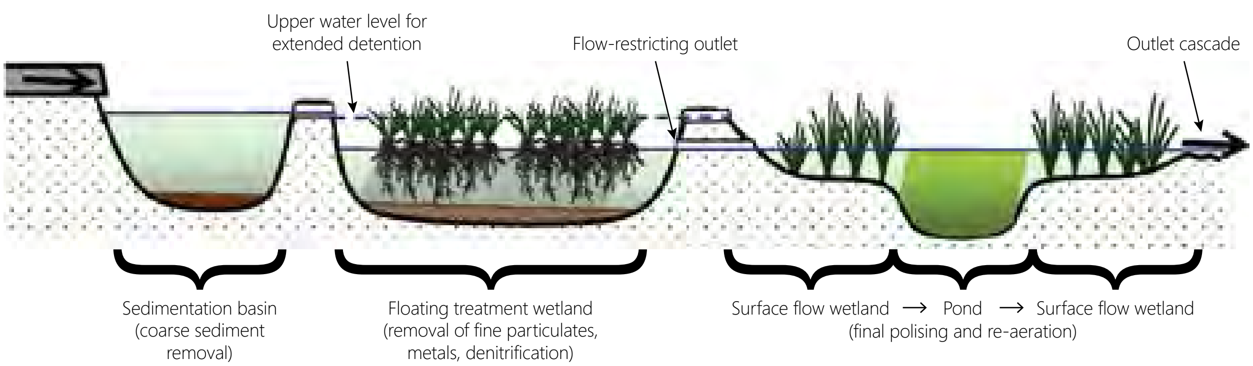
[313] *Technical standards for design and maintenance of wet detention basins and other stormwater management practices can be found at dnr.wi.gov/topic/stormwater/standards/postconst_standards.html.*

Figure 3.7
Schematic of Floating Treatment Wetland Design Applications

Emergent plants are grown within a floating artificially constructed material within a wet detention stormwater basin. The roots are directly in contact with the water column and can intercept suspended particles. The roots also provide a high surface area for microbiological activity that aid in adsorbing pollutants.



Conceptual longitudinal cross-section through a "newly designed" stormwater treatment system incorporating floating wetlands, ponds, and surface flow wetlands (not to scale).



Source: I. Dodkins, A. Mendzil, and L. O'Dea, Floating Treatment Wetlands (FTWs) in Water Treatment: Treatment Efficiency and Potential Benefits of Activated Carbon, *FROG Environmental LTD., March 2014; T.R. Headley and C.C. Tanner, "Constructed Wetlands With Floating Emergent Macrophytes: An Innovative Stormwater Treatment Technology,"* Critical Reviews in Environmental Science and Technology, *42: 2261-2310, 2012 and SEWRPC*

- Engage, and possibly subsidize, agricultural producers to implement practices that improve water quality. Provide information, technical support, tools and equipment, and financial support.
- Promote engagement by the farming community in decision-making and equip farmers with monitoring tools and methods.
- Target action-oriented messages about water quality and conservation practices to key groups.
- Produce and distribute newsletters, exhibits, fact sheets, and/or web content to improve communication around these issues.

Riparian Buffer Protection and Prioritization Strategies

Riparian buffers provide multiple benefits including mitigating pollutant runoff into surface waters, improving streambank stability, and providing habitat for wildlife and aquatic organisms (Figure 2.27). All riparian buffers provide some level of protection; however, wider buffers provide more benefits (infiltration, temperature moderation, and species diversity) than narrower buffers. Therefore, it is important that existing buffers be protected and expanded where possible. The riparian buffer network to the 75-foot, 400-foot, and 1,000-foot widths as summarized in Section 2.3, "Water Quality and Pollutant Loading" provides the framework upon which to protect and improve water quality and wildlife within the Lake Comus watershed. This framework can be achieved by combining strategies such as land acquisition, conservation easement acquisition, regulation, and best management practices, as discussed in the following subsection.

Regulatory and Other Opportunities

Chapter NR 115, "Wisconsin's Shoreland Protection Program," of the *Wisconsin Administrative Code* establishes a minimum 75-foot development setback from the ordinary high-water mark of navigable lakes, streams, and rivers. A minimum tillage setback standard of five feet from surface water channels is also called for under Section NR 151.03 of the *Wisconsin Administrative Code*. Insufficient buffer between a field and a waterway can contribute to significant sediment and phosphorus loading to the waterway and can significantly limit wildlife habitat. In addition, based upon the water quality and wildlife goals for this watershed, neither the 5-foot tillage setback nor the 75-foot buffer requirement are adequate to achieve pollutant load reduction goals and resource protection concerns.

Crop yield losses have been found to be greatest near drainage ditches that flood. Therefore, adding buffer to areas prone to flooding would not displace agriculture from prime production areas. Fields with high slopes (Map 2.2) and high soil erodibility, fields where the minimum riparian buffer width of 75 feet is not being met (Map 2.23) and/or crop land is located within the 1-percent-annual-probability floodplain, and fields containing potentially restorable wetlands within 1,000 feet of a waterway could be considered priority fields for riparian buffer installation. In addition, the 75 foot wide buffers adjacent to waterways are envisioned to be harvestable buffers, enabling periodic livestock fodder harvest or pasturing. Expanding riparian buffers to the 400- and 1,000-foot widths, or greater to the extent practicable, are not likely to be achievable until such time that the agricultural land is converted to urban uses. At that time, it may be possible to design portions of the development to accommodate such buffer widths. From a practicality standpoint, this may be the last chance to establish critical protective boundaries and/or open space and habitat connections around waterways.

Primary environmental corridors have a greater level of land use protections compared to secondary corridors, isolated natural resource areas, or designated natural areas outside of PEC. Therefore, the regulatory strategy to expand protection for vulnerable existing and potential riparian buffers would be to increase the extent of designated primary environmental corridor lands within the Lake Comus watershed. Expanding the narrow SEC connection between the PEC areas along Turtle Lake and the extensive PEC along Turtle Creek south to the Lake presents the greatest opportunity to expand primary environmental corridors in this watershed. Since these two areas already meet the minimum size requirements for designation as a PEC, any lands with sufficient natural resource features adjacent or connecting to this existing PEC could potentially be incorporated into this designation.

Wetlands located within PEC lands have been designated as Advanced Delineation and Identification wetlands under Section 404(b)(1) of the Federal Clean Water Act and are deemed generally unsuitable for the discharge of dredge and fill material. In addition, the nonagricultural performance standards specified in Section NR 151.125 of the *Wisconsin Statutes*, require a 75-foot impervious surface protective area adjacent to these higher-quality wetlands. This designated protective area boundary is measured horizontally from the delineated wetland boundary to the closest impervious surface.[314] Hence, these wetlands would have additional protections from filling and from being encroached upon by future development, enabling their riparian buffer functions to be retained.

Best Management Practices and Programs for Riparian Buffers

Most existing and potential future riparian buffers in the watershed are privately owned and are situated within wetland and agricultural areas. It is the private landowner's choice to maintain or establish buffers. In addition, although riparian buffers can effectively mitigate negative water quality effects attributed to urbanization and certain agricultural management practices, they cannot on their own address all the pollution problems associated with these land uses. Therefore, riparian buffers need to be combined with other management practices, such as infiltration facilities, wet detention basins, porous pavements,

[314] *Runoff from impervious surfaces located within the protective area must be adequately treated with stormwater BMPs.*

green roofs, and rain gardens to mitigate the effects of urban stormwater runoff. To mitigate the effects of agricultural runoff, riparian buffers need to be combined with other management practices, such as barnyard runoff controls, manure storage, filter strips, nutrient management planning, grassed waterways, cover crops, and reduced tillage. Therefore, BMPs to improve and protect water quality in both agricultural and urban areas are essential elements for protecting water quality, water quantity, and wildlife within the Lake Comus watershed.

Recent research has indicated that converting up to eight percent of cropland at the field edge from production to wildlife buffer habitat leads to increased yields in the remaining cropped areas of the fields, and that this positive effect becomes more pronounced with time.[315] As a consequence, despite the initial loss of cropland for habitat creation, overall yields for an entire field can be maintained, and even increased, for some crops compared to control areas. Although it took about four years for the beneficial effects on crop yield to manifest themselves in this research project, this yield increase was largely attributed to increased abundance and diversity of crop pollinators within the wildlife habitat areas. Such results suggest that at the end of a five-year crop rotation, there would be no adverse impact on overall yield in terms of monetary value or nutritional energy, and that in subsequent years, pre-buffer yields would be maintained or increased. Hence, establishing buffers or sacrificing marginal cropland edges to create wildlife buffer habitat or potential restorable wetland within the Lake Comus watershed may lead to increased crop yields, so this practice may be economically viable over the longer term. More importantly, these results also demonstrate that lower yielding field edges can be better used as non-crop habitats to provide services supporting enhanced crop production, benefits for farmland biodiversity, and protecting water and soil health.[316]

➤ **Recommendation 3.18: Increase extent of riparian buffers**

This recommendation should be considered a high priority, particularly for the 179 acres of unbuffered lands within 75 feet of a Lake tributary. Increasing the amount of riparian buffers coverage in the watershed helps enhance the water quality of Turtle Creek and Lake Comus as well as provide greater ecological connectivity between upland areas and the lowland wetland complex flanking Turtle Creek. Riparian buffer expansion priority (including primary and secondary environment corridors (PECs and SECs), isolated natural resource areas (INRAs), and natural areas (NAs)) should be based upon the following order of importance (from highest to lowest priority):

1. Existing riparian buffer (protect what already exists on the landscape)

2. Potential riparian buffer lands up to 75 feet wide (minimum level of protection for reducing pollutant loads reaching waterbodies)

3. Potentially restorable wetlands within 1,000 feet of Lake Comus or its tributaries (see Map 2.17) or the one-percent-annual-probability-floodplain (see Map 2.8), whichever provides greater coverage (priority for pollutant removal and wildlife habitat protection)

4. Potential riparian buffer lands up to 400 feet wide (minimum for wildlife protection)

5. Potential riparian buffer lands up to 1,000 feet wide (optimal for wildlife protection)

[315] *R. Pywell, M.S. Heard, B.A. Woodcock, et al., "Wildlife-Friendly Farming Increases Crop Yield: Evidence for Ecological Intensification,"* Proceedings of the Royal Society B: Biological Sciences, *282(1816), 2015.*

[316] Ibid.

In addition, special consideration should be given to acquiring riparian buffers in locations designated as having high to very high groundwater recharge potential as shown on Map 2.9 and areas that help connect and expand critical linkages between habitat complexes to protect wildlife abundance and diversity. Furthermore, connecting SEC lands and multiple INRAs throughout the Lake Comus watershed to larger PEC areas, as well as building and expanding upon existing protected lands as shown in Map 2.15, represents a sound approach to enhance the corridor system and wildlife areas within the watershed. This approach mirrors the proposed open space preservation strategy outlined in the 2014 Walworth County Park and Open Space Plan.[317]

In Wisconsin, the USDA offers technical assistance and funding to support implementing riparian buffers and wetlands on agricultural lands. A 10- to 15-year contract must be entered into by the landowner or operator and the land is only eligible under certain conditions. Land enrolled in these programs normally must be currently or very recently used for agricultural production. Because the program requires a substantial commitment, it is often difficult to get farmers and/or landowners to commit to installing and maintaining riparian buffer strips. To overcome this, a custom program offering a shorter time commitment, potentially five years, with a yearly payment incentive greater than what the USDA program offers, has found favor in other counties in the State, and could potentially be developed for the Lake Comus watershed.

3.5 AQUATIC PLANTS

Lake Comus does not have populations of EWM and CLP dense enough to substantially interfere with recreation or navigation. Therefore, intensive aquatic plant management via chemical application, harvesting, and dredging is not recommended at this time. Instead, encouraging, enhancing, and maintaining a healthy aquatic plant community in the Lake will help achieve other desired water quality and fishery goals. A healthy aquatic plant community will help reach water quality and fishery goals by reducing Lake phosphorus concentrations during critical time periods, hindering sediment resuspension, enhancing water clarity, and providing food and habitat for aquatic organisms. As described in Section 2.4, "Aquatic Plants", the Lake currently exhibits characteristics of a algae-dominated state rather than a macrophyte-dominated state (Figure 2.37). Consequently, the following recommendations intend to promote healthy aquatic plant community establishment and growth within the Lake by encouraging a shift towards a macrophyte-dominated state.

