INVENTORY FINDINGS AND RELEVANCE TO RESOURCE MANAGEMENT 2

Credit: SEWRPC Staff

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

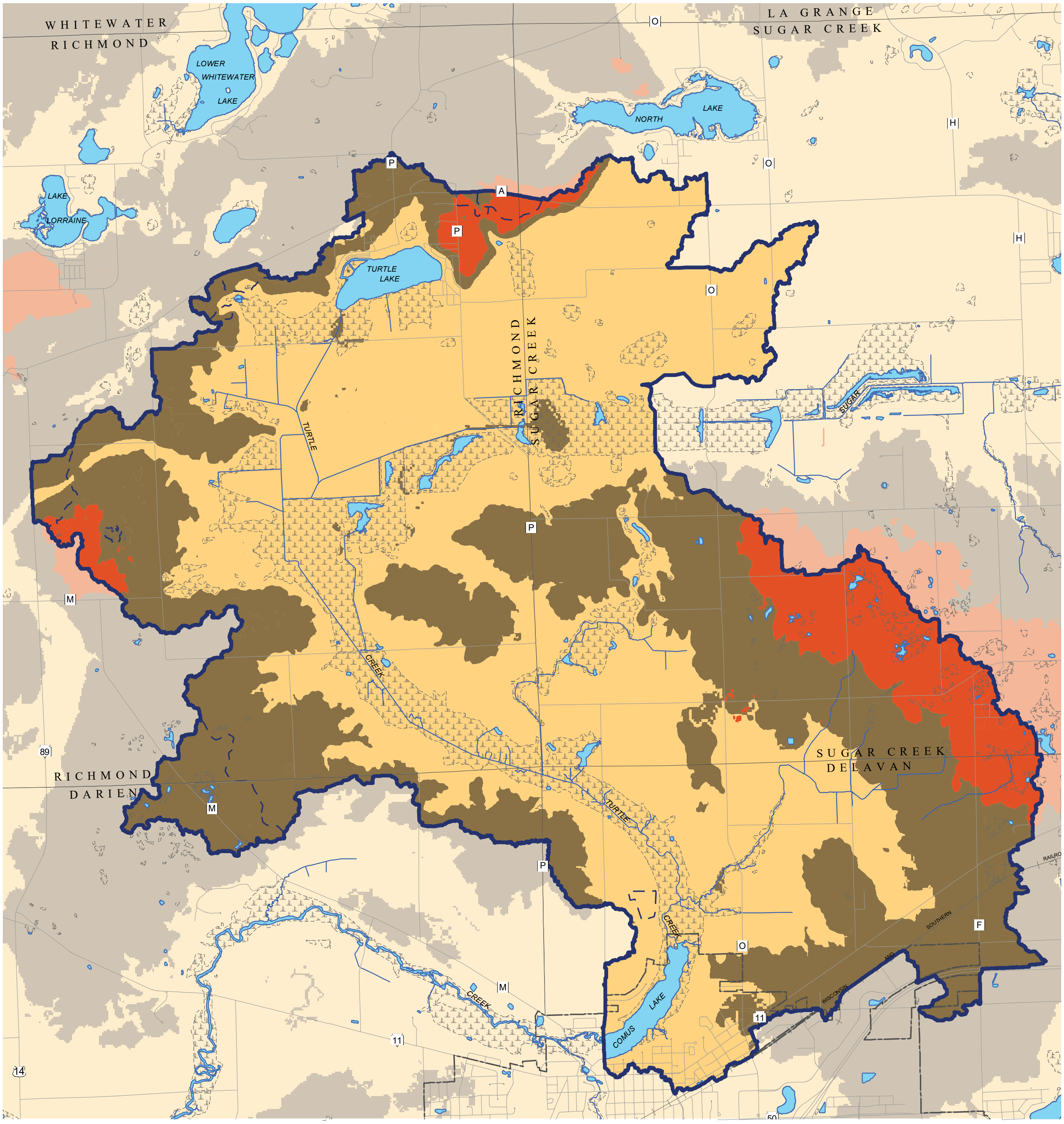
Lake Comus covers 131 acres and receives runoff from a 21,009-acre watershed draining west-central Walworth County.[9] The watershed's upstream reaches are located north of Turtle Lake in the Town of Richmond, an area over six miles to the north of the Lake. Much of the watershed is in the Turtle Valley, 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

[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
	975 - 1000
	1025

ELEVATION IN FEET ABOVE NATIONAL GEODETIC VERTICAL DATUM, 1929 ADJUSTMENT

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

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]

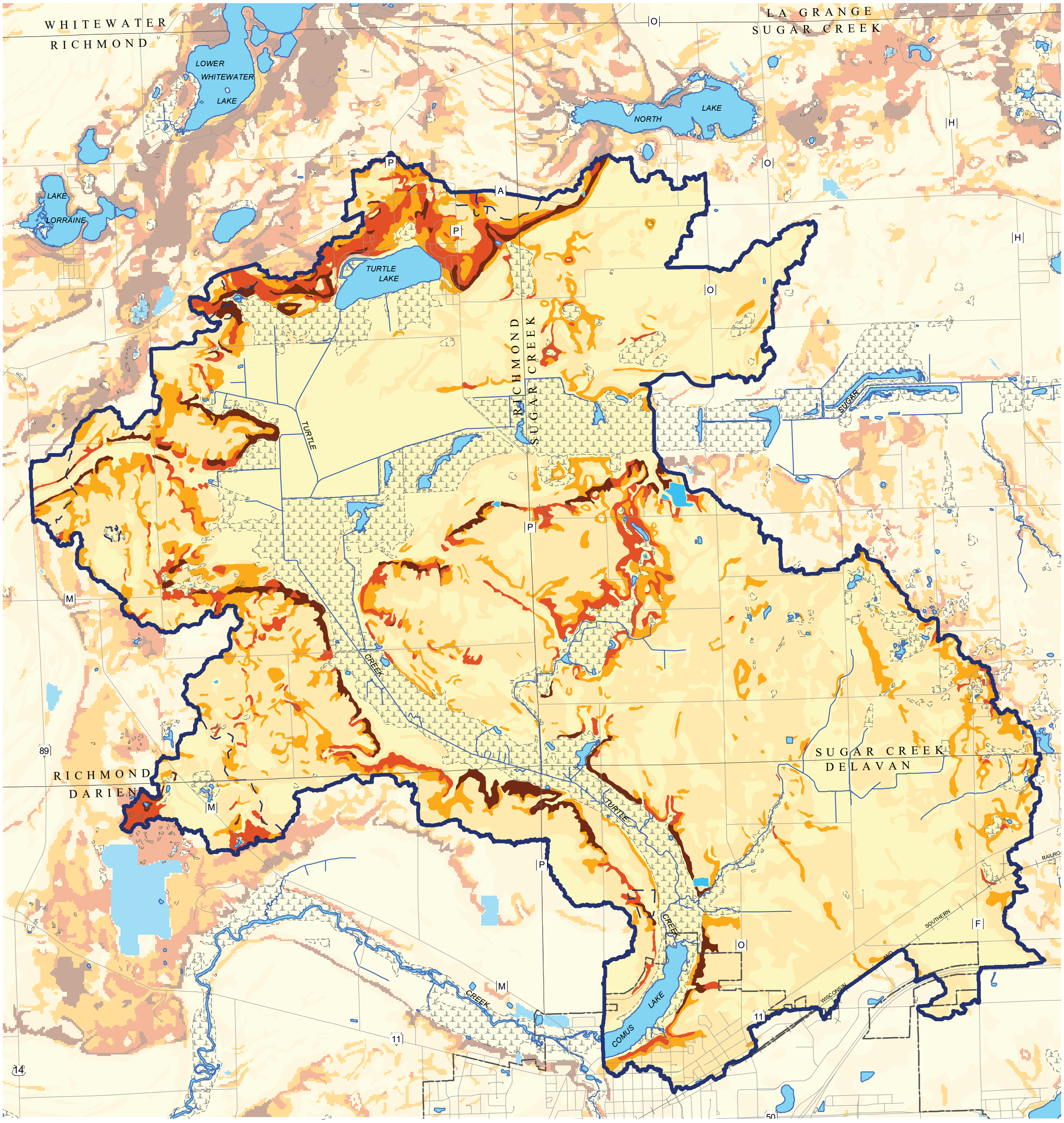
[10] Turtle Creek Priority Watershed Plan*, Department of Land Conservation, Rock County, Wisconsin, 1984.*

[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.

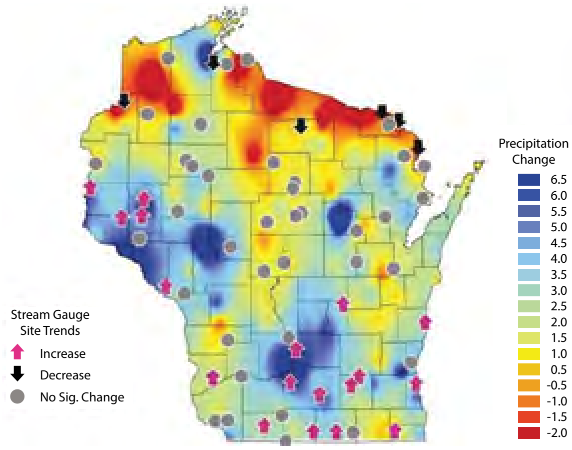
[14] *Wisconsin Initiative on Climate Change Impacts, February 2011,* op. cit.

[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.

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

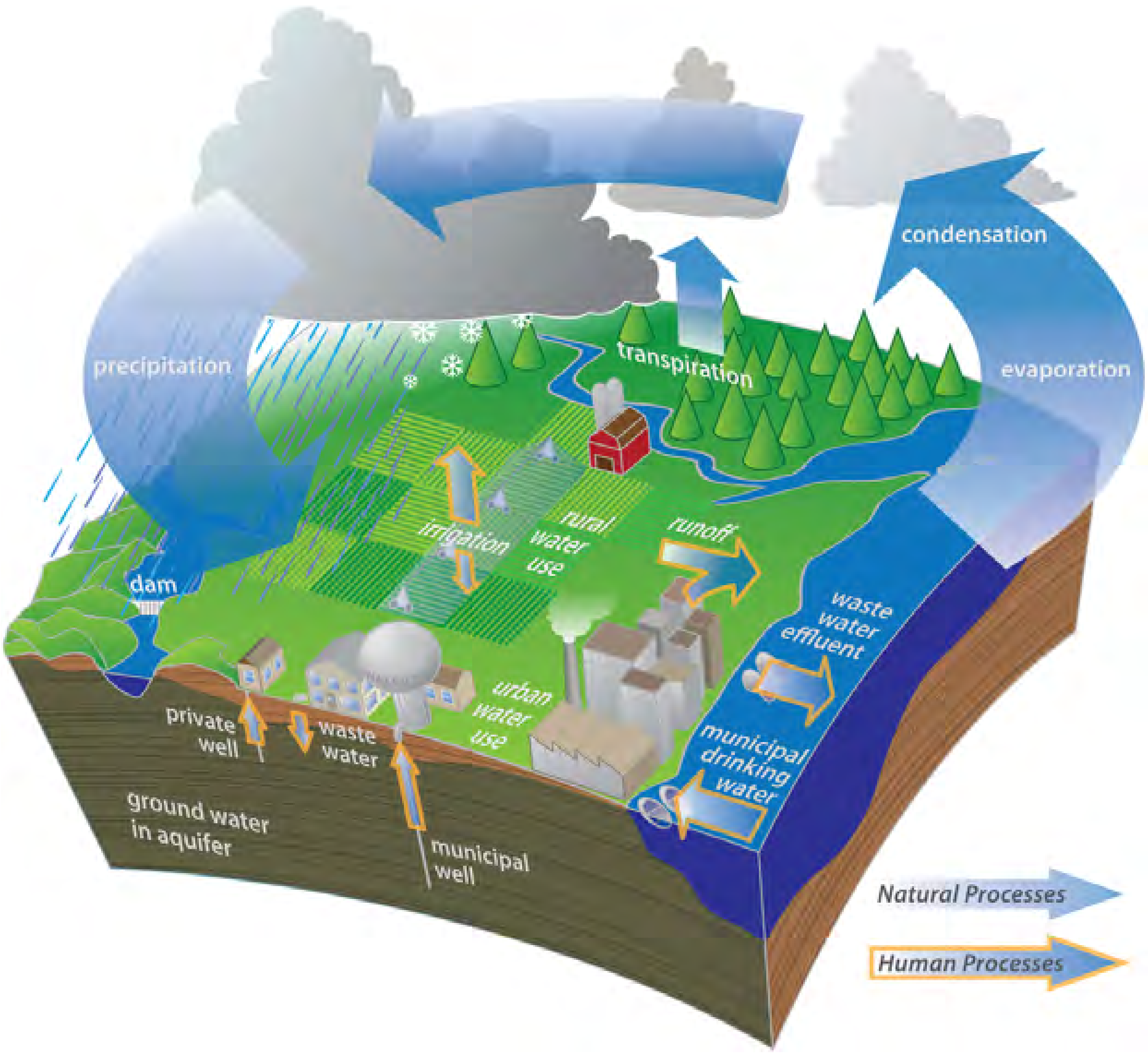
- **Stabilize future variations in water quantity and availability by managing water as an integrated resource, keeping water "local" and supporting sustainable and efficient water use.** Many of our water management decisions are made under separate rules, statutory authorities, administrative frameworks, 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.

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.*

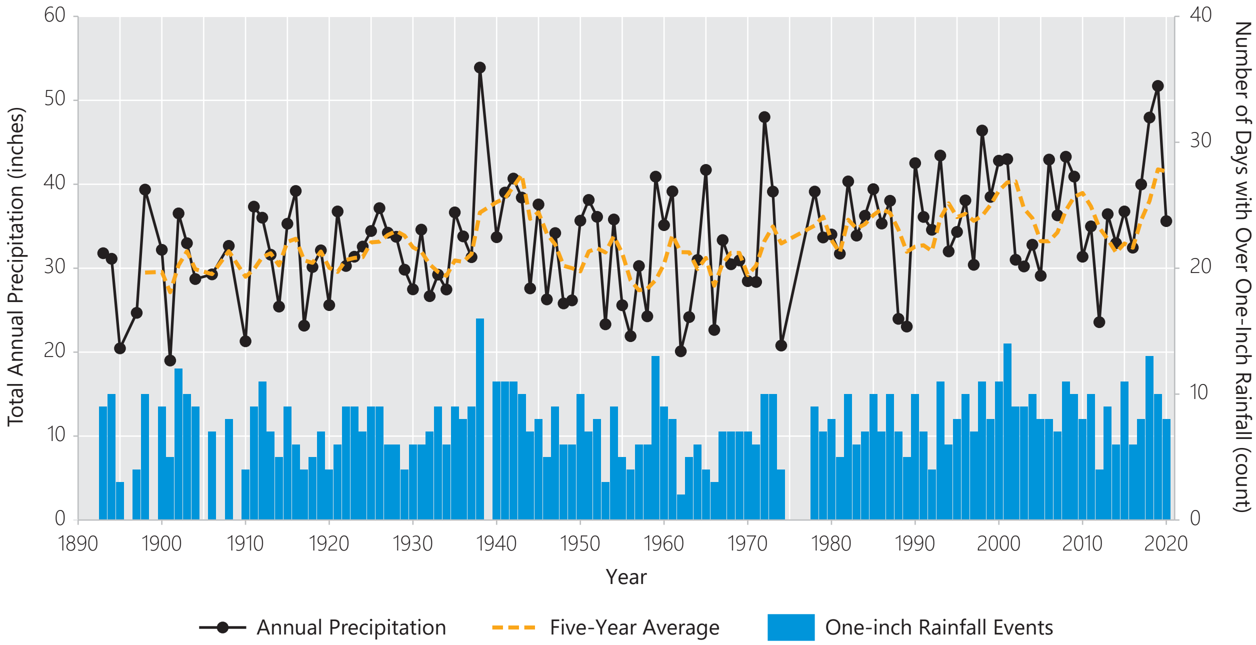
Table 2.3
Climate Normals for Delavan Wastewater Treatment Facility: 1991-2020 and 2005-2020

	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

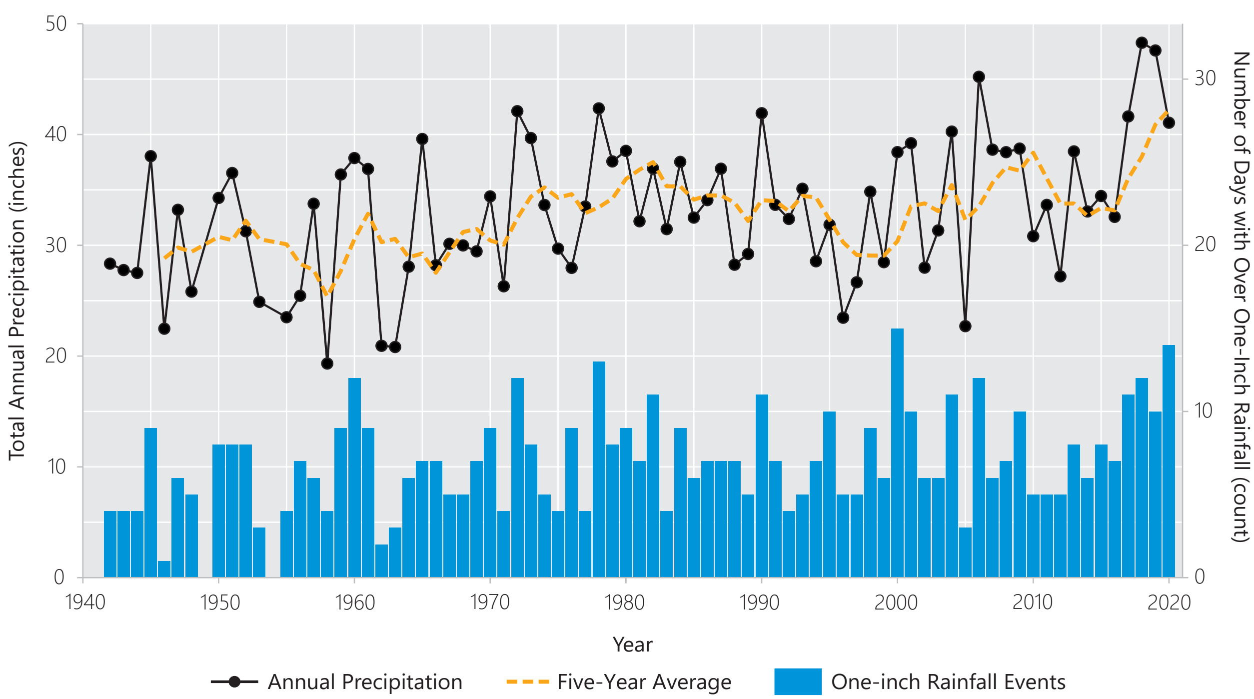
Figure 2.3
Beloit Total Annual Precipitation and One-Inch Rainfall Events: 1893-2020



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.*

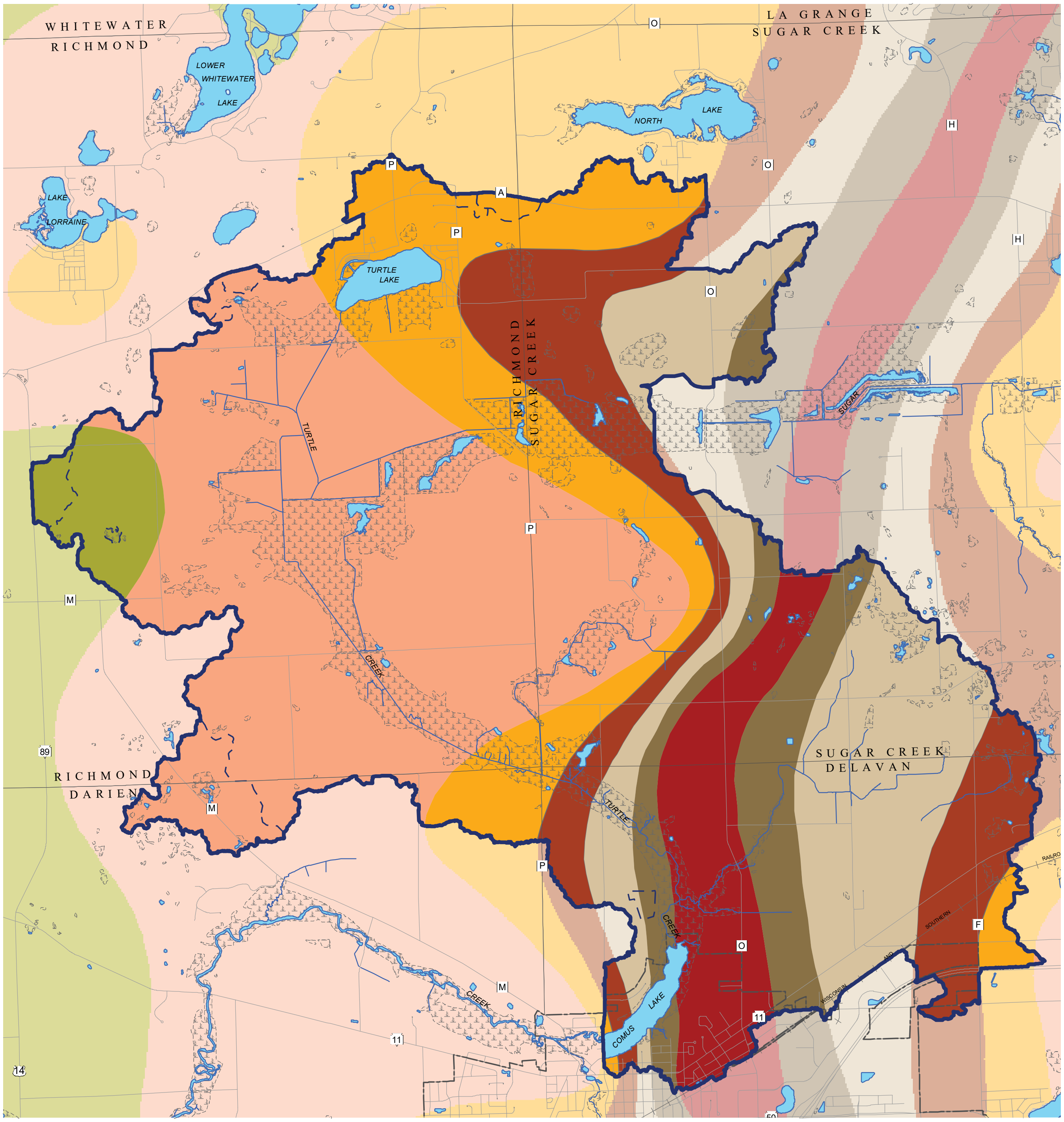
[26] Ibid.

[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.

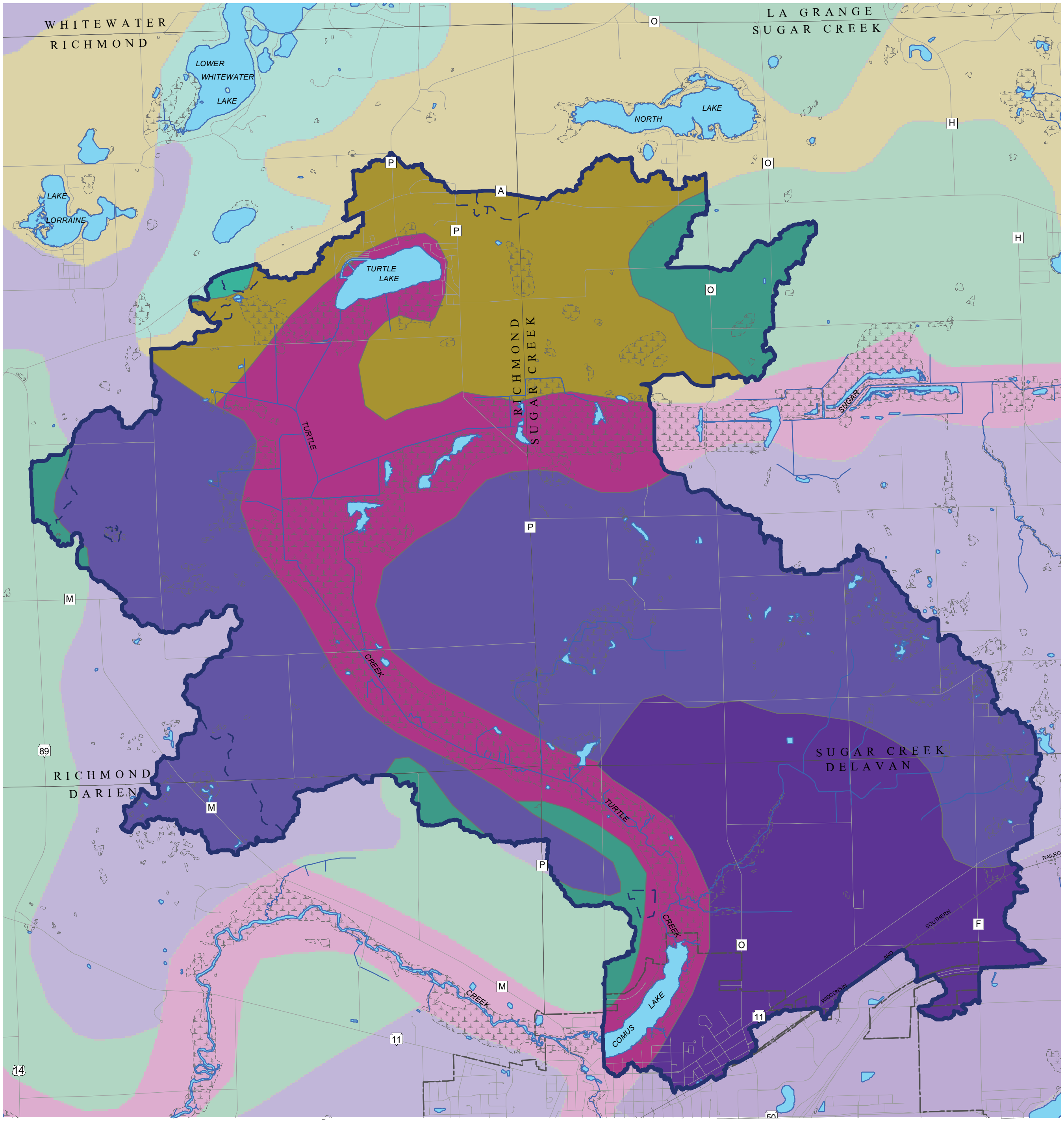
Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

N

0 2,500 5,000 Feet

Source: Wisconsin Geological and Natural History Survey and SEWRPC

Map 2.4
Comus Lake Watershed Soil Association



CASCO-FOX ASSOCIATION

CASCO-RODMAN ASSOCIATION

HOUGHTON-PALMS-ASSOCIATION

HOUGHTON-PALMS-ADRIAN ASSOCIATION

MIAMI-MCHENRY ASSOCIATION

PLANO-GRAVELLY SUBSTRATUM-WARSAW ASSOCIATION

PLANO-GRISWOLD ASSOCIATION

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

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.

