MEMORANDUM REPORT NO. 123 (3RD EDITION)

A LAKE MANAGEMENT PLAN FOR SILVER LAKE

WASHINGTON COUNTY, WISCONSIN

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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WASHINGTON COUNTY, WISCONSIN

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A LAKE MANAGEMENT PLAN FOR SILVER LAKE

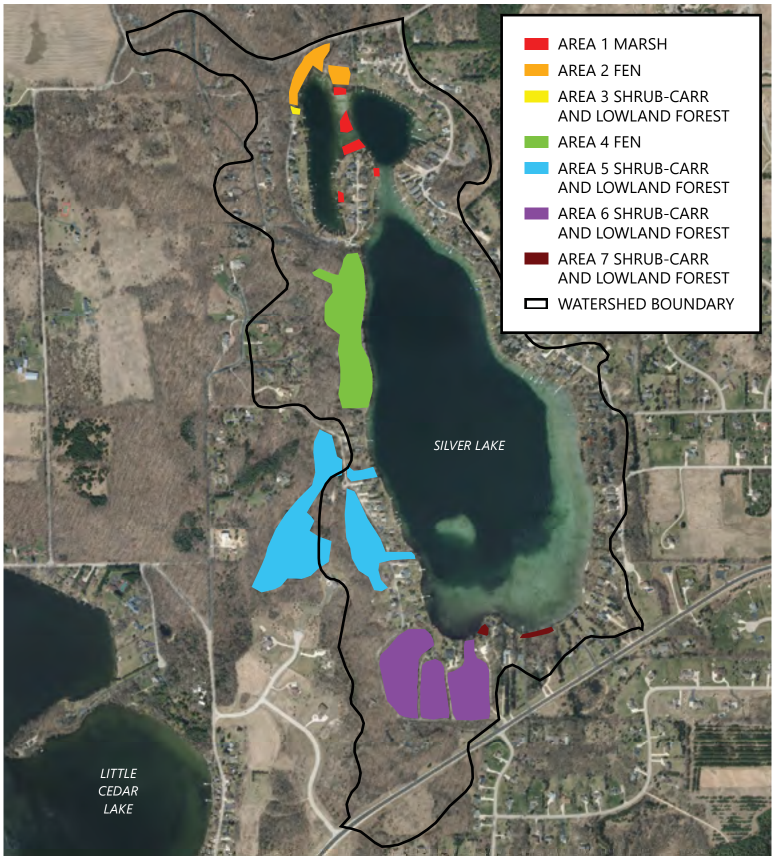
EXECUTIVE SUMMARY

A Management Plan for Silver Lake and its Watershed

The health of a lake ecosystem is usually a direct reflection of the use and management of the land within its watershed. While Silver Lake (the Lake) is generally healthy, high rates of phosphorus and sediment loading have and will continue to harm the Lake if active management action is not taken. The Silver Lake Management Plan (the Plan) is the third comprehensive management plan for this Lake and was developed to provide a set of targeted, specific recommendations to improve Silver Lake and ecological conditions throughout the watershed and groundwatershed. This Plan supplements and builds upon previous plans and recommendations developed by the Southeastern Wisconsin Regional Planning Commission (Commission) in 1997 and 2005 (see sewrpc.org), as well as a study by the U.S. Geological Survey in 2002.

Characteristics of Silver Lake and its Watershed and Groundwatershed

Silver Lake and its watershed have a wide variety of natural resource and human use assets, particularly given their limited sizes. The Lake supports a broad variety of recreational uses such as swimming, waterskiing, wakeboarding, fishing, canoeing, and kayaking. The Lake is also able to support a varied fishery that includes largemouth and smallmouth bass, panfish, and northern pike. Additionally, the Lake's watershed contains wetlands, woodlands, fallow agricultural lands, natural areas, and critical species habitat. It is expected that the Lake and its watershed support several small upland game species as well as a number of resident and migratory bird species. The Lake is fed by a 126 acre watershed and a 179 acre groundwatershed, which are both located within Washington County. Woodlands and residential land uses are the most common land uses within the watershed.



The Silver Lake watershed contains several natural areas and critical species habitats.

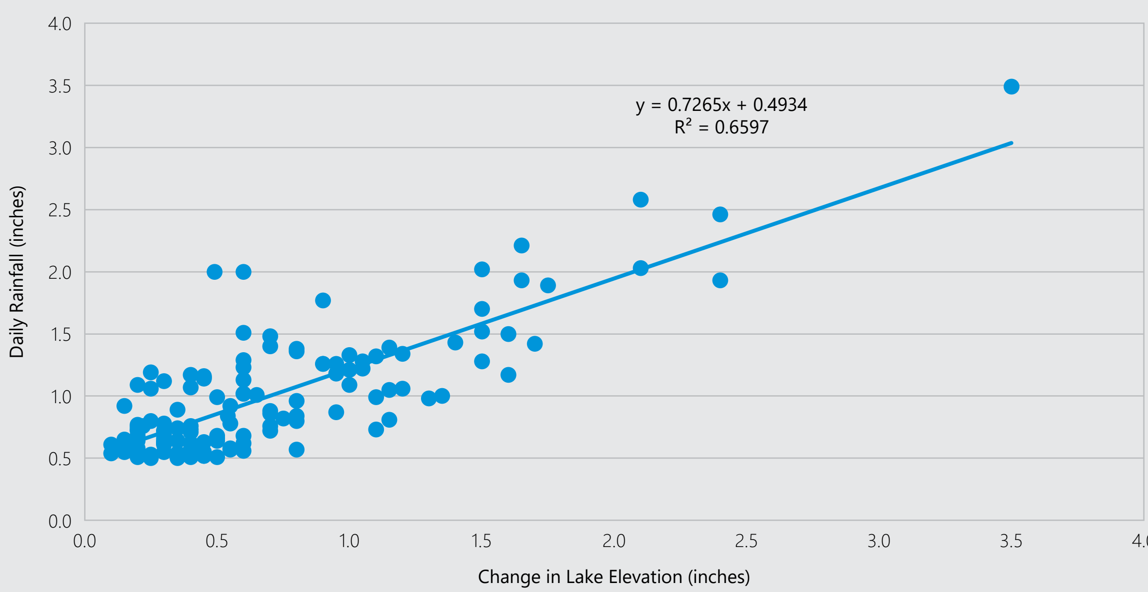
Justification for Plan

While the Lake enjoys generally good water quality and conditions supporting a wide variety of uses, issues of concern exist that justify further study. These issues of concern addressed in this management plan include the following:

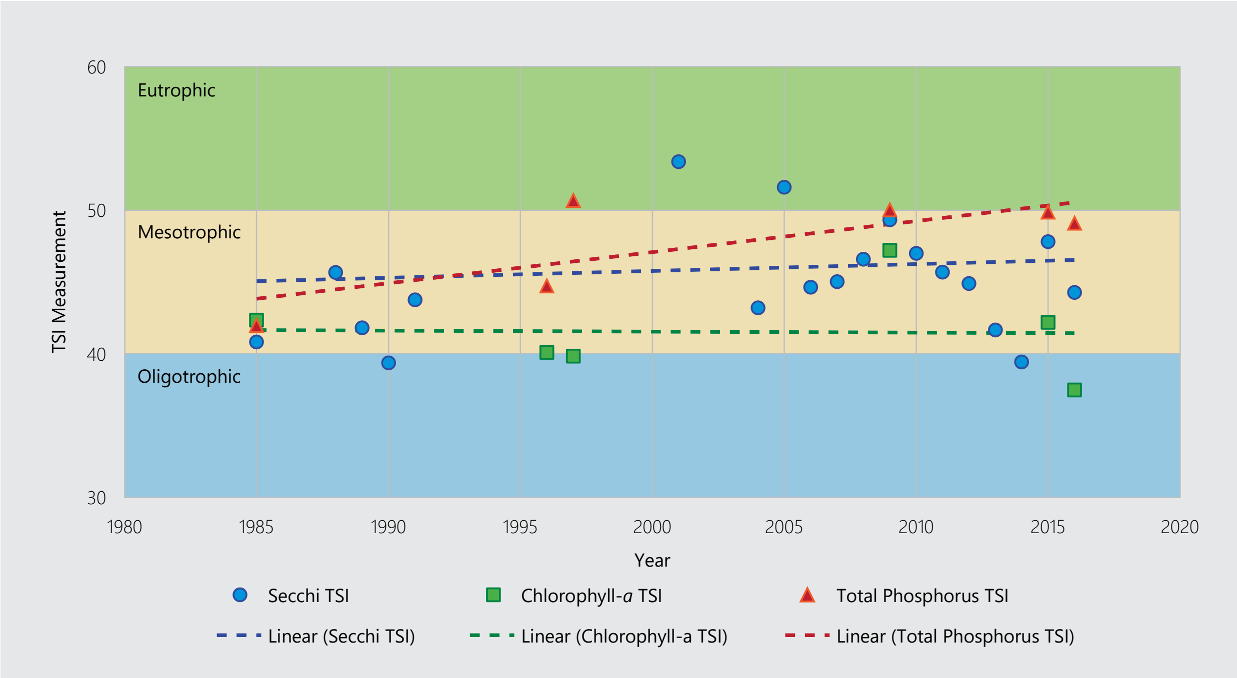
- Hydrology and Water Quantity
- Lake Water Quality
- Sedimentation and Shoreline Maintenance
- Aquatic Plant Management

Hydrology and Water Quantity

Water quantity and lake levels have been long-time concerns of Silver Lake residents. All waterbodies gain and lose water through various means. The source of all water supplied to the Region's waterbodies is precipitation. Although some water bodies derive most water from runoff, tributary streams, and groundwater, these sources also ultimately depend upon precipitation. Waterbodies lose water in a number of 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 streamflow can be reduced or eliminated. During heavier than normal precipitation, lake and river levels may rise. The Commission evaluated lake levels within the Lake, as well as water sources to the Lake. Since Silver Lake is a groundwater-fed headwater lake, protecting groundwater recharge is essential for maintaining baseflow discharge to Silver Lake to maintain its water quality, lake levels, and recreational potential in the future. Land practices that hasten stormwater runoff, eliminate native vegetative cover, ditch, tile, or otherwise drain wet areas, disconnect floodplains from streams, and increase the amount of impervious land surface can all contribute to reduced stormwater infiltration, increased runoff, and reduced groundwater recharge. In this plan, the Commission identified potential areas within the Lake watershed and groundwatershed that should be conserved and/or retrofitted to protect groundwater infiltration. Actions suggested in this plan will help preserve groundwater recharge that in turn will help to maintain desirable Lake levels.



Silver Lake's water level is highly dependent on rainfall and groundwater input. Maintaining areas for groundwater infiltration is essential to sustain desirable future lake levels.



While algal abundance indicates fairly steady water quality, increasing phosphorus concentrations and decreasing secchi depths (indicating declining water clarity) are issues of concern.

Lake Water Quality

In order to identify potential water quality management efforts, current lake conditions were quantified and then contrasted with past values, and used to estimate future water quality. Silver Lake water quality data has been collected intermittently since at least 1960. By analyzing oxygen/temperature profiles, phosphorus concentrations, chlorophyll-*a* concentrations, and secchi depth measurements, it was determined that Silver Lake thermally stratifies during the summer, is prone to internal loading of phosphorus, and has maintained a mesotrophic status for decades. Recent trends indicate that phosphorus concentrations are increasing and secchi depths are decreasing, without a corresponding increase in chlorophyll-*a*, a measure of algae abundance. Furthermore, although zebra mussels, an invasive species that removes particulate matter from the water column and often dramatically improves water clarity, have been present in Silver Lake since 2011, algal abundance has not decreased, and secchi depth has not significantly increased. If these trends continue, excessive phosphorus may threaten Silver Lake's long-held mesotrophic status by further decreasing water clarity, fueling excessive growth of algae and aquatic plants, and impairing the Lake's ability to support its current recreational uses. The recommendations provided within this management plan will help to mitigate and monitor these trends.

Silver Lake has maintained a mesotrophic status for decades.

Sedimentation and Shoreline Maintenance

Sedimentation and shoreline stability have been long-time concerns of Lake residents. The Commission performed field inventories of Lake sediment depths and shoreline conditions, examined previous studies, and conducted pollutant load modeling throughout the watershed. Sedimentation appears to be occurring along the shoreline areas and has some potential to restrict recreational use of the Lake. The sedimentation results from several sources that include natural marl formation, stormwater runoff, in-Lake aquatic plant remains, terrestrial leaf and miscellaneous plant litter from upland areas, shoreline erosion, and redistribution of sediment from recreational boat traffic.

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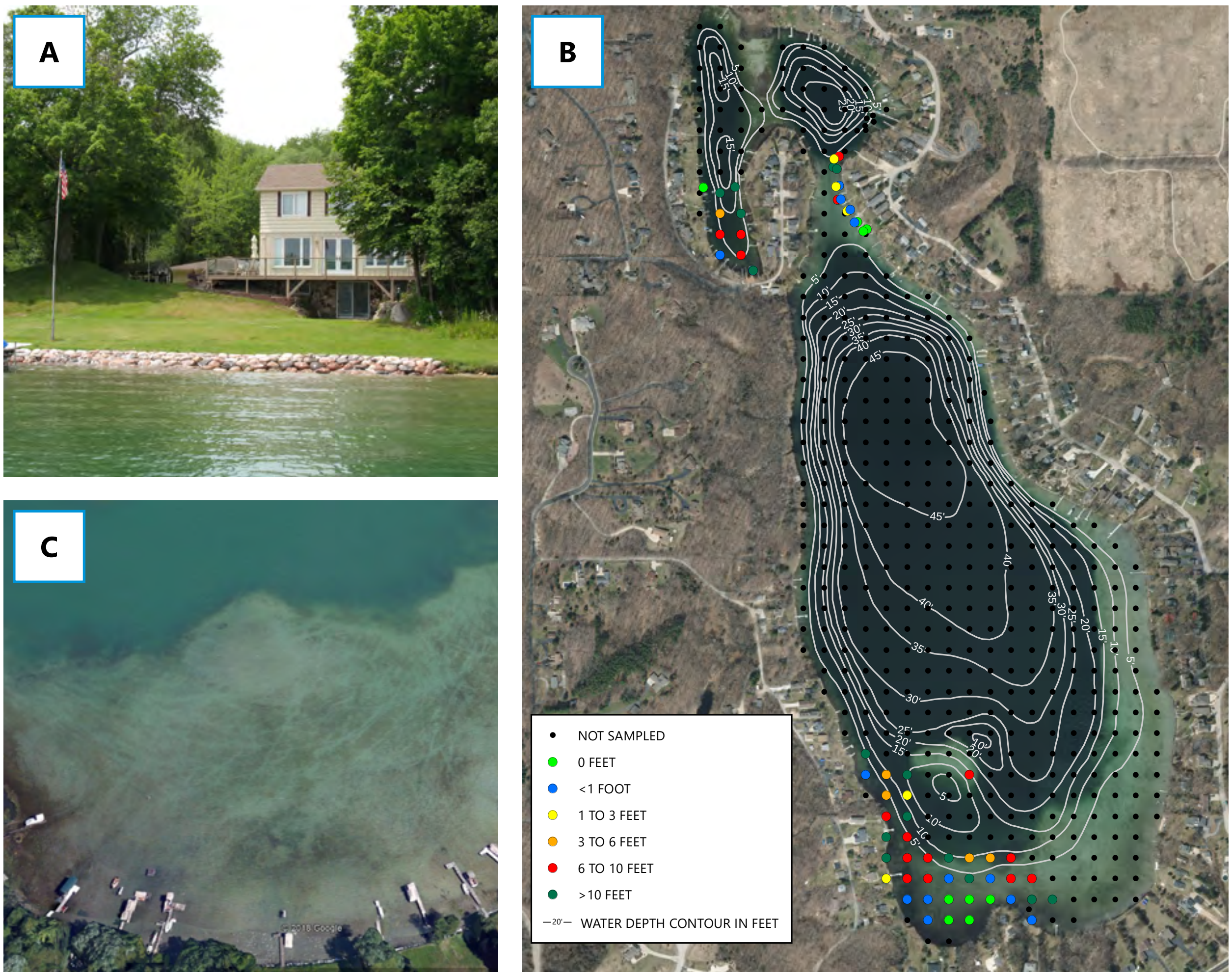
Wake boats, or bladder boats, have been a particular concern for Silver Lake residents because they are specially designed to increase wave height for specific water sports such as wakeboarding. The hull of these boats is shaped to achieve maximum wake and many have a hydrofoil device and/or built-in ballast tanks to displace more water and create larger waves. This artificially intense wave action can exceed the ability of natural shorelines to absorb energy and remain stable, increasing the potential for shoreline erosion and increased sedimentation. In addition, due to the specific wake boat design criteria, the stern of such boats is lowered. Therefore, the propeller runs deeper in the water compared to other motorboats, causing wake boats to have greater potential to disrupt lake-bottom sediment.

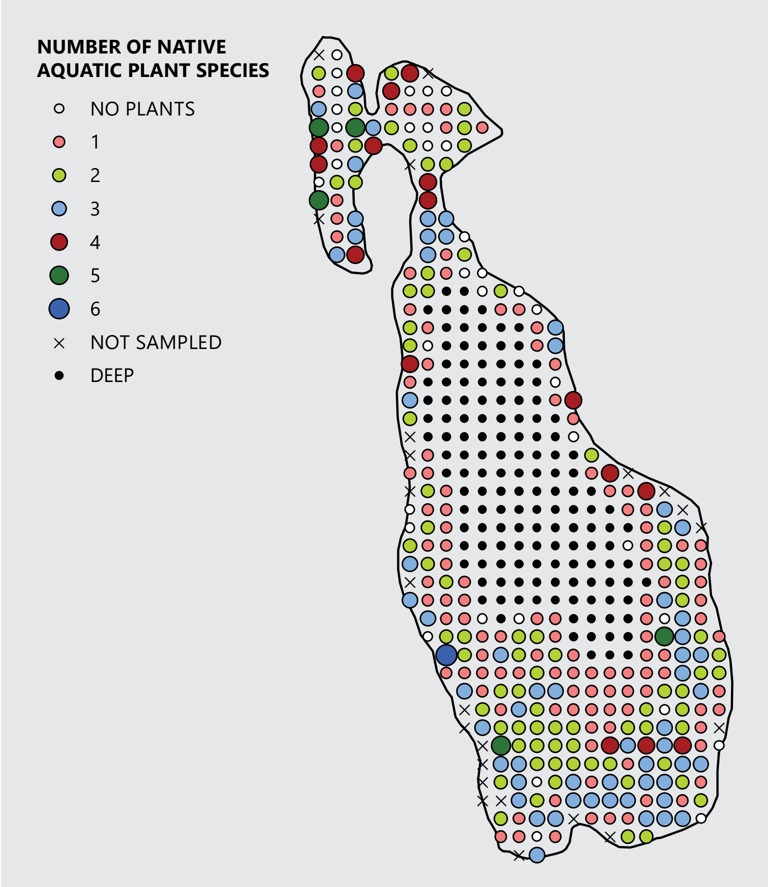
This plan provides recommendations for managing potential sources of sediment and includes guidance for managing boat traffic in the lake to reduce potential impacts to shorelines and lake-bottom sediment.



A) The shoreline of Silver Lake has many opportunities for vegetated buffers to reduce phosphorus and sediment loading as well as protect the shoreline from erosion. Deep-rooted native vegetation stabilizes shorelines and helps filter phosphorus and sediment from runoff. B) Monitoring sediment depths can benefit long-term management goals. C) Excessive boat wakes have the potential to erode shorelines and resuspend lake-bottom sediment.

Aquatic Plant Management

The aquatic plant community of Silver Lake is diverse with 13 native species identified in a 2017 survey, including many beneficial native species. Muskgrass (*Chara* spp.), the most dominant species, is a native that stabilizes lake bottom sediment and removes phosphorus from the water column; this species should be a priority for protection. The invasive species Eurasian watermilfoil (EWM) (*Myriophyllum spicatum*) was present in the Lake but was not widespread, covering less than 10 percent of the Lake. A new invasive species, starry stonewort (*Nitellopsis obtusa*), has been present in Silver Lake since 2015. Several strategies, including diver assisted suction harvesting (DASH) and dredging are being employed to reduce and manage the present population. It will take time to assess the effectiveness of these treatments and balance management of starry stonewort and EWM while protecting the native aquatic plant community. The Plan provides detailed aquatic plant management recommendations, including measures to maintain a diverse aquatic plant community and prevent introduction of new potentially invasive species.



Silver Lake has a healthy native aquatic plant community. Species richness within the Lake is highest in its northern portion.

A new invasive species, starry stonewort (Nitellopsis obtusa), was first identified in Silver Lake in 2015 and is being carefully monitored and managed.

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Key Management Objectives to Improve the Silver Lake Watershed and Groundwatershed

- Protect groundwater sources feeding the Lake by preserving areas with high groundwater infiltration potential and enhancing use of green infrastructure to protect groundwater sources
- Continue water quality monitoring to track progress toward improving water quality
- Prioritize implementation of buffers, rain gardens, and other best management practices (BMPs), especially along shorelines
- Promote native aquatic plant species, monitor and manage existing invasive species, and prevent introduction of new invasive species
- Establish partnerships between municipalities and districts to collaborate on water quality goals and pursue funding to implement best management practices

Partnership and Collaboration are Necessary to Achieve Lake Management Goals

The Silver Lake watershed currently has substantial recreational, aesthetic, and ecological value. Water quality within the Lake has remained at mesotrophic levels overall, but elevated phosphorus concentrations, sedimentation, and long-term depletion of groundwater resources remain challenges. Following the recommendations provided in this Plan will lead to improved water quality and quantity for human needs and will help improve the hydrological and ecological integrity of the water resources.

Meeting the goals for the Silver Lake watershed and groundwatershed will continue to be a challenge requiring the collaboration of many participating organizations adopting the efforts of a unified plan. The measures presented in this Plan primarily focus on those that can be implemented through collaboration between local organizations and individuals, such as the Silver Lake Protection and Rehabilitation District (SLPRD) the Silver Lake Sanitary District; Lake residents; the Town of West Bend; Washington County; and the WDNR. The plan must be adaptable to addresses challenges that will arise during implementation. Watershed implementation is primarily a volunteer effort, but this effort needs support via targeted technical and financial assistance. All communities within the surface- and groundwatershed must commit and collaborate to reach compliance with existing regulations, which in turn help improve the Lake's condition.

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INTRODUCTION 1

Credit: SEWRPC Staff

1.1 PLAN PURPOSE AND OVERVIEW

This plan examines the land and water resources of the Silver Lake (the Lake) watershed, human-induced changes to these land and water resources, the ways humans enjoy the Lake, and impressions and goals of Lake users. Using this information, strategies and tactics are recommended that help protect Silver Lake and the resources it depends upon from undue human-induced deterioration. The plan's recommendations are appropriate and technically feasible lake management measures that help preserve or enhance the Lake's aquatic plant community, water quality, water supply, fishery, and overall ecological health. Preserving or enhancing these elements allows the Lake to sustainably provide safe, varied, and enjoyable recreational opportunities.

This plan is divided into three chapters. Chapter 1 discusses the plan's purpose, the Lake's basic physical characteristics and assets, and general study goals and objectives. Chapter 2 examines Lake-user identified issues of concern and information relevant to understanding the nature and cause of these concerns. Using the information presented in Chapters 1 and 2, Chapter 3 recommends concepts to address identified concerns, evaluates the relative importance of these activities, and briefly discusses implementation logistics.

This plan complements previous plans,[1] programs, and ongoing management actions in the Silver Lake watershed. The new plan represents the continuing commitments of government agencies, municipalities, and citizens to sustainable human use balanced with diligent natural resource protection. The plan is effectively a tool to be used by State agencies, local units of government, nongovernmental organizations, businesses, and citizens to cooperatively promulgate approaches that help answer to Lake user concerns and help protect long-term Lake health. By using the concepts outlined in this plan, results will be achieved that help enrich and preserve the public's enjoyment of the Lake.

[1] *SEWRPC Memorandum Report No. 123,* A Lake Protection and Recreational Use Plan for Silver Lake, Washington County, Wisconsin*, September 1997; and SEWRPC Memorandum Report No. 123 (2nd Edition),* A Lake Protection and Recreational Use Plan for Silver Lake, Washington County*, Wisconsin, December 2005.*

This planning program was funded in part by the Silver Lake Protection and Rehabilitation District (SLPRD) and, in part, through a Chapter NR 190 Lake Management Planning grant awarded to the SLPRD and administered by the Wisconsin Department of Natural Resources (WDNR). The inventory and aquatic plant management plan elements presented in this report conform to the requirements and standards set forth in the relevant *Wisconsin Administrative Codes.*[2]

1.2 SILVER LAKE CHARACTERISTICS AND ASSETS

Located within U.S. Public Land Survey Sections 27 and 34, Township 11 North, Range 19 East, in the Town of West Bend, Washington County (see Map 1.1), 126-acre Silver Lake, together with its watershed,[3] is a high-quality natural resource and a substantial asset to the local and regional community. The Lake has an extremely small watershed contributing surface-water runoff to the Lake (179 acres excluding the Lake itself) and is relatively deep with a maximum water depth of 47 feet (see Map 1.2).[4] Given these physical features, the Lake is classified by the WDNR as a "deep, headwater" lake,[5] which means that the Lake has a small watershed and stratifies (forms separate layers of water during summer - a phenomenon described in detail in Chapter 2). The Lake's water level is maintained by a small, privately-owned dam (crest elevation of 999.27 feet above National Geodetic Vertical Datum, 1929 adjustment (NGVD 29)) located at the northern end of the Lake where the Lake flows into Silver Creek. Silver Lake is a groundwater-fed lake, receiving much of its water supply from springs located along its western and southern shores, as well as surface runoff from its *watershed* (the lands draining directly to the Lake). In contrast, water that soaks into the earth and recharges groundwater is nearly five times as big (835 acres). Table 1.1 provides further detail on the hydrologic and morphologic characteristics of the Lake. Chapter 2 discusses the importance of these characteristics.

Silver Lake and its watershed host a wide variety of natural resource and human use assets, particularly given their limited sizes. The Lake supports a broad variety of recreational uses such as swimming, pleasure boating, waterskiing, wakeboarding, fishing, canoeing, and kayaking. The Lake also supports a varied fishery that includes largemouth and smallmouth bass, panfish, and northern pike. Additionally, the Lake's watershed contains wetlands, woodlands, fallow agricultural lands, natural areas, and critical species habitat. The Lake and its watershed supports upland game species, furbearers as well as a number of resident and migratory bird species.

1.3 LAKE PROTECTION PROGRAMS AND GOALS

This planning project updates the Southeastern Wisconsin Regional Planning Commission's (SEWRPC's or Commission's) 2005 lake protection and recreational use plan for Silver Lake. Some of the primary objectives of this planning project are summarized below.

- Determine existing and planned future land use within the Silver Lake watershed. Identify change and potential sediment, nutrient, and contaminants sources to the Lake. Examine in-Lake nutrient and contaminant dynamics.

- Quantify the composition of, and changes in, the Lake's aquatic plant community with emphasis on the occurrence and distribution of nonnative species. This report primarily relies upon the Commission's 2015 and WDNR's 2017 WDNR aquatic plant inventories. These data are used to help quantify the status of the aquatic plant community.

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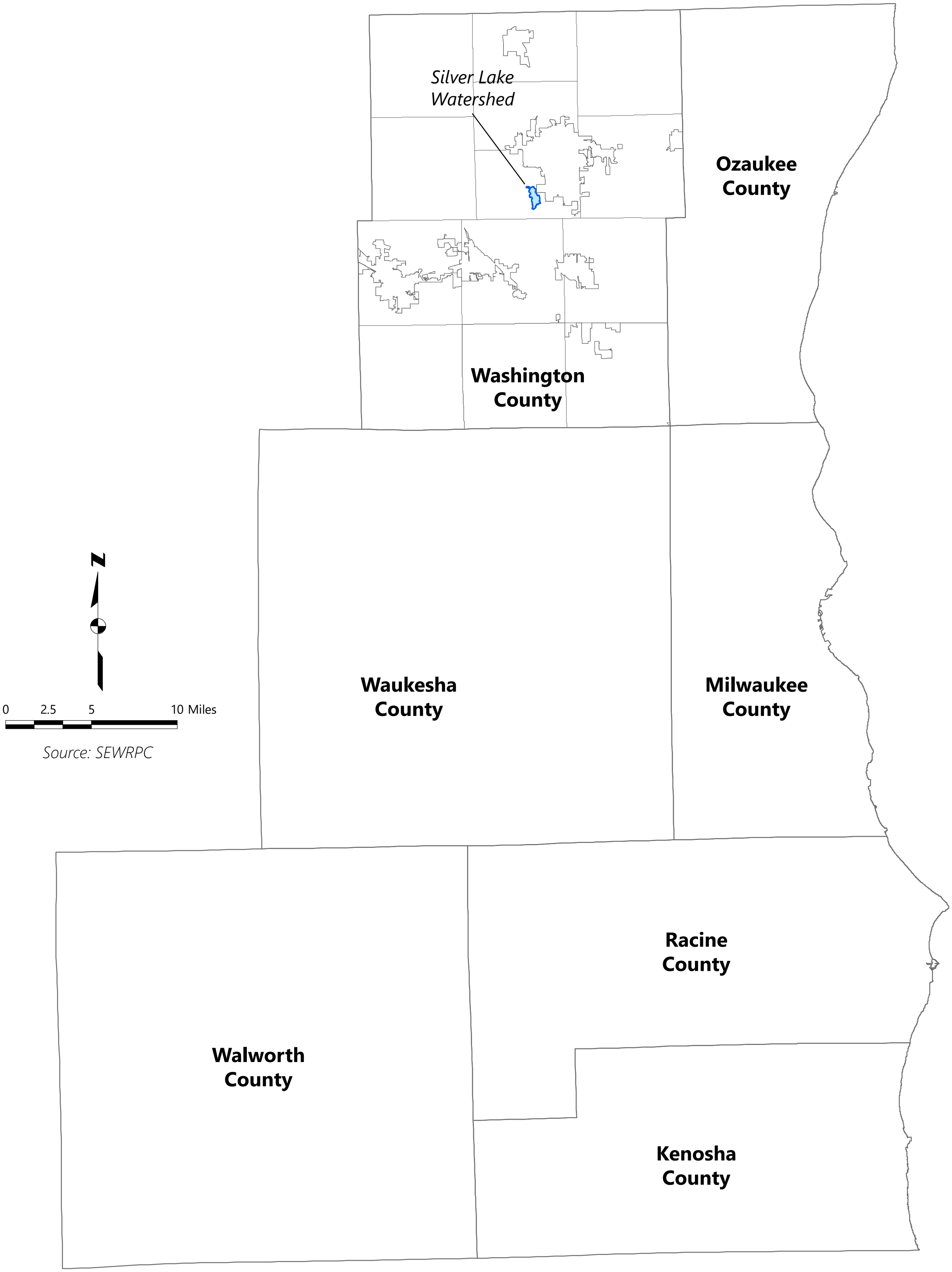
[2] *This plan has been prepared pursuant to the standards and requirements set forth in the following chapters of the* Wisconsin Administrative Code*: Chapter NR 1, "Public Access Policy for Waterways;" Chapter NR 40, "Invasive Species Identification, Classification and Control;" Chapter NR 103, "Water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

[3] *The Lake's watershed is the land area that contributes surface-water runoff to the Lake.*

[4] *The previous SEWRPC plan reported the Lake's surface area to be 118 acres. More refined data for lake acreage for this report were derived from the Geographical Information System (GIS) software program ArcMap 10.3 used by SEWRPC staff in 2017.*

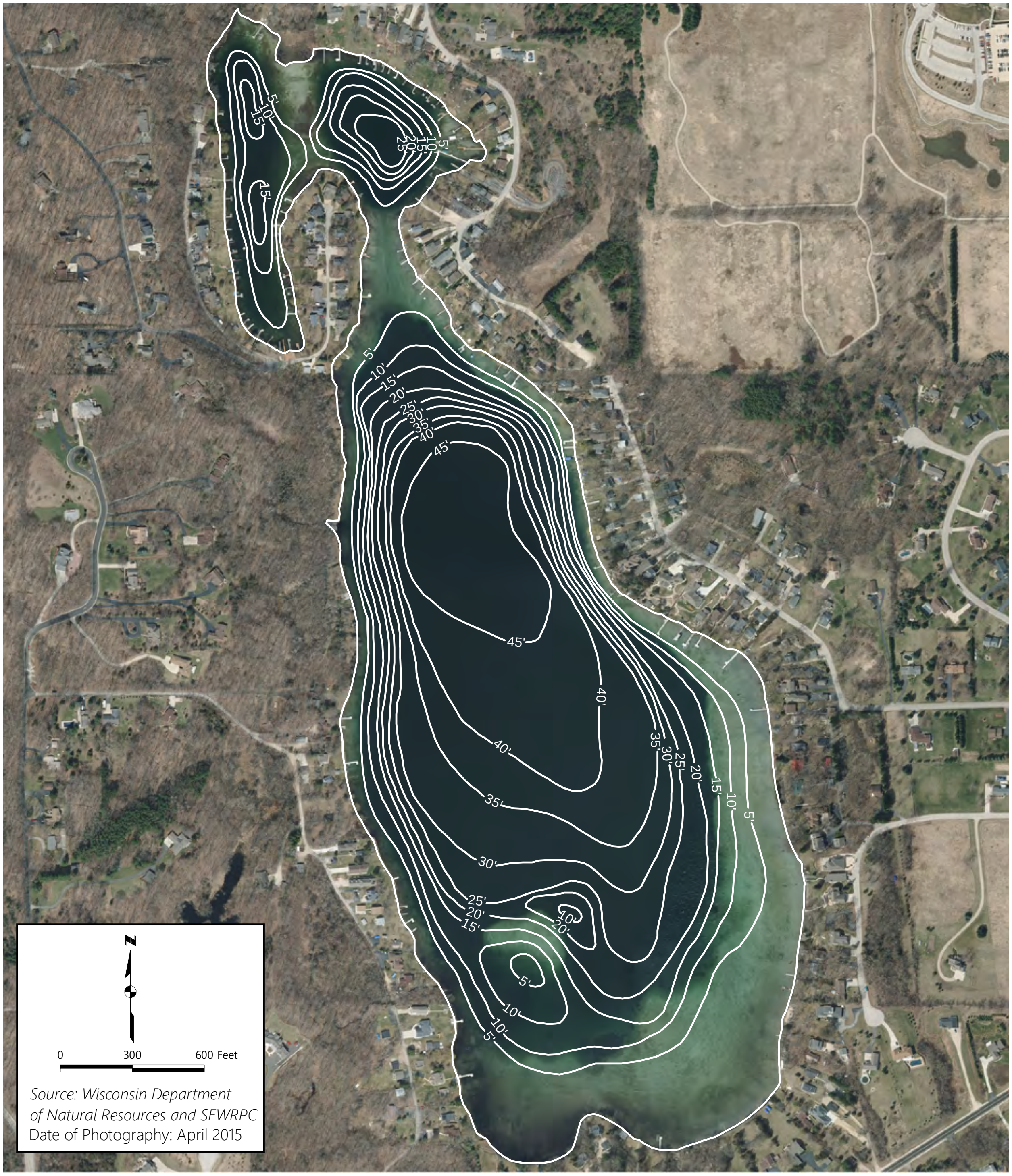
[5] *In the previous report (SEWRPC Memorandum Report No. 123, 2nd Edition, op. cit.) Silver Lake was identified as a "groundwater-fed, drained lake." Since the time of that report, the WDNR has revised its lake classification criteria; this report uses the revised WDNR scheme.*

Map 1.1
Location of the Silver Lake Surface Watershed



Source: SEWRPC

Map 1.2
Bathymetry of Silver Lake



—20'— WATER DEPTH CONTOUR IN FEET

- Evaluate existing and potential future water quality concerns. This effort includes examining readily available Lake water quality monitoring data along with estimating the magnitude of potential future changes. This report draws conclusions from these data and provides appropriate recommendations to help safeguard future water quality. Furthermore, as a lake highly dependent on groundwater, the source of groundwater and threats to this source are also examined.

- Formulate appropriate Lake protection programs, including aquatic plant management, land protection, monitoring tactics, public information, educational strategies, and other actions useful to address identified problems and issues of concern.

This information described above is used to address the issues and concerns of Silver Lake residents by developing recommendations to protect and enhance the Lake. Implementing recommended actions helps promote long-term, sustainable Lake health and use value.

Table 1.1
Hydrology and Morphometry of Silver Lake

Parameter	Measurement
Size and Shape	
Lake Surface Area	126 acres
Contributing Watershed Area[a]	179 acres
Contributing Groundwatershed Area	835 acres
Shoreline Length	2.8 miles
General Lake Orientation	North-South
General Shape	Irregular Elongated Oval
Maximum Length	0.90 miles
Maximum Width	0.34 miles
Shoreline Development Factor[b]	1.8
Depth	
Maximum Depth	47 feet
Mean Depth	18.3 feet
Area Less Than 3 Feet Deep	15 acres (12 percent)
Area Greater Than 20 Feet Deep	55 acres (56 percent)
Hydrology	
Lake Volume	2,306 acre-feet
Lake Type	Spring
Residence Time[c]	
Average Weather Years	3.2 years
Dry Weather Years	4.1 years
Wet Weather Years	0.8 years

[a] *Does not include Silver Lake area.*

[b] *Shoreline development factor is the ratio of the shoreline length to the circumference of a circle of the same area. It can be used as an indicator of biological activity (i.e., the higher the value, the more likely the lake will be to have a productive biological community). Higher shoreline development factors are also commonly associated with lakes with a higher number of homes per acre of lake surface.*

[c] *Residence time is the number of years required for natural water sources under typical weather conditions to fill the lake one time. Natural water sources include runoff from surrounding areas, precipitation falling directly upon a lake, water entering from tributary streams, and water contributed to a lake by groundwater.*

Source: Wisconsin Department of Natural Resources and SEWRPC

INVENTORY FINDINGS AND RELEVANCE TO RESOURCE MANAGEMENT 2

Credit: SEWRPC Staff

2.1 INTRODUCTION

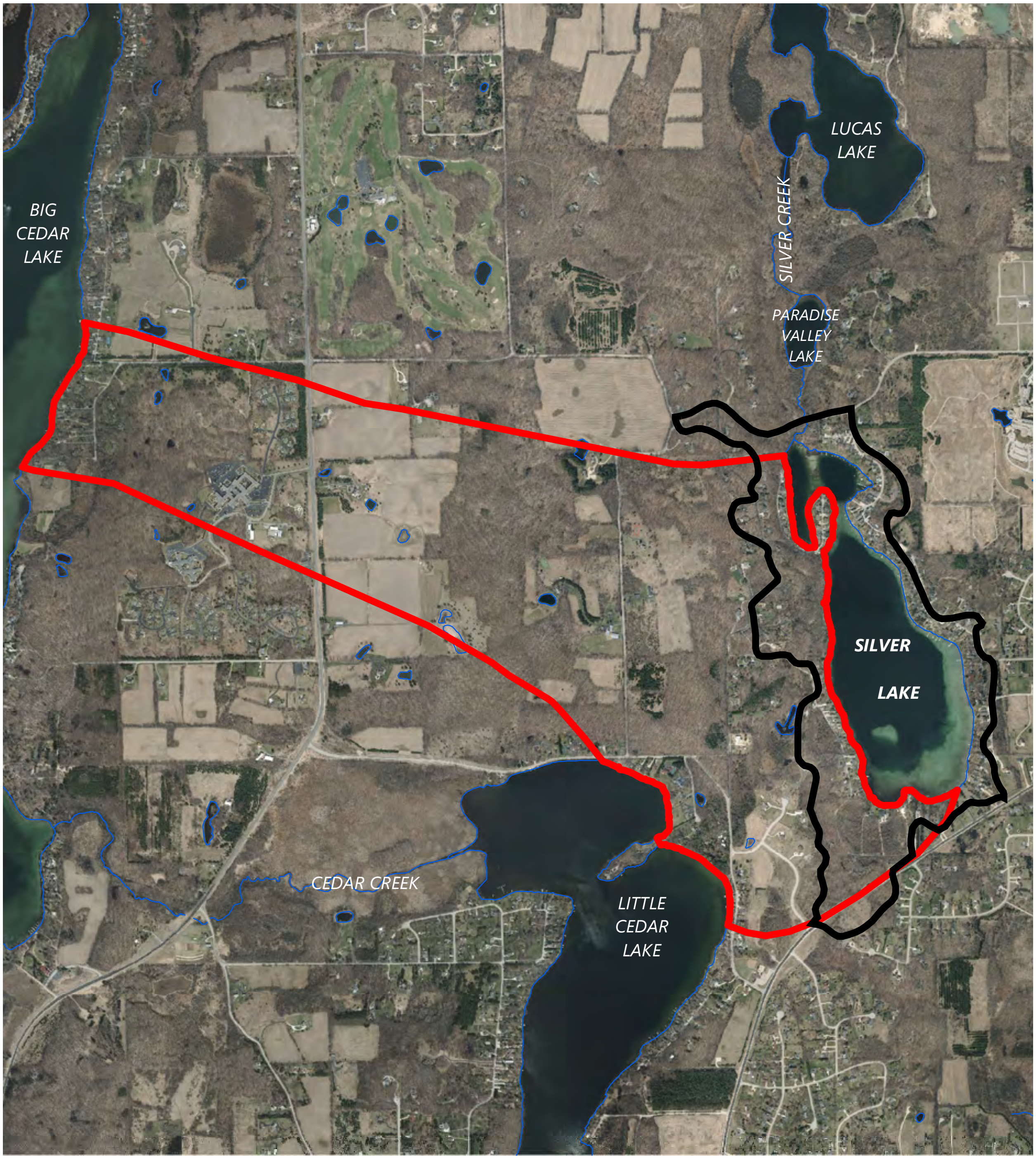
Even though lakes are treasured community assets, human activity often diminishes the tangible benefits provided by lakes and their resultant value to the community and surrounding ecology. Such change stimulates community concern and could portend new, or sometimes more serious, lake-use and ecological challenges. Identifying and understanding existing and potential future lake management issues helps lake managers develop strategies and tactics that counteract negative influences. Such plans help waterbodies maintain characteristics supporting high-quality recreational use while protecting the waterbody's latent ecological value. In collaboration with the Wisconsin Department of Natural Resources (WDNR), the Silver Lake Protection and Rehabilitation District (SLPRD) and the Southeastern Wisconsin Regional Planning Commission (SEWRPC or Commission) executed an agreement to study the nature of concerns related to Silver Lake and to develop a management plan addressing these concerns.

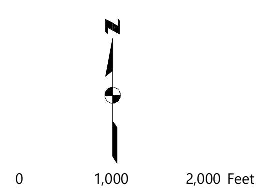
For this report, Silver Lake, together with its watershed (the area around the Lake contributing surface-water runoff to the Lake) and its groundwatershed (the area where infiltrating surface water feeds groundwater flow systems that sustain the Lake), comprise the project study area (see Map 2.1). As a part of the planning process, the Commission developed a list of the issues of most concern (see Table 2.1). The concerns were identified by consulting the SLPRD and Lake community members, analyzing available information from previously completed studies, and collecting information in the field. Issues identified by this endeavor are addressed in this lake management plan. Chapter 2 provides information and interpretations that help answer questions posed by the SLRPD and concerned community members or left unanswered by previous work. In turn, these data are used in Chapter 3 to help develop concepts promoting long-term Lake health and human-use values.

2.2 PHYSIOGRAPHY AND HUMAN INFLUENCE

The condition and overall health of a waterbody is directly related to the natural and human-induced characteristics and features within the area draining to the waterbody. This section describes many salient features including the shape and arrangement of landscape features, the composition and arrangement of soil and rock, waterbody physiography, how water moves through the area, and how humans influence the landscape and with it water quality and quantity.

Map 2.1
Area Contributing Water to Silver Lake





Source: Wisconsin Department of Natural Resources and SEWRPC
Date of Photography: April 2015

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 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:

Table 2.1
Silver Lake Issues of Concern

Issues and Concerns	
1	Lake Water Supply
2	Lake Water Quality and Pollutant Loads
3	Lake Sedimentation and Shoreline Conditions
4	Aquatic Plant Abundance, Types, and Management
5	Cyanobacteria and Floating Algae
6	Recreational Use and Use-Conflict Potential
7	Fish and Wildlife
8	Plan Implementation

Source: SEWRPC

- **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 define the area where surface water runoff reaches a waterbody. This analysis determines whether certain potential pollutant sources threaten a waterbody. For example, if a pollution source is near a waterbody but outside the watershed, contaminated surface runoff from that source would not reach the waterbody and therefore would not influence the subject waterbody's water quality.

- **The type and location of existing land use within the watershed.** The extent, type, and location of various land use practices can help scientists predict the type and amount of pollution reaching a waterbody. Pollutant loads associated with certain land uses and geographical areas can be estimated using models and can help predict the consequences of land use change. Once loads are estimated, management efforts can be focused on areas or activities that efficiently address lake management concerns. For example, if excessive phosphorus is believed to be the root cause of a lake's primary management concerns, and if model simulations suggest that agricultural land use in a certain subwatershed is the primary source of phosphorus to this lake, refining agricultural practices in that subwatershed is likely an efficient way to mitigate lake management concerns.

- **The type and location of past land use changes within the watershed.** Awareness of past land use patterns helps lake managers identify conditions that may have contributed to past waterbody health concerns. Such analyses are particularly useful when considered jointly with contemporaneous water quality monitoring data and well-documented events. For example, if a long-term lake property owner remembers (or better yet, succinctly recorded) periods of abundant aquatic plant growth, large algal blooms, or low or high water levels, such lake conditions can be contrasted to historical land use patterns and other records to examine potential causative agents. In this example, changes such as expanded impermeable surfaces or engineered stormwater infrastructure could possibly be correlated to observed in-lake changes. Such analyses can help predict how a waterbody may react to future change.

- **The type and location of planned land use within the watershed.** Planned land use can be used to predict future lake conditions. Such information helps identify areas that may benefit from active or pre-emptive management.

- **The location of known pollution sources in the watershed (if applicable).** Many human activities contribute pollutants to waterbodies. Many potential pollutant sources are stringently regulated. However, some pollutant sources are poorly understood, diffuse, difficult to identify, and/or control, and may continue to significantly influence lake health despite water quality regulation. An 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.

Location and Local Topography

Silver Lake and its watershed are located entirely within the Town of West Bend, Washington County, Wisconsin. The Lake is located within easy driving distance of major population centers including the cities of West Bend and Hartford as well as Milwaukee and its suburbs. Nearby population centers increase development pressure and overall lake-use demand which in turn can result in heavy pressure on the Lake's natural resource assets.

Silver Lake receives runoff from a relatively small, 179-acre surface watershed (Map 2.1).[6] The basin from which the Lake receives surface-water runoff is elongated north to south, generally mirroring the shape of the Lake. Roughly 100 feet of topographic relief are found in the Silver Lake surface watershed. The Lake water surface elevation varies but is commonly slightly less than 1,000 feet above National Geodetic Vertical Datum, 1929 adjustment (NGVD 29). Prominent hills and ridges in the western portions of the Lake's surface-water drainage basin have elevations ranging up to between 1,125 and 1,175 feet above NGVD 29 (see Map 2.2).

Steeply sloping lands are less likely to store or infiltrate water and are more prone to significant erosion, especially when actively cropped, developed, or urbanized. Eroded sediments are transported to lakes, streams, and wetlands where they settle and have the potential to cover desirable coarse-grained granular substrates. Furthermore, eroded sediment often contains significant amounts of nutrients and can contain a variety of pollutants.

Steep slopes are common throughout the Lake's watershed. Slopes in the Silver Lake surface watershed range from less than one percent to greater than 20 percent. As shown on Map 2.3, areas adjacent to Silver Lake's shoreline are relatively level. However, the land surface dramatically steepens farther away from the shoreline near the periphery of the Lake's watershed. In fact, steeply sloping areas (areas with slope of greater than 20 percent) occupy more than a quarter of the Lake's watershed, including some areas close to the Lake.

Geology and Soils

Washington County was entirely covered by glacial ice until roughly 15,000 years ago. Eastern Washington County was overridden by glaciers flowing southwest out of the Lake Michigan Basin, depositing sediment now known as the Oak Creek Formation and the Waubeka and New Berlin Members of the Holy Hill Formation. Glaciers overriding western Washington County followed Green Bay, Lake Winnebago, and other lowlands, and entered Washington County from the northwest depositing sediments known as the Horicon Member of the Holy Hill Formation. The two lobes of glacial ice met and formed the prominent ridges of the Kettle Interlobate Moraine (commonly referred to as the "Kettle Moraine").

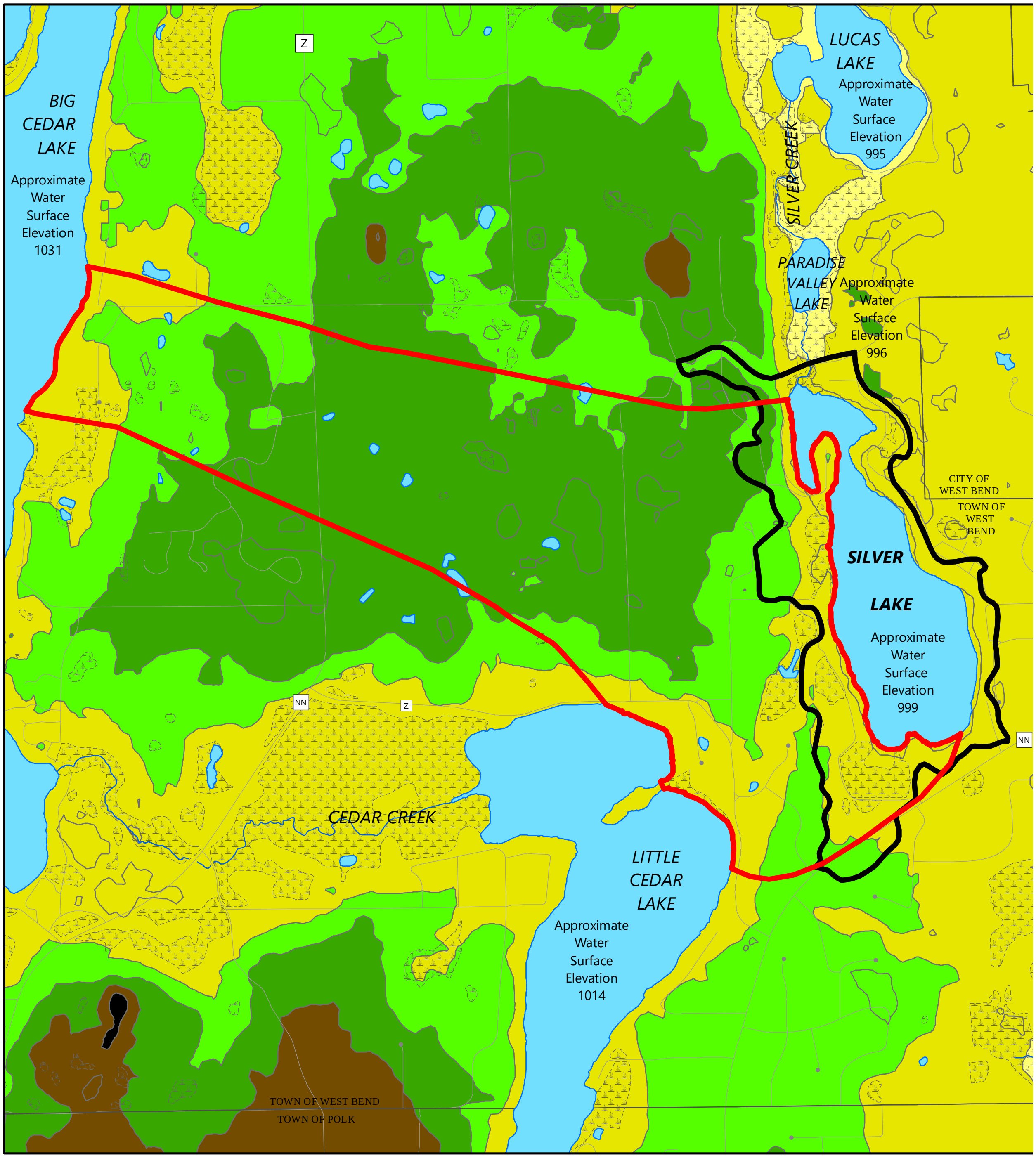
Glaciers transported vast quantities of unsorted sediment (diamicton) to the area and deposited these sediments under and at the distal end of glacial ice. When glacial diamicton is deposited directly by glacial ice, it is referred to as till. Till deposited under glacial ice is termed ground moraine, 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 can 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. Many of the lakes of west-central Washington County occupy kettles. Sediments surrounding Silver Lake are composed of pitted glacial outwash with numerous kettles. Silver Lake occupies a particularly large and deep kettle. Sediments of the New Berlin Member of the Holly Hill Formation extend to the eastern shoreline of Silver Lake. Most sediment to the west of the lake was deposited in the interlobate area and is therefore either Holy Hill or Horicon Formation sediment.[7]

Silver Lake is situated on the northern flank of a prominent northwest-southeast trending bedrock valley. The bedrock surface is roughly 200 feet lower under the Lake's southern end compared to its northern end. This bedrock valley is tributary to a regionally extensive northeast-southwest trending bedrock valley. These bedrock valleys were eroded by rivers but are now deeply buried by glacial sediment. Between 200 and 350

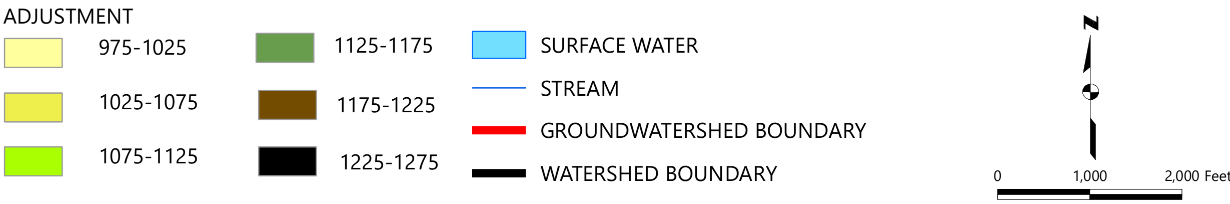
[6] *At the time of drafting the initial lake protection plan (SEWRPC Memorandum Report No. 123,* A Lake Protection and Recreational Use Plan for Silver Lake, Washington County Wisconsin*, September 1997), the Lake's watershed was estimated to be approximately 718 acres. This total included internally drained areas, areas that contribute runoff to Silver Lake only during very large runoff events. Current mapping suggests that only 179 acres typically contribute surface-water runoff to the Lake. The Silver Lake watershed boundary was delineated using two-foot interval ground elevation contours developed from the 2003 digital terrain model. The Lake itself covers about 126 acres.*

[7] *Mickelson, David M. and Kent M. Syverson,* Quaternary Geology of Ozaukee and Washington Counties, Wisconsin, *Geological and Natural History Survey Bulletin 91, 1997.*

Map 2.2
Local Topography

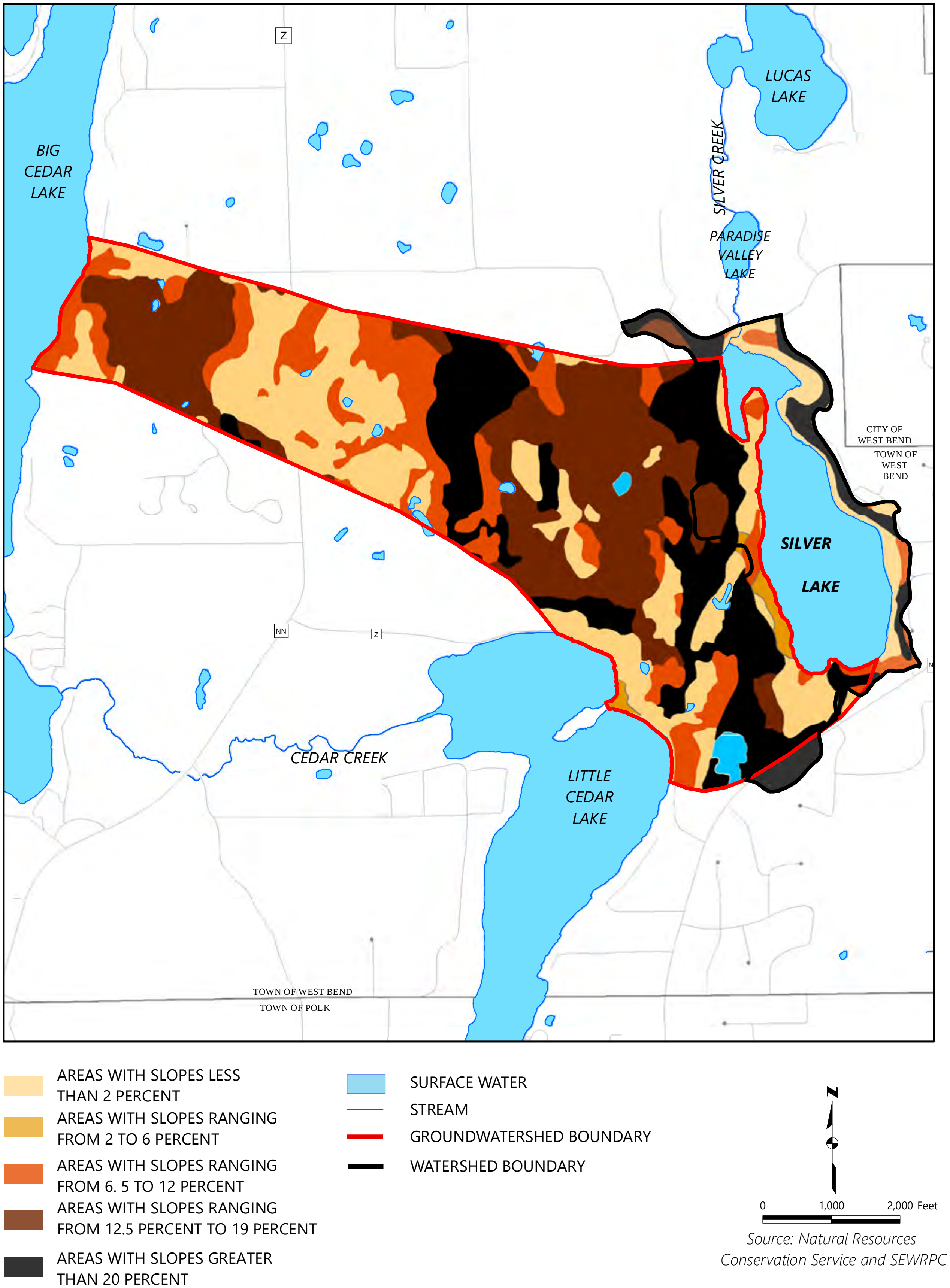


ELEVATION IN FEET ABOVE NATIONAL GEODETIC VERTICAL DATUM, 1929 ADJUSTMENT



Source: SEWRPC

Map 2.3
Land-Surface Slope Near Silver Lake



Source: Natural Resources Conservation Service and SEWRPC feet of unconsolidated sediment are found below Silver Lake. Bedrock below the southernmost portion of the Lake and its watershed and at the floor of the buried bedrock valley is composed of easily eroded Ordovician-age shale. Bedrock under the balance of the Lake and its watershed is composed of Silurian-age Niagara Dolomite. The erosion-resistant Niagara dolomite forms the walls of the buried bedrock valley.[8]

Soils are the uppermost layers of terrestrial sediment and are the result of weathering and biological activity. The type of soil underlying the area depends on several factors, including landscape position and slope, parent material, hydrology, and the types of plants and animals present. Soils to the west of Silver Lake are primarily Hocheim-Theresa association soils; soils in the eastern portion of the surface watershed are primarily Casco-Fox-Rodman association soils. Hocheim-Theresa soils are generally well drained and have subsoil consisting of clay loam and silty clay loam, with parent materials being glacial till and loess (wind-deposited silt). They are generally nearly level to steep and occur on till moraines. Fox-Casco and Rodman-Casco soils are both formed in outwash deposits, with Rodman-Casco soils generally having less topsoil, and being coarser grained and more droughty. These soils generally consist of gently sloping to very steep soils and are on outwash terraces formed by glacial meltwater. The general topography of such soils consists of rolling hills to hilly ridges—typical of the terrain west of Silver Lake.[9]

Vegetation

Before European settlement, forest dominated the local landscape (see Map 2.4). The northern portion of Silver Lake's watershed and the great majority of the area with the Lake's groundwater recharge area located between the Cedar Lakes and Silver Lake were covered with maple-basswood forest. The southern half of the Lake's eastern shoreline and uplands between Little Cedar and Silver Lakes were covered with beech-maple forest. Lowlands around the Lake were occupied by conifers such as tamarack (*Larix laricina*) and white cedar (*Thuja occidentalis*) or marsh vegetation.