- **Recommendation 4.1: Protect native aquatic plants to the highest degree feasible through careful implementation of aquatic plant management and water quality recommendations**
  Lake Comus supports a limited number of aquatic plant species, and its community is dominated by invasive species. The few native species already present can provide food and habitat for wildlife and aquatic organisms. Seeding and/or planting fast-growing native species, such as bulrush (*Schoenoplectus* spp.), naiads (*Najas* spp.), and muskgrass (*Chara* spp.), may help to reduce sediment disturbance and provide better habitat for aquatic organisms, particularly following any large-scale actions like water level manipulations or dredging.[318] Protecting the Lake's native species and encouraging their growth should be a priority for fostering a healthier aquatic plant community. This recommendation should be considered a medium priority.

- **Recommendation 4.2: Avoid disrupting bottom sediment or leaving large areas of bottom sediment devoid of vegetation**
  Disturbing the lake bottom can decrease water clarity and uproot submerged aquatic vegetation. Large areas of sediment devoid of vegetation are more prone to sediment resuspension into the water column and colonization by invasive species. Reducing sediment disturbance and enhancing lake-bottom coverage with aquatic plant species can improve water clarity. Rooted aquatic plants compete with algae for dissolved phosphorus, decreasing. More abundant rooted plants also reduce the propensity for lake-bottom agitation, lowering turbidity and phosphorus resuspension. This recommendation should be considered a low priority.

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[317] *SEWRPC Community Assistance Planning Report No. 135 (3rd Edition),* A Park and Open Space Plan for Walworth County, *March 2014.*

[318] *Introducing invasive and exotic species to the Lake and the Creek is strictly prohibited. Any plans to seed and/or plant native species will require a permit and should be thoroughly discussed with WDNR biologists.*

➤ **Recommendation 4.3: Reduce the Lake's carp population**

Common carp consume aquatic plants and agitate bottom sediment, reducing water clarity and making difficult for native plant species to establish and thrive in the Lake. Reducing the Lake's common carp population can reduce disturbance to native plant populations as well as increase water clarity, allowing greater and deeper vegetation coverage of the Lake. Refer to Sections 2.6, "Fisheries" and 3.6, "Fish and Wildlife" for guidance on reducing and controlling the carp population. This recommendation should be considered a high priority.

➤ **Recommendation 4.4: Prevent the introduction of new invasive species**

Introduction of new invasive species is a constant threat. Preventing introduction is crucial to maintaining healthy lakes. This is particularly true for Lake Comus with its large expanses of vegetation-devoid sediment that are susceptible to colonization by invasive species. To help decrease the chance of introducing new invasives the following recommendations are given a low priority:

- **Educate residents** as to how they can help prevent invasive species from entering the Lake.

- **Participate in the Clean Boats Clean Waters program** (a State program targeting invasive species prevention) to proactively encourage Lake users to clean boats and equipment before launching and using them in Lake Comus.[319]

- **Target the boat launch**. Since boat launches are likely entry points for alien species, the boat launch should be targeted for focused aquatic plant control.

- **Take immediate action to evaluate and eradicate newly identified invasive species.** If a new alien species infestation is found in the Lake, efforts to eradicate the new species should immediately be evaluated and, if possible, be employed to help prevent establishment. The WDNR has funding that can aid early eradication efforts, particularly as it pertains to aquatic plants (Table 3.4). Therefore, citizen monitoring for new invasive species is recommended. The Wisconsin Citizen Lake Monitoring Network provides training to help citizens participate in these efforts.

➤ **Recommendation 4.5: Consider manipulating water levels to encourage native plant growth**

As discussed in Section 2.4, "Aquatic Plants", water level manipulation can be an effective management tool for reducing populations of invasive aquatic plant species, particularly EWM and CLP, while encouraging the growth of certain desirable native species, such as naiads, muskgrass, and bulrush. While native species were not observed in Lake Comus as part of the Commission's aquatic plant study, there may be a seedbank present in the lake sediment that could be stimulated through a winter drawdown.[320] Additionally, the LCPRD can embark on a study to determine if transplanting native species in the Lake following a drawdown is feasible if no native species emerge once the Lake is refilled.

Water level manipulation can also be a useful tool for helping drive the shift from an algae-dominated state to a macrophyte-dominated state, resulting in improved water quality and clarity, greater aquatic plant growth, fewer carp, and a larger population of predatory sport fish. However, water level manipulation, particularly summer and early fall drawdowns, may facilitate expansion of the cattail marsh further into the Lake and can also reduce the population of water lilies, one of the native species observed in the Lake. Lake managers should carefully consider the goals of a lake drawdown to help ensure that the timing, frequency, and intensity of the water level manipulation will contribute to goals. This recommendation is a medium priority, however, as mentioned in Recommendation 1.7, high priority should be given to any retrofit of the outlet dam that helps reliably lower reservoir water levels over an extended period.

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[319] *More information about Clean Boats, Clean Waters can be found on the WDNR website at dnr.wi.gov/lakes/cbcw.*

[320] *Drawdowns on Tripp and Cravath lakes, two impounded lakes in northwestern Walworth County, from 2019 to 2021 stimulated the growth of several native aquatic plant species, including long-leaf pondweed* (Potamogeton nodosus)*, wild rice* (Zizania *spp.*)*, softstem bulrush* (Schoenoplectus tabernaemontani)*, water smartweed* (Persicaria amphibia)*, bullhead lilies* (Nuphar *spp.*)*, and cattails* (Typha *spp.*).

Table 3.4
Example WDNR Grant Programs Supporting Lake and River Management Activities

Program	Grant Program	Maximum Grant Award	Minimum Grantee Match (percent)	Application Due Date
Water				
Surface Water Grants	Aquatic Invasive Species (AIS) Prevention and Control	Clean Boats, Clean Waters: $24,000	25	November 1
		Established Population Control: $150,000	25	November 1
		Early Detection and Response: $25,000	25	Year-Round
		Research and Development annual funding limit: $500,000	25	November 1
	Surface Water Education	$5,000 per project $50,000 per waterbody	33	November 1
	Surface Water Plan	$10,000	33	November 1
	Comprehensive Management Plan	$25,000	33	November 1
	County Lake Grant	$50,000	33	November 1
	Ordinance Development	$50,000	25	November 1
	Management Plan Implementation	Lakes: $200,000 Rivers: $50,000	25	November 1
	Healthy Lakes & Rivers	$1,000 per practice $25,000 per waterbody	25	November 1
	Surface Water Restoration	Lakes: $50,000 Rivers: $25,000	25	November 1
	Land Acquisition and Easement	Lakes: $200,000 Rivers: $50,000	25	November 1
Citizen-Based Monitoring Partnership Program	--	$5,000	None	Spring
Targeted Runoff Management	--	Small-Scale: $225,000	30	May 15
		Large-Scale: $600,000	30	May 15
Urban Nonpoint Source and Stormwater Management	--	Planning: $85,000 Property Acquisition: $50,000 Construction: $150,000	50	May 15
Conservation and Wildlife				
Knowles-Nelson Stewardship Program	Habitat Areas	--	50	March 1
	Natural Areas	--	50	March 1
	Streambank Protection	--	50	March 1
	State Trails	--	50	March 1

Table continued on next page.

Table 3.4 (Continued)

Program	Grant Program	Maximum Grant Award	Minimum Grantee Match (percent)	Application Due Date
Boating				
Boat Enforcement Patrol	--	Up to 75% reimbursement	None	Various
Boating Infrastructure Grant	--	Up to $200,000 per state	50	June 1
Recreation				
Knowles-Nelson Stewardship Program	Acquisition and Development of Local Parks	--	50	May 1
	Acquisition of Development Rights	--	50	May 1
	Urban Green Space	--	50	May 1
	Urban Rivers	--	50	May 1
Sport Fish Restoration	Boat Access	Varies annually	25	February 1
	Fishing Pier	Varies annually	25	October 1

Note: This table incorporates information from NR 193, which was made effective on June 1st, 2020. More information regarding these example grant programs may be found online at the following address: dnr.wi.gov/aid/grants.html. Additional federal, state, and local grant opportunities are available. Eligibility varies for each grant program.

Source: Wisconsin Department of Natural Resources and SEWRPC

3.6 FISH AND WILDLIFE

Biological communities are a direct consequence of waterbody health—an indicator of the ability of a waterbody to support aquatic life. The Lake Comus fishery is locally popular and, supported by WDNR stocking efforts, maintains substantial panfish, largemouth bass, and northern pike populations. Fish and wildlife depend upon the health of the Lake, its tributaries, and the environmental corridors found throughout the watershed. Abundant and healthy fish and wildlife increases the Lake's recreational value, aesthetic appeal, overall enjoyment by humans, and the functionality of the Lake as an ecosystem.

Habitat Quality

Preserving and enhancing habitat quality is essential to promoting healthy fish and wildlife populations within the watershed. Recommendations to improve habitat quality follow.

- **Recommendation 5.1: Preserve and expand wetland and terrestrial wildlife habitat, while making efforts to ensure connectivity between such areas**

  Most existing wetland adjacent to Turtle Creek and within the Turtle Valley Wildlife Area ranks very high for its capacity to support fish and aquatic life by The Nature Conservancy's Wetlands by Design GIS tool. This is particularly true for animals in the shallow marsh guild (e.g., American bittern, blue-winged teal, many aquatic invertebrates) and shrub swamp guild (e.g., American woodcock, flycatchers). Preserving these wetland through land or acquisition, conservation easements, and/or expansion of the Turtle Valley Wildlife Area would promote protection of this important wildlife habitat.

  Habitat connectivity could be improved by implementing the buffer and wetland protection recommendations provided in Section 3.4, "Pollutant and Sediment Sources and Loads." Benefit could also be accrued by hydraulically reconnecting floodplains to ditched and straightened tributary streams. These reconnected floodplains detain floodwater diminish downstream flooding, retain sediment ad nutrients improving downstream water quality, promote groundwater recharge, and provide seasonally wet areas of great value for a wide range of birds, fish, amphibians, insects, and terrestrial animals. The Nature Conservancy's Wetland by Design tool identifies 759 acres of potentially restorable wetland between Turtle and the confluence of the Turtle Creek headwaters as particularly suitable for enhancing fish and aquatic habitat via conversion to wetland, Restoring natural or semi-natural condition in this area would also enhance habitat connectivity between Turtle Lake and the Creek.[321] This recommendation should be assigned a <u>high priority</u>.

- **Recommendation 5.2: Preserve and enhance instream features providing critical fish spawning and rearing habitats**

  Stream flow is fundamental to stream health. Actions to mitigate the negative consequences of channelization and physical impediments to aquatic organism along tributaries and adjacent floodplains should be considered a <u>high priority</u>. While doing this natural stream features such as riffles, pools, riparian wetlands and vegetation, and stable instream stable wood that does not significantly obstruct flow should be preserved and, depending on the situation, enhanced, to provide valuable fish habitat, protection from predators, feeding areas, and refuges from summer and winter temperature extremes. Protecting instream habitat features should be a focus in the Creek tributaries with higher gradients and less channelization, such as the CTH O tributary, where these features are more likely to exist. Due to the extensive channelization and low gradient of the Creek itself, there is little existing instream habitat.

  Like humans, aquatic organisms need a variety of habitat types to survive and prospers. Human often install infrastructure features and modify streams morphology ins ways that partially or completely block migration of aquatic organisms from life-cycle-critical habitat types. Features such as culverts, dams, levees, and ditched channels produce leaping obstacles, excessively shallow water, in-channel hazards and blockages, and velocity barriers. The LCPRD should consider completing an inventory of all mapped stream channels upstream of the Lake to locate and quantify potential aquatic organism

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[321] *Miller et al., 2017*, op. cit.

passage impediments and barriers.[322] As part of the inventory, preliminary design standards and priorities can be generated.

The LCPRD should also monitor water-related infrastructure construction and repair in areas tributary to the Lake. When projects are proposed, the LCPRD should petition for use of modern, aquatic-organism friendly infrastructure design be used as part of project conceptualization and design. Many publications from a variety of agencies discuss such methods.[323]

➤ **Recommendation 5.3: Restore natural meanders and improve floodplain connectivity to Turtle Creek and its tributaries**

Most of Turtle Creek upstream of the Lake has been extensively channelized. Due to the channel's low gradient and attendant limited ability to move coarse-grained sediment, restoring stream channel function in a reasonable period requires physically reconstructing a new channel that emulates natural channel form. Reconstructing meanders or restoring more natural sinuosity, particularly in low gradient systems, is one of the most effective ways to restore instream habitat, hydrology, and the stream's ability to transport sediment and to function more like a healthy stream system. Pollutant loads from restored streams by allowing floodwater to spread onto floodplains and be temporarily detained. This can be done by reconnecting floodplains, restoring historical stream channel profiles, and reconstructing new channels and/or two-stage channel systems (Figures 3.5 and 3.8).