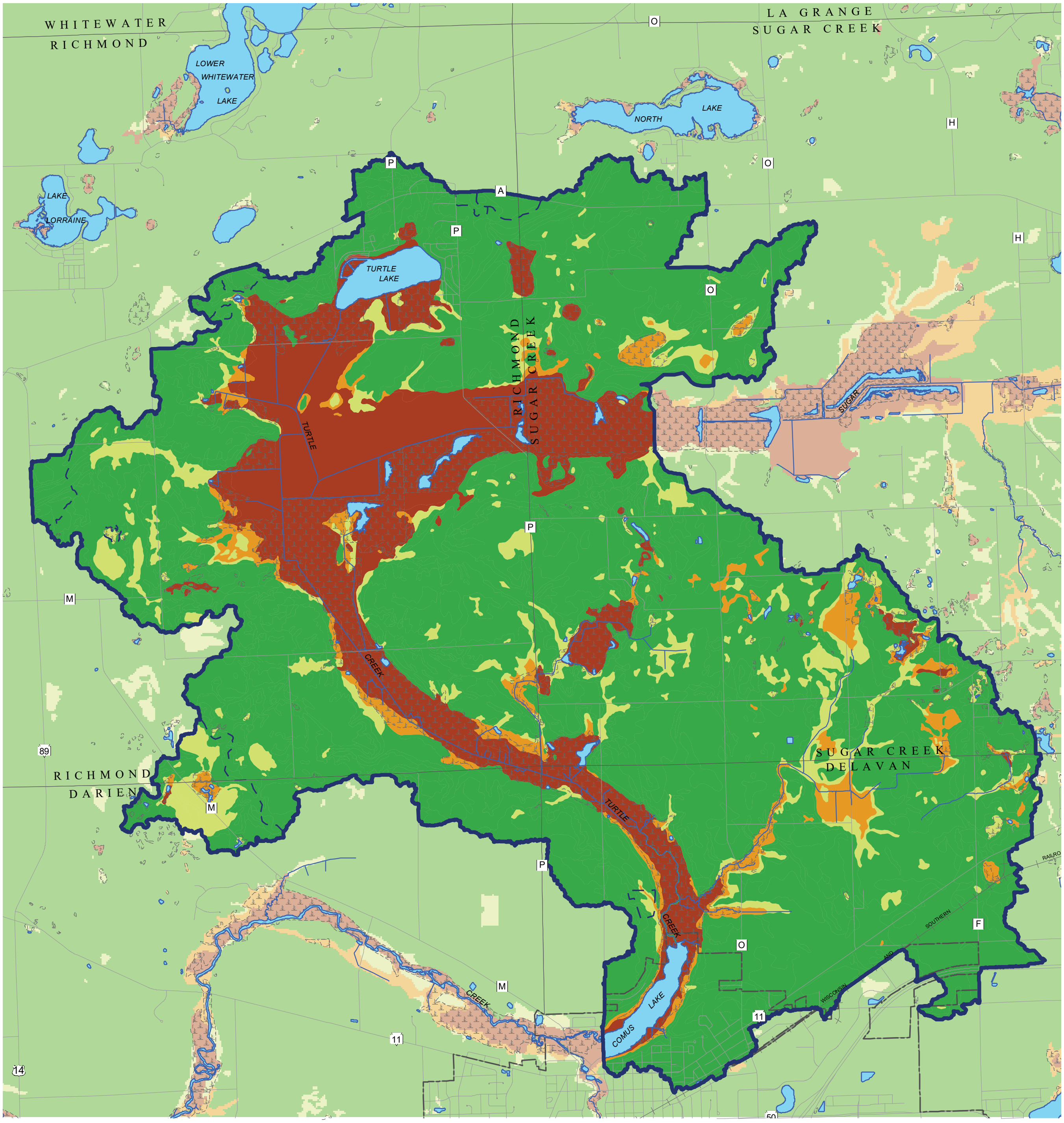
- **Surface runoff** (or overland flow) that travels over the land surface to a waterbody. Surface runoff is the primary source of wet-weather stream flow in most watersheds.

- **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

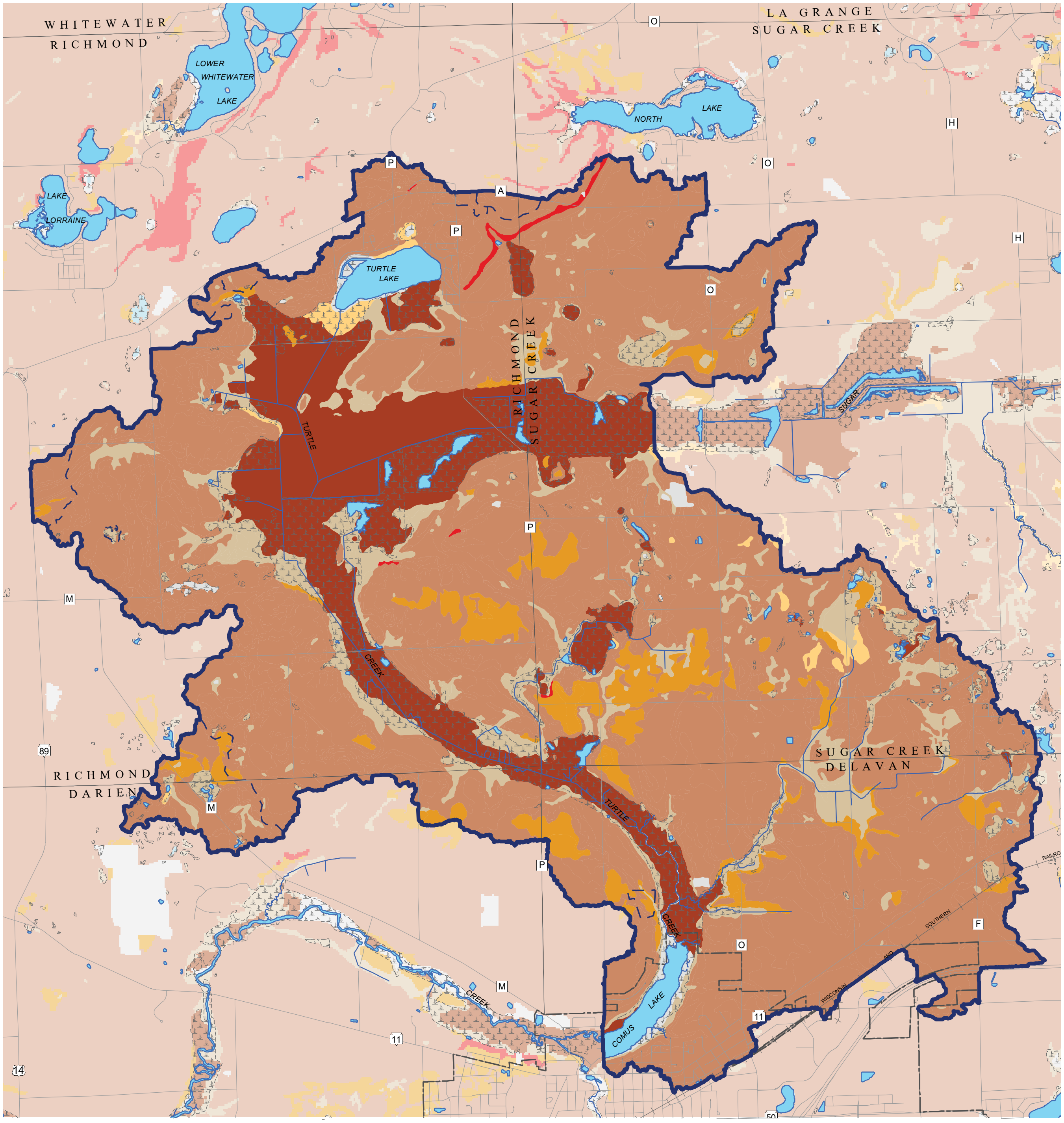
Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

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.

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

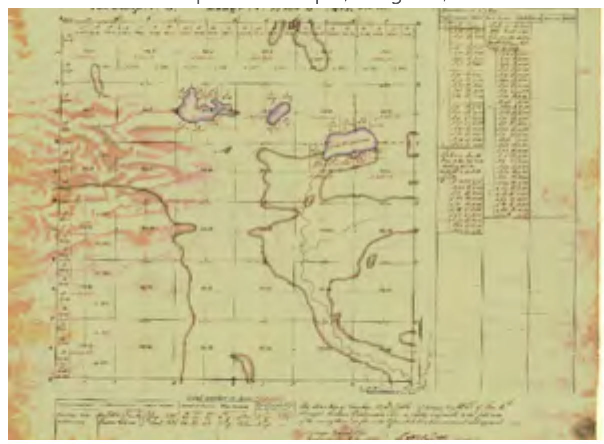
[30] *Stream order refers to a stream classification concept developed by Arthur Strahler and Robert Horton during the 1940s and 1950s. Headwater perennial tributaries are assigned a stream order of one and are labeled first order streams. When two first order streams converge, a second order stream 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.

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

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.

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

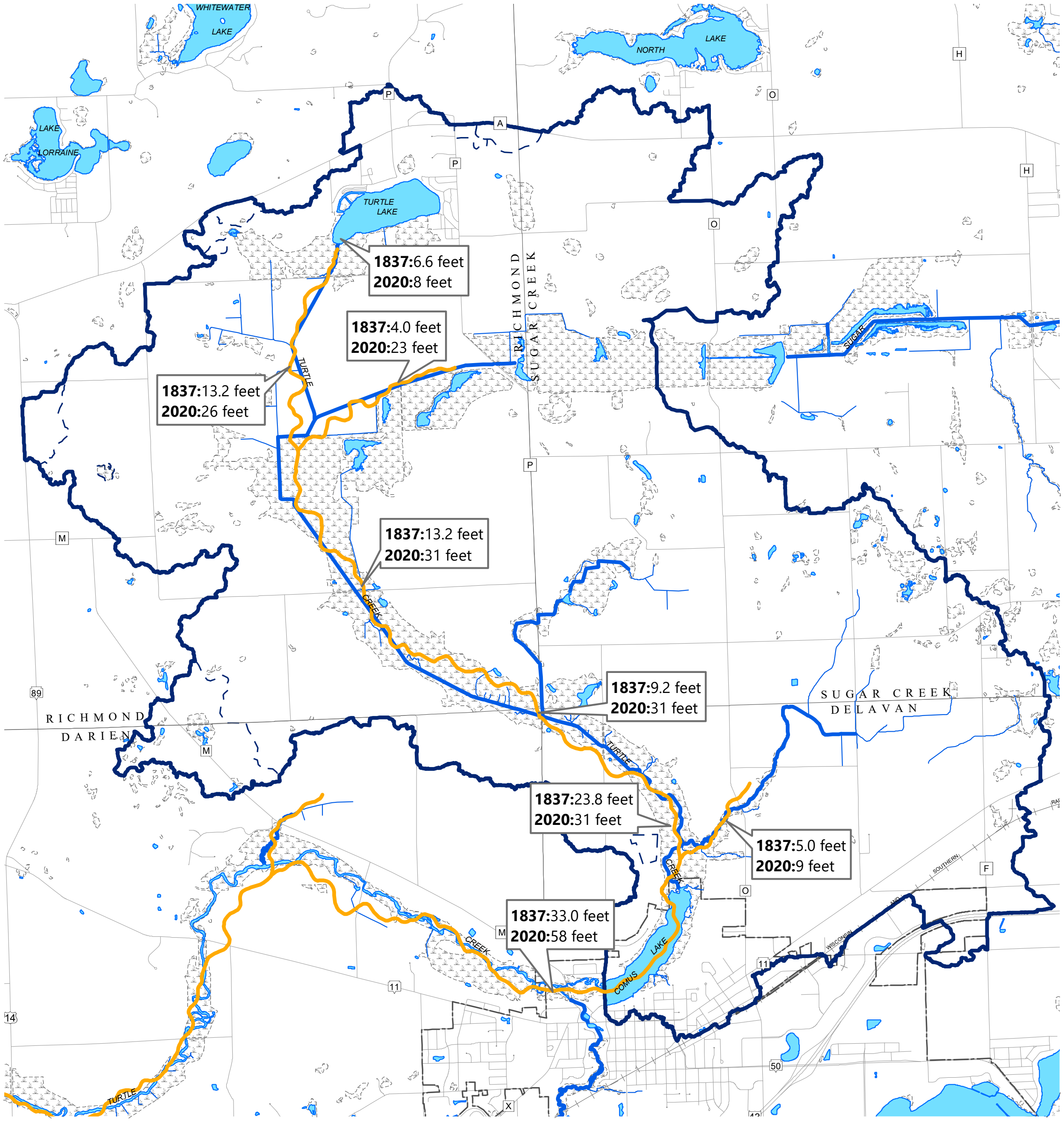
[31] *For more information on the Presto-Lite model, see dnr.wisconsin.gov/topic/SurfaceWater/PRESTO.html*

[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.

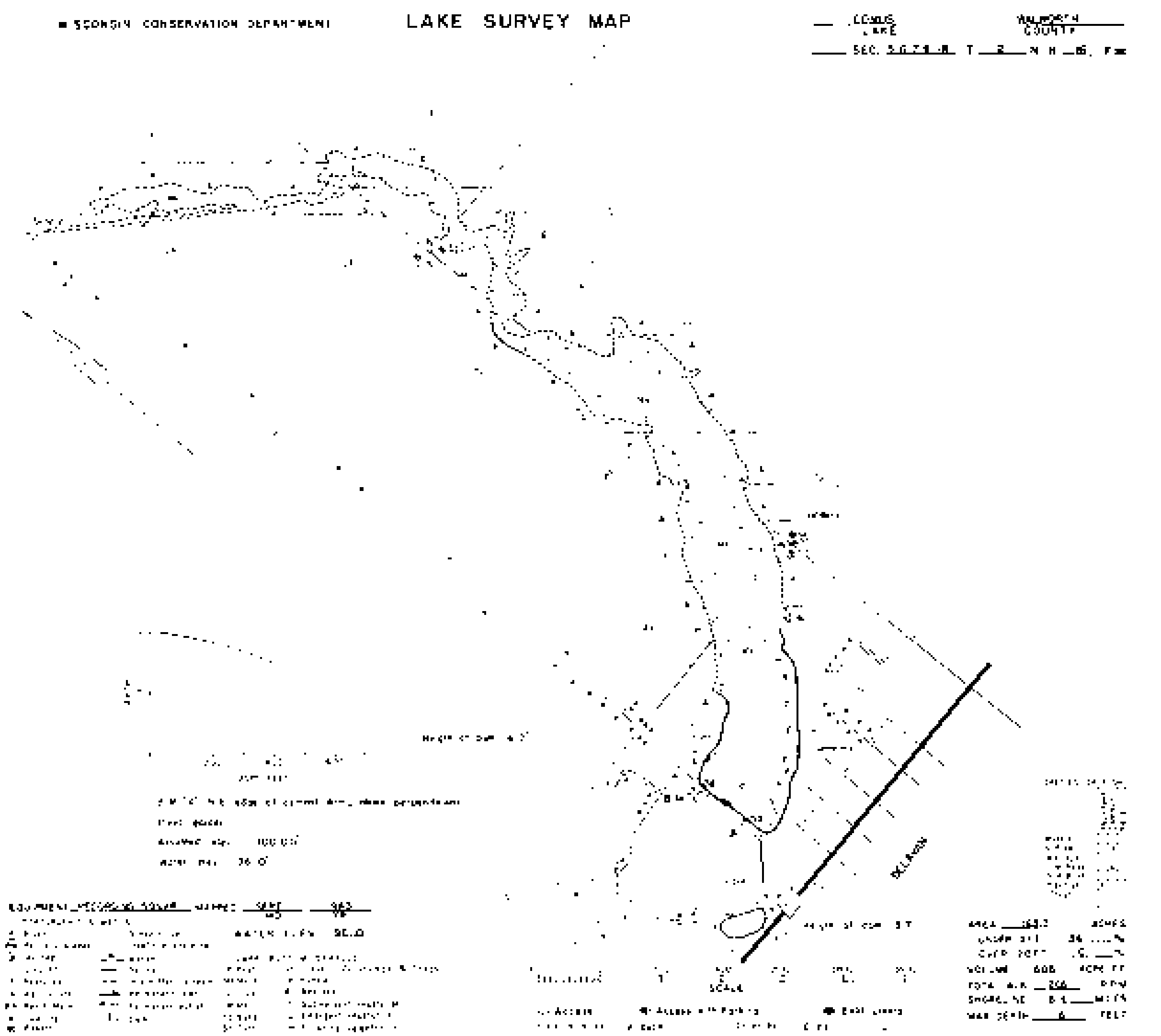
The Lake was reported to be between eight to ten feet in the 1929 Lake bathymetry map (Figure 2.11). This map also reveals that cattail marsh has expanded into the Lake over time. In the more distant past, the Lake was undoubtedly deeper and more extensive. The earliest dam inspection report (1915) available 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

[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



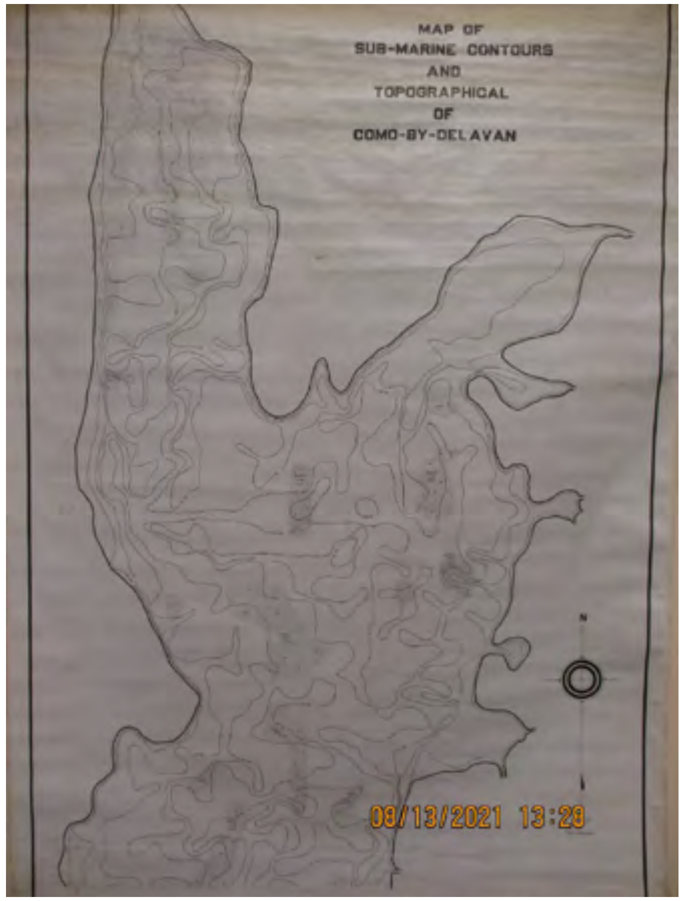
Source: Wisconsin Department of Natural Resources 608-266-2621 Comus Lake – Walworth County, Wisconsin DNR Lake Map Date – Sep 1963 - Historical Lake Map - Not for Navigation

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.

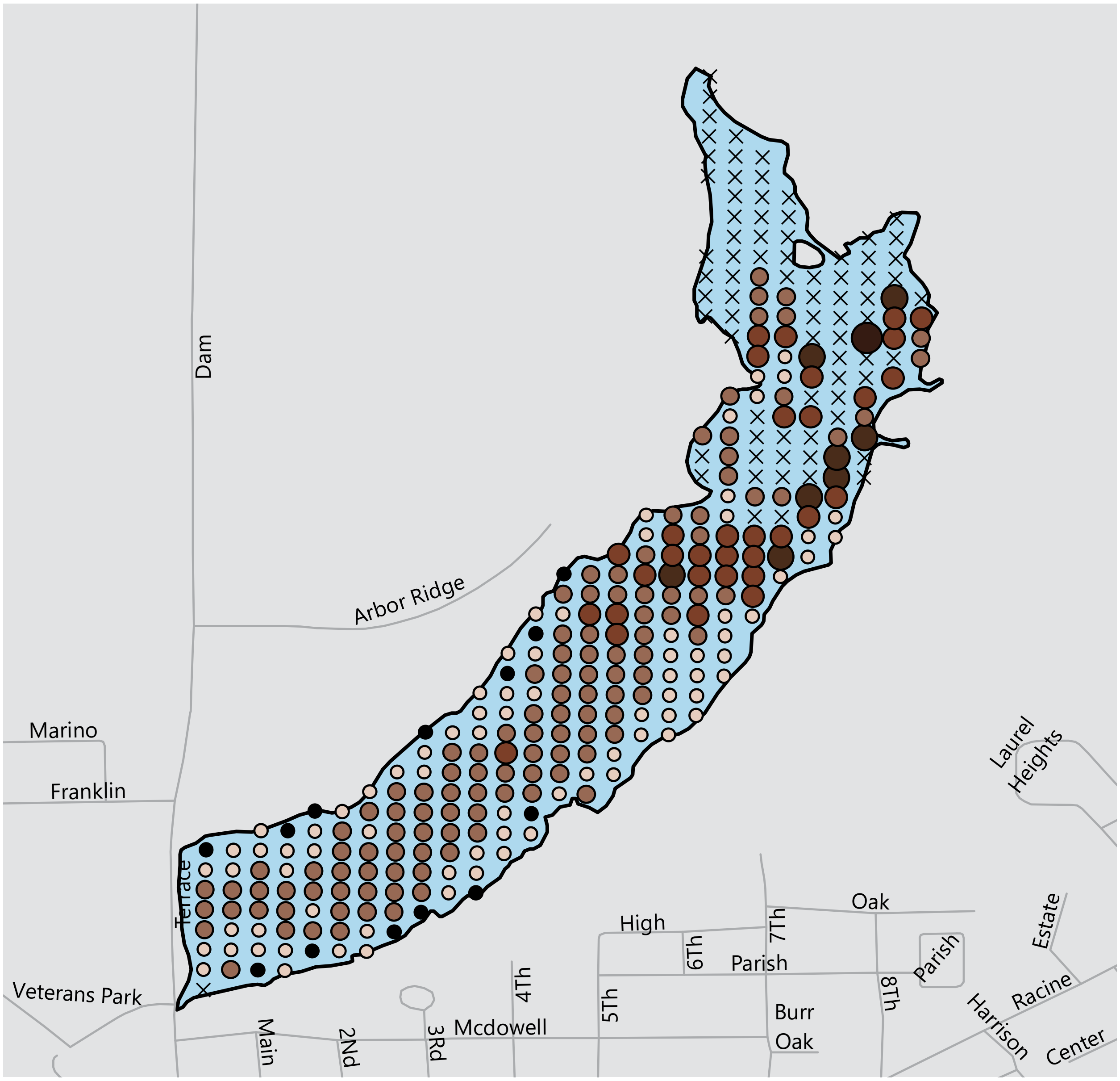
A water budget is an accounting of significant lake water inflows and outflow, assigning volumes to various water source and loss factors. Lake water budgets help managers evaluate Lake processes and sources of nonpoint source pollution. Gaged streamflow information, local weather data, groundwater monitoring 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

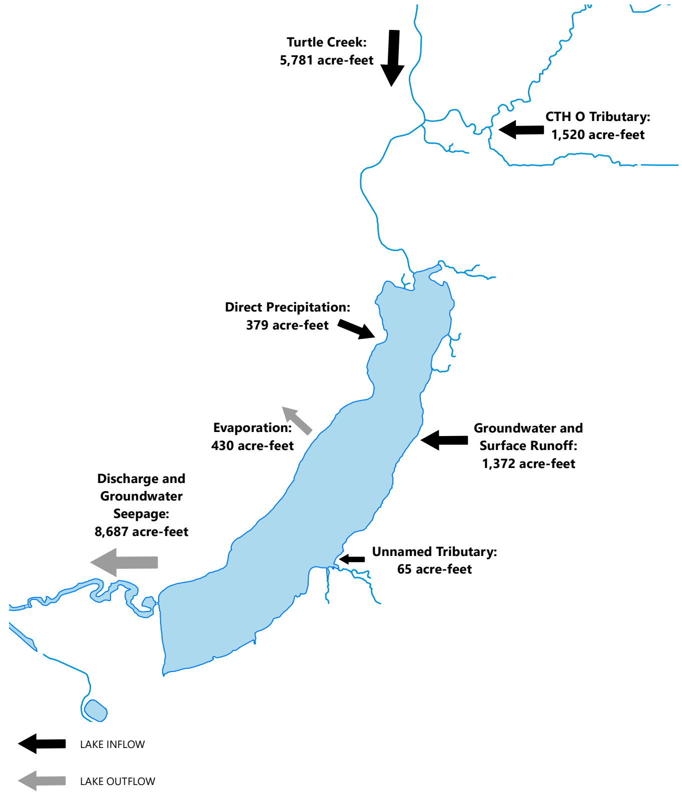
Note: Measurements taken in Lake Comus between August 23 and September 4,

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.

<u>Human Influences on Groundwater</u>

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.

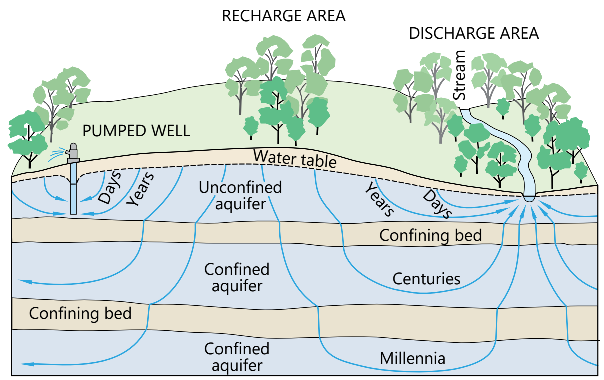
[56] *SEWRPC Technical Report No. 37, 2002,* op. cit.