Much of the land in the watershed is suitable for agriculture use. As such, much of the original vegetation was cleared to make room for farming and to provide raw materials to support initial settlement. Today's vegetation has been manipulated to support human wants and needs. Although much land is devoted to providing space for agriculture and residences, many areas are not used for intensive human activity and are mantled with vegetation supporting wildlife and other natural resource functions. Upland cover types are shown on Map 2.5. Wetlands, environmental corridors, floodplains, and other undeveloped areas also can host vegetation supporting wildlife and natural resource functions. These areas are discussed in subsequent sections of this chapter.

Historical Urban Growth

Historical urban growth within the Silver Lake watershed is summarized on Map 2.6 and in Table 2.2. Until the 1970s, urban development in the watershed occurred almost entirely along the shoreline of Silver Lake. Since that time, the majority of growth has occurred immediately to the west of the lake as well as farther west in the groundwatershed, some of which is associated with development near Big Cedar Lake.

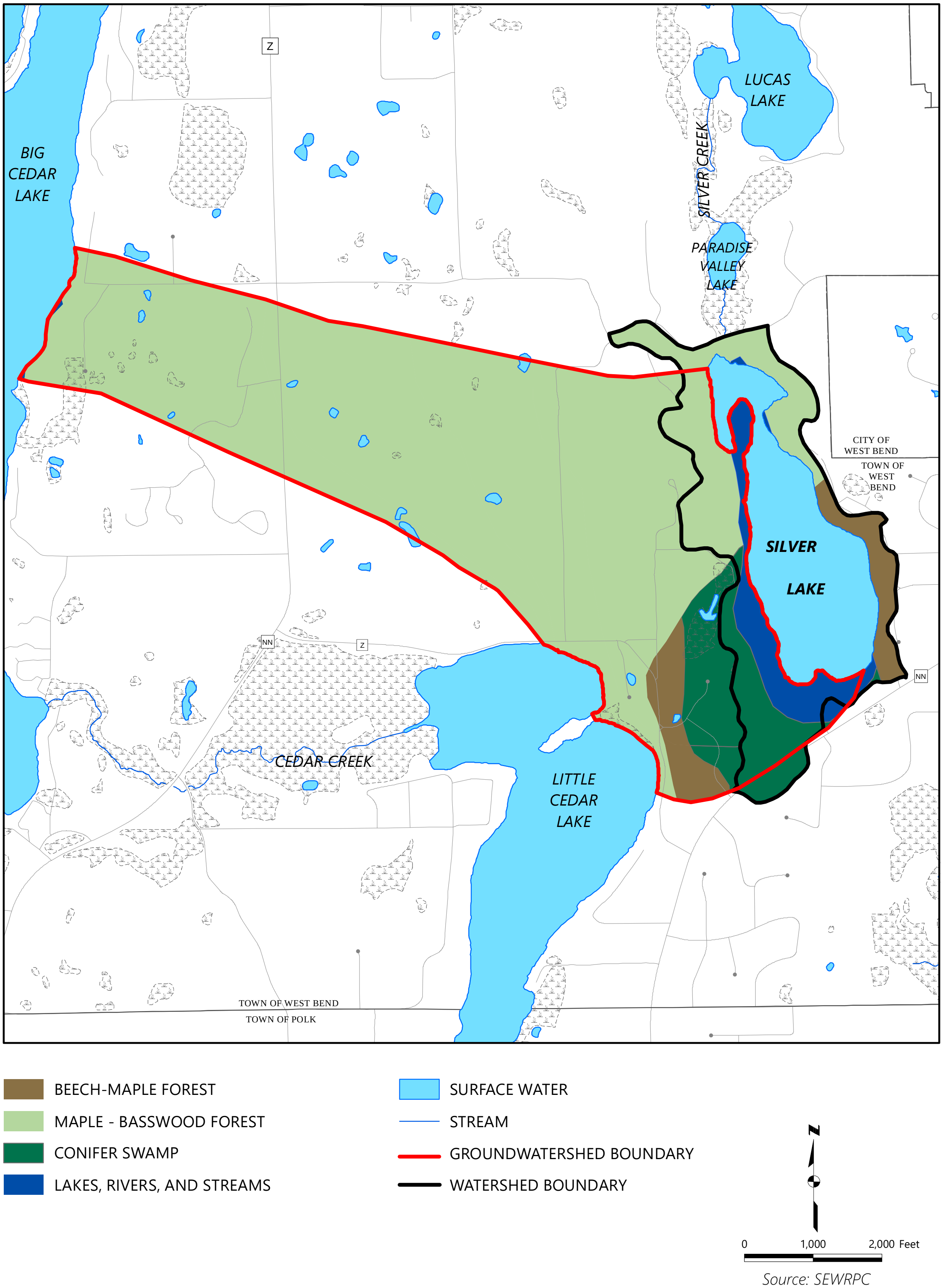
Population and Households

Changes in the human population and numbers of households in the Silver Lake surface watershed and groundwatershed are summarized in Tables 2.3 and Table 2.4, respectively. During the 50-year period between 1960 and 2010, the human population in the Lake-direct drainage area grew more slowly than the population in the groundwatershed. Since most of Silver Lake's total Lake-direct drainage area is confined to areas near Silver Lake's shoreline, much of the watershed is already developed, a situation limiting further development. On the other hand, comparatively little development has historically occurred in the groundwatershed, allowing substantial opportunity for additional development. Similarly, households are generally smaller in the Lake-direct drainage area compared to the groundwatershed. Until recently, the number of residents per household in the groundwatershed were two to three times greater than areas draining directly to the Lake. In recent years, groundwatershed households remain slightly larger than those in the Lake-direct watershed.

[8] *Massie-Ferch, K. M, and R. M. Peters,* Preliminary Bedrock Geology of Washington County Wisconsin, Wisconsin*, Wisconsin Geological and Natural History Survey Open-File Report 2004-17A, 2004.*

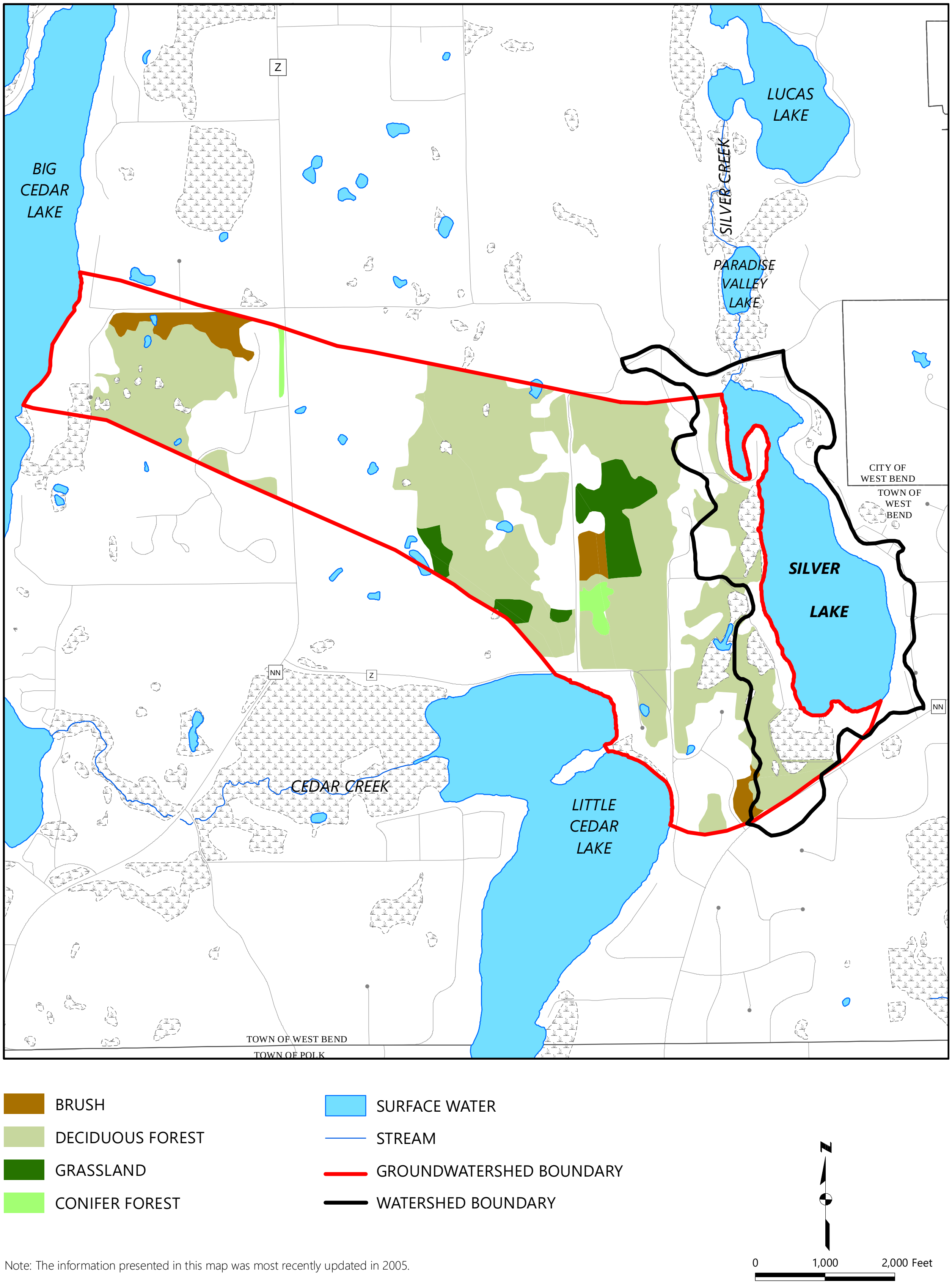
[9] *Schmude, Keith,* Soil Survey of Washington County, Wisconsin*, United States Department of Agriculture, 1971.*

Map 2.4
Presettlement Vegetation Near Silver Lake



Source: SEWRPC

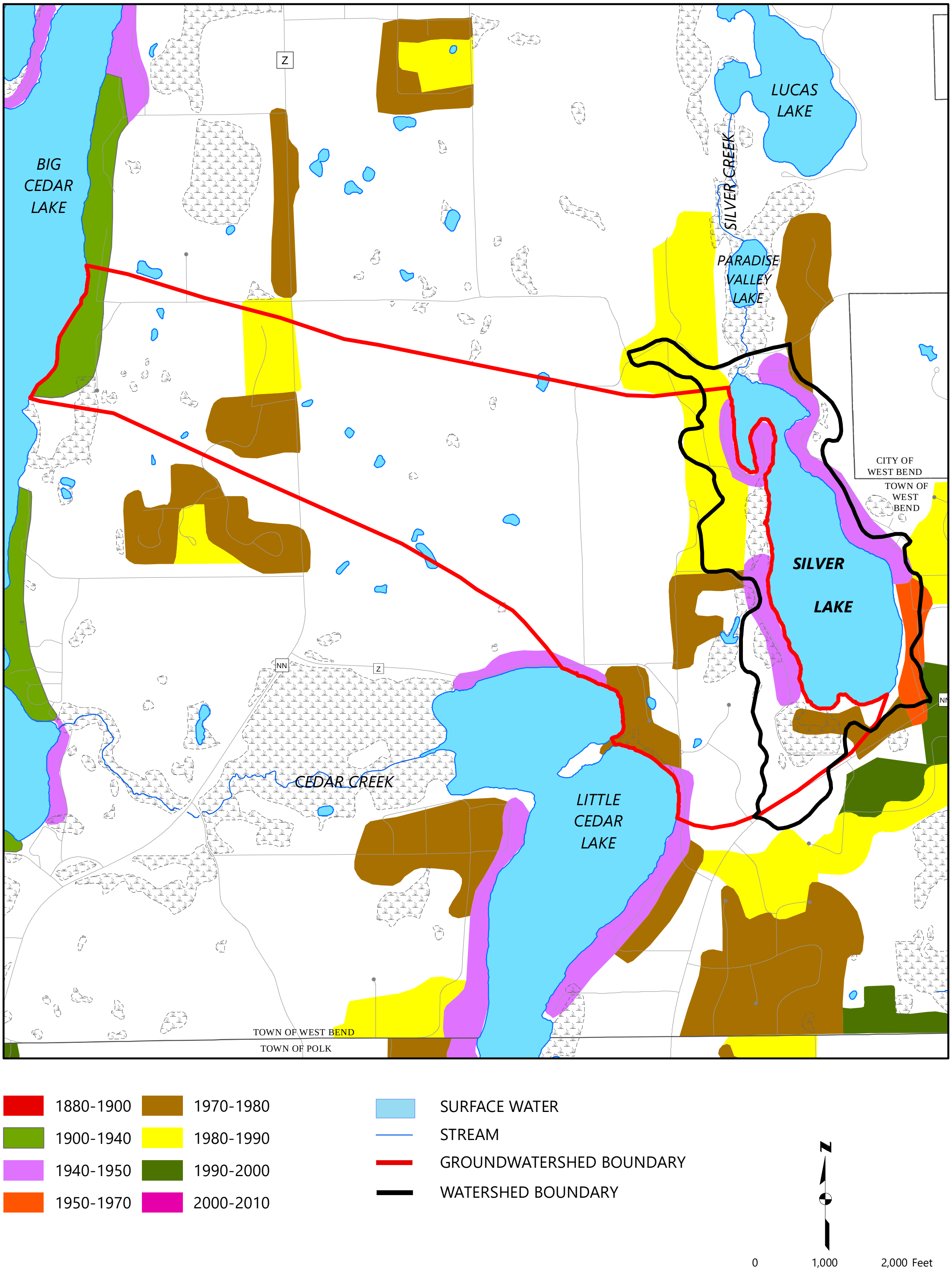
Map 2.5
Upland Habitat Cover Near Silver Lake



Note: The information presented in this map was most recently updated in 2005.

Source: SEWRPC

Map 2.6
Historical Urban Growth Near Silver Lake



Source: SEWRPC

The numbers of people and households in the Silver Lake watershed and groundwatershed has increased over the years, but most growth has been episodic. At times, the population of the watershed and groundwatershed has actually decreased, including the 2000 through 2010 time period. Population and household growth was robust through much of the 1970s. The adopted 2050 regional land use plan projects the population and number of resident households in the Silver Lake watershed and groundwatershed to continue to slowly increase, a projection consistent with planned increases in urban land uses.[10]

Table 2.2
Historical Urban Growth in the Silver Lake Watershed

Year	Growth in Urban Land Use (acres)
1900-1950	52.3
1951-1963	10.6
1964-1975	0.3
1976-1980	9.1
1981-1985	20.9
1986-1990	17.1
1991-2000	0.2
2001-2010	0.0

Source: SEWRPC

Jurisdictional Roles and Responsibilities

Natural resources are protected to some extent under Federal, State, and local law. The Clean Water Act regulates surface-water quality at the national level. In Wisconsin, the WDNR has the authority to administer the provisions of the Clean Water Act. The U.S. Environmental Protection Agency (USEPA), U.S. Army Corps of Engineers, Natural Resources Conservation Service, and the U.S. Fish and Wildlife Service work with the WDNR to protect and enhance natural areas, wetlands, and threatened and endangered species. The Federal Safe Drinking Water Act also protects surface and groundwater resources.

Counties and other local municipalities enforce ordinances regulating land development and protecting surface waters. Comprehensive zoning ordinances are an important and significant tool used by local units of government to encourage sustainable land use within their jurisdictions. Local zoning regulations include general, or comprehensive, zoning regulations and special-purpose regulations governing floodplain and shoreland areas. General zoning and special-purpose zoning regulations may be adopted as a single ordinance or as separate ordinances; they may or may not be contained in the same document. Any analysis of locally proposed land uses must consider the provisions of both general and special-purpose zoning. Relevant ordinances administered by the units of government within the watershed are summarized in Table 2.5. Since State laws governing County and local zoning regulations are often revised, the Commission periodically summarizes regulatory changes.[11] Other governmental entities with watershed jurisdictional or technical advisory roles include: the Wisconsin Department of Agriculture, Trade, and Consumer Protection, the University of Wisconsin-Extension, and the Washington County Planning and Parks Department.

Land Use and Anticipated Land-Use Change

The Commission mapped existing year 2015 land use data and planned year land use projections for the areas contributing water to the Lake.[12,13] As of 2015, urban land uses occupy about a third of the Lake-direct drainage area (Map 2.7 and Table 2.6). Homes and roadways account for essentially of this land use type. The balance of the watershed is used for rural land use purposes. The open water surface of the Lake accounts for over 40 percent of this area. Woodlands and wetlands also occupy significant-sized areas in the watershed. The amount of the Lake's watershed devoted to urban land uses is not forecast to change with planned land use, a situation largely attributable to the fact that most buildable land in this area has already been developed.

Land use and anticipated land-use change were also examined in Silver Lake's groundwatershed (Table 2.7). Urban land uses currently cover about a quarter of the Lake's groundwatershed. Similar to the Lake's Lake-direct drainage area, homes and roadways constitute almost all urban land uses. However, unlike the watershed, agricultural and open lands occupy large portions of the groundwatershed, areas that often are relatively easy to develop in the future. A modest amount (23 acres) of agricultural and open land is expected to be developed by planned land use.

[10] *SEWRPC Planning Report No. 55,* VISION 2050: A Regional Land Use and Transportation Plan for Southeastern Wisconsin*, July 2017.*

[11] *sewrpc.org/SEWRPCFiles/CommunityAssistance/Smartgrowth/fact_sheet_implementation_of_comp_plans.pdf.*

[12] *Ibid.*

[13] *"Existing" land use data is based upon year 2015 orthophotography and cadastral mapping. SEWRPC has over 60 land cover classifications mapped at a scale of 1 inch equals 200 feet.*

Table 2.3
Population and Households in the Silver Lake Watershed: 1960-2010

	Human Population			Number of Households		
		Change from Preceding Decade			Change from Preceding Decade	
Year	Number	Number	Percent	Number	Number	Percent
1960	117	--	--	42	--	--
1970	109	-8	-7	28	-14	-33
1980	314	205	188	103	75	268
1990	306	-8	-3	112	9	9
2000	400	94	31	151	39	35
2010	389	-11	-3	145	-6	-4
Planned	410	21	5	147	2	1

Source: U.S. Bureau of Census and SEWRPC

Table 2.4
Population and Households in the Silver Lake Groundwatershed: 1960-2010

	Human Population			Number of Households		
		Change from Preceding Decade			Change from Preceding Decade	
Year	Number	Number	Percent	Number	Number	Percent
1960	157	--	--	25	--	--
1970	320	163	104	35	10	40
1980	533	213	67	47	12	34
1990	645	112	21	97	50	106
2000	645	0	0	100	3	3
2010	506	-139	-22	139	39	39
Planned	617	111	22	153	14	10

Source: U.S. Bureau of Census and SEWRPC

Table 2.5
Land Use Regulations Within the Area Contributing Water to Silver Lake

	Community	
Type of Ordinance	Washington County	Town of West Bend
General Zoning	--[a]	Adopted
Floodplain Zoning	Adopted[a]	County ordinance
Shoreland Zoning	Adopted[a]	County ordinance
Subdivision Control	Adopted	Adopted and County ordinance
Erosion Control and Stormwater Management	Adopted	Adopted

[a] *Washington County rescinded its general zoning ordinance in 1986. All towns in the County have adopted a town zoning ordinance. County floodplain and shoreland regulations continue to apply in unincorporated (town) areas.*

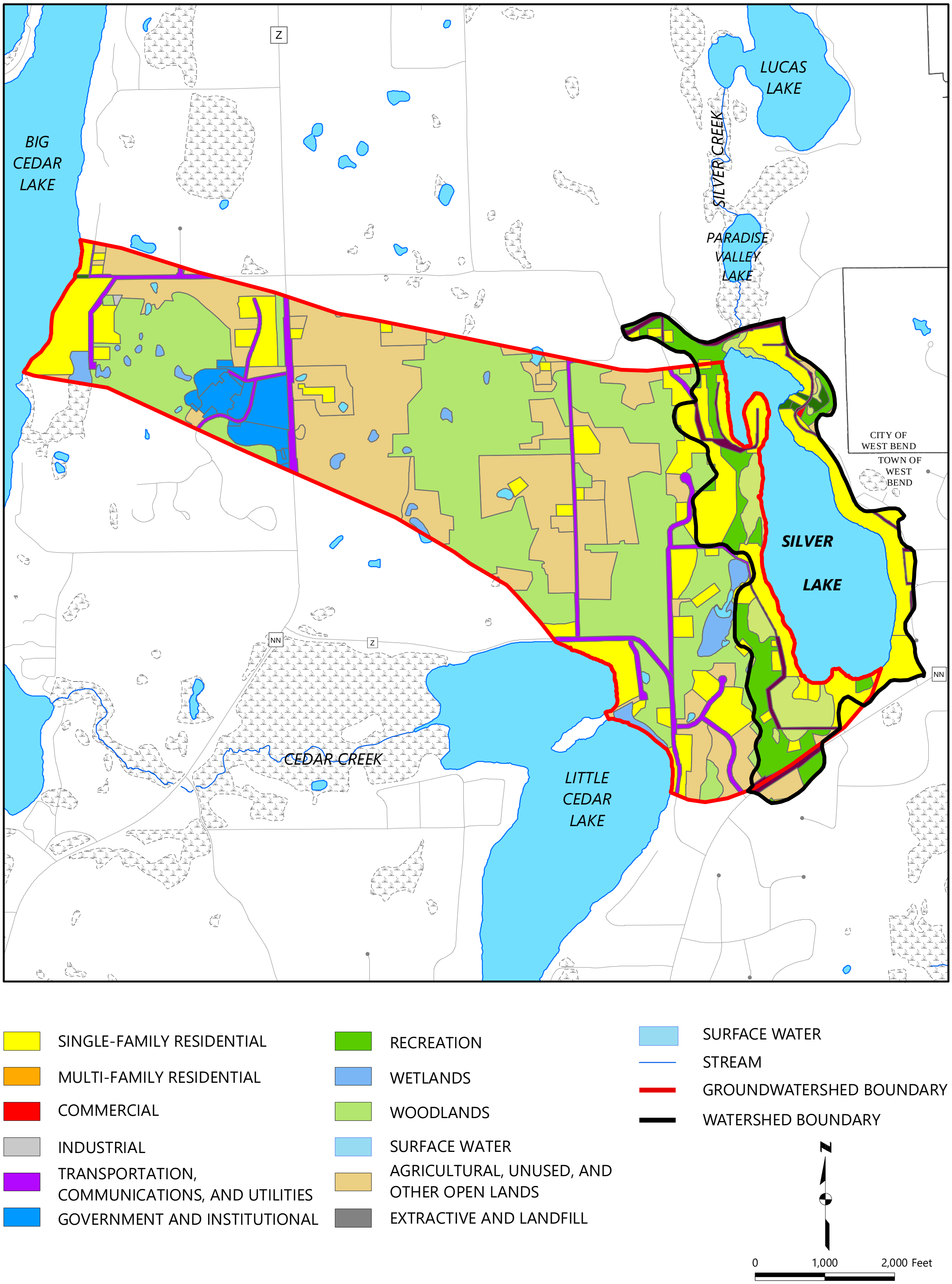
Source: SEWRPC

Urban development increases the amount of impervious surface covering the land. Impervious surface decreases the amount of water infiltrating into the ground, increases runoff volume, and increases the speed of water delivery to surface-water features. On account of this, urbanization often diminishes groundwater supplies, increases flooding, and reduces dry-weather flow in streams. Many researchers throughout the United States, including researchers at the WDNR, report that the amount of connected impervious surface is the best indicator of the level of urbanization in a watershed.[14] Directly connected impervious area is area that discharges directly to the stormwater drainage system, and, ultimately, to a stream without the potential for infiltration through discharge to pervious surfaces or facilities specifically designed to infiltrate runoff. In the absence of mitigating controls on runoff, impervious surfaces:[15]

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

[15] *Dane County Regional Planning Commission*, Dane County Waterbody Classification Study-Phase I, *March 2007.*

Map 2.7
Land Use Near Silver Lake: 2015



Source: SEWRPC

Table 2.6
Existing (2015) and Planned Land Use Within Silver Lake's Watershed

	2015		Planned		Change 2015-Planned	
Land Use Categories[a]	Acres	Percent of Total	Acres	Percent of Total	Acres	Percent of Total
Urban						
Residential						
Single-Family						
Rural Density	3	1.0	3	1.0	0	0.0
Suburban Density	1	0.3	1	0.3	0	0.0
Low Density	36	11.8	36	11.8	0	0.0
Medium Density	48	15.7	48	15.7	0	0.0
High Density	0	0.0	0	0.0	--	--
Multifamily	0	0.0	0	0.0	--	--
Commercial	0	0.0	0	0.0	--	--
Industrial	0	0.0	0	0.0	--	--
Governmental and Institutional	0	0.0	0	0.0	--	--
Transportation, Communication, and Utilities	15	4.9	15	4.9	0	0.0
Recreational	2	0.7	2	0.7	0	0.0
Urban Subtotal	105	34.4	105	34.4	0	0.0
Rural						
Agricultural	0	0.0	0	0.0	--	--
Other Open Lands	6	2.0	6	2.0	0	0.0
Wetlands	25	8.2	25	8.2	0	0.0
Woodlands	43	14.4	44	14.4	1	2.3
Water[b]	126	41.0	125	41.0	-1	<-1.0
Extractive	0	0.0	0	0.0	--	--
Landfill	0	0.0	0	0.0	--	--
Rural Subtotal	200	65.6	200	65.6	0	0.0
Total	305	100.0	305	100.0	--	--

[a] *Parking included in associated use.*

[b] *Includes Silver Lake.*

Source: SEWRPC

- Contribute to the hydrologic changes that degrade waterways
- Are a major component of the intensive land uses that generate pollution
- Prevent natural pollutant attenuation or removal in the soil by preventing infiltration
- Serve as an efficient conveyance system transporting pollutants into waterways

Research over the last 20 years shows a strong relationship between the imperviousness of a drainage basin and the health of receiving streams.[16] Studies have found that relatively low levels of urbanization (8 to 12 percent connected impervious surface) can cause subtle changes in physical (increased temperature and turbidity) and chemical (reduced dissolved oxygen and increased pollutant levels) properties of a stream, leading to a decline in the biological integrity of the stream. For example, each 1 percent increase

[16] *Wang, L., J. Lyons, P. Kanehl, R. Bannerman, and E. Emmons, "Watershed Urbanization and Changes in Fish Communities in Southeastern Wisconsin Streams,"* Journal of the American Water Resources Association *Volume 36, Number 5:1173-1189, 2000; Wang, L., J. Lyons, P. Kanehl, and R. Gatti, "Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams",* Fisheries *Volume 22, Number 6:6-12, 1997; Arnold, C., and C. J. Gibbons, "Impervious Surface Coverage, The Emergence of a Key Environmental Indicator,"* Journal of the American Planning Association *Volume 62, Number 2:243-258, 1996; Schueler, T.,* Site Planning for Urban Stream Protection*, Center for Watershed Protection, 1995; Ellicot, M. D., Masterson, J. P., and R. T. Bannerman, "Impacts of Stormwater Runoff on Urban Streams in Milwaukee, Wisconsin," In* National Symposium on Water Quality, American Water Resources Association*, Middleburg, VA, 1994; Schueler, T, "The Importance of Imperviousness.* Watershed Protection Techniques,*" Volume 1:100-111, 1994.*

Table 2.7
Existing (2015) and Planned Land Use Within Silver Lake's Groundwatershed

Land Use Categories[a]	2015 Acres	2015 Percent of Total	Planned Acres	Planned Percent of Total	Change 2015- Planned Acres	Change 2015- Planned Percent of Total
Urban						
Residential						
Single-Family						
Rural Density	15	1.8	15	1.8	0	0.0
Suburban Density	10	1.2	32	3.8	22	68.8
Low Density	92	11.0	93	11.0	1	1.1
Medium Density	22	2.6	22	2.6	0	0.0
High Density	0	0.0	0	0.0	--	--
Multifamily	0	0.0	0	0.0	--	--
Commercial	0	0.0	0	0.0	--	--
Industrial	1	0.1	1	0.1	0	0.0
Governmental and Institutional	28	3.4	29	3.5	1	3.4
Transportation, Communication, and Utilities	44	5.3	44	5.3	0	0.0
Recreational	1	0.1	1	0.1	0	0.0
Urban Subtotal	213	25.5	236	28.2	23	9.7
Rural						
Agricultural	195	23.4	189	22.8	-6	-3.2
Other Open Lands	64	7.7	47	5.6	-17	-36.2
Wetlands	40	4.8	40	4.8	0	0.0
Woodlands	318	38.1	318	38.1	0	0.0
Water	4	0.5	4	0.5	0	0.0
Extractive	0	0.0	0	0.0	--	--
Landfill	0	0.0	0	0.0	--	--
Rural Subtotal	621	74.5	598	71.8	-23	-3.8
Total	834	100.0	834	100.0	--	--

[a] *Parking included in associated use.*

Source: SEWRPC

in watershed imperviousness can lead to an increase in water temperature of nearly 2.5°F.[17] While this temperature increase may appear to be small in magnitude, this small increase can have significant impacts on fish, such as trout and other biological communities that have a low tolerance to temperature fluctuations or require specific thermal ranges.

The proportion Silver Lake's watershed and groundwatershed devoted to urban land likely is within the threshold level of 6 to 11 percent connected imperviousness. This suggests that impermeable surfaces in both and watershed and groundwatershed have the potential to negatively affect waterbody ecology.[18] Hence, local stormwater management practices affecting runoff volume and quality have the potential to benefit the Lake. Such practices include promoting infiltration, encouraging green infrastructure projects, and preserving riparian buffers and floodplains.

Comprehensive Plans and Plan Implementation

In 1999, the Wisconsin Legislature expanded the scope and significance of comprehensive planning in the State. The resultant legislation, sometimes referred to as the State's "Smart Growth" law, provides a framework for regional planning commissions, counties, cities, villages, or towns to develop, adopt, implement, amend, and update comprehensive plans.[19] The Commission developed information on several

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

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

[19] *See Section 66.1001* Wisconsin Statutes *for more information.*

topics to assist county and local governments with comprehensive planning.[20] Examples of these topics include the following.

- Summary of Wisconsin Comprehensive Planning Requirements
- Status of Comprehensive Plans in Southeastern Wisconsin
- Land Use Related Extraterritorial Areas
- Incorporating Commission Plans into County and Local Comprehensive Plans
- Implementation of Comprehensive Plans

Although comprehensive planning law requires a 10-year update pursuant to Section 66.1001(2)(i) of the *Wisconsin State Statutes*, there is no guidance on the scope or content of plan updates. Plan updates are currently underway for the Multi-Jurisdictional Comprehensive Plans for Washington County (including plan updates adopted by the Towns of Farmington, Polk, Trenton, and Wayne). The Town of West Bend has elected not to participate in the ongoing multi-jurisdictional comprehensive planning process. However, the Town of West Bend adopted its Comprehensive Plan in 2005. The Town of West Bend also adopted a procedure that plan amendments be reviewed periodically (every five years) to ensure that the planning districts, maps, policies, and implementation measures reflect current conditions, and that the plan is achieving its intended goals.[21] On September 10, 2019, the Town updated and adopted a revised zoning map and ordinance.[22] [23]

Based upon a review of the Town of West Bend comprehensive 2025 land use plan and recent updated zoning ordinance and maps, the following potential issues of concern have emerged regarding the protection of Silver Lake:

- The current adopted zoning map is not consistent with the comprehensive 2025 land use plan—plan map. Specifically, many primary environmental corridor lands identified on the land use plan as "Environmental Conservancy District" land use are not shown on the Town of West Bend Zoning map. In addition, conservancy district zoning does not provide comprehensive protection to upland areas within primary environmental corridors (PECs), secondary environmental corridors (SECs), or isolated natural resource areas (INRAs). Preserving, protecting, and enhancing upland PEC areas within the Lake's groundwatershed helps maintain and improve groundwater quality and quantity, helps mitigate flooding and control storm water runoff; protects groundwater recharge and discharge areas; protects wildlife habitat; protects native plant communities; and protects the Lake's recreational resources.

- The C-1 Conservancy District is intended to preserve, protect, and enhance lowland areas (e.g., lakes, ponds, streams, and wetland areas). However, the current C-1 zoning delineation is not consistent with updated year 2010 Wisconsin Wetland Inventory (WWI) boundaries.[24] Hence, multiple wetlands throughout the Town of West Bend are not properly identified as C-1 Districts (see also "Natural Resource Elements" subsection below for more details on mapped wetlands).

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[20] *More information can be found at the following website: sewrpc.org/SEWRPC/communityassistance/ProjectPlanningServices.htm.*

[21] *Town of West Bend,* Town of West Bend Comprehensive Plan: 2025*, prepared by Planning and Design Institute, Inc., October 2005.*

[22] *The Town of West Bend zoning ordinance and map can be found at townofwestbend.com/zoning-information.*

[23] *County and local governments often periodically amend plans and should consider consulting legal counsel whether periodic amendments are considered plan updates that meet the requirement of Section 66.1001(2)(i).*

[24] *See Surface Water Data Viewer (SWDV), a Wisconsin DNR data delivery system that provides interactive web mapping tools for a wide variety of datasets including chemistry (water, sediment), physical, and biological (macroinvertebrate and fish) data. Identify wetlands using the mapped wetlands data layer. SWDV can be accessed via this following URL: dnrmaps.wi.gov/H5/?Viewer=SWDV.*

- The current zoning ordinance specifies that the Rural Residential District (R-1R) areas may be allowed an overall base density of no more than 1 dwelling unit per 3.5 acres. However, this base density is not consistent with the recommendation for residential development outside urban service areas at a density of no more than 1 dwelling unit per 5.0 acres, as recommended pursuant to the VISION 2050 regional land use and transportation plan.[25]

- Development design standards do not consider groundwater recharge potential (i.e., protecting landscapes underlain by high and very high groundwater recharge potential areas as identified in the regional water supply plan). This is further addressed in Section 2.4 "Local Conditions."

- Development standards do not consider natural areas and critical species habitat information as identified in the Commission's natural areas plan. More information can be found in Section 2.3 "Natural Areas and Critical Species Habitat Sites."

- The ordinance continues to consider Class I, II, and III wildlife habitat areas identified by the Commission; however, this information is obsolete.

Sewer Service Area

Sewer service areas have been 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, the plans become a formal amendment to the regional water quality management plan and the Commission forwards the plans to the WDNR for approval.

Adopted sanitary sewer service areas near Silver Lake are shown on Map 2.8. No wastewater treatment plants are located within the Silver Lake watershed. Instead, sewage is pumped to the City of West Bend sanitary sewer system for treatment and discharge to the Milwaukee River. Areas outside the sanitary sewer service areas rely upon POWTS, systems which commonly rely upon septic tanks, leach beds, or holding tanks.

Approximately 145 acres (81 percent) of Silver Lake's watershed is served by public sanitary sewers. A large area near Big Cedar Lake outside of Silver Lake's watershed but within its groundwatershed is also served by sanitary sewers. Including areas with Silver Lake's watershed, about 201 acres (24 percent) of Silver Lake's groundwatershed is served by sanitary sewer service. Water discharged to sewers in the area is derived from private or community wells, some of which draw water from the aquifer supplying Silver Lake.

2.3 NATURAL RESOURCE PLANNING ELEMENTS

Natural resources elements are integral to the landscape, provide for many human needs and desires, and are vital to continued ecological health. Their function and benefit rely upon a complex network of abiotic and biotic relationships. Deterioration or removal of a single relationship may upset the integrity of the entire network. For example, draining a wetland not only disrupts wetland plants but also can eliminate 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. Loss of ecosystem function may further affect groundwater supply for domestic, municipal, and industrial use or its contribution to low flows in streams and rivers. Preserving natural resource elements not only improves local environmental quality but can also sustain, and possibly enhance, aquatic, avian, and terrestrial wildlife populations across the Region.

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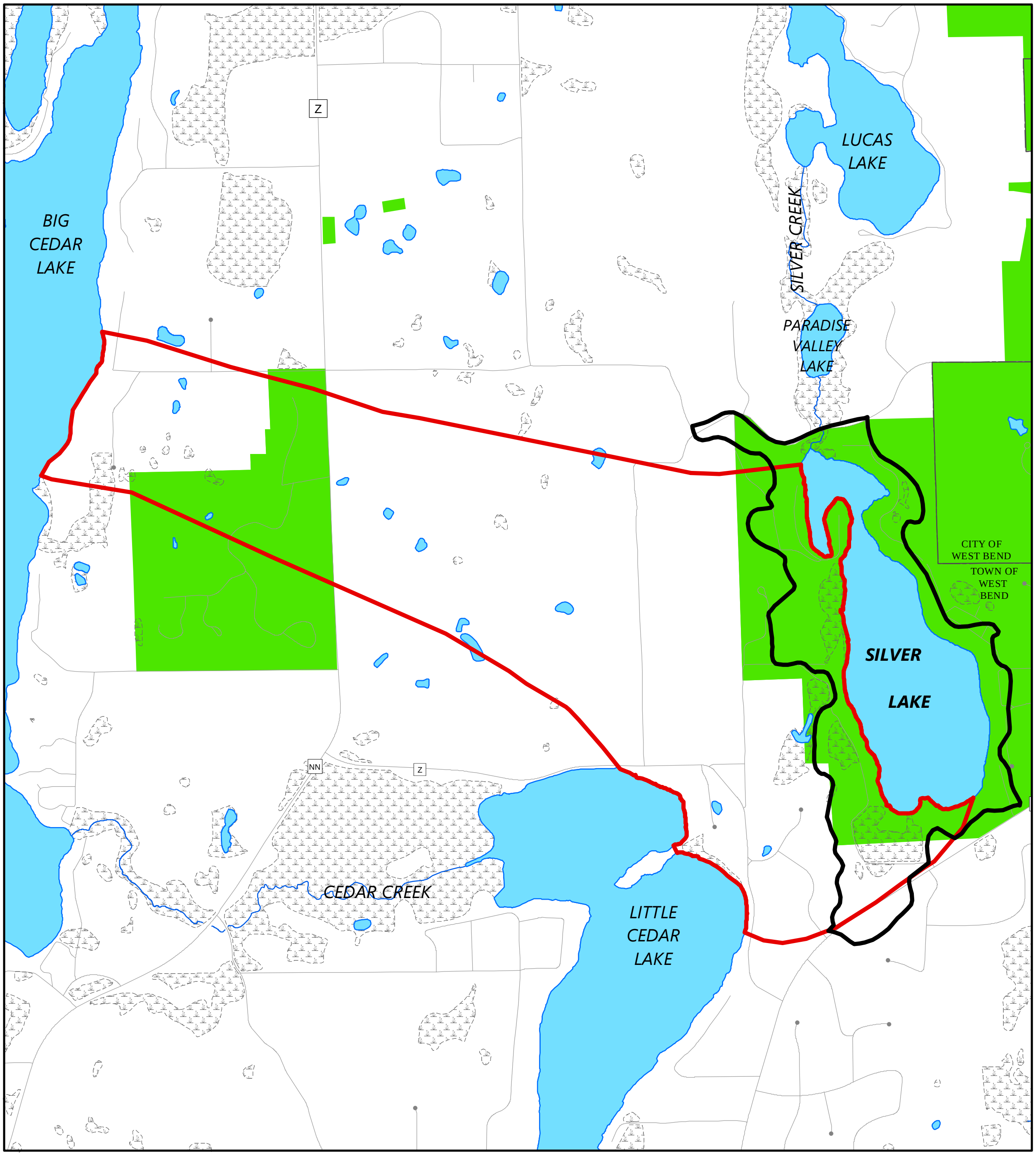
[25] *See Table K on page 211 within SEWRPC Planning Report No. 55,* VISION 2050 Volume III: Recommended Regional Land Use and Transportation Plan*, July 2017, sewrpc.org/SEWRPCFiles/Publications/pr/pr-055-vol-3-complete-final.pdf*

Map 2.8
Adopted Sanitary Sewer Service Areas Near Silver Lake



CITY OF WEST BEND SEWERAGE DISTRICT

SURFACE WATER

STREAM

GROUNDWATERSHED BOUNDARY

WATERSHED BOUNDARY

0 1,000 2,000 Feet

Source: SEWRPC

Floodplains

Section 87.30 of the *Wisconsin Statutes* requires that counties, cities, and villages adopt floodplain zoning to preserve floodwater conveyance and storage capacity and prevent new flood-damage-prone development in identifiable flood hazard areas. The minimum standards that such ordinances must meet are described in Chapter NR 116 "Wisconsin's Floodplain Management Program" of the *Wisconsin Administrative Code*. These 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. Areas within the 1-percent-annual-flood inundation probability (commonly referred to as the 100-year recurrence flood) within the Silver Lake watershed are shown on Map 2.9.

Chapter NR 116 requires that local floodland zoning regulations prohibit nearly all forms of development within the floodway, which is that portion of the floodplain required to convey the 1-percent-annual-probability peak flood flow. Local regulations must also restrict filling and development within the flood fringe, which is that portion of the floodplain located outside the floodway temporarily detaining floodwater during the one-percent-annual-probability flood. Filling and developing flood fringe area reduces a waterbody's floodwater detention capacity and may therefore increase downstream flood flows and stages. All of Silver Lake is considered floodplain. An additional nine acres of land adjacent to the Lake are also considered floodplain. Therefore, about 135 acres of floodplain are found within the Silver Lake watershed (Map 2.9).

Washington County 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 attendant to the 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. Since it is an unincorporated area, Washington County is responsible for floodplain zoning in and around Silver Lake (see Table 2.5).

Wetlands

Historically, wetlands were viewed as wastelands. At best, wetlands were viewed as obstacles to agricultural production and development, while arguments were sometimes made that wetlands were unhealthy places that could encourage spread of disease. Private interests as well as governmental institutions pursued large-scale projects to "reclaim" wetlands. Wetland habitat continued to be drained and filled until scientific research revealed how wetlands provide a long list of vital services to human habitation and the environment. For example, wetlands help mitigate floods, benefit water quality, and provide productive and biologically diverse ecosystems.[26] Thus, wetlands are now known to be economically ecologically valuable.

Wetlands are known for their diverse plant and animal life. Wetlands are plant community mosaics that include submerged plants, floating-leaf plants, emergent species such as cattails and bulrush, and woody species such as tamarack. Wildlife that relies upon, or is associated with, wetlands for at least part of their lives include crustaceans, mollusks, and other aquatic insect larvae and adults; forage fish, gamefish such as walleye, northern pike, and largemouth bass; amphibians; reptiles; mammals including furbearers and deer; resident bird species like turkeys, and migrant birds like cranes ducks, and geese.

Wetlands provide many functions that benefit human needs and desires. In addition to maintaining biodiversity, wetlands:

- Detain floodwater during wet periods, mitigating downstream flood severity
- Slowly release detained water during dry weather, nourishing stream flows and lakes levels
- Are often important sites of surface-water/groundwater interchange, helping maintain groundwater supplies and waterbody health

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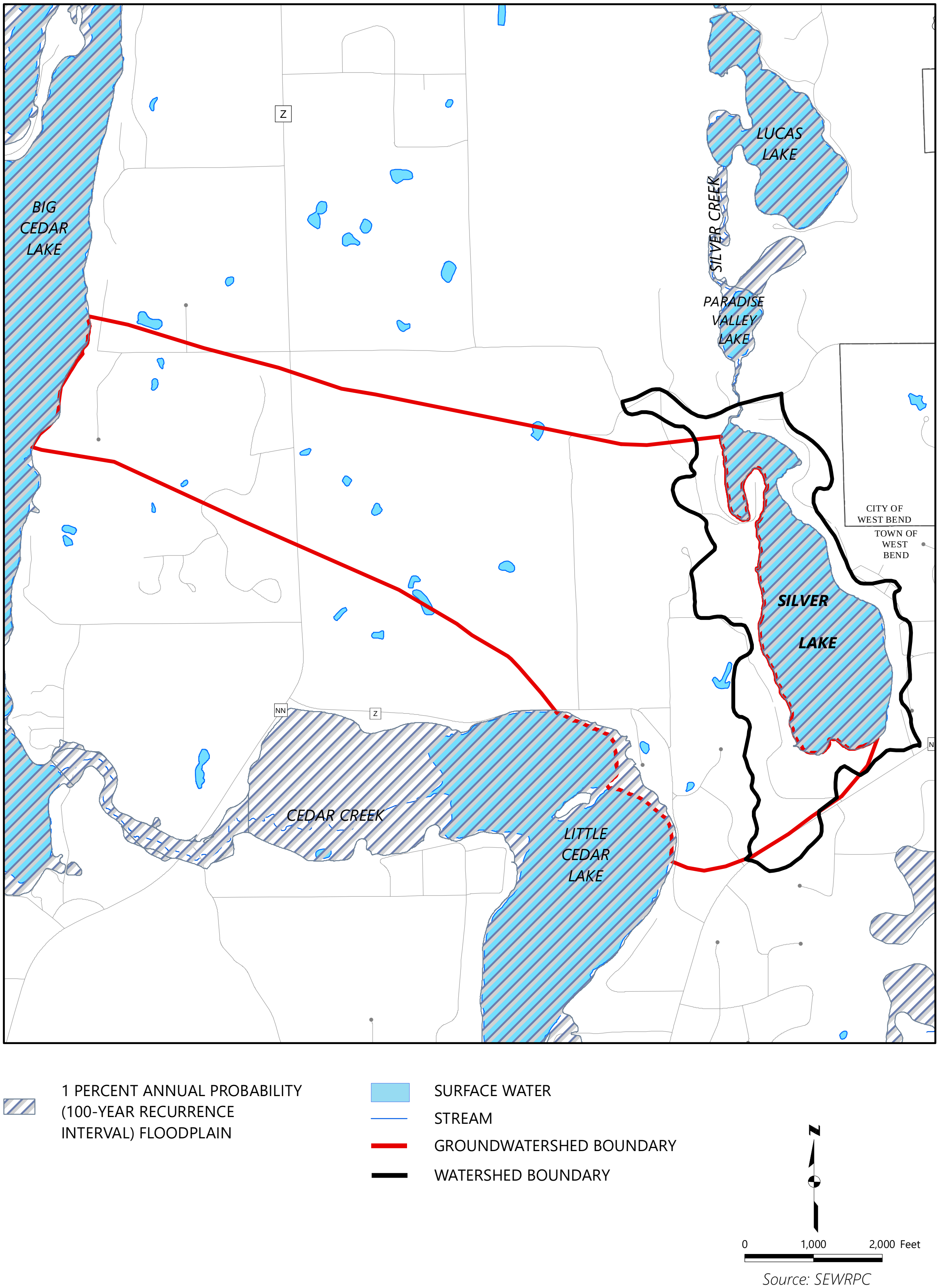
[26] *Cherry, J. A., "Ecology of Wetland Ecosystems: Water, Substrate, and Life,"* Nature Education Knowledge*, Volume 3, Number 10: 16, 2012, www.nature.com/scitable/knowledge/library/ecology-of-wetland-ecosystems-water-substrate-and-17059765.*

Map 2.9
Floodplains in the Silver Lake Area



Source: SEWRPC

- Cleanse surface water through several processes including allowing sediment to settle and nutrients to be absorbed or transformed

- Provide and sustain valuable recreational opportunities including boating, hunting, and fishing.

Recognizing the value and importance of wetlands, rules and regulations were promulgated to protect wetlands globally, nationally (e.g., the Federal Clean Water Act of 1972), statewide, and locally. Most recently, the U.S. Army Corps of Engineers and USEPA, in coordination with the U.S. Fish and Wildlife Service, WDNR, and the Commission have updated the delineation of wetlands in areas of special natural resource interest for the entire regional area to protect these areas and their associated critical species habitats (Advanced Delineation and Identification – ADID – lands).[27] These efforts help protect or conserve wetlands and the provisioning services they provide.

The term "ecosystem services" refers to any of the benefits that ecosystems—both natural and semi-natural—provide to humans.[28] In other words, ecosystem functions are classified by their abilities to provide goods and services that satisfy human needs,[29] either directly or indirectly. Examples of ecosystem services provided by wetland ecosystems are illustrated in Figure 2.1. The economic value of 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.[30] Society gains a great deal from wetland conservation. Therefore, it is essential to incorporate wetland conservation and restoration targets as part of this plan to guide management and policy decisions regarding the use and preservation of such ecosystems.

Wetlands are transitional areas, often possessing characteristics of both aquatic and terrestrial ecosystems while at the same time possessing features unique unto 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 hydrophilic vegetation and which has soils indicative of wet conditions. Three specific characteristics of wetlands are evaluated when delineating wetlands. These characteristics include the presence of:

- Hydrologic conditions causing soils to be perennially wet or flooded

- Soils dominated by anaerobic (without oxygen) processes

- Rooted vascular plants adapted to life in flooded, anaerobic environments

These characteristics pose severe limitations for urban development, as wetlands have high water tables as well as high soil compressibility, instability, shrink-swell potential, and low bearing capacity. Developments on wetland sites commonly experience flooding, excessive settlement and frost heaving, wet basements, unstable foundations, failing pavements, and failing sanitary sewer and water lines. Developing wetland sites commonly involves complex and costly onsite preparation and maintenance costs, particularly in connection with roads, foundations, and public utilities.