An ideal location to restore stream function is where pre-existing channel segments or stream traces remain visible (Figure 3.9). Even if historical stream channels have been obliterated or cannot be located, many opportunities are available to rehabilitate or increase stream sinuosities and associated habitat and stream function within channelized stream reaches. For example, spoil piles excavated during channel ditching often parallel ditched streams, a situation isolating the stream from its floodplain. Perforating the levee-like spoil pile can reactivate the streams floodplain located beyond the spoil pile.

Due to the high potential cost, remeandering streams and reconnecting floodplains should be considered a medium priority. Sod toe restoration could be used as a lower-cost alternative in the Creek to facilitate remeandering, narrow over-widened stream reaches, and create a low-flow channel alongside the current stream to reduce pollutant loading and enhance habitat.[324] As sod-toe restoration shares many of the benefits of stream remeandering at a significantly lower cost per lineal foot, implementing sod toe restoration projects should be considered a high priority. These projects could be particularly effective to restore conditions in areas where a historic stream channel is not apparent in aerial imagery or via field surveys.

➤ **Recommendation 5.4: Preserve natural areas of county-wide and local significance, particularly those with critical species habitat**

Critical species habitats are essential for protecting rare native species, including those on the state's endangered and threatened species list (Table 2.14 and Map 2.16). This recommendation is a high priority.

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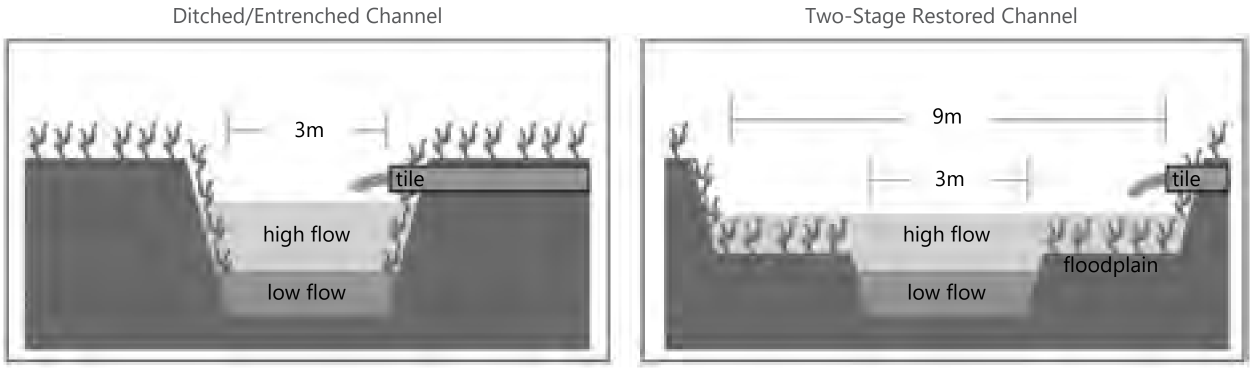
[322] *Many organizations have completed aquatic organism passage inventories in Southeastern Wisconsin, with most of these inventories completed in streams tributary to Lake Michigan. An example are projects completed in Ozaukee County, elements of which are described on the County's website: co.ozaukee.wi.us/619/Fish-Passage.*

[323] *For example, road/stream crossings are a common water-resource feature benefiting from aquatic organism friendly design. A few of the many agencies providing aquatic organism friendly design guidance include the United States Forest Service, the United States Fish and Wildlife Service, and the NRCS. A few websites discussing aquatic organism passage from these example agencies are found below: www.fs.usda.gov/restoration/Aquatic_Organism_Passage/index.shtml, www.fws.gov/service/fish-passage-technical-and-planning-assistance, www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_033247.pdf.*

[324] *Minnesota Department of Natural Resources, 2010,* op. cit. *www.files.dnr.state.mn.us/publications/waters/toe_woodsod_mat_dec2010.pdf.*

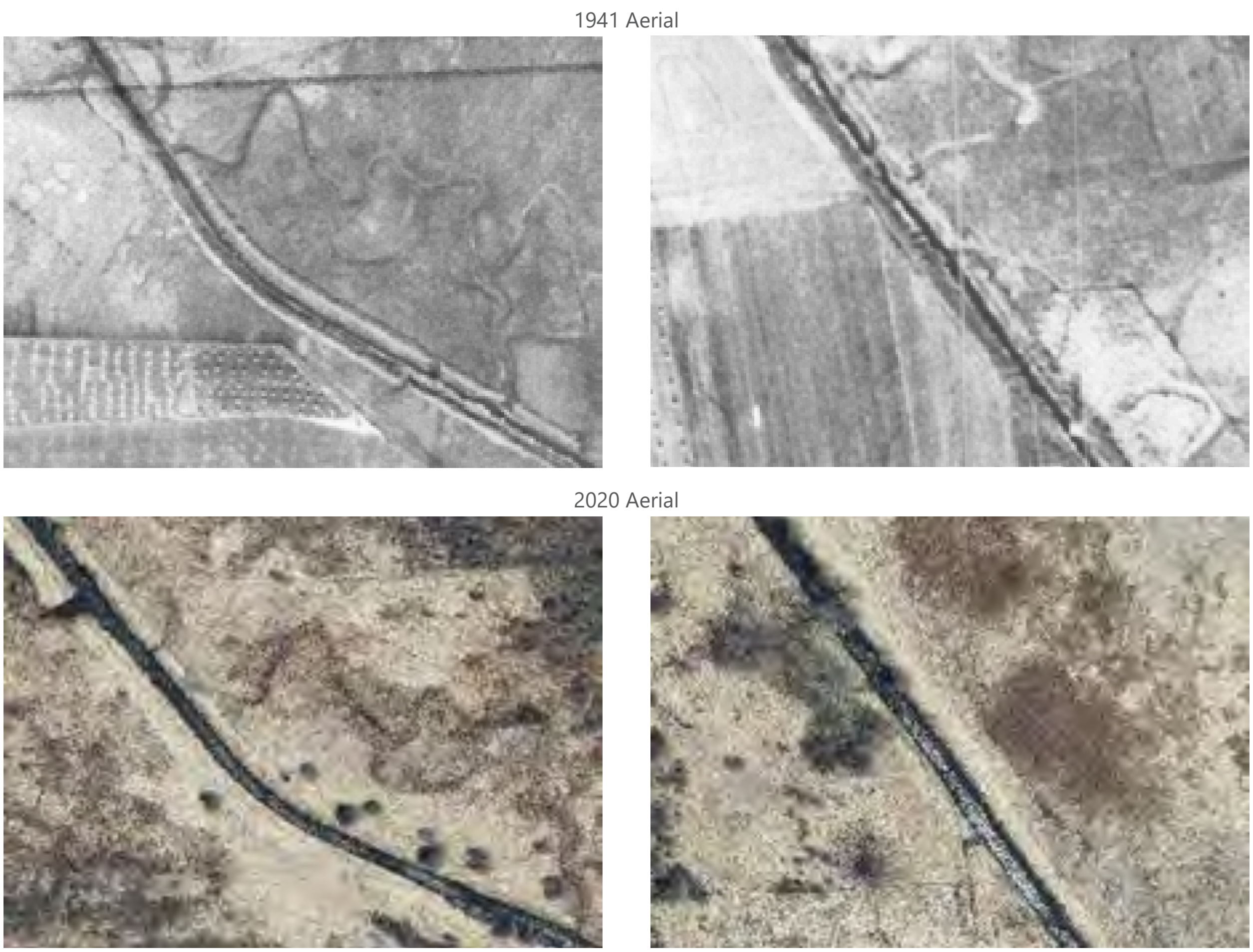
Figure 3.8
Schematic of a Two-Stage Design Channel



Note: The two-stage ditch design: a) Trapezoidal channel, with steep slopes, lack of floodplain connectivity, and drain tile, prior to floodplain restoration; b) restored two-stage ditch, with drain tiles cut back. The dark gray represents water levels during base flow and the light gray represents water levels during stormflow.

Source: Modified from S.S. Roley, J.L. Tank, and M.A. Williams, "Hydrologic Connectivity Increases Denitrification in the Hyporheic Zone and Restored Floodplains of an Agricultural Stream," Journal of Geophysical Research, *117(G3), p. 2, 2012 and SEWRPC*

Figure 3.9
Turtle Creek Potential Remadering Locations: 1941 Aerial and 2020 Aerial



Source: SEWRPC

➤ **Recommendation 5.5: Incorporate upland conservation and restoration targets into management and policy decisions**

Upland areas provide a wide range of ecosystem services but are often among the first targeted for urban development (Map 2.11). While most of the upland areas within the watershed have already been developed through agricultural or urban land uses, small areas of grassland and woodland remain scattered throughout the watershed. Protecting these areas should be assigned a medium priority.

➤ **Recommendation 5.6: Improve in-Lake aquatic habitat by maintaining and adding large woody debris and/or vegetative buffers along the Lake's edge**

As the majority of the Lake's shoreline remains naturally vegetated, adding additional woody habitat should be considered a low priority while maintaining existing woody habitat should be considered a medium priority. WDNR grant money is available through the Healthy Lakes and Rivers program on a competitive basis for implementing additional "fish sticks" projects.

➤ **Recommendation 5.7: Mitigate water quality stress on aquatic life and maximize the extent of areas habitable to desirable fish**

The primary ongoing in-Lake issue affecting aquatic organisms are excessively turbid water, elevated summer water temperatures, and oxygen supersaturation. The most direct route to reduce water quality stress on fish and other aquatic life is to take action to reduce phosphorus inputs to the Lake and thereby decrease overly abundant algae. This can be done by implementing recommendations noted in Sections 3.3, "Water Quality" and 3.5 "Aquatic Plants." Since the groundwater springs on the Lake's eastern shoreline provide cool, clear waters that are likely beneficial to the Lake's fish population, these springs should be preserved in a natural state and the groundwater recharge potential of the areas feeding these springs should be maintained. The water quantity and quality recommendations discussed earlier in this chapter would help protect these areas. Implementation of those recommendations should be considered a high priority to reduce stressors on aquatic life. Other stressors may develop in the future (e.g., new invasive species) and conditions should be carefully monitored for their impact on aquatic life (medium priority).

➤ **Recommendation 5.8: Mitigate streambank erosion**

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 conservation-minded stormwater management practices. Such actions are considered a low priority as streambank erosion does not appear to be a major source of sediment pollution in the watershed.

Fish Population Management

Lake Comus is locally recognized and enjoyed for its fishing opportunities. However, the Lake's abundant common carp population is detrimental to water quality, the aquatic plant community, and potentially the overall fishery. The following recommendations can help maintain healthy populations of fish and wildlife.

➤ **Recommendation 5.9: Reduce and control the Lake's carp population**

As discussed in Sections 3.3 "Water Quality" and 3.5 "Aquatic Plants", the watershed's abundant carp are likely contributing to the Lake's poor water clarity, depauperate aquatic plant community, and subsequently are likely affecting desirable fish species vigor and abundance. Given the abundant habitat suitable for carp upstream of the Lake, a carp eradication program focusing on the Lake successfully reduce carp populations. Barriers are impractical, restrict movement of desirable native fish populations, and generally inadvisable. For these reasons, eradicating common carp from Lake Comus is not a practical alternative.

Since eradicating common carp from Lake Comus is impractical, management efforts should focus on reducing the carp population to a level at which harmful effects are minimized. A study on a shallow Minnesota lake suggested that a carp density of 90 pounds per acre or greater can be detrimental to water quality and aquatic vegetation.[325] An effective long-term management strategy may begin with a large-scale removal technique, such as seining during a lake drawdown, to sharply reduce the adult population (see Section 2.6, "Fisheries" for more detail regarding removal techniques). This reduction should be followed with persistent predation pressure by maintaining a healthy population of native piscivorous fish that prey upon young carp, particularly bluegill and northern pike, as well as carp harvest bounties and/or carp tournaments. Lake-wide chemical treatments, e.g., using Rotenone, require a WDNR permit and are not recommended due to their non-selective impact on native fish species. Given the widespread and manifold effect of the carp population on the Lake, this recommendation should be considered a high priority.