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

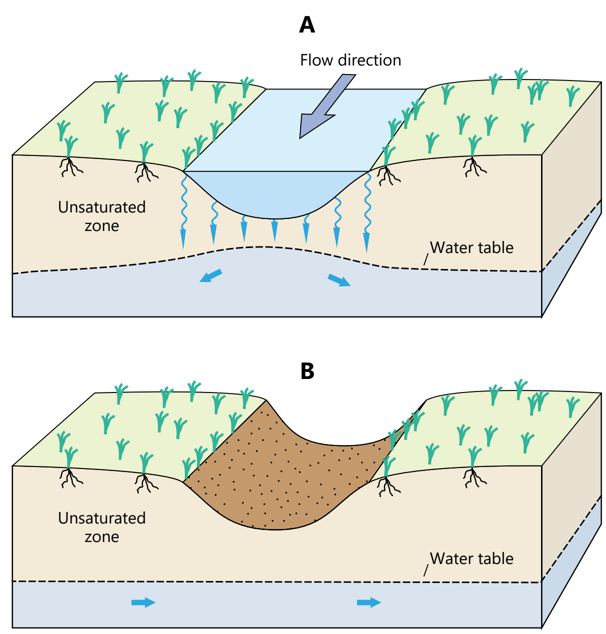
Figure 2.14
Regional vs. Local Groundwater Flow Paths



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.

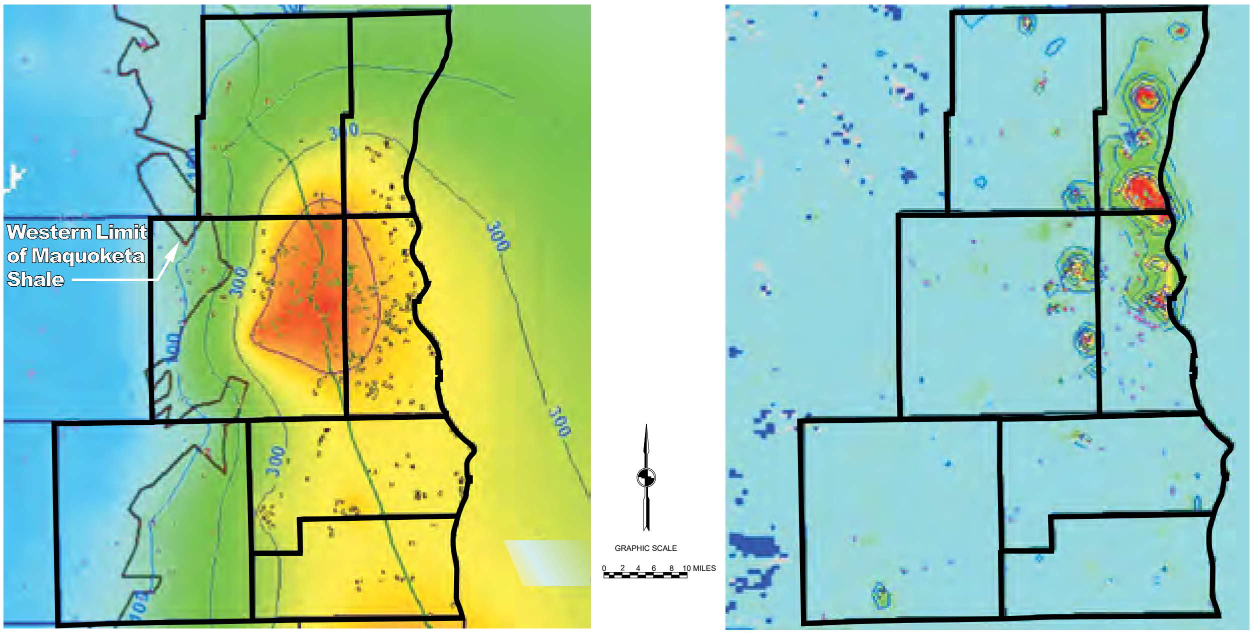
[62] *SEWRPC Technical Report No. 41,* A Regional Aquifer Simulation Model for Southeastern Wisconsin*, June 2005.*

[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.

Groundwater Conditions in the Lake Comus Watershed

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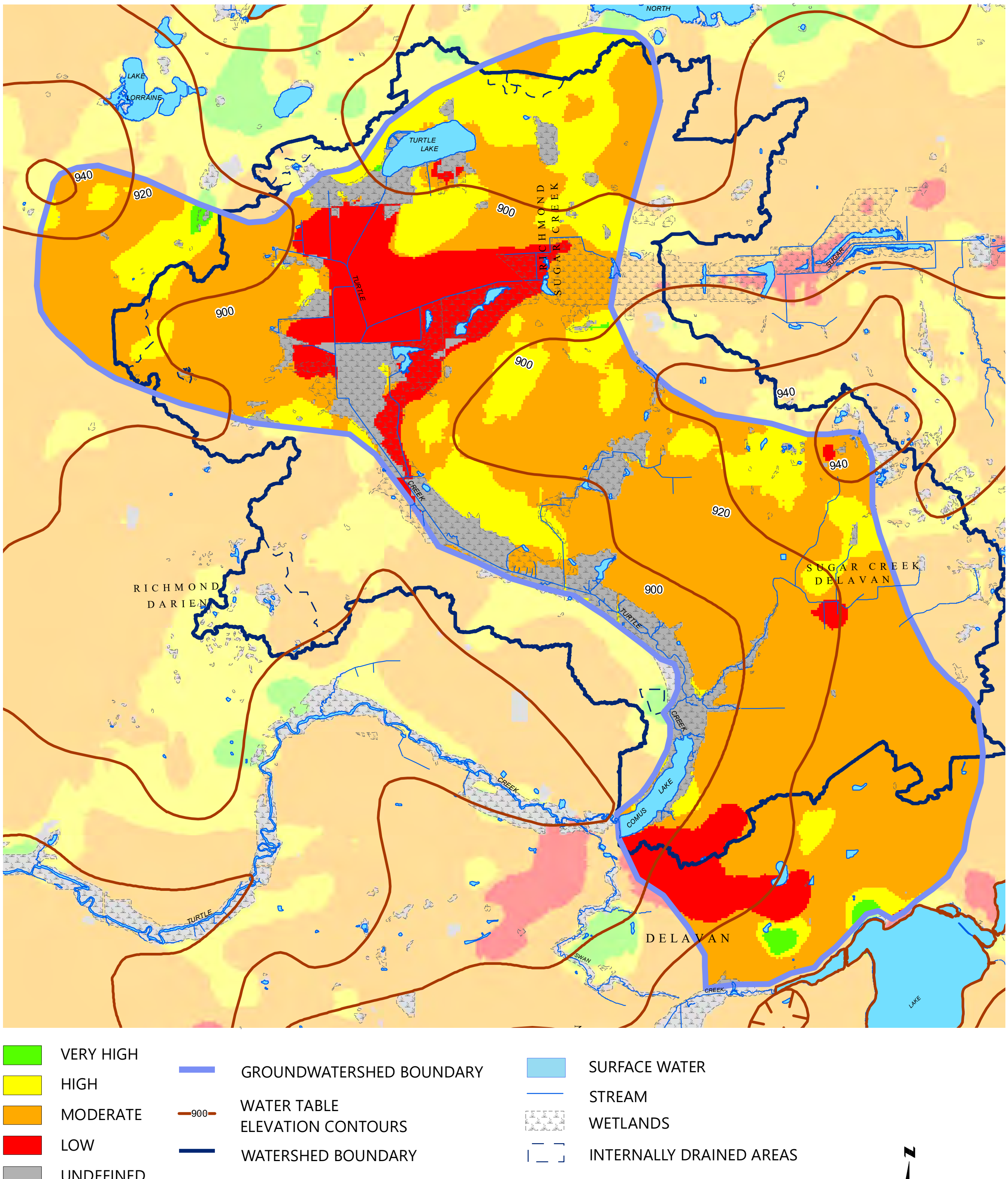
[66] *The depth to groundwater for a particular location can be estimated by subtracting groundwater elevation values from surface topography values.*

[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.

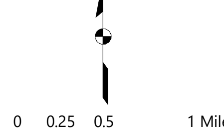
[69] *Care needs to be taken to infiltrate water that does not degrade the quality of groundwater resources. More information regarding stormwater infiltration is available from many sources, including the following website: learningstore.uwex.edu/assets/pdfs/g3691-3.pdf.*

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."

[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.*

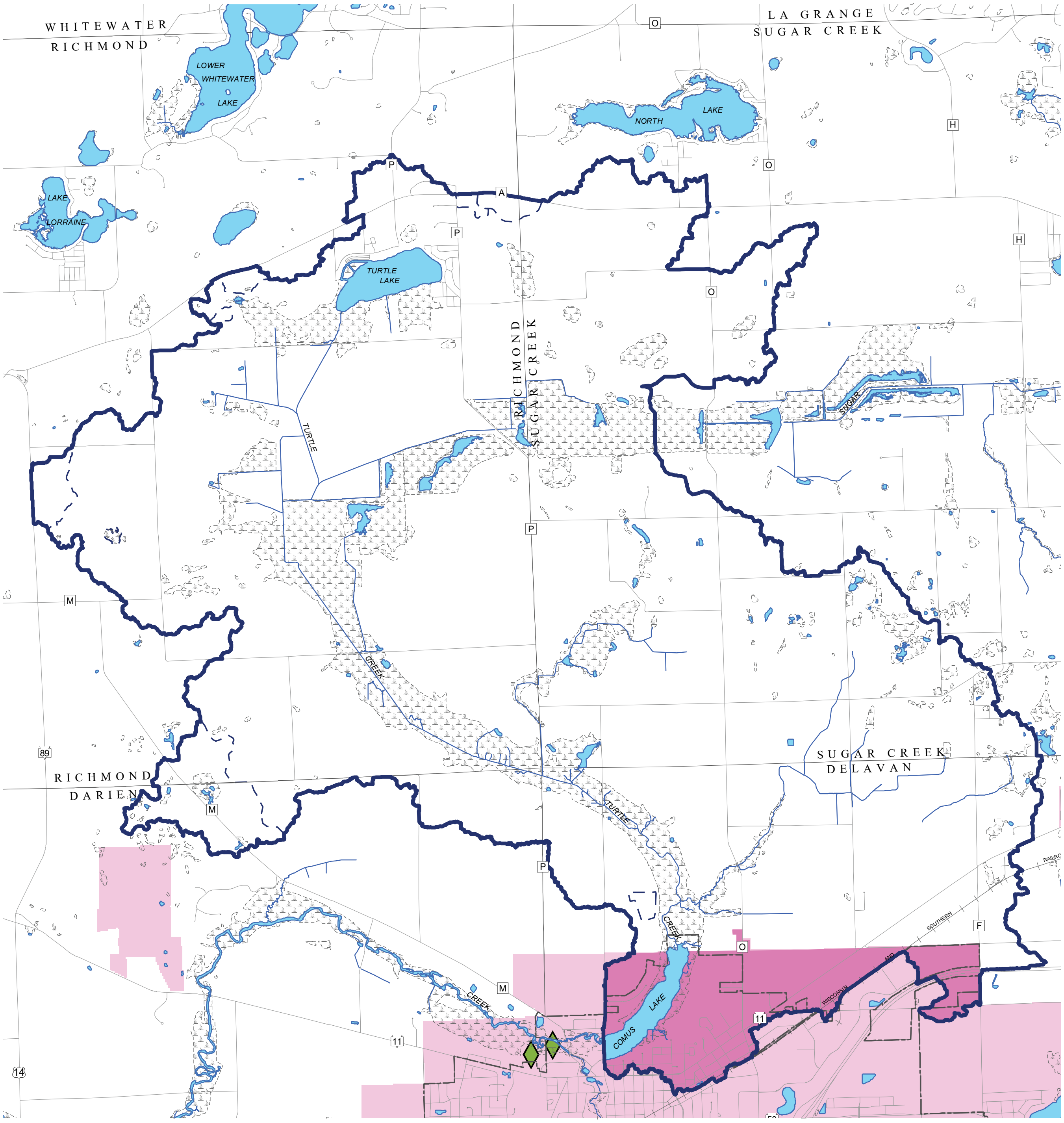
[71] *University of Wisconsin – Whitewater,* Assessing Nitrate Pollution Potential in Walworth County through GIS, *2017. For more information, see www.co.walworth.wi.us/DocumentCenter/View/4199/UW-Whitewater-Assessing-Nitrate-Pollution-Potential-in-Walworth-County-through-GIS-PDF.*

[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

N

0 2,500 5,000 Feet

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]

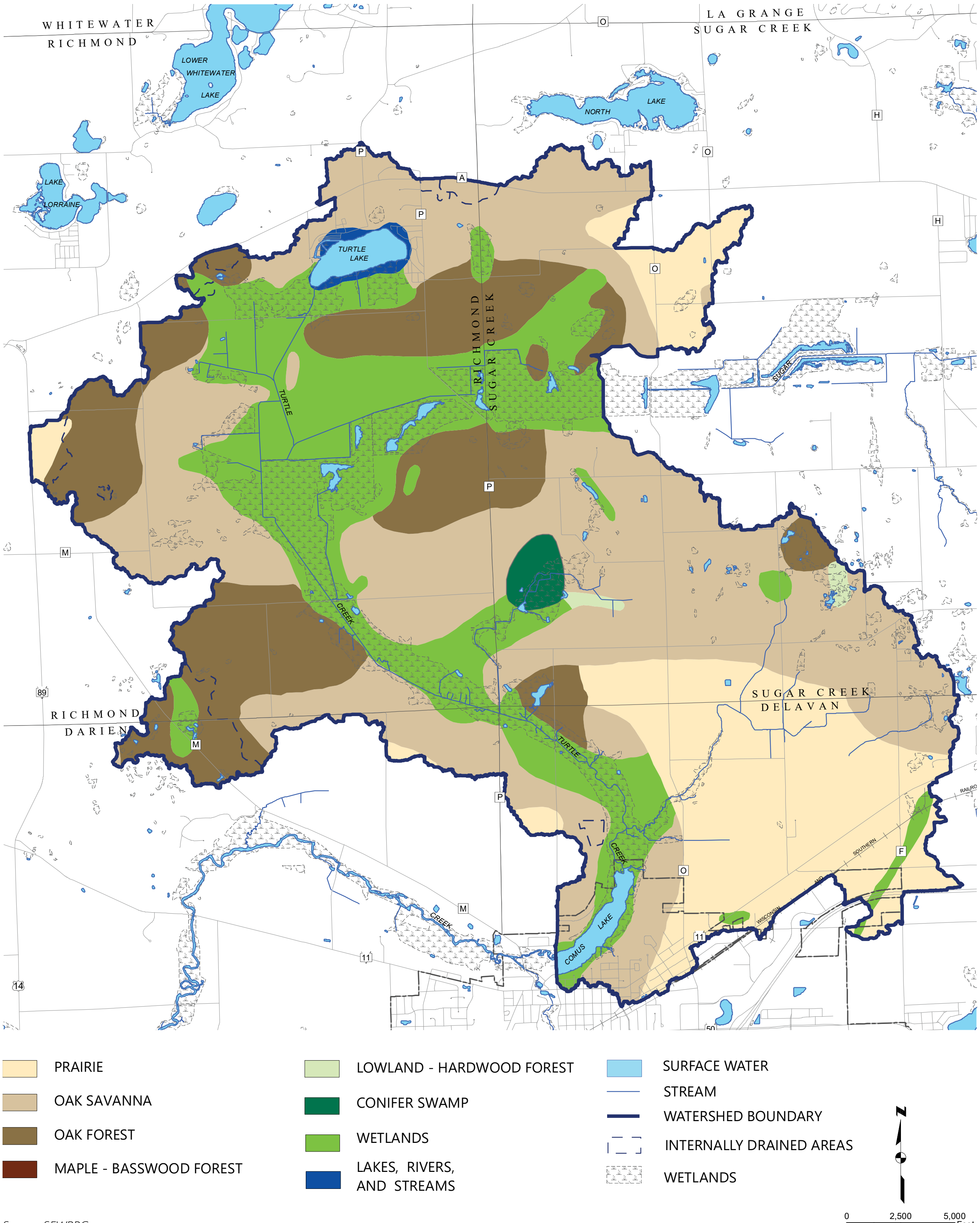
Although a few European adventurers, missionaries, trappers, and traders visited the area since the 1600s, the 1800s witnessed the first great influx of European settlers to the Lake Comus area. These settlers brought sweeping changes to the natural environment. The first Europeans settled in the vicinity 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.

[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.

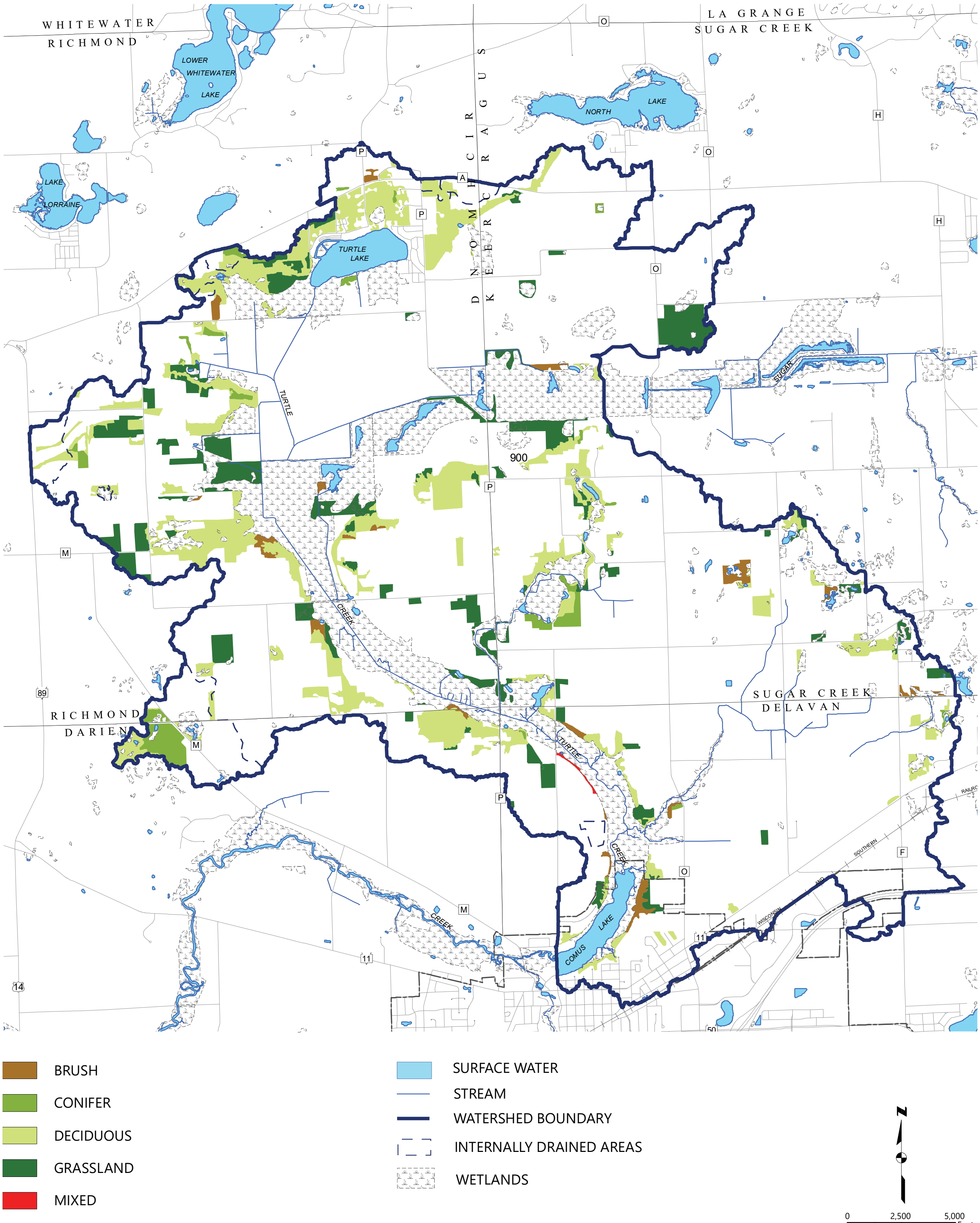
[78] *City of Delavan and Vandewalle & Associates, Inc.*, Downtown Delavan Strategic Plan: City of Delavan, Wisconsin, *May 2013.*

[79] Ibid.

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

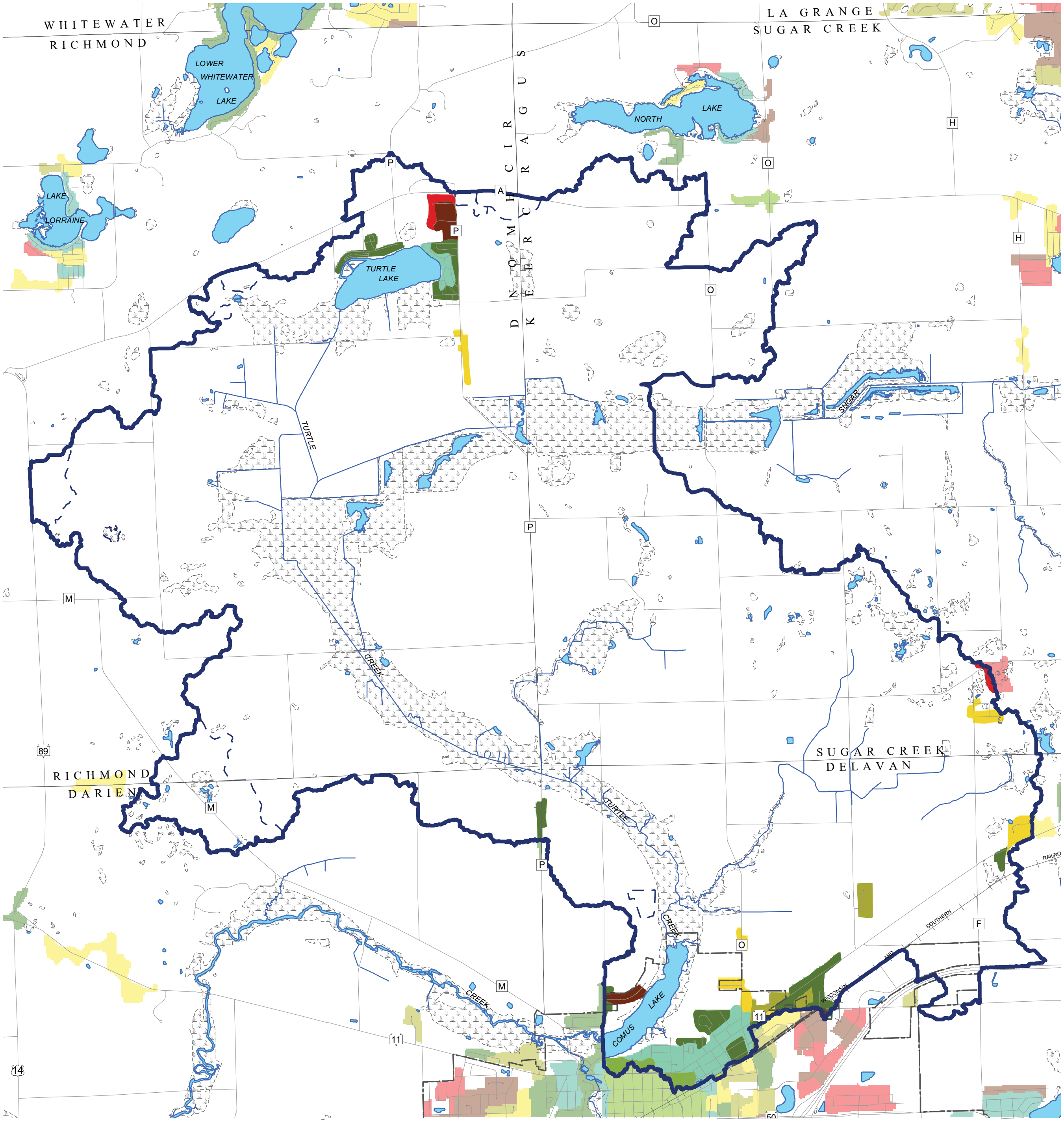
Source: Natural Resources Conservation Service and SEWRPC

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
1900 - 1950
1951 - 1970
1971 - 1980
1981 - 1990
1991 - 2000
2001 - 2010
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

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

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

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.

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

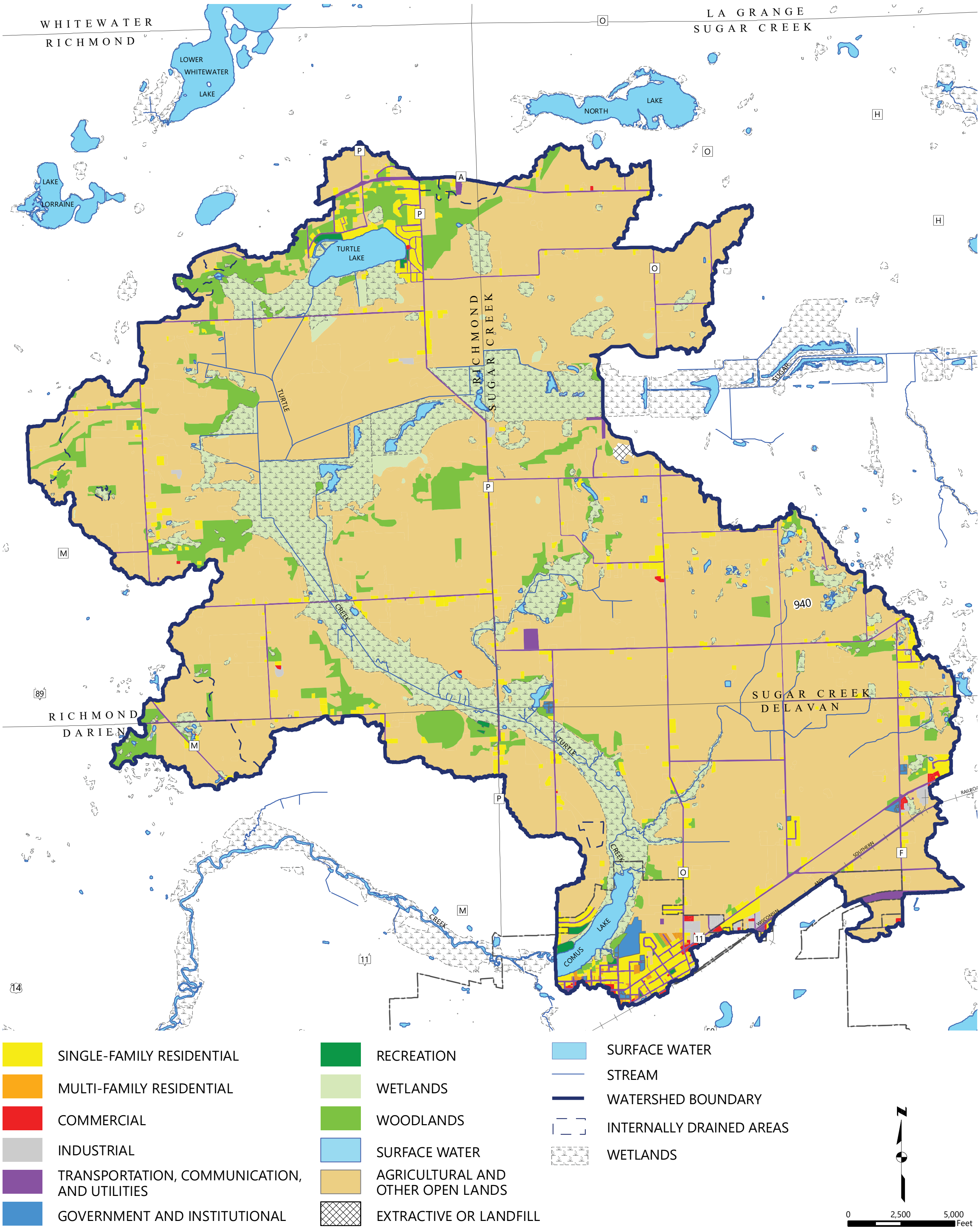
the plans become a formal amendment to the regional water quality management plan and the Commission forwards the plans to the Wisconsin Department of Natural Resources for approval.