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[27] *Pursuant to Section NR 103.04(4) of the* Wisconsin Administrative Code*, wetlands in areas of special natural resources interest include those wetlands both within the boundary of designated areas of special natural resource interest and those wetlands that are in proximity to or have a direct hydrologic connection to such designated areas, which include Advanced Delineation and Identification study (ADID) areas. See SEWRPC Planning Report No. 42,* Amendment to the Natural Areas and Critical Species Habitat Protection and Management Plan for the Southeastern Wisconsin Region*, December 2010. www.sewrpc.org/SEWRPCFiles/Publications/pr/pr-042-natural-areas-crit-species-habitat-amendment.pdf.*

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

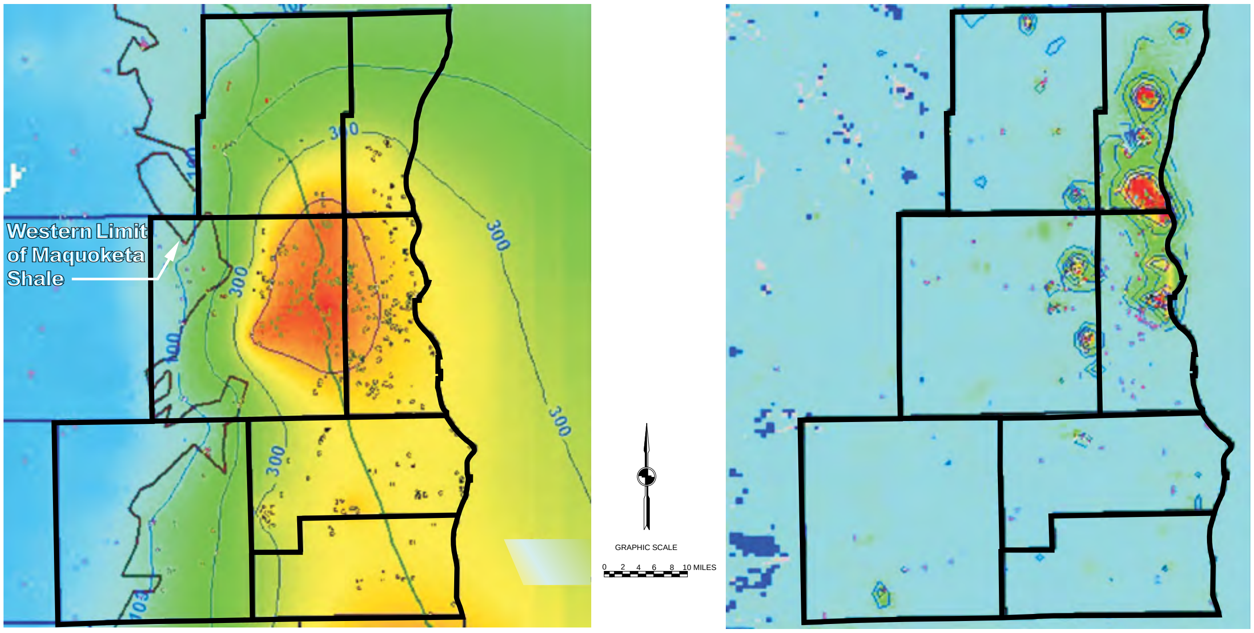
[29] *de Groot, R. D. S., M.A. Wilson, and R.A.M. Bauman, "A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services,"* Ecological Economics*, 41: 393-408, 2000, www.sciencedirect.com/science/article/pii/S0921800902000897.*

[30] *Costanza, R.W., 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.*

Figure 2.1
Simulated Groundwater Drawdowns for the Region: 2000

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*

Wetlands occupy 60 acres of the Silver Lake watershed, or about 34 percent of the total watershed area (Map 2.10). Large wetlands expanses are found along the Lake's western shoreline, areas generally coincident with the area where most of the Lake's springs and seeps discharge. About 46 acres of wetlands are found in the Lake's groundwatershed, an area equaling about 6 percent of the total groundwatershed area. Wetland community types include aquatic beds, emergent/wet meadows, scrub/shrub, and forested.

Upland Natural Areas

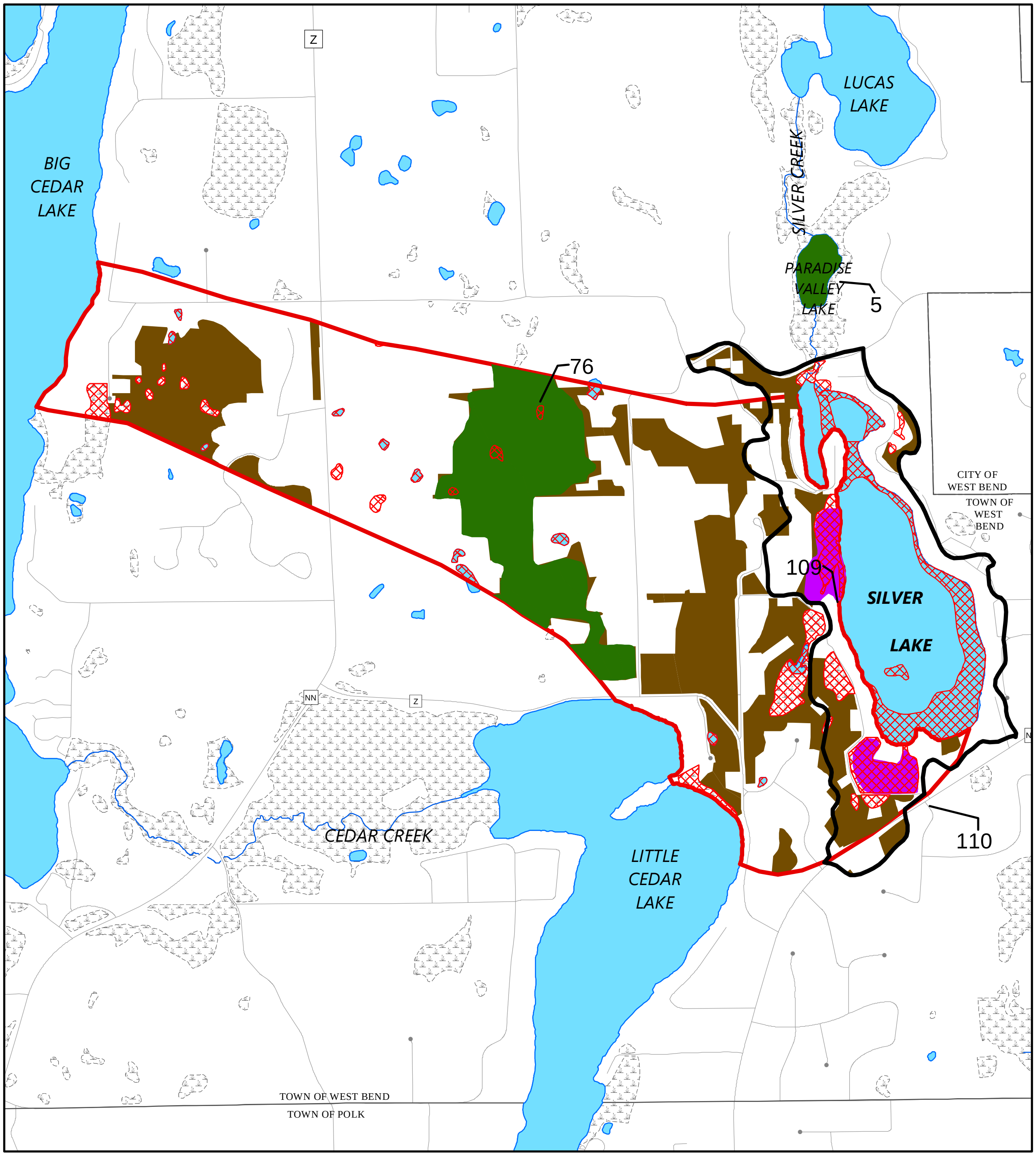
Upland natural areas are usually topographically higher and farther from open water than wetlands and thus are generally not as moist. However, many exceptions exist in this broad generalization as can be seen within the Silver Lake watershed. Upland habitat can sometimes be very difficult to distinguish from wetland because features form broad and complex habitat mosaics or combinations across the landscape. It is precisely this combination and the linkages between these unique community types that provides the critical habitats to sustain healthy and diverse aquatic and terrestrial wildlife.

Deciduous woodlands are presently the dominant natural upland cover in area contributing water to Silver Lake. In addition to deciduous woodlands, grasslands, brushlands, and conifer plantations cover modest acreages (Map 2.5).[31] Upland habitat also provide a variety of ecosystem services, although the economic value of their ecosystem services is not as large as wetland ecosystems. Nevertheless, upland habitat is worth protecting.[32] Even if natural land cover is removed, undeveloped uplands provide significant human and ecosystem service value. To illustrate, uplands sustain human food production activities, are typically groundwater recharge areas which in turn enhances water quality and reduces flood risks in lower elevation areas, can be critical wildlife breeding, nesting, resting, feeding, and refuge areas, provide appeal to landscape aesthetics, and are popular sites for recreation, tourism, and educational opportunities.

[31] *SEWRPC Planning Report No. 42, 1997 amended 2010,* op. cit.

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

Map 2.10
Natural Areas, Critical Species Habitat, Wetlands, and Woodlands Near Silver Lake



NATURAL AREAS

CRITICAL SPECIES HABITAT

WOODLANDS: 2010

WETLANDS: 2010

109 SITE IDENTIFICATION NUMBER

SURFACE WATER

STREAM

GROUNDWATERSHED BOUNDARY

WATERSHED BOUNDARY

N

0 1,000 2,000 Feet

Source: SEWRPC

Upland areas generally pose fewer urban development challenges when compared to wetland and riparian areas. For example, when compared to lowland sites, soils underlying upland areas are drier to greater depths, have better foundation characteristics and bearing capacity, are less prone to frost heave, and have lower shrink-swell potential. Furthermore, lowland areas commonly include setbacks and building restrictions related to water features, a situation complicating development and reducing developable land area. Therefore, developing upland areas is usually less costly and not as technically complex. For these reasons, customized upland conservation and restoration targets should be included in a watershed plan to guide management and policy decisions regarding the use and preservation of such ecosystems.

Natural Resource Planning Features

The Commission has studied the character and distribution of Southeastern Wisconsin's natural resource elements for decades. As part of these studies, the Commission labelled, ranked, and mapped natural resource elements useful to land use planning. This section describes these elements.

Environmental Corridors

To facilitate land-use planning, the Commission identifies certain land as "environmental corridors." These interconnected green space networks are composed of natural areas and features, public lands, and other open spaces that provide natural resource value. Depending upon their attributes, the Commission labels environmental corridor areas as primary environmental corridors, secondary environmental corridors, or as isolated natural areas. Each category is described in more detail below.

Primary environmental corridors (PECs) include a wide variety of important resource and resource-related elements. By definition, they are at least 400 acres in size, two miles in length, and 200 feet in width.[33] PECs include open water areas such as lakes. Approximately 493 acres of PEC are found in the combined Silver Lake watershed/groundwatershed. This area includes the open-water surface of Silver Lake and is equivalent to about 43 percent of this area (Map 2.11). PEC lands near Silver Lake are component to a much larger PEC mosaic extending far beyond the Silver Lake area. PEC lands represent a composite of the critical remaining elements of the natural resource base and contain almost all the best remaining uplands, wetlands, and wildlife habitat areas. Hence, Silver Lake at its associated terrestrial PECs represent the highest quality natural resources remaining within the area contributing water to Silver Lake and beyond. This is why carefully managing these areas is vital to protecting and maintaining the quality and integrity of Silver Lake and the surrounding area.

Secondary environmental corridors (SECs) generally connect with primary environmental corridors and are at least 100 acres in size and one mile long. Secondary environmental corridors are remnant resources that have been reduced in size by land development supporting intensive urban or agriculture purposes. However, secondary environmental corridors preserve ecosystem function by facilitating surface water drainage, maintaining pockets of natural resource features, as well as providing corridors for the movement of wildlife and dispersal of vegetation seeds. No SECs are found in the Silver Lake watershed or groundwatershed.

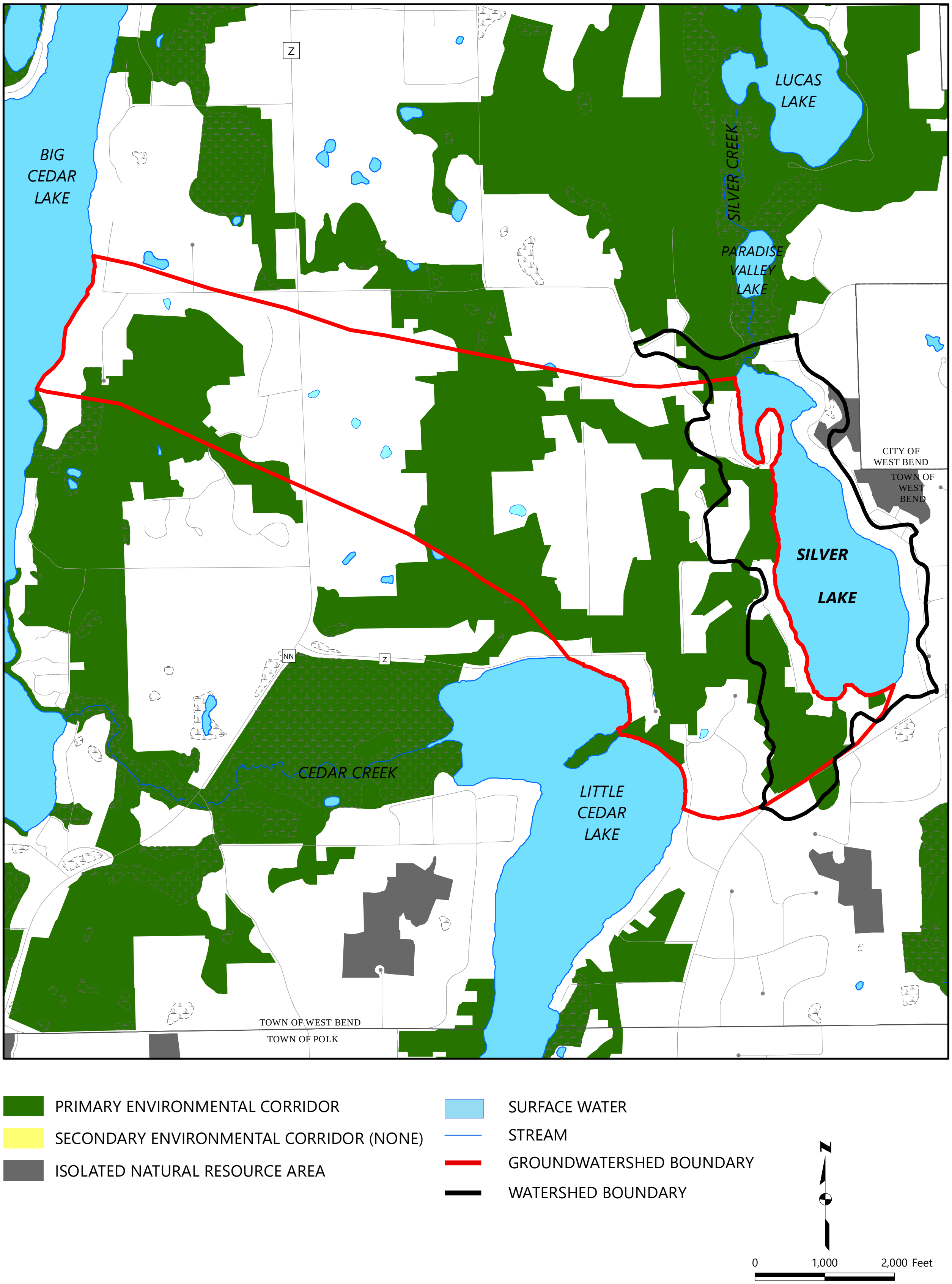
Smaller concentrations of natural resource features physically separated from the environmental corridors by intensive urban or agricultural land uses have also been identified. These natural resource areas, which are at least five acres in size, are referred to as isolated natural resource areas (INRAs). A single INRA is found in the area contributing water to Silver Lake. This three-acre site is located immediately east of the Silver Lake (Map 2.11). This INRA still contains a variety of resource functions that include facilitating surface water drainage and maintaining pockets of natural resource features.

Natural Areas and Critical Species Habitat Sites

Natural areas, as defined by the Wisconsin Natural Areas Preservation Council, are tracts of land or water so little modified by human activity, or sufficiently recovered from the effects of such activity, that they contain intact native plant and animal communities believed to be representative of the pre-European settlement landscape. Natural areas 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 the Southeastern Wisconsin Region are wetland complexes that have maintained adequate or undisturbed linkages (i.e., landscape connectivity) between the upland-wetland habitats, which

[33] *SEWRPC Planning Report No. 42,1997, amended 2010,* op. cit.

Map 2.11
Environmental Corridors And Isolated Natural Features Near Silver Lake



Source: SEWRPC

is consistent with research findings in other areas of the Midwest.[34] The extent and distribution of wetland and upland areas in the area contributing water to Silver Lake and their relationship to designated natural areas and critical species habitats are shown on Map 2.10.

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 2010. This plan was developed to assist Federal, State, and local units and agencies of government, and nongovernmental organizations, in making environmentally sound land use decisions including acquisition of priority properties, management of public lands, and location of development in appropriate localities that will protect and preserve the natural resource base of the Region. Washington County uses this document to guide land use decisions.

Identified natural areas were classified into the following three categories:

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

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

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

Classification of an area into one of these three categories was based upon consideration of several factors, including the diversity of plant and animal species and community types present; the structure and integrity of the native plant or animal community; the extent of disturbance by human activity, such as logging, grazing, water level changes, and pollution; the frequency of occurrence within the Region of the plant and animal communities present; the occurrence of unique natural features within the area; the size of the area; and the educational value. As reported in the previous Silver Lake management plan,[35] the Silver Lake watershed and groundwatershed contain parts of two designated natural areas as listed below.

- Paradise Lake Fen (Site Number 5)—a 22-acre wetland is actually located just downstream of Silver Lake along the eastern shore of Silver Creek; however, it is part of the contiguous environmental corridor of the Lake. This area has been given a rating of NA-1, identifying it as a site of statewide or greater significance.

- Ziegler Woods (Site Number 76)—a 172-acre southern mesic to dry mesic hardwood forest located west of Silver Lake. This area is rated NA-3, identifying it as an area of local significance.

These are the highest quality plant and animal communities known to exist in the Silver Lake watershed and groundwatershed and can serve as a potential seed sources for restoration in other areas.

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 170 of the *Wisconsin Administrative Code,* can designate environmentally sensitive areas on lakes that 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 home to approximately eighty percent of the plants and animals on Wisconsin's endangered and threatened species list. A significant part of the critical habitat designation lies in the fact that it assists waterfront owners by identifying 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 these sensitive resources.

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[34] *Attum, O., 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*, Volume 275, 2008, pages 245-251.*

[35] *SEWRPC Memorandum Report No. 123, 2nd Edition,* A Lake Protection and Recreational Use Plan for Silver Lake, Washington County, Wisconsin, *December 2003.*

Critical species habitats are defined as those tracts of land or water which support federally or State-listed rare, threatened, and/or endangered plant or animal species as defined by State or Federal agencies. These habitats include the abiotic and biotic factors necessary for the long-term support of the critical species population. Two identified critical species sites have been identified, as listed below.

- Silver Lake Woods (Site Number 109)—an 11-acre woodland located along the western edge of Silver Lake. This area is a critical species habitat site that provides nesting habitat for red-shouldered hawk, which is a State-designated threatened species.

- Silver Lake Swamp (Site Number 110)—a 10-acre wet mesic forest critical species habitat adjacent the southwest shore of Silver Lake. This area is a critical species habitat site that contains a small population of the showy lady's slipper orchid (*Cypripedium reginea*), which is a State-designated special concern species.

Silver Lake itself is listed as one of the Critical Lakes of Southeast Wisconsin and has been given an AQ-2 designation identifying it as an area of countywide or regional significance. A State Special Concern species, the Least Darter (*Etheostoma microperca*) and a State Threatened species, the Pugnose shiner (*Notropis anogenus*) have been identified as present in Silver Lake.

In addition to critical species habitat areas identified in published Commission plans, seven new critical species habitat areas were identified by Commission staff as part of this study's shoreline assessment of Silver Lake (see Map 2.12). Habitat types associated with each of these areas are listed below.

- Area 1: deep marsh combined with a smaller portion of shallow marsh.

- Area 2: calcareous fen with elements of southern tamarack poor fen.

- Area 3: undifferentiated community with shrub-carr and lowland hardwoods combined with a smaller portion of deep marsh.

- Area 4: calcareous fen with southern tamarack poor fen. Broad seeps and three or four springs feed into the Lake in this area.

- Area 5: undifferentiated community with shrub-carr and lowland hardwoods along outlet of wetland area west of the Lake.

- Area 6: undifferentiated community with shrub carr, lowland hardwoods combined with a smaller portion of shallow marsh adjacent to the outlet of wetland area southwest of the Lake.

- Area 7: undifferentiated community with shrub-carr and lowland hardwoods. Skunk cabbage indicates a likely groundwater seepage area.

Two special concern plant species were observed in these areas: *Eleocharis quinqeflora* (few-flowered spike-rush) and *Triglochin palustre* (slender bog arrow-grass). There is also one special concern herptile that was observed by both call and sight in one of these areas: *Lithobates catesbeianus (*bullfrog).

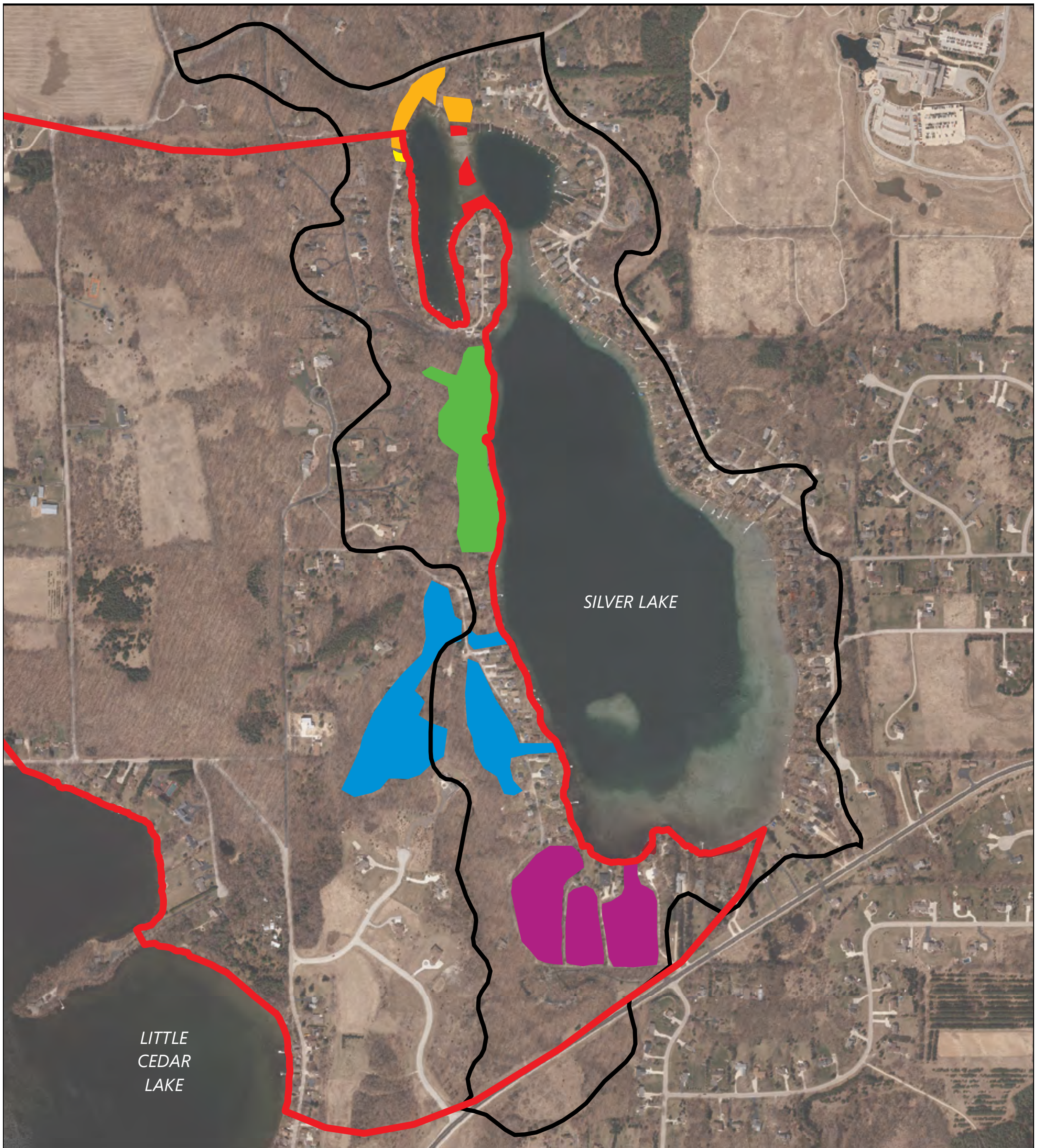
Not to be confused with Critical Habitat areas, the WDNR also designates Sensitive Areas on the Lake in which aquatic plant management options are limited. No portion of Silver Lake is identified as sensitive area.

Protecting and enhancing natural areas (PECs, INRAs, and critical species habitat areas) requires a number of actions, including the following examples.

1. Prevent or limit development within these areas

2. Ensure that any development that does occur does not sever ecological continuity with adjoining natural areas

Map 2.12
New Critical Species Habitat Areas Identified During 2016



AREA 1 MARSH
AREA 2 FEN
AREA 3 SHRUB-CARR AND LOWLAND FOREST
AREA 4 FEN
AREA 5 SHRUB-CARR AND LOWLAND FOREST
AREA 6 SHRUB-CARR AND LOWLAND FOREST
AREA 7 SHRUB-CARR AND LOWLAND FOREST
GROUNDWATERSHED
WATERSHED BOUNDARY LINE

0 500 1,000 Feet

Note: See Section 2.3, "Natural Resource Planning Elements" for more details.

Source: SEWRPC
Date of Photography: April 2015

3. Expand natural areas where practical (e.g., reestablish wetland vegetation in areas that are currently mowed or farmed)

4. Ensure that natural areas continue to function by controlling and/or removing invasive plants

2.4 WATER RESOURCES

All water found in Silver Lake ultimately originates as precipitation. Some of the precipitation falling upon the landscape runs downhill and is labelled runoff. Runoff from broad areas coalesces forming visible rivulets and streams. The area feeding runoff to a stream is called the stream's watershed. Some precipitation evaporates or is absorbed by plants and is released to the atmosphere. Precipitation that does not run off or evaporate from the landscape soaks into the ground. This infiltrating water contributes water to groundwater supplies. Groundwater ultimately feeds such features as aquifers, springs, seeps, and water supply wells.

Waterbody water sources include:

- **Precipitation** falling directly upon a waterbody. 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 flow to most watersheds.

- **Hyporheic flow** (stream flow occurring in stream bed materials paralleling the general direction of stream flow). This is only important in streams and rivers. Hyporheic flow commonly persists even when visible stream flow ceases. Hyporheic flow initiates and sustains a large number of 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.

Surface runoff and interflow are important during storm events 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.

The following sections examine factors component to understanding where Silver Lake's water comes from, how water behaves while in the Lake, and how water ultimately leaves the Lake.

Silver Lake

Morphometry and Watershed Size

Silver Lake covers 126 acres, has a maximum reported depth of 47 feet, a mean depth of 18 feet (see Map 1.2 and Table 1.1). The Lake typically has a volume of about 2,300 acre-feet.[36] The Lake receives runoff from 179 acres of land surrounding the Lake.[37] The total surface area draining to the Lake is 305 acres (179 acres of land bordering the Lake plus 126 acres occupied by Silver Lake itself).

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[36] *Lake bathymetry is often imprecisely mapped, and in many instances was collected decades ago with primitive equipment. Variation in bathymetric mapping changes computed lake water volumes. Additionally, a variety of methods exist to estimate lake water volume meaning that the formula selected for determining lake volume influences results. This report computes lake volume by summing horizontal water volume "layers" using all available depth contours.*

[37] *As is common with lakes everywhere, the reported surface area and depth of the Lake varies. Surface area measurements are somewhat subjective, especially when lakes are fringed with marshland and low areas. Water elevations commonly fluctuate and can greatly influence the size of lakes. Shoreland vegetation may change over time, making it appear as if shoreline outlines as interpreted from aerial photography have changed. Lake bathymetric maps are commonly imprecise, very dated, and may not fully reflect actual present-day water depths.*

Several morphologic and hydrologic parameters are used to judge the potential impact human influence can have on a lake. Such parameters are described below.

- **Watershed/Lake Area Ratio** contrasts the size of a lake to its watershed. Lakes with higher ratios (large surface watershed) are typically considered more vulnerable to human influence and prone to water quality problems. However, the way a watershed is used can greatly influence the amount of pollutants carried to the Lake. As a rule of thumb, lakes with a watershed/lake ratio greater than 10:1 often experience some water quality issues.[38] Silver Lake's watershed/lake area ratio is approximately 1.4:1, while the typical Wisconsin stratified seepage lake has a watershed/lake Area ratio of 9:1.[39] This finding suggests that the Lake is less vulnerable to human influence and land use than many of the lakes in the Region.

- **Retention Time** refers to the average length of time needed to replace the lake's entire water volume.[40] In general, lakes with larger watershed/lake area ratios have shorter retention times. Retention time is significant because it can help determine how quickly pollution problems can be resolved. For example, if retention times are short, pollutants are flushed out of a lake fairly quickly. 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. In this case, in addition to preventing external pollution, it also may be necessary to employ in-lake water quality management efforts. Silver Lake's average retention time of about 3.2 years is significantly longer than that for a typical Wisconsin inland lake, which has a retention time of about 11 months. Average retention time is based upon typical weather conditions. During long periods of atypically dry or wet weather, the amount of water evaporating from a lake and contributed by precipitation changes from the average condition, influencing retention time.[41] The available data suggest that extended hot, dry weather periods could lengthen retention time, while long periods of cool, wet weather could shorten retention time.

- **Shoreline Development Factor** compares the length of a lake's shoreline to the perimeter 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 larger proportions of shallow zones conducive to aquatic plant growth which may impede navigation. Such lakes are also more prone to greater numbers of lots per surface area of lake, due to greater length of shoreline for development. Silver Lake has a natural Shoreline Development Factor of about 1.8, meaning its shoreline would be nearly twice that of a perfectly circular lake with the same surface area. This relatively modest shoreline development factor, along with the Lake's fairly steep bottom contours as revealed in its bathymetric map, imply that Silver Lake might have a relatively narrow zone of biologic activity and, thus, might not be as biologically productive as some lakes in the Region.

- **Lake Depth** significantly affects the water quality and biology of lakes. Deep lakes (water depths over 20 feet) tend to stratify, a condition (as will be explained later in this chapter) that inhibits mixing of the lake's entire water volume during summer and to a lesser degree during winter. Deep, cold lakes can host fish species that shallow lakes are incapable of supporting. However, stratification can

[38] *Uttormark, Paul D. and Mark L. Hutchins,* Input/Output Models as Decision Criteria for Lake Restoration*, University of Wisconsin Water Resources Center Technical Report No. 78-03, 1978.*

[39] *Lillie, Richard A. and John W. Mason, Limnological Characteristics of Wisconsin Lakes, Wisconsin Department of Natural Resources Bulletin Number 138, 1983.*

[40] *The terms "flushing rate" and "hydraulic residence time" are also commonly used to describe the amount of time natural water sources are required to completely 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).*

[41] *In the Silver Lake area, the amount of precipitation falling on a waterbody's surface is about three inches per year more than the amount of water lost due to evaporation. R. P. Novitsky, "Hydrology of Wisconsin Wetlands,"* Wisconsin Geological and Natural History Survey Information Circular Number 40*, 1982.*

foster anoxic water at depth and geochemical reactions that release nutrients to the water column and degrade water quality. Silver Lake, at 47 feet maximum depth, is one of the deeper lakes in Southeastern Wisconsin and, as such, it regularly stratifies, making it vulnerable to anoxic water conditions. The ramifications of this phenomenon are explored in the "Water Quality" and "Fish and Wildlife" sections below. The proportion of Lake area underlain various depths is graphed on Figure 2.2. The proportion of the Lake's total volume stored at certain depths is graphed on Figure 2.3.

Water Surface Elevation

A fixed crest artificially controls Silver Lake's water elevation (Figure 2.4). The outlet dam spillway elevation is approximately 999.3 feet above NGVD 29. Given what is known about the outlet dam and bed configuration, the fixed crest spillway likely raises Silver Lake's fair weather water level by roughly 1.5 feet.

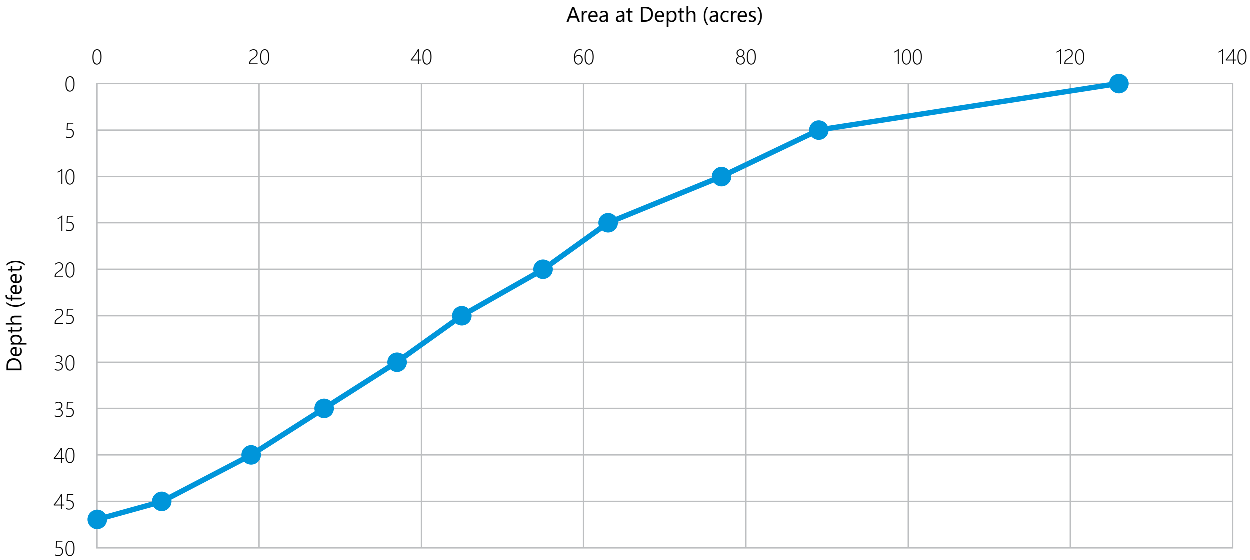
Even though the outlet dam exerts substantial control on the Lake's water elevation, other features also influence the Lake's water surface elevation. The outlet dam is located several hundred feet north of the Lake itself at the end of low gradient stream channel. When outflow from the lake is modest, information collected by the SLPRD suggests that water levels in the Lake may be about a third of an inch higher that the water surface at the crest of the Lake outlet dam during late summer 2018. This elevation difference is likely caused by channel conditions tending to impede flow (e.g., snags, aquatic plants, bed and bank flow constrictions), conditions that may change year-to-year and season-to-season. When Lake outlet flow is greater, the difference between water levels measured in the Lake and at the dam outlet may be either higher or lower than the difference estimated under modest flow conditions. Furthermore, a pipe-arch culvert is located immediately downstream of the outlet dam. This culvert's apparent dimensions (roughly 2.5 feet vertical by 3.25 feet horizontal) coupled with flotsam and mineral staining suggests that the culvert pipe may be submerged at times of high flow. In such events, the hydraulic capacity of the culvert pipe controls upstream water levels. In such instances, the outlet dam likely would be submerged and would exert little influence on Lake-water surface elevation.

The SLPRD monitors Silver Lake's water elevation as well as precipitation, air temperature, and wind speed/direction at a location on the south end of the Lake. Water level measurements are generally taken once per day, with records extending back to 2011.[42] These water levels are measured in inches and are reportedly referenced to the elevation of the outlet dam spillway. For example, a measurement value of two inches at the Lake gage would mean that the Lake elevation is roughly two inches higher than the outlet dam spillway elevation. However, as mentioned in the previous paragraph, the water level immediately upstream of the outlet dam is often significantly lower than the water level in the lake. Therefore, a water level of two inches at the Lake gage does not mean that precisely two inches of water are spilling over the outlet dam spillway.

Using the SLPRD data, the Commission plotted daily water level trends since 2011 (see Figure 2.5). Compared to many lakes in the Region, Silver Lake's water level is remarkably static. The Lake's water level does vary in response to prevailing weather, longer term weather cycles (e.g., drought, intense and/or frequent rainfall) and seasonal trends. However, other than occasional rainfall and drought induced fluctuation, the lake generally has remained within a two inch elevation range since 2011. At times of drought, the Lake's water surface has decreased approximately one inch and has remained lower than typical for weeks or months. Intense/extended precipitation has caused Lake levels to abruptly rise up to 6 inches. These quick and short-lived upticks in Lake elevation are of a magnitude and duration suggesting the increase may be attributed to the precipitation falling directly upon the Lake's open water surface. Snowmelt may also contribute to Lake level increases. During times of higher water elevation, excess water quickly drains from the Lake and water levels return to normal in a few days. Longer term trends reveal that the Lake's water level gradually decreased by about an inch between 2011 and mid-2017. Water levels have increased since mid-2017, a condition undoubtedly related to the frequent and sometimes heavy rainfall that has occurred during the past few years. Average Current Lake water elevation appears to be about one-half inch higher than the long-term average Lake elevation.

[42] *Lake levels are recorded daily by John Behrens (address 3482 County Trunk Highway NN) using a staff gage located in a still well six feet from the Lake shore. Measurements can be collected remotely using a live camera activated from his home allowing convenient access during all weather conditions. The rain gauge was located at this residence until 2016 when it was moved to the Sanitary District building about one-quarter of a mile to the east of his home on Highway NN. The rain gauge was upgraded to an electronic gauge in 2016. Winter precipitation is recorded in inches of water equivalent, with snow accumulated in the rain gauge melted to estimate the amount of water in the snowfall.*

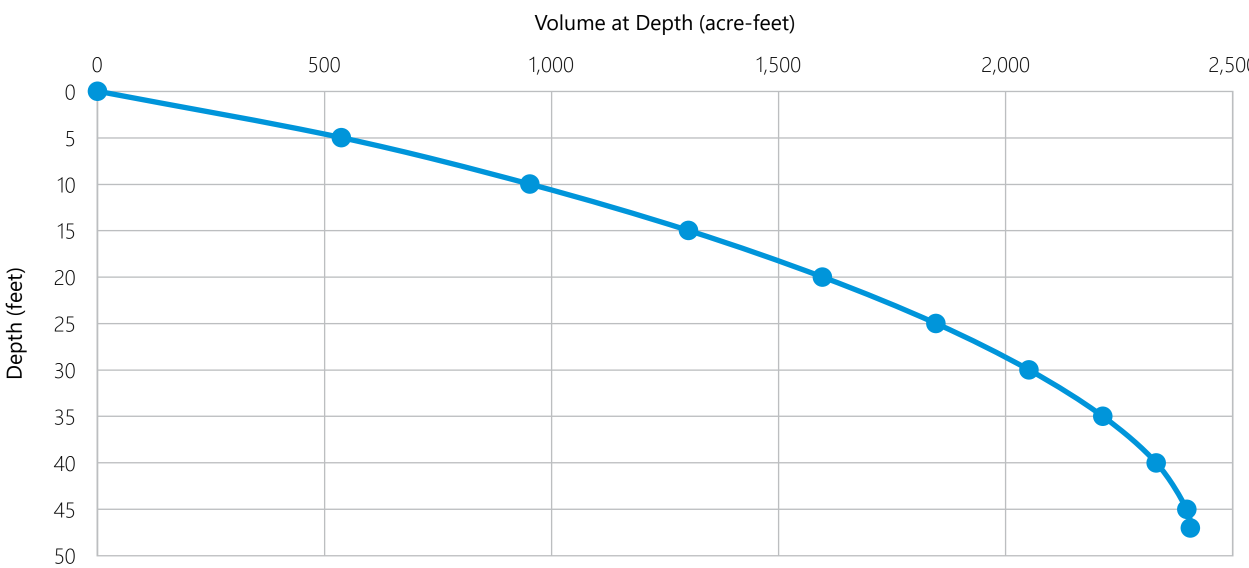
Figure 2.2
Silver Lake Water Depth Versus Surface Area



Note: This graph summarizes the area of the Lake underlain by water depth equaling or exceeding a particular value. For example, roughly 28 acres of the Lake are underlain by water at least 35 feet deep.

Source: Wisconsin Department of Natural Resources and SEWRPC

Figure 2.3
Silver Lake Water Depth Versus Volume



Note: This graph relates the volume of water found at or above a certain lake depth. For example, roughly 950 acre-feet of the Lake's water volume is found in areas shallower than ten feet deep.

Source: Wisconsin Department of Natural Resources and SEWRPC

Water Sources and Fate

Silver Lake has no significant tributary streams but does have a perennial outlet. The outlet's flow is fed by springs and seeps, including prominent springs along and near the western and southern shorelines. Since the Lake has no significant inlet streams but does have a perennial outlet, and is largely fed by groundwater, Silver Lake should be considered a spring lake. Water from Silver Lake's outlet flows north to Paradise Valley and Lucas Lakes via Silver Creek. After receiving water from several tributaries and flowing through the City of West Bend's Regner Park, Silver Creek discharges to the Milwaukee River a short distance north of downtown West Bend. In addition to water leaving the Lake through its outlet, water evaporates from the Lake's open water surface. Some water also infiltrates into the lakebed and contributes to groundwater flow. Lakebed infiltration is most likely to occur along the Lake's eastern shoreline and near the outlet dam.

Figure 2.4
Silver Lake Outlet Dam

Source: SEWRPC

During the late 1960s or early 1970s, the WDNR estimated Silver Lake's outflow to average roughly 0.75 cubic feet per second. The WDNR also noted that flow did not vary greatly throughout the year. The source of much of this water was noted to be small springs found in shrub and timber swamp along the Lake's western shoreline.[43] During the late 1970s, a study was completed to quantify the quantity of water entering and leaving the Lake.[44] Flow measurements were measured at Silver Lake's outlet and at a prominent spring complex between February 1, 1976 and January 31, 1977. This study reported that flow from the primary springs along the southwest shoreline area averaged about 0.1 cubic feet per second, with short episodes of increased flow (up to 0.5 cubic feet per second). Similarly flow over the outlet dam ranged from 0.4 to 5.2 cubic feet per second. Flow from Lake was highest between late winter and late spring, averaging roughly 3 cubic feet per second. Lake outlet low was lowest during late summer and fall, a typically warm, dry period. Dry weather flow fell to less than 1.0 cubic feet per second for extended periods of time but appear to have averaged slightly more than 1.0 cubic feet per second for the period as a whole. For the entire 11 month monitoring period, outlet from Silver Lake was roughly 1.7 cubic feet per second.

The available data demonstrates that the volume of water leaving the Lake through the outlet dam varies by season and with changing weather patterns. It must be remembered that 1976-1977 flow measurements only reflect a single year—changing weather patterns significantly alter the amount of precipitation falling upon the area contributing water to Silver Lake and therefore the amount of water exiting the Lake through the outlet dam. Long term data sets from nearby watersheds can be used to contrast measurement period flows against longer term trends. The Cedar Creek watershed's headwaters drain through the nearby Cedar Lakes and a gaging station near Cedarburg tracks daily flows since the 1930s.[45]

Reviewing Cedar Creek gaging station information, it is clear that water years 1974, 1975, and 1975 were much wetter than normal as were the first months of water year 1976.[46] However, conditions became much drier during summer 1977, making water year 1977 the driest of the past 50 years. Based upon the Cedar Creek gaging station information, flow measurements measured at Silver Lake during spring and early summer 1976 may have been higher than typical while flow measurements collected during late 1976 and early 1977 may be lower than typical. Lake outlet flow volume appears to be synchronized with large rainfall events. In contrast, water levels appear to decline during periods with repeated minor rainfall events or no rainfall (see Figure 2.6).

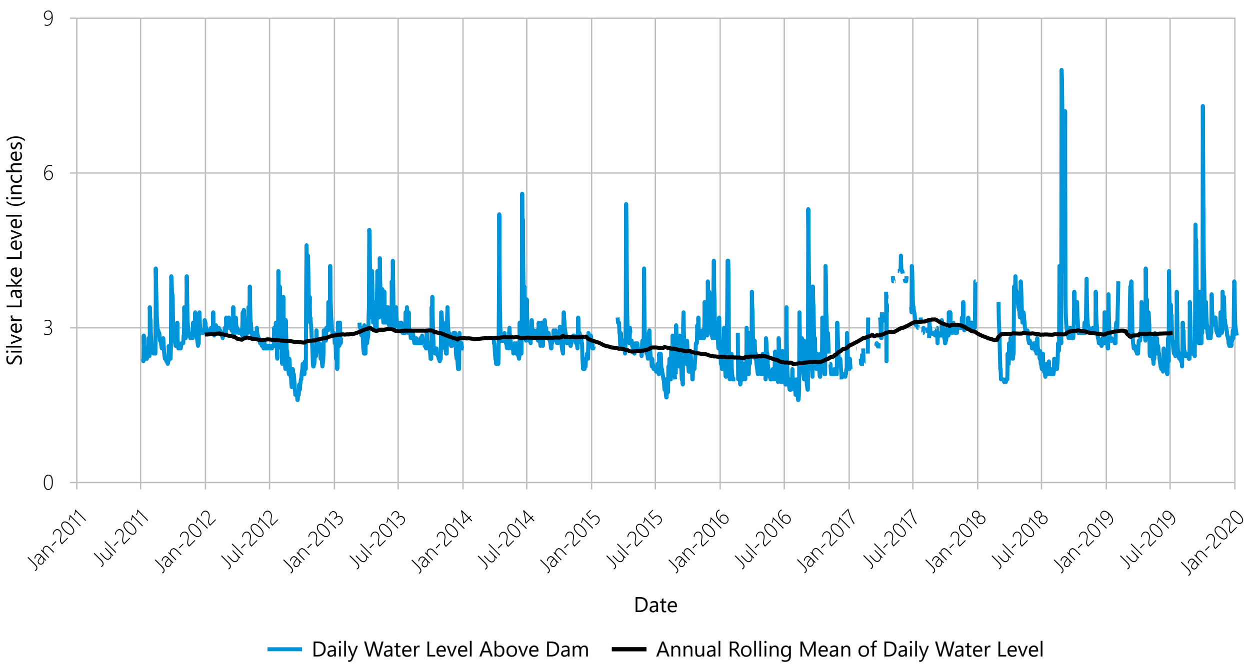
[43] *Wisconsin Department of Natural Resources, Silver Lake,* Washington County, Wisconsin, An Inventory with Planning Recommendations, *Prepared for the Southeastern Wisconsin Regional Planning Commission, Lake Use Report MI-8, 1973.*

[44] *CDM/Limnetics,* An Environmental Study of Silver Lake and the Hydrological and Water Quality Characteristics of Its Associated Watershed for the Inland Lake Protection and Rehabilitation District of Silver Lake, Washington County, Wisconsin*, report submitted to the SLPRD, 1977.*

[45] *USGS gaging station 04086500 Cedar Creek near Cedarburg, Wisconsin. Please visit the following website for more information: waterdata.usgs.gov/wi/nwis/uv?site_no=04086500.*

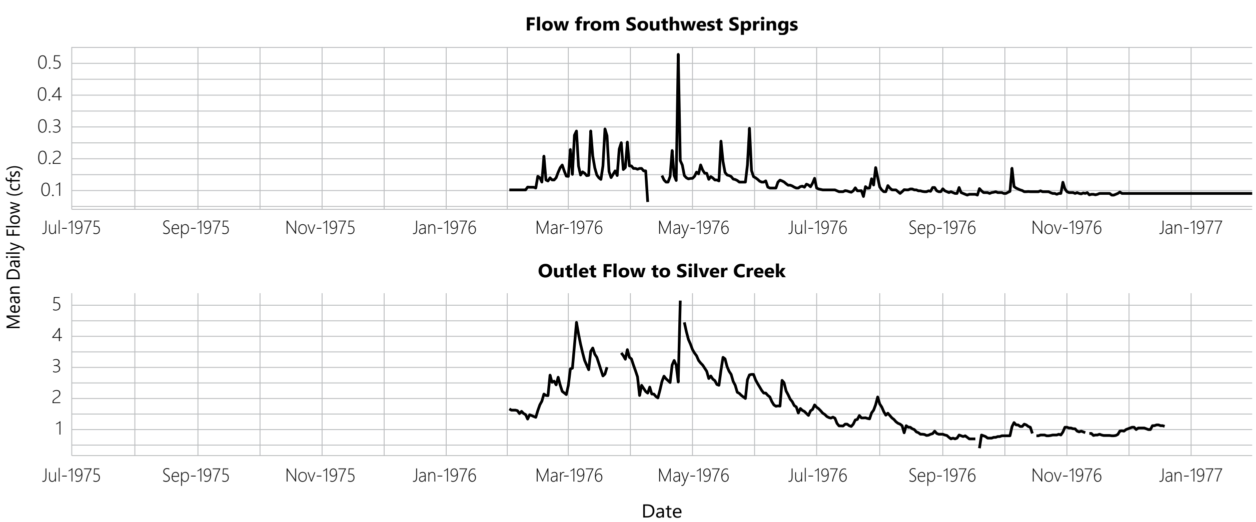
[46] *A water year begins October 1 and ends September 30. For example, water year 1977 began on October 1, 1976 and ended on September 30, 1977.*

Figure 2.5
Daily Water Surface Elevation Fluctuation: Silver Lake

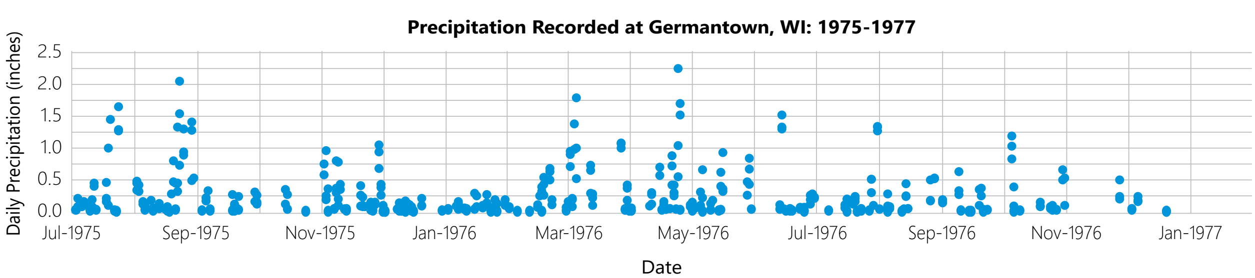


Source: Silver Lake Sanitary District and SEWRPC

Figure 2.6
Rainfall's Effect on Spring Discharge to Silver Lake



Source: USGS and SEWRPC



Source: NOAA and SEWRPC

During the year 2000, the USGS initiated a study of local groundwater flow and the Lake's water budget.[47] As part of this initiative, the USGS measured flow at the Lake outlet on three occasions believed to represent baseflow and found that Lake outlet flow varied between 0.7 and 5.2 cubic feet per second. Based upon the information used to construct the model, the USGS estimated the following average water inputs and outputs from Silver Lake.

- Groundwater discharge adds 1.08 cubic feet per second
- Net precipitation upon the Lake's open water surface adds 0.04 cubic feet per second[48]
- Flow over the outlet dam removes 1.04 cubic feet per second
- Seepage into the Lake bottoms removes 0.08 cubic feet per second

Based upon this water balance, groundwater is by far and away the dominant water source to Silver Lake, as is responsible for over 96 percent of the Lake's outflow. It should be remembered that some of the Lake-specific values used to calibrate this model could represent unusual precipitation patterns and therefore may not represent typical water balance scenarios. The net precipitation value was based upon regional averages and may not represent unique conditions (e.g., extended periods of heavy rainfall, drought).

Empirical relationships can be used to estimate flow over weirs. Using Sanitary District daily Lake water surface elevations, the Commission developed an empirical relationship to help approximate Lake outlet flow during the past nine years (see Figure 2.7). Sanitary District staff provided equipment and assisted Commission staff measure Lake outlet flow on two different fair weather flow days to help calibrate the weir equation.[49,50] Using the water level information and calibrated empirical relationship, the overall mean discharge from Silver Lake between 2011 and early 2020 was roughly 4 cubic feet per second. During this period, discharge ranged from slightly more than 1 cubic feet per second to just over 17 cubic feet per second. High flows were extremely short-lived and are likely related to heavy lake-incident rainfall passing directly out of the Lake. In contrast, low-flow periods can extend for considerable lengths of time. Long-term average Lake outflow slightly decreased between 2011 and summer 2016 suggesting slow depletion of groundwater contributions to the Lake. This period of time was generally drier than normal with less effective precipitation.[51] Precipitation has been plentiful since 2017 and Lake outflow has increased to former volumes, suggesting groundwater resources feeding the Lake have been replenished.

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[47] *Dunning, C. P., J.C. Thomas, and Y-R Lin,* Simulation of the Shallow Aquifer in the Vicinity of Silver Lake, Washington County, Wisconsin, Using Analytic Elements*, United States Geological Survey, Water-Resources Investigations Report 02-4204, 2003.*

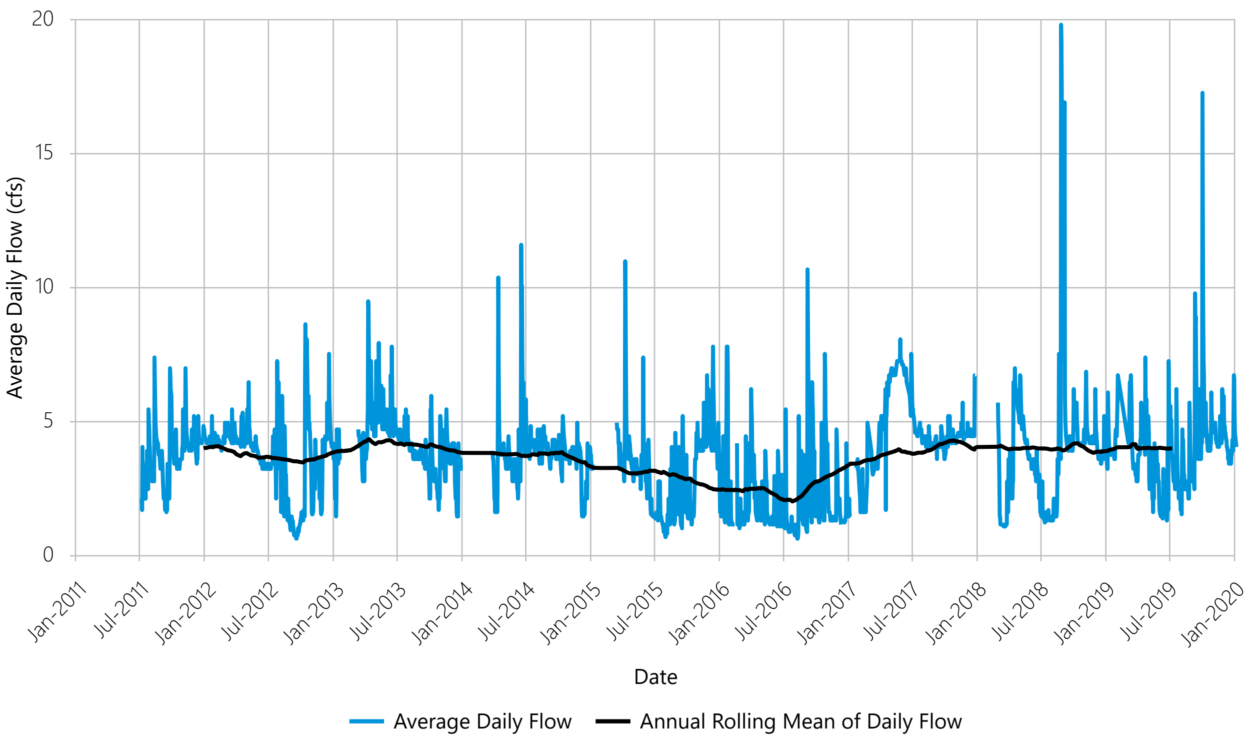
[48] *"Net precipitation" is the value that results when the amount of water that evaporates from an open lake surface is subtracted from the amount of precipitation falling upon a lake's open water surface.*

[49] *The Commission related Lake outlet water elevation to Lake outlet flow using the following general weir equation:* $Q=CLH^{3/2}$ *where Q equals flow in cubic feet per second, C is a weir discharge coefficient (unitless), L is weir length in feet, and H is water head at the weir crest in feet. The Commission used a C value of 2.6. Based upon the stream flow measurement made as part of this study, the weir equation appears to roughly approximate fair-weather flow at the Lake outlet, although low flows may be slightly overestimated and higher flows may be slightly underestimated.*

[50] *Many variables may influence water elevation differences between the open Lake and the Lake outlet area (e.g., the amount of vegetation growing in the outlet channel, debris in the channel, wind, downstream culvert limitations, turbulence, flow convergence), all of which could increase or decrease actual outlet flow at a given Lake elevation. Based upon Silver Lake Sanitary District measurements, water levels measured on the south end of Silver Lake have been roughly three-quarters of an inch higher than water in the Lake outlet area during baseflow conditions. However, this elevation difference likely changes day-to-day and season to season. For the purpose of this study, the open water to outlet water level differential was assumed to be three-quarters of an inch. Furthermore, the u-shape of the weir, relatively gently sloping downstream weir face, and a rather small downstream culvert may all influence actual flow. If the District wishes to better quantify Lake outflow, additional information should be collected and the weir equation should be more rigorously examined and calibrated.*

[51] *"Effective precipitation" is the proportion of rainfall that infiltrates a land surface and recharges underlying aquifers. Stormwater runoff, evaporation, and plant use all decrease the proportion of precipitation that becomes effective precipitation.*

Figure 2.7
Estimated Silver Lake Outlet Discharge Rate: 2011-2020



Note: Outlet flow is estimated using Lake stage data. Given that the outlet dam is located several hundred feet north of the Lake at the end of a small channel, water elevation at the outlet dam does not always match Lake elevation. Therefore, outlet flow could be overestimated or underestimated at times and the resultant flow values are approximate.