- **Recommendation 5.10: Improve wildlife populations by encouraging best management practice adoption**

  This should be a medium priority, although this should increase to a high priority if wildlife populations decline. The acceptance and employment of BMPs can be fostered through voluntary, educational, or incentive-based programs for properties adjacent to the shoreline, and by directly implementing these practices on public and protected lands. Special interest non-governmental organizations ("NGOs", e.g., Pheasants Forever, Ducks Unlimited, etc.) exist to foster habitat improvement projects, some of which collaborate with landowners to install beneficial projects. When this recommendation is implemented, a complete list of BMPs and relevant NGOs should be compiled and provided to landowners.

- **Recommendation 5.11: Continue to monitor fish and wildlife populations**

  In general, tracking the diversity and abundance of fish and wildlife helps future Lake managers detect change. Consequently, continued monitoring of fish populations and periodic recording of the types of animals found on and in the Lake and within its watershed is also a medium priority. Monitoring data can be collected from government agencies, non-governmental organizations (e.g., Audubon Society), and from volunteers around the Lake and throughout the watershed.

Eastern Massasauga Rattlesnake and Other Rare Reptiles

The eastern Massasauga rattlesnake (EMR) (*Sisturus catenatus*, a state Endangered and federally Threatened species), Blanding's Turtle (*Emydoidea blandingii*, a state Special Concern species), and Queensnake (*Regina septemvittata*, a state Endangered species) have been observed and reported within and near the Lake Comus watershed. Landowners in the watershed, particularly those with wetland and riparian habitat on their property, should be aware of the EMR, Blanding's Turtle, and Queensnake as well as best management practices for maintaining and enhancing habitat for these protected reptiles as well as reducing accidental habitat or population loss. The following recommendations are provided to assist and educate landowners on best management practices for these species.

- **Recommendation 5.12: Follow WDNR and US Fish and Wildlife Service guidance on land management BMPs in potential EMR, Blanding's Turtle, and Queensnake habitat**

  The EMR requires early successional habitat but can also be susceptible to incidental mortality during the activities that preserve such habitat, like mowing and prescribed burning. Consequently, the WDNR and FWS published guidelines with best management practices to enhance EMR habitat and reduce incidental mortality during land management.[326,327] Using soil temperature information can help landowners conduct land management activities before EMR spring emergence and following fall dormancy to minimize incidental mortality. Following these guidelines should be considered a high priority.

  Blanding's turtles require shallow water with abundant aquatic vegetation – a habitat that is plentiful within the Lake Comus watershed. However, they prefer sandy, disturbed sites for nesting, which can lead to incidental mortality along roadways. WDNR guidance for this species suggests that implementing turtle barriers, particularly when combined with turtle-friendly underpasses and/or culverts, could reduce

[325] *P.G. Bajer, G. Sullivan, and P.W. Sorensen, "Effects of a Rapidly Increasing Population of Common Carp On Vegetative Cover and Waterfowl in a Recently Restored Midwestern Shallow Lake,"* Hydrobiologia 632(1): 235-245, 2009.

[326] *For more information regarding land management in Eastern Massasauga habitat, see dnr.wi.gov/topic/EndangeredResources/documents/LandManagementEasternMassasaugaHabitat.pdf.*

[327] *www.fws.gov/midwest/endangered/section7/bo/2018_Rangewide_EMRLandManagementByUSFWS06282018.pdf.*

road mortality and allow passage between habitats.[328] Burning and mowing in potential Blanding's turtle habitat areas should be conducted when the turtles are least likely to be using those areas (e.g., conduct work in nesting habitats during the non-nesting period).[329]

Queensnakes utilize riparian habitat alongside small to medium-sized, clear, spring-fed streams within Southeastern Wisconsin. Within the Lake Comus watershed, the most likely habitat for this species is along the small, spring-fed tributaries of Turtle Creek and Lake Comus in the eastern half of the watershed. As with the EMR and Blanding's Turtle, management activities like prescribed burning and mowing in potential Queensnake habitat should be conducted when the species is inactive. Riparian vegetation alongside these spring-fed streams should be preserved to the greatest extent possible.[330,331]

➤ **Recommendation 5.13: Consider impacts to EMR and Blanding's Turtle when considering water level manipulation for lake management**

Both the EMR and Blanding's turtles can be negatively affected by fluctuating water levels, particularly during late fall, winter, and early spring while EMR hibernate in cavities and Blanding's turtles remain under ice.[332,333] Prolonged flooding of cavities can cause loss of habitat with a subsequent decline in the EMR population. Winter drawdowns can reduce the amount ice-covered surface waters that Blanding's turtle utilize for overwinter habitat. In most instances, water levels should not be manipulated after early October or before April. If water level manipulation is utilized for other lake management activities, this manipulation should be appropriately timed to be of least impact to EMR and Blanding's turtle populations and habitat by following the WDNR and FWS guidelines referenced above. This recommendation should be considered a high priority.

3.7 RECREATIONAL USE AND FACILITIES

Lake Comus supports diverse recreational activities including birdwatching, fishing, hunting, and paddle sports. Maintaining the Lake's ability to provide safe, high-quality recreational pursuits is a priority issue. In support of this goal, the following recommendations are made.

➤ **Recommendation 6.1: Maintain and enhance fishing opportunities by protecting and improving aquatic habitat and water quality**

Fishing is one of the most popular activities for residents and visitors to Lake Comus. The Lake's fishery can be further enhanced by improving aquatic habitat, particularly the abundance of native aquatic vegetation, and water quality. This recommendation can be achieved by implementing the water quality recommendations provided in Section 3.3, "Water Quality" and the aquatic wildlife recommendations provided in Section 3.6, "Fish and Wildlife." This is a high priority issue.

➤ **Recommendation 6.2: Maintain public boat launch sites**

Launch site maintenance should be considered a medium priority. Maintenance should include incorporating management and maintenance activities that help reduce the chance of spreading invasive species. An example of one such activity would be deploying trained volunteers to inspect boats and distributing literature (Clean Boats, Clean Waters program) during high use periods. Such activities could help reduce the chance of spreading invasive species.

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[328] *For more information on WDNR guidance for Blanding's turtles, see Wisconsin Department of Natural Resources,* Wisconsin Blanding's Turtle Species Guidance, *Bureau of Natural Heritage Conservation, Wisconsin Department of Natural Resources, Madison, Wisconsin, PUB-ER-683, 2014*: www.*dnr.wi.gov/files/PDF/pubs/er/ER0683.pdf.*

[329] *In Wisconsin, Blanding's Turtles typically nest sometime between mid-May and mid-July.*

[330] *In Wisconsin, Queensnakes are commonly active between April and October.*

[331] *For more information on WDNR guidance for Queensnakes, see Wisconsin Department of Natural Resources,* Wisconsin Queensnake Species Guidance*, Bureau of Natural Heritage Conservation, Wisconsin Department of Natural Resources, Madison, Wisconsin, PUB-ER-673, 2012: www.dnr.wi.gov/files/PDF/pubs/er/ER0673.pdf.*

[332] Ibid.

[333] *WDNR, 2014,* op. cit.

- **Recommendation 6.3: Maintain natural shorelines in planned development**
  One of the most treasured aspects of Lake Comus is its largely natural shoreline. The lack of intensive development along the Lake and infrequent powerboating activity makes it ideal for recreational activities such as paddle sports, fishing, and watching wildlife. Ensuring that planned development does not disrupt these activities by protecting the Lake's natural shorelines should be considered a high priority.

- **Recommendation 6.4: Incorporate the City of Delavan's planned recreational facilities**
  The Downtown Delavan Strategic Plan envisions Lake Comus as a regional hub for water sports, such as kayaking and canoeing, as well as a greater connection between downtown Delavan and the lakefront.[334] As discussed in Chapter 2, this vision calls for developing recreational facilities in Veterans Memorial Park (across Terrace Street from the Lake) as well as the creating a walking trail and boardwalk along the western and southern shores of the Lake. Given that the Lake's shoreline is largely undeveloped wetland suitable for such activities and that Turtle Creek downstream of the Lake is already quite popular with paddlers, these facilities would further enhance the capacity of residents as well as regional visitors to recreate on the Lake and the Creek. Enhancing the water quality, fishery, and wildlife habitat in and around the Lake would further enhance recreational paddling. Implementing the strategic vision and actions recommended in the Downtown Delavan Strategic Plan should be considered a high priority.

- **Recommendation 6.5: Enhance public access with a walkway as part of the dam replacement project**
  As discussed earlier in Section 3.2, "Hydrology, Water Quantity, and Water Resource Infrastructure", the City of Delavan plans to replace the Lake Comus outlet dam, providing opportunities to enhance recreation and public access integrated directly into the new dam design. The City of Delavan and LCPRD envision greater access to the Paul Lange Arboretum and the Lake Comus boat launch from downtown Delavan, as outlined in the Downtown Delavan Strategic Plan.[335] There is currently no walkway over the existing Lake Comus outlet dam, limiting pedestrian access across the dam to the trafficked portion of North Terrace Street. A dedicated pedestrian walkway should be installed during dam replacement to facilitate pedestrian access between downtown Delavan and the Lake Comus boat launch and Arboretum. This recommendation should be considered a high priority.

- **Recommendation 6.6: Develop and improve walkway and parkway along western shoreline**
  Continuing the goal of enhancing pedestrian access between downtown Delavan and Arboretum, the walkway along the western shoreline of Lake Comus should be more fully developed to better facilitate pedestrian traffic.[336] While a sidewalk already exists on the western side of North Terrace Street, developing a walkway on the eastern side of the road would allow safer access to the Arboretum and boat launch using the dam walkway discussed in Recommendation 6.5. This recommendation should be considered a high priority.

- **Recommendation 6.7: Collaborate with the City of Delavan to develop planned lakeshore trail**
  The Downtown Delavan Strategic Plan calls for developing a lakeshore trail extending along the southern and eastern shoreline of the Lake.[337] This lakeshore trail would pass through privately owned parcels by way of a trail easement. Collaborating with the City of Delavan on developing the lakeshore trail has been identified as a medium priority.

- **Recommendation 6.8: Create a designated portage route as part of outlet dam replacement**
  To further encourage paddle sport recreation on Lake Comus, and to better connect with the already popular canoeing and kayaking route downstream of the Lake, a formalized portage route for canoes and kayaks could be created during outlet dam replacement. One potential option is to add a dock downstream of the dam, a cement staircase and/or ramp to connect to the sidewalk on the western side of North Terrace Street, a marked crosswalk to more easily cross North Terrace Street, and then connect

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[334] *City of Delavan and Vandewalle & Associates, Inc.*, Downtown Delavan Strategic Plan: City of Delavan, Wisconsin, *May 2013.*

[335] Ibid.

[336] Ibid.

[337] Ibid.

to the planned lakeshore trail on the eastern side of North Terrace Street (Figure 3.10). The LCPRD and City of Delavan should consider meeting with local paddling groups, such as the Friends of Turtle Creek, to get their insight and input on this recommendation and other potential improvements (e.g., portage route around the low-head dam downstream of the dam operated by the Walworth County Metropolitan Sewerage District) for paddle sport recreation on Turtle Creek downstream of the outlet dam.[338] Incorporating consideration of the formalized portage route into the dam design process should be given a high priority. Implementing this recommendation is a medium priority.

➤ **Recommendation 6.9: Enhance shoreline erosion protection, particularly along Paul Lange Arboretum**

The LCPRD and City of Delavan have expressed concern regarding shoreline erosion along the Paul Lange Arboretum on the northwestern shore of the Lake. Comparing aerial imagery and field surveys determined that shoreline erosion was notable along the Paul Lange Arboretum and localized erosion has occurred in the southeastern corner of the Lake. A 2019 shoreline inventory identified approximately 2,200 linear feet of unprotected shoreline in these areas (Map 2.22). Due to low wave activity on Lake Comus, techniques that incorporate both riparian and aquatic vegetation and low-lying structural surfaces, such as edging and sills, may be sufficient to protect the Arboretum's shoreline from further deterioration (Appendix A).[339] However, this should be verified with further survey of the shoreline's condition. Furthermore, since the Arboretum property was once used for disposing of solid waste, the lakeshore should be inspected to assure that no waste is exposed or could be potentially exposed by future erosion. The LCPRD can apply for a shoreland protection project under the Surface Water Restoration subprogram of the WDNR Surface Water Grants program to help fund this effort (Table 3.4). This recommendation is a high priority.