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

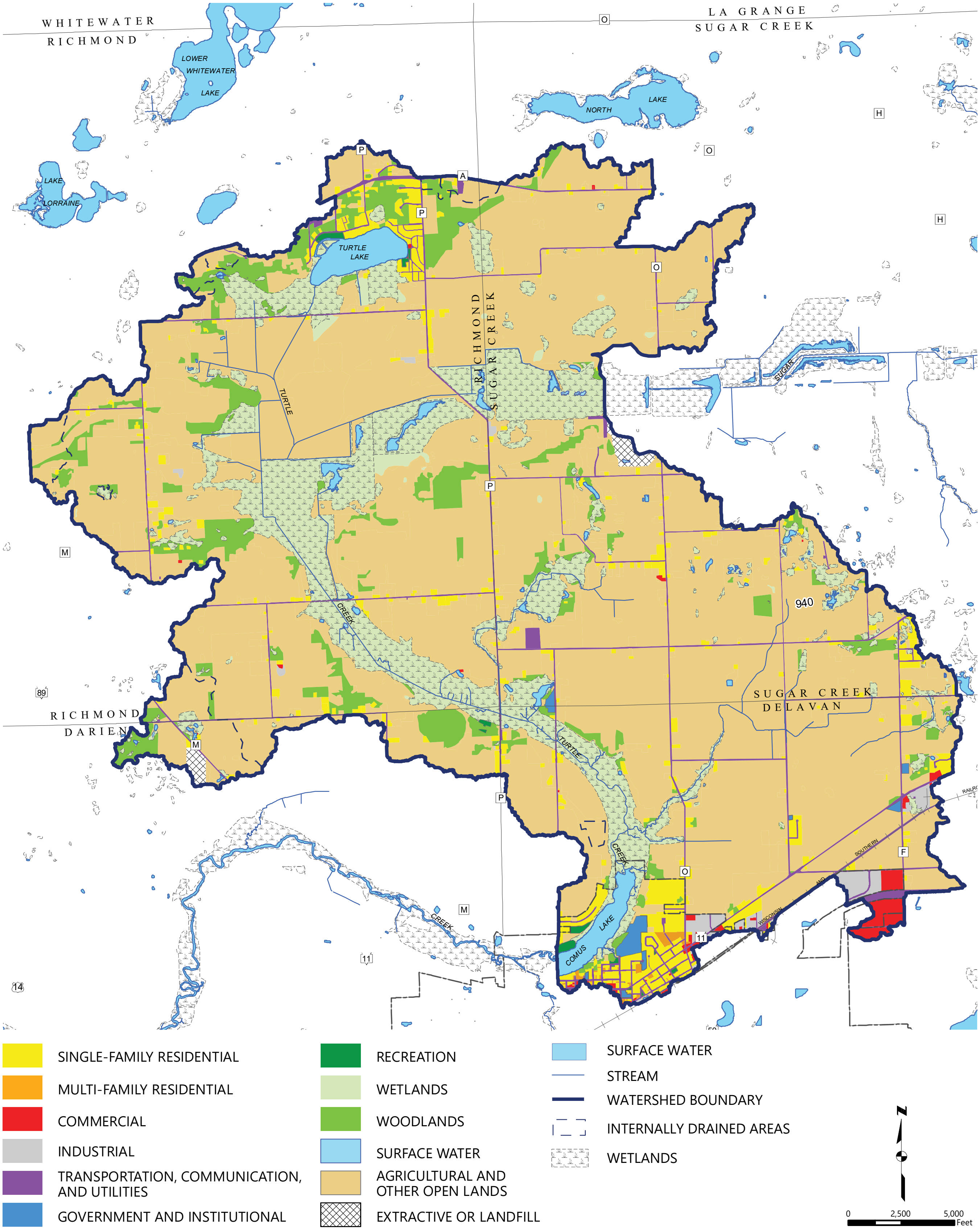
Natural resources elements are features that remain integral parts of the Southeastern Wisconsin landscape provisioning many human needs and desires. Natural resource elements are vital to continued environmental health. The ability of natural resource elements to provision human needs and desires and 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



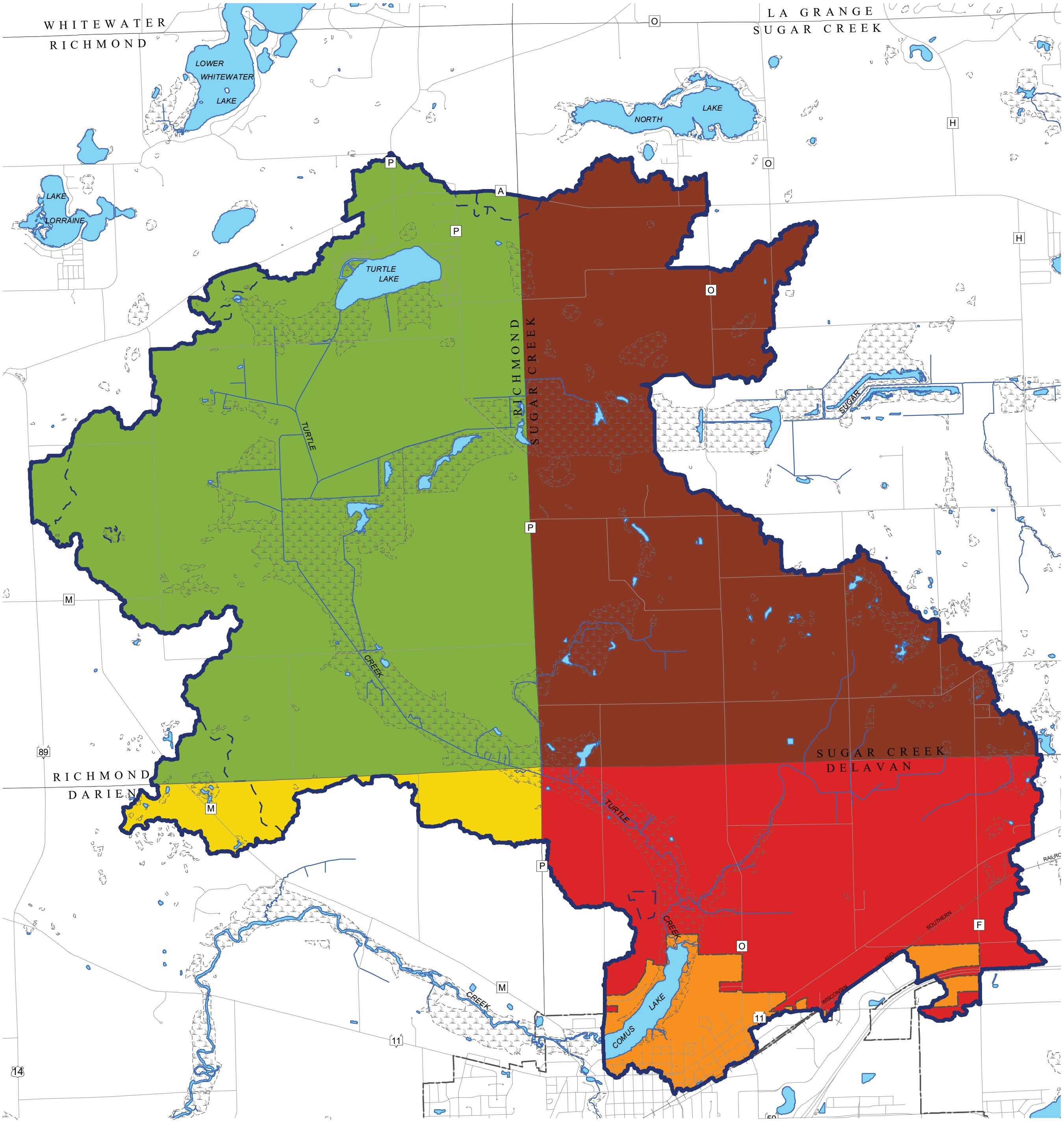
Source: SEWRPC

Map 2.14
Planned Land Use Within the Lake Comus Watershed



Source: SEWRPC

Map 2.15
Comus Lake Watershed Civil Divisions: 2015



CITY OF DELAVAN

TOWN OF DARIEN

TOWN OF DELAVAN

TOWN OF RICHMOND

TOWN OF SUGAR CREEK

SURFACE WATER

STREAM

WATERSHED BOUNDARY

INTERNALLY DRAINED AREAS

WETLANDS

N

0 2,500 5,000 Feet

Source: SEWRPC

Floodplains

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

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.

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

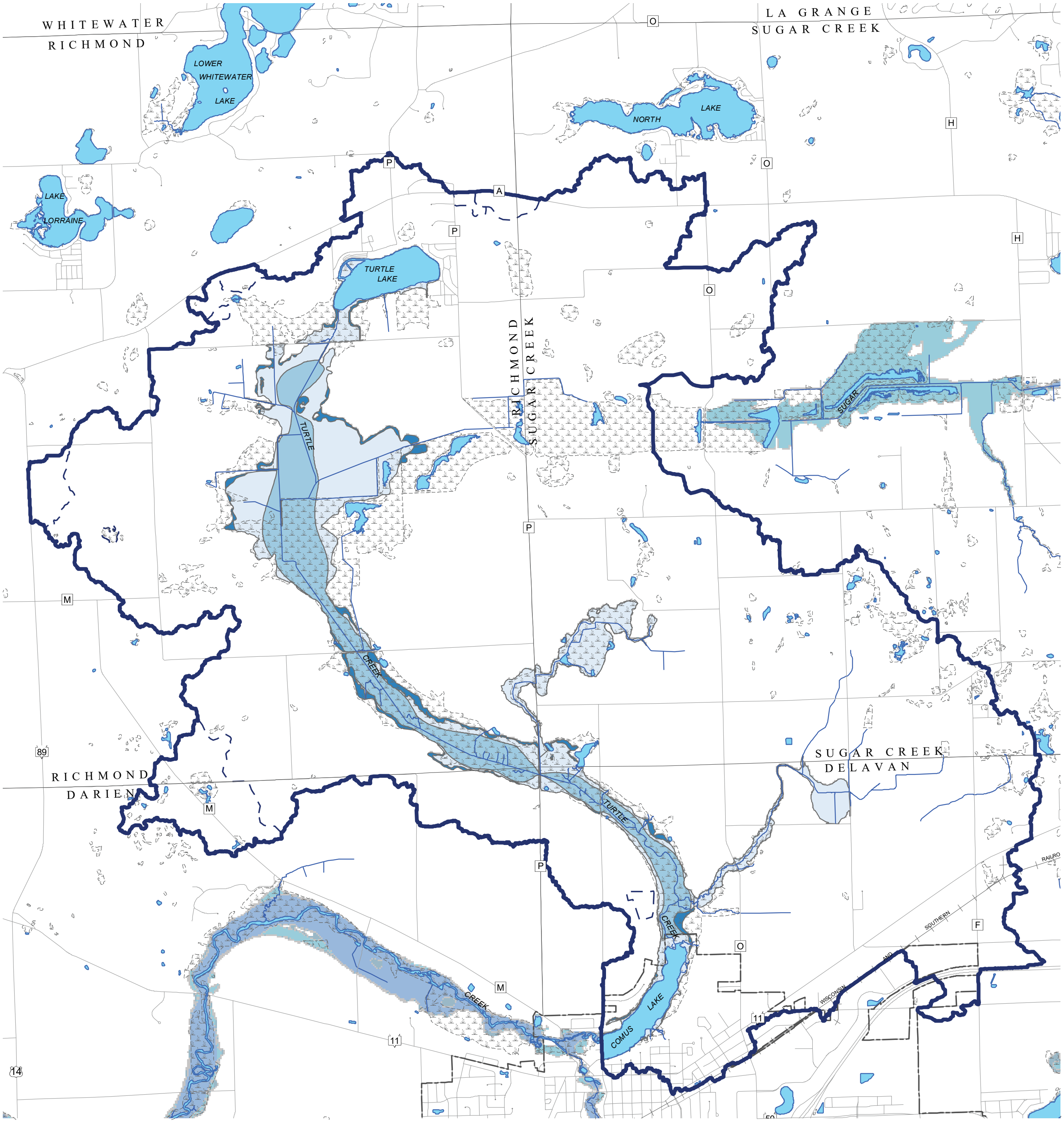
Historically, wetlands were largely viewed as wastelands, lands presenting obstacles to agricultural production and development. Private interests as well as governmental institutions supported the transformation of wetlands through large-scale draining and filling. Wetland habitat was aggressively removed 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.

N

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,

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[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

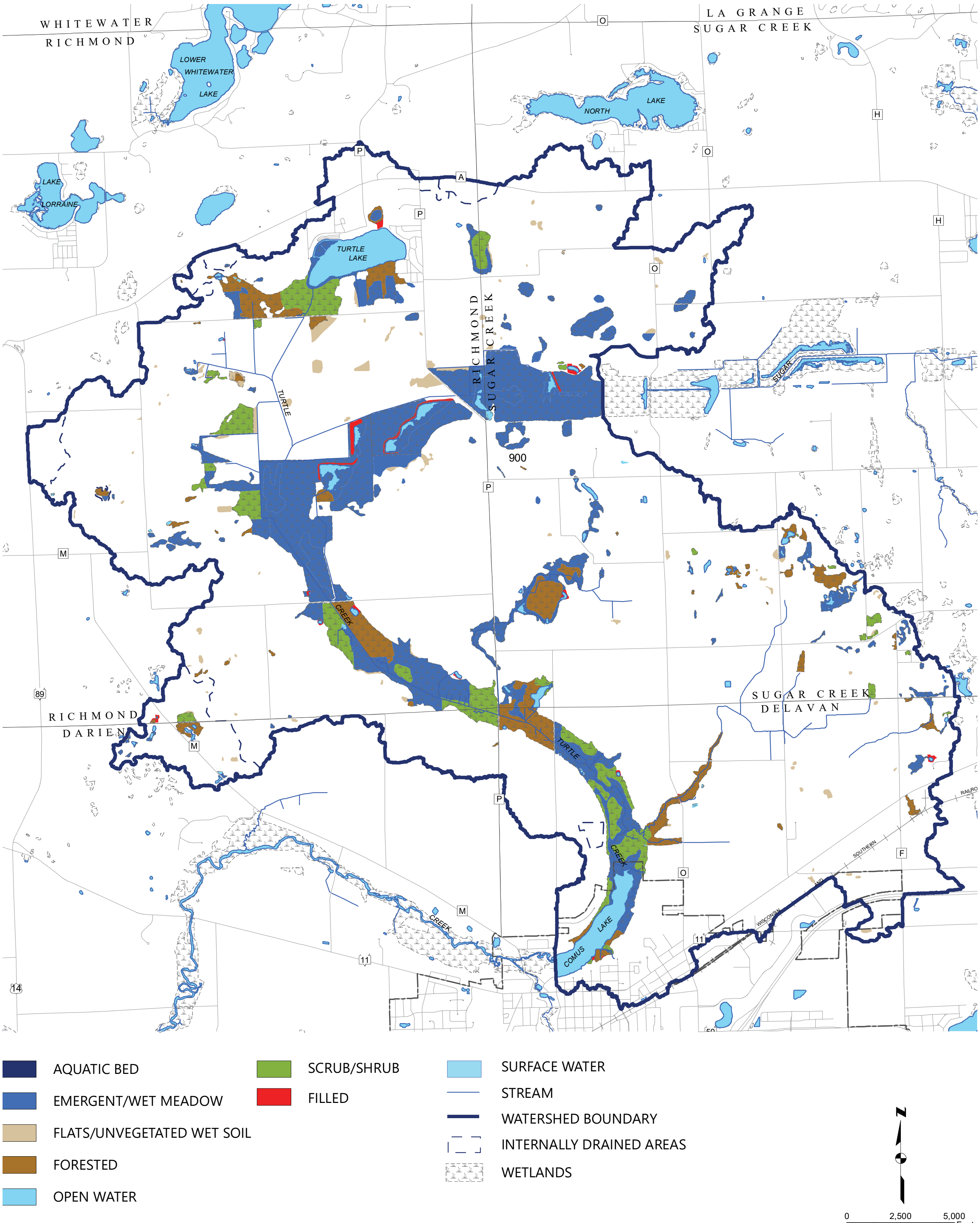
Service	Examples of Goods and Services Derived	Estimated value (1994 US $/ac^{-1} yr^{-1})[a]
REGULATION SERVICES		
Water quality		
Erosion control and sediment retention	Sediment filtration and storage capabilities that prevent downstream migration of sediment and improve downstream water quality.	NA
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

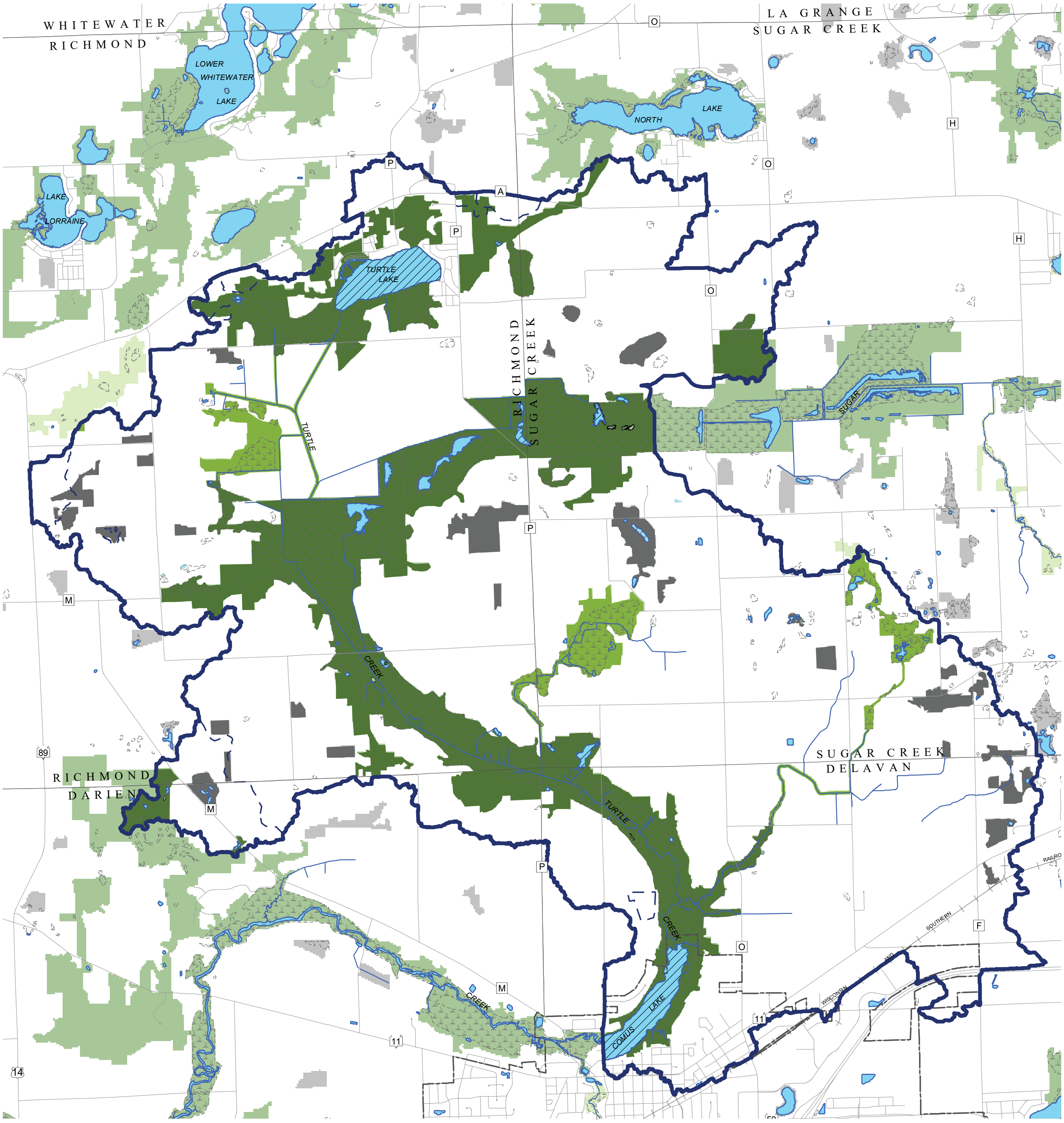
Primary environmental corridors (PECs) encompass a wide variety of important resources and resource-related elements. PECs are at least 400 acres in size, two miles in length, and 200 feet in width.[86] During 2015, PECs covered about 3,980 acres, or about 19 percent, of the Lake Comus watershed. Much 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.

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

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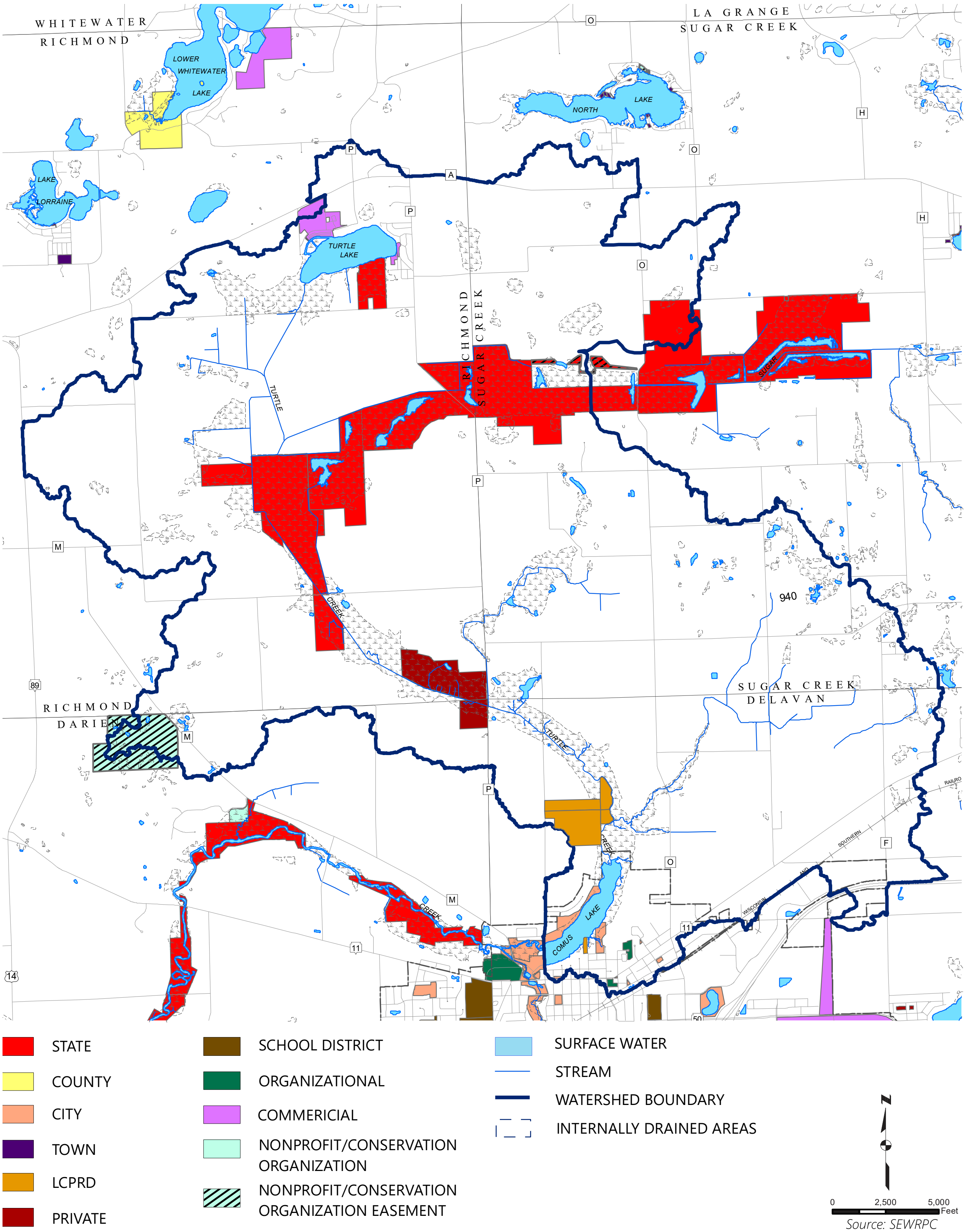
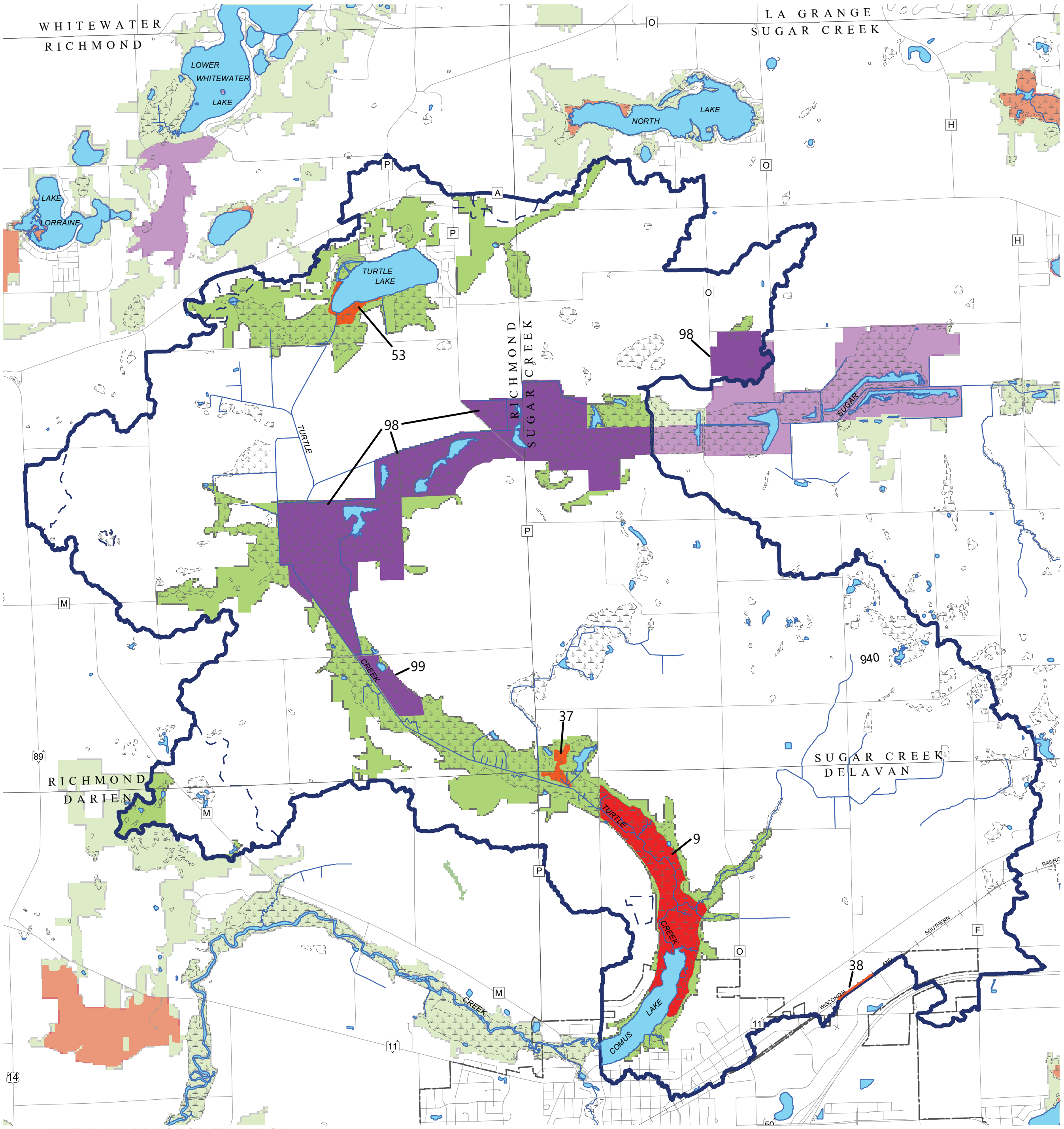
[87] *O. Attum, Y.M. Lee, J.H. Roe, and B.A. Kingsbury, "Wetland Complexes and Upland-Wetland Linkages: Landscape Effects on the Distribution of Rare and Common Wetland Reptiles,"* Journal of Zoology*, 275: 245-251, 2008.*

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))		SURFACE WATER
	NATURAL AREA OF COUNTYWIDE OR REGIONAL SIGNIFICANCE (NA-2)		STREAM
	NATURAL AREA OF LOCAL SIGNIFICANCE (NA-3)		WATERSHED BOUNDARY
	CRITICAL SPECIES HABITAT SITE		INTERNALLY DRAINED AREAS
	PRIMARY ENVIRONMENTAL CORRIDOR	9	COMUS LAKE WETLAND COMPLEX
	WETLANDS	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.