Source: Silver Lake Protection and Rehabilitation District and SEWRPC

The outflow data clearly demonstrate that the Lake's water supply is highly dependent on locally infiltrated precipitation and is therefore very susceptible to human-induced change. Activities or events that occur in the watershed to reduce infiltration or increase groundwater export from the groundwatershed would influence the amount of groundwater entering the Lake. Such things could include decreased precipitation, increased evapotranspiration, more impervious area, hastened runoff, expanded sanitary sewer networks that collect wastewater from homes using a private well, high capacity wells providing water to areas beyond the local area, or modifications to areas of concentrated recharge. Therefore, protection of groundwater recharge is an essential component for maintenance of baseflow discharge to Silver Lake in order to maintain its water quality and recreational potential in the future, which is further described in Chapter 3. This information also demonstrates why it is important to monitor future Lake water surface elevations.

Groundwater

General Principles

Groundwater includes water that has percolated into the earth and has reached areas of saturation below the Earth's surface. In Southeastern Wisconsin, essentially all groundwater is stored and moves in the natural pore spaces and fractures found in unconsolidated sediment and bedrock. Sediment and rock units with significant porosity or fracturing are able to supply useable amounts of water over prolonged periods and are referred to as "aquifers." Three aquifers underlie the Silver Lake watershed as summarized below in order of increasing depth below the land surface.

- **Sand and gravel aquifer.** This aquifer is primarily found in porous, coarse-grained sand and gravel deposited by glacial action. 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 under many portions of Washington County. Roughly 200 to 400 feet of unconsolidated sediment overlay bedrock in the area near Silver.[52] Studies report that the sand and gravel aquifer is generally about 100 feet thick near Silver Lake.[53] The sand and gravel aquifer 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 surface-water features and the underlying Niagara dolomite aquifer. Water in the sand and gravel aquifer originates as precipitation infiltrating soils in upland areas or seeping into the bed of water features. The sand and gravel aquifer supplies water to most springs and seeps in the local area, therefore, the sand and gravel aquifer is very important to sustaining water supplies to local surface-water features during dry weather.

- **Niagara dolomite aquifer.** Water in this aquifer is primarily stored and transmitted in fractures. The water-bearing characteristics and thickness of this aquifer vary widely. Although thin or absent under portions of the local area, when thick it is an important water supply aquifer. When located under a relatively thick layer of unconsolidated sediment, it is somewhat less vulnerable to contamination and overexploitation. This aquifer is not present in the area southwest of Silver Lake and is thin under most of the remaining area near Silver Lake.

- **Deep sandstone aquifer.** The sandstone aquifer is commonly deeply buried, found at depths well below the shallow sand and gravel aquifer and the Silurian dolomite bedrock.[54] 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. Because of the low permeability of the shale overlying the sandstone aquifer, water feeding this aquifer enters well to the west of Silver Lake, making the sandstone aquifer less vulnerable to local land use. This aquifer is a regionally important public and industrial water supply, but because of cost, is not commonly used for residential water supplies in the immediate area.

Water that infiltrates into the land surface and is temporarily held in the soil column. This water either returns to the surface via evapotranspiration or moves deeper into the earth where it eventually reaches saturated sediment. Groundwater is replenished by precipitation that has soaked into the ground and has entered aquifers, water that is referred to as "groundwater recharge." The ability for precipitation to infiltrate the land surface and contribute water to groundwater supply is termed groundwater recharge potential. Precipitation is the 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. For example, a flat area with no impervious cover and highly permeable soils likely has high or very high groundwater recharge potential, whereas a hilly area underlain with low permeability soils (e.g., clay soils) and drained by storm sewers would be classified as low potential. Nevertheless, water that runs off an area less conducive for infiltration can still flow to an area more conducive to groundwater recharge and become a component of groundwater flow. Groundwater recharge occurs during periods of low natural water demand (i.e., when plants are dormant) and/or abundant precipitation or runoff. Little groundwater recharge occurs from small summer rains even on the best sites because plants and higher temperatures consume the incident precipitation, returning it to the atmosphere. Evaluating groundwater recharge potential helps identify areas most important to sustainable groundwater supplies. As described in more detail in a subsequent section, the Commission evaluated groundwater recharge potential for all of 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.

In most instances, the elevation of the water surface of the shallowest water bearing unit (commonly referred to as the "water table") is a subdued reflection of surface topography. Topographically higher areas are commonly recharge areas, while lakes, wetlands, and streams are commonly groundwater discharge

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[52] *Massie-Ferch, K. M, and R. M. Peters, 2004, op. cit.*

[53] *Dunning C. P., J.C. Thomas, and Y.-F. Lin, 2003, op. cit.*

[54] *The local sand and gravel aquifer varies from 50 to 200 feet thick and is about 100 feet thick near Silver Lake. The deep sandstone aquifer is buried about 300 to 400 feet below the land surface in the area.*

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

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 waterbody's overall water budget. While localized groundwater flow systems are commonly confined within a lake's surface water 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-water watershed boundary. The relationship between short- and long-distance flow paths is illustrated in Figure 2.8.

Because groundwater and surface water systems are connected, 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 (see Figure 2.8). Since water normally moves perpendicular to elevation contours, groundwater flow directions can be predicted. When performing such analysis, it is necessary to consider the locations and elevations of streams, ponds, and lakes (see Figure 2.9). This relationship can be used to predict if a surface waterbody is fed by groundwater, recharges groundwater, or has little interaction with groundwater. By combining these data, maps can be prepared identifying land areas that likely contribute recharge and are therefore sources of baseflow to a surface water feature, and areas that convey groundwater to a lake.

A waterbody (stream or lake) gains water where groundwater is discharged into the waterbody through its bed and bank sediment, wherever water table elevations are higher than the waterbody surface elevation. Conversely, a waterbody loses water wherever the elevation of the water table is lower than the waterbody's elevation. In such an instance, water seeps into the underlying groundwater system (see Figure 2.9). Stream reaches that receive groundwater discharge are called gaining reaches and those that contribute water to the underlying aquifer are called losing reaches.[56]

The rate at which water flows between a stream and its adjoining aquifer depends on the hydraulic gradient between the two waterbodies and also on the hydraulic conductivity of geologic materials that may be located at the groundwater/surface-water interface. A clay-lined streambed, for example, will tend to reduce the rate of flow between a stream and aquifer compared to a sandy or gravelly streambed. A stream can have both gaining and losing reaches simultaneously. Hence, the rate of streamflow increases along gaining reaches and decreases along losing reaches.

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 of time to the next. Losing reaches can occur under conditions in which the underlying sediments are fully saturated or when the sediments are unsaturated. A losing stream reach that is underlain by an unsaturated zone is said to be disconnected from the underlying aquifer. Some stream reaches are ephemeral (that is, they periodically become dry), and, as a consequence, flow between the stream and underlying aquifer may periodically cease.

Groundwater is a dynamic resource. Groundwater that discharges to waterbodies is replaced with water infiltrating in recharge areas. By combining data regarding recharge potential, groundwater flow direction, and the elevation of waterbodies, a broad understanding of the interconnected nature of surface water and groundwater can be surmised. Maps can be prepared identifying 1) land areas that likely contribute recharge and are, therefore, sources of baseflow to a waterbody; 2) areas that convey groundwater to the waterbody; and 3) if a waterbody gains or loses water to the groundwater flow system. This helps managers plan where work should be focused to maintain or enhance the landscape's ability to provide groundwater recharge or where features purposely designed to detain and infiltrate stormwater are most desirable.

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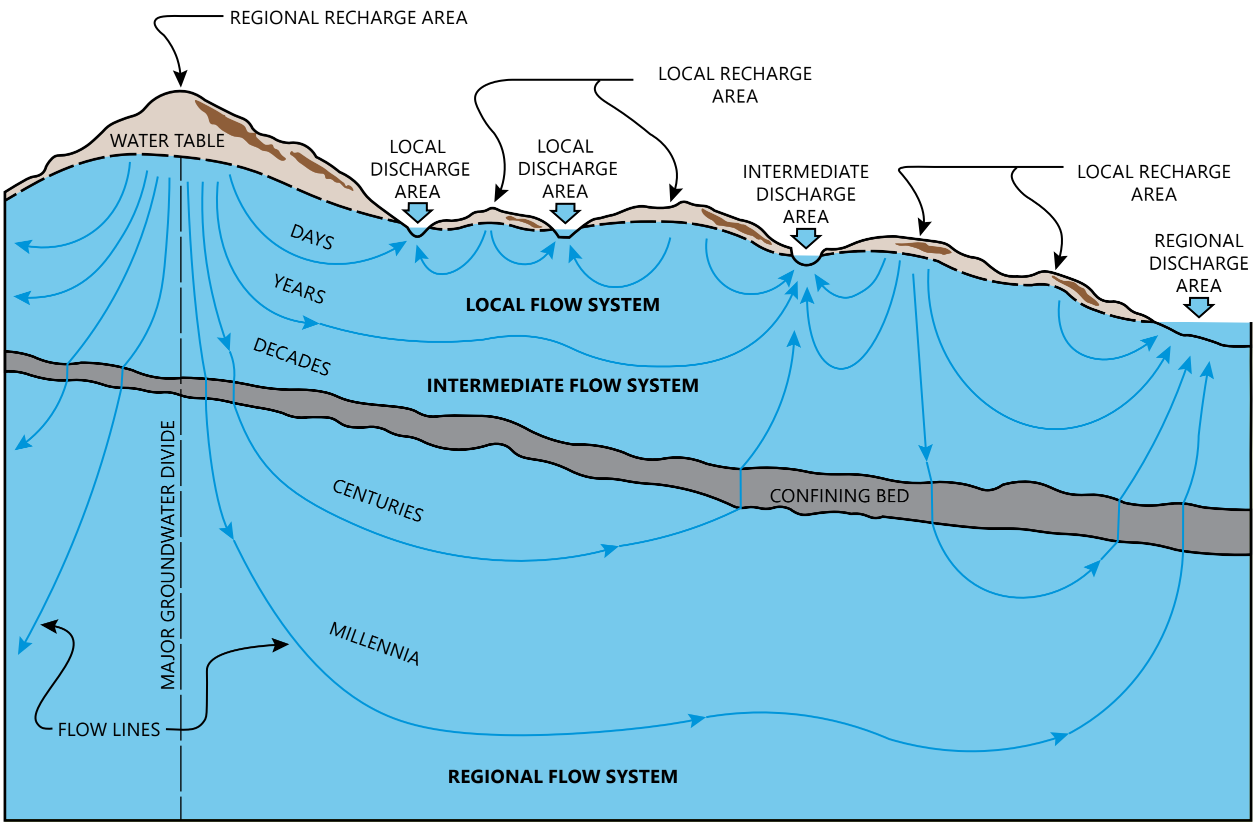
[56] *All surface-water features interact with their beds and banks. Water may be gained from groundwater, lost to groundwater, or may be largely separate from groundwater flow systems. Groundwater feeds Silver Lake along its western shoreline while the Lake feeds groundwater flow systems on the east side of the Lake and around the outlet dam. Water infiltrating the lakebed near the outlet dam likely re-emerges as springs and seeps along Silver Creek a short distance downstream of the outlet dam.*

Figure 2.8
Regional Versus Local Groundwater Flow Systems



Source: Modified from A. Zaporozec in SEWRPC Technical Report No. 37, Groundwater Resources of Southeastern Wisconsin, *2002*

Local Conditions

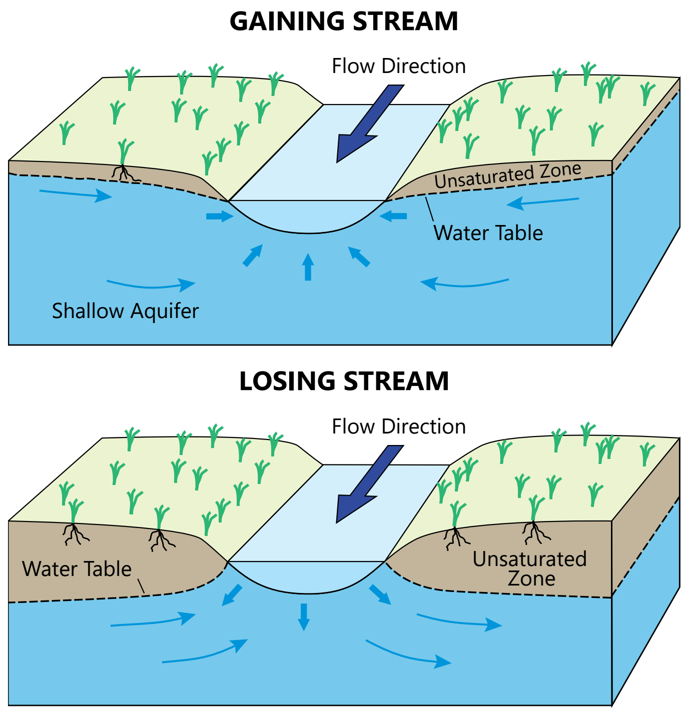
With no significant surface tributary streams and a very small watershed (179 acres), Silver Lake depends almost entirely on groundwater and precipitation to sustain the Lake's water elevation and outflow. The Lake's small watershed, the adjacent irregular terrain, and granular soils promote infiltration and therefore limits surface runoff directly to the Lake. Less runoff from surrounding lands often translates to lower human-sourced sediment, nutrient, and pollutant loads to a Lake. Given the great thickness of the sand and gravel aquifer in the Silver Lake area, the sand and gravel aquifer is the only hydrostratigraphic unit of consequence to Silver Lake's hydrology. Therefore, the water table flow system in the sand and gravel aquifer is examined in detail in the following paragraphs.

Previous studies report that Silver Lake receives groundwater along its western and southern shoreline. Indeed, significant point discharges are visible as springs in this area. This water originates as recharge to the west of the Lake, some flowing through the Cedar Lakes before re-entering groundwater flowpaths that feed Silver Lake (see Figures 2.10 and 2.11).[57] USGS water table elevation contours and model output were used to estimate shallow groundwater flowpaths, the areal extent of the area where infiltrating precipitation and waterbody seepage provide water that ultimately discharges to Silver Lake (the Lake's groundwatershed), and the amount of time needed for groundwater to travel to Silver Lake (Map 2.13. Under natural conditions, surface water percolating into the land surface within this area eventually enters Silver Lake. This water leaves the Lake in a variety of ways: as evaporation, as surface water flow over the Lake outlet dam into Silver Creek, by infiltrating into the lakebed and re-emerging in Silver Creek, or by infilitrating the lakebed and flowing east where it likely discharges to Quaas Creek.

[57] *Dunning, C. P., J.C. Thomas, and Y.-F. Lin, 2003, op. cit.*

The Commission mapped groundwater recharge potential throughout Southeastern Wisconsin.[58] Groundwater recharge potential as shown on this map is divided into three categories: moderate, high, and very high; any areas that are not defined are placed into a fourth category—"undefined." Undefined areas are often associated with groundwater discharge areas which is why they tend to be located adjacent to streams and lakes. The Commission mapped groundwater recharge potential of the Silver Lakes groundwatershed as part of this study (see Map 2.14). Most of the groundwatershed has a high groundwater recharge potential, meaning that surface water has a great tendency to soak into the ground and enter the groundwater flow systems feeding Silver Lake's springs and seeps. As such, groundwater recharge within these areas is vital to sustaining flows to springs and seeps feeding Silver Lake. The amount and quality of recharge in these areas can be radically altered by human activity, with the most vulnerable areas found in high and very high groundwater recharge potential area such as those feeding Silver Lake. The Lake clearly also receives water that seeps into the bed of both Big Cedar and Little Cedar Lakes.

Figure 2.9
Surface-Water/Groundwater Interaction



Source: Modified from T.C. Winter, J.W. Harvey, O.L. Franke, and W.M. Alley, Ground Water and Surface Water: A Single Resource, *U.S. Geological Survey Circular 1139, p. 9, 1998, and SEWRPC*

Importance

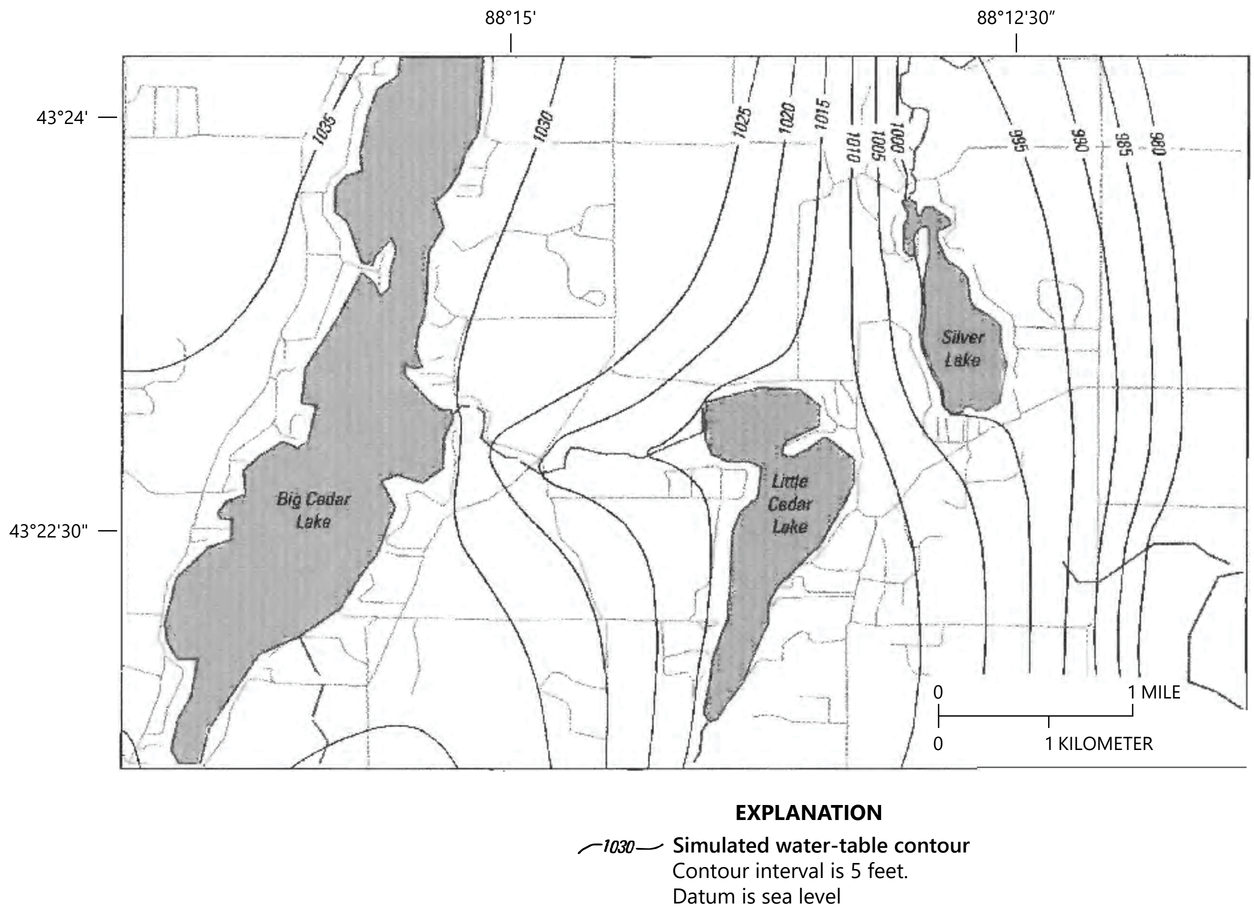
Groundwater is not visible to casual observation except where it discharges to surface water (e.g., springs and seeps). Even though groundwater is largely invisible, it is vitally important to the Region's ecology and human inhabitants. Moreover, groundwater supplies are often extremely vulnerable to unintended, human-induced, depletion and degradation.

Private and public water supplies throughout inland portions of Southeastern Wisconsin depend entirely upon groundwater making it a natural resource critical to modern human habitation. In general, groundwater supplies are adequate in the Region to support growing populations, agriculture, commerce, and viable and diverse industry. However, overexploitation and attendant water shortages may occur in areas of concentrated development, nonconductive geology, and/or intensive water demand. 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. The continued growth of population and the continued vitality of valuable natural resource elements necessitates wise development and management of the watershed's groundwater resources.

In addition to supplying human needs, groundwater sustains water levels and flow in lakes, wetlands, and perennial streams and may be the only source of water to surface-water features during dry weather. Groundwater also modulates flood and fair weather stream flows by detaining water during wet weather and gradually releasing it over time. Water that reaches waterbodies via groundwater is commonly referred to as "baseflow." Baseflow can either directly enter large waterbodies, or it can discharge to small streams, ponds, springs, and seeps tributary to larger waterbodies. Baseflow sustains dry-weather lake elevations, wetlands, and the flow of rivers and streams. In comparison to surface water runoff, groundwater typically contains little to no sediment or phosphorus, has a more stable temperature regimen, and commonly contains a lower overall pollutant load—all of which are favorable to aquatic life and the ecology of waterbodies.

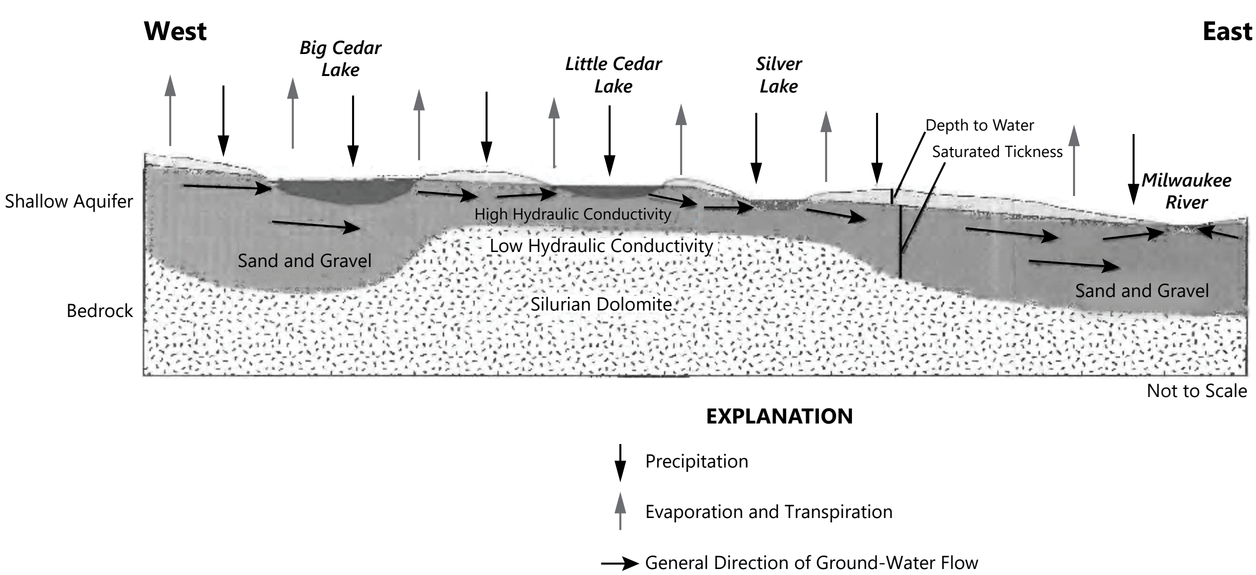
[58] *SEWRPC Technical Report No. 47,* Groundwater Recharge in Southeastern Wisconsin Estimated By a GIS-Based Water Balance Model*, July 2008.*

Figure 2.10
Water-Table Elevation Contours Near Silver Lake



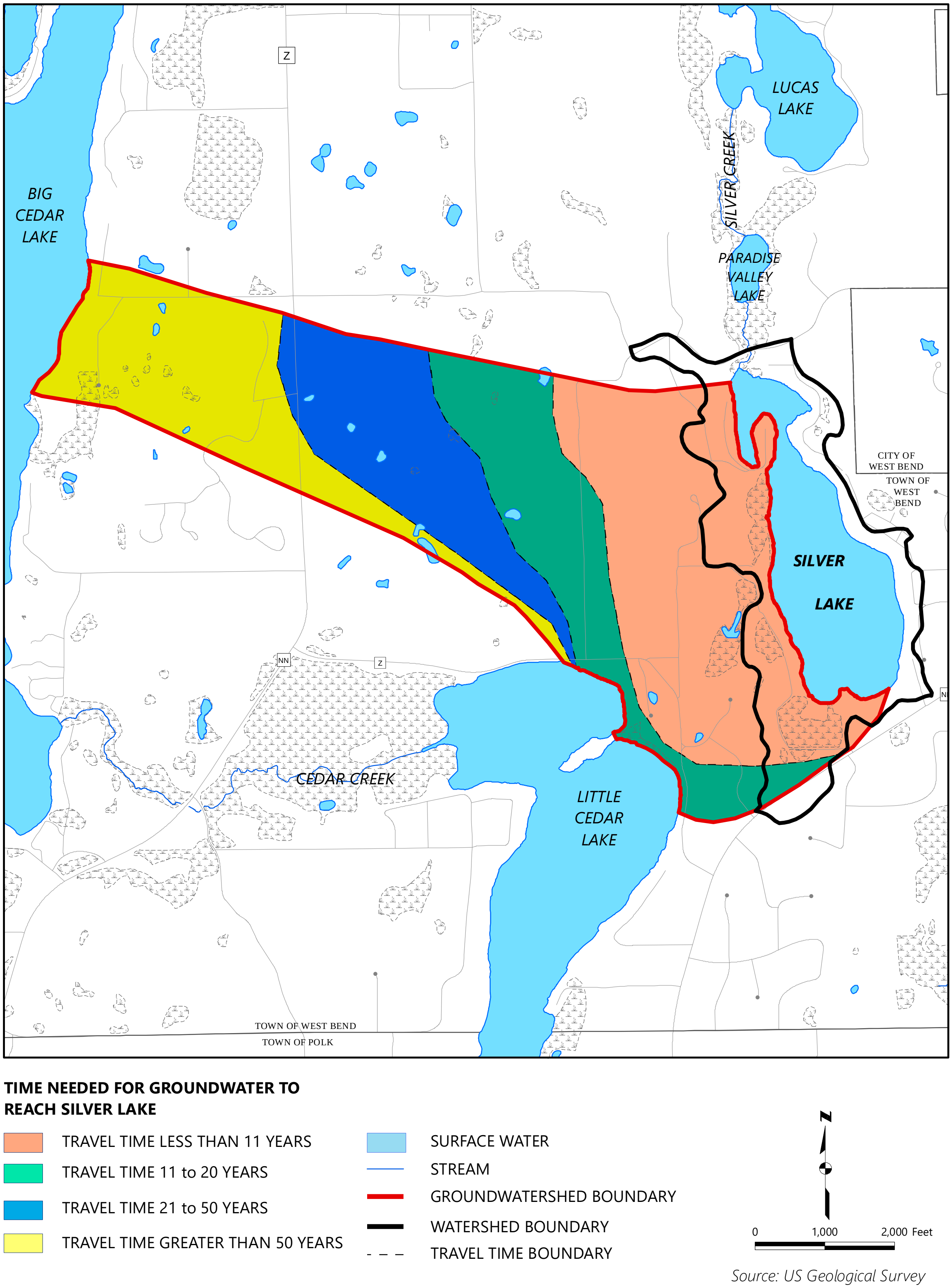
Source: U.S. Geological Survey and SEWRPC

Figure 2.11
Conceptualized Cross Section Illustrating the Hydrology of the Groundwater System Feeding Silver Lake



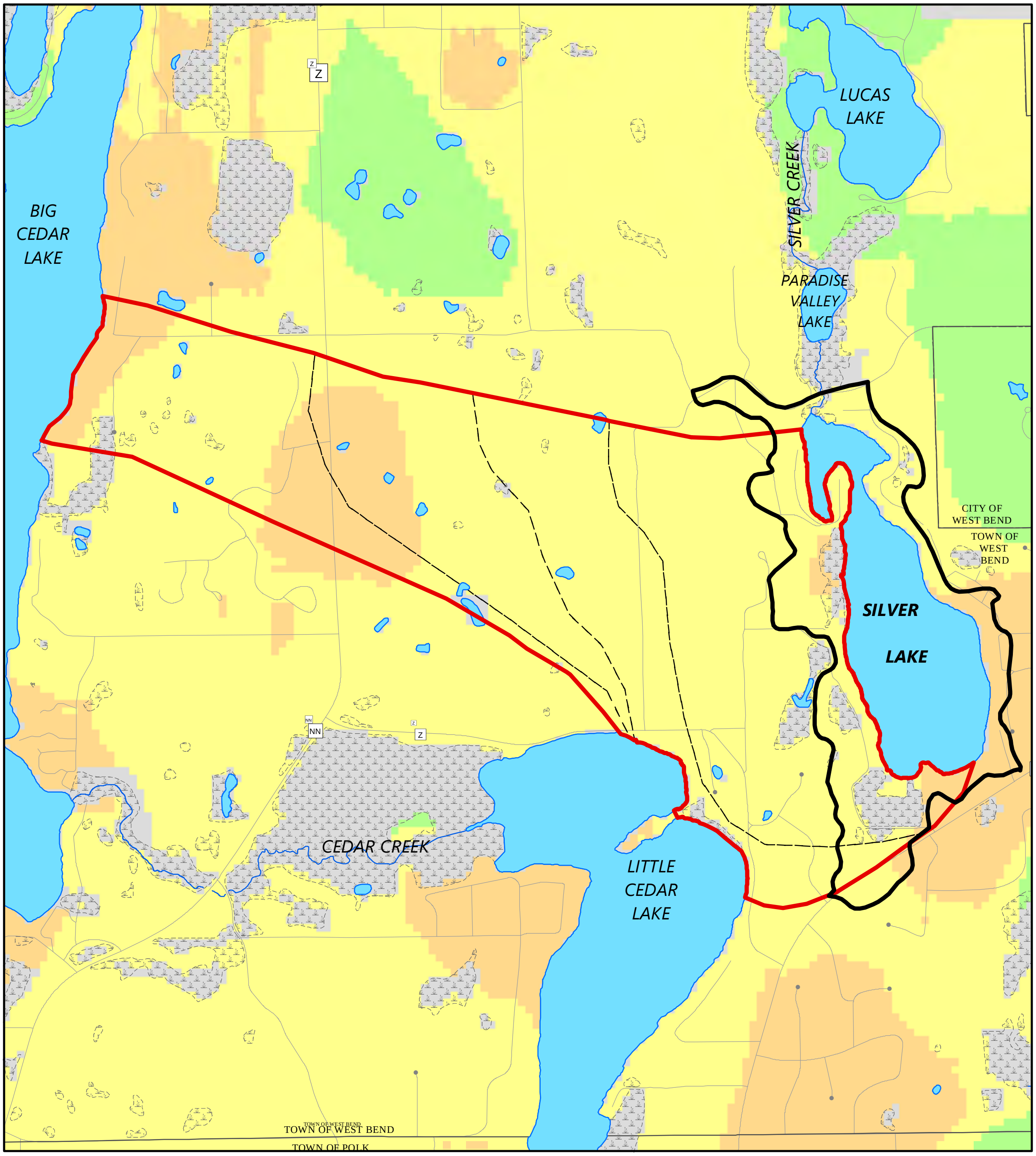
Source: U.S. Geological Survey and SEWRPC

Map 2.13
Silver Lake's Groundwatershed



Source: US Geological Survey and SEWRPC

Map 2.14
Groundwater Recharge Potential Near Silver Lake



ESTIMATED GROUNDWATER RECHARGE POTENTIAL

- MODERATE
- HIGH
- VERY HIGH
- UNDEFINED

- SURFACE WATER
- STREAM
- GROUNDWATERSHED BOUNDARY
- WATERSHED BOUNDARY
- TRAVEL TIME BOUNDARY (SEE MAP 2.8)

N

0 1,000 2,000 Feet

Source: US Geological Survey and SEWRPC

Groundwater-derived baseflow sustains waterbodies allowing them to maintain a diverse assemblage of plants and animals and enable them to provide unique ecological functions.

As a spring Lake, Silver Lake is exceedingly dependent upon groundwater, therefore, protecting groundwater is a key component to protecting Silver Lake's health.

Human Influence

To meet a variety of perceived needs and desires, humans modify land cover types, soil conditions, vegetation, stream channels and floodplains, lake elevations, groundwater flow patterns, and a host of other factors across broad swathes of landscape. These actions modify the amount, sources, and timing of water reaching waterbodies which in turn can influence waterbody water quality and ecology. In general, human activity typically increases runoff volume and intensity, reduces groundwater recharge and relatedly groundwater contributions to waterbodies, and diminishes the quality of water reaching waterbodies. This section discusses common ways humans influence waterbody hydrology and relates these examples to Silver Lake's watershed and groundwatershed. Water quality and waterbody ecology issues are examined in subsequent sections.

Stormwater Runoff

Human activity generally diminishes a landscape's ability to absorb runoff. In turn, the proportion of precipitation leaving the land surface as stormwater runoff increases while the amount contributing to groundwater recharge decreases (see Figure 2.12). This is largely related to covering natural soils with impervious surfaces such as roofs and pavement. Moreover, runoff typically is delivered to waterbodies more quickly. Runoff is hastened by a variety of human activity including creating impervious surfaces, grading that eliminates temporary ponding, ditching, tiling, and installing storm sewer systems, all of which quickly convey runoff directly to waterbodies. Increasing runoff volumes and decreasing runoff detention times cause waterbodies to exhibit "flashy" hydrographs—a situation where water levels change quickly and more radically in reaction to precipitation or snowmelt (see Figure 2.13). This situation usually increases the volume of water transmitted by waterbodies during high runoff periods and diminishes dry weather flow, which in turn can cause of undesirable consequences. For examples, human-induced can:

- Increase flood elevations
- Destabilize waterbody beds and banks
- Impede aquatic organism migration
- Compromise waterbody and riparian habitat function and value
- Exacerbate water safety concerns
- Threaten infrastructure integrity.

To help mitigate the negative effects associated with human land use, modern stormwater regulations require actions to dampen the negative influence of human-induced change on watershed hydrology.[59,60,61] Impervious surfaces that drain to engineered storm sewer systems are an excellent example of a common feature that influences runoff quality, quantity, and timing. Directly connected impervious surfaces increase the volume and velocity of runoff during and directly after rainfall. Many studies link increased impervious land surface to decreased habitat quality and ecological integrity. For example, a 2003 study of 47 southeastern Wisconsin streams reported that fish and insect populations decline dramatically when impervious surfaces cover more than about 8 to 10 percent of the watershed and that streams with more

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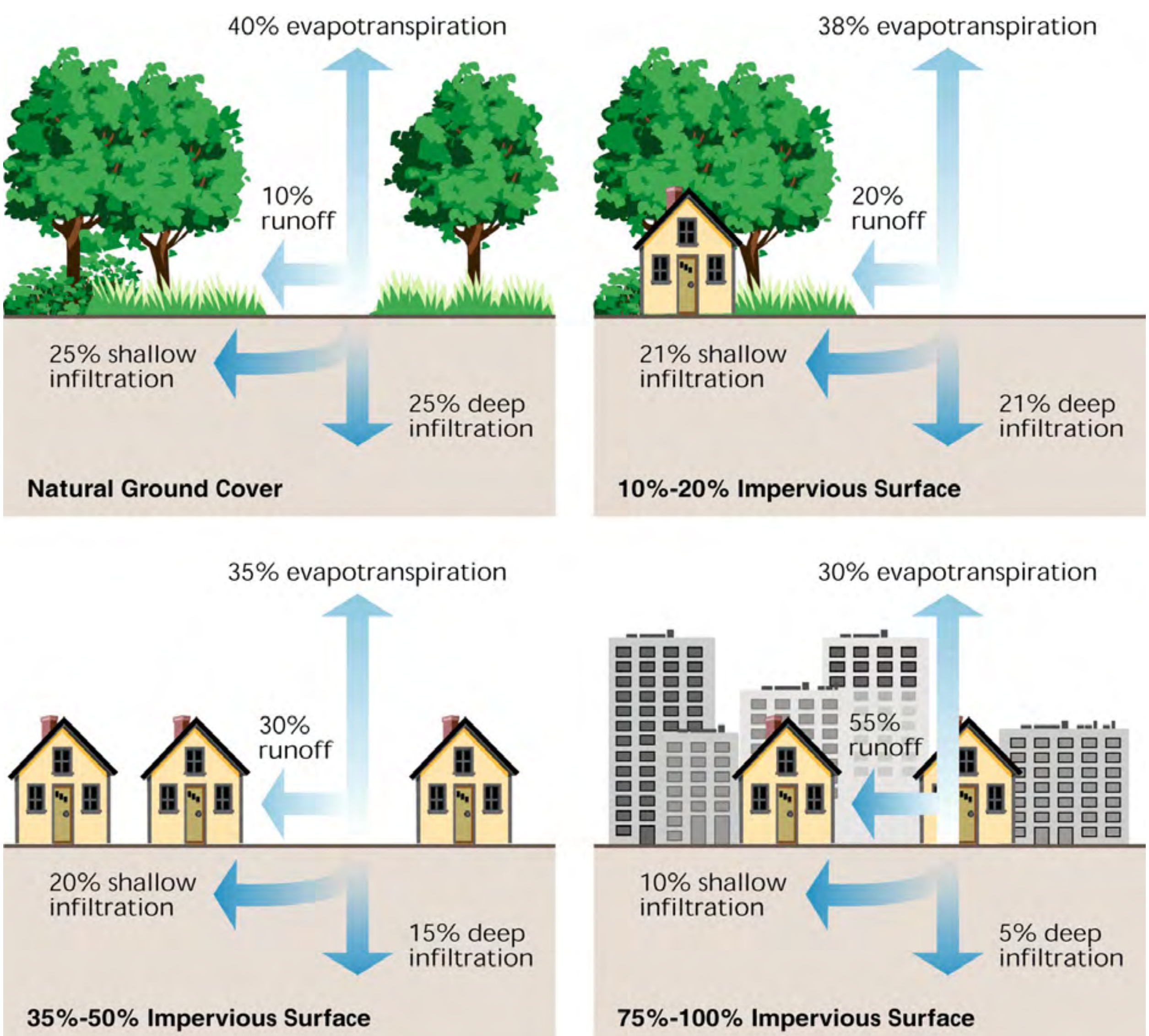
[59] *For example, see* Wisconsin Administrative Code *Chapter NR 151* Runoff Management*, 2018.*

[60] *Center for Land Use Education. Page 13. www.uwsp.edu/cnr/landcenter/pdffiles/Imp_Surf_Shoreland_Dev_Density.pdf.*

[61] *Wang, L., J. Lyons, P. Kanehl, R. Bannerman, and E. Emmons*, *"Watershed Urbanization and Changes in Fish Communities in Southeastern Wisconsin Streams,"* Journal of the American Water Resources Association*, Volume* 36, Number 5 pp. 1173-1187, *2000*.

Figure 2.12
Schematic Effect of Impervious Surfaces on Runoff and Groundwater Recharge



Source: Federal Interagency Stream Restoration Working Group

than 12 percent watershed impervious surface consistently have poor fish communities.[62] Consequently, reducing impervious land cover, or installing measures that reduce runoff from impervious surfaces (e.g., rain gardens and buffers), help reduce peak wet-weather runoff intensity and volume while helping support dry-weather water supply. The negative effects of impervious surfaces can be reduced in many ways, including the following examples:

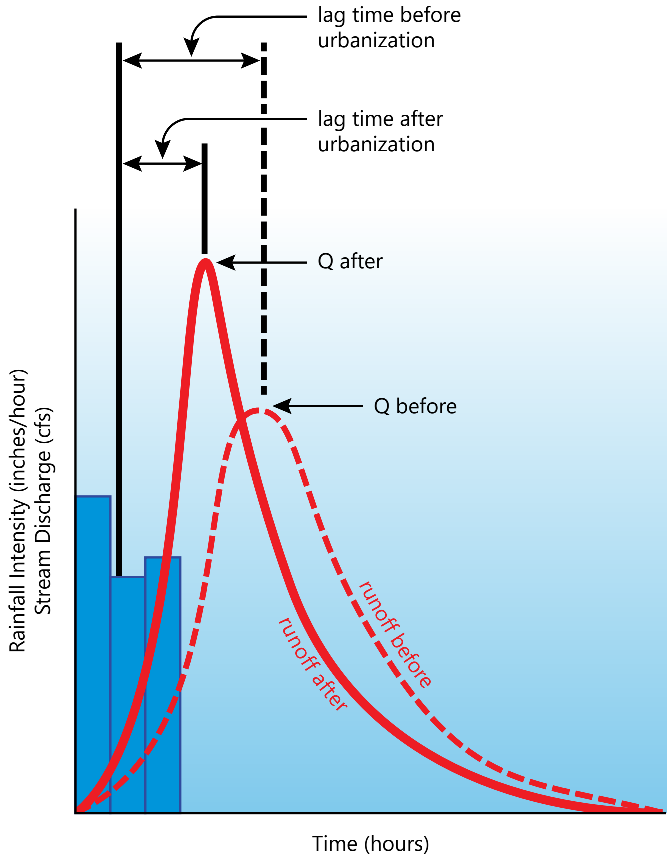
- Limit the size of hard surfaces:
    - Limit driveway width or share between neighbors
    - Minimize building footprints (i.e., build taller instead of wider or deeper, consistent with local zoning ordinances)
    - Remove unneeded sidewalks and parking areas

[62] *Wang, L., J. Lyons, and P. Kanehl, "Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spatial Scales,"* Environmental Management*, Volume 28, Number 2 pp. 255-266, 2001.*

- Opt for pervious materials:
    - Green roads (e.g., incorporate bioswales, grassed ditches, and similar design components)
    - Install mulch walkways as opposed to concrete walkways
    - Use permeable pavers for walkways and driveways
- Capture or infiltrate runoff:
    - Use rain barrels
    - Establish rain gardens
    - Channel gutters and downspouts to rain barrels, rain gardens, or places water can soak into the ground
    - Assure that lawn area soils are not compacted
- Maintain and restore shoreline buffers (as discussed under "Issue 4: Shoreline Maintenance")

Numerous resources are available that examine how impervious surfaces effect waterbodies and measures that can be taken to offset these affects. An example resource may be found at a University of Wisconsin Stevens Point website: www.uwsp.edu/cnr-ap/clue/Documents/Water/ImperviousSurfaces2013.pdf.

Figure 2.13
Schematic Effect of Urbanization on Rainfall/Runoff Timing



Note: "Q" denotes runoff rate. Development tends to increase runoff speed and increase peak runoff volume.

Source: Federal Interagency Stream Restoration Working Group (FISRWG), Stream Corridor Restoration: Principles, Processes, and Practices, *p. 15, October 1998*

Groundwater

Despite laws mandating runoff infiltration, as practical, in new developments,[63] new land development typically reduces the landscape's ability to absorb water and supply groundwater recharge. In addition to reducing groundwater recharge, developments place additional demands on groundwater supplies as water is extracted for various uses. Removing water from natural groundwater flow paths reduces groundwater elevations and natural discharge to lakes, streams, wetlands, springs, and seeps.

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 and developing a municipal water system with homeowners connecting to higher-capacity municipal wells. In some cases, these communities have an overall negative groundwater balance because wastewater treatment plant effluent leaves the community via surface water or is exported to regional treatment works located in other watersheds. Furthermore, long-term dewatering and commercial/municipal high capacity wells can dramatically influence groundwater flow paths.[64]

[63] Wisconsin Administrative Code *Chapter NR 151, "Runoff Management."*

[64] *Long-term dewatering is commonly employed at Southeastern Wisconsin aggregate pits and rock quarries. High capacity wells are used to support industry, water supplies for municipalities, large residential areas, industry, agriculture, and other uses (e.g., golf course irrigation, ski hill snow making).*

The magnitude of groundwater impact depends on a variety of factors, including the following examples.

- Development density
- The location of the development
- If groundwater is exported from the watershed
- the character of existing water resources

Not surprisingly, lot size (which directly correlates to well density and overall water demand influences overall groundwater impact. Groundwater elevation and stream baseflow decrease linearly as lot size decreases. Reinfiltrating treated wastewater on site (e.g., through use of private onsite wastewater treatment systems, or septic systems) significantly mitigates the impacts of development on groundwater levels and stream baseflows. However, even though return flow may largely mitigate water quantity impact, wastewater return flow may degrade local groundwater and surface water quality, particularly as development density increases. Sustainable groundwater use must consider both water quantity and water quality.

Waterbody Depletion

Human-induced change to local hydrology can profoundly affect waterbodies. Waterbodies commonly become even more dependent on groundwater discharge to sustain dry-weather flow when humans modify the landscape. If a waterbody does not receive significant amounts of water from seeps or springs, human influence can cause the dry-weather water surface elevation of lakes, ponds, and wetlands to decline and some hereto perennial streams may cease flowing at times of the year. These are examples of a process called waterbody depletion. Waterbody depletion can profoundly influence water quality, aquatic ecology, and overall habitat value.

The complex interconnection and interaction between surface water and groundwater makes managing depletion challenging, particularly because significant delays may occur between the times when hydrologic change (i.e., recharge reduction, extraction) begins and when the effects are noted at the surface. Other complicating factors may confound analysis and influence the timing, rate, and location of depletion. Nonetheless, managers should keep in mind several important factors when studying the relationship between surface water features and groundwater pumping, including the following:

- Individual wells may not produce noticeable change, but concentrations of small wells or unfavorable aquifer properties can combine to significantly decrease groundwater discharge to surface-water features.
- Decreased groundwater discharge may focus on certain waterbodies or may be pervasive throughout the area.
- Basin-wide groundwater development typically occurs over a period of several decades. Resulting cumulative effects may not be recognizable for decades.
- Depletion may persist for extended periods of time after groundwater withdrawal ends. Aquifers take time to recover from long-term extraction stress.
- Depletion can affect water quality in surface-water features and/or the aquifer. For example, in many streams, groundwater discharge moderates seasonal temperature fluctuations, cooling stream temperatures in the summer and warming stream temperatures in the winter, thus improving year-round habitat for fish and other aquatic organisms. Reduced groundwater discharge can degrade these moderating influences.
- The major factors that affect depletion timing are the distance from the well to the stream and the properties and geologic structure of the aquifer.

Sustainable groundwater exploitation 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 considers both surface-water features and groundwater supplies.

Areas with high groundwater recharge potential within the more developed areas of the watershed are ideal sites to position stormwater infrastructure designed to infiltrate detained stormwater.[65] Infiltrating stormwater provides conditions that generally improve waterbody health by reducing peak flow during smaller storms and increasing cool, high quality, baseflow to waterbodies during dry periods.

Potential Influence on Silver Lake

Human manipulation influences the amount of water delivered to, stored within, and draining from Silver Lake. Issues that likely influence Silver Lake's hydrology are discussed below.

- **Lake outlet dam.** A dam raises Silver Lake's outlet about 1.5 feet. This Lake level increase would tend to slightly reduce the amount of water discharging to the Lake, modestly increase the amount of water infiltrating into the Lake bottom, and slightly increase the amount of water stored within the Lake. These changes would tend to slightly increase Lake-water residence time.

- **Local land use.** The area contributing surface and groundwater to Silver Lake were essentially completely covered with forest before European settlement. Unlike some lakes, large blocks of the area contributing surface and groundwater to the Lake retain natural or semi-natural land cover, with the balance occupied by a patchwork of residential areas and open areas formerly used for agricultural purposes. Residential and agricultural land uses tend to increase overall runoff volume and intensity and diminish groundwater recharge.

- **High capacity water supply wells and long-term dewatering.** Two high-capacity wells were permitted in or very near the Lake's groundwatershed. One well was installed in 1968 and the other in 1978, and both are believed to supply water to for use at a communal living facility. Together, these wells are authorized to withdraw up to 96,000 gallons per day.[66]

- **Local potable water supplies and wastewater management.** Private wells provide potable water to residences within Silver Lake's watershed and groundwatershed. Most of these wells draw water from the aquifer feeding Silver Lake. Highly populated portions of the local area and near lakes are served with public sanitary sewers (see Map 2.8). Therefore, most well water extracted by homes in Silver Lake's watershed and groundwatershed no longer reaches the Lake diminishing the volume of groundwater entering Silver Lake. Concern has been expressed that export of water from the Silver Lake watershed could tangibly reduce groundwater discharge to the Lake.

  The volume and significance of water diverted from the Lake by water supply wells supplying homes near Silver Lake can be estimated using available records. The Silver Lake Sanitary District reports that approximately 21,000 gallons of water per day are discharged to sanitary sewers in the Silver Lake area. This water is sourced from relatively shallow private wells near or directly adjacent to Silver Lake, and likely drawing water from aquifers that are in good hydraulic communication with the Lake. Even though wells on the east side of the Lake are technically hydraulically downgradient of the Lake, pumping from these wells can induce supplemental infiltration into the Lake bed. Therefore, assuming little water is used for irrigation or other consumptive use in Silver Lake residences, the

[65] *Care needs to be taken to infiltrate high quality stormwater. Runoff laden with salt and other pollutants can degrade groundwater quality.*

[66] *Cedar Lake Home was identified as the only high capacity well (Number 87816) located in the western part of groundwatershed. The well was constructed in December 23, 1978, with a capacity of 250 gallons per minute and maximum withdrawal of 2,600 gallons per day. WDNR's Water Quantity Data Viewer* website (*dnrmaps.wi.gov/H5/?viewer=Water_Use_Viewer*) and Well Driller Viewer (*dnrmaps.wi.gov/H5/?viewer=Well_Driller_Viewer*) provide *excellent information regarding water supplies and water-supply wells.*

wastewater flow is a reasonable proxy of total groundwater export from the area immediately around Silver Lake. The quantity of water exported from the Silver Lake area represents no more than 3 percent of the average surface water discharged from the Lake over the outlet dam, a quantity that would not be discernable to a casual observer.

Management Tools – Plans and Models

Urbanization generally reduces hastens stormwater runoff, increases wet-weather runoff volume, decreases dry weather streamflow, reduces groundwater recharge, diverts water from natural discharge points, often decreases the volume of groundwater discharge, and increases the incidence of groundwater export. Since the Lake's water surface elevation is reportedly remaining within desirable ranges during dry weather, groundwater pumping and impervious surfaces apparently are not unduly reducing baseflow to the Lake. Nevertheless, since groundwater-dependent waterbodies such as Silver Lake typically respond slowly to change, decreased groundwater discharge may only be noticeable over extended lengths of time, a situation requiring vigilance and pre-emptive monitoring. Consequently, to maintain adequate groundwater supply to the Lake, the importance of high and very high groundwater recharge potential areas must be embraced, practices that maintain groundwater recharge potential should be employed, and Lake elevation should continue to be monitored.

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 of the Southeastern Wisconsin Region. Understanding recharge and its distribution is key to making informed land use decisions so that the groundwater needs of society and the environment can continue to be met. This model is based on a relatively small spatial grid size (about 100 feet on a side) that can be used for local level groundwater planning purposes. Therefore, these model results are generally applicable to the Silver Lake 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.

The area supplying recharge to the Lake's groundwater supply are mostly west of the Lake. This area is largely underlain by high recharge potential soil and is mostly undeveloped. This is a key resource to sustain groundwater recharge to Silver Lake. In addition to supporting groundwater dependent natural resource elements, groundwater recharge areas supply potable water to all wells in the watershed. Without sufficient recharge, groundwater elevations fall, and can compromise the utility of existing pumps and wells. This is especially important to the relatively shallow wells commonly used for household water supply.

Current land use plans do not identify significant acreages of new development in the Lake's watershed or groundwatershed. Furthermore, no plans for public sanitary sewer area expansion are known. For these reasons, human influence is not expected to significantly change groundwater contributions to the Lake in the near future. Nonetheless, development and land management activities need to consider groundwater recharge and local consumptive demand. Protecting high and very high groundwater recharge areas should be a priority. Some communities have recognized the complex interaction between land use, water use, surface water, and groundwater and have promulgated regulations to foster sustainable development. For example, the Village of Richfield in southern Washington County is has studied its groundwater resource potential and limitations and actively enforces a groundwater protection ordinance.[67]

The Commission developed a water supply system plan for the Southeastern Wisconsin Region.[68] This plan considers existing water demands, future development, sustainability, and protection of natural resource features. This plan is the third component of the Commission regional water supply planning program. The other two elements were a basic groundwater inventory and development of a regional groundwater model. The regional aquifer simulation model allows water levels in the deep and shallow aquifers to be forecast under historical, current, and planned conditions. The model 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 could be developed to investigate site-

[67] *More information regarding the Village of Richfield's groundwater program may be found at the following website: www.richfieldwi.gov/300/Groundwater-Protection.*

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

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

Although the resolution of the regional groundwater models was considered sufficient and valid to compare differences resulting from alternative plans, it may not be sufficiently fine to predict site-specific effects or may not be able to resolve differences in affect between surface water or groundwater features that are in close proximity to one another. 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, or output, from this regional modeling effort are not applicable for determining 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 Silver Lake watershed, because this area is too small.

The recent USGS groundwater simulation model can be used or updated for local level groundwater supply and land use planning purposes for the Town of West Bend within the Silver Lake surface and groundwatershed areas. The USGS report states that "whereas the calibrated model can be used for general interpretive evaluation of the Silver Lake area, it also can be used to test potential changes affecting the watershed." For instance, the effect of groundwater extraction either hydraulically upgradient or downgradient of the Lake could be simulated. Specific changes to ground-water recharge areas (such as adding impervious areas like parking lots) could also be simulated. The model provides a tool for assessing the effect of a wide range of activities or land-management choices.[69]

2.5 WATER QUALITY AND POLLUTANT SOURCES

Actual and perceived water quality is important concern to most lake users and residents. Lake residents express concern that specific pollutants may enter the Lake from various sources and could compromise water quality over time. Pollutants that typically figure prominently in such discussion include the following examples.

- Sediment and nutrients carried by stormwater runoff
- Sediment eroded from lake shorelines
- Petroleum, heavy metals, and salt from roadways
- Fertilizer and pesticide runoff from shoreline properties
- Fertilizer runoff from properties within the lake's watershed
- Groundwater contaminants

Human activity often decreases a landscape's ability to filter and absorb pollutants carried to a lake with stormwater causing pollutant loads to lakes to increase even if pollutant sources remain unchanged. Concerns about excessive aquatic plant growth reinforce the importance of water quality given that water quality profoundly influences the type and amount of aquatic plant growth in waterbodies.

When discussing water quality, it is important to define what "water quality" means since individuals have varying perceptions and levels of understanding. Most individuals evaluate water quality through water appearance. For example, the presence of algae or cloudy water can cause a casual observer to conclude that a lake is "unclean." However, to succinctly quantify water quality, quantitative data must be

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[69] *Dunning, C. P., J.C. Thomas, and Y-R Lin, 2003, op. cit.*

collected over extended periods of time. The values and trends of specific chemical, physical, and biological parameters that influence or indicate water quality helps lake managers examine and judge water quality and waterbody health. Some of the most common metrics to assess water quality include water clarity and temperature as well as the concentrations of chloride, phosphorus, chlorophyll-*a*, and dissolved oxygen (see Table 2.8 for further information regarding these parameters). A number of other parameters can also help define waterbody health. For example, the abundance of the bacteria *Escherichia coli*, commonly known as E-coli, is often measured to determine if water is safe for swimming while chloride concentrations indicate overall human-derived pollution entering a lake.[70]

Water quality parameters interact with one another in a variety of ways. For example, fertilizers and excessive organic matter carried to lakes can cause a lake's phosphorus concentrations to increase, its clarity to decrease (due to algal growth in the water column), and chlorophyll-*a* (a measure of algae content) to increase. Effective water quality maintenance and improvement programs depend upon key water-quality indices regularly measured over extended periods of time. This allows lake managers to establish baselines, identify trends, and propose management actions.