3.8 PLAN IMPLEMENTATION

The methods to implement this plan vary with recommendation type, with efforts required, and can be achieved by education and outreach, ordinances and regulations, as well as partnership and collaboration. This section provides recommendations on how to successfully implement projects and recommendations provided in the management plan.

Awareness, Education, and Outreach

One of the most effective ways to promote plan implementation is educating lake residents, users, and governing bodies regarding the content of this plan. The following recommendations are intended to increase awareness of the management plan, engage interested parties, and encourage outreach that can lead to potential partnerships and collaboration.

➤ **Recommendation 7.1: Integrate lake users and residents into management efforts**

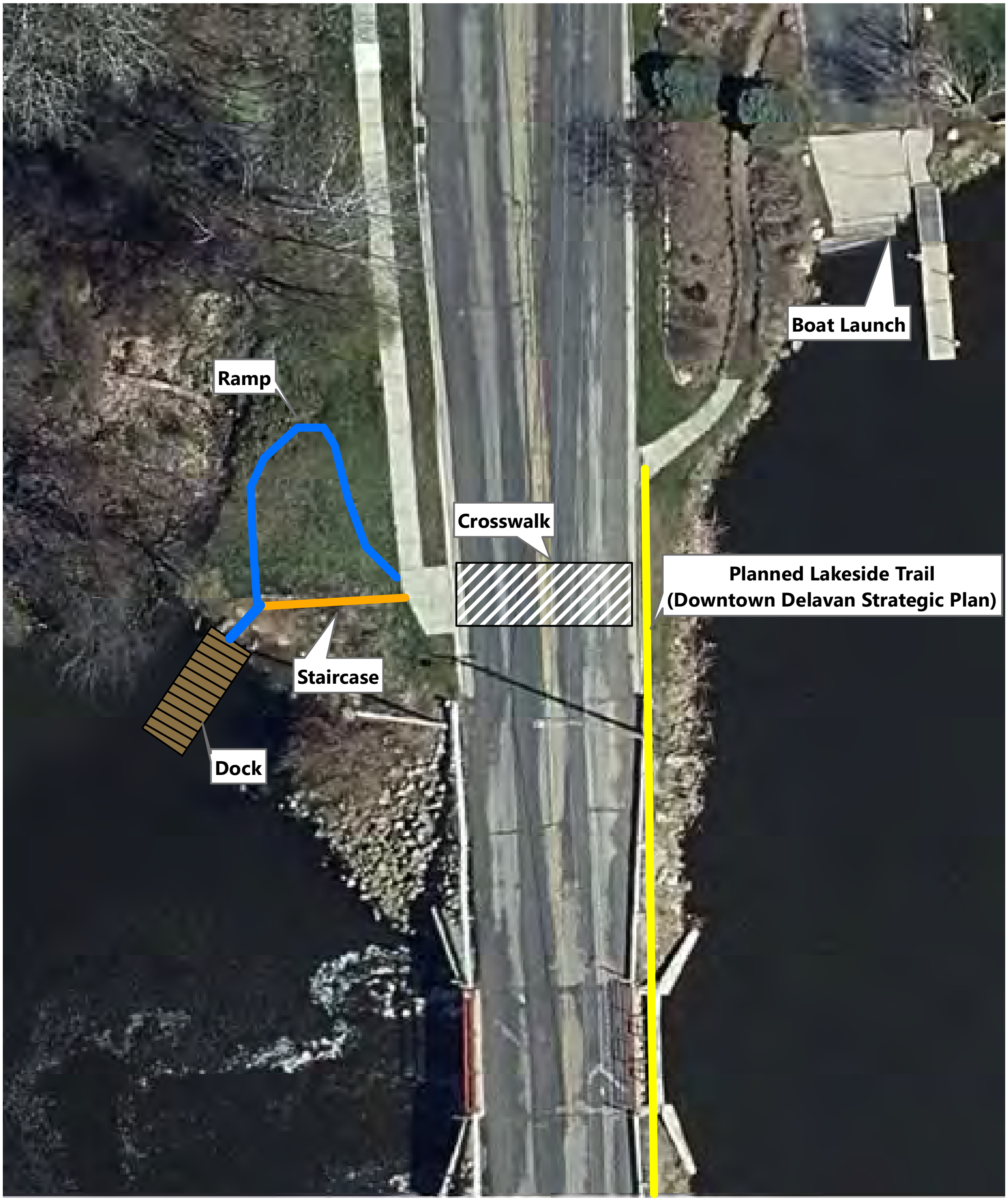
This is recommended as a high priority. The aim of this effort is to add to the donor and volunteer base working toward improving the Lake, improving community buy-in, and receiving greater community input on lake planning and management decisions. Private donations and volunteer time can be used as cost match for some grants.

As part of this effort, the LCPRD and the Commission will share this management plan for public comment and will strive to incorporate these comments as feasible into the plan. The LCPRD will be hosting a special meeting in spring 2023 to present the plan and expects to receive public comments at that time. Additionally, the Commission will host the plan on their website with an option to provide public comment; this option will remain open until the completion of the LCPRD's meeting. All public comments received either through the Commission's website or the LCPRD meeting process will be compiled in Appendix B of this plan.

[338] *For more information, see the Friends of Turtle Creek webpage: www.friendsofturtlecreek.com/*

[339] *See NRCS Technical Guide,* Streambank and Shoreline Protection Standard 580, *2018.*

Figure 3.10
Potential Canoe and Kayak Portage Route Around Lake Comus Outlet Dam



Note: This illustration is only provided as a general concept and should not be used for construction planning purposes.

Source: SEWRPC

- **Recommendation 7.2: Encourage key players to attend meetings, conferences, and/or training programs to build their lake management knowledge**
  These actions as recommended as a medium priority as they will enhance institutional capacity. Some examples of capacity-building events are Wisconsin Water Week (which targets local lake managers) and the "Lake Leaders" training program (which teaches the basics of lake management and provides ongoing resources to lake managers). Both are hosted by University of Wisconsin Stevens Point Extension Lakes.[340] Additionally, courses, workshops, on-line training, regional summits, and general meetings can also be used for this purpose. Another excellent local source of good information for pursuing soil health initiatives includes attending free meetings and field demonstrations sponsored by producer-led groups.[341] Attendance at these events should include follow-up documents and meetings so that the lessons learned by the attendee can be shared with the larger lake group.

- **Recommendation 7.3: Continue to ensure inclusivity and transparency with respect to all Lake management activities**
  If stakeholders do not fully understand the aims and goals of a project, or if they do not trust the process, excess energy can be devoted to conflict, a result that benefits no one. For this reason, this element is assigned high priority. These efforts should be implemented through public meetings and consensus building so that conflicts can be discussed, addressed, and mitigated before implementing projects.

- **Recommendation 7.4: Foster and monitor management efforts to communicate actions and achievements to future lake managers**
  Institutional knowledge is a powerful tool that should be preserved whenever possible. Actions associated with this are sometimes embedded in organization bylaws (e.g., minutes) and are therefore assigned medium priority. Open communication helps increase the capacity of lake management entities. This may take the form of annual meetings, websites, newsletters, emails, reports, and any number of other means that help compile and report action, plans, successes, and lessons learned. These records should be kept for future generations and made publicly accessible.

- **Recommendation 7.5: Consider installing "Turtle Creek," "This is Our Watershed," and "Adopt a Highway" signage throughout the watershed**
  Such signs should be placed where public roadways cross Turtle Creek and its major tributaries, along the Lake's watershed boundaries, and along major transportation routes. Such signs act help raise awareness for environmental concerns. Increased awareness usually leads to increased involvement as more of the public begins to see themselves as stakeholders in maintaining the quality of the natural resources around them. This is recommendation is assigned a medium priority.

- **Recommendation 7.6: Increase visibility of Lake Comus on City of Delavan website**
  Lake Comus is entirely within the City of Delavan boundaries and the City is interested in promoting recreational and tourism opportunities on the Lake. However, very little information regarding the Lake is found on the City's website to make residents and visitors aware of the Lake resources and its recreational opportunities. Adding a link to information regarding the lake and highlighting recreational opportunities on the web page banner could help increase the Lake's public visibility. This is recommended as a medium priority.

Ordinances and Regulations

Several important recommendations relate to enforcing current ordinances (e.g., shoreline setbacks, zoning, construction site erosion control, and boating). Public agencies often have limited resources available to monitor compliance and affect enforcement. Consequently, the following recommendations are aimed at local citizens and management groups and are made to enhance the ability of responsible entities to monitor compliance and enforce regulations.

[340] *www.uwsp.edu/cnr-ap/UWEXLakes/Pages/default.aspx*

[341] *The closest producer-led group meetings are held by the Watershed Protection Committee of Racine County. A link to their website follows: www.wpcracinecounty.org/.*

- **Recommendation 7.7: Actively share this plan and work with municipalities to adopt it by maintaining and enhancing relationships with County, municipal zoning administrators, directors of public works/municipal engineers, and law enforcement officers**
  This helps build open relationships with responsible entities and facilitates efficient communication and collaboration whenever needed. This should be assigned a high priority.

- **Recommendation 7.8: Keep abreast of activities within the watershed that can affect the Lake**
  Certain activities (e.g., construction, filling, excessive erosion) could potentially affect the Lake. This initiative includes maintaining good records (e.g., notes, photographs) and judiciously notifying relevant regulatory entities of problems when deemed appropriate. Given the modest amount of such activity known in the watershed, this is currently assigned a low priority. If flagrant violation of existing ordinances becomes commonplace, this should be assigned a high priority.

- **Recommendation 7.9: Educate watershed residents about relevant ordinances. Update ordinances as necessary to face evolving use problems and threats**
  This helps assure that residents know why rules are important, that permits are required for almost all significant grading or construction, and that such permits offer opportunity to regulate activities that could harm the Lake. This should be considered a medium priority.

Partnership and Collaboration

Numerous opportunities exist for partnership and collaboration to improve water quality within the watershed. The following recommendations provide ideas and collaboration opportunities intended to inspire further action.

- **Recommendation 7.10: Encourage formation and growth of producer-led group covering the watershed**
  Producer-led watershed groups are a recent innovation that has greatly enhanced the ability to actively promote sustainable agriculture and allied conservation practices in Wisconsin. Producer-led groups sponsor programs that endeavor to improve soil health, water quality, and farm profitability by a variety of means, including the following examples.

  - Recruiting producers to apply for and install low-cost conservation BMPs to improve soil and water quality
  - Providing education and outreach (field days, workshops, tours) to area producers about the principles of soil health, soil improvement practices, equipment use, and water quality improvement conservation practices
  - Collectively leasing or buying novel equipment and sharing ideas for modifying existing equipment
  - Improving the image of agriculture by showcasing various local producer leaders, outreach activities, farms and/or fields through signage, and being active in the community promoting good farming practices

  The LCPRD and/or other interested organizations are highly encouraged to actively support the formation and growth of producer-led initiative covering the Turtle Creek watershed. The LCPRD should collaborate with Walworth County and their Producer-Led Group Coordinator, as well as others in nearby Rock River basin watersheds, to support creation of a producer-led group covering the Turtle Creek watershed. Some conservation-themed organizations, with goals like the LCPRD, actively support local producer-led groups by offering financial and logistical support to the initiative. Examples of financial support include stipends to offset tuition and fees associated with key educational events; hosting educational and outreach events; purchasing key equipment (which is often a barrier to initiating soil health practices) and leasing this equipment to producers; and offering subsidies to help offset the cost and financial risk of initiating conservation practices on farm fields. This is recommended as a high priority.

- **Recommendation 7.11: Consider inter-governmental agreements with neighboring municipalities**
  The LCPRD has opportunities to create partnerships with other local government units through inter-government agreements. As previously discussed, the LCPRD is already working closely with the City of Delavan to enhance recreational opportunities in and along Lake Comus and to more closely tie the waterfront with downtown Delavan. Regarding dredging, the Town of Delavan is currently dredging the Mound Road ponds and will continue to periodically dredge them into the foreseeable future. The LCPRD could create an inter-governmental agreement to mobilize dredging equipment to Delavan and dispose of spoil material. Exploring options via inter-government agreements is recommended as a medium priority.

- **Recommendation 7.12: Foster open relationships with potential project partners**
  Continue to partner with and maintain good relations with volunteer groups, municipalities, and governing bodies, which promotes effective solutions to issues shared. This is recommended as a high priority.