0 2,500 5,000 Feet

Source: SEWRPC

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

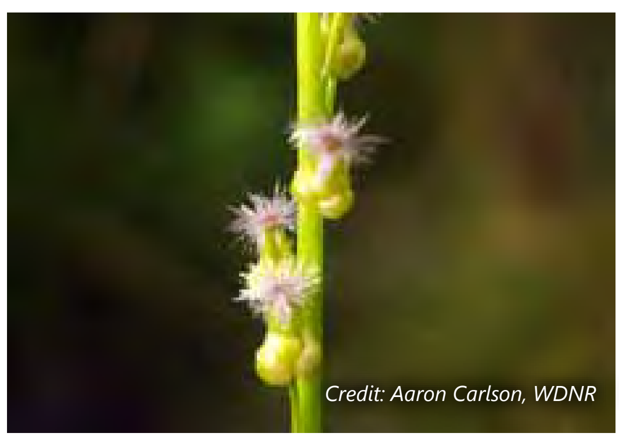


Figure 2.18 (Continued)

SMALL WITE LADY'S SLIPPER
Cypripedium candidum


Credit: Flickr User: Justin Meissen

UPLAND SANDPIPER
Bartramia longicauda


Credit: Flickr User: Dominic Sherony

YELLOW-HEADED BLACKBIRD
Xanthocephalus xanthocephalus


Credit: Flickr User: Becky Matsubara

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] Median	Southeastern Wisconsin Values[a] Range	Regulatory Limit or Guideline	Lake Comus Values Median	Lake Comus Values 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] Median	Southeastern Wisconsin Values[a] Range	Regulatory Limit or Guideline	Lake Comus Values Median	Lake Comus Values 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.*

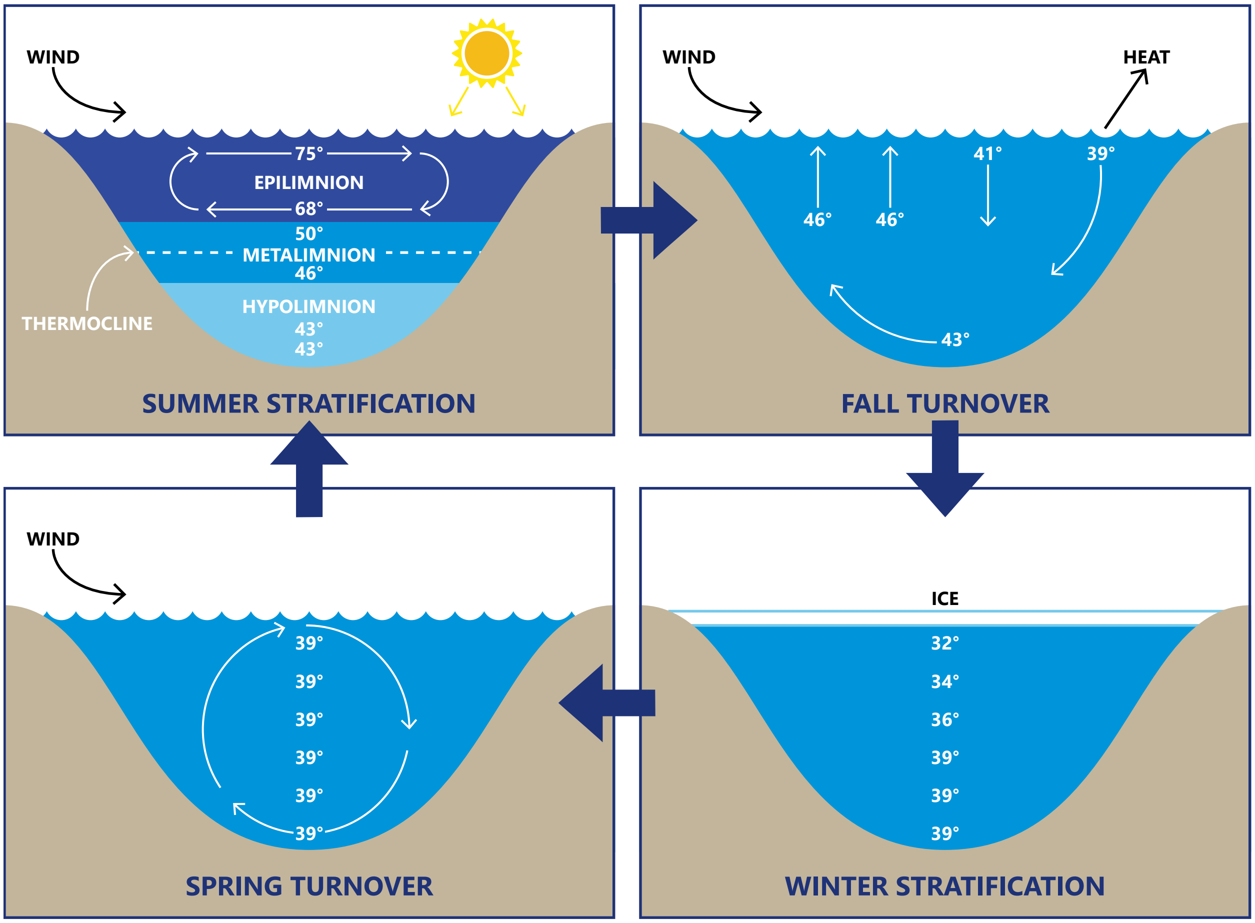
Source: Wisconsin Department of Natural Resources, Wisconsin

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

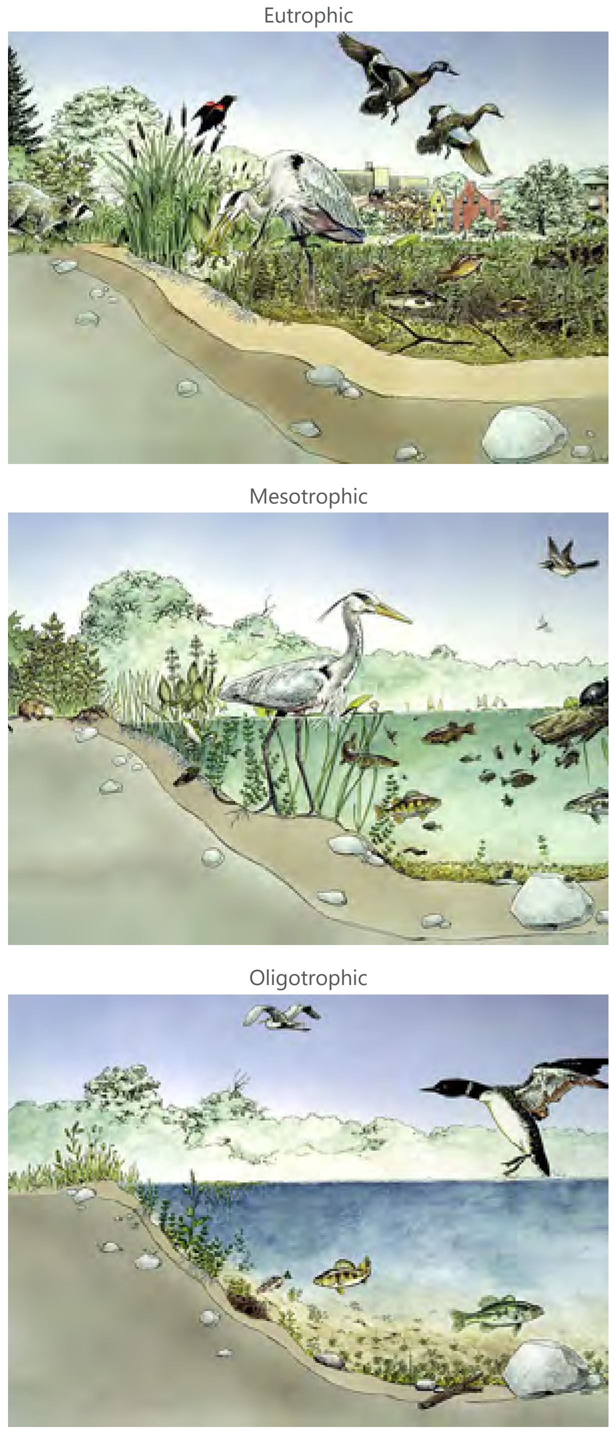


Source: Modified from B. Shaw, C. Mechenich, and L. Klessig, Understanding Lake Data, *University of Wisconsin-Extension, p. 3, 2004 and SEWRPC*

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.

Figure 2.20
Comparison of Trophic Lake Status



Source: UW-Extension Lakes Program and SEWRPC

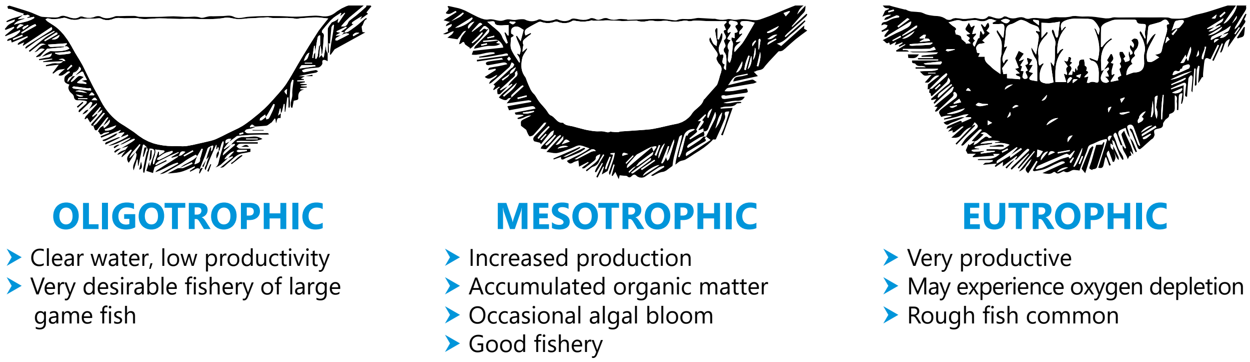
Dissolved oxygen profiles indicate high dissolved oxygen concentrations (Figure 2.24). While there does appear to be low oxygen concentrations in September 2018 and May 2019, these concentrations are more likely due to extremely high biological oxygen demand from decomposition than due to any stratification 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-

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

Figure 2.21
Lake Aging's Effect on Trophic Status



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.

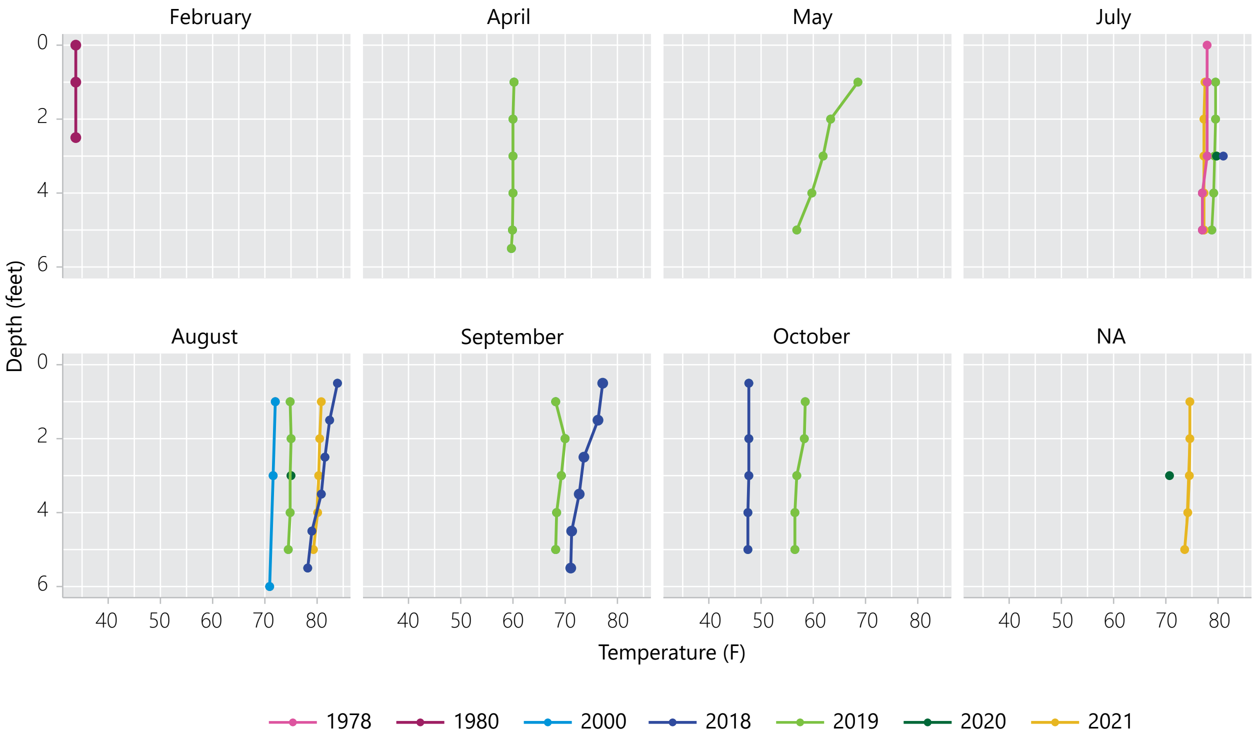
[95] *www.air-quality.org.uk/13.php.*

[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

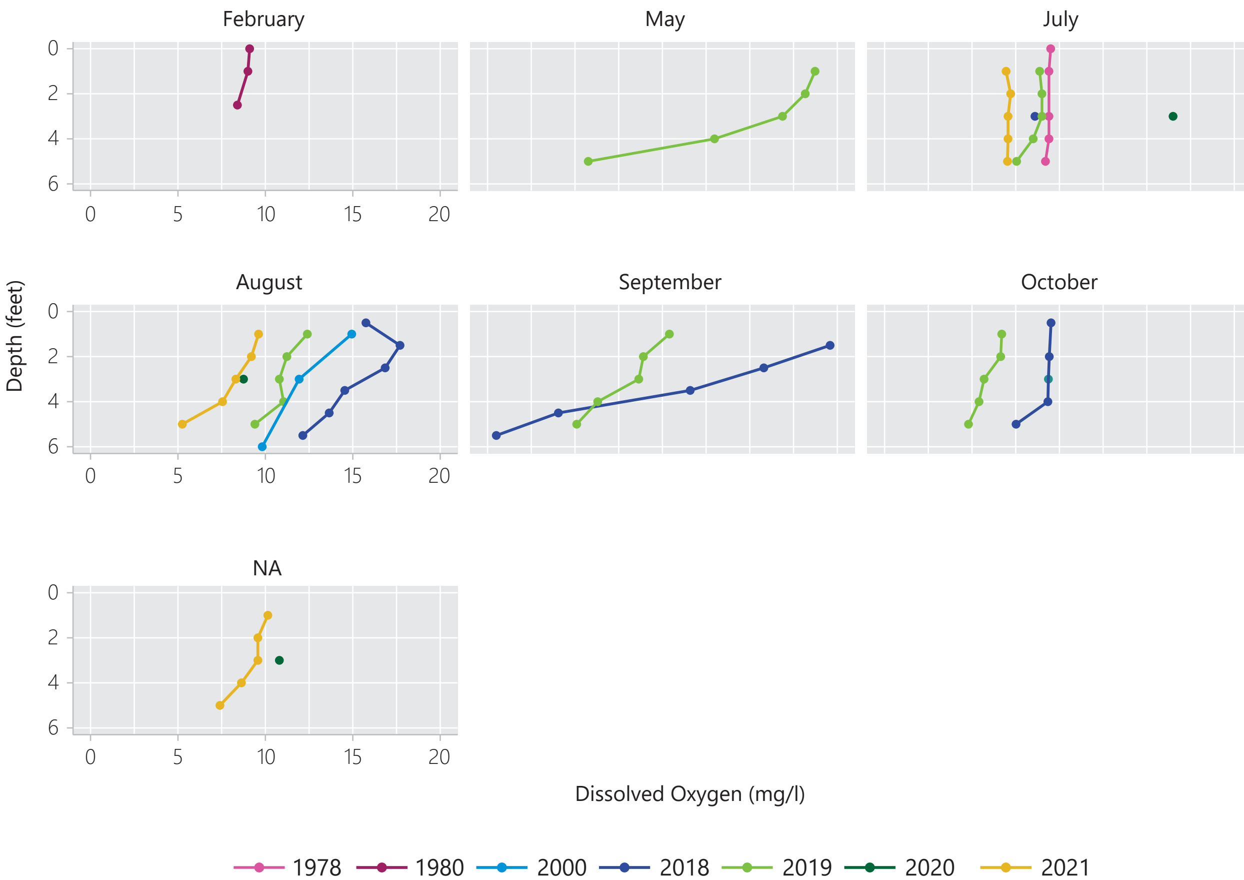
Specific conductance is a measure of the ability of a liquid, such as lake water, to conduct electricity, standardized at a specific temperature (25°C). Water's specific conductance relates to dissolved solids concentration: as dissolved solids increase, specific conductance increases. While many of 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]

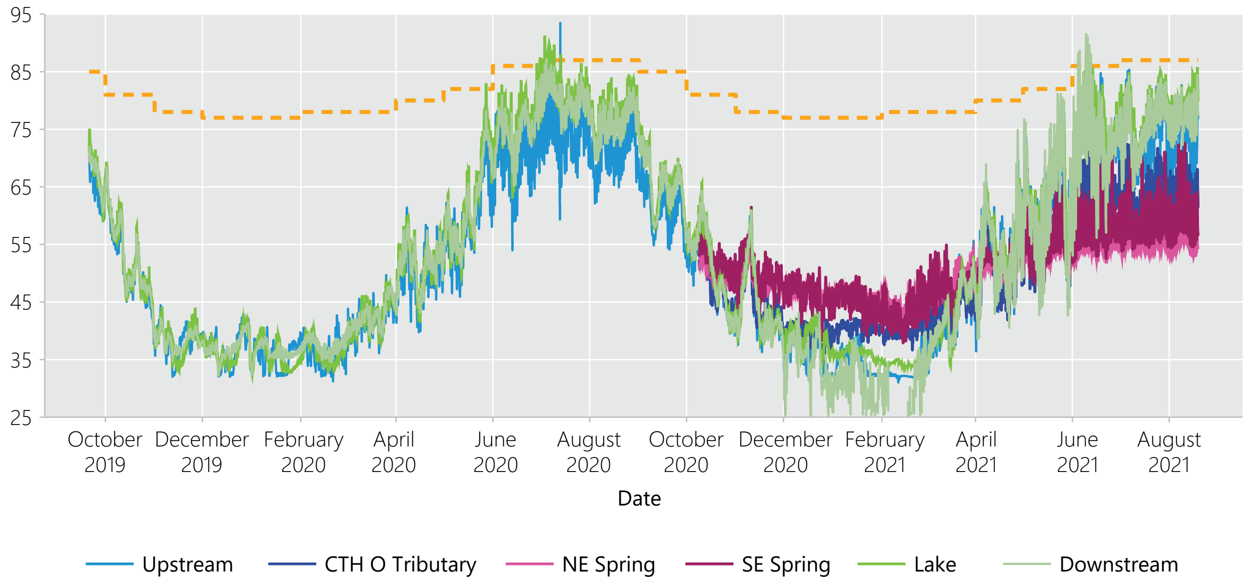
Nutrients and Trophic State

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:

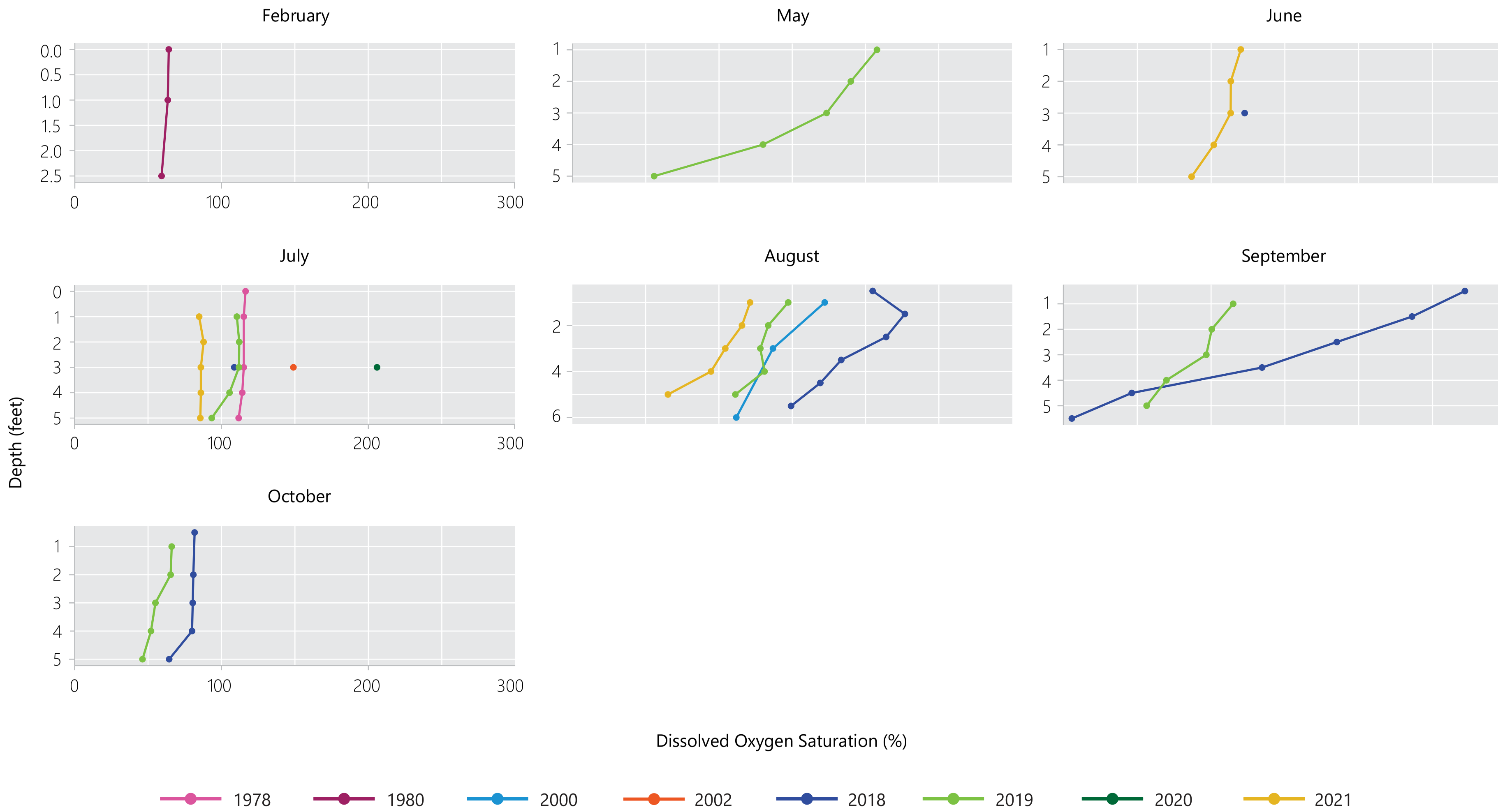
- high concentrations of small, aquatic organisms, such as algae and zooplankton
- suspended sediment and/or inorganic particles