To design a viable and valuable water quality maintenance and improvement program, a variety of factors need to be considered, including the following.

- **A lake's past and current water chemistry, hydrology, and morphometry.** To identify water quality management efforts that help achieve specific goals, it is important to quantify current lake conditions, contrast past values, and estimate pre-settlement and future water quality. To do this, critical parameters (e.g., phosphorus, water clarity, chlorophyll-*a*, dissolved oxygen, temperature, conductivity, alkalinity, chloride, and potentially other substances) are measured, simulated, and tracked over time to evaluate how water quality changes during each year and over long time periods. Water quality values from various depths are also contrasted to evaluate in-lake distribution, circulation, and processes. Values that suggest deteriorating conditions can help identify pollutants and issues that should be targeted for management action. General lake characteristics (e.g., depth, shape, water circulation patterns) can help provide context for understanding water quality data, help determine the extent of water quality problems, and help identify viable methods for water quality management. Monitoring, hydrology, and lake morphometry information helps lake managers evaluate a waterbody's ability to support various organisms and recreational uses, examine the extent and nature of pollution, estimate risks associated with identified pollution, and judge overall waterbody health.

- **A lake's watershed characteristics, including land use and associated pollutant loadings.** The type and amount of pollutants entering most lakes depend on the ways land surrounding the lake (i.e., its watershed) is used. Different land uses yield different pollutants and channel changes (see Figure 2.14). For example, cultivated land can be a significant contributor of sediment (from soil eroded and carried in runoff) and nutrients (from fertilizers, manure, and soil washed off fields). The types of agricultural practices employed influence the amount and timing of erosion and sediment and nutrients delivered to a lake. As an example, tillage loosens soils promoting erosion while tiles and ditches may hasten runoff and reduce the ability of sediment and nutrients to be captured before they enter waterways. Conversely, conservation tillage, cover crops, and pastured lands can reduce erosion and nutrient delivery. Similarly, urban land uses (e.g., residential, industrial, and commercial development) can contribute significant amounts of sediment and nutrients and an array of other pollutants such as heavy metals, petroleum products, and organic compounds (e.g., roadside dust containing brake dust, oil leaked onto pavement, pavement binders and sealers). Pollutant transport potential is influenced by the permeability, degree of cover, and slope of soils within the watershed. For example, the amount of pollutant actually reaching waterbodies may be higher if slopes are steep and ground is bare, paved, or relatively impermeable.

[70] *Chloride is useful indicator of human-derived water pollution because it is widely used by humans and, under natural conditions, is normally present only at low concentrations in Southeastern Wisconsin's surface water and shallow groundwater. Furthermore, 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 deicer runoff, fertilizer application, private onsite wastewater treatment systems, and other human-derived sources.*

Table 2.8
Water Quality Parameter Descriptions, Typical Values, and Regulatory Limits/Guidelines

Parameter	Description	Southeastern Wisconsin Values[a]		Regulatory Limit or Guideline	Silver Lake Values	
		Median	Range		Median	Range
Chloride (mg/L)	Low concentrations (e.g. < 5 mg/L) naturally occur in lakes due to natural weathering of bedrock and soils. Human activities increase concentrations (e.g., road salts, wastewater, water softener regeneration) and can effect certain plants and animals. Chloride remains in solution once in the environment and **can serve as an excellent indicator of other pollutants.**	16	1-223	Acute toxicity[b,c] 757 Chronic toxicity[b,c] 395	11.3[d]	3.2-27.2
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[e]	2.5[f]	1.3-5.4[f]
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[e]	--[g]	0-13.2
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 30 μg/L is the concentration considered necessary in a deep headwater lake such as Silver Lake** to limit algal and aquatic plant growth to levels consistent with recreational water use objectives. Phosphorus concentration exceeding 30 μg/L are considered to be indicative of eutrophic lake conditions	30	8-720	30[e]	11[f]	5-18[f]

Table continued on next page.

Table 2.8 (Continued)

Parameter	Description	Southeastern Wisconsin Values[a] Median	Range	Regulatory Limit or Guideline	Silver Lake Values Median	Range
Water Clarity (feet)	Measured with a Secchi disk (a ballasted black-and-white, eight-inch-diameter plate) which is lowered into the water until a depth is reached at which the disk is no longer visible. It can be affected by physical factors, such as suspended particles or water color, and by various biologic factors, including seasonal variations in planktonic algal populations living in a lake. **Measurements less than 5 feet are considered indicative of poor water clarity and eutrophic lake conditions**	4.6	3-12	10.9[h]	8.7[f]	2.1-19.0[f]
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[e] 35-77 Sub-lethal[e] 49-80 Acute[e] 77-87	- -[g]	32-82.2

[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] *Chloride concentrations have been consistently increasing across the region, and current chloride concentrations are likely higher.*

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

[f] *Values collected, during growing season (June 1 through August 31).*

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

[h] *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 State Legislature, U.S. Environmental Protection Agency, and SEWRPC

To understand pollutant load magnitude and change, past, present and planned land use within the watershed are examined. Models can estimate the amount of pollutants entering a waterbody under various conditions from various practices and areas. Land use activities and portions of the watershed that are more likely to contribute to water quality deterioration can then be identified. This helps focus pollution reduction strategies and efforts where they are most needed.

- **The filtration capacity of a lake's watershed and shorelines.** A variety of natural or nature-like features can help cleanse polluted runoff. For example, wetlands and vegetative buffers can intercept pollutants carried in runoff, significantly decreasing the amount of pollution entering a lake.[71] Pollutants can either by absorbed and utilized (in the case of nutrients) and/or trapped (such as sediment).

These factors are discussed in the following sections.

[71] *Vegetative buffers (e.g., forests, grassed waterways, and vegetative strips) and wetlands slow runoff velocity and typically spread flow. This encourages sediment and pollutant carried by stormwater to be deposited, detained, and/or consumed before they enter an adjacent waterbody.*

Water Chemistry

Physical and chemical information useful to evaluate Silver Lake's water quality have been collected since at least 1960.[72,73] The first comprehensive limnological study of the Lake was completed in 1977.[74] The WDNR and Citizen Lake Monitoring Network (CLMN) volunteers have more systematically collected water quality information since the 1980s.[75] In addition, the U.S. Geological Survey (USGS) studied Silver Lake's hydrology and water quality data during 1996 and 1997.[76]

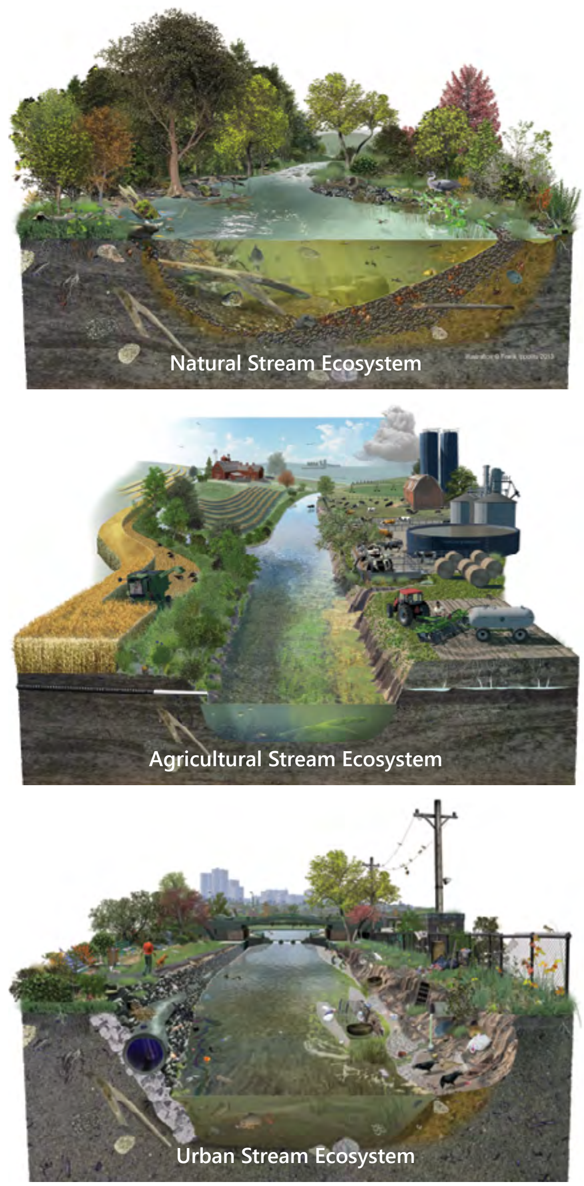
Lake Conditions Influencing Water Chemistry

The physical and chemical properties of lake water fluctuate over short- and long-term time periods. Therefore, water quality evaluation relies on regular and reproducible data collection, ideally at the same depths and locations over protracted time periods. When examining lake water chemistry, it is important to consider certain lake characteristics that provide context for evaluation. These lake characteristics include the following.

- **A lake's hydraulic residence time.** Hydraulic residence time refers to the average length of time needed to replace a lake's entire water volume (see Section 2.4 "Morphometry and Watershed Size" for more detail). Residence time helps determine how quickly pollution problems can dissipate. For example, if retention times are short, pollutants may be flushed out of the lake fairly quickly. In such cases, management efforts may 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 lake-bottom sediment. In this case, in addition to preventing external pollution loads, it also may be necessary to employ in-lake water quality management efforts to address legacy pollutants.

- **Whether a lake stratifies, and, if it does, when it mixes.** Stratification refers water temperature driven density differences between a lake's warmer near-surface waters (its *epilimnion*) and

Figure 2.14
Components of Ecological Stream Health



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*

[72] *Wisconsin Conservation Department,* Surface Water Resources of Washington County, Lake and Stream Classification Project*, 1962.*

[73] *Wisconsin Department of Natural Resources,* Silver Lake, Washington County, Wisconsin, An Inventory with Planning Recommendations*, Prepared for the Southeastern Wisconsin Regional Planning Commission, Lake Use Report No. ML-8, 1973.*

[74] *CDM/Limnetics, 1977, op. cit.*

[75] *See Surface Water Data Viewer (SWDV), a WDNR data delivery system that provides interactive web mapping tools for a wide variety of datasets including chemistry (water, sediment), physical, and biological (macroinvertebrate and fish) data. Website link: dnrmaps.wi.gov/H5/?Viewer=SWDV.*

[76] *Dunning, C. P., J.C. Thomas, and Y-R Lin, 2003, op. cit.*

colder, deeper waters (a lake's *hypolimnion*). When a lake is stratified, shallow water is considerably warmer and is well oxygenated, and is the portion of the lake supporting the greatest abundance and diversity of aquatic life. Stratification impedes vertical water circulation which in turn limits transfer of oxygen, other dissolved gases, and chemicals between near-surface water and deepwater areas (see Figure 2.15). When a lake stratifies, deeper hypolimnetic water cannot exchange gases with the atmosphere. Metabolic processes continue to consume oxygen in the hypolimnion. If oxygen demands are high (such as in an enriched lake), and/or if the volume of deep isolated hypolimnetic water is small (limiting oxygen storage potential), oxygen concentrations in deep areas can become extremely low (hypoxic) or fall to zero (anoxic) for periods of time.

A lake must be relatively deep to generate sufficient temperature differences between surface and bottom waters for the lake to stratify. In general, lakes in Southeastern Wisconsin less than 15 feet deep are unlikely to stratify, whereas lakes with depths greater than 20 feet are likely to stratify. A lake's propensity to stratify is heavily influenced by the lake's shape, size, orientation, landscape position, surrounding vegetation, through flow, water sources, and a host of other factors. Depth to the *thermocline* (the transition layer between the epilimnion and hypolimnion, sometimes also called the *metalimnion*) can range from less than 10 feet to 30 feet in typical Southeastern Wisconsin lakes. Even within the same lake, the depth and thickness of the thermocline may differ season to season and year to year. Water within the thermocline rapidly cools with depth and often contains less oxygen than the epilimnion. Below the thermocline, water in the hypolimnion is much colder than water at the lake's surface and may not mix with the epilimnion until fall. Little sunlight penetrates past the thermocline; therefore, deeper portions of lakes generally do not support significant photosynthetic activity and hence do not receive oxygen from plants.

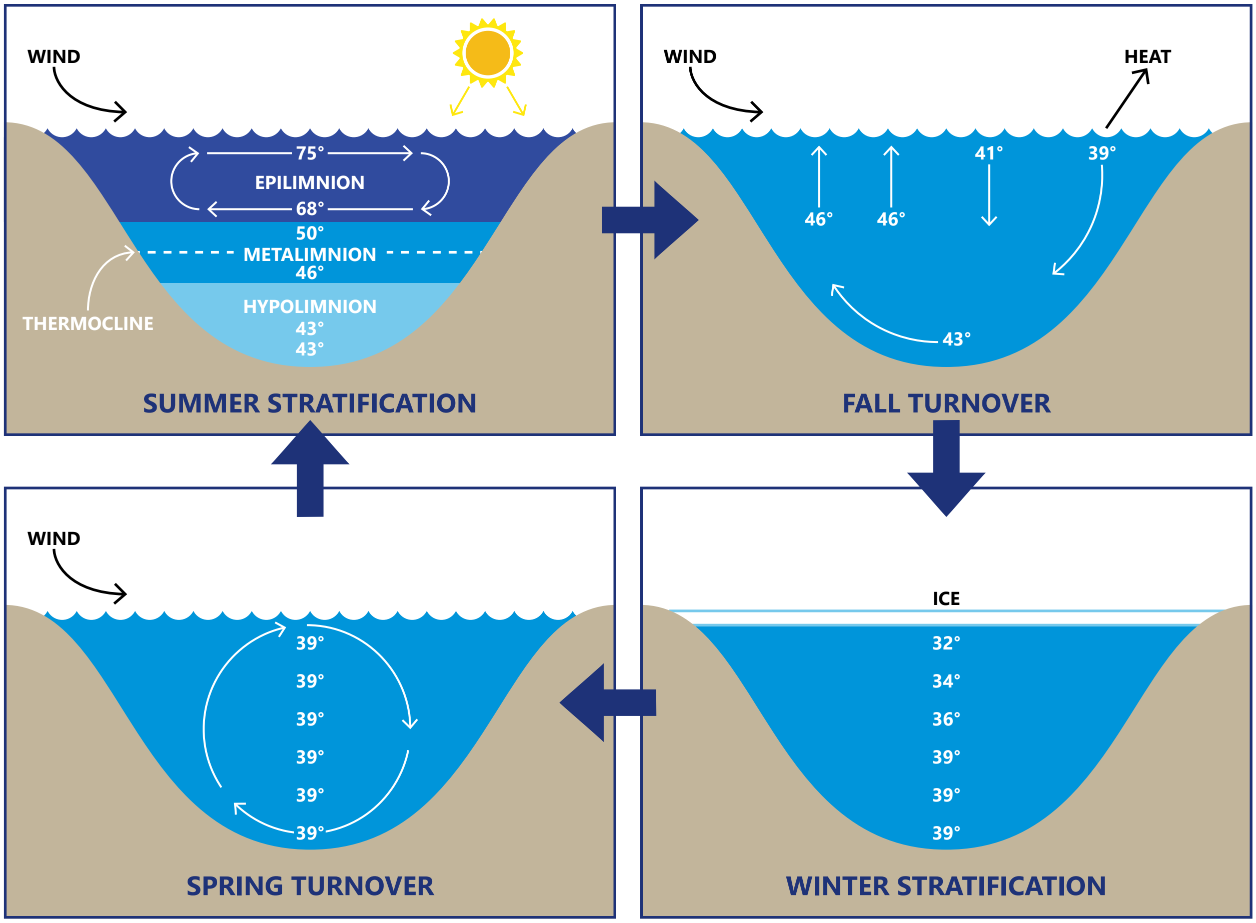
Most deep lakes in the Region stratify sometime during mid to late spring, with a short (usually less than a week) period of whole-lake water circulation and mixing (turnover) that takes place once during spring and once again in fall (see Figure 2.15). While some lakes remain permanently stratified, stratification in most Wisconsin lakes breaks down at least twice per year in response to changing seasons and ambient weather conditions. Lakes that mix twice per year are termed *dimictic* lakes. At turnover, the lake's temperature and water chemistry are uniform from the lake surface to the lake bottom. Lakes that stratify and turn over in the spring and fall are termed *dimictic*. Some lakes may also mix in summer in response to windy conditions. Lakes can also weakly stratify in winter when warmer, denser water is found in the deeper portions of the lake.

Determining if a lake stratifies is important because nutrients, low-oxygen water, and, in some cases, pollutants and sediment, accumulated in hypolimnion can suddenly mix into the entire water column during the turnover period. This can cause water quality and plant management problems. For example, abundant nutrients from the isolated deep portions of a lake can mix into near-surface water which in turn can fuel nuisance-level growth of algae and aquatic plants.

- **A 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, healthy fish, and other aquatic life communities is often correlated with the lake's degree of nutrient enrichment. Three terms describe the trophic state of a lake: *oligotrophic* (nutrient poor), *mesotrophic* (moderately fertile), and *eutrophic* (nutrient rich) (see Figure 2.16). Each trophic state occurs naturally. Lakes tend to shift to a more nutrient-rich state over time, a progression often referred to as "aging" (see Figure 2.17). However, if a lake rapidly shifts to a more eutrophic state, human-induced pollution is often responsible for this change. Under severe pollution and highly enriched conditions, a lake enters the "hyper-eutrophic" condition (see Figure 2.18). Hyper-eutrophic conditions do not commonly occur naturally and are nearly always related to human pollution sources.

- **Whether internal loading is occurring.** Over time, sediment accumulates on lake bottoms. This sediment is composed of the remains of dead plants and animals, chemical precipitates, and fine-grained inorganic sediment. *Internal loading* refers to release of phosphorus stored in lake-bottom sediment occurring under water quality conditions associated with stratification. Phosphorus is typically not particularly soluble and forms precipitates or adheres to particles that settle to the

Figure 2.15
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*

lake bottom. When organic detritus and sediment settle to the lake bottom, decomposer bacteria break down the organic substances, a process that consumes oxygen. If lake-bottom waters become devoid of oxygen, the activity of certain decomposer bacteria, together with certain geochemical reactions that occur only in the absence of oxygen, can allow phosphorus from lake-bottom sediment to dissolve. This allows phosphorus that was hereto trapped in deep lake-bottom sediment to be released into lake water. Released phosphorus can mix into the lake's entire water volume during the next turnover period, fueling plant and algae growth. In most lakes, phosphorus is the nutrient limiting overall plant and algal growth. Therefore, adding phosphorus to a lake can increase aquatic plant and algal abundance. If internal loading is a primary component of a lake's phosphorus budget, water quality management may need to focus on in-lake phosphorus management efforts in addition to preventing polluted runoff from entering the lake.

- **Lake tributary area/type**. Lakes with large tributary streams and/or large watersheds generally receive higher sediment and nutrient loads than lakes fed primarily by precipitation or groundwater. Watershed characteristics and land use greatly affect pollutant loads carried by tributary streams. Lakes that are fed primarily by tributary streams are labeled drainage lakes.

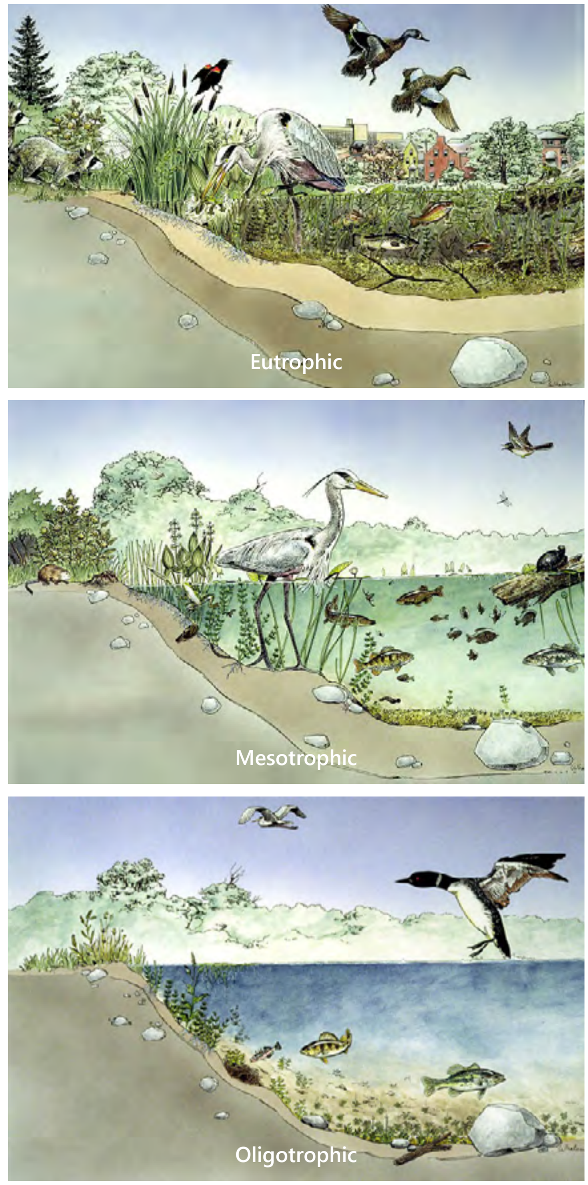
By analyzing oxygen/temperature profiles, phosphorus concentrations, chlorophyll-*a* concentrations, and Secchi depth measurements, it was determined that Silver Lake is a drainage lake that thermally stratifies during the summer, is prone to internal loading of phosphorus, and is mesotrophic. These characteristics are examined and discussed in more detail in the following subsections.

Temperature and Oxygen

Temperature and oxygen concentration profiles were assembled from data spanning over 40 years. Temperature and oxygen concentration profiles suggest that Silver Lake stratifies every year and remains stratified throughout the summer (see explanation of boxplot symbols on Figure 2.19 and profiles on Figure 2.20). The depth and thickness of the thermocline varies from month-to-month and year-to-year. However, the summer thermocline is generally found somewhere between 16 and 35 feet below the Lake's surface.[77] There are few oxygen/temperature profile data outside the summer months, but, based upon available data, the Lake has historically stratified as early as April.

During summer (June, July, and August), Silver Lake's hypolimnion contains little to no oxygen. Approximately half of Wisconsin lakes containing similar phosphorus concentrations develop hypoxic or anoxic hypolimnia during summer.[78] During most years, by mid to late-July, waters below 30 feet contain less than 5 mg/L oxygen (Figure 2.20), a condition that was already noted 50 years ago by the WDNR.[79] This means that approximately 30 percent of the Lake's total water volume cannot fully support fish and most other desirable aquatic life during a typical summer when anoxic waters cover about 37 acres, or nearly 30 percent, of the Lake's bottom (Figure 2.21). Available data demonstrates that Silver Lake has developed anoxia in its hypolimnion since at least the 1970s.

Figure 2.16
Comparison of Lake Trophic Status



Source: UW-Extension Lakes Program and SEWRPC

Water reaches its maximum density at a temperature of 39 degrees Fahrenheit, meaning that water near its freezing point is actually less dense than slightly warmer water. Winter (December, January, and February) temperature data suggest that the Lake is relatively isothermal in the winter with a fairly consistent temperature throughout all depths. Warmer water occasionally accumulates in the deepest areas of the Lake during winter, producing weak stratification.[80] Based upon the available profiles, the deepest portions of Silver Lake commonly have less oxygen than overlying colder water during winter, but waters shallower than 30 feet are fully capable of supporting aquatic life. Winter stratification breaks down in early spring and the Lake usually fully mixes sometime in March or April. When fully mixed, sufficient oxygen is available to support aquatic life at essentially all depths.

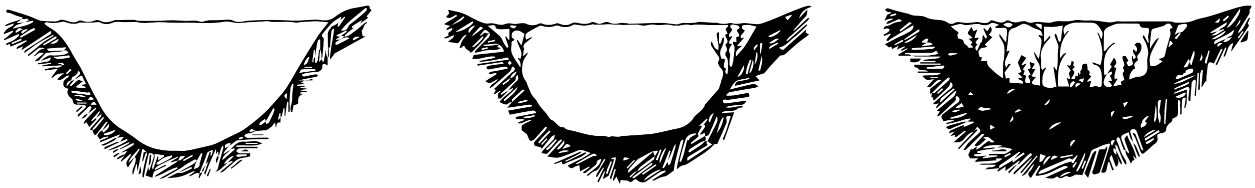
[77] *In the past, temperature and dissolved oxygen measurements have been randomly collected at inconsistent depths making it difficult to determine thermocline location. In the future, temperature and oxygen data should be collected at one-foot intervals from the surface to the Lake bottom.*

[78] *Lillie, Richard A. and John W. Mason, 1983, op. cit.*

[79] *WDNR, Lake Use Report No. MI-8, 1973, op. cit.*

[80] *Liquid water achieves is most dense at approximately 39 degrees Fahrenheit. Therefore, freezing water is less dense than slightly warmer water.*

Figure 2.17
Lake Aging's Effect on Trophic Status



OLIGOTROPHIC

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

MESOTROPHIC

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

EUTROPHIC

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

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

As opposed to oxygen *concentration*, oxygen *saturation* relates measured oxygen concentration to the maximum theoretical oxygen concentration in equilibrium with the atmosphere at a given temperature. Values between 90 and 110 percent saturation are generally considered desirable for aquatic life, with values greater and less than this range being increasingly injurious to aquatic life. Oxygen saturation values in Silver Lake epilimnion are generally within the desirable range.

Water Clarity

Secchi depth, a measure of water clarity, is an often used and easy to measure and understand water quality indicator. Water transparency can be affected by physical factors such as water color, suspended inorganic particles, and by various biological factors including planktonic algal. Secchi depth is often greatest during winter, indicating high water clarity, and lowest during spring and summer when suspended algae is commonly most abundant. Secchi depths have been collected at the "deep hole," or deepest area of the Lake since 1980. Measurements have been collected several times a year since 1985.

Summer (June through August) secchi depth measurements are used to compare water clarity and evaluate the Lake's trophic status. As shown in Figure 2.22, long-term average Secchi depth suggest fair to good water quality with recorded values averaging about 10 feet during the summer months. During the late 1960s, Silver Lake was identified by the WDNR as the clearest major lake in the entire Milwaukee River watershed. Even though the data set has large data gaps and is rather sparse, water clarity appears to be slightly decreasing over time.[81] It is important to consider that secchi depth variations can be at least partially related to sampling protocol. During some years, only one secchi reading was taken over the entire summer and such a measurement could represent a non-representative water clarity condition.

While on-the-water Secchi measurements are accurate and easy to collect, they are commonly limited to only one point in the Lake. Satellite water clarity estimates allow water clarity differences throughout the Lake to be noted and studied. In the past few years, water clarity estimates for Wisconsin lakes have been derived from satellite imagery. The most current satellite imagery data suggest that Silver Lake should have a secchi depth between eight and 16 feet, a value that agrees well with actual measurements made on the Lake. In general, satellite imagery suggests water in the southeastern quarter of the lake is not as clear as in the remainder of the Lake (Figure 2.23). A variety of factors, such as runoff, marl formation, and disturbance of bottom sediment can influence water clarity variation throughout the Lake.

Zebra mussels (*Dreissena polymorpha*) have been shown to increase water clarity. This nonnative species of shellfish rapidly colonizes nearly any clean, stable, flat underwater surface, artificial or natural. Massive colonies have become a significant nuisance in some lakes. Zebra mussels were first verified as present in Silver Lake in 2011. Although zebra mussels remove particulate matter from the water column and have the tendency to improve water clarity, Secchi depth measurements have not significantly increased since 2011, suggesting that zebra mussels have not significantly changed Silver Lake's planktonic algae abundance.

[81] *WDNR, Lake Use Report No. MI-8, 1973, op. cit.*

Chlorophyll-a

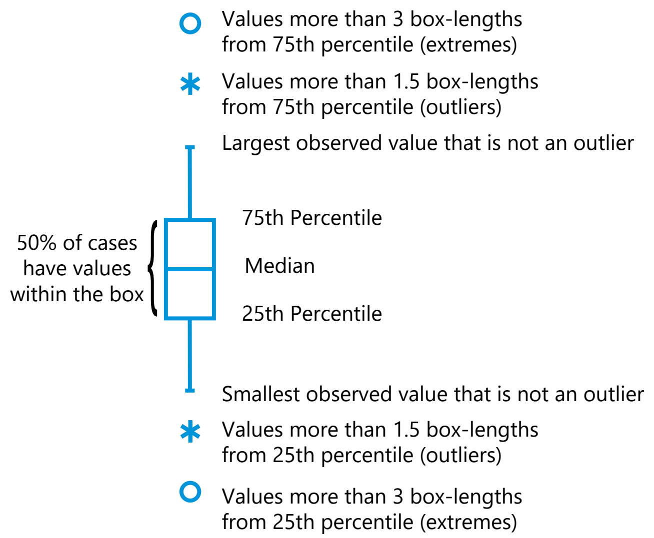
Chlorophyll-*a* is a major photosynthetic ("green") pigment in algae. The amount of chlorophyll-*a* present in water is directly proportional to the amount of algae in the water. Chlorophyll-*a* concentrations above 10 μg/L tend to impair recreational activity. The median chlorophyll-*a* concentration for lakes in Southeastern Wisconsin is approximately 9.9 μg/L but can range from 1.8 to 706.1 μg/L (see Table 2.8).[82]

Chlorophyll-*a* concentrations have been measured in Silver Lake since 1980 (Figure 2.24). These data reveal that chlorophyll-*a* concentrations are consistently well below 10 *μ*g/L, a value associated with eutrophic conditions and are significantly lower than the regional median. This suggests that algal blooms are generally not a threat in Silver Lake, that the Lake's phosphorus concentrations are moderately low, and that the aquatic plant community is healthy. Furthermore, since nitrogen and phosphorus measurements indicate that algal growth in the Lake is phosphorus limited (see "Nutrients" subsection below), reducing phosphorus in the Lake will further reduce chlorophyll-*a* concentrations, yielding clearer water.

Figure 2.18
Example of a Hyper-Eutrophic Lake

Source: University of Minnesota, College of Natural Resources, 2003

Figure 2.19
Explanation of Symbols in Boxplot Figures



Source: SEWRPC

Nutrients

Nitrogen and Phosphorus

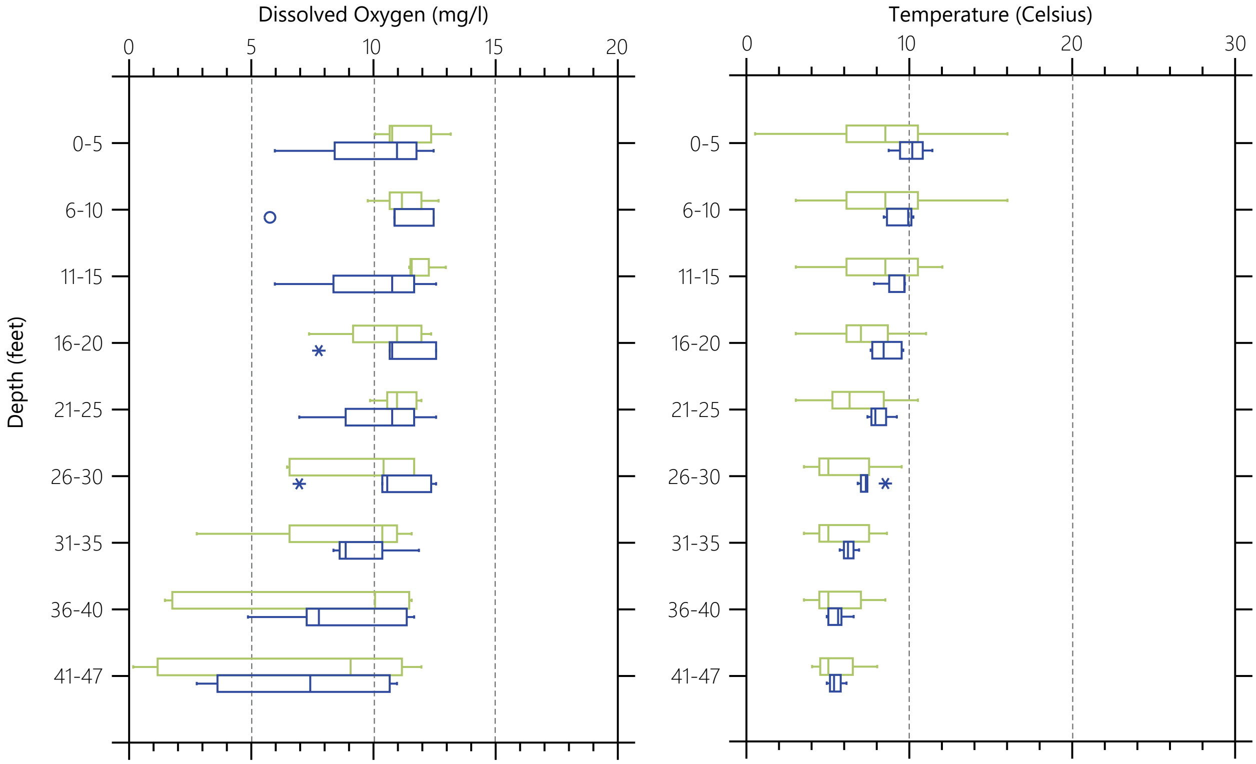
Nitrogen and phosphorus are two substances that plants need in fairly large quantities to grow. Silver Lake's phosphorus and nitrogen data set is relatively modest, with samples intermittently collected over the past four decades. Available data demonstrates that phosphorus concentrations in near-surface Lake water are consistently low,[83] easily achieving *Wisconsin Administrative Code* Chapter NR 102 *Water Quality Standards for Wisconsin Surface Water* stratified drainage lake standard and the WisCALM deep headwater drainage lake standard, both of which are 0.03 mg/L. Over the period of record, near-surface spring-season phosphorus concentrations are now typically around 0.015 mg/L (see Figure 2.25). while winter-season near-surface phosphorus concentrations are more variable but still low (see Figure 2.26). While spring and winter near-surface phosphorus concentrations have not significantly changed over the period of available record, summer near-surface concentrations appear to be very slowly increasing over time (Figure 2.27).

[82] *Lillie, Richard A. and John W. Mason, 1983, op. cit.*

[83] *A sample collected from the "surface" on June 25, 2009 reportedly contained 0.36 mg/L phosphorus, an unprecedentedly high concentration well above any other sampling period. Since it was collected at the surface, and since the value is abnormally high, this value was considered suspect and was therefore not used to evaluate trends.*

Figure 2.20
Silver Lake Seasonal Dissolved Oxygen and Temperature Profiles

Spring (March-May)



Summer (June-August)

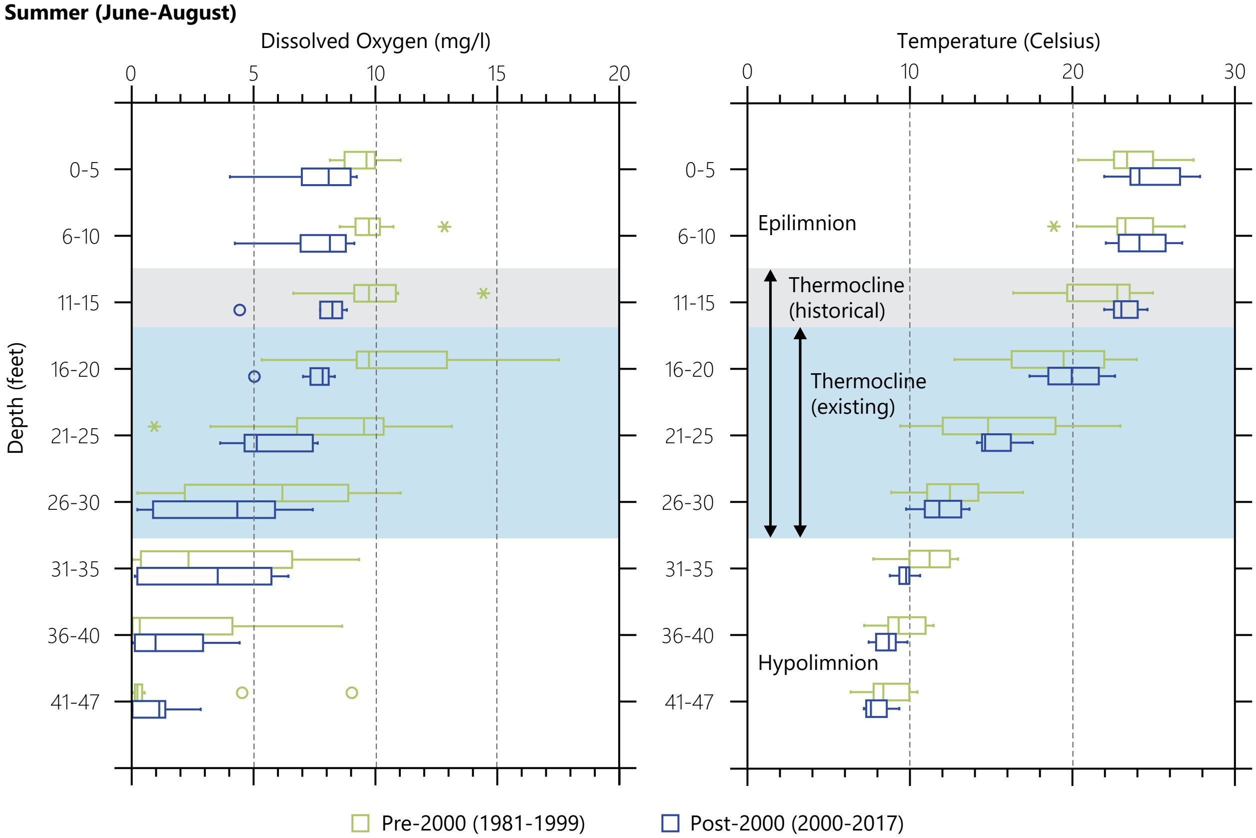
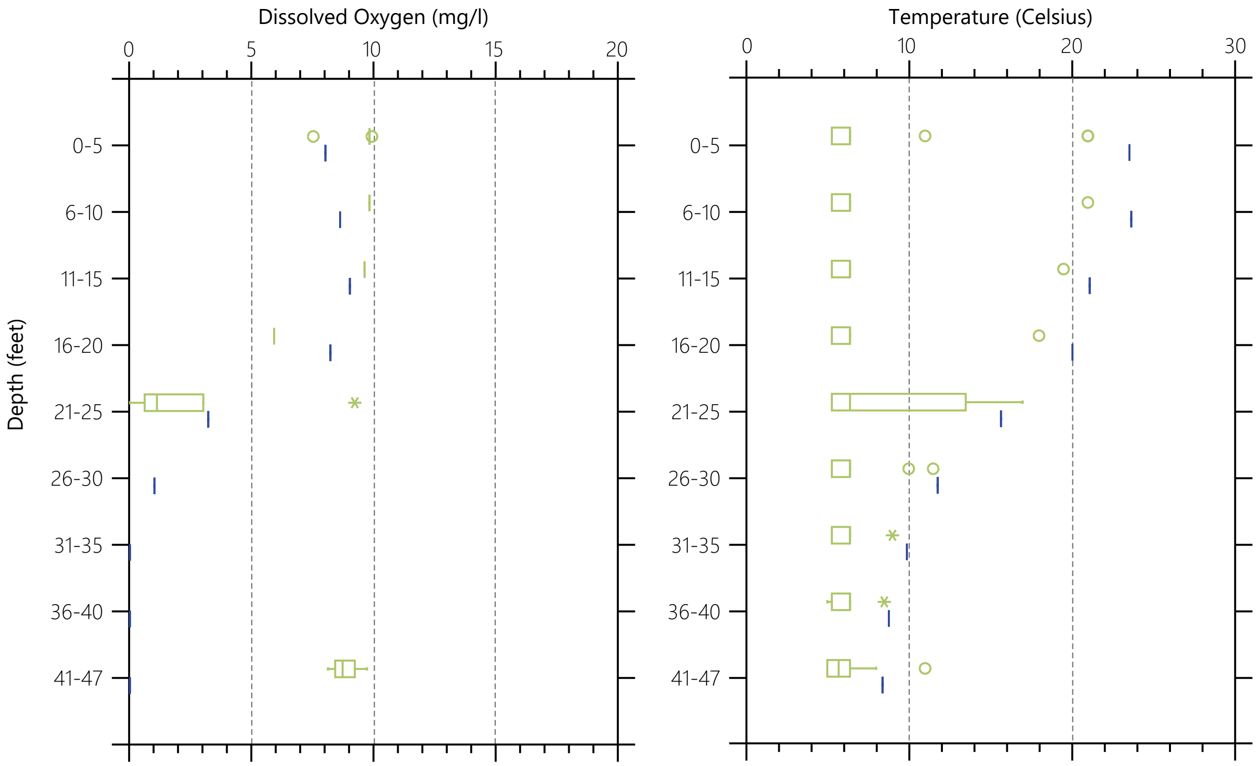
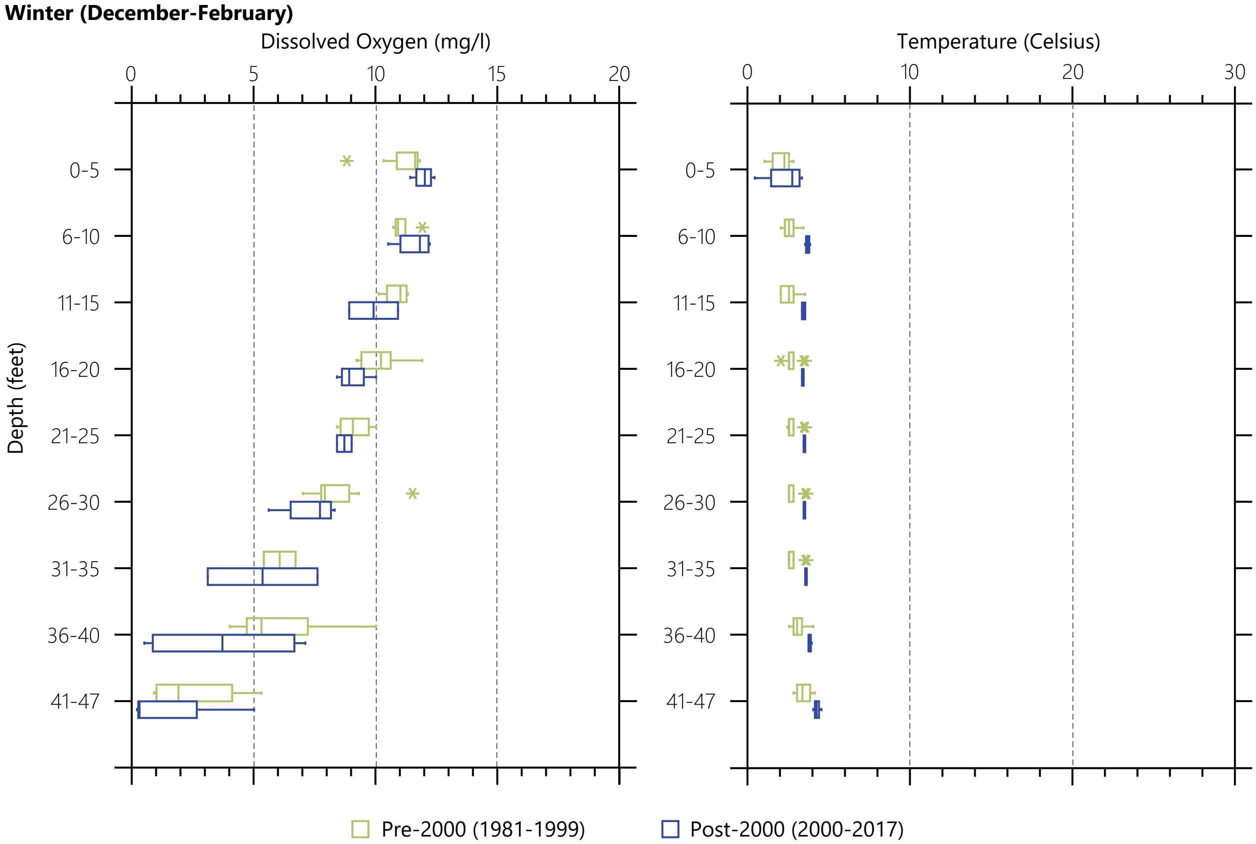


Figure 2.20 (Continued)

Fall (September-November)

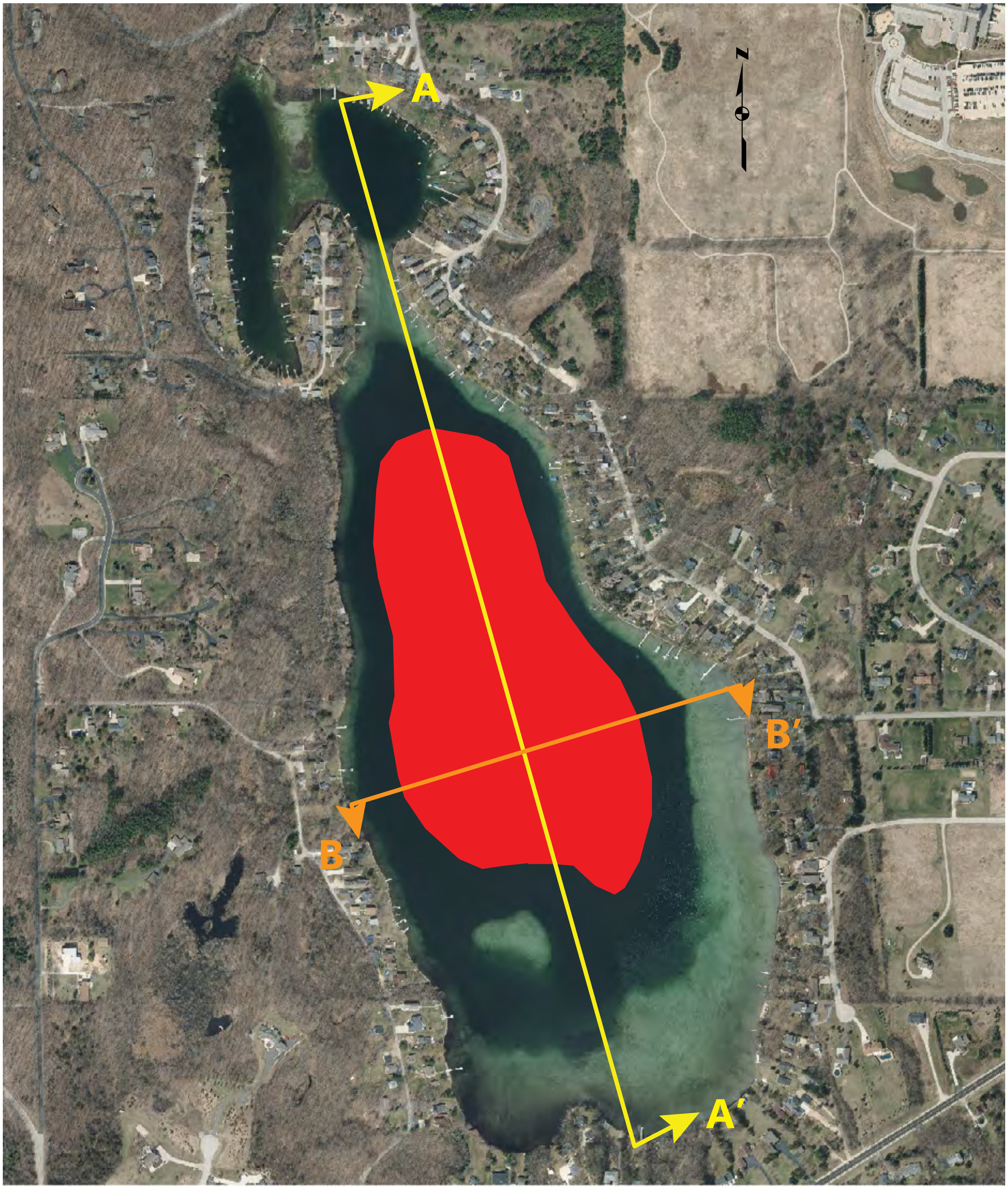


Winter (December-February)



Source: Silver Lake Management District, Wisconsin Department of Natural Resources, and SEWRPC

Figure 2.21
Typical Midsummer Extent of Silver Lake Bottom Sediment Overlain by Anoxic Water



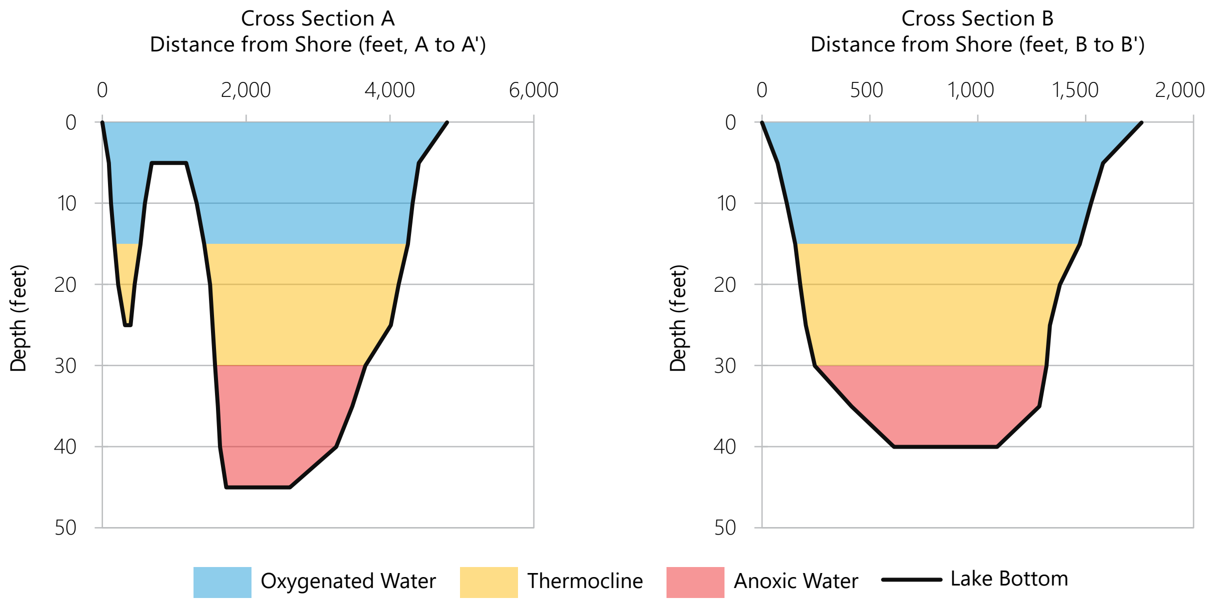
APPROXIMATE EXTENT OF BOTTOM SEDIMENT IN CONTACT WITH ANOXIC WATER

CROSS SECTION A

CROSS SECTION B

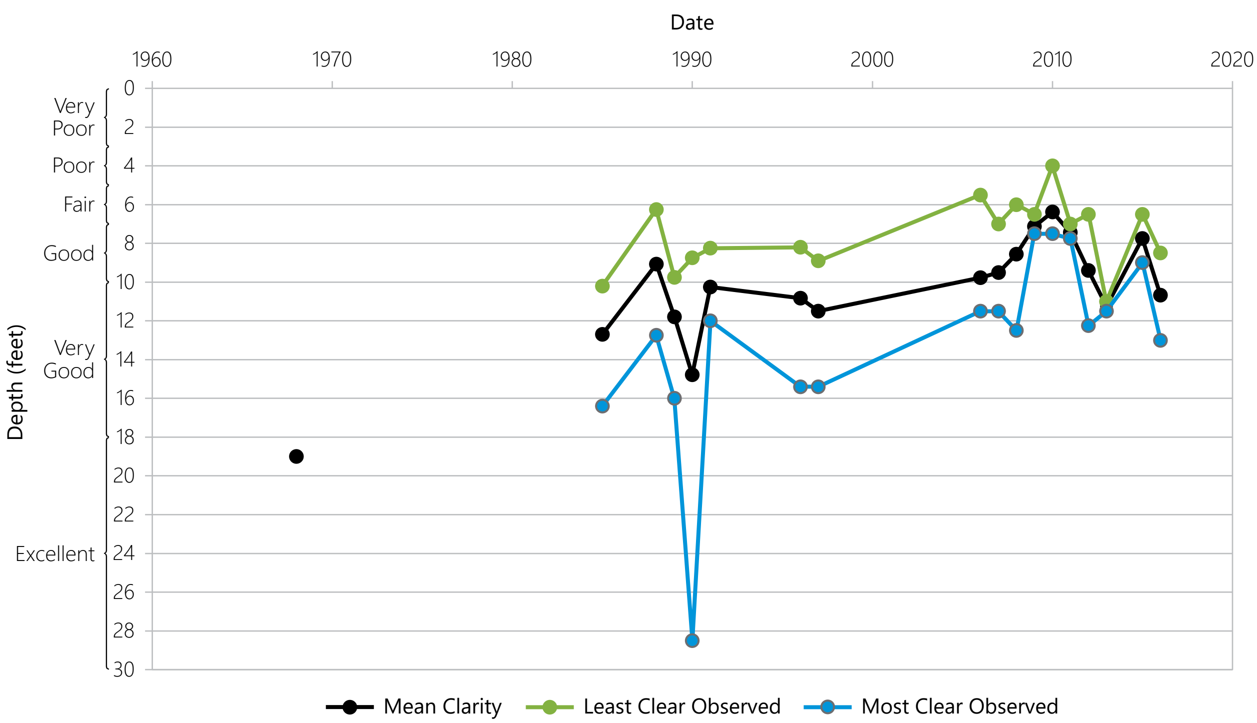
DATE OF PHOTOGRAPHY: APRIL 2015

Figure 2.21 (Continued)



Source: Wisconsin Department of Natural Resources and SEWRPC

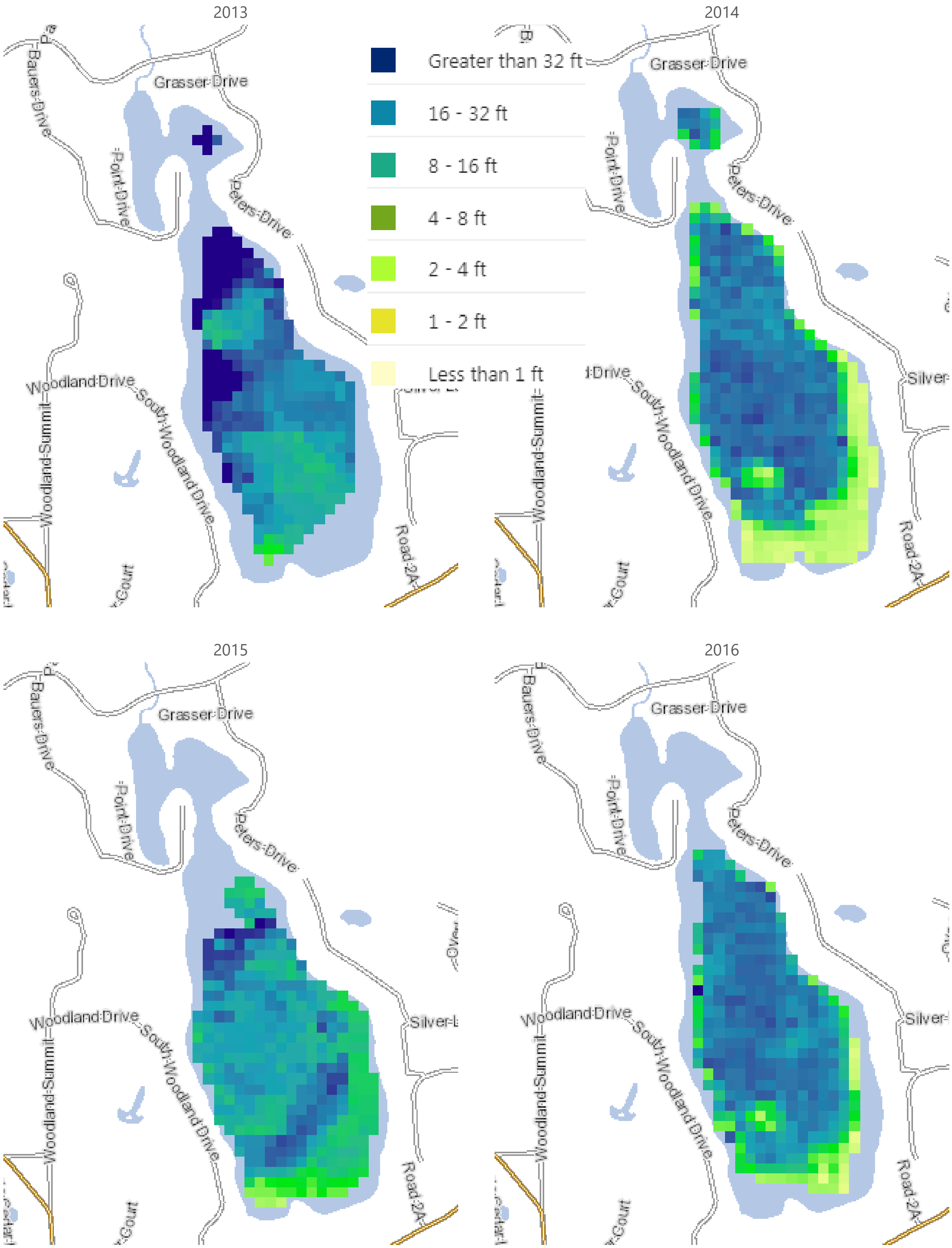
Figure 2.22
Silver Lake Summer Secchi Depth Range



Note: For the purpose of this graph, "summer" was defined as measurements collected during June, July, or August.