- **Recommendation 7.13: Apply for available grants to support implementing programs recommended as part of this plan**
  The LCPRD, City of Delavan, Walworth County, and/or other local units of government may apply for grants from WDNR to control non-point source pollution and meet the TMDL load allocation as well as for other surface water related projects. The WDNR, DATPC, and the Federal government support nonpoint source pollution abatement by administering and providing cost-sharing grants to fund BMPs through various grant programs (Table 3.4 and "Funding Sources" subsection below). Sponsoring and applying for such grants is potentially the most important avenue for the LCPRD to implement recommended BMPs within the Lake Comus watershed. Having multiple collaborators providing external funding support, including equipment, volunteer hours, and cash, enhances the odds of a successful WDNR grant application. This is recommended as a high priority.

Funding Sources

The following subsection briefly describes potential State and Federal funding sources available to help fund BMPs and other plan recommendations in the watershed. This is not an exhaustive list. However, the list but does include some of the more common funding sources.

State

- **Surface Water Grant Program (SWG)** – A WDNR program that offers competitive grants for local governments, counties, lake districts, and other eligible organizations to address a range of surface-water issues.[342] Several subprograms could be useful for implementing plan recommendations and that the LCPRD, City of Delavan, and Walworth County could sponsor. These subprograms include:

  - **Surface Water Restoration** – Provides funds to implement shoreline, in-water, and wetland restoration projects that follow appropriate NRCS guidelines as well as funding to develop ordinances that protect surface water resources. Cost-share is up to 75 percent of eligible costs for up to $75,000 for lakes and $50,000 for rivers.

  - **Management Plan Implementation** – Provides funds to implement recommendations in a WDNR-approved surface water management plan. Eligible projects include nonpoint source pollution control, habitat restoration, water quality improvements, landowner incentives, and management staffing. Cost-share is up to 75 percent of eligible costs for up to $200,000 for lakes and $50,000 for rivers.

  - **Healthy Lakes and Rivers** – Provides funding to implement approved best practices for shoreland landowners following technical guidance. Practices include fish sticks, native plantings, water diversions, rain gardens, and rock infiltration. Cost-share is up to 75 percent of eligible costs for up to $25,000.

[342] *For more information on the WDNR Surface Water Grant program, see dnr.wisconsin.gov/aid/SurfaceWater.html and Wisconsin Department of Natural Resources,* 2021 DNR Surface Water Grant Application Guide, *July 2021*: dnr.wi.gov/files/pdf/pubs/cf/CF0002.pdf.

- **Clean Boats, Clean Waters** – Provides funding to help prevent spread of aquatic invasive species through education and monitoring at boat launches. Eligible costs include supplies, training, and payment to any paid staff or in-kind donations from volunteers. Cost-share is up to 75 percent of eligible costs for up to $4,000 per boat launch.

- **Land Acquisition** – Provides funding to permanently acquire land to protect surface waters. Eligible costs including costs associated with appraisal, land survey fees, title costs, and any historical, cultural, or environmental assessments. Cost-share is up to 75 percent of eligible costs for up to $200,000 for lakes and $50,000 for rivers.

- **Targeted Runoff Management (TRM) Grant Program** – WDNR program that offers competitive grants for local governments for controlling nonpoint source pollution. Grants reimburse costs for agricultural or urban runoff management practices in critical areas with surface water or groundwater quality concerns. The cost-share rate for TRM projects is up to 70 percent of eligible costs.[343]

- **Soil and Water Resources Management Grant Program** - DATCP program that provides funds to Counties allowing them to enter cost-share contracts with landowners implementing eligible conservation practices. The cost-share rate depends on the conservation practice being implemented but can be up to 70 percent for practices associated with NR 151 performance standards and up to 90 percent if the landowner qualifies for economic hardship. Practices required as part of a CAFO or other WPDES permit are ineligible for cost-sharing.[344]

- **Farmland Preservation Program** – DATCP program that provides a tax credit per acre to eligible farmlands complying with NR 151 agricultural performance standards. Tax credits can vary from $5.00 to $10.00 per acre, depending on the zoning status of the farmland.[345] As discussed in Section 3.4, "Pollutant and Sediment Sources and Loads," cultivated lands within the Lake Comus watershed are zoned for farmland preservation and thus eligible farms can receive a $7.50 per acre tax credit if in compliance with NR 151.

- **Notice of Intent/Discharge Grant Program** – Joint WDNR and DATCP program that provides funds to local governmental units working with livestock operation owners and/or operators that have received a Notice of Discharge or Notice of Intent to Issue a Notice of Discharge from WDNR. Eligible BMPs include those designed to improve water quality affected by livestock pollutant discharge. The cost-share rate for these projects is up to 70 percent of eligible costs.[346]

Federal

- **Environmental Quality Incentives Program (EQIP)** – USDA NRCS program that provides financial and technical assistance to implement conservation practices addressing natural resource concerns.[347] Farmers receive flat rate payments for installing and implementing runoff management practices. The following agricultural practices are eligible for cost sharing:
  - Cover crop
  - Critical Area Planting
  - Diversion
  - Fence
  - Field Border
  - Filter Strip
  - Forage and Biomass Planting
  - Grade Stabilization Structure

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[343] *For more information on TRM, see dnr.wisconsin.gov/aid/TargetedRunoff.html.*

[344] *For more information, see www.datcp.wi.gov/Pages/Programs_Services/SWRMGrantResources.aspx.*

[345] *For more information, see www.datcp.wi.gov/Pages/Programs_Services/FarmlandPreservation.aspx.*

[346] *For more information, see dnr.wisconsin.gov/aid/NOD.html.*

[347] *For more information on EQIP, see www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip.*

- Grassed Waterway
- Heavy Use Area Protection
- Lined Waterway or Outlet
- Livestock Pipeline
- Mulching
- Obstruction Removal
- Prescribed Grazing
- Streambank and Shoreline Protection
- Strip Cropping
- Surface for Water Control
- Subsurface Drain
- Terrace
- Trails and Walkways
- Tree/Shrub Establishment
- Tree/Shrub Site Preparation
- Underground Outlet
- Vegetated Treatment Area
- Water and Sediment Control Basin
- Water Well
- Watering Facility
- Wetland Restoration

- **Conservation Reserve Program (CRP)** – A land conservation program administered by the USDA Farm Service Agency. Farmers enrolled in the program receive a yearly rental payment for environmentally sensitive land that they agree to remove from production. Contracts are 10 to 15 years in length. Eligible practices include buffers for wildlife habitat, wetland buffers, riparian buffers, wetland restoration, filter strips, grass waterways, shelter belts, living snow fences, contour grass strips, woodland establishment, and shallow water areas for wildlife.[348]

- **Conservation Reserve Enhancement Program (CREP)** – Joint effort between County, State, and the Federal government providing funds for practice installation, rental payments, and an installation incentive. Administered by the Farm Service Agency. Interested parties can enter a 15-year contract or perpetual contract conservation easement. Eligible practices include filter strips, buffer strips, wetland restoration, tall grass prairie and oak savanna restoration, grassed waterway, and permanent native grasses.[349]

- **Agricultural Conservation Easement Program (ACEP)** – USDA NRCS program that consolidates three former programs (Wetlands Reserve Program, Grassland Reserve Program, and Farm and Ranchlands Protection Program). Under this program, NRCS provides financial assistance to eligible partners for purchasing Agricultural Land Easements that protect the agricultural use and conservation values of eligible land.[350]

- **Conservation Stewardship Program (CSP)** – USDA NRCS program that offers funding for participants that take additional steps to improve resource condition. Program provides two types of funding through five-year contracts: 1) annual payments for installing new practices and maintaining existing practices and 2) supplemental payments for adopting a resource-conserving crop rotation.[351]

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[348] *For more information on CRP, see www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program.*

[349] *For more information on CREP, see www.datcp.wi.gov/Pages/Programs_Services/CREPLandowners.aspx.*

[350] *For more information on ACEP, see www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/acep.*

[351] *For more information on CSP, see www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp.*

- **Farmable Wetlands Program (FWP)** – USDA Farm Service Agency program designed to restore previously farmed wetlands and wetland buffer to improve both vegetation and water flow. The Farm Service Agency runs the program through the Conservation Reserve Program with assistance from other government agencies and local conservation groups.[352]

- **Aquatic Ecosystem Restoration Program (AERP)** – United States Army Corps of Engineers (USACE) program to plan, design, and implement aquatic ecosystem restoration projects located in the public interest and that have a non-federal public agency sponsor willing to maintain and rehabilitate the project site.[353]

- **Partners for Fish and Wildlife Program** – United Stated Fish & Wildlife Service program providing technical assistance and cost-share funding to incentivize fish and wildlife habitat restoration on privately owned lands.[354]

Non-Governmental Organizations

- **Kettle Moraine Land Trust** – Non-profit land trust based in East Troy, Wisconsin that works to preserve high-quality natural habitats through land acquisition, conservation easements, and partnerships with Walworth County and WDNR.

- **Wisconsin Waterfowl Association** – Non-profit organization focused on conserving and restoring wetland and waterfowl habitat in Wisconsin. Among other activities, the Wisconsin Waterfowl Association provides technical expertise on project design and grant funding opportunities as well as a potential funding match to other funding sources.[355]

Plan Implementation Timeline

Watershed restoration, particularly with heavily modified ecosystems, is a long-term process that requires sustained effort and engagement from all stakeholders. The LCPRD, Walworth County, WDNR, and other partners have already been active in recognizing the challenges facing the watershed and implementing many plan recommendations. Improvements in the condition of natural resource features may not be immediately apparent due to legacy effects from nearly two centuries of hydrologic modification, pollutant loading, habitat loss, invasive species introductions, and changes in climate. Consequently, continued monitoring of more rapidly responding conditions, such as water quality, macroinvertebrates, and aquatic plants, paired with semi- to annual meetings with stakeholders regarding plan progress is highly recommended.

Tracking progress on recommendation implementation, particularly those focused on non-point source pollutant loading outlined in Table 3.3 and Section 3.4, "Pollutant and Sediment Sources and Loads," should be a major focus of stakeholder meetings. As lake management plans are considered active for ten years after WDNR approval, annual target for acreages and linear feet of recommended BMPs in Table 3.3 can be easily calculated by dividing the recommended total quantity by ten (e.g., 2,510 acres of no-till over ten years would require 251 acres per year). However, these improvements are unlikely to occur in such a linear fashion due to challenges in acquiring the necessary funding, ability to identify willing partners, and the time required to design and construct some recommended BMPs. Progress is more likely to occur in a staggered or steplike fashion as grants are secured, watershed collaborators identified, and as management activities are permitted. The LCPRD and other stakeholders need to remain fully engaged in the process of identifying willing partners and managing available funds with the goal of implementing improvements in higher priority areas (e.g., as identified on Map 3.4).

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[352] *For more information on FWP, see www.fsa.usda.gov/programs-and-services/conservation-programs/farmable-wetlands/index.*

[353] *For more information on AERP, see www.sas.usace.army.mil/Missions/CAP/Section-206-Aquatic-Ecosystem-Restoration/.*

[354] *For more information on the Partners for Fish and Wildlife Program, see www.fws.gov/midwest/partners/getinvolved.html#a.*

[355] *For more information on the Wisconsin Waterfowl Association, see https://www.wisducks.org/.*

3.9 SUMMARY

The future will bring change to Lake Comus and its watershed. It is critical that proactive measures be pursued to lay the groundwork for effectively dealing with and benefiting from future change. Working relationships with appropriate local, County, and State entities need to be nurtured now and, in the future, to help protect critical natural areas in the watershed during development, to initiate actions, and to instill attitudes among current and future residents fostering cooperation and coordination of effort on many levels.

To help implement plan recommendations, Table 3.1 summarizes all recommendations and their suggested priority level. The maps referenced in this chapter indicate where recommendations should be implemented. These guides will provide current and future Lake Comus managers with a visual overview of where to target management efforts.

As stated in the introduction, this chapter is intended to stimulate ideas and action. Therefore, these recommendations should provide a starting point for addressing the issues identified in Lake Comus and its watershed. Successfully implementing this plan requires vigilance, cooperation, and enthusiasm, not only from local management groups, but also from State and regional agencies, Walworth County, municipalities, and Lake residents, Lake users, and the public. Implementation of the recommended measures will provide the water quality and habitat protection necessary to maintain or establish conditions in the watershed that are suitable for maintaining and improving the natural beauty and ambiance of Lake Comus and its ecosystem. This, in turn, benefits the Region today and in the future.