[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.*

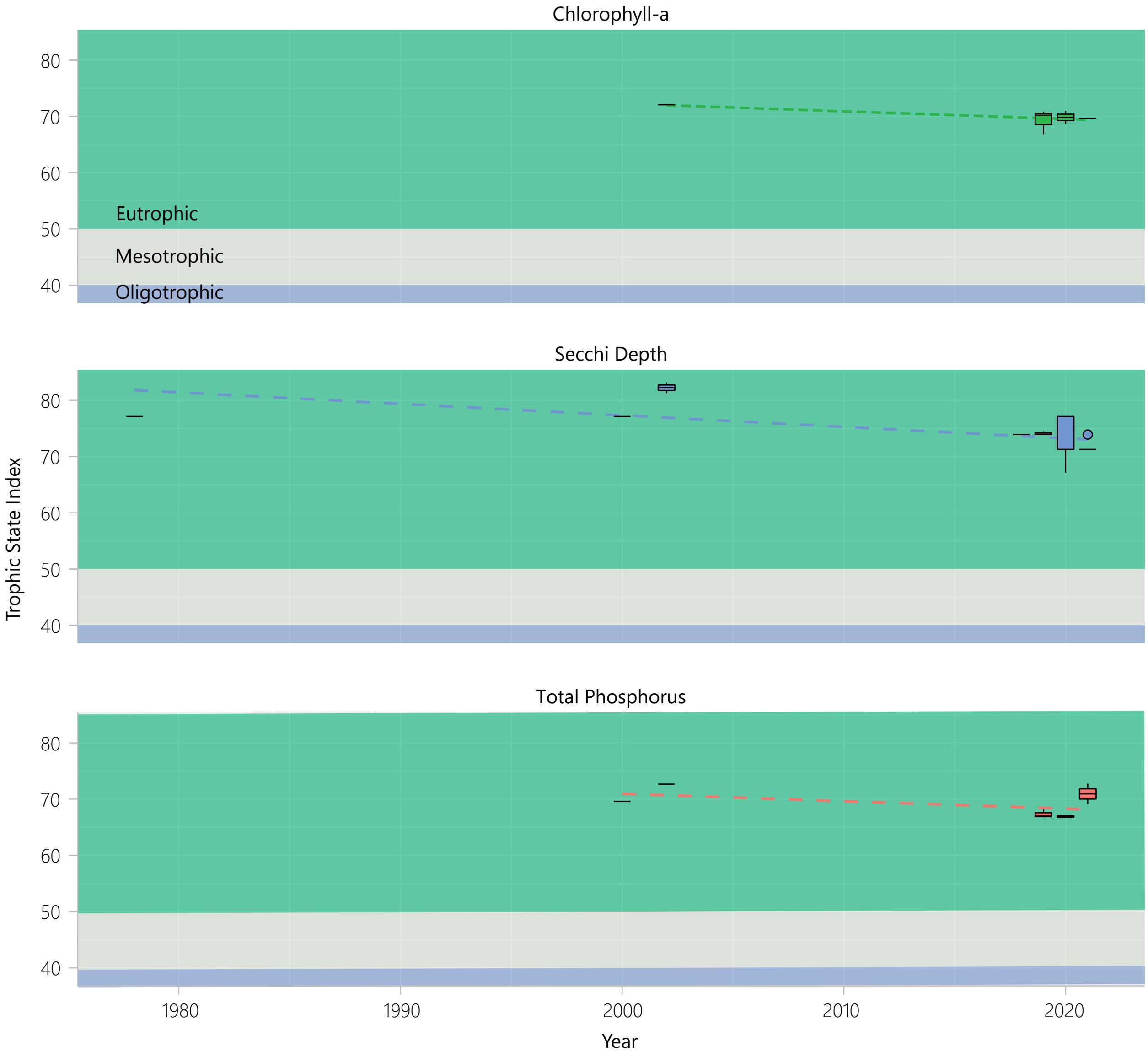
Figure 2.26
Dissolved Oxygen Saturation in Lake Comus: 1978-2021



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)

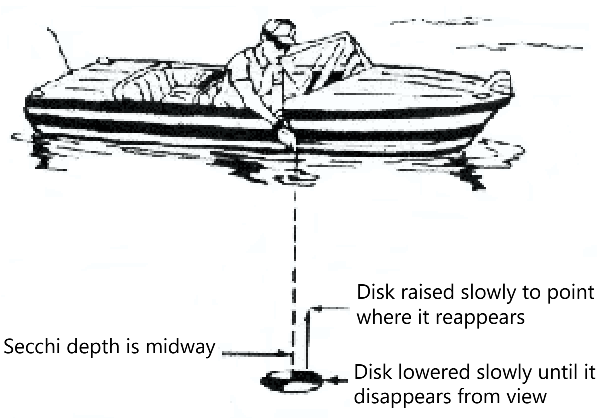
In most Southeastern Wisconsin lakes, water clarity is influenced by the abundance of algae and suspended sediment. Water clarity varies throughout the year as algal populations increase and decrease in response to changes in lake temperature, sunlight, and nutrient availability. Large rainfall events 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

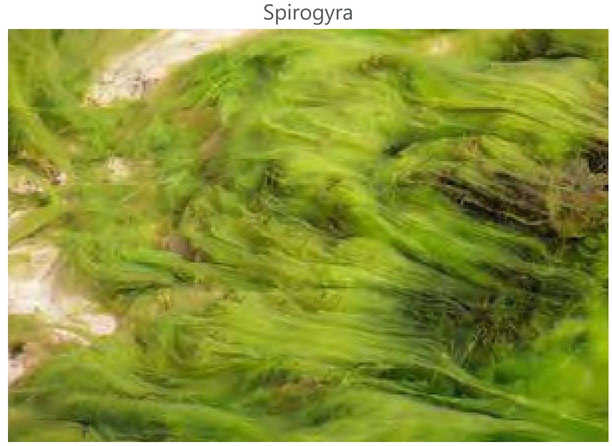
Surface waters contain a variety of nitrogen compounds that are nutrients for plants and algae. Typically, only a small number of forms of nitrogen are examined and reported in water quality sampling. Total nitrogen includes all the nitrogen in dissolved or particulate form in the water, excluding all 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.

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

<u>Bacteria</u>

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.

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) Geometric Mean Maximum	 200 400	 200 400	 200 400	 1,000 2,000	 1,000 --	 200 400	NR 102.04(5) NR 102.04(6) NR 102.06(2)
Total Phosphorus (mg/l) Designated Streams[f] Other Streams	 0.100 0.075	 0.100 0.075	 0.100 0.075	 0.100 0.075	 0.100 0.075	 0.100 --	NR 102.06(3) NR 102.06(4) NR 102.06(5) NR 102.06(6)
Chloride (mg/l) Acute Toxicity[g] Chronic Toxicity[h]	 757 395	 757 395	 757 395	 757 395	 757 395	 757 395	NR 105.05(2) 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.*

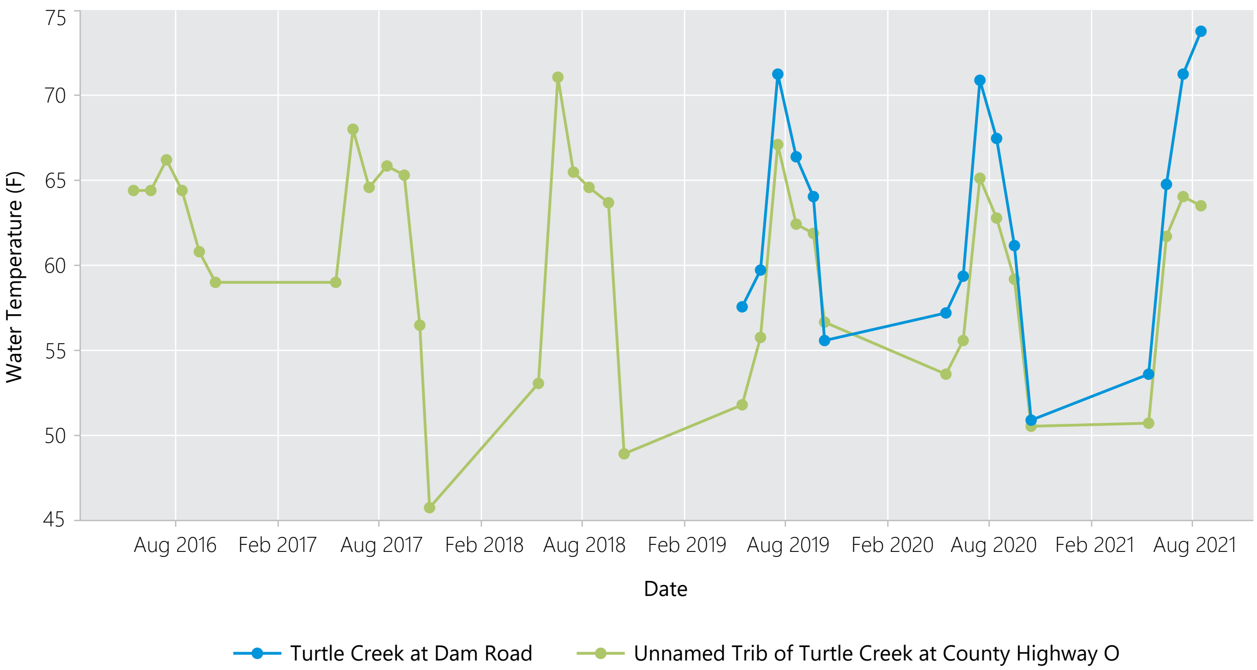
[f] *Designated in Chapter NR 102.06(3)(a) of the* Wisconsin Administrative Code. *There are no designated streams in the Pewaukee Lake watershed*

[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

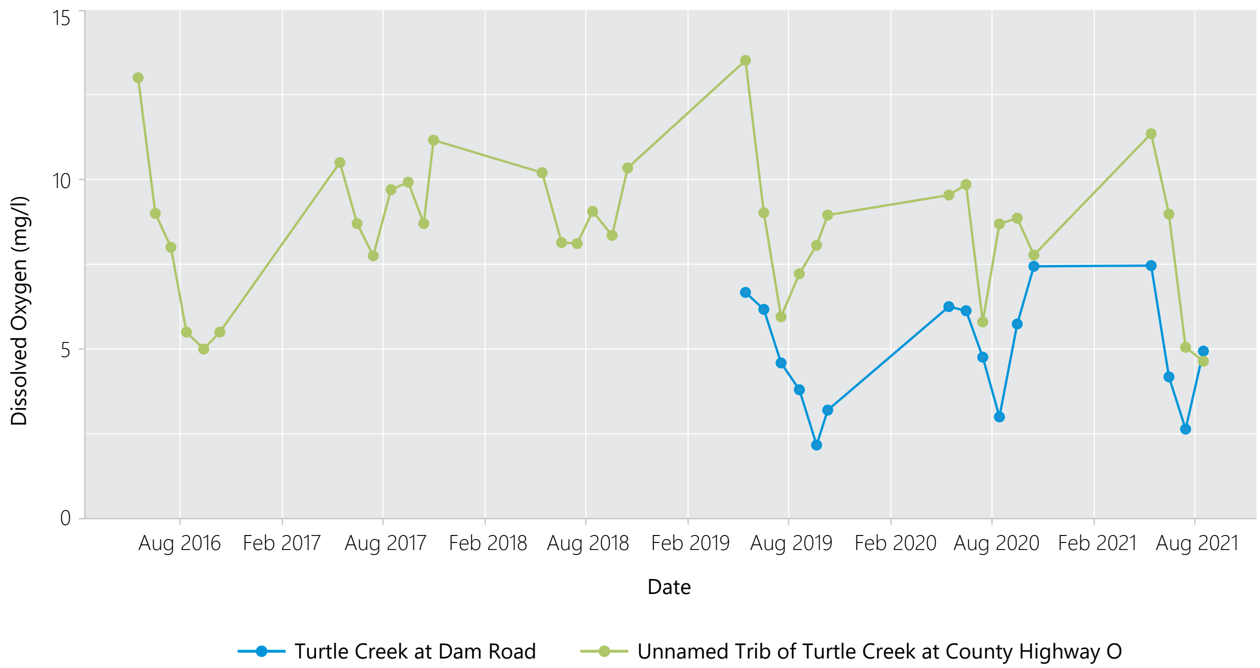
the Lake at the Dam Road. The Lake was also between two and five degrees Fahrenheit warmer than the downstream Richmond Road site. However, the downstream site generally had slightly higher summer temperatures than the Upstream site. The CTH O tributary temperatures were generally 10°F lower than Turtle 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

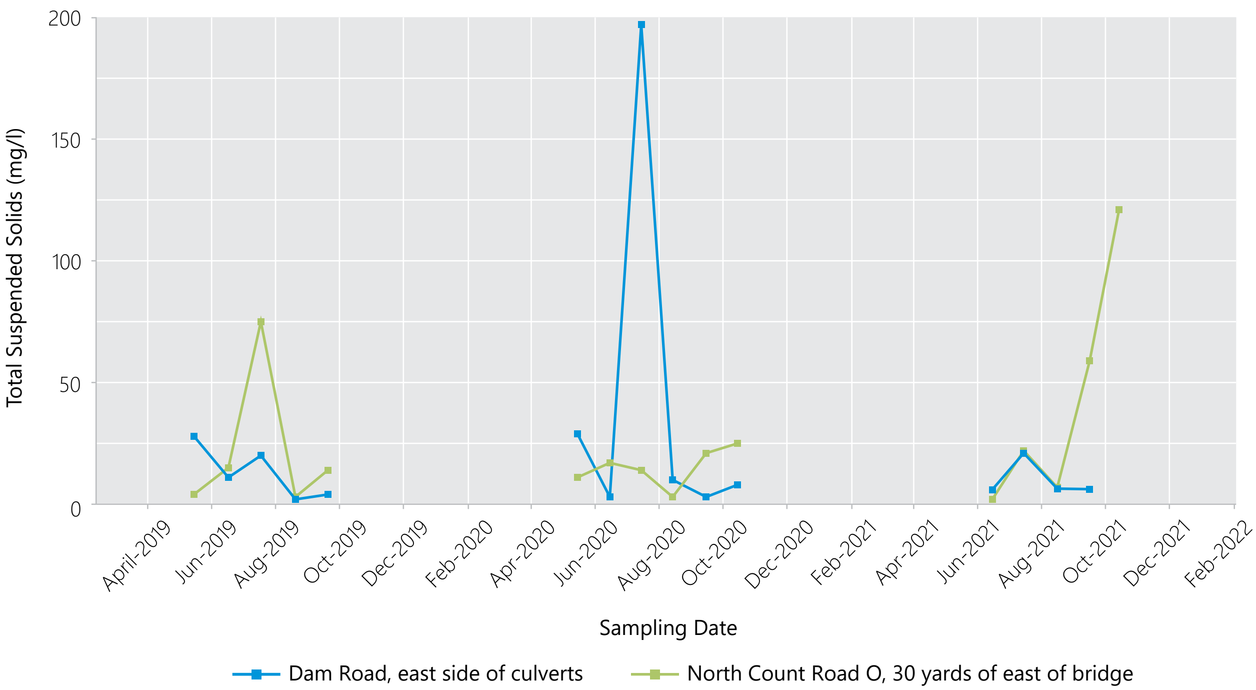
As with lakes, high specific conductance values and chloride concentrations may indicate human influence upon stream water quality. As was discussed in the Lake Comus water quality section, humans release a variety of substances into the environment that increase water conductance and chloride concentrations. 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.

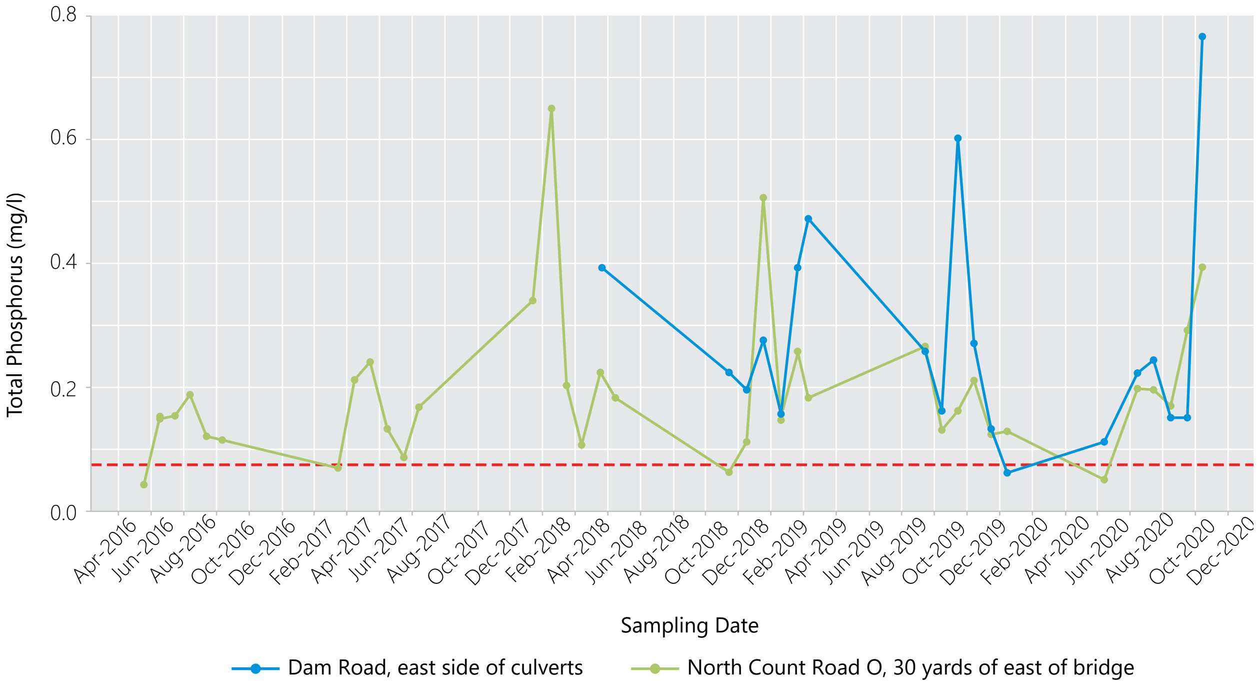
As part of 2020-2021 sampling effort, total phosphorus concentrations were measured in agricultural drain tile effluent.[112] Drain tiles have been shown to export multiple forms of phosphorus and can be a substantial portion of total phosphorus loss from agricultural systems.[113] Drain tile effluent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

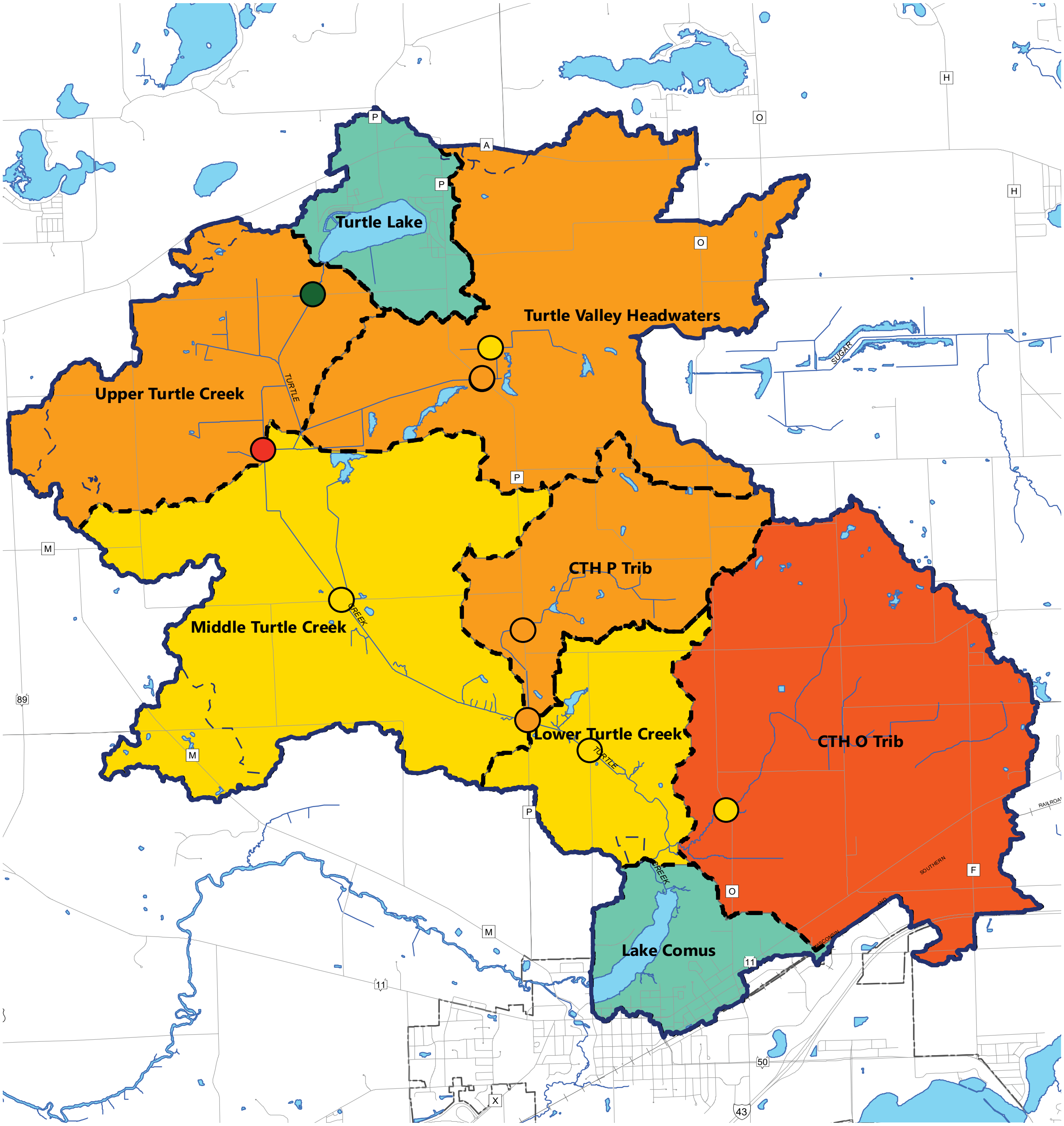
concentrations ranged from non-detectable to 0.63 mg/l in the 2020-2021 monitoring. Of the six drain tile samples collected, four were higher than the 0.075 mg/l total phosphorus standard for streams and small rivers. Several of these samples were collected after heavy rainfall and thus may not represent 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



MODELED TOTAL PHOSPHORUS LOADING PER ACRE (LBS/ACRE)

- 0.30 - 0.49
- 0.50 - 0.59
- 0.60 - 0.69
- 0.70 - 0.75
- WETLANDS

MEAN TOTAL PHOSPHORUS CONCENTRATIONS (MG/L)

- 0.060
- 0.061 - 0.074
- 0.075 - 0.299
- 0.300 - 0.499
- 0.500 - 1.10

- SURFACE WATER
- STREAM
- WATERSHED BOUNDARY
- INTERNALLY DRAINED AREAS
- WATERSHED SUBBASINS

0 0.25 0.5 1 Mile

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

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[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.

Sediment

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

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[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.

Phosphorus

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

Historic Estimates of Soil Loss

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.

Current Pollutant Loading Estimates

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.

[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

	Pollutant Loads: Pre-settlement		Pollutant Loads: 2015 Land Use	
Land Use Category	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

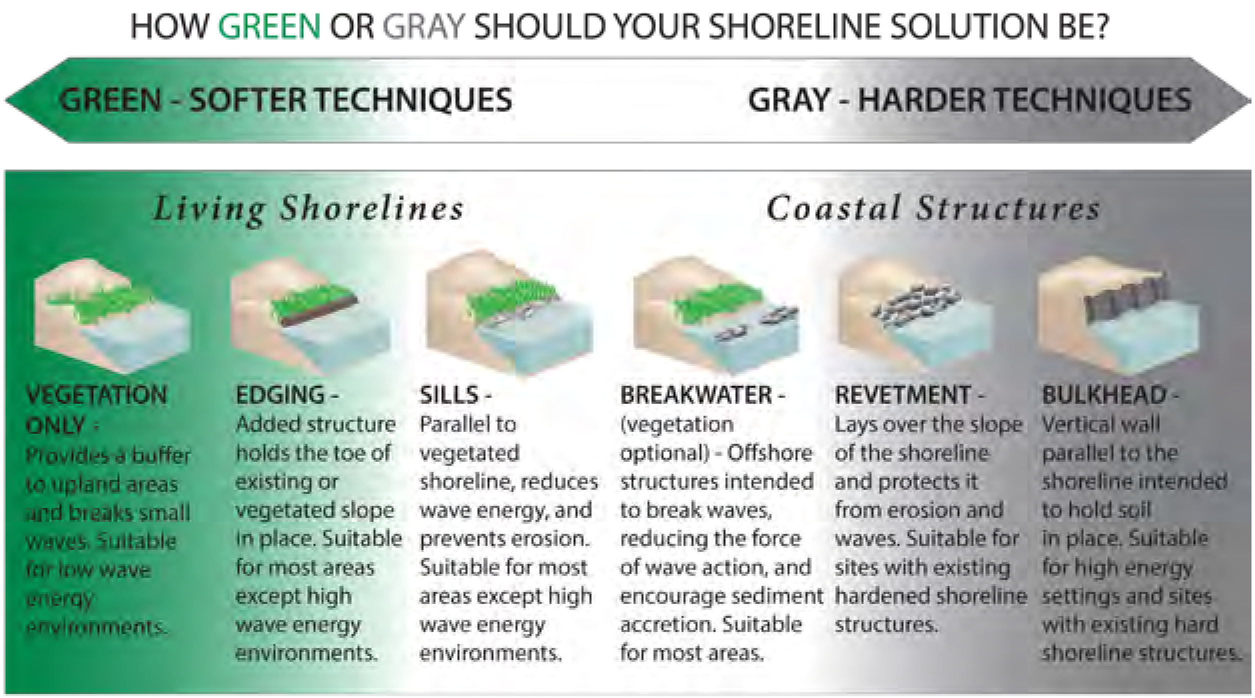
- *Buffers* are areas of plant growth—engineered or natural—in the riparian zone (lands immediately back from the shoreline) that trap sediment and nutrients emanating from upland and nearshore erosion

"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]

[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.

<u>Lake Shoreline Survey</u>

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.