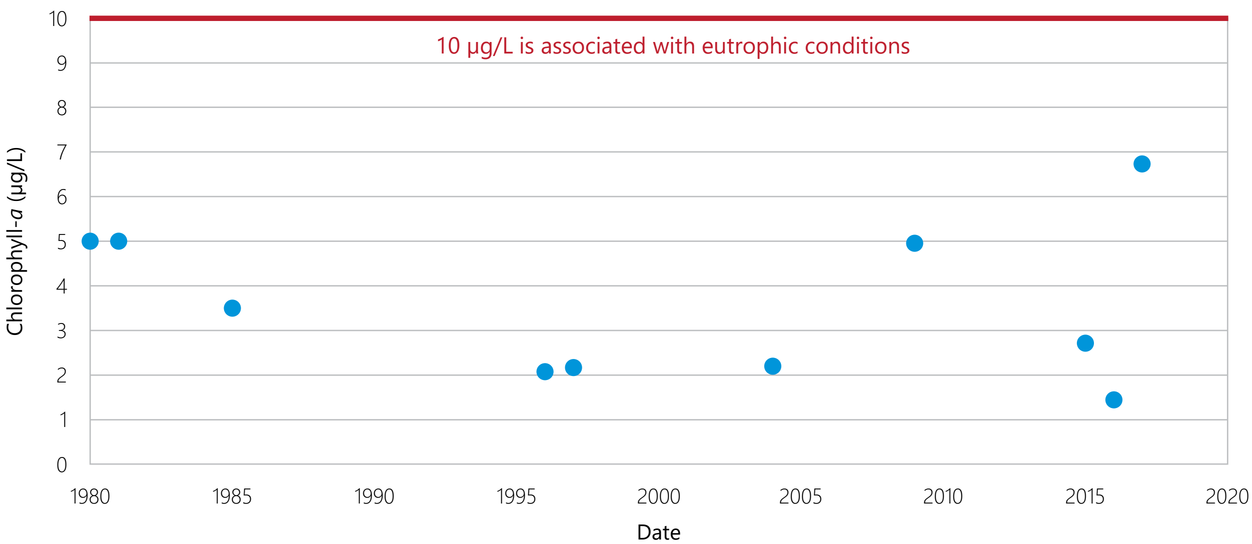
Source: Wisconsin Department of Natural Resources and U.S. Geological Survey

Figure 2.23
Silver Lake Satellite-Derived Water Clarity



Source: Wisconsin Department of Natural Resources and SEWRPC

Figure 2.24
Silver Lake Mean Chlorophyll-*a* Concentrations



Source: Wisconsin Department of Natural Resources and SEWRPC

When Silver Lake is fully mixed in the spring, phosphorus concentrations should theoretically be at all depths. While Silver Lake's phosphorus concentration are not identical at all depths when the Lake is fully mixed, they are much more similar over the Lake's water column compared to those measured when the Lake is stratified. Available data demonstrates that the Lake's hypolimnion contains considerably more phosphorus when the Lake is stratified (see Figures 2.26 and 2.27). During summer, phosphorus concentrations in water residing in the deep portions of Silver Lake approach approximately 0.100 mg/L, a value roughly six times higher than water found in shallow areas, with concentrations generally increasing as summer progresses. Similarly, during winter, phosphorus concentrations have been moderately but consistently higher in deep portions of the Lake when compared to shallow water areas (see Figure 2.27). This phenomenon suggests that Silver Lake's sediment is a likely source of phosphorus to the Lake under certain conditions (see the "Internal Loading" section below for more detail). When the Lake turns over in fall and spring, phosphorus-rich water from the Lake's depth mix with surface waters enhancing conditions favoring abundant algal growth.

Silver Lake's nitrogen concentrations also vary with season. Less nitrogen is found in near-surface water during the summer month while nitrogen concentrations are commonly higher in deep areas of the Lake when the Lake is stratified.

Nitrogen/Phosphorus Ratio

Nitrogen and phosphorus are the two nutrients most commonly limiting aquatic plant and algae growth. Phosphorus availability controls aquatic plant and algal growth in most Wisconsin lakes, however, in some lakes, nitrogen availability limits growth. Knowing which nutrient constrains plant and algal growth helps guide lake management decisions.

In general, when the ratio of total nitrogen to total phosphorus concentration is 15:1 or greater, phosphorus availability limits algal growth. Conversely when this proportion is less than 10:1, nitrogen availability limits plant growth. Ratios between 15:1 and 10:1 are transitional. It must be remembered that nitrogen/phosphorus ratios can differ seasonally and by the depth from which samples are drawn. Available data reveal that Silver Lake is consistently phosphorus limited (Table 2.9). Spring turnover nitrogen/phosphorus ratios in Silver Lake's near surface waters range from as low as 40:1 to as high as 67:1. When stratified during summer, the Lake's surface waters are even more phosphorus limited. Samples collected within the Lake's thermocline are still very phosphorus limited but samples collected from the hypolimnion, while still phosphorus limited, are approaching the transitional range at which time nitrogen becomes the nutrient limiting plant and algal growth. Because phosphorus is the nutrient in short supply, relatively small amounts of additional phosphorus fuel large increases in aquatic plant and algal abundance. For that reason, it is important to understanding the Lake's phosphorus dynamics.

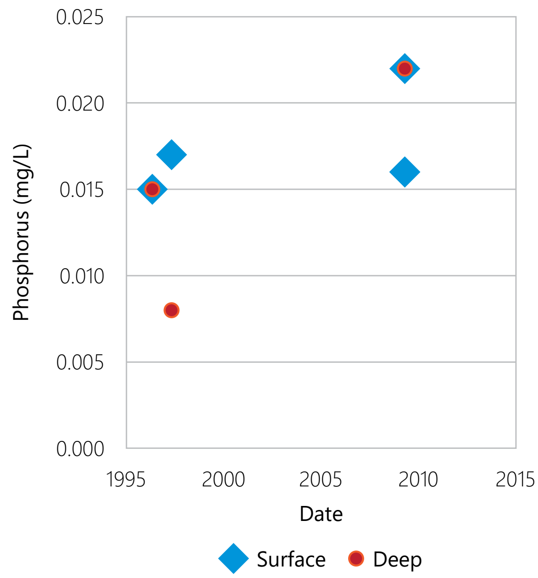
Phosphorus Sequestration

Lakes fed by calcareous mineral-rich ("hard") groundwater often develop marl deposits. Marl forms when dissolved minerals carried in groundwater are discharged to surface water yielding a solid precipitate. This process is akin to the more familiar formation of stalagmites in underground caves. Marl is mainly composed of calcium carbonate, clays, silts, and some organic detritus. Dissolved phosphorus is often coprecipitated with marl, a process that often helps reduce phosphorus available to algae and plants in lakes. In such instances, co-precipitated phosphorus is deposited as a stable mineral upon the lake bed. Over fifty percent of a lake's external phosphorus loading is typically retained in lake-bottom sediment. The actual amount of phosphorus retained in a lake varies widely with watershed and lake characteristics, but up to ninety percent can be retained in some instances.[84]

Marl formation is fostered by growth of certain aquatic plant and algae species. Marl accumulates on plant stems and leaves, and ultimately falls to the lake bottom as the algae grows and dies. Photosynthesis increases water pH in the immediate vicinity of the plant, enhancing precipitation of calcite. Muskgrass (also known as chara) is an algal species very well known for its ability to form marl. In fact, the plant's crusty nature results from deposition of hardwater minerals upon the algae's surface. Muskgrass and marl deposits are abundant in Silver Lake.

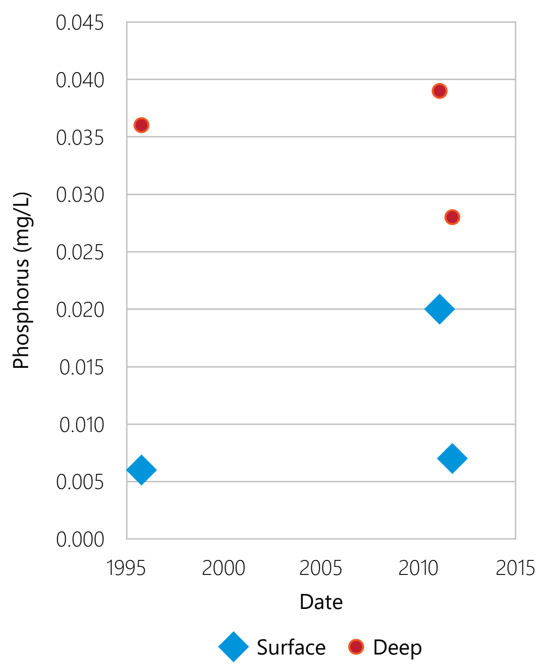
Since enriched lakes generally support more algae, enriched lakes can have a self-reinforcing positive feedback loop to sequester more phosphorus. However, calcite/phosphorus minerals may become less stable at high pH ranges, potentially reducing the effect of this feedback loop. Research in Europe has found that although marl lakes are resistant to phosphorus enrichment and eutrophication, the bottom-dwelling species of algae that promote marl production can be sensitive to long-term excessive phosphorus enrichment. Decreased water clarity associated with higher phosphorus concentrations and associated greater abundance of free-floating algae can decrease the water depth where bottom dwelling algae can grow. In turn, the extent of the lake bottom habitable to marl-precipitating algae is decreased. Less marl precipitation increases overall dissolved phosphorus in the lake which in turn fosters higher abundance of free-floating algal species. This further decreases water clarity, forming a self-reinforcing negative loop that eventually destabilizes the beneficial marl formation process. Some formerly clear European marl lakes that had successfully buffered heavy, long-term external phosphorus loads underwent rapid

Figure 2.25
Silver Lake Spring Total Phosphorus Concentrations



Source: Wisconsin Department of Natural Resources and SEWRPC

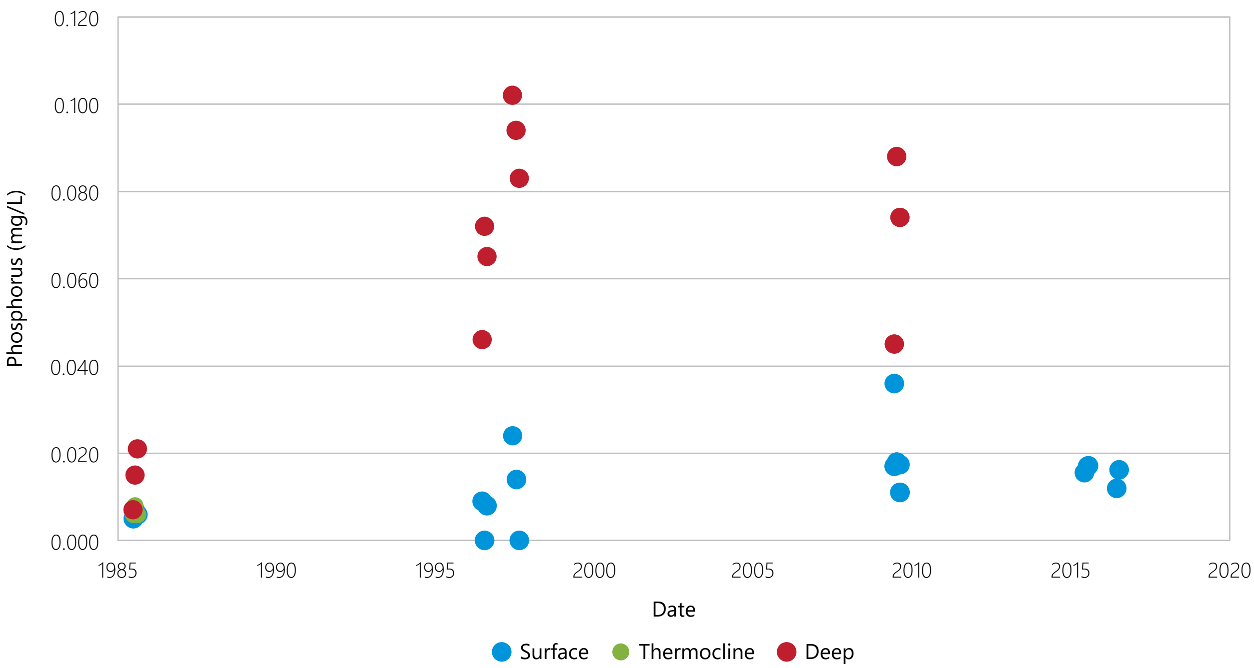
Figure 2.26
Silver Lake Winter Total Phosphorus Concentrations



Source: Wisconsin Department of Natural Resources and SEWRPC

[84] *Lijklema, L., "Phosphorus Accumulation in Sediments and Internal Loading,"* Hydrological Bulletin, *Volume 20, Issue 1, pp. 213-224, November 1986.*

Figure 2.27
Silver Lake Summer Total Phosphorus Concentrations



Source: Wisconsin Department of Natural Resources and SEWRPC

change after the lake's buffering capacity was exceeded and are now eutrophic lakes with low water clarity.[85] This illustrates how the algae-based phosphorus sequestration process is vulnerable to excessive long-term phosphorus loads, demonstrating the importance of reducing external phosphorus loads to lakes and maintaining healthy native aquatic plant communities. Furthermore, other factors that decrease water clarity (i.e., suspended sediment) can also likely disrupt phosphorus sequestration. Phosphorus sequestration may be enhanced if water clarity improves, reinforcing this beneficial process.

Sediment samples collected from the bottom of Silver Lake were found to be 21 and 36 percent calcium carbonate.[86] Since marl is composed largely of calcium carbonate, this finding suggests the significance of marl deposition in Silver Lake. Furthermore, following methods outlined in previous reports, lake water and groundwater chemistry suggests that well over 1000 pounds of calcium carbonate may be deposited as marl in Silver Lake each day.[87]

Silver Lake's shallow water phosphorus concentrations appear to have increased since the 1980s. Water clarity has also slightly declined over the same period, and the decrease appears to be related to suspended sediment. [88] Increasing phosphorus concentrations and decreasing water clarity seem to correlate with an apparent decrease in the abundance of muskgrass in the Lake. Although this three-part relationship is tentative, it does suggest that increasing suspended sediment in the water column may be decreasing the ability of muskgrass to grow in some parts of the Lake. This in turn may be reducing muskgrass's ability to precipitate

[85] *Wiik, Emma, Helen Bennion, Carl D. Sayer, Thomas A. Davidson, Suzanne McGowan, Ian R. Patmore, and Stewart J. Clarke, "Ecological sensitivity of marl lakes to nutrient enrichment: Evidence from Hawes Water,* UK", Freshwater Biology, *Volume 60, Issue 11, pp. 2226-2247, November 2015.*

[86] *SEWRPC Memorandum Report No. 123,* A Lake Protection and Recreational Use Plan for Silver Lake, Washington County, Wisconsin*, September 1997.*

[87] *SEWRPC Memorandum Report No. 123, 2nd Edition, December 2005,* op. cit.

[88] *Increased suspended sediment appears to be the primary cause of decreasing water clarity in Silver Lake. Many issues can contribute suspended sediment to the Lake. Sediment laden runoff is one potential source. However, little runoff is known to enter the Lake. Other contributors include eroding shorelines or bottom sediment resuspension, both of which can be exacerbated by excessive high-speed boat traffic and/or boating in shallow waters.*

phosphorus from the water column to the Lake bottom. If water clarity continues to decrease, a self-reinforcing loop could be strengthened where phosphorus concentrations rise, water clarity falls because of increased free-floating algal growth, and muskgrass becomes less abundant. Water clarity has not as of yet been appreciably affected by increasing free-floating algal populations. However, if phosphorus concentrations continue to rise, free floating algae could become much more abundant.

Table 2.9
Nutrient Concentrations Found Within Silver Lake's Shallow Water During April and May

Year	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	N:P Ratio
2009	0.72	0.018	40
1997	0.84	0.017	49
1996	1.00	0.015	67

Source: Wisconsin Department of Natural Resources and SEWRPC

Marl formation/phosphorus co-precipitation depends upon continued discharge of mineral-rich groundwater to springs and seeps feeding the Lake. If the supply of groundwater is reduced, the vigor of hardwater algae may be reduced, compromising the phosphorus sequestration cycle. Therefore, the Lake's groundwater supply must be protected to ensure that phosphorus sequestration remains active.

Internal Loading

In well-oxygenated water, phosphorus binds with iron, creating an insoluble mineral that settles to and accumulates upon lake bottoms. Unlike calcium-based phosphorus precipitates, iron-bound phosphorus is sensitive to the oxygen content of adjacent water. Under low-oxygen conditions, iron-bound phosphorus minerals dissolve and release phosphorus to the water column. This source of phosphorus, an important component of what is commonly referred to as *internal loading*. Internal loading can be a significant contributor to the total phosphorus available to algae in lakes, especially in lakes that have fewer sources of external phosphorus during the growing season. For this reason, the presence of anoxic water can profoundly influence the nutrient dynamics of certain lakes.

The amount of sediment exposed to anoxic water is controlled by the lake-basin shape and the depth where anoxic bottom water is found. For example, even though two lakes may have equivalent maximum depths, a lake with broad shallow areas and a small deep hole has less deepwater bottom sediment area when compared to a lake of similar maximum depth that is uniformly deep. Since sediment exposed to anoxic water can release phosphorus into the water column, lakes with more deep water sediment area are more susceptible to significant phosphorus internal loading. Moderate depth/size stratified lakes are among the most prone to internal phosphorus loading. Such lakes lack large water volumes, and, hence, have comparatively little stored oxygen in the hypolimnion, making them prone to anoxia. Up to about a third of Silver Lake's bottom can be covered by water prone to oxygen depletion during much of the summer, making internal loading of phosphorus a potential lake management concern.

It should be noted that phosphorus released to the hypolimnion is not directly available to most algae growing in a lake since little sunlight penetrates to these depths. Even though the thermocline is a barrier to circulation, it is imperfect and some phosphorus can migrate to shallower areas. For this reason, the highest levels of algal productivity are often found just above the thermocline in lakes with phosphorus internal loading creating an area prone to oxygen supersaturation in productive lakes. Wind generated mixing and/or seasonal turnover can cause water containing high phosphorus concentrations to suddenly mix with surface water, a situation that can lead to algal blooms.

Using available information and several broad assumptions, the amount of phosphorus released by sediment to lake water during a typical summer can be estimated. Anoxic water is typically found greater than 30 feet below the Lake's surface. The volume of water contained by the Lake below 30 feet is approximately 356 acre-feet. Before the Lake stratifies, the entire water column's phosphorus concentration is roughly 15 mg/L. After the Lake stratifies, phosphorus concentrations in the Lake's hypolimnion commonly increase to about 80 mg/L, a 65 mg/L increase which is likely attributable to internal loading. Assuming that little mixing occurs between the hypolimnion and epilimnion when the Lake is stratified, these data suggest that internal loading contributes roughly 63 pounds of phosphorus to Silver Lake's water column during a typical summer. Since anoxic water typically covers about 37 acres of the Lake bottom during a typical year, each acre of Lake bottom exposed to anoxic water contributes approximately 1.7 pounds of phosphorus to the water column during a typical summer. This is a relatively modest loading rate. For reference, nearby Pike Lake's internal loading rate was recently estimated to be roughly 11 pounds of phosphorus per acre per year.

Although phosphorus concentration trends in Silver Lake vary considerably from year to year, the rate at phosphorus release from the lake bottom can be roughly estimated if one assumes phosphorus is typically contributed uniformly throughout the summer (i.e., between June 1 and August 31). Typically, about 37 acres of Silver Lake's bottom sediment is covered by anoxic water (the portion of the Lake 30 or more feet deep). Using these values and the 63 pounds of phosphorus estimated to be released into the Lake during a typical summer, the unit area phosphorus flux rate can be computed.[89] Silver Lake's computed unit area phosphorus flux rate is 0.2 milligrams per square meter per day (roughly 0.02 pounds per acre per day). This value is very low when compared to the range of values determined as part of a State of Michigan lake sediment column study. The Michigan study reports unit-area phosphorus flux rates ranging from 1.6 to 29.5 milligrams per square meter per day.[90] Minnesota lakes that were eventually treated to reduce internal phosphorus loading exhibited unit area phosphorus flux rates ranging from 9.3 to 14.1 milligrams per square meter per day.[91] These comparisons suggest that internal loading is not likely a primary phosphorus source to Silver Lake.

Chloride

Chloride is toxic to aquatic life and can damage ecosystem health. For this reason, surface-water chloride concentration standards are established by *Wisconsin Administrative Code* NR 105 Surface Water Quality Criteria and Secondary Values for Toxic Substances and are used in the Wisconsin 2020 Consolidated Assessment and Listing Methodology (WisCALM) to evaluate if a waterbody is impaired. Chloride concentrations above 395 mg/L are considered to exceed chronic toxicity values while values above 757 exceed acute toxicity values.[92]

Under natural conditions, surface water and shallow groundwater in Southeastern Wisconsin contains very little chloride. Historical data suggests that before extensive development, Southeastern Wisconsin lakes commonly contained water with less than 5 mg/L chloride. Most Wisconsin lakes saw little increase in chloride concentrations until the 1960s, but concentrations rapidly increase thereafter. By the late 1970s, chloride concentrations of water from Southeastern Wisconsin lakes were markedly higher than other parts of the state. At that time, the mean chloride concentration of Southeastern Wisconsin lakes was 19 mg/L.[93]

Chloride is a "conservative pollutant" meaning that natural processes (other than evaporation) typically do not detain or remove it from water. Humans use chloride-rich substances for a multitude of purposes (e.g., road anti-icing and deicing, water softening, industrial processes). Therefore, chloride concentrations are normally positively correlated with human-derived pollutant concentrations and suggest the potential presence of a suite of human-sourced and human-enriched pollutants. These pollutants include agricultural nutrients and pesticides, pharmaceuticals, petroleum products, and a host of other substances commonly used by modern society. Since chloride is not removed by natural processes and is prolifically used by humans, chloride concentrations are an effective indicator of the overall level of human activity, potential impact, and possibly the overall health of a waterbody. Increasing chloride concentrations suggest that a lake is subject to cultural pressure and has a propensity to accumulate human-introduced substances, a condition that could reduce water quality and overall ecosystem function over time.

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[89] *Unit-area flux rate refers to the mass of a substance delivered by an area of a certain size during a unit of time.*

[90] *Steinman, Alan, Rick Rediske and K. Ramesh Reddy, "The Reduction of Internal Phosphorus Loading Using Alum in Spring Lake, Michigan,"* Journal of Environmental Quality, *Volume 33:2040-2048, 2004.*

[91] *Bassett Creek Watershed Management Commission,* Twin Lake Phosphorus Internal Loading Investigation, *March, 2011.*

[92] Wisconsin Administrative Code *Chapter NR105 Water Quality Standards for Wisconsin Surface Waters provides the following definitions. "Chronic toxicity" means the ability of a substance to cause an adverse effect in an organism which results from exposure to the substance for a time period representing a substantial portion of the natural life expectancy of that organism. "Acute toxicity" means the ability of a substance to cause mortality or an adverse effect in an organism which results from a single or short-term exposure to the substance.*

[93] *Lillie, Richard A. and John W. Mason, 1983, op. cit.*

Silver Lake's chloride concentrations have been measured over time (see Figure 2.28). Chloride concentrations have increased nearly linearly from 3 to 4 mg/L in 1968 to almost 37 mg/L during 2019. Chloride concentrations in water issuing from springs feeding the southwest corner of Silver Lake were also measured as part of the current study. Given that groundwater is a major source of water to the Lake, it is not surprising to find that the concentrations of chloride in the springs feeding the Lake have increased from 12.4 mg/l during 1976 to 28.9 mg/L in 2018. The rate of groundwater chloride concentration increase is similar, yet slightly lower, than the rate of chloride concentration in Lake water. This finding suggests that chloride carried in surface runoff is likely a significant supplemental source of chloride to the Lake.

Although Silver Lake's chloride concentrations are increasing, the Lake has some of the lowest chloride concentrations found in surface water in Southeastern Wisconsin. Nevertheless, chloride concentrations are nearly ten times higher than they were only 51 years ago and are continuing to increase. Furthermore, although the Lake's chloride concentrations do not exceed acute or chronic toxicity values and are low when compared to many other waterbodies in Southeastern Wisconsin, different plant and animal species have varying abilities to survive or thrive in saltier environments. For example, reed canary grass, a common invasive species of wetland and riparian settings, is well-adapted to saltier environments.[94] Similarly, Eurasian watermilfoil (EWM) (*Myriophyllum spicatum*) can survive levels of industrial and salt pollution that eliminates native aquatic plants.[95] At least a few invasive animal species are also more tolerant of saltier water than native fish species. For example, invasive round goby (*Neogobius melanostomus*), a fish introduced from brackish water areas of Eurasia, grows better in higher salt environments and tolerates salt concentrations that are lethal to native fish species.[96] Progressively higher chloride concentration may increasingly favor undesirable changes to the Lake's flora and fauna. For this reason, lake management decisions should consider ways to reduce the mass of salt imported and applied to the land area contributing surface water and groundwater recharge feeding Silver Lake.

Responding to questions posed during the SLPRD's 2018 annual meeting, the Commission evaluated the influence of the public sanitary sewer system on Lake chloride concentrations. The public sanitary sewers receive water from residences ringing the Lake, and export water from the Lake's watershed through a lift station. If these homes were instead served by septic tanks and absorption beds, most chloride discharged by these homes would ultimately reach the Lake. The Commission collected two samples from the sanitary sewer lift station and submitted them for laboratory analysis. The October 19, 2018 sample contained 999 mg/L chloride while the December 17, 2019 sample contained 686 mg/L chloride, for an average of 843 mg/L chloride. The Silver Lake Sanitary District reports that the approximately 21,000 gallons of day are discharged to sanitary sewers in the Silver Lake area. Therefore, using average flow and concentrations, the public sanitary sewers divert roughly 15,000 pounds per year of chloride that may otherwise discharge to the Lake. This is equal to the chloride found in roughly 12 ½ tons of rock salt, the maximum amount of salt typically carried in two large road service dump trucks. If this amount of salt entered the Lake, estimates of Lake volume and hydraulic residence time suggest that current Lake water chloride concentrations would increase by roughly 8 mg/L. Following similar logic, and assuming that all chloride entering the Lake is sodium chloride sourced, this line or reasoning suggests that human influence is currently contributing over 50 tons of salt to the Lake each year.

The USGS estimated the amount of chloride discharged to the Lake each year as part of its 2003 report.[97] Using the 12.4 mg/l chloride concentration measured during 1976, the USGS estimated that groundwater contributed roughly 33 kilograms of chloride to the Lake each day. During October 2018, water entering the Lake from springs near the Lake's southwest corner contained 28.9 mg/L chloride. Substituting the 2018 chloride values for the 1976 values suggests that groundwater presently contributes roughly 77 kilograms

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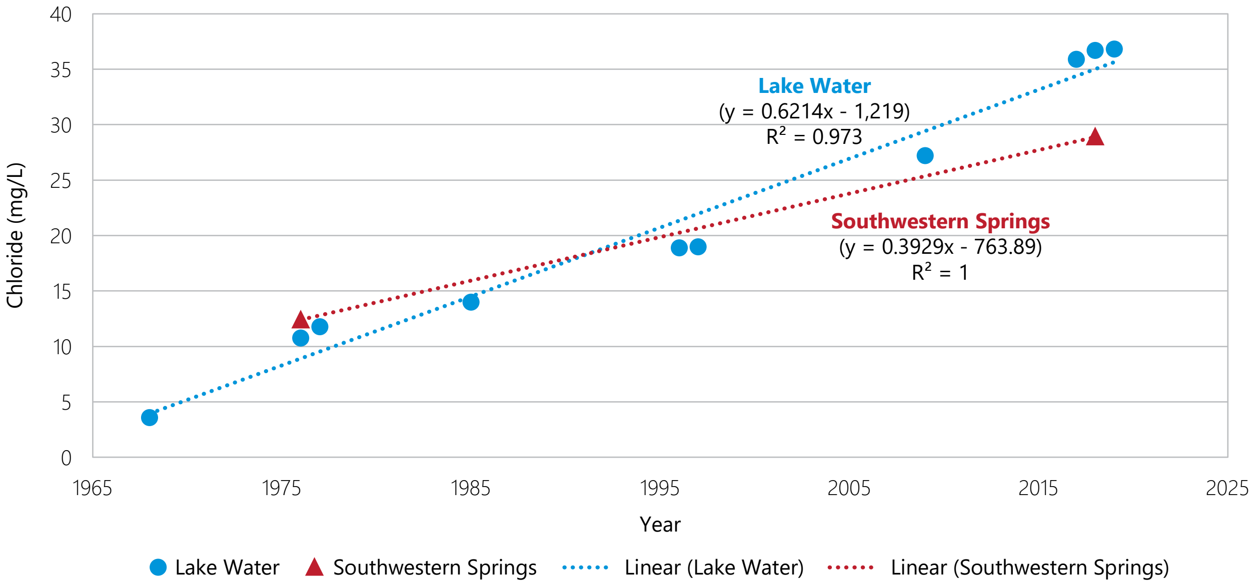
94 *Prasser, Nick and Joy Zedler, "Salt Tolerance of Invasive Phalaris arundinacea Exceeds That of Native Carex Stricta (Wisconsin)*," Ecological Restoration *Volume 28, Number 3: 238-240, August 2010*.

95 *Schuyler, A. E., S. B. Anderson, and V. J. Kolaga, "Plant Zonation Changes in the Tidal Portion of the Delaware River*," Proceedings of the Academy of Sciences of Philadelphia, *Volume 144: 263-266, 1993*.

96 *Karsiotis, Susanne, Lindsey Pierce, Joshua Brown, and Carol Stepien, "Salinity Tolerance of the Invasive Round Goby: Experimental Implications for Seawater Ballast Exchange and Spread to North American Estuaries,"* Journal of Great Lakes Research, *Volume 38, Issue 1, pp 121-128, March 2012*.

97 *Dunning, C. P., J.C. Thomas, and Y-R Lin, 2003, op. cit.*

Figure 2.28
Chloride Concentrations Measured in Silver Lake and Contributing Springs



Note: An arithmetic mean was calculated for each sample date, if multiple samples were taken at different depths, in order to generate a single value per sample date.

Source: Wisconsin Department of Natural Resources and SEWRPC

of chloride to the Lake each day. Similarly, since pre-settlement groundwater chloride concentrations in surface and shallow groundwater in Southeastern Wisconsin typically were 4 mg/L, groundwater naturally delivers about 11 kilograms of chloride to Silver Lake each day. This suggests that human activity currently delivers 66 kilograms of chloride to Silver Lake each day. Sixty-six kilograms of chloride is roughly equivalent to the mass of chloride contained in 109 kilograms of rock salt. Therefore, the USGS approach suggests that during late 2018, human activity likely contributes roughly 44 tons of salt per year through groundwater. It must be remembered that the USGS study only accounts for chloride delivered to the Lake via groundwater. Contrasting this value to the Commission's Lake volume derived salt loading of 50 tons suggests that most human-activity derived salt entering Silver Lake is delivered to the Lake via groundwater.

Alkalinity

Alkalinity expresses water's ability to neutralize acid. Lakes in Southeastern Wisconsin are generally well buffered by highly alkaline water. In the Region, alkalinity correlates with water hardness. Hardwater lakes commonly experience marl precipitation and, relatedly, phosphorus sequestration. Rainwater is essentially free of hardness and is acidic. Most lake water alkalinity is derived from minerals dissolved from rock and sediment. For this reason, groundwater is the major source of alkalinity to most lakes and rivers in Southeastern Wisconsin. Therefore, groundwater sourced lake water supplies in concert with healthy native aquatic plant communities drives the important phosphorus sequestration process.

Relatively little alkalinity data is available for Silver Lake. However, alkalinity levels have varied very little over time, with concentrations varying between 217 to 268 mg/L from 1985 to 2009. At times, alkalinity concentrations from deep portions of Silver Lake are slightly higher than concentrations for shallower areas. The most recent alkalinity sample (collected from shallow water during spring 2009) exhibited an alkalinity concentration of 248 mg/L.

Trophic State

Trophic state index (TSI) equations are used to convert summer water clarity, chlorophyll-*a*, and phosphorus measurements to a universal unit used to assess the overall productivity of a lake and allow lake-specific information to be compared and contrasted to other lakes.[98] TSI values based upon chlorophyll-*a* are considered the most reliable estimators of lake trophic state.

Silver Lake's historical TSI values are compared in Figure 2.29. From these data, It is clear that Silver Lake is a mesotrophic Lake. Mesotrophic lakes are typically clear, have little oxygen in their hypolimnia, have good fisheries, commonly have organic-rich sediment on portions of the lake bottom, and have beds of submerged aquatic plants. Mesotrophic lakes can occasionally experience algal blooms. Over the 31-year period of record, Silver Lake's TSI values have varied, with water clarity experiencing the largest variation. Both water clarity and phosphorus TSI have very slight increasing trends while chlorophyll-*a* values appear to be static or possibly slightly declining.

Contrasting TSI values provides insight on in-Lake processes. Chlorophyll-*a* TSI values appear to have declined since about 2010 (Figure 2.29), but overall seem to have been reasonably stable or slightly declining throughout the period of available record, suggesting that the Lake may be gradually shifting to a condition more representative of a less nutrient rich state. However, the phosphorus and Secchi trend lines for the same period are increasing. This apparent contradiction of decreased algae in the face of increasing phosphorus (the primary nutrient utilized by algae) would likely be related to zooplankton grazing or zebra mussels (zooplankton and zebra mussels feed on algae).[99] Given that chlorophyll-*a* values are slightly decreasing, factors other than algal abundance may be responsible, at least in part, for causing the Lake to be less clear than in the past. Suspended sediment could be the cause. Given that the modeling conducted for this plan does not suggest that more sediment is reaching the Lake from the watershed, sediment disturbed and resuspended by boat traffic may be a cause. And, as discussed in the phosphorus section, decreasing water clarity may be decreasing the abundance of muskgrass which in turn decreases muskgrass' phosphorus sequestration function in Silver Lake, which in turn could cause phosphorus concentrations to further rise.

Sediment

As part of the natural aging process, lake basins gradually fill with sediment. Most sediment is derived from four sources as described below.

- **Sediment carried from external sources to a lake by moving water.** Much of the sediment carried to lake basins by moving water is comprised of inorganic materials such as sand, silt, and clay. Tributaries are the primary source of such sediment to most lakes, but general overland flow and shoreline erosion can also be significant contributors to a lake's overall sediment load. In general, lakes with large watersheds and tributaries receive most sediment load from streams and rivers while lakes with small watersheds receive most of their sediment load from direct overland flow. Coarser-grained sediments (i.e., silt, sand, and gravel) are commonly deposited near the point where moving water enters a lake. Therefore, areas well offshore or otherwise distant from moving water sediment sources are only likely to accumulate clay-size sediment. The amount and composition of sediment entering lakes is highly dependent on lake- and watershed-specific factors and is, therefore, highly variable.

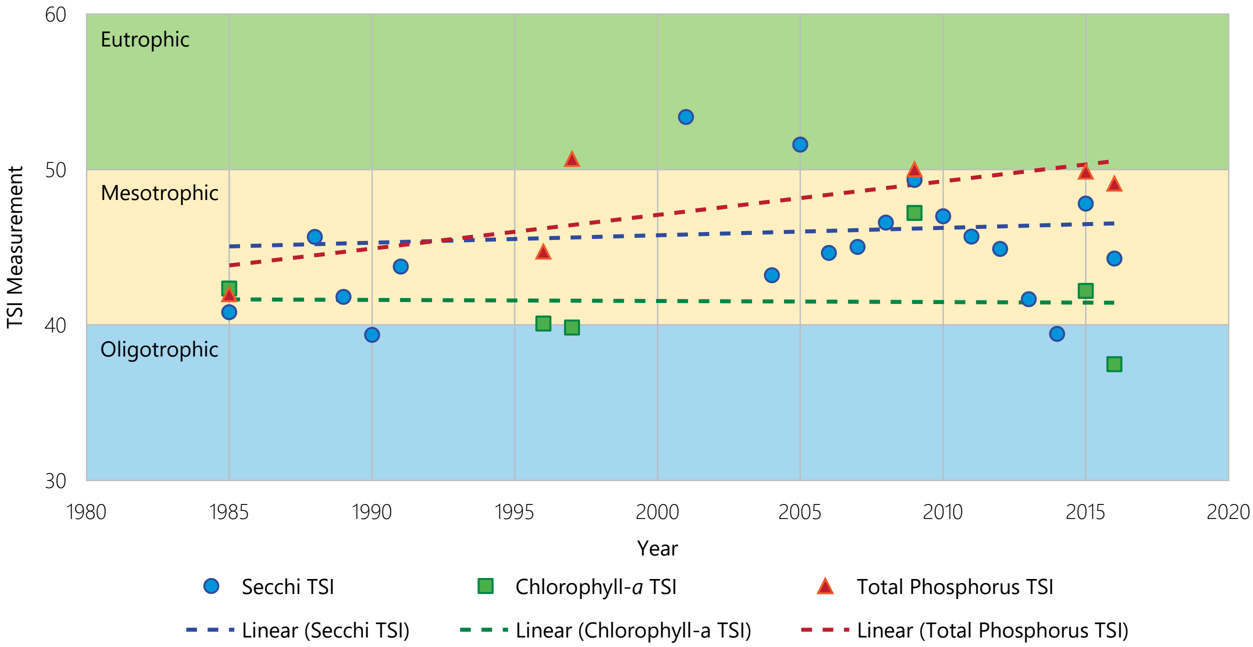
- **Sediment carried to lakes by wind.** Significant amounts of sediment can be deposited into lakes from the atmosphere. Southeastern Wisconsin lakes commonly receive roughly 200 pounds of sediment per acre from atmospheric fallout.

- **Sediment formed by geochemical processes within a lake.** In most Southeastern Wisconsin lakes, groundwater entering the lake is "hard" meaning that it is rich in carbonate minerals. These minerals precipitate in a lake, a process promoted by biogeochemical processes associated with photosynthesis. As noted previously, the carbonate minerals precipitated from lake water often co-precipitate phosphorus, and the mixture of carbonate and phosphate minerals that settles to the lake bottom is often termed "marl." Marl deposits are common in Southeastern Wisconsin lakes that receive abundant groundwater discharge. The amount of marl deposited in lakes is extremely variable.

[98] *Lillie, R. A., 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.*

[99] *Zebra mussels were verified to exist in Silver Lake during 2011.*

Figure 2.29
Silver Lake Summer-Season Trophic State Indices



Note: June-August data of each year was averaged to produce the resultant values.

Source: Wisconsin Department of Natural Resources and SEWRPC

- **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 is highly variable and is highly dependent upon the level of lake nutrient enrichment.

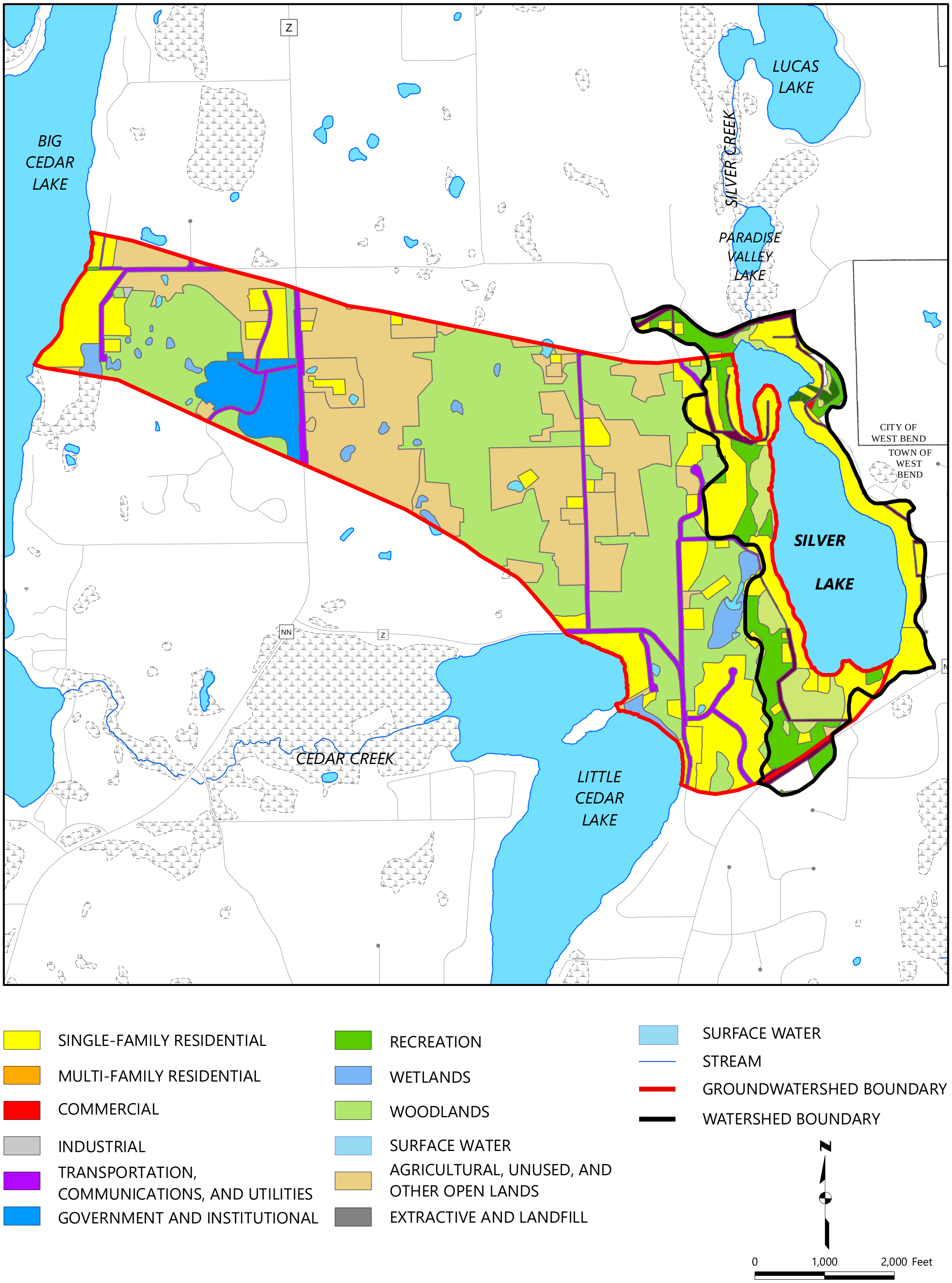
Watershed Sourced Loads

Different land uses can contribute different types of substances to a lake. Although it is normal for some sediment and nutrients to enter a lake from the surrounding lands (contributing to the natural lake aging process), it becomes an issue of concern when human activity accelerates erosion and nutrient loss to lakes or when people introduce pollutants not normally found in the environment of Southeastern Wisconsin (examples include heavy metals, fertilizers, and oils). Sediment and nutrient loads can greatly increase when land is disturbed through tilling and construction, processes that destroy natural vegetation, loosen soils, promote to loosen and thereby promote soil erosion and nutrient release. Furthermore, human disturbance typically increases and/or more intensifies runoff, a situation that typically diminishes the watershed's ability to filter and absorb pollutants before they enter lakes and streams.

The amount of sediment, phosphorus, and certain other pollutants released by various land uses have been studied for many years. The amount of pollutants entering a waterbody can therefore be estimated by examining watershed hydrology and land use. The extent of the watershed and the presence of internally drained areas within the watershed was estimated. Historical, current (2015, Map 2.8), and planned (Map 2.15) watershed land use information were mapped. Models were then used to estimate annual sediment, nutrient, and pollutant loads to Silver Lake.[100]

[100] *Nonpoint-source phosphorus, suspended solids, and urban-derived metal inputs to Silver Lake were estimated using the Wisconsin Lake Model Spreadsheet (WiLMS version 3.3.18), and SEWRPC's Unit Area Load (UAL) model developed for use within Southeastern Wisconsin. Both models presume that each acre of a particular land use emits a typical pollutant mass each year.*

Map 2.15
Planned Land Use Near Silver Lake



Source: SEWRPC

The Commission's unit area load (UAL) model used land use and watershed configuration information to estimate past, present, and near-term future pollutant (sediment, phosphorus, copper, and zinc) loads potentially entering the Lake (see Table 2.10). This model assumes that urban land use is the only significant source of heavy metals. Heavy metal monitoring has not occurred within the Lake. However, urbanized areas should be targeted if heavy metals become an issue within the Lake in the future. On account of its very small watershed, the UAL model predicts that the atmosphere was the dominant source of sediment and phosphorus to the Lake before European settlement. Before settlement, the atmosphere contributed 97 percent of the sediment and almost 70 per cent of the phosphorus entering the Lake. At the present time, the UAL model suggests that the atmosphere remains the dominant source of sediment to the Lake, now accounting for about 80 percent of the sediment entering the Lake from atmospheric fallout and runoff.[101] The UAL model predicts that about 15 tons of sediment are contributed to the Lake each year by external sources. Although the atmosphere remains the predominant source of sediment to the Lake, the UAL models predicts that runoff from lands used for residential, transportation, and recreational purposes now contribute over half of the phosphorus entering the Lake. The UAL model predicts that 43 pounds of phosphorus enter the Lake each year from atmospheric fallout and runoff. Furthermore, the UAL model predicts that one pound of copper and 7.3 pounds of zinc also are believed to enter the Lake each year. Given that the watershed is small and essentially fully developed, sediment, phosphorus, and heavy metal loads under planned land use conditions are not expected to increase.

The Wisconsin Lake Model Suite (WiLMS) also estimates external phosphorus loading to the Lakes. Similar to the approach employed by the UAL model, information regarding land use, hydrologic, and watershed area are used to estimate the total flux of phosphorus to a lake during a typical year. The WiLMS model produces a range of probable phosphorus load values (low, most likely, and high). Load estimates are 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 equations are designed for reservoirs, some for deep lakes, while others are general lake models.

Under 2015 land use conditions, the WiLMS model predicts between 33 and 83 pounds of phosphorus could be delivered to Silver Lake per year by runoff and atmospheric deposition, values that agree well with the phosphorus load estimates generated by the UAL model. Contrasting the output of the two models, phosphorus loads to the Lake likely lie midway between the WiLMS model low and high range estimates.

The WiLMS model has the capacity to include point source loads in the in-lake phosphorus prediction model. This function is useful for Silver Lake, which is heavily influenced by groundwater contributions. The groundwater phosphorus contribution can be included in the in-lake phosphorus prediction module by entering it as a point source load. Based upon data obtained by CDM/Limnetics (1976/1977), the groundwater inflow rate of 1.08 cubic feet per second, and with the use of data from wells upgradient of Silver Lake, the USGS calculated about 48 pounds of phosphorus were transported by groundwater to Silver Lake each year.[102] Adding this value doubles total estimated phosphorus load to the lake and dramatically influences in-lake phosphorus estimates.

Several in-lake phosphorus models provided relatively accurate estimates of growing season mean phosphorus concentrations in Silver Lake. However, the Dillon-Rigler-Kirchner model seems to best match available phosphorus data and would be most useful for predicting past and future in-lake phosphorus concentrations. Since phosphorus loads are not projected to increase under planned land use conditions, models predict static phosphorus concentrations in the near future. Under pre-settlement conditions, the model predicts that the Lake's growing season mean phosphorus concentrations would have been 0.007 to 0.010 mg/L compared to the 0.015 mg/L measured in the recent past. With phosphorus concentrations this low, Silver Lake was likely an oligotrophic lake before the advent of significant human influence.

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[101] *Sediment loads to most Southeastern Wisconsin lakes dramatically increased after European settlement, with post-settlement sediment loads commonly up to ten times higher compared to pre settlement conditions. Another fact underscoring the Lake's unique setting and watershed is that agriculture contributes no sediment or phosphorus to the Lake. Agriculture is the dominant external present-day sediment and phosphorus source to most Southeastern Wisconsin Lakes.*

[102] *Dunning, C. P., J.C. Thomas, and Y-R Lin, 2003, op. cit.*

Table 2.10
Silver Lake's Estimated Annual Pollutant Loading

Land Use Category	Pre-settlement Estimate Pollutant Load			
	Sediment (tons/year)	Phosphorus (pounds/year)	Copper (pounds/year)	Zinc (pounds/year)
Urban				
Residential	0.0	0.0	0.0	0.0
Commercial	0.0	0.0	0.0	0.0
Industrial	0.0	0.0	0.0	0.0
Government	0.0	0.0	0.0	0.0
Transportation	0.0	0.0	0.0	0.0
Recreational	0.0	0.0	0.0	0.0
Urban Subtotal	0.0	0.0	0.0	0.0
Rural				
Agricultural	0.0	0.0	0.0	0.0
Wetlands	0.1	1.8	0.0	0.0
Woodlands	0.3	5.4	0.0	0.0
Rural Subtotal	0.4	7.2	0.0	0.0
Water				
Silver Lake Atmospheric Deposition	11.8	16.4	0.0	0.0
Other Water Body Atmospheric Deposition	0.0	0.0	0.0	0.0
Water Subtotal	11.8	16.4	0.0	0.0
Total	12.2	23.6	0.0	0.0

Land Use Category	Pollutant Loads: 2015			
	Sediment (tons/year)	Phosphorus (pounds/year)	Copper (pounds/year)	Zinc (pounds/year)
Urban				
Residential	2.8	21.0	1.0	7.3
Commercial	0.0	0.0	0.0	0.0
Industrial	0.0	0.0	0.0	0.0
Government	0.0	0.0	0.0	0.0
Transportation	0.1	1.7	0.0	0.0
Recreational	0.0	0.5	0.0	0.0
Urban Subtotal	2.9	23.2	1.0	7.3
Rural				
Agricultural	0.0	0.7	0.0	0.0
Wetlands	0.0	1.0	0.0	0.0
Woodlands	0.1	1.8	0.0	0.0
Rural Subtotal	0.1	3.5	0.0	0.0
Water				
Silver Lake Atmospheric Deposition	11.8	16.4	0.0	0.0
Other Water Body Atmospheric Deposition	0.0	0.0	0.0	0.0
Water Subtotal	11.8	16.4	0.0	0.0
Total	14.8	43.1	1.0	7.3

Table continued on next page.

The reader should note that these model predictions are based solely on watershed conditions and do not include factors such as changes to rough fish control, shoreline management, aquatic plant harvesting, and other management tools. For example, stringent stormwater quality practices could decrease external phosphorus loads reaching the Lake. Another example would be widespread adoption of lake friendly residential best management practices. Finally, some of the watershed and much of the groundwatershed lie beyond planned sanitary sewer service areas. Without proper maintenance, septic systems can malfunction possibly causing bacterial contamination and increased phosphorus loadings to the Lake and the groundwater. Therefore, management of current systems and any new systems is discussed in Chapter 3 of this report.

Table 2.10 (Continued)

Land Use Category	Pollutant Loads: Planned Land Use Sediment (tons/year)	Phosphorus (pounds/year)	Copper (pounds/year)	Zinc (pounds/year)
Urban				
Residential	2.8	21.0	1.0	7.3
Commercial	0.0	0.0	0.0	0.0
Industrial	0.0	0.0	0.0	0.0
Government	0.0	0.0	0.0	0.0
Transportation	0.1	1.7	0.0	0.0
Recreational	0.0	0.5	0.0	0.0
Urban Subtotal	2.9	23.2	1.0	7.3
Rural				
Agricultural	0.0	0.7	0.0	0.0
Wetlands	0.0	1.0	0.0	0.0
Woodlands	0.1	1.8	0.0	0.0
Rural Subtotal	0.1	3.5	0.0	0.0
Water				
Silver Lake Atmospheric Deposition	11.8	16.4	0.0	0.0
Other Water Body Atmospheric Deposition	0.0	0.0	0.0	0.0
Water Subtotal	11.8	16.4	0.0	0.0
Total	14.8	43.1	1.0	7.3

Source: SEWRPC

Lake Basin Sedimentation

The Commission's 2005 plan mapped sediment composition and identified areas of the Lake bottom covered with silt, sand, or a silt/sand mixture.[103] Most of the Lake's basin was reported to be covered with a silt/sand mixture. However, sand was the predominant substrate in water less than 20-feet deep along the east and west shorelines. Smaller areas of sand bottom, mostly confined to shallow depths, were found in the southeastern corner and the far north end of the Lake. Silt was the predominant lake bottom substrate in four areas around the Lake: in the southeastern and southwestern corners of the Lake, along the west shore just south of the narrows, and in the narrows, itself. Sediment samples from selected areas of the Lake were analyzed for selected pesticides, hydrocarbons, and metals. The laboratory results demonstrated that the concentrations of selected pollutants in Lake sediments at the sampled locations were below State of Wisconsin sediment guideline values.

Soft sediment depths in the Silver Lake basin were measured by Commission staff in 2007 and again in 2015. The 2015 survey included a modest number of measurements in several isolated areas of the Lake (see Figure 2.30). Soft sediment depth in the Lake ranged from zero to over 10 feet in the south end of the northern kettle; mostly less than three feet along the east side of the narrows, although one or two spots in the narrows had sediment in excess of six fee. In the extreme southwestern corner of the Lake, less than a foot of soft sediment was found in the nearshore area, while six to ten feet of soft sediment were found farther from shore.