APPENDICES

NATURAL AND STRUCTURAL MEASURES FOR SHORELINE STABILIZATION

APPENDIX A

RESILIENT SHORELINES

SAGE

THRIVING COMMUNITIES

Natural and Structural Measures for Shoreline Stabilization

Living Shorelines

Innovative approaches are necessary as our coastal communities and shorelines are facing escalating risks from more powerful storms, accelerated sea-level rise, and changing precipitation patterns that can result in dramatic economic losses. While the threats of these events may be inevitable, understanding how to adapt to the impact is important as we explore how solutions will ensure the resilience of our coastal communities and shorelines.

This brochure presents a continuum of green to gray shoreline stabilization techniques, highlighting Living Shorelines, that help reduce coastal risks and improve resiliency though an integrated approach that draws from the full array of coastal risk reduction measures.

Coastal Risk Reduction and Living Shorelines

Coastal Risk Reduction

Coastal systems typically include both natural habitats and man-made structural features. The relationships and interactions among these features are important variables in determining coastal vulnerability, reliability, risk and resilience.

Coastal risk reduction can be achieved through several approaches, which may be used in combination with each other. Options for coastal risk reduction include:

- Natural or nature-based measures: Natural features are created through the action of physical, biological, geologic, and chemical processes operating in nature, and include marshes, dunes and oyster reefs. Nature-based features are created by human design, engineering, and construction to mimic nature. A living shoreline is an example of a nature-based feature.
- Structural measures: Structural measures include sea walls, groins and breakwaters. These features reduce coastal risks by decreasing shoreline erosion, wave damage, and flooding.
- Non-structural measures: Includes modifications in public policy, management practices, regulatory policy and pricing policy (e.g., structure acquisitions or relocations, flood proofing of structures, implementing flood warning systems, flood preparedness planning, establishment of land use regulations, emergency response plans).

The types of risk reduction measures employed depend upon the geophysical setting, the desired level of risk reduction, objectives, cost, reliability, and other factors.

SAGE – Systems Approach to Geomorphic Engineering

USACE and NOAA recognize the value of an integrated approach to risk reduction through the incorporation of natural and nature-based features in addition to non-structural and structural measures to improve social, economic, and ecosystem resilience. To promote this approach, USACE and NOAA have engaged partners and stakeholders in a community of practice called SAGE, or a Systems Approach to Geomorphic Engineering. This community of practice provides a forum to discuss science and policy that can support and advance a systems approach to implementing risk reduction measures that both sustain a healthy environment and create a resilient shoreline.

SAGE promotes a hybrid engineering approach that integrates soft or 'green' natural and nature-based measures, with hard or 'gray' structural ones at the landscape scale. These stabilization solutions include "living shoreline" approaches which integrate living components, such as plantings, with structural techniques, such as seawalls or breakwaters.

Living Shorelines achieve multiple goals, such as:

- Stabilizing the shoreline and reducing current rates of shoreline erosion and storm damage;
- Providing ecosystem services (such as habitat for fish and other aquatic species) and increasing flood storage capacity; and
- Maintaining connections between land and water ecosystems to enhance resilience.

In order to determine the most appropriate shoreline protection technique, several site-specific conditions must be assessed. The following coastal conditions, along with other factors, are used to determine the combinations of green and gray solutions for a particular shoreline.

REACH: A longshore segment of a shoreline where influences and impacts, such as wind direction, wave energy, littoral transport, etc. mutually interact.

RESILIENCE: The ability to avoid, minimize, withstand, and recover from the effects of adversity, whether natural or man made, under all circumstances of use. This definition also applies to engineering (i), ecological (ii), and community resilience (iii).

FETCH: A cross shore distance along open water over which wind blows to generate waves. For any given shore, there may be several fetch distances depending on predominant wind direction.

PHYSICAL CONDITIONS: The slope of the foreshore or beach face, a geologic condition or bathymetry offshore.

TIDAL RANGE: The vertical difference between high tide and low tide.

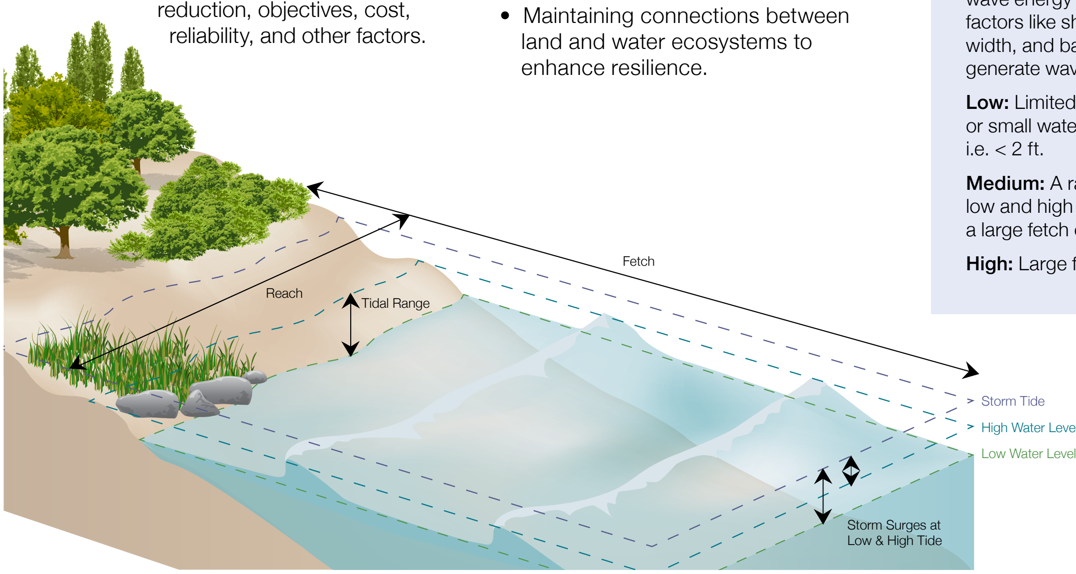
STORM SURGE: The resulting temporary rise in sea level due to the action of wind stress on the water surface and low atmospheric pressure created during storms which can cause coastal flooding. Surge is the difference from expected tide level. Storm tide is the total water level.

WAVE ENERGY: Wave energy is related to wave height and describes the force a wave is likely to have on a shoreline. Different environments will have lower or higher wave energy depending on environmental factors like shore orientation, wind, channel width, and bathymetry. Boat wakes can also generate waves.

Low: Limited fetch in a sheltered, shallow or small water body (estuary, river, bay) i.e. < 2 ft.

Medium: A range that combines elements of low and high energy (e.g., shallow water with a large fetch or partially sheltered) i.e. 2 - 5 ft.

High: Large fetch, deep water (open ocean).



HOW GREEN OR GRAY SHOULD YOUR SHORELINE SOLUTION BE?

GREEN - SOFTER TECHNIQUES

Small Waves | Small Fetch | Gentle Slope | Sheltered Coast

LIVING SHORELINE

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VEGETATION ONLY

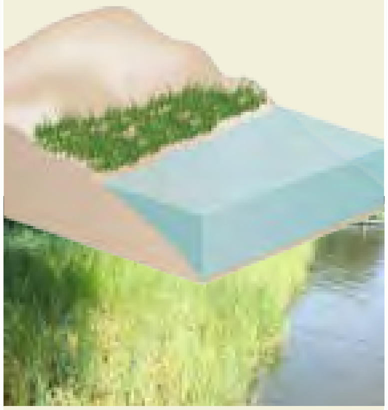

Photo Credit: Maryland Department of Natural Resources - Shoreline Conservation Service

Roots hold soil in place to reduce erosion. Provides a buffer to upland areas and breaks small waves.

Suitable For

Low wave energy environments.

Material Options

- Native plants*

Benefits

- Dissipates wave energy
- Slows inland water transfer
- Increases natural storm water infiltration
- Provides habitat and ecosystem services
- Minimal impact to natural community and ecosystem processes
- Maintains aquatic/terrestrial interface and connectivity
- Flood water storage

Disadvantages

- No storm surge reduction ability
- No high water protection
- Appropriate in limited situations
- Uncertainty of successful vegetation growth and competition with invasive

Initial Construction: ●
Operations & Maintenance: ●

EDGING

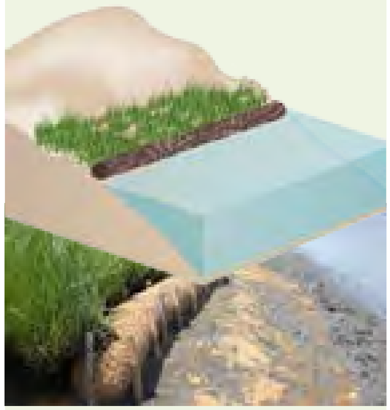

Photo Credit: Partnership for Delaware Estuary

Structure to hold the toe of existing or vegetated slope in place. Protects against shoreline erosion.

Suitable For

Most areas except high wave energy environments.

Vegetation* Base with Material Options

(low wave only, temporary)

- "Snow" fencing
- Erosion control blankets
- Geotextile tubes
- Living reef (oyster/mussel)
- Rock gabion baskets

Benefits

- Dissipates wave energy
- Slows inland water transfer
- Provides habitat and ecosystem services
- Increases natural storm water infiltration
- Toe protection helps prevent wetland edge loss

Disadvantages

- No high water protection
- Uncertainty of successful vegetation growth and competition with invasive

Initial Construction: ●●
Operations & Maintenance: ●

SILLS

Photo Credit: Maryland Department of Natural Resources - Shoreline Conservation Service

Parallel to existing or vegetated shoreline, reduces wave energy and prevents erosion. A gapped approach would allow habitat connectivity, greater tidal exchange, and better waterfront access.

Suitable For

Most areas except high wave energy environments.

Vegetation* Base with Material Options

- Stone
- Sand breakwaters
- Living reef (oyster/mussel)
- Rock gabion baskets

Benefits

- Provides habitat and ecosystem services
- Dissipates wave energy
- Slows inland water transfer
- Provides habitat and ecosystem services
- Increases natural storm water infiltration
- Toe protection helps prevent wetland edge loss

Disadvantages

- Require more land area
- No high water protection
- Uncertainty of successful vegetation growth and competition with invasive

Initial Construction: ●●
Operations & Maintenance: ●

* Native plants and materials must be appropriate for current salinity and site conditions.

Initial Construction: ● = up to $1000 per linear foot, ●● = $1001 - $2000 per linear foot, ●●● = $2001 - $5000 per linear foot, ●●●● = $5001 - $10,000 per linear foot
Operations and Maintenance (yearly for a 50 year project life): ● = up to $100 per linear foot, ●● = $101 - $500 per linear foot, ●●● = over $500 per linear foot

HOW GREEN OR GRAY SHOULD YOUR SHORELINE SOLUTION BE?

GREEN - SOFTER TECHNIQUES
Small Waves | Small Fetch | Gentle Slope | Sheltered Coast

LIVING SHORELINE

CONTINUED FROM LAST PAGE

BEACH NOURISHMENT ONLY

Photo Credit: USACE New York District Public Affairs

Large volume of sand added from outside source to an eroding beach. Widens the beach and moves the shoreline seaward.

Suitable For

Low-lying oceanfront areas with existing sources of sand and sediment.

Material Options

- Sand

Benefits

- Expands usable beach area
- Lower environmental impact than hard structures
- Flexible strategy
- Redesigned with relative ease
- Provides habitat and ecosystem services

Disadvantages

- Requires continual sand resources for renourishment
- No high water protection
- Appropriate in limited situations
- Possible impacts to regional sediment transport

Initial Construction: ●●●
Operations & Maintenance: ●●

BEACH NOURISHMENT & VEGETATION ON DUNE

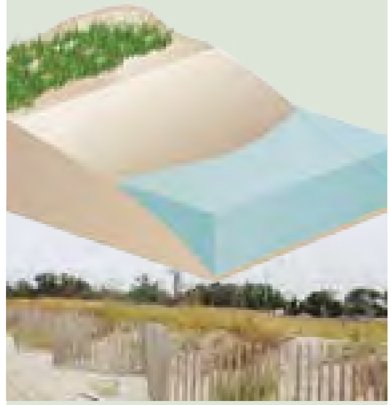

Photo Credit: USACE New York District Public Affairs

Helps anchor sand and provide a buffer to protect inland area from waves, flooding and erosion.

Suitable For

Low-lying oceanfront areas with existing sources of sand and sediment.