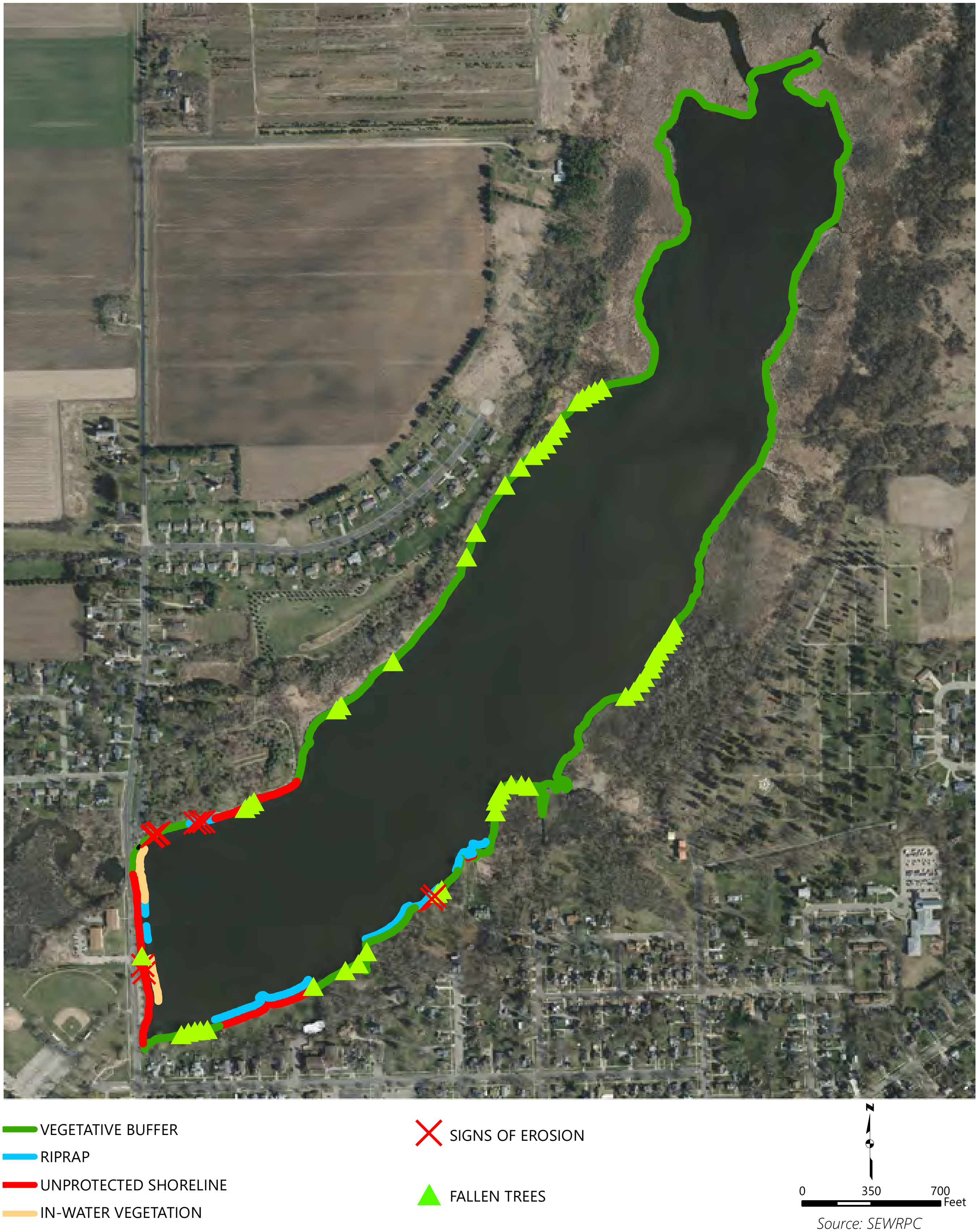
[140] Ibid.

[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

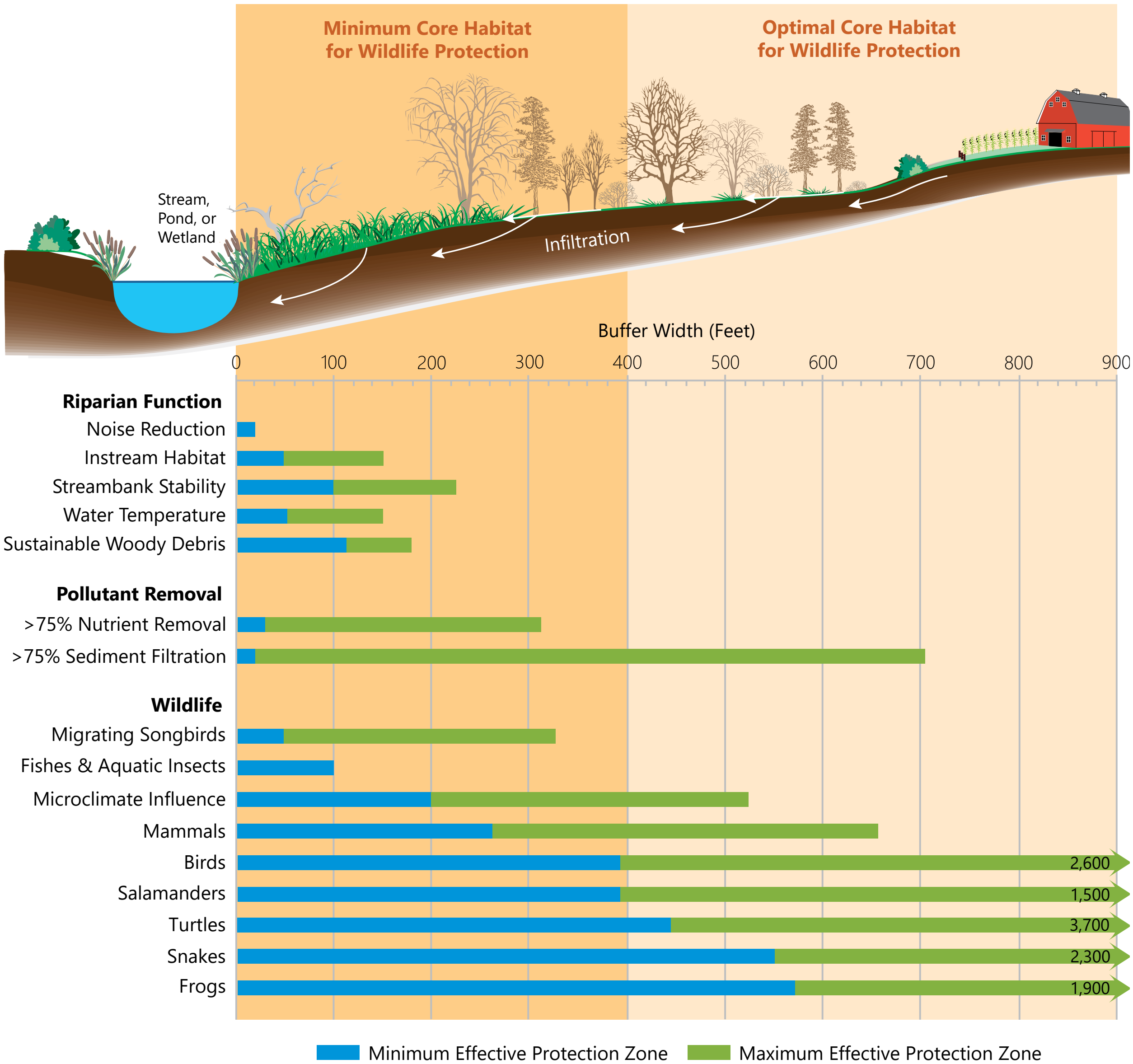
Table 2.18
Effect of Buffer Width on Contaminant Removal

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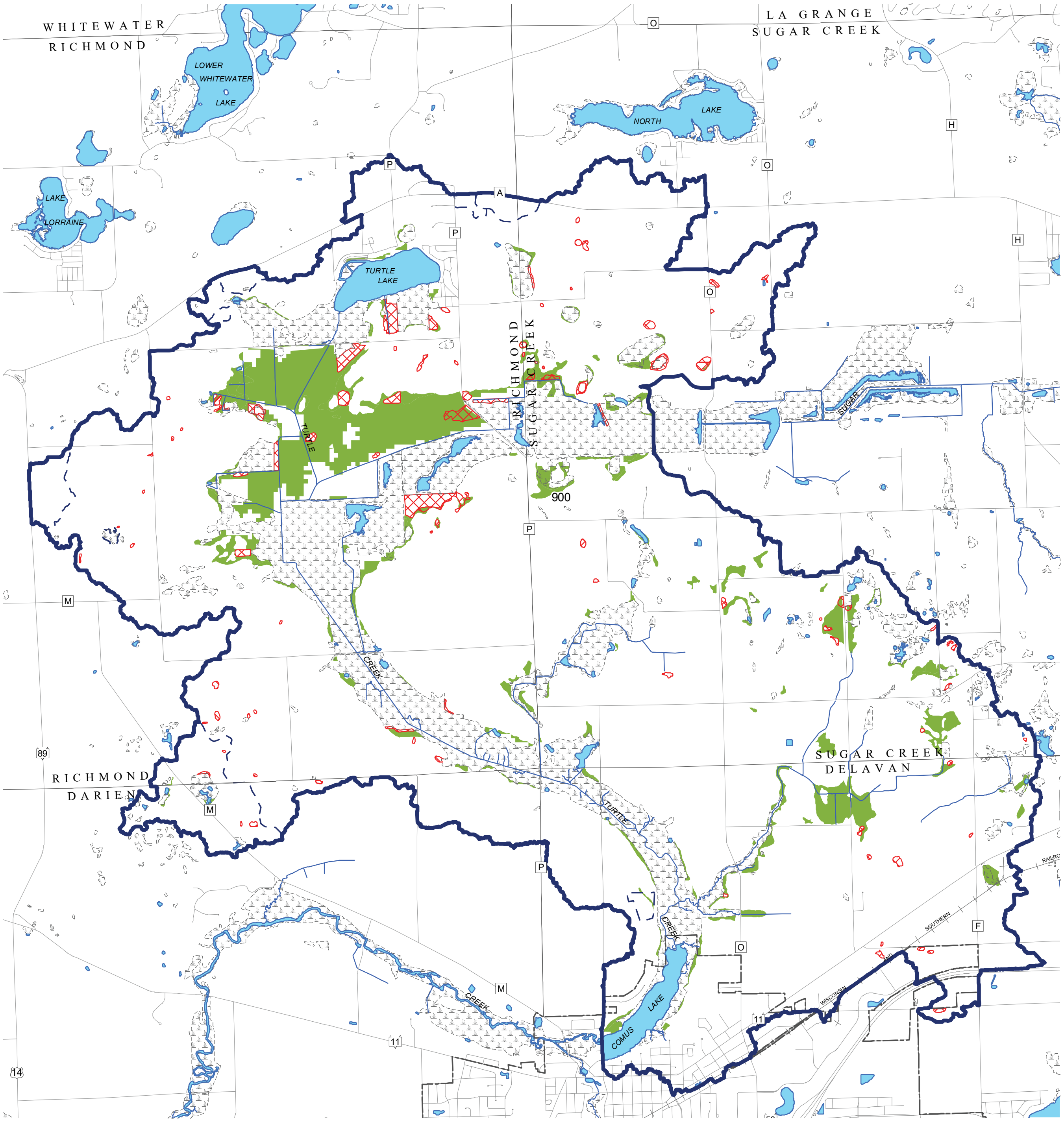
[148] *U.S. Environmental Protection Agency (USEPA),* Wetlands: Protecting Life and Property from Flooding*, May 2006, USEPA843-F-06-001, Website: water.epa.gov/type/wetlands/outreach/upload/Flooding.pdf.*

[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



POTENTIAL RESTORABLE WETLAND

FARMED WETLAND

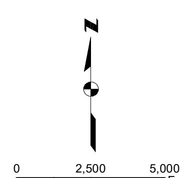
WETLANDS

SURFACE WATER

STREAM

WATERSHED BOUNDARY

INTERNALLY DRAINED AREAS



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.

<u>Existing and Potential Riparian Buffers</u>

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]

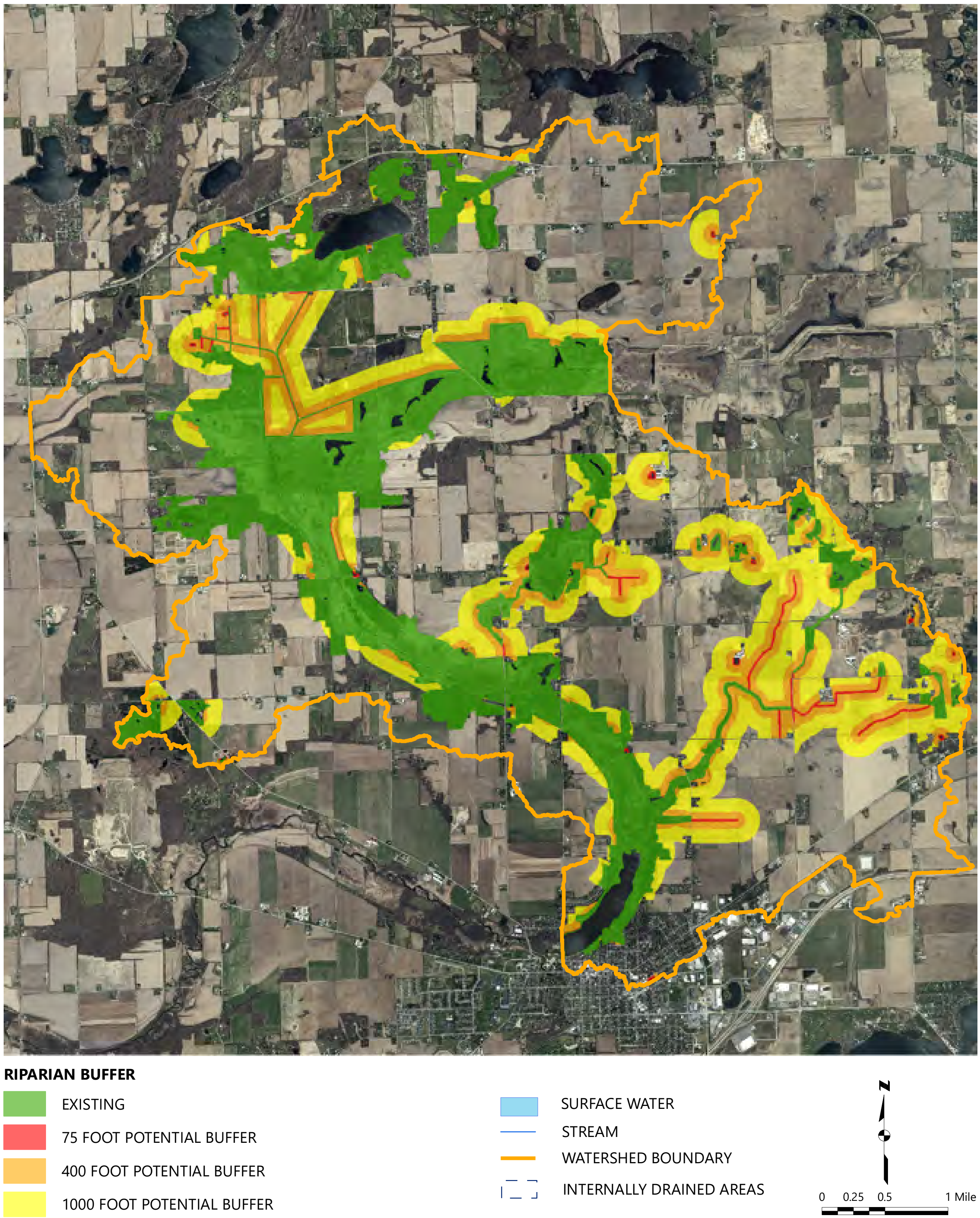
The western and southern shorelines of Lake Comus, the upper reaches of Turtle Creek, and much of the CTH O tributary have rather limited and narrow existing buffers. These narrow buffers likely provide insufficient protection to these waterways (Map 2.24). Some of these areas have the potential to expand 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).

[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.

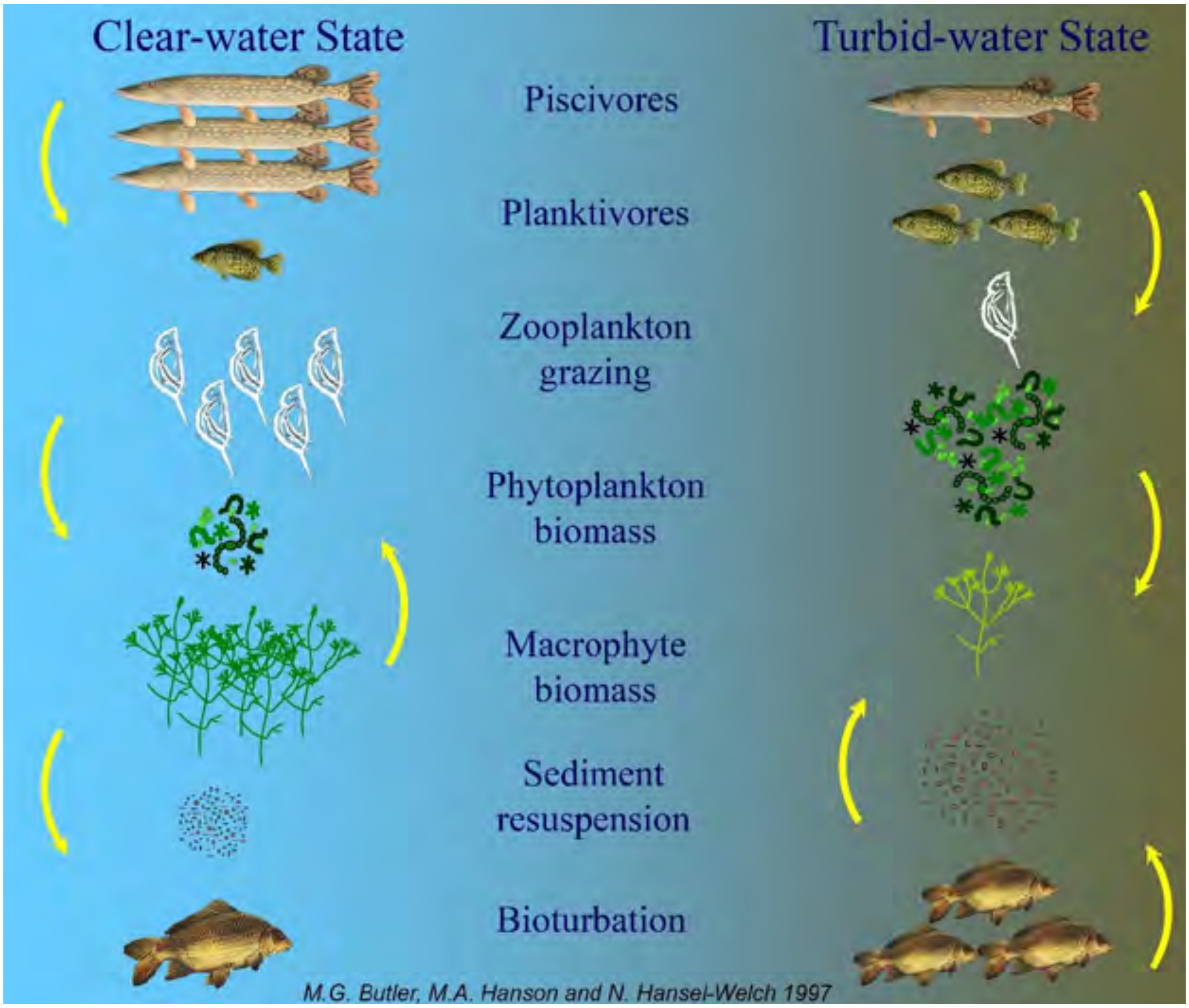
Since phytoplankton and rooted plants compete for nutrients, an abundance of rooted aquatic plants means fewer nutrients (usually phosphorus) available to phytoplankton, in turn reducing the abundance of free-floating algae and increasing water clarity. Conversely, when rooted aquatic plants senesce 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.

<u>Eurasian Watermilfoil</u>

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.

<u>Curly-leaf Pondweed</u>

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.*

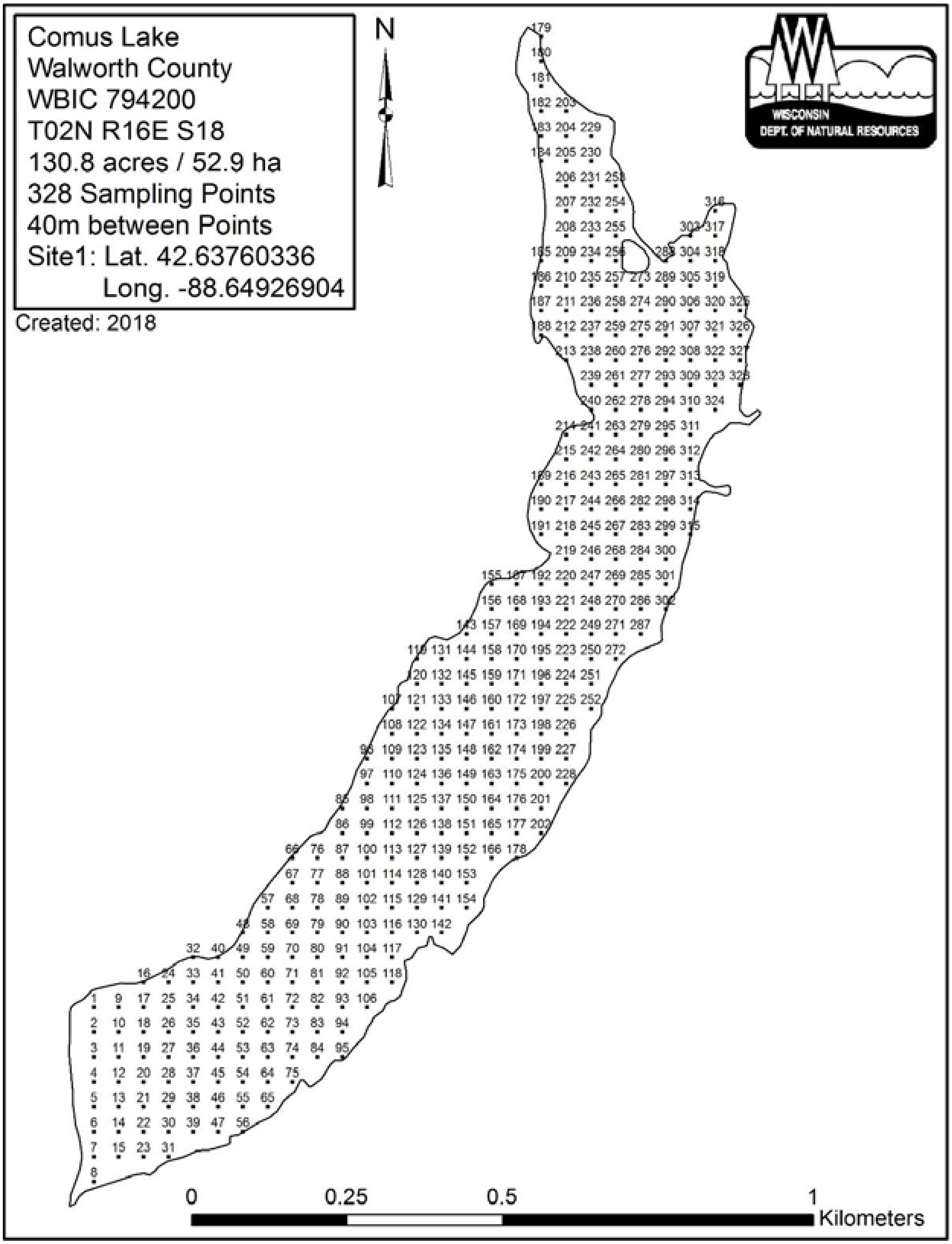
[157] *Canfield Jr, D.E., Langeland, L., and Haller, W.T. "Relations between water transparency and maximum depth of macrophyte colonization in lakes." Journal of Aquatic Plant Management 23, 1985.*

[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.

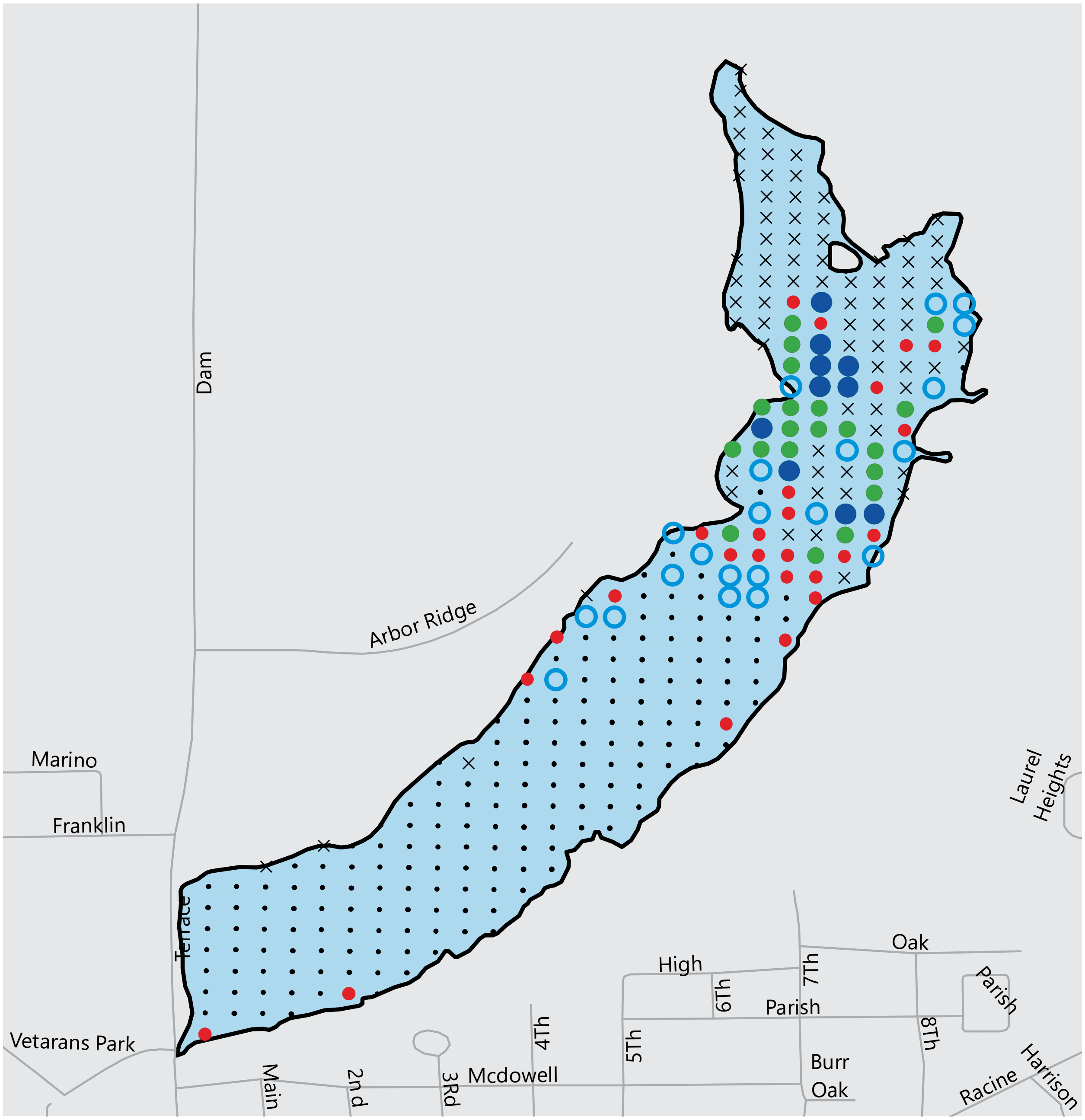
- *Manual measures* – physical removal of plants by individuals using hand-held rakes or by hand.