Soft sediment accumulation for a much larger portion of the Lake bottom can be crudely estimated by contrasting water depths measured as part of the 2015 aquatic plant inventory to the WDNR's Silver Lake bathymetric map. Since 46 years elapsed between the time when WDNR mapped Lake water depths and the 2015 aquatic plant inventory, a loss of water depth at any given sampling site can be interpreted as sediment accretion. Figure 2.31 superimposes 2015 water depths over the 1969 WDNR bathymetric map. Based on this method, the 2015 water depths appear to be fairly similar to the WDNR bathymetry lines except for nearshore areas in the south and southeast shorelines where 2015 water depths of less than five feet are well outside the 1969 bathymetric map five-foot depth contour. While this method provides very

[103] *SEWRPC Memorandum Report No. 123, 2nd Edition, December 2005, op. cit.*

Figure 2.30
Soft Sediment Thickness Measured in Silver Lake: July 2015

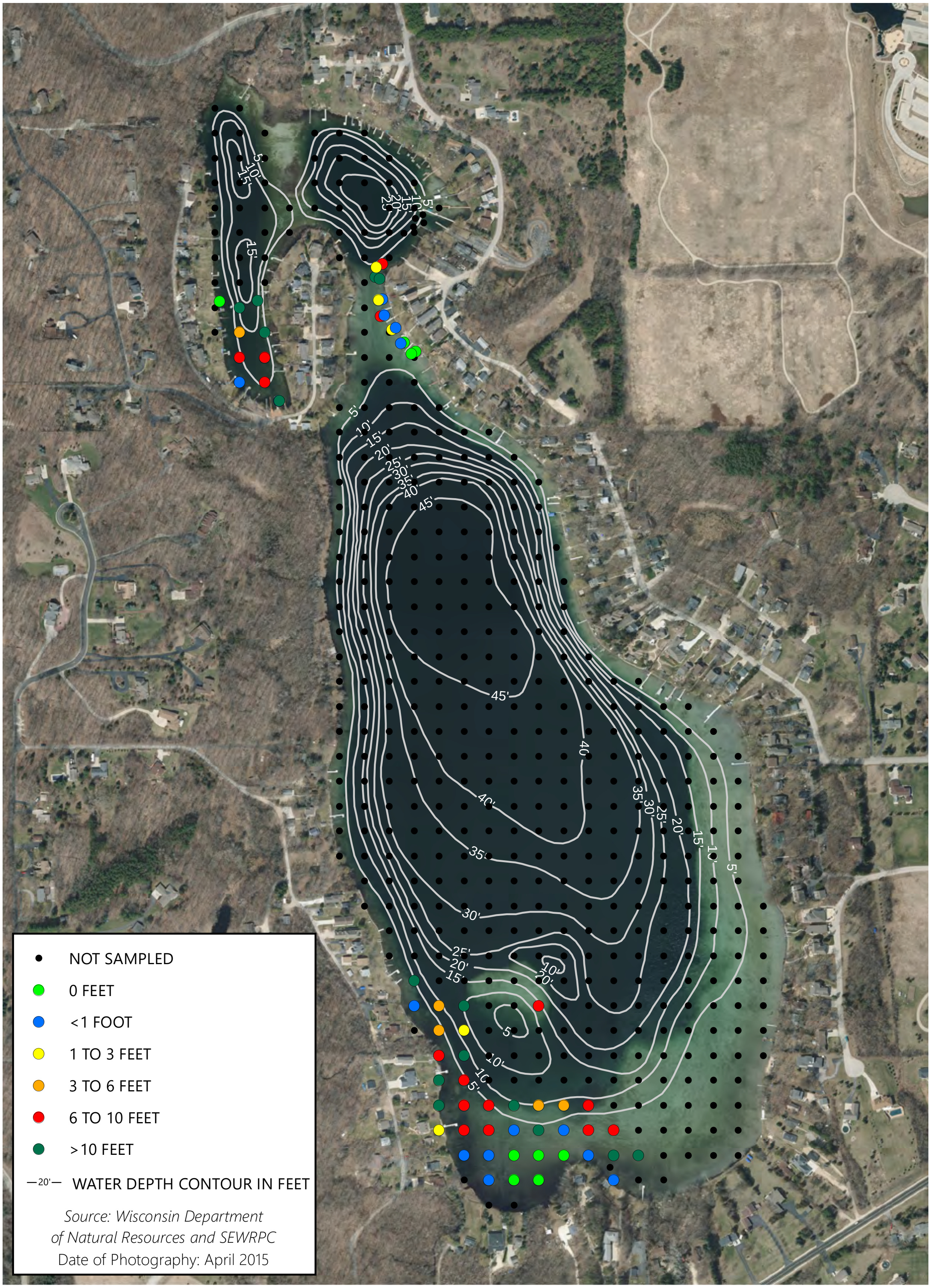
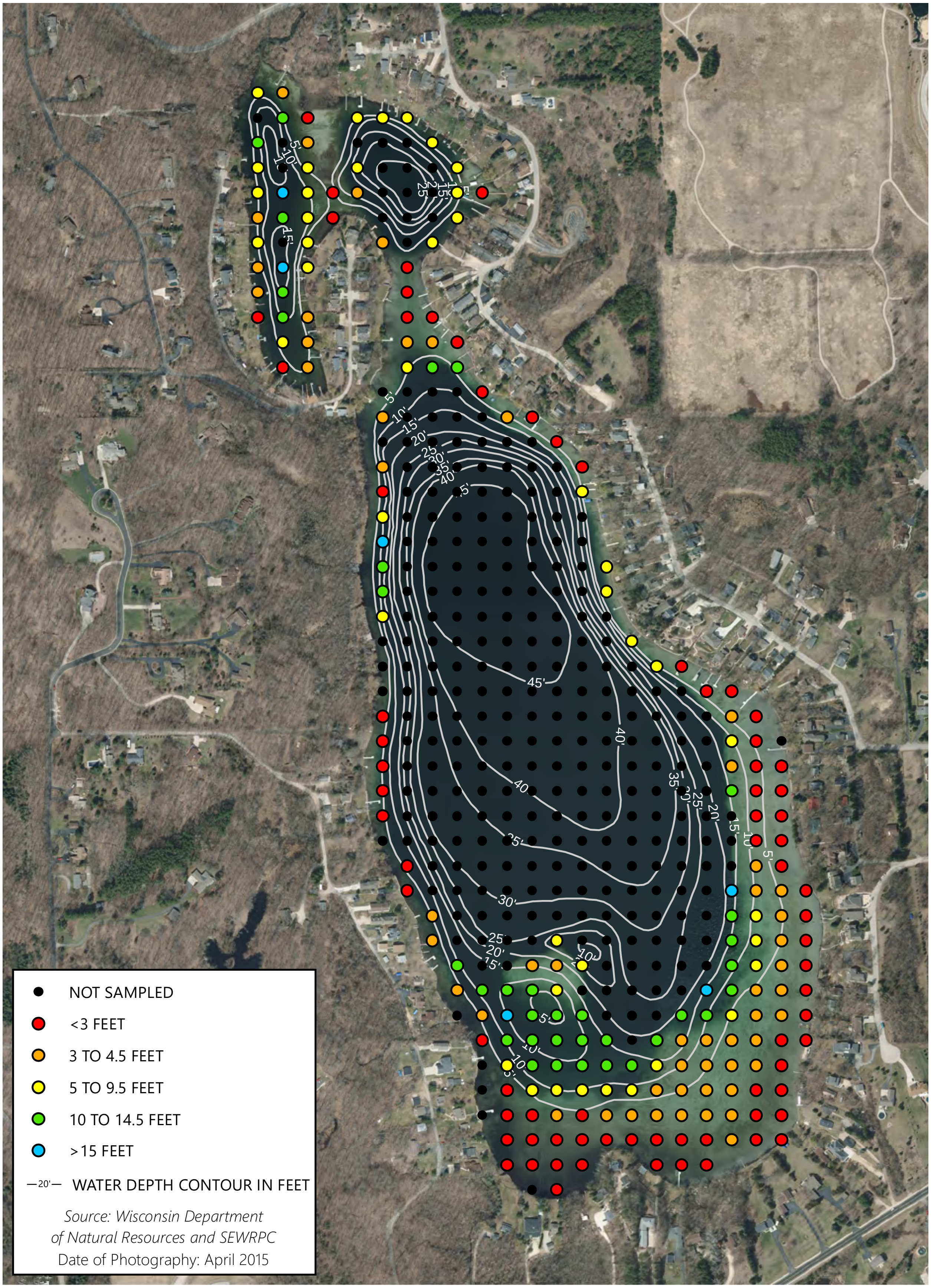


Figure 2.31
Water Depths Measured in Silver Lake: July 2015



approximate results,[104] it appears that little additional sediment has accumulated on most of Silver Lake's bottom. Nevertheless, based upon the available information, the southern and southeastern portions of the Lake do possibly appear to be shallower.

During May 2016, eight property owners along the southwestern shore received a permit to dredge roughly two feet of accumulated lake-bottom soft sediment. Dredging in 2017 employed a floating barge-mounted hydraulic dredging apparatus that pumped a mixture of Lake-bottom sediment and Lake water through pipes to onshore sediment traps (large filter bags). Entrained water ultimately drained back to the Lake (see Figure 2.32). According to anecdotal information, approximately 1,100 cubic yards of sediment were removed at a cost of about $80,000. Several owners at the north end of the Lake applied for a dredging permit for 2018 to conduct a similar dredging operation along their shorelines located on the northeastern side of the Lake near the property known locally as the "Yacht Club."

Shoreline Conditions

Many Silver Lake shoreline residents are concerned with maintaining their shoreline so that it promotes recreational use and provides aesthetic appeal without unduly jeopardizing Lake health. This issue of concern is further emphasized by the fact that several other Lake resident concerns (e.g., water quality, sedimentation, nuisance aquatic plant growth) are often intimately tied to shoreline maintenance practices in various ways.

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) against the erosive forces of lake waves, currents, and ice.

- *Buffers* are areas of plant growth—engineered or natural—in the riparian zone (lands immediately back from the shoreline) that capture sediment and nutrients emanating from upland and nearshore erosion. Buffers also provide many additional benefits beyond water quality protection (see "Existing Buffers" subsection below and Appendix A for more detail).

When it comes to shoreline protection, several engineered options are available to home owners. Most are installed to dissipate erosive forces, check shoreline recession, reduce soil loss to a lake, and oftentimes to provide a "finished" or "manicured" appearance to the water's edge of developed lots. Structures used to protect shorelines include the following common examples.

- "Bulkheads" are typically a solid vertical wall of engineered material set at the water's edge and constructed of materials such as concrete, steel, or timber.

- "Revetments" are similar to bulkheads; however, the wall is not vertical but instead slopes up toward the shoreline. Materials such as rock, concrete, and asphalt are often used to build revetments.

- "Riprap" generally refers to a process where large stones and boulders are placed along a shoreline. where rocks and/or stones are placed along the shoreline.[105]

[104] *Contrasting sediment depth using this method is highly dependent upon 2015 sample site location accuracy and the accuracy, precision, and scale of the 1969 bathymetric map. For example, a small portion of the bathymetric map in the southwest part of the Lake where water depth is mapped to range from 15 to 20 feet deep coincides with 2015 water depths between 5.0 and 9.5 feet. In this example area, the 1969 water depth contour lines are tightly spaced and imprecise placement of 2015 sampling locations and/or 1969 bathymetric contours can create large, yet erroneous, sediment depth differences.*

[105] *In the 28 years since the original SEWRPC plan for Silver Lake was published, the number of shoreline property owners using riprap—an extremely robust form of shoreline protection for a lake the size of Silver Lake—has significantly increased. New riprap shoreline protection is most pronounced on either side of the narrows connecting the main lake to the kettle as well as along the southwestern and southeastern shorelines of the main lake.*

All engineered shoreline protection systems require permits from WDNR to construct. During the two decades since publishing the Commission's first comprehensive lake plan for Silver Lake, the amount of shoreline protected by riprap has significantly increased. These additions are most noticeable on either side of the narrows and along the southwestern and southeastern shorelines.

"Hard" engineered seawalls of stone, riprap, concrete, timbers, and steel, once considered "state-of-the-art" shoreline protection, are now recognized as only one solution to protect and restore a lake's water quality, wildlife, recreational opportunities, and scenic beauty. Indeed, evidence suggests that, in some cases, the inability of hard shorelines to absorb wave energy increases wave energy in other portions of a lake, since wave energy is reflected back into the lake.

In certain cases, shoreline protection does not need to rely on artificial, engineered structures and is better addresses by emulating nature. Many types of natural shorelines offer substantial protection against erosive forces. For example, dense nearshore vegetation can absorb much of the energy in waves and dissipate erosive forces before they reach the water's edge. Bulrush beds, water lilies, cattails, a broad range of aquatic plants that reach to the surface, and even dead plant material such as fallen trees can effectively dissipate and absorb wave energy.

Figure 2.32
2016 Dredging Near Silver Lake's Public Boat Launch

Source: Silver Lake Protection Rehabilitation District and SEWRPC

In recent years, engineered "soft" shoreline protection techniques, referred to as "vegetative shoreline protection" are becoming more commonly employed. Shoreline residents have become increasingly aware of the multiple values of not only protecting their shorelines, but also improving their shoreline's overall aesthetic appeal while providing valuable wildlife habitat. Vegetative shoreline protection techniques typically involve a combination of materials including native plantings. Vegetative shoreline protection is increasingly required pursuant to Chapter NR 328 "Shore Erosion Control Structures in Navigable Waterways" of the *Wisconsin Administrative Code*. A dividend of shorelines protected with vegetation is that such plantings often help shield a lake from both land-based and shoreline pollution and sediment deposition.

Given the benefits of soft shoreline protection approaches, the WDNR no longer permits construction of new hard shoreline protection structures in many situations. However, existing hard shoreline protection structures may be repaired. Consequently, the shoreline protection recommendations in this plan focus on soft measures, including native planting, maintaining or re-establishing a diverse aquatic plant community along shorelines, and using materials that foster shoreline vegetation such as biodegradable/temporary breakwaters, fiber rolls, brush layering, brush mattresses, and live stakes.[106] Beach areas, which legally need to be made from pea gravel,[107] 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.

[106] *More information regarding these biologically based approaches may be found on the WDNR's website. An example webpage follows: dnr.wi.gov/topic/waterways/shoreline/erosioncontrol-biological.html.*

[107] *WDNR does not permit the use of sand because it is commonly very mobile once added to a lake, and therefore, contributes to lake sedimentation.*

2015 Shoreline Inventory

To quantify shoreline condition, restoration targets, and maintenance needs around Silver Lake, and to help develop recommendations related to shoreline management and pollution reduction, Commission staff inspected the Lake's entire shoreline during summer 2015, the results of which are summarized on Figure 2.33. The following insights are drawn from the shoreline inspection.

- Developed lakefront parcels around Silver Lake include few shoreline buffers. However, substantial stretches of shoreline are relatively unmodified wetland and are therefore well buffered. More specifically, buffered shorelines are present along approximately 1.04 miles (38.5 percent) of the Lake's shoreline while the remaining 1.66 miles (61.5 percent) of the Lake's shoreline is not buffered and is largely devoted to residential use. Silver Lake is not unique in this regard as most Southeastern Wisconsin Lakes are ringed by residential development that does not include significant stretches of shoreline buffers.

- Stretches of eroded shoreline were scattered around the Lake, but were most prevalent on the eastern shore, the western shore of the "kettle" at the north end of the Lake, and along the southern end of the Lake; there was also some undercutting in the "narrows."

- Fallen trees (a positive habitat feature) were found mostly along the western shore with a few examples in the northern kettle and at the southern tip of the Lake. Large woody structure was largely lacking from the eastern shoreline of the Lake.

- Shorelines buffered by vegetation were most common in the northern kettle and the western shoreline. Very little of the eastern shores was buffered by vegetation.

- The greatest concentration of natural shoreline was in the northwestern shoreline area. This area is designated as a primary environment corridor and is also a critical species habitat area.

- The dominant form of shoreline protection, artificial or natural, was riprap.

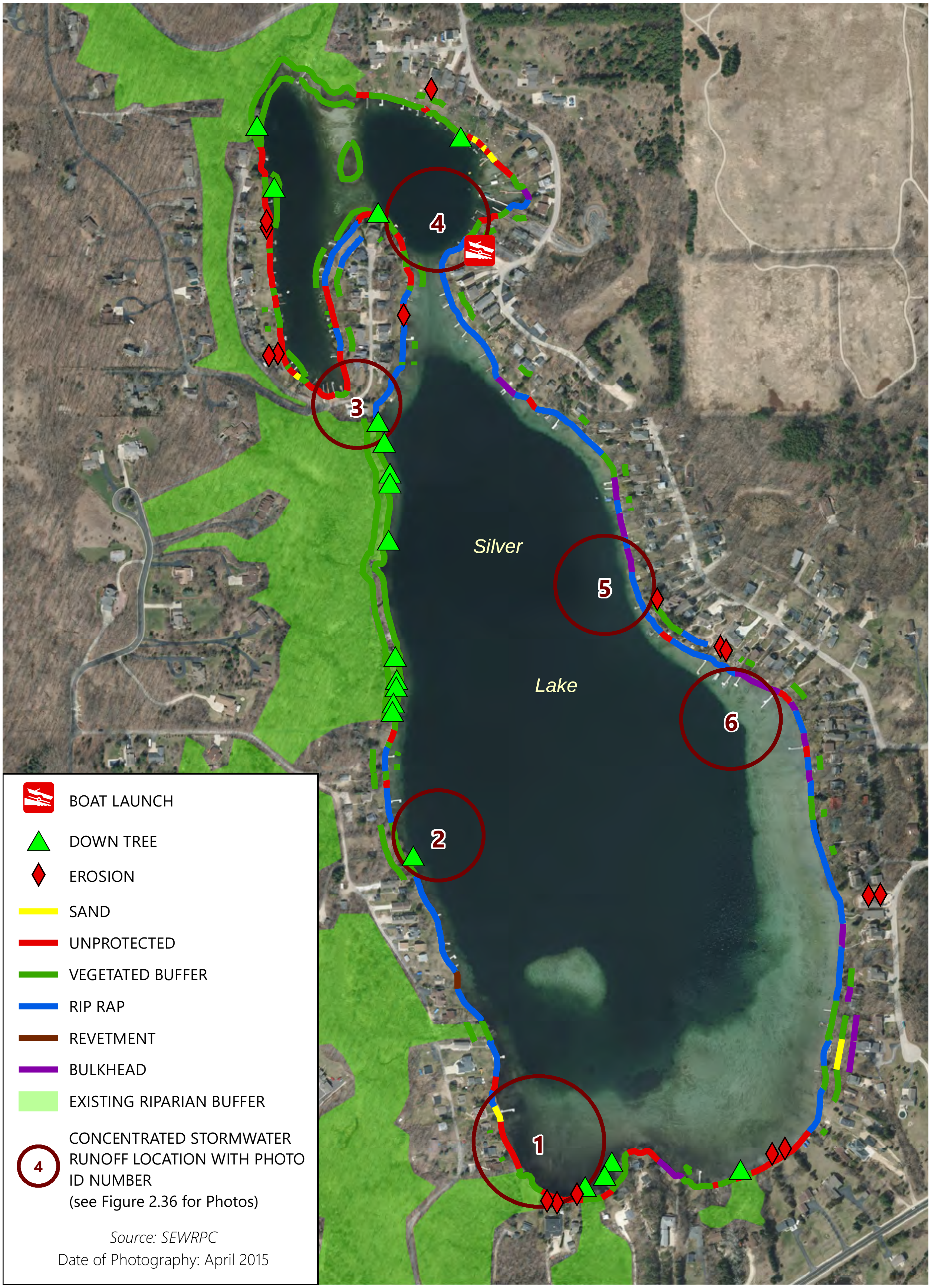
Residents have expressed concern about wave action eroding shorelines around the Lake, as well as the concern for a degrading western shoreline seemingly undercut by erosion as evidenced by brighter green leaf/grass foliage on top (fountain like appearance) and brown-like color on the bottom. This appearance is normal for the tussock sedge vegetation that is common along much of this shoreline area (see Figure 2.34). Tussock sedges provide valuable wetland habitat and is often used as part of restoration strategies to help control erosion.

Other concerns regarding Silver Lake's shoreline include the recent increased use of powerful boats, shoreline ice damage, and concentrated stormwater runoff. Examples of these concerns are discussed in more detail below.

- Wake boats (also known as bladder boats) are designed to displace water and create a stern wave used for wakeboarding. Wave energy created by wake boats propagates considerable distances across waterbodies as rolling waves, but eventually dissipate, are absorbed by plants or other in-water structure, or strike shorelines. Wave energy moving across deeper water areas is often rather inconspicuous yet becomes visible when the waves reach shallow water. Large waves produced close to shorelines do not have sufficient distance to dissipate energy. In such a situation, waver energy is transmitted to the lake bottom, shoreline vegetation, the shoreline itself, or, on hard armored surfaces, is reflected back into the lake. Silver Lake is a modest sized and narrow lake, meaning that few areas are distant from shoreline areas. This means that Silver Lake's shoreline and bottom are particularly vulnerable to damage from large artificial waves. Such damage could manifest itself as uprooted or damaged vegetation, bottom sediment resuspension, or disruption of shoreline sediment.

- Ice damage can damage lake shorelines when strong winds or temperature changes cause ice to move. Such movement may push lake ice onto shoreline vegetation, armor, and infrastructure resulting in damage. An example of shoreline damage caused by ice movement on Silver Lake can be seen in Figure 2.35.

Figure 2.33
Silver Lake Shoreline Assessment



- Humans commonly alter surface-water drainage patterns to facilitate a variety of desires. For example, diffuse runoff is often directed to swales and ditches to eliminate standing water and rapidly convey runoff to a discharge point. This is often done to align drainage patterns with property boundaries and development concepts. Such "drainage improvements," when combined with impermeable surfaces that typically accompany such areas, increase the volume and speed of runoff. Furthermore, when drainage is directed along oftentimes straight and confined trapezoidal channels, water velocity is very high, a situation destabilizing vegetation and sediment, enabling small ephemeral watercourses to carry large sediment loads.

  This situation commonly manifests itself with watercourses with a "gully-like" appearance and prominent sediment accumulations where the watercourses enter lakes or larger streams.

  Silver Lake residents have expressed concern about sediment transported to the Lake from a variety of ephemeral watercourses. Commission staff inspected several sites along the Silver Lake lakeshore identified by residents as areas of concentrated stormwater runoff (see Figures 2.33 and 2.36). Although no prominent eroded channels were observed and no significant sediment accumulations were seen where watercourses enter the Lake, the physical characteristics of certain drainage paths foster sediment transport to the Lake. Examples of such characteristics include long stretches of pavement or ditches that capture water from large areas and funnels runoff in straight lines downslope, areas where road drainage is channeled directly to the Lake or its tributaries, and areas where steep urbanized areas drain directly through the Lake or its tributaries without intervening buffers. Action can be taken to lessen sediment contributions from such sources (see Chapter 3 for more detail). Concentrated stormwater runoff sites should be the subject of continued scrutiny. Therefore, a monitoring regimen is suggested in Chapter 3.

Figure 2.34
Tussock Sedge Growing Along Silver Lake's Shoreline

Source: SEWRPC

Figure 2.35
Example of Ice Damage Along Silver Lake's Shoreline

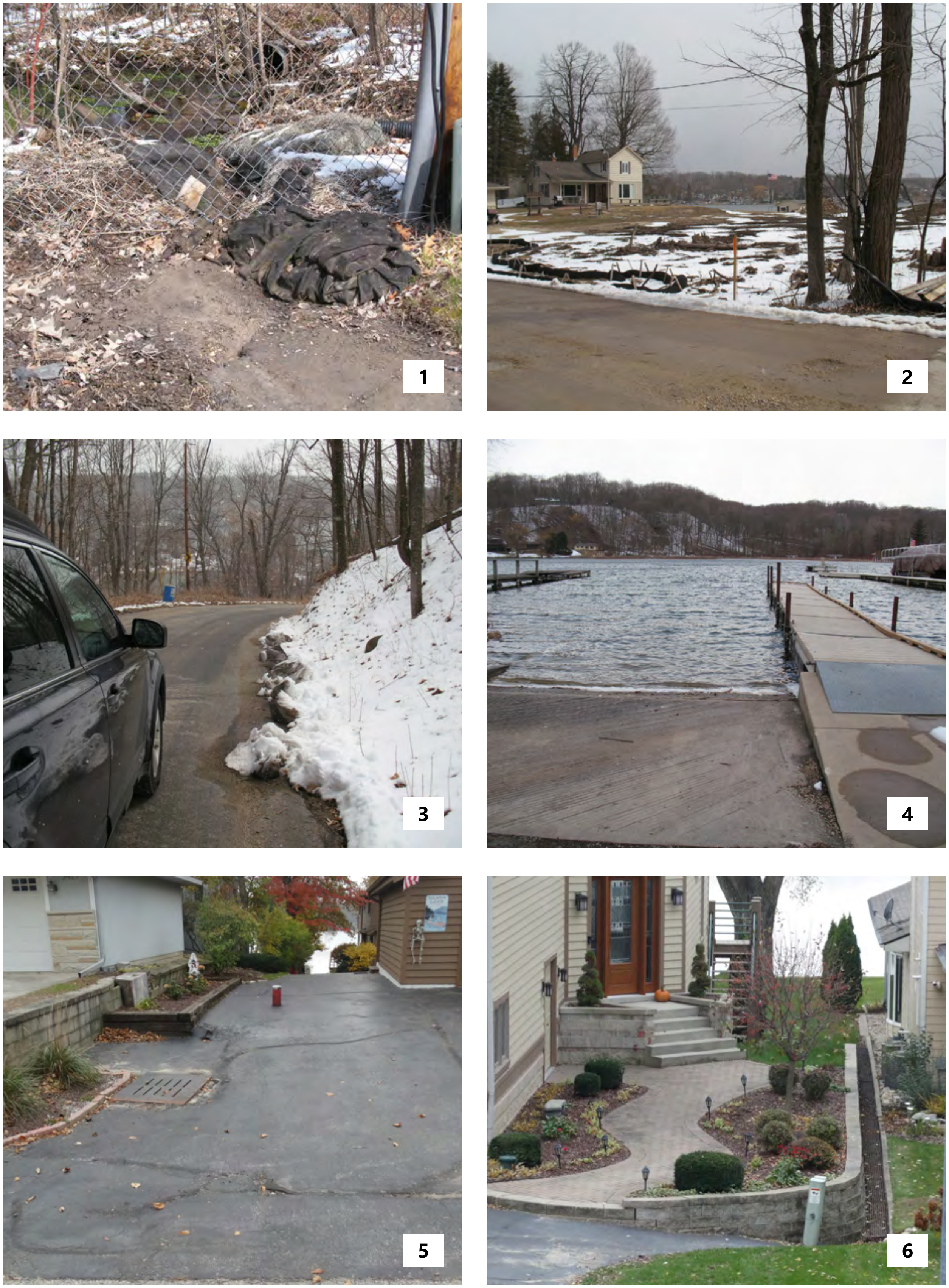
Source: SEWRPC

Existing Buffers

Healthy riparian corridors help to protect water quality, groundwater, fisheries and wildlife, ecological resilience, help to counter invasive species, and can reduce flood severity, and can help waterbodies better contend with climate change.[108] The health of riparian corridors is largely dependent upon width and

[108] *N.E. Seavy, et al., "Why Climate Change Makes Riparian Restoration More Important than Ever: Recommendations for Practice and Research,"* Ecological Restoration*, Volume 27, Number 3, September, 2009, pages 330-338; Association of State Floodplain Managers*, Natural and Beneficial Floodplain Functions: Floodplain Management—More Than Flood Loss Reduction, 2008."

Figure 2.36
Concentrated Stormwater Runoff Areas Around Silver Lake



Source: SEWRPC

continuity. Therefore, efforts to protect and expand the remaining riparian corridor width and continuity are foundational elements for protecting and improving the fishery, wildlife, and recreation within the Silver Lake watershed.

Healthy riparian corridors include buffers that help protect waterbodies. The location of shorelines and lands with the potential to act as buffers were identified using 2015 digital orthophotography, 2010 WDNR Wisconsin Wetland Inventory data, and Commission inventories of environmental corridors and isolated natural resources areas. Polygons were created using geographic information system (GIS) techniques to delineate contiguous natural lands (i.e., nonurban and nonagricultural lands) comprised of wetland, woodland, and other open lands adjacent to waterbodies. Those lands comprise a total of about 56.3 acres, or 31 percent, of the total land area (not including water area) within the Silver Lake surface watershed. The extent of buffered shorelines, and nearby upland areas with the ability to serve as buffers, are illustrated in Map 2.16.

Maintaining or re-establishing buffer strips is an important tool to mitigate anthropogenic pollutant and sediment sources to waterbodies. Even relatively narrow buffer strips provide appreciable environmental benefit (see Table 2.11 and Figure 2.37).[109] The Wisconsin Buffer Initiative (WBI) 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.[110] It is important to note that the WBI's assessment and recommendations were limited to protecting water quality and did not consider the varied supplemental benefits of riparian buffers. Research clearly shows that riparian buffers can provide many potential benefits. For example, buffers can help:

- Mitigate flood volume, elevation, and timing
- Diminish bed and bank erosion
- Improve waterbody water quality
- Stabilize and/or improve waterbody temperature regimens
- Encourage healthy riparian and aquatic vegetative communities
- Provide or enhance critical fish and wildlife habitat.

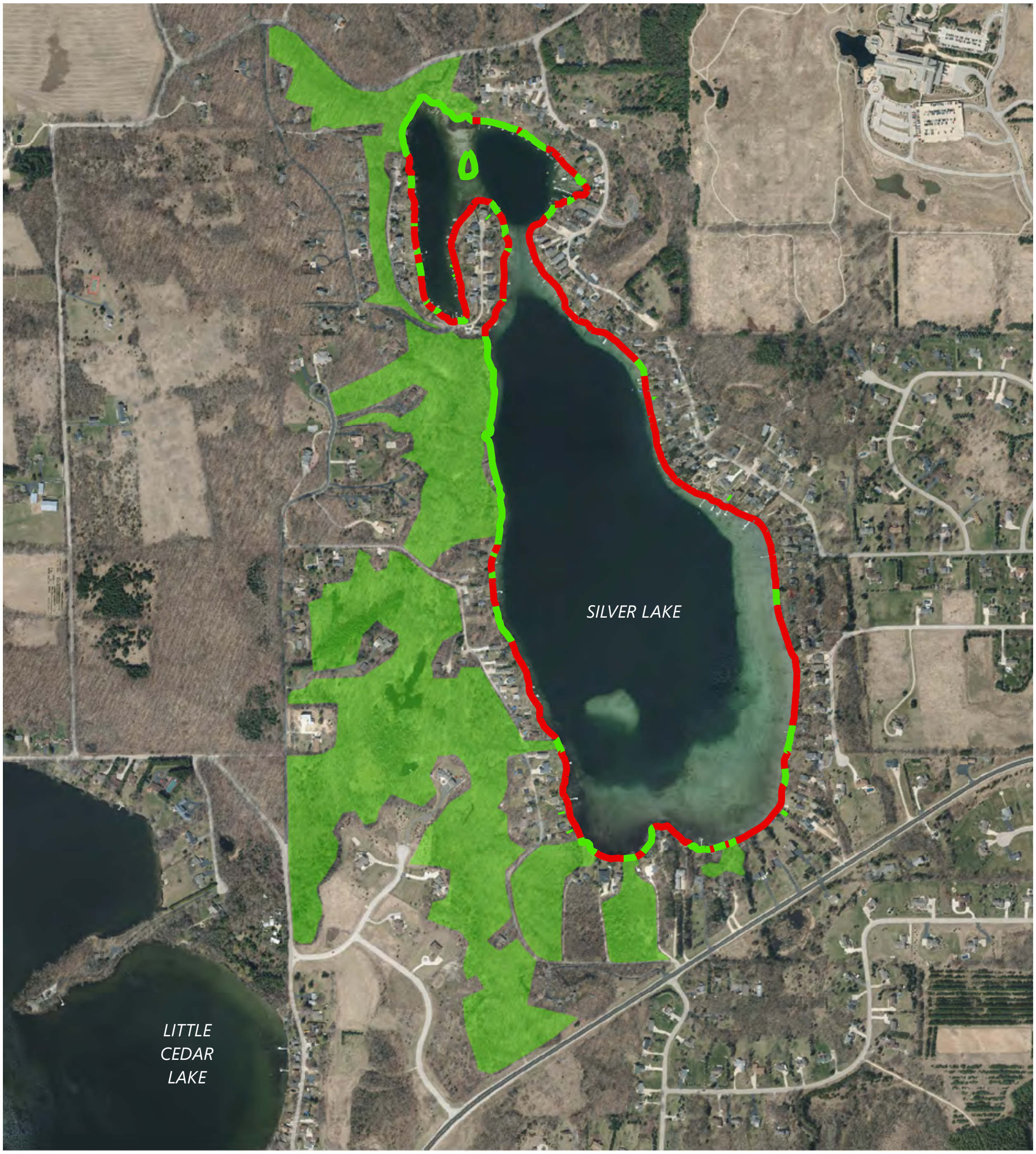
The nature of benefits and extent of benefits provided by buffers is very site-specific. Consequently, the width range for each buffer function is large. Buffer width should be based on desired functions as well as site conditions. For example, based upon a number of studies of sediment removal, buffer widths ranging from about 25 to nearly 200 feet achieved removal efficiencies of between 33 and 92 percent. Sediment removal efficiency was influenced by site-specific variables such as soil type, slope, vegetation, contributing area, and influent concentrations. As shown by Figure 2.37, any selected buffer width (for example 75 feet) can provide multiple benefits ranging from water temperature moderation to enhancement of wildlife species diversity. Buffers can also stabilize shorelines and protect important habitat features.

Healthy and sustained aquatic and terrestrial wildlife diversity is dependent upon adequate riparian buffer width and habitat diversity. Specifically, recent research has found that the protection of wildlife species 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, preservation of riparian buffers to

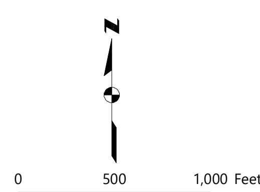
[109] *Data were drawn from Desbonnet, A., P. Pogue, V. Lee, and N. Wolff, "Vegetated Buffers in the Coastal Zone – A Summary Review and Bibliography,"* CRC Technical Report No. 2064. *Coastal Resources Center, University of Rhode Island, 1994.*

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

Map 2.16
Buffers Near Silver Lake: 2017



EXISTING BUFFER
EXISTING RIPARIAN BUFFER
UNBUFFERED SHORELINE



Source: SEWRPC
Date of Photography: April 2015

Table 2.11
Effect of Buffer Width on Contaminant Removal

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

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

Source: University of Rhode Island Sea Grant Program

widths of up to 1,000 feet or greater represents the optimal condition for the protection of wildlife in the Silver Lake watershed.[111]

While it is clear from the literature that wider buffers can provide a greater range of values for aquatic systems, the need to balance human access and use with the environmental benefits to be achieved suggests that a 75-foot-wide riparian buffer provides a minimum width necessary to contribute to good water quality and a healthy aquatic ecosystem. Riparian buffers are vital conservation tools providing landscape-scale ecological connectivity, a situation that improves of wildlife population viability and resilience.[112] Throughout the Silver Lake watershed, the highest quality environmental corridors, natural areas, and vegetation communities are located within, and adjacent to, the riparian buffer network.

The development patterns and infrastructure that humans create on the landscape lead to a number of obstructions that can limit both habitat availability and accessibility. Obstructions are primarily a result of roadways, railways, fences, buildings, and other human infrastructure that commonly crisscrosses landscapes and separates suitable/accessible habitat into discrete, yet ecologically isolated, fragments. Therefore, an effective management strategy to protect wildlife abundance and diversity in the Silver Lake watershed would be to maximize critical linkages between habitat areas on the landscape, ensuring the ability of species to access these areas. Examples of critical linkages include the following:

- 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)

[111] *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.*

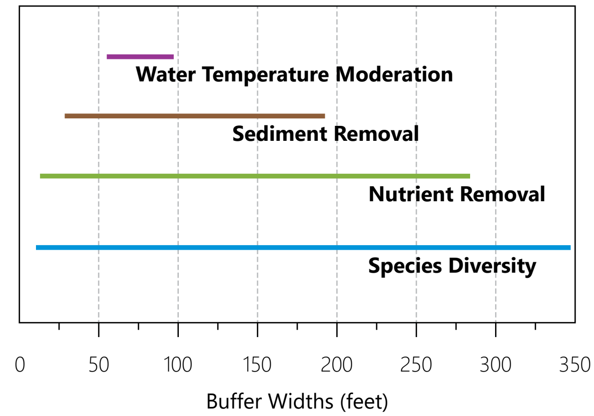
[112] *Paul Beier and Reed F. Noss, "Do Habitat Corridors Provide Connectivity?,"* Conservation Biology, *Volume 12, Number 6, December 1998.*

Efforts to remove barriers and knit together isolated habitat pays many dividends. For examples, reconnecting isolated natural resource areas (INRAs) to the larger primary environmental corridor (PEC) areas, as well as building and expanding upon the existing protected lands, represent a sound approach to enhance the corridor system and wildlife areas within the watershed.

Potentially Restorable Wetlands

Wetlands provide a number of benefits such as water quality improvement, wildlife habitat, and flood mitigation. According to the USEPA a typical one-acre wetland can detain about one million gallons of runoff.[113] Restoring wetlands typically decreases overall runoff volume, decreases wet weather flow rates, increases dry weather flow rates, has the potential to increase groundwater recharge, and should reduce sediment and phosphorus loading to the receiving waterbodies. Restored wetlands, particularly those occupying riparian buffer can help reduce pollutant loads from roadways, impermeable urbanized areas, agricultural lands, drain tiles, barnyards, and upland runoff. Key areas to restore as wetlands include croplands that frequently flood or are too wet to support establishment, growth, and/or harvest of reasonable crops types and yields. Although predicting load reductions associated with specific wetland restoration sites is 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.[114]

Figure 2.37
Buffer Width Ranges Providing Various Protective Functions



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

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

Land areas that are not currently wetlands but are underlain by hydric soils were formerly wetland and are likely locations to restore wetland vegetation and hydrology. Hydric soils characteristic form when soil is saturated for long time periods. In such situations, soil properties change, a situation fostering dominance of a unique suite of plants that thrive in wet, oxygen-deprived soil. Most wetlands remaining in the Silver Lake watershed are found near the Lake. As previously noted in the land use description above, wetlands currently cover 8.2 percent of the Silver Lake watershed. However, good potential likely exists to restore wetlands throughout the Silver Lake watershed. Based on information from the WDNR "potentially restorable wetlands" geographic information system layer, approximately 10 acres and 18 acres of potentially restorable wetland identified within the Silver Lake surface and groundwatersheds, respectively (see Map 2.17). Wetland restoration should be component to overall strategies that aim to protect the Lake.

Unprotected Land

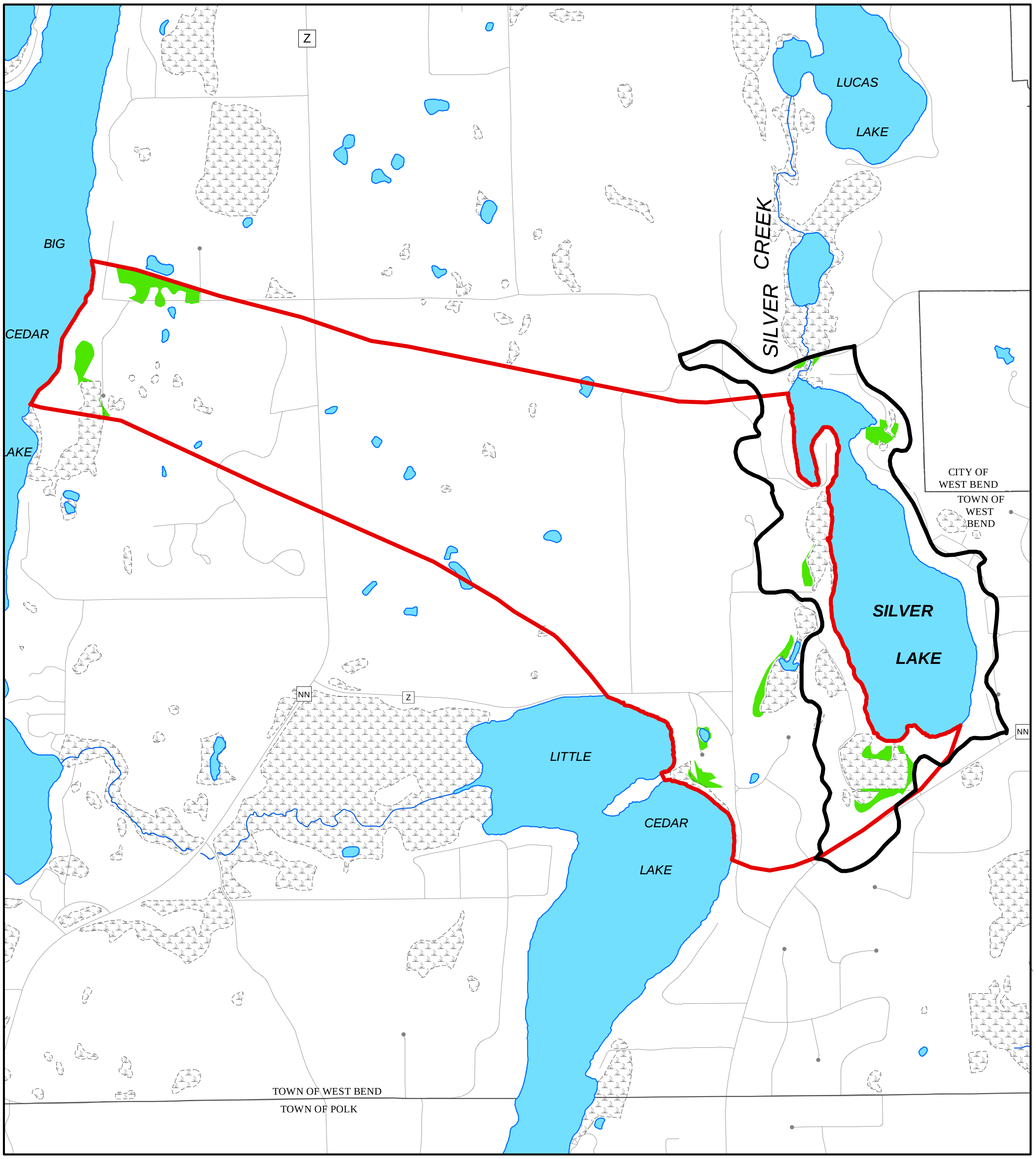
Although the environmental corridors (Map 2.11), natural areas and critical species habitats (Maps 2.10 and 2.12), and existing buffers (Map 2.16) have been identified throughout the Silver Lake surface and groundwatersheds, it is important to recognize that some of these lands are more vulnerable to potential loss than others. For example, some of these lands are protected through regulations while others are in some form of public ownership and are therefore already protected. Land areas not included in one of the following categories should be considered vulnerable to potential loss over time:

- Publicly owned or conservation organization owned open lands (white land areas as shown on Map 2.18

[113] *U.S. Environmental Protection Agency (USEPA),* Wetlands: Protecting Life and Property from Flooding, May 2006*, USEPA843-F-06-001, Website: www.epa.gov/wetlands/wetlands-factsheet-series.*

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

Map 2.17
Potentially Restorable Wetlands Near Silver Lake



POTENTIALLY RESTORABLE WETLANDS

SURFACE WATER

STREAM

GROUNDWATERSHED BOUNDARY

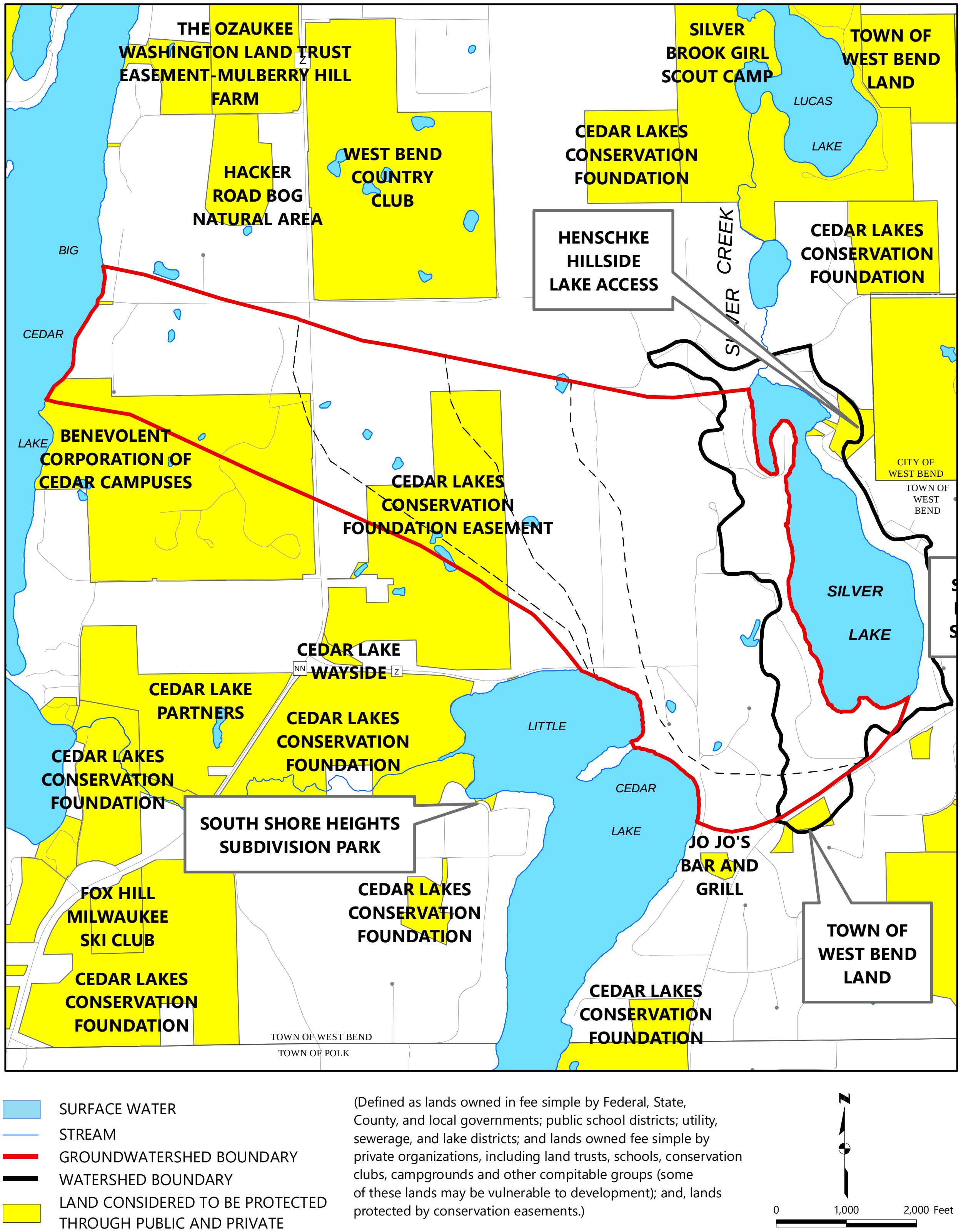
WATERSHED BOUNDARY

Note: This map illustrates Potentially Restorable Wetlands as defined by the Wisconsin Department of Natural Resources.

0 1,000 2,000 Feet

Source: SEWRPC

Map 2.18
Protected Land Near Silver Lake



Source: SEWRPC

- Federal Emergency Management Agency one-percent-annual-probability (100-year recurrence interval) regulatory floodplains (see Map 2.9)

- Undeveloped lands (i.e., woodland, wetland, and agriculture and other open land) with greater than 12 percent slope as shown on Map 2.3[115]

Approximately 150 acres of land within the surface and groundwatershed areas combined are protected through public and private ownership. Most significantly, the single largest piece of protected land in the groundwatershed area of Silver Lake is within a Cedar Lake Conservation Foundation (CLCF) easement (77.5 acres) (Map 2.18).[116] Twelve acres of the surface-water and groundwatershed areas are occupied by floodplain while roughly 600 acres in this same area have slopes steeper than 12 percent.

2.6 AQUATIC PLANT MANAGEMENT

Nuisance aquatic plants are a visible and well known concern for Lake residents and users. This section first examines the general need for aquatic plant management by quantifying the state of aquatic plants in Silver Lake. Recent aquatic plant surveys are compared to historical data. By using plant inventory information as well as information regarding the Lake's physical condition and ecosystem, appropriate aquatic plant management techniques are considered.[117]

All lakes have aquatic plants and algae, every lake is unique, and native aquatic plants are a fundamental and integral part of lake ecosystems. In fact, the Region's nutrient-rich soil causes most lakes in the Southeastern Wisconsin to host abundant aquatic plant communities.[118] Aquatic plants are a natural part of essentially all natural lake communities and provide a number of valuable functions, including:

- Improving water quality through plant-driven biogeochemical processes that co-precipitate phosphorus

- Suppressing algal growth by competing for essential plant nutrients

- Providing habitat for invertebrates and fish

- Stabilizing lake bottom sediments

- Absorbing wave energy, thereby protecting shorelines

- Supplying food and oxygen to the lake through photosynthesis

A lake's water clarity, configuration, depth, nutrient availability, wave action, and fish population assemblage affect the abundance, diversity, and distribution of aquatic plants. Given the importance of native aquatic plants to overall lake health, it is desirable to periodically re-examine the abundance, distribution, and diversity of aquatic plants. Such data is contrasted to historical lake conditions and other similar lakes; both comparisons help quantify the overall health of the aquatic plant community. A judgement can subsequently be made regarding the need for active aquatic plant management and locations and methods

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[115] *The Town of West Bend zoning ordinance specifies that design standards for conservation development within the Rural Residential District (R-1R) areas consider protecting existing natural environmental lands with slopes of 12 percent or greater.*

[116] *The CLCF is one of the oldest land trusts in Wisconsin. Its mission is protecting ecosystem health of Washington County's Cedar Lakes watershed that encompasses six lakes, including Silver Lake. Since founding in 1974, CLCF has protected in perpetuity over 60 properties totaling more than 2,400 acres via measures such as fee simple purchase, conservation easements, and deed restrictions.*

[117] *The Commission's discovery of starry stonewort in Silver Lake during 2015 prompted great attention to be focused on the Lake's aquatic plant community. WDNR and Washington County staff have completed several aquatic plant evaluations subsequent to the Commission's 2015 inventory.*

[118] *Soils in Southeastern Wisconsin are typically abundant in phosphorus. Phosphorus is a key, and oftentimes plant-growth-limiting, plant nutrient in freshwater systems.*

that provide the most overall apparent benefit to the Lake's health and user needs can be identified. Data and interpretations related specifically to Silver Lake are presented below.

Aquatic Plant Inventory

Commission staff completed an on-the-water aquatic plant survey during July 2015. The WDNR completed another survey during August 2017. Both surveys used point-intercept methodology.[119] It is important to note that both the 2015 and 2017 surveys provide valuable information on the aquatic plant community that is further summarized below. Since the 2017 survey is more recent, the Commission assume it best characterizes Silver Lake's extant aquatic plant community. Nevertheless, because of the rapidly evolving response to the Commission's discovery of starry stonewort in the Lake, a number of other aquatic plant surveys have been completed since 2015 by Washington County, the WDNR, and potentially others.

The point-intercept method uses predetermined sampling sites arranged in a grid pattern across the entire lake surface (see Figure 2.38). The WDNR assigns a grid layout to each lake depending on lake morphology, size, and other factors. Each survey site is located in the field using global positioning system (GPS) technology. At each site, a single rake haul is taken and a qualitative assessment of the rake fullness, on a scale of zero to three, is then made for each identified species (see Figure 2.39). Of the 451 sites sampled in Silver Lake during in 2017, 280 had vegetation. The survey detected the presence of 17 aquatic plant species (14 species collected plus 3 visuals). Of the 17 species identified in Silver Lake, 13 were native species while four were nonnative species. Table 2.12 lists aquatic plant species identified as part of the 2017 survey as well as plant type (submerged, floating, or emergent) as well as data regarding each plant's abundance and dominance. [120] Species distribution maps, key species identification features, and other pertinent information along with data from the surveys in 2015 and 2017 are included in Appendix B.

During 2017, Silver Lake's most abundant aquatic plant species (listed in descending order of abundance) were:

1. Muskgrass (*Chara* spp. – a form of algae)
2. Slender Nitella (*Nitella flexilis* – a form of algae)
3. Illinois pondweed (*Potamogeton illinoesnsis*)
4. Slender naiad (*Najas flexilis*)
5. Eurasian watermilfoil (*Myriophyllum spicatum*)
6. Spiny naiad (*Najas marina*)

Of these six species, EWM and spiny naiad are nonnative. It should also be noted that, of these six species, muskgrass was significantly more abundant than any other species in the Lake.[121] As shown in the distribution map for muskgrass (see Appendix B), this highly dominant plant is found along nearly all the shoreline of

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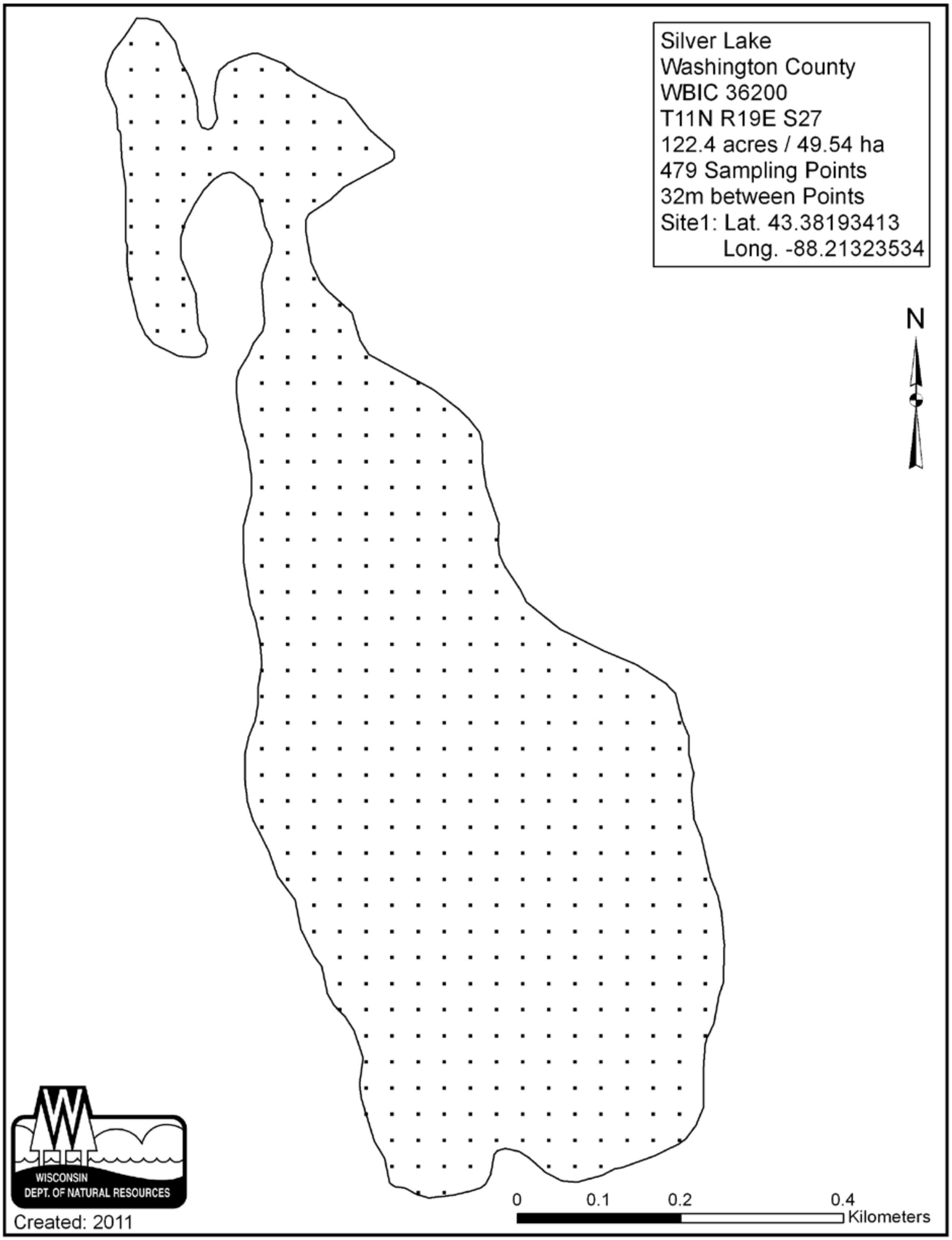
[119] *More detail regarding methodology can be found in Wisconsin Department of Natural Resources, Publication Number PUB-SS-1068,* Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry and Analysis, and Applications*, 2010.*

[120] *Aquatic macrophytes are often described using the terms "submerged", "floating", and "emergent", depending on where the plant is found in the lake ecosystem. All three plant types have significant roles in overall waterbody ecosystem function as summarized below:*

- *Submerged plants are typically found in deeper water. Although most are rooted in bottom substrate, some forms, such as coontail (*Ceratophylum demersum*) are free-floating.*
- *Floating 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 underlain by loose bottom sediments. Floating plants may be rooted (water lily) or free-floating (duckweed,* Lemna *spp.).*
- *Emergent plants are those that grow along waterbody shorelines and include plants such as the bulrush and cattail.*

[121] *Of the 280 sites visited that had aquatic vegetation, 169 had muskgrass.*

Figure 2.38
WDNR Aquatic Plant Survey Grid Points: Silver Lake



Source: Wisconsin Department of Natural Resources and SEWRPC

Silver Lake, with the greatest amounts found in the kettle at the north end of the Lake and in the extreme south end of the Lake.

Figure 2.39
WDNR Rake Fullness Assessments for Point-Intercept Aquatic Plant Sampling

Fullness Rating	Coverage	Description
1		Only few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover the tines.
3		The rake is completely covered and tines are not visible.

Source: Wisconsin Department of Natural Resources and SEWRPC

Some state that muskgrass grows at "nuisance" levels in Silver Lake. Nevertheless, it is important to note that even though some people may perceive that a plant grows to nuisance levels, it may also be serving many beneficial functions. Muskgrass is a case in point. Muskgrass is largely responsible for marl formation, which reduces phosphorus concentration (a key nutrient for plant and algae growth) in the Lake and helps improve water quality. Additionally, native species, such as muskgrass and elodea (also observed in Silver Lake), play major roles in providing shade, habitat, and food for fish and other important aquatic organisms. These plant species also significantly reduce shoreline erosion and lake bed resuspension, since they help dampen wave action and currents. Furthermore, the shade provided by these plants helps reduce growth of undesirable plants such as EWM. These example attributes underscore the importance of protecting native plant species and reinforce the concept that excessive native plant removal or overall plant elimination are not component to sustainable, balanced, aquatic plant management plans.

Plant Biodiversity

Two key aspects of a natural system's ecological integrity are: biological diversity (or, biodiversity), and species richness. Although these two terms are often used somewhat interchangeably, the subtle difference in meaning is significant. Diversity is based upon the number of species present in a habitat along with the abundance of each of those species. Diversity can be measured several ways. One method employs the Simpson Diversity Index which expresses diversity on a 0 to 1 scale, with higher numbers representing more diversity. Using this measure, a community dominated by one or two species would be considered less diverse than a community in which several different species have similar abundance. For example, as shown in Table 2.12, Silver Lake appears to be strongly dominated by muskgrass compared to all other species, yet the Lake's Simpson Diversity Index value is high i.e., 0.85). The reason that the Simpson value for a lake so strongly dominated by only one species is so high lies in the second key aspect of this value – species richness. Species richness is simply the number of species in a particular habitat. As mentioned above, the 2017 aquatic plant survey of Silver Lake identified 14 different plant species (17 counting visuals). Such a high number of different species offsets the fact that muskgrass is so highly abundant relative to other species in the Lake.

With 13 native plant species identified during the 2017 aquatic plant survey,[122] it is evident that Silver Lake has a diverse aquatic plant community. The number of plant species detected throughout the Lake is illustrated in Figure 2.40. Protecting the biodiversity of plants in Silver Lake is important. Conserving biodiversity is critical to the long term health of the Lake because it not only helps sustain and increase the robustness of the existing system, but also helps preserve a spectrum of options for future management decisions.

Nonnative and Invasive Plants

The terms "nonnative" and "invasive" are often confused and are commonly incorrectly assumed to be synonymous. Nonnative is an overarching term describing living organisms introduced to new areas beyond their native range with intentional or unintentional human help. Nonnative species may not necessarily

[122] *Of the 13 native species identified during 2017, two were not sampled but were detected by visual observation. A "visual" observation refers to a species that, although not captured on the rake at a specific sampling site, was observed growing within several feet of the sampling site and whose population was documented yet not quantified.*

Table 2.12
Silver Lake Aquatic Plant Abundance: August 2017

Aquatic Plant Species	Number of Sites Found	Frequency of Occurrence Within Vegetated Areas (%)[a]	Relative Frequency[b]	Average Rake Fullness (max=3.0)	Visual Sightings
Ceratophyllum demersum (coontail)	4	1.43	0.6	1.25	0
Chara spp. (muskgrasses)	169	60.36	27.1	1.72	2
Elodea canadensis (common waterweed)	3	1.07	0.5	1.33	0
Lythrum salicaria (purple loosestrife)	0	0	0	0	1
Myriophyllum spicatum (Eurasian watermilfoil)	48	17.14	7.7	2.04	1
Najas flexilis (slender naiad)	72	25.71	11.5	1.43	0
Najas marina (spiny naiad)[c]	46	16.43	7.4	1.80	1
Nitella flexilis (slender nitella)	111	39.64	17.8	2.19	0
Nitellopsis obtusa (starry stonewort)	4	1.43	0.6	1.25	0
Nuphar variegata (spatterdock)	0	0	0	0	1
Nymphaea odorata (white water lily)	7	2.50	1.1	1.71	10
Potamogeton illinoensis (Illinois pondweed)	84	30.00	13.5	1.36	2
Potamogeton zosteriformis (flat-stem pondweed)	20	7.14	3.2	1.15	0
Schoenoplectus acutus (hardstem bulrush)	0	0	0	0	4
Stuckenia pectinata (sago pondweed)	15	5.36	2.4	1.47	0
Utricularia vulgaris (common bladderwort)	26	9.29	4.2	1.15	0
Vallisneria americana (wild celery)	15	5.36	2.4	1.33	0

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] *Data represents Frequency of Occurrence. 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.*

[c] *Spiny naiad was added to the NR 40 list as a restricted species in 2015, meaning it is not allowed to be transported, transferred, or introduced without a permit.*

Source: Wisconsin Department of Natural Resources and SEWRPC

harm ecological function or human use values in their new environments. Invasive species are the subset of nonnative species that damage ecological health in their new environments and/or are considered nuisances to human use values. More plainly stated: all invasive species are nonnative, but not all nonnative species are invasive.

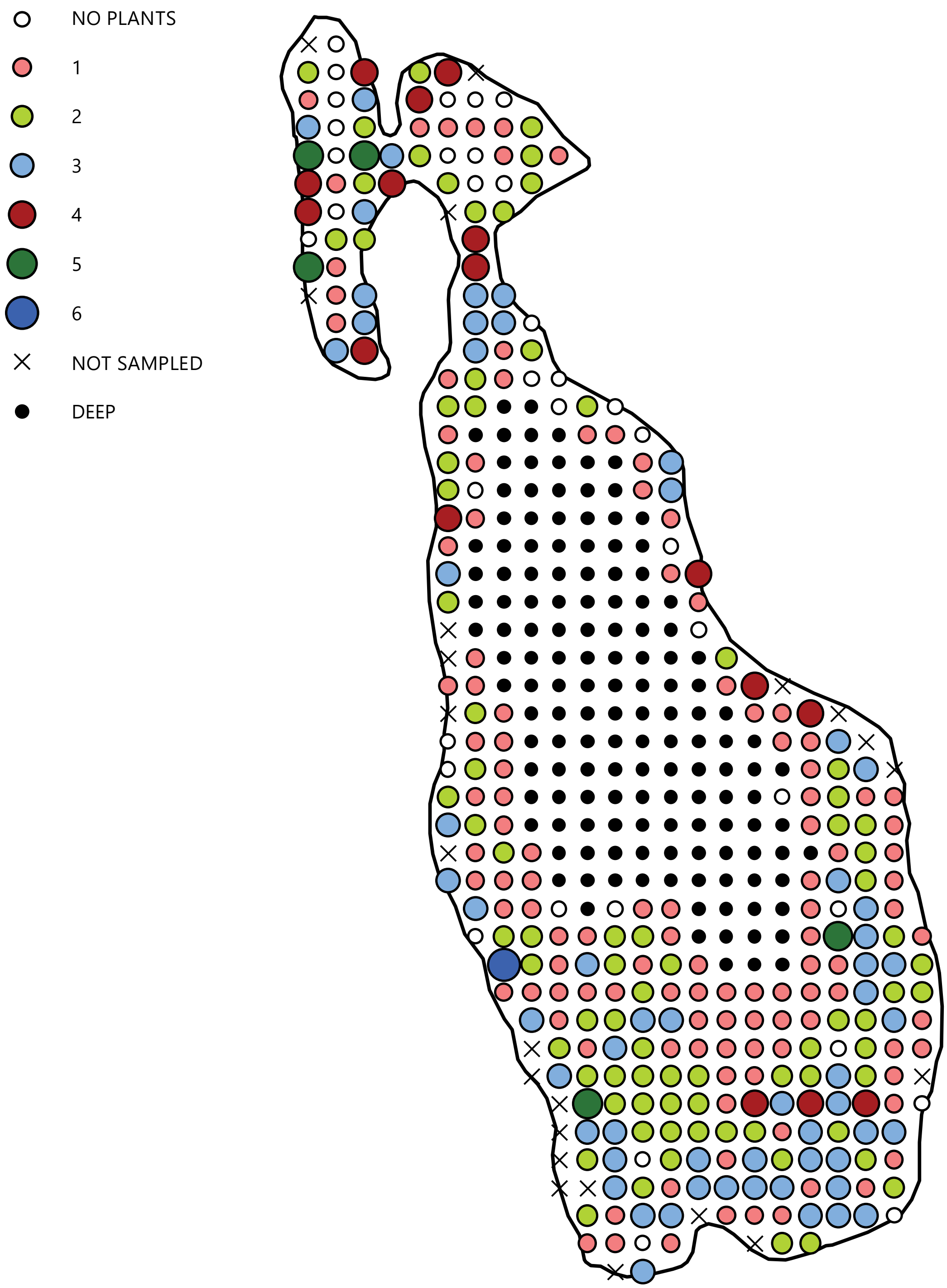
Invasive species (either plants or animals) can severely disrupt both terrestrial and aquatic natural systems. Invasive species often reproduce prolifically. Populations commonly flourish since few or no natural predators or other control agents are present in their new homes. This allows them to out-compete native species for space and other necessary resources, a situation that commonly diminishes the populations of native species with similar life requirements. Furthermore, other native species that depend upon crowded out plants and animals also decline. An example are fish and birds that use particular native plants for food and shelters.

The Commission's July 2015 aquatic plant survey confirmed the presence of starry stonewort in the Lake for the first time and demonstrated the continued presence of two other nonnative species: invasive EWM and nonnative spiny naiad (*Najas marina*). Fortunately, to date these plants are sparsely distributed throughout the Lake. Subsequent aquatic plant surveys (August 2016, August 2017, and July 2018) confirmed the continued presence of these nonnative species.

Eurasian watermilfoil can cause severe recreational use problems in Southeastern Wisconsin lakes since it can grow to the water surface and can displace native plant species. Although EWM populations are relatively sparse (see Figure 2.41), the presence of EWM warrants conscientious monitoring and aquatic plant management in certain instances. Comparing 2015 and 2017 aquatic plant survey data suggests

Figure 2.40
Silver Lake Aquatic Plant Species Richness: 2017

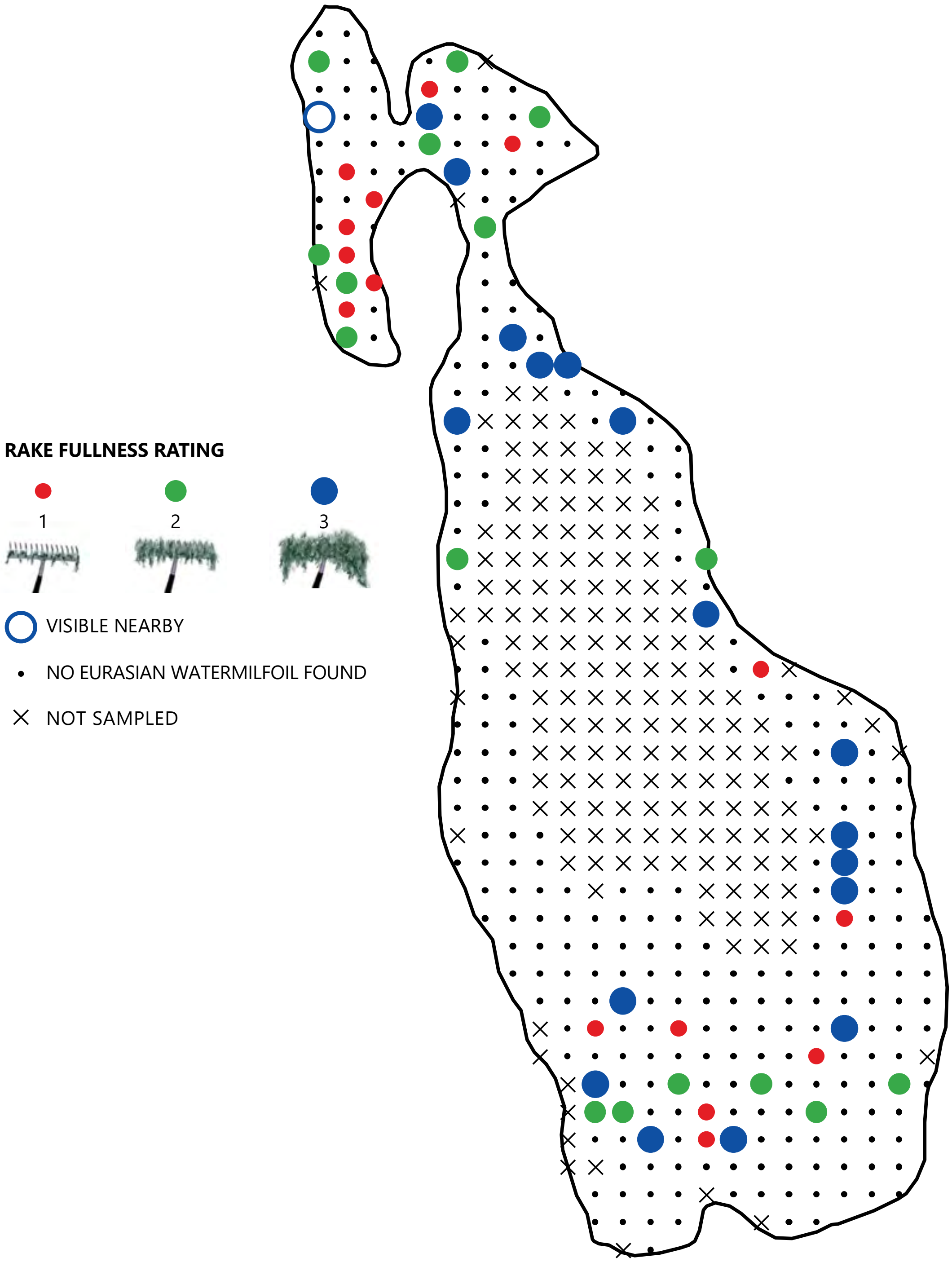
NUMBER OF NATIVE AQUATIC PLANT SPECIES



Note: The above diagram presents the data for number of species observed in Silver Lake at each sampling site during the 2017 aquatic plant survey; sampling occurred at 451 sampling sites, 280 had vegetation.

Source: Wisconsin Department of Natural Resources and SEWRPC

Figure 2.41
Eurasian Watermilfoil Occurrence in Silver Lake: 2017



Note: Samples were collected in Silver Lake between August 7 and August 9, 2017.

Source: Wisconsin Department of Natural Resources and SEWRPC

slowly increasing EWM populations (see Table 2.13), particularly in the northern kettle area and along the south and eastern shorelines (see Figure 2.42).

During fall 2014, the WDNR confirmed that a new invasive aquatic plant species (starry stonewort, see Figure 2.43) was present in the State, specifically in southeastern Wisconsin.[123] Discovery of this new invasive species in Southeastern Wisconsin led to random sampling of other lakes. A team of WDNR employees searched and identified starry stonewort in several other lakes in Southeastern Wisconsin. Starry stonewort can form extremely dense mats, which may affect the species richness of a lake's aquatic plant community and impede recreational use. Dense starry stonewort growth can also reduce movement of fish and other animals and may reduce suitable the suitability of fish spawning, nursery, refuge, and feeding areas.

Starry stonewort was first detected in Silver Lake as part of the Commission's July 2015 aquatic plant survey. The infestation was estimated to cover about one acre in the Lake's northeastern corner near the public boat launch (see Figure 2.44). Upon discovery of this invasive species, the SLPRD coordinated with the Washington County Aquatic Invasive Species (AIS) Coordinator to apply for a rapid response grant. The grant was approved and allowed SLPRD to utilize a technique known as Diver Assisted Suction Harvesting (DASH) to remove starry stonewort from the boat launch area. DASH was completed in August 2015 and reduced the known starry stonewort infestation area by 80 to 90 percent. Only two small patches of visible plants remained according to Washington County's AIS coordinator (see Figure 2.45). However, a 2016 AIS meander survey of Silver Lake revealed that the starry stonewort infestation had again spread (see Figure 2.46).

Since starry stonewort is a new aquatic invasive species in Wisconsin, management techniques to eliminate, or even reduce and control, its population are still being evaluated. As a follow up to DASH, select dredging was planned for Silver Lake in 2018. However, starry stonewort remained prevalent in each lobe of the northern bay as of August 2018 and was discovered in areas beyond the immediate boat launch area (see Figure 2.47). While the public boat launch area continues to be a key area of concern, numerous colonies ranging from dinner plate to pontoon boat size have been seen under docks and piers (see Figure 2.48).[124] It will take time to assess treatment effectiveness and ways to balance management of starry stonewort with EWM, all while protecting the native aquatic plant community of Silver Lake.

Community Composition Trends

The Commission has completed three aquatic plant surveys at Silver Lake during the past 25 years. These surveys were completed during 1995, 2000, and 2015. As was standard practiced during the time, the 1995 and 2000 surveys utilized transect-based survey methodology. The Commission's 2015 survey followed point-intercept methods as have subsequent comprehensive aquatic plant surveys. Fortunately, for use in aquatic plant community evaluation and management plan formulation, statistical differences in data generated by transect and point-intercept methods are low. This allows historical data to be used to draw reasonably reliable quantitative comparisons of aquatic plant communities over time.[125] Thus, it is reasonable to compare the data generated by the 1995 and 2000 transect surveys and more recent point-intercept surveys.

Based upon data collected between 1995 and 2018, aquatic plant diversity has increased over the years (see Table 2.13). Muskgrass has consistently been the most frequently encountered species in the Lake. The frequency of occurrence of most other aquatic plants have varied over the years (see Figure 2.49). On an overall basis, frequency of occurrence for nearly all aquatic plants is higher during certain years (e.g., 2000). Since the year 200, some plants appear to be becoming less common (e.g., common bladderwort, water celery).

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[123] "Aquatic Invasive Species Quick Guide: Starry Stonewort (*Nitellopsis obtusa L.*)". *Golden Sands Resource Conservation and Development Council, Inc. This Quick Guide is part of a series on aquatic invasive species and may be reproduced for educational purposes. Visit www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/clmn/training.aspx#factsheets or www.goldensandsrcd.org/aquatic-invasive-species to view or download this information. Developed by Golden Sands Resource Conservation & Development Council, Incorporated as part of an aquatic invasive species education program, supported by a grant from the Wisconsin Department of Natural Resources. Maintained and updated by the Wisconsin Citizen Lake Monitoring Network.*

[124] *This information was provided by Richard Barrett, Secretary, SLPRD.*

[125] *See SEWRPC Community Assistance Planning Report No. 193,* A Lake Protection Plan for Powers Lake, Kenosha and Walworth Counties, Wisconsin, *2011.*

Table 2.13
Historical Aquatic Plant Frequency of Occurrence[a]: Silver Lake 1995-2018

Aquatic Plant Species	June 1995	July 2000	July 2015	August 2016	August 2017	July 2018
Ceratophyllum demersum (coontail)	--	15.0	1.5	1.1	1.4	1.7
Chara spp. (muskgrasses)	95.5	95.0	75.6	55.7	60.4	84.5
Elodea canadensis (common waterweed)	1.5	15.0	2.5	1.8	1.1	2.3
Heteranthera dubia (water stargrass)	--	25.0	--	0.7	--	0.3
Lemna minor (common duckweed)	--	--	--	--	--	0.3
Lemna trisulca (forked duckweed)	--	--	--	--	--	1.7
Lythrum salicaria (purple loosestrife)	--	--	--	--[b]	--	--
Myriophyllum sibiricum (northern watermilfoil)	--	5.0	--	4.4	--	--
Myriophyllum spicatum (Eurasian watermilfoil)	33.3	55.0	11.7	12.1	17.1	15.2
Najas flexilis (slender naiad)	0.5	40.0	24.9	23.4	25.7	22.8
Najas marina (spiny naiad)	--	5.0	14.7	19.1	16.4	13.9
Nitella flexilis (slender nitella)	--	--	7.6	20.2	39.6	35.0
Nitellopsis obtusa (starry stonewort)	--	--	0.5	1.5	1.4	2.0
Nuphar variegata (spatterdock)	--[b]	--	1.0	0.4	--[b]	0.3
Nymphaea odorata (white water lily)	--[b]	--	2.5	2.2	2.5	2.3
Potamogeton amplifolius (large-leaf pondweed)	--	30.0	2.0	2.2	--	1.0
Potamogeton friesii (Fries' pondweed)	--	--	10.2	6.6	--	5.6
Potamogeton gramineus (variable pondweed)	12.1	50.0	12.7	9.9	--	4.0
Potamogeton illinoensis (Illinois pondweed)	--	--	7.6	3.7	30.0	19.1
Potamogeton nodosus (long-leaf pondweed)	4.6	--	--	--	--	--
Potamogeton strictifolius (stiff pondweed)	--	--	--	--	--	7.6
Potamogeton zosteriformis (flat-stem pondweed)	10.6	20.0	5.1	0.4	7.1	2.3
Schoenoplectus acutus (hardstem bulrush)	--	--	--	--	--[b]	0.7
Stuckenia pectinata (sago pondweed)	10.6	45.0	18.3	8.8	5.4	16.8
Utricularia gibba (creeping bladderwort)	--	--	--	--	--	0.3
Utricularia vulgaris (common bladderwort)	30.3	45.0	11.7	10.3	9.3	8.9
Vallisneria americana (wild celery/eelgrass)	19.7	45.0	8.6	7.0	5.4	8.9
Number of Native Species[c]	11	12	15	17	12	20

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] *Data represents Frequency of Occurrence. 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] *The species was observed and documented but not quantified.*

[c] *Total does not include emergent, nonnative, or invasive species.*

Source: Wisconsin Department of Natural Resources and SEWRPC

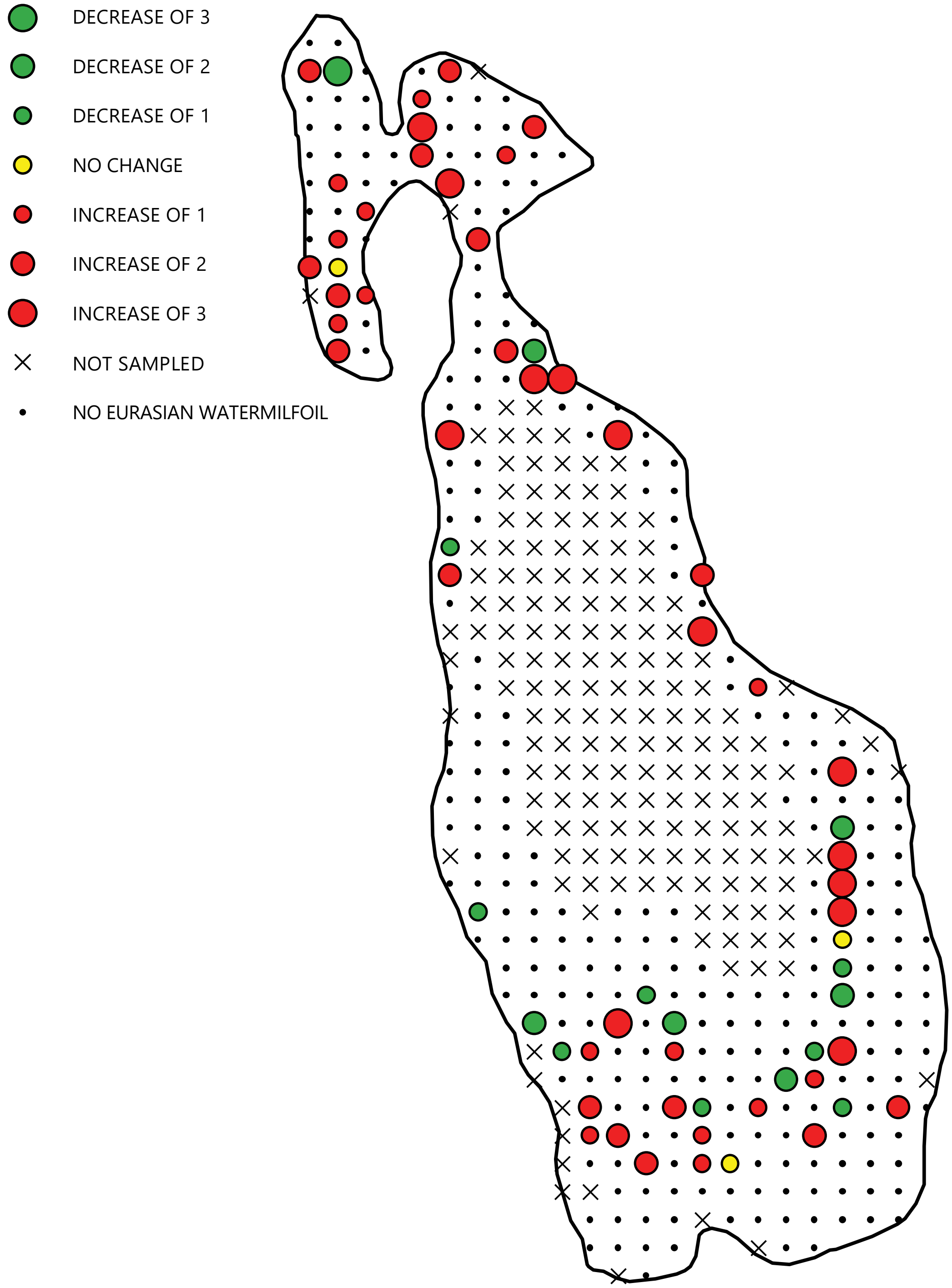
Although the number of species found in Silver Lake has slowly increased, the frequency of occurrence of dominant species has, in general, declined. At the same time, the frequency of occurrence of many less dominant species has increased in recent years, a situation suggesting better species balance. The overall increase in species diversity combined with more balanced native species abundance and reduced EWM abundance demonstrates that aquatic plant management strategies employed at Silver Lake have been very effective. Nevertheless, the presence of invasive EWM and starry stonewort demand close and frequent evaluation and may require decisive management action.

Aquatic Plant Management Alternatives

Aquatic plant management techniques can be classified into the following five categories.

- *Physical measures* – Barriers, such as lake-bottom coverings, are used to block sunlight and/or plant growth.

Figure 2.42
Change in Eurasian Watermilfoil Rake Fullness: 2015 Versus 2017



Source: Wisconsin Department of Natural Resources and SEWRPC

- *Biological measures* – Natural agents, such as herbivorous insects, are used to impede undesirable plant growth.

- *Manual measures* – Human "hands-on" manipulation of plant mass. This generally involves physically removing plants by hand pulling individual plants or using hand-held rakes or similar tools.

- *Mechanical measures* – Plant mass manipulation using machines and artificial power sources. This includes cutting plants (cut plants must be removed from the water), harvesting plants (where a barge-mounted machine both cuts and recovers cut plants and fragments), and suction harvesting aquatic plants from the lake bottom.

- *Chemical measures* – Plant mass manipulation using herbicides. This involves introducing liquid or solid chemical compounds toxic to, or restraining, plant growth. Chemical measures can also be used to control free-floating algae.

Figure 2.43
Starry Stonewort (*Nitellopsis obtusa*)

Note the tiny white star-like bulbils.

Source: Paul Skawinski

All aquatic plant 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, "Navigable Waters, Harbors, and Navigation," 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 alternatives described below consider provisions stipulated by Chapters 107 and 109 of the *Wisconsin Administrative Code*, Chapter 30 of the *Wisconsin Statutes*, the requirements of Chapter NR 7, "Recreational Boating Facilities Program," of the *Wisconsin Administrative Code* and 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

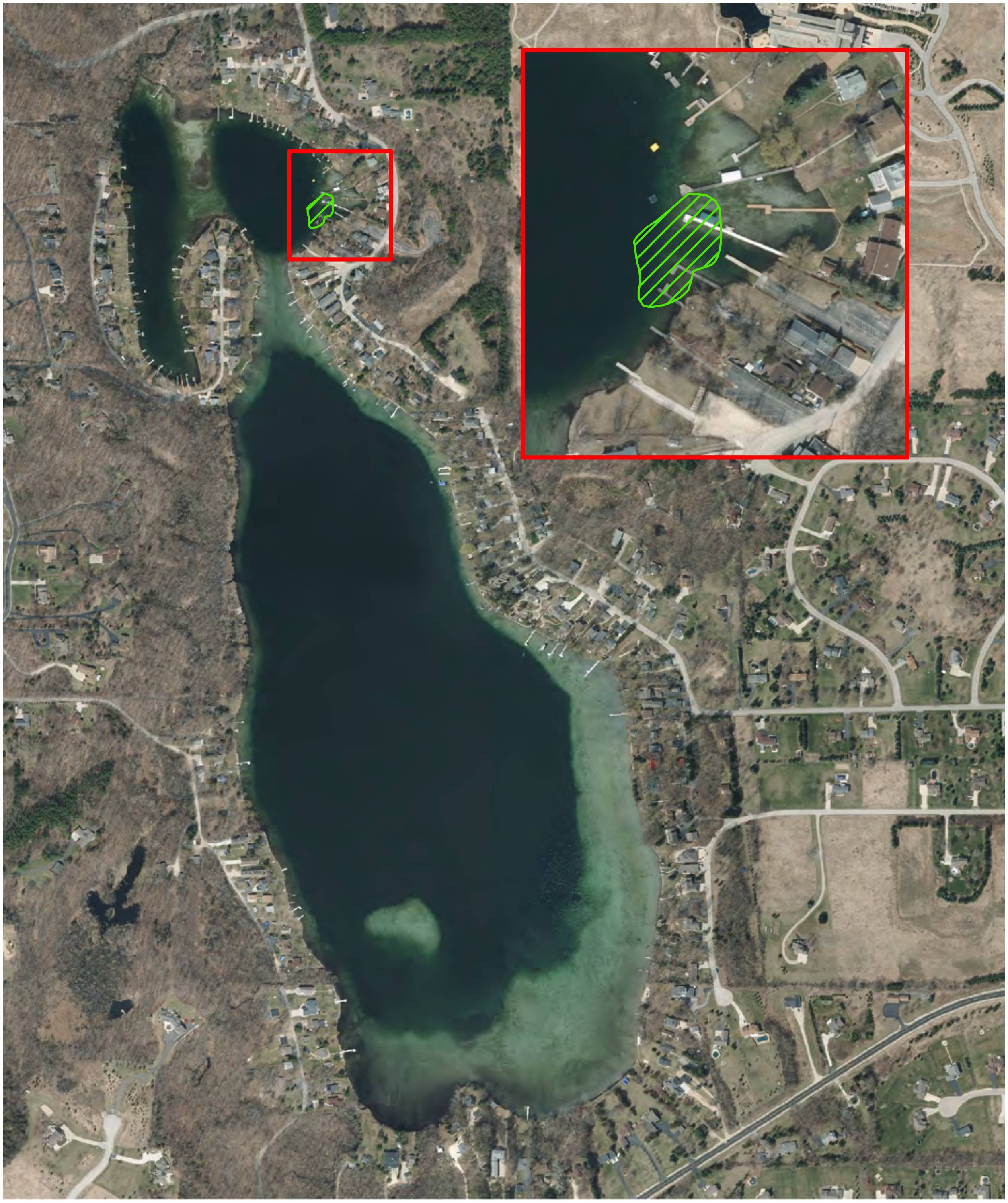
Lake-bottom covers and light screens control rooted plants by creating a physical barrier that reduces or eliminates plant-available sunlight. Bottom covers are often used to create swimming beaches on muddy shores, to improve the appearance of lakefront property, and to open channels for motorboats. Various materials have been used with varied levels of success. For example, pea gravel, which is usually widely available and relatively inexpensive, is a used bottom cover material despite the fact that plants readily recolonize pea gravel deposited upon lake bottoms. Other options include synthetic materials such as polyethylene, polypropylene, fiberglass, and nylon. Synthetic barriers can provide relief from rooted plants for several years. However, they are susceptible to disturbance by watercraft propellers and to gas build-up and flotation from decaying plant biomass trapped under the barrier. Therefore, synthetic covers may have to be placed and removed seasonally each year. Whatever the case, the WDNR does not permit these kinds of controls.

Biological Measures

Biological agents 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.[126] An example of this type of control is the milfoil weevil

[126] *Moorman, B., "A Battle with Purple Loosestrife: A Beginner's Experience with Biological Control,"* Lake Line, *Volume 17, Number 3, pp. 20-21, 34-37, September 1997; Huffacker C. B., D. L. Dahlsen, D. H. Janzen, and G.G . Kennedy, "Insect Influences in the Regulation of Plant Population and Communities," pp. 659-696, 1984; Huffacker C. B., and R.L. Rabb, editors,* Ecological Entomology, *John Wiley, New York, New York, 1984.*

Figure 2.44
Silver Lake Starry Stonewort Distribution: 2015, Before DASH Treatment



STARRY STONEWORT

Date of Photography: April 2015

Source: Washington County Planning and Parks Department and SEWRPC

Figure 2.45
Silver Lake Starry Stonewort Distribution: 2015, After DASH Treatment

Source: Washington County Land Conservation and SEWRPC

Figure 2.46
Silver Lake Starry Stonewort Distribution One Year After 2015 DASH Treatment

Source: Washington County Land Conservation and SEWRPC

Figure 2.47
Locations Where Starry Stonewort Was Observed on August 10, 2018

Source: Marine Biochemists and SLPRD

(*Eurhychiopsis lecontei*). Milfoil weevils do best in lakes with dense EWM beds where the plants reach the surface and are close to shore. Furthermore, to prosper, milfoil weevils prefer lakes with little boat traffic, balanced panfish populations, and natural shoreline areas where leaf litter provides habitat for over-wintering.[127] This technique is not presently commercially available making use of introduced milfoil weevils a non-viable option.

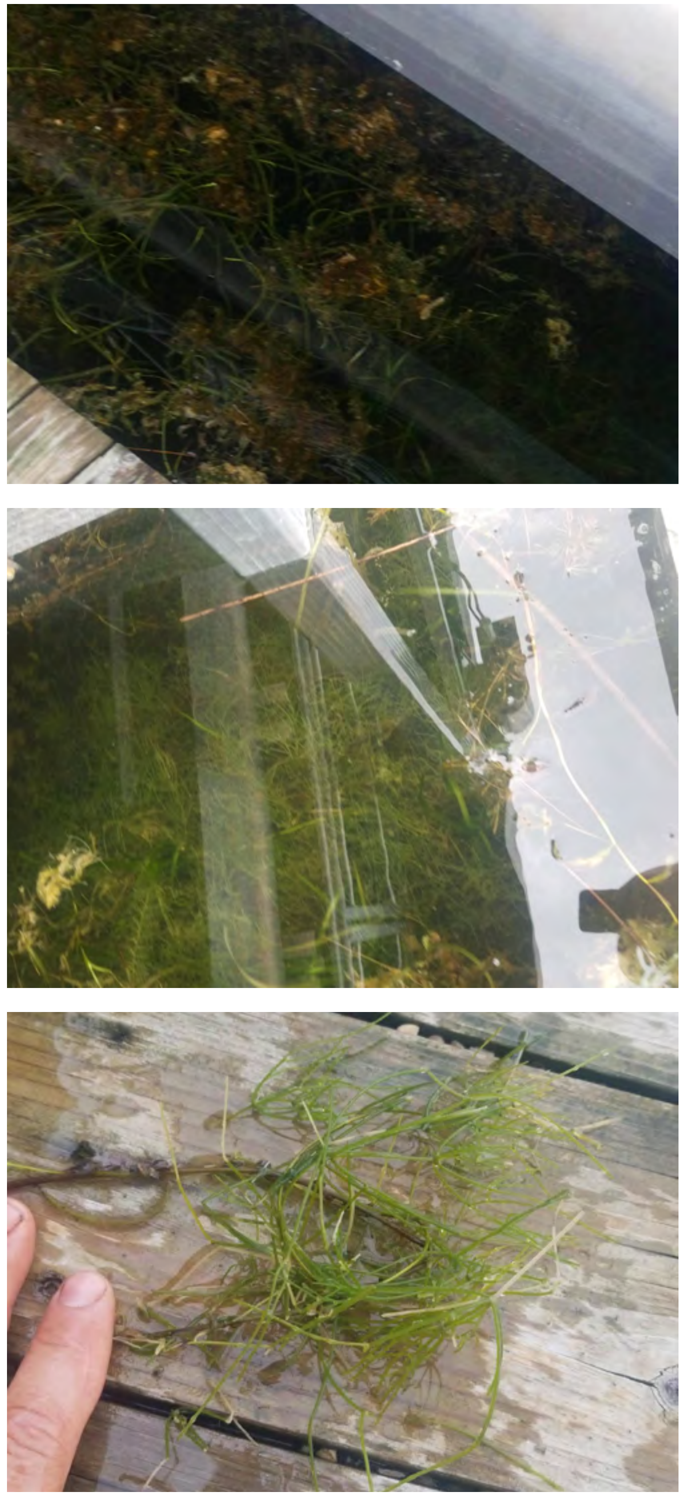
Manual Measures

Manually removing specific types of vegetation provides highly selective control of nuisance aquatic plant growth, including invasive species such as EWM. Hand raking and hand pulling are two of the most common manual control methods. Each relies upon individuals having the ability to differentiate target plants from valuable native plants. Plant material is then collected and physically removed from the lake. Removing plant material from a lake reduces nutrient loads and the volume of material contributing to lake-bottom sediment accumulation. This in turns helps this method contribute to water depth preservation and better water quality. Furthermore, removing target plants reduces the reproductive potential of nuisance vegetation. Hand-raking and hand-pulling methods are described in more detail in the following paragraphs.

Raking is nearshore activity with specially designed hand tools. Raking is typically used in shallow areas to remove nonnative plants but can also be a safe and convenient method to control aquatic plants in somewhat deeper nearshore waters around piers and docks. Examples of advantages associated with rakes include:

- Rakes are relatively inexpensive ($100 to $150 each)
- Rakes are easy to use
- Raking generates immediate results
- Raking immediately removes plant material from a lake

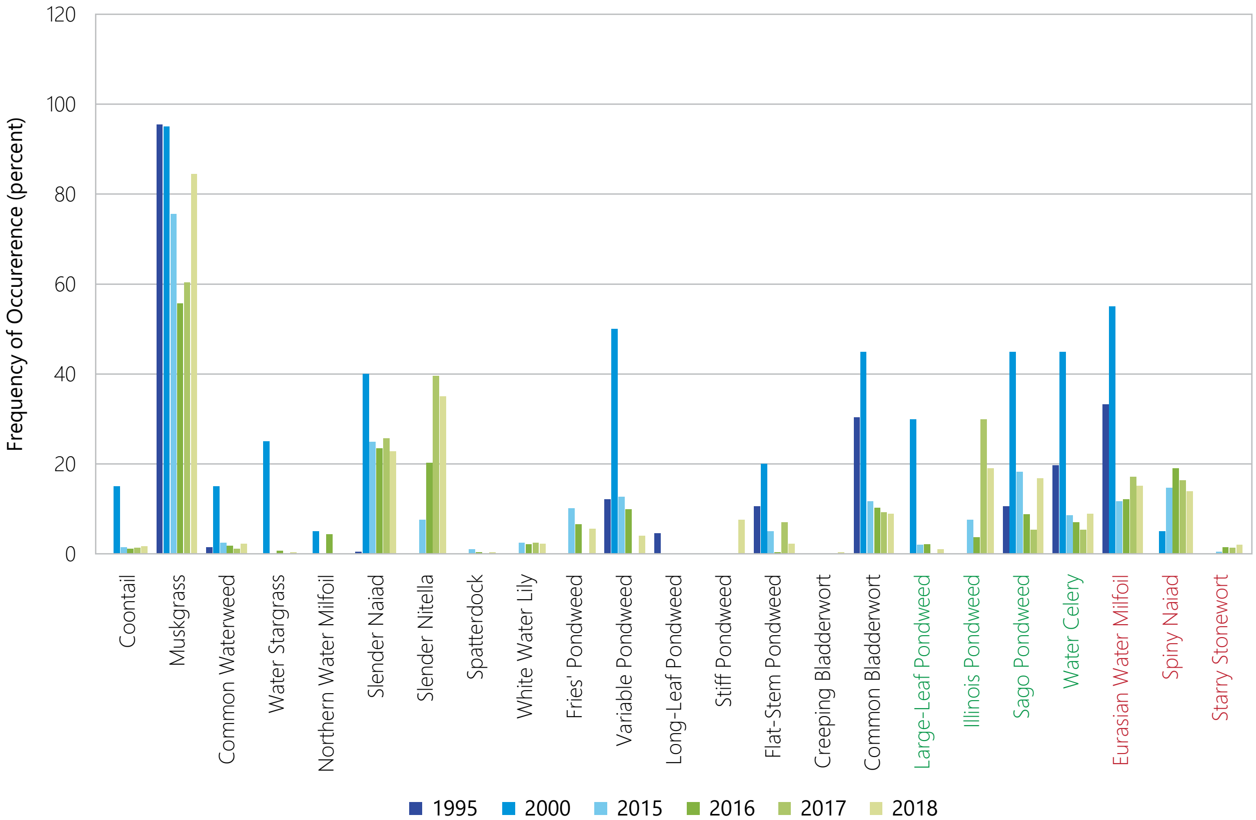
Figure 2.48
Photographs of Starry Stonewort in Silver Lake: 2018



Source: Marine Biochemists and SLPRD

[127] *Panfish such as bluegill and pumpkinseed feed upon herbivorous insects. High populations of panfish lead to excessive milfoil weevil predation.*

Figure 2.49
Silver Lake Aquatic Plant Frequency of Occurrence Changes Over Time



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.

Source: Wisconsin Department of Natural Resources and SEWRPC

By removing plant material from the lake (including seeds and plant fragments that propagate new plants), raking removes nutrients from the lake and alleviates sedimentation related to decomposing plant material. Furthermore, if carefully completed, native plants remain to fill the voids left by nonnative plant removal, allowing natives to recolonize portions of the lake.

Should Silver Lake residents wish to implement this control method, an interested party (e.g., the SLMRD) could acquire a number of these specially designed rakes and loan them to riparian owners to use on a trial basis. If Lake users are satisfied with rakes, additional property owners should be encouraged to purchase and use rakes. In areas where other management efforts are not feasible, raking is a viable option to manage overly abundant or undesirable plant growth.

The second manual control method - hand-pulling whole plants (stems, roots, leaves, and seeds) where they occur in isolated stands - provides an alternative means of controlling plants such as EWM and curly-leaf pondweed. This method is particularly helpful when attempting to target nonnative plants in the high growth season when native and nonnative species often coexist and intermix. This method is even more selective than rakes, mechanical removal, and chemical treatments, and, if carefully applied, is less damaging to native plants. Additionally, physically removing plant material prevents sedimentation and nutrient release from targeted plants, which incrementally helps maintain water depth and better water quality. Physical removal also reduces the amount of target plant seeds and plant fragments, which helps reduce the reproductive ability of the target plants. Volunteers or homeowners could employ this method, as long as they are properly trained to identify EWM or any other invasive plant species of interest. WDNR provides a wealth of guidance materials, including an instructional video describing manual plant removal, to help educate volunteers and homeowners.

Pursuant to Chapter NR 109 of the *Wisconsin Administrative Code*, aquatic plants may be raked or hand-pulled without a WDNR permit under the following conditions:

- Eurasian watermilfoil, curly-leaf pondweed, and purple loosestrife may be removed if the native plant community is not harmed in the process.
- No more than 30 lineal feet of shoreline may be cleared (this total must include shoreline lengths occupied by docks, piers, boatlifts, rafts, and areas undergoing other plant control treatment). In general, regulators allow vegetation to be removed up to 100 feet out from the shoreline.
- Plant material that drifts onto the shoreline must be removed.
- The shoreline cannot be a designated sensitive area.
- Raked and hand-pulled plant material must be removed from the lake.

Any other manual removal program requires a State permit, unless specifically used to control designated nonnative invasive species such as EWM. In general, State manual aquatic plant removal permits call for all hand-pulled material to be removed from the lake. No mechanical equipment (e.g., towing equipment such as a rake behind a motorized boat or using weed rollers) may be legally used without a WDNR-issued permit. Recommendations regarding hand pulling and raking are included in Chapter 3.

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.

<u>Mechanical Harvesting</u>

Aquatic plants can be mechanically cut, gathered, and transported using specialized equipment known as harvesters. Harvesters are typically mounted on shallow-draft barges. They include an adjustable-depth cutting apparatus that cuts aquatic plant at depths ranging essentially from the water surface to up to about five feet below the water surface. An integral collection system (e.g., a conveyor and a basket) then gathers most cut plant material and stores it on the harvester. When on-board cut plant storage capacity is exhausted, the harvester visits an offloading area where conveyors transfer cut plants to onshore storage areas or trucks. The cut plants are commonly hauled offsite to areas where they are used as soil amendments or composted. Mechanical harvesting can be a practical and efficient way of controlling nuisance plant growth in open water areas. Furthermore, since cut plants are physically removed from the lake and disposed elsewhere, harvesting can remove significant amounts of nutrients from a lake and can help reduce in-lake sedimentation. This can create an elegant mechanism to recycle vital nutrients to places where they have been lost and humans need them (e.g., agricultural areas and lawns). Mechanical harvesting is particularly effective to manage large areas of abundant plant growth.

An advantage of mechanical harvesting is that the harvester, when properly operated, "mows" the tops of aquatic plants, leaving enough living plant material in the lake to provide shelter for aquatic wildlife and to stabilize lake-bottom sediment. None of the other aquatic plant management methods leave living plant material in place after treatment**.** Aquatic plant harvesting also has been shown to facilitate regrowth of suppressed native aquatic plants by allowing light to penetrate to the lakebed. This is particularly effective when controlling invasive plant species that commonly grow very early in the season when native plants have not yet emerged or appreciably grown. Finally, harvesting does not kill native plants in the way that other control methods do. Instead, this method simply trims plants back.

A disadvantage of mechanical harvesting is that the harvesting process may fragment plants and, thereby, can foster unintentional spread of EWM and starry stonewort, both of which utilize fragmentation as a means of propagation, particularly in areas where plant roots have been removed. This further emphasizes the need to prevent plant management actions that remove native plant the roots. Harvesting may also agitate bottom sediments in shallow areas, increasing turbidity and sediment resuspension which can smother fish breeding habitat and nesting sites. Agitating bottom sediment also increases the risk of nonnative species recolonization, as invasive species tend to thrive on disrupted and/or bare lake bottom. To this end, most WDNR-issued permits do not allow deep-cut harvesting in water less than three feet deep,[128] which limits the utility of this alternative in many littoral areas. Nevertheless, if employed correctly and carefully under suitable conditions, harvesting can maintain and promote navigation and recreational use, can remove nutrients from the lake, can selectively reduce nuisance plant dominance, and can promote desirable native plant communities.

Some cut plant fragments commonly escape the harvester's collection system. To compensate for this, most harvesting programs include a plant pickup program. This kind of program, when applied systematically and with good shoreline owner participation, can reduce plant propagation from plant fragments and can help alleviate the negative aesthetic consequences of plant debris accumulating on shorelines. Since there are no current plant harvesting operations on Silver Lake, there is no plant pickup program. However, it is important to note that plant fragments from normal boating activity on Silver Lake (particularly during weekends) can create many plant fragments. The most significant accumulations are typically be found along eastern shorelines due to prevailing wind patterns but plant fragments can accumulate anywhere. Promoting shoreline owners to collect and dispose plant fragments may help reduce invasive plant propagation throughout the Lake.

Suction Harvesting (DASH)

Diver Assisted Suction Harvesting (DASH) is a relatively new aquatic plant harvesting method. 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 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 evaluations will be needed to evaluate the efficacy of the technique. Nevertheless, many apparent advantages are associated with this method, including:

- 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

- Increased plant selectivity when compared to harvesting and raking, thereby reducing the loss of native plants

- Lower potential for disturbing fish habitat

DASH can provide relief from nuisance native and nonnative plants around piers. If individual property owners choose to employ DASH, an NR 109 permit is required. DASH was used in 2015 to remove both EWM and starry stonewort from selected areas within Silver Lake.

Both mechanical and suction harvesting are regulated by WDNR and require a permit. Non-compliance with permit requirements is legally enforceable and may lead to fines and/or complete permit revocation. The information and recommendations provided in this report help frame permit requirements. Permits typically can cover a five year period.[129] At the end of that period, a new plant management plan must be developed. The updated plan must consider the results of a new aquatic plant survey and must evaluate the success or failure and effects of completed plant management activities.[130] These plans and plan execution are overseen by the WDNR aquatic invasive species coordinator for the region.[131]

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[128] *Deep-cut harvesting is harvesting to a distance of only one foot from the lake bottom. This is not allowed in shallow areas because it is challenging to properly ensure that the harvester does not hit the lake bottom in these areas.*

[129] *Five-year permits are granted so that a consistent aquatic plant management plan can be implemented over that time. This process allows the actively used aquatic plant management measures to be evaluated at the end of the permit cycle.*

[130] *Aquatic plant harvesters must submit reports documenting harvesting activities as an integral part of permit requirements.*

[131] *Amy Kretlow (telephone 920-893-8552, email Amy.kretlow@wisconsin.gov) is currently the WDNR invasive species coordinator responsible for Washington County.*

Chemical Measures

Chemical herbicide applications in aquatic environments are stringently regulated. Such treatments require a WDNR permit and WDNR staff oversight during application. Chemical herbicide treatment is a short-term method to control nuisance aquatic plant growth. Either liquid or granular chemicals are applied to actively growing plants. Chemical herbicide treatments typically do not require significant capital investment, are easily contracted to service providers, and are relatively easy, fast, and convenient to execute. However, many concerns must be addressed when considering chemical herbicide applications. Several examples are listed below.

- **Unknown and/or conflicting evidence about long-term effects of chemical herbicides on fish, fish food sources, and humans.** The USEPA studies chemical to evaluate short-term (acute) effects on humans and wildlife. Additionally, some studies also examine long-term (chronic) effects of chemicals on animals (i.e., 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.[132] For example, conflicting studies/opinions exist regarding the role of the chemical 2,4-D as a human carcinogen.[133] 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 chemical herbicides are used, they should be applied as early in the season as practical and possible. This helps assure that the applied chemical decomposes before swimmers and other lake users begin to actively use the lake.[134]

- **Increased risk of algal blooms.** Waterborne nutrients promote growth of aquatic plants and algae. If rooted aquatic plant populations are reduced, demand for waterborne nutrients decreases which may cause nutrient levels to rise. Increased waterborne nutrients can cause free-floating algae to become more abundant. Care must be taken to avoid native plant loss and excessive or indiscriminate chemical use, actions which can compromise the health of a lake's native plant community, encourage spread of invasive plants, 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 abundance of the other may increase to nuisance levels. In addition to decreasing competition for waterborne nutrients, the death and decomposition of aquatic plants increases nutrient levels in lake water.

- **Potential increase in organic sediment and associated anoxic conditions.** When chemicals are used to control large mats of aquatic plants, much of the dead plant material settles to the lake bottom where it subsequently decomposes. This process generates organic-rich lake-bottom sediment. Bacterial action associated with decomposing organic material in lake-bottom sediment depletes oxygen from the lake's water column. Stratified lakes, such as Silver Lake, are particularly vulnerable to oxygen depletion, especially during summer within deeper areas of the Lake. Excessive oxygen loss can inhibit a lake's ability to support certain fish and can trigger 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.

- **Adverse effects on desirable aquatic organisms due to loss of native species.** Native plants, such as pondweeds, provide critical feeding, refuge, spawning, and nursery habitat for fish and other wildlife. A robust and diverse native plant community is a foundational element to overall lake health. Native aquatic plants support desirable gamefish populations since fish, and the organisms fish eat, require aquatic plants for food, shelter, and oxygen. If native plants are lost due to indiscriminate herbicide application, fish and wildlife populations often suffer. Consequently,

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132 *U.S. Environmental Protection Agency, 2,4-D* RED Facts, *publication number, EPA-738-F-05-002, June 2005.*

133 *Ibrahim, M. A., et al., "Weight of the Evidence on the Human Carcinogenicity of 2,4-D,"* Environmental Health Perspectives*, Volume 96, pp. 213-222, December 1991.*

134 *Though the manufacturers allege that swimming in 2,4-D-treated lakes is allowable after 24 hours, some swimmers may desire more time to lessen chemical exposure. Consequently, allowing extra time is recommended. This practice helps reassure the entire lake user community feels comfortable with wait times and that they are not being unduly exposed.*

if chemical herbicides are applied to the Lake, these chemicals must preferentially target invasive EWM or curly-leaf pondweed.[135] In any case, herbicides should be applied in early spring when native plants have not yet emerged.

- **Need for repeated treatments.** Since plants treated with aquatic herbicides are not removed from the lake, viable seeds and plant fragments often remain after treatment, promoting target plants' ability to rebound. Additionally, leaving large swaths of lakebed devoid of plants (both native and invasive) creates disturbed areas without a healthy array of aquatic plants. Eurasian watermilfoil thrives in disturbed areas. In summary, applying chemical herbicides to large areas can provide opportunities for target species re-infestation and possibly foster conditions that promote spread of invasives. This situation, in turn, necessitates repeated herbicide applications.

- **Hybrid water milfoil's resistance to chemical treatment.** Hybrid water milfoil[136] complicates management since research suggests that certain strains may have higher tolerance to commonly utilized aquatic herbicides such as 2,4-D and Endothall.[137,138] Further research on the efficacy and impacts of herbicides on hybrid watermilfoil must be conducted to better understand appropriate dosing protocol. Fortunately, hybrid watermilfoil has not yet been verified to exist in Silver Lake.

Other factors further complicate chemical herbicide application in lakes, namely, intermingled coincident growth of EWM and native species, the physical similarities between native water milfoils and EWM, and the presence of hybrid water milfoil. Since EWM tends to grow early in the season, early spring chemical application is an effective way to target EWM while minimizing impacts to desirable native plants. Early spring is a subjective term that is tied to overall weather conditions, ice-off dates, the type of chemicals applied, and the plant species targeted by the application effort. With these conditions in mind, "early spring" can mean as early as April or as late as June. Early spring application also has the advantage of being more effective due to the colder water temperatures, a condition enhancing herbicidal effects and reducing the dosing needed for effective treatment. Early spring treatment also reduces human exposure (swimming is not particularly popular in very early spring) and limits the potential for unintentional damage to native species.

Chemical spot treatments were used in Silver Lake at least as early as 1950 and continuing through 2014 (see Table 2.14). Spot control treatment was primarily used to manage EWM. Chemical treatments have been postponed recently on account of intense mechanical plant management methods. However, chemical treatment may continue to be a viable option to control nuisance and invasive aquatic plants in the future. Recommendations are included in Chapter 3.

Other Aquatic Plant Management Issues of Concern