Material Options

Sand with vegetation
Can also strengthen dunes with:

- Geotextile tubes
- Rocky core

Benefits

- Expands usable beach area
- Lower environmental impact
- Flexible strategy
- Redesigned with relative ease
- Vegetation strengthens dunes and increases their resilience to storm events
- Provides habitat and ecosystem services

Disadvantages

- Requires continual sand resources for renourishment
- No high water protection
- Appropriate in limited situations
- Possible impacts to regional sediment transport

Initial Construction: ●●●
Operations & Maintenance: ●●

Initial Construction: ● = up to $1000 per linear foot, ●● = $1001 - $2000 per linear foot, ●●● = $2001 - $5000 per linear foot, ●●●● = $5001 - $10,000 per linear foot
Operations and Maintenance (yearly for a 50 year project life): ● = up to $100 per linear foot, ●● = $101 - $500 per linear foot, ●●● = over $500 per linear foot

HOW GREEN OR GRAY SHOULD YOUR SHORELINE SOLUTION BE?

GRAY - HARDER TECHNIQUES

Large Waves | Large Fetch | Steep Slope | Open Coast

COASTAL STRUCTURE

BREAKWATER

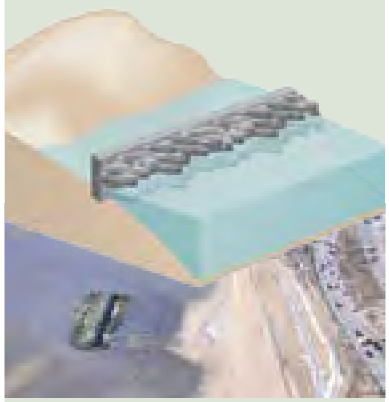

Photo Credit: USACE New York District Public Affairs

Offshore structures intended to break waves, reducing the force of wave action and encourages sediment accretion. Can be floating or fixed to the ocean floor, attached to shore or not, and continuous or segmented. A gapped approach would allow habitat connectivity, greater tidal exchange, and better waterfront access.

Suitable For

Most areas except high wave energy environments often in conjunction with marinas.

Material Options

- Grout-filled fabric bags
- Armorstone
- Pre-cast concrete blocks
- Living reef (oyster/mussel) if low wave environment
- Wood
- Rock‡

Benefits

- Reduces wave force and height
- Stabilizes wetland
- Can function like reef
- Economical in shallow areas
- Limited storm surge flood level reduction

Disadvantages

- Expensive in deep water
- Can reduce water circulation (minimized if floating breakwater is applied)
- Can create navigational hazard
- Require more land area
- Uncertainty of successful vegetation growth and competition with invasive
- No high water protection
- Can reduce water circulation
- Can create navigation hazard

GROIN

Photo Credit: USACE New York District Public Affairs

Perpendicular, projecting from shoreline. Intercept water flow and sand moving parallel to the shoreline to prevent beach erosion and break waves. Retain sand placed on beach.

Suitable For

Coordination with beach nourishment.

Material Options

- Concrete/stone rubble‡
- Timber
- Metal sheet piles

Benefits

- Protection from wave forces
- Methods and materials are adaptable
- Can be combined with beach nourishment projects to extend their life

Disadvantages

- Erosion of adjacent sites
- Can be detrimental to shoreline ecosystem (e.g. replaces native substrate with rock and reduces natural habitat availability)
- No high water protection

‡ Rock/stone needs to be appropriately sized for site specific wave energy.

CONTINUED ON NEXT PAGE

GRAY CAN BE GREENER: e.g., 'Living Breakwater' using oysters to colonize rocks or 'Greenwall/Biowall' using vegetation, alternative forms and materials

Breakwater:
Initial Construction: ●●●●
Operations & Maintenance: ●●●

Groin:
Initial Construction: ●●●
Operations & Maintenance: ●●

Initial Construction: ● = up to $1000 per linear foot, ●● = $1001 - $2000 per linear foot, ●●● = $2001 - $5000 per linear foot, ●●●● = $5001 - $10,000 per linear foot
Operations and Maintenance (yearly for a 50 year project life): ● = up to $100 per linear foot, ●● = $101 - $500 per linear foot, ●●● = over $500 per linear foot

HOW GREEN OR GRAY SHOULD YOUR SHORELINE SOLUTION BE?

GRAY - HARDER TECHNIQUES
Large Waves | Large Fetch | Steep Slope | Open Coast

COASTAL STRUCTURE

CONTINUED FROM LAST PAGE

REVETMENT

Photo Credit: Maryland Department of Natural Resources - Shoreline Conservation Service

Lays over the slope of a shoreline. Protects slope from erosion and waves.

Suitable For

Sites with pre-existing hardened shoreline structures.

Material Options

- Stone rubble†
- Concrete blocks
- Cast concrete slabs
- Sand/concrete filled bags
- Rock-filled gabion basket

Benefits

- Mitigates wave action
- Little maintenance
- Indefinite lifespan
- Minimizes adjacent site impact

Disadvantages

- No major flood protection
- Require more land area
- Loss of intertidal habitat
- Erosion of adjacent unreinforced sites
- Require more land area
- No high water protection
- Prevents upland from being a sediment source to the system

† Rock/stone needs to be appropriately sized for site specific wave energy.

BULKHEAD

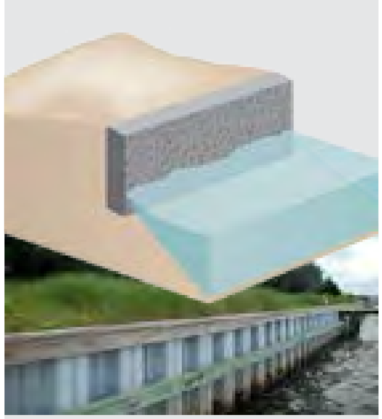

Photo Credit: North Carolina Department of Environment and Natural Resources

Parallel to the shoreline, vertical retaining wall. Intended to hold soil in place and allow for a stable shoreline.

Suitable For

High energy settings and sites with pre-existing hardened shoreline structures. Accommodates working water fronts (eg: docking for ships and ferries).

Material Options

- Steel sheet piles
- Timber
- Concrete
- Composite carbon fibers
- Gabions

Benefits

- Moderates wave action
- Manages tide level fluctuation
- Long lifespan
- Simple repair

Disadvantages

- No major flood protection
- Erosion of seaward seabed
- Erosion of adjacent unreinforced sites
- Loss of intertidal habitat
- May be damaged from overtopping oceanfront storm waves
- Prevents upland from being a sediment source to the system
- Induces wave reflection

SEAWALL

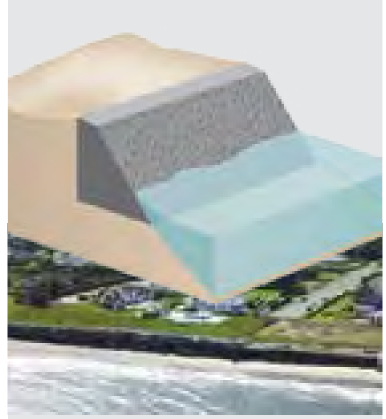

Photo Credit: USACE New York District Public Affairs

Parallel to shoreline, vertical or sloped wall. Soil on one side of wall is the same elevation as water on the other. Absorbs and limits impacts of large waves and directs flow away from land.

Suitable For

Areas highly vulnerable to storm surge and wave forces.

Material Options

- Stone
- Rock
- Concrete
- Steel/vinyl sheets
- Steel sheet piles

Benefits

- Prevents storm surge flooding
- Resists strong wave forces
- Shoreline stabilization behind structure
- Low maintenance costs
- Less space intensive horizontally than other techniques (e.g. vegetation only)

Disadvantages

- Erosion of seaward seabed
- Disrupt sediment transport leading to beach erosion
- Higher up-front costs
- Visually obstructive
- Loss of intertidal zone
- Prevents upland from being a sediment source to the system
- May be damaged from overtopping oceanfront storm waves

GRAY CAN BE GREENER: e.g., 'Living Breakwater' using oysters to colonize rocks or 'Greenwall/Biowall' using vegetation, alternative forms and materials

	Revetment	Bulkhead	Seawall
Initial Construction	●●●●	●●●	●●●●
Operations & Maintenance	●●	●●	●●●

Initial Construction: ● = up to $1000 per linear foot, ●● = $1001 - $2000 per linear foot, ●●● = $2001 - $5000 per linear foot, ●●●● = $5001 - $10,000 per linear foot

Operations and Maintenance (yearly for a 50 year project life): ● = up to $100 per linear foot, ●● = $101 - $500 per linear foot, ●●● = over $500 per linear foot

6

Is a Living Shoreline a Good Fit for What I Need?

Living Shorelines achieve multiple goals such as:

- Stabilizing the shoreline and reducing current rates of shoreline erosion and storm damage
- Providing ecosystem services, such as habitat for fish and other aquatic species and increasing flood storage capacity
- Maintaining connections between land and water ecosystems to enhance resilience

Site-specific conditions will influence your choice of shoreline protection technique (ex: wave energy level, fetch lengths, rate and pattern of erosion, etc). Here are some additional factors to keep in mind as you consider Living Shorelines.

WHAT ARE THE BENEFITS?

- Erosion control and shore stabilization.
- Restored and enhanced habitat which supports fish and wildlife populations.
- Increased property values.
- Enhanced community enjoyment.
- Opportunities for education.
- Improved public access to waterfront through recreational activities such as fishing, boating and birding. Can be used to satisfy zoning and permitting requirement for waterfront development projects.
- Complemented natural shoreline dynamics & movement; increased resilience and absorption of wave energy, storm surge and floodwaters; and an adaptive tool for preparation of sea level rise.
- Improved water quality from settling or trapping sediment (e.g. once established, a marsh can filter surface water runoff or oysters can provide coastal water filtration).

WHAT ARE SOME CHALLENGES?

- Uncertainty in risk because of lack of experience of techniques.
- Public funds are often tied to government permit compliance.
- Permitting processes can be lengthy and challenging. The existing regulatory process is centered on traditional "gray" or "hard" techniques. Regulators and project sponsors alike are learning how to design living shorelines projects. Talk with someone about your state's permitting process or to hear about their experiences.
- It takes time to develop and test new shoreline protection methods.
- There may be land ownership constraints. Consider where federal and state jurisdiction for the water body starts and ends.
- In urban environments, there is limited land (bulkheads may seem like the only option), a variety of upland uses (industrial past use may have left legacy contaminants) and high velocity waters.
- The overall sediment system needs to be taken into account to protect neighboring properties from experiencing starved down drift shorelines or other consequences as a result of a project.
- Lack of public awareness of performance and benefits of living shorelines.
- Not all techniques have the same level of performance or success monitoring. Less practiced techniques may require more monitoring.

WHAT INFLUENCES COST?

- The materials chosen for the project influence cost.
- Including green techniques can be cheaper than traditional gray techniques.
- Sometimes it's possible to install the project yourself, other times you will need help from a professional.
- Long term maintenance is required as any landscape project (e.g. replanting may be needed after a storm).

HOW TO FIND OUT MORE

If you have a Living Shorelines permitting question, contact your state's office of Environmental Protection, Conservation or Natural Resources, your coastal zone manager such as your state's Department of State, as well as your local U.S. Army Corps of Engineers (USACE) district office.

If you would like science or engineering advice, or to talk to people who have experience studying or constructing living shorelines, reach out to some of the following: your local universities, your City's Department of Planning and Department of Parks, Sea Grant Chapter, Littoral Society, The Nature Conservancy, The Trust for Public Land, The Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), USACE, engineering firms and other organizations that focus on your local waterfront.

These and other websites are good references to learn more about Living Shorelines:

SAGE
www.SAGEcoast.org

NOAA Restoration
www.habitat.noaa.gov/livingshorelines

USACE Engineer Research Development Center, Engineering with Nature
el.erdc.usace.army.mil/ewn

USACE North Atlantic Division, National Planning Center of Expertise for Coastal Storm Damage Reduction
www.nad.usace.army.mil/About/NationalCentersofExpertise/CoastalStormDamageReduction(Planning).aspx

Virginia Institute of Marine Science (VIMS) Center for Coastal Resources Management
ccrm.vims.edu/livingshorelines/index.html

Coasts, Oceans, Ports & Rivers Institute (COPRI)
www.mycopri.org/livingshorelines

The Nature Conservancy
www.nature.org/ourinitiatives/habitats/oceanscoasts/howwework/helping-oceans-adapt-to-climate-change.xml

Developed with support and funding from SAGE, NOAA and USACE; February 2015

PUBLIC COMMENTS
APPENDIX B

[To be written following Public Comments]