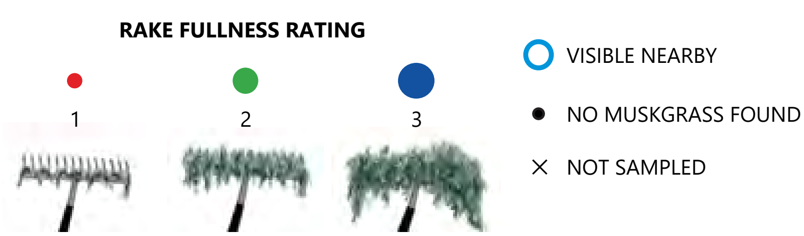
- *Mechanical measures* – including harvesting and removing aquatic plants with a machine known as a harvester or by suction harvesting.

- *Chemical measures* – including using aquatic herbicides to kill nuisance and nonnative aquatic plants.

[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.

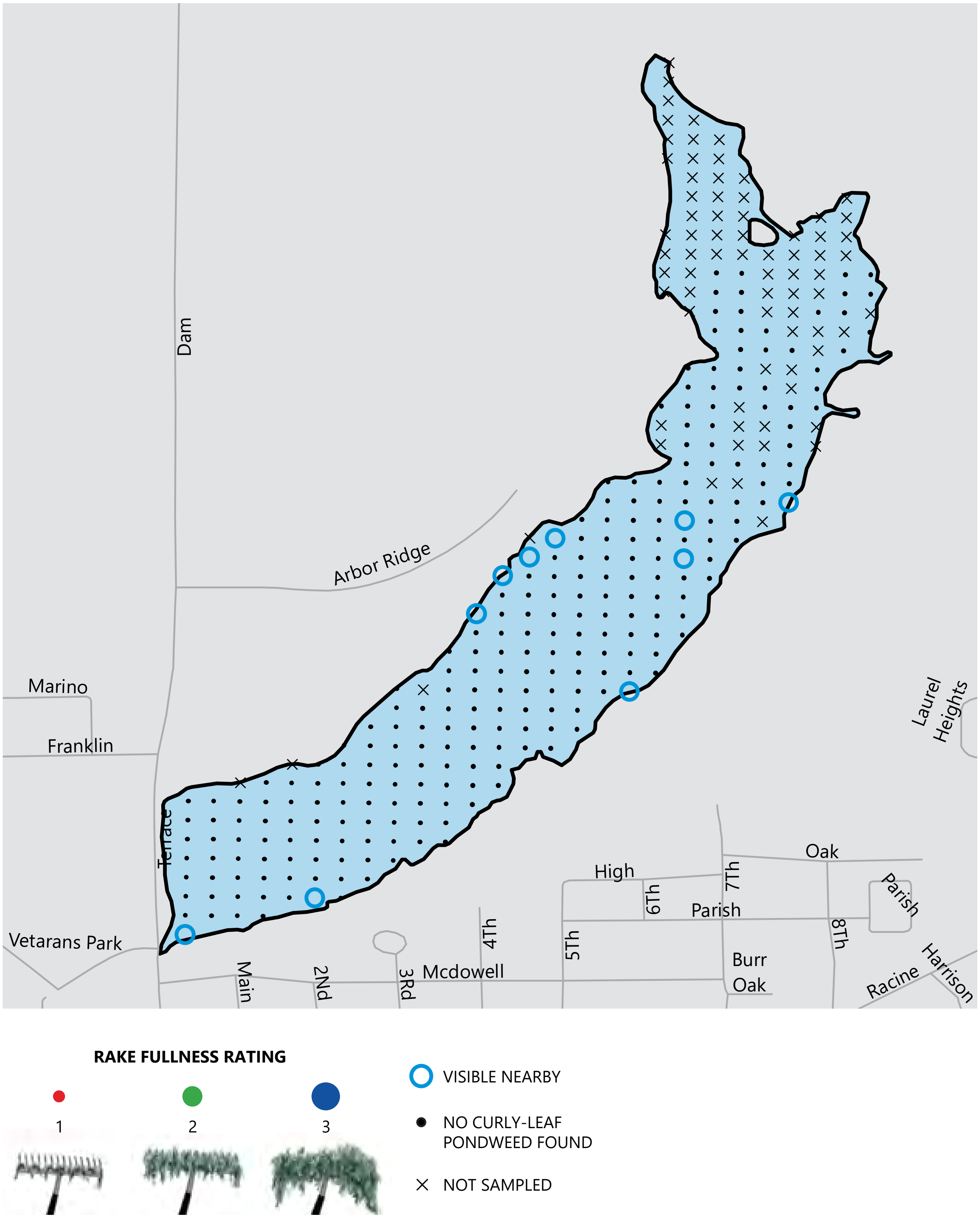
More information regarding these alternatives is provided below. All control measures are stringently regulated and most require a State of Wisconsin permit. Chemical controls, for example, require a permit and are regulated under Chapter NR 107, "Aquatic Plant Management," of the *Wisconsin Administrative 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.

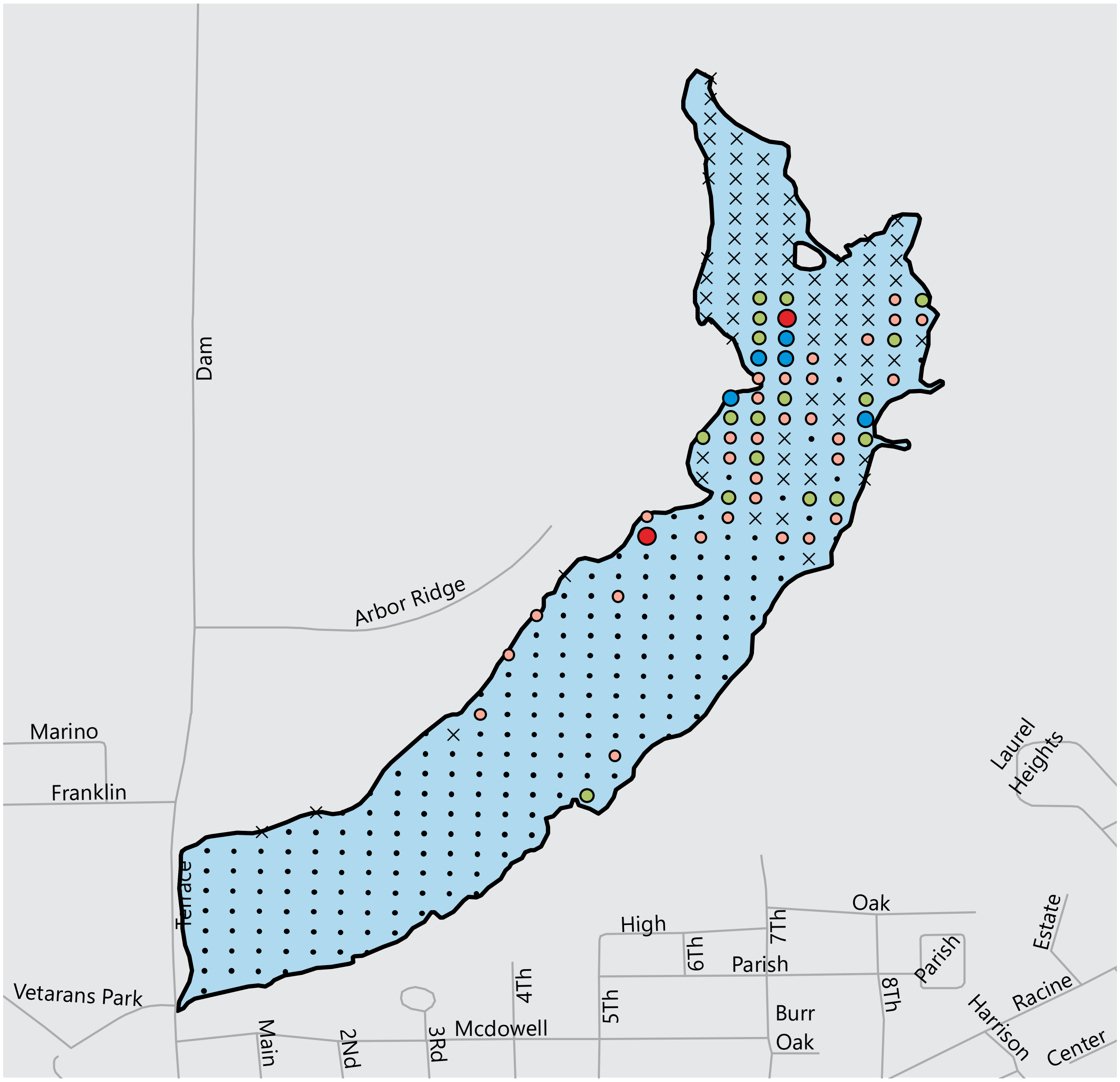
Figure 2.42
Curly Leaf Pondweed Occurrence in Lake Comus: August 2019



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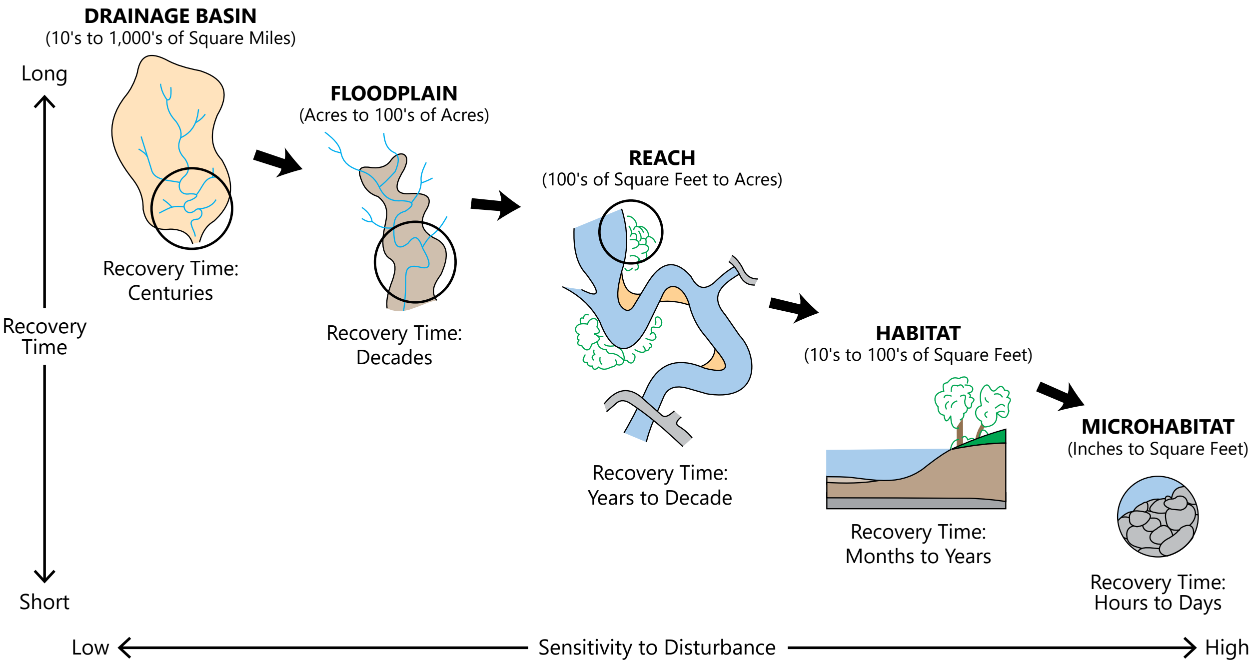
[185] *C.A. Frissell, W.J. Liss, C.E. Warren, and M.D. Hurley, "A Hierarchical Framework for Stream Classification: Viewing Streams in a Watershed Context,"* Journal of Environmental Management*, 10: 199-214, 1986.*

[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.

Changes in Land Use

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.

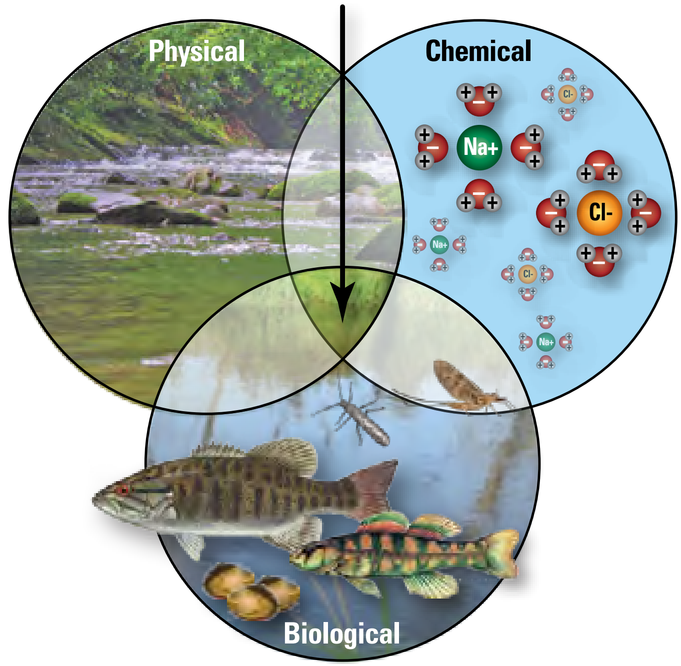
- **Irrigation.** Irrigation can supplement natural soil moisture and increase groundwater recharge. If irrigation water is sourced beyond the local watershed or draws upon groundwater not normally discharging to waterbodies in the watershed, irrigation can increase the supply of groundwater to local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

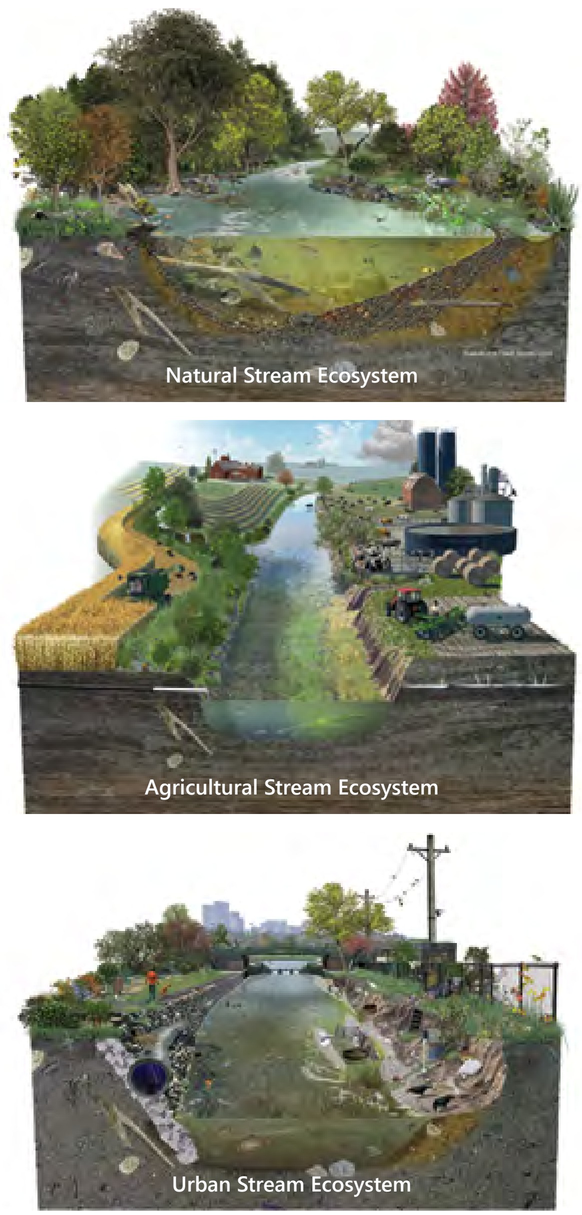
[190] *Personal Communication, Dr. Jeffrey J. Steuer, U.S. Geological Survey.*

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.

<u>Stream Channelization</u>

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

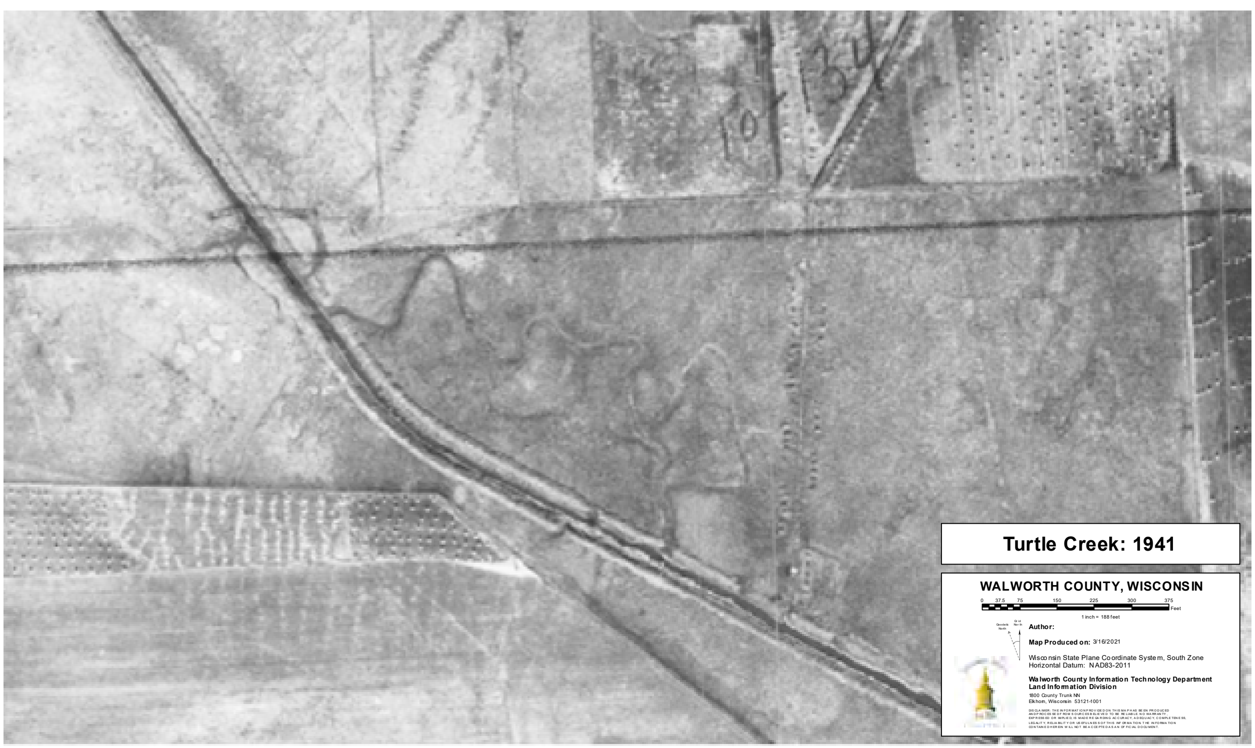
Source: SEWRPC

[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, Szcytko, 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.

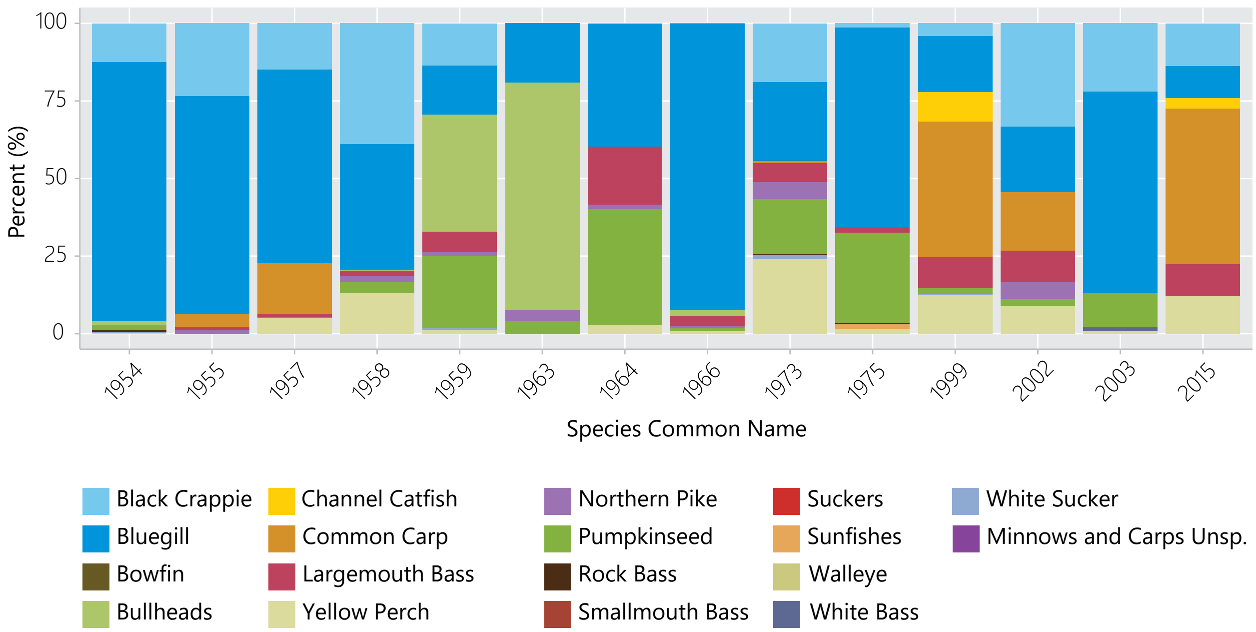
The high common carp populations from WDNR fishery surveys are a concern of the LCPRD and previous measures have been taken to reduce the carp population in the Lake. A Lake drawdown was conducted in 1937 to reduce the population of rough fish but was considered generally unsuccessful.[215] Large amounts 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:

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[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

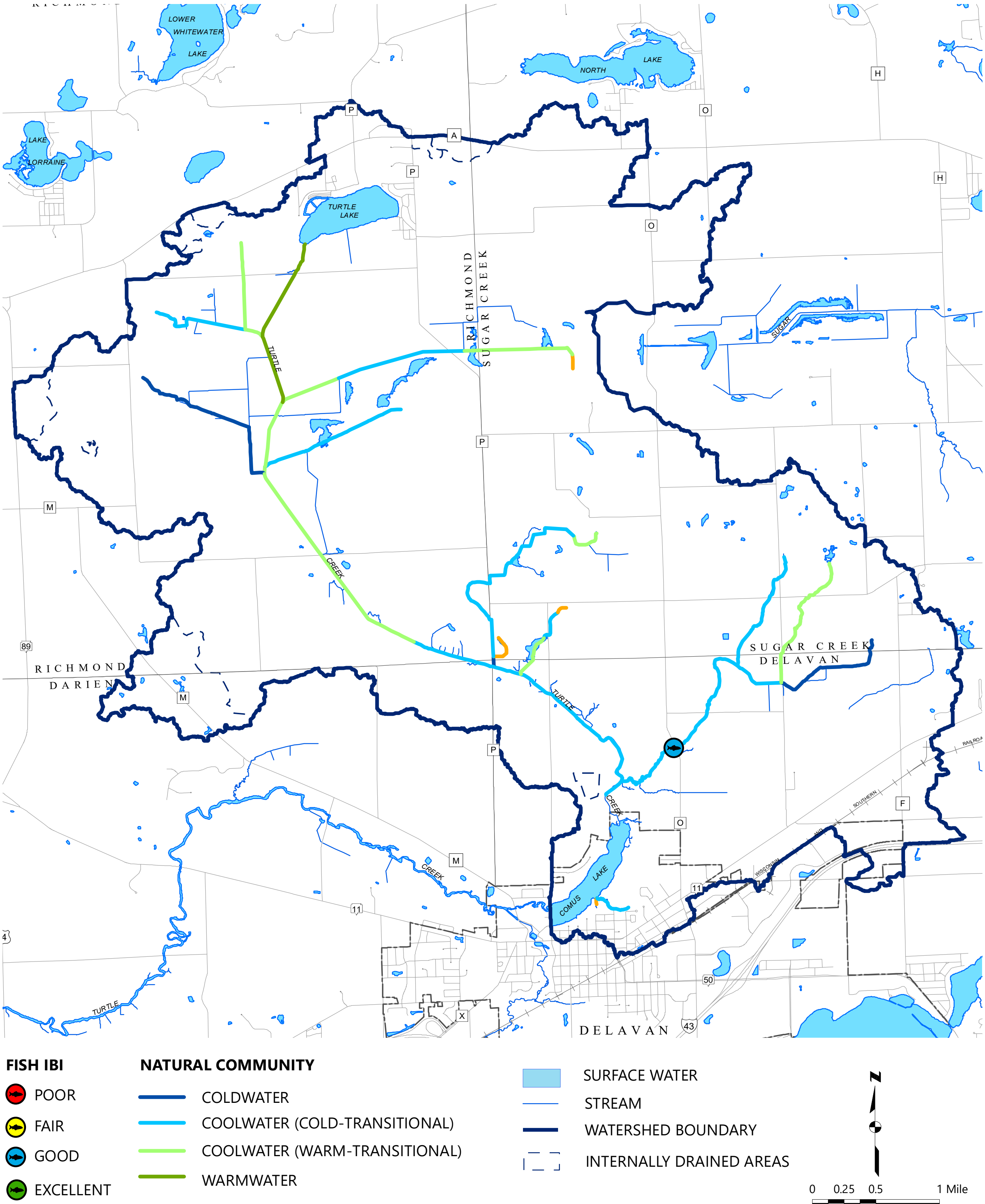
The USGS has developed the "FishVis" decision support tool to display model projections of changes in stream temperature, streamflow, and fish species occurrence throughout the 21st century for watersheds within the Great Lakes Region, including the Lake Comus watershed.[229] The model was developed 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.

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[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]

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[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]

[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]

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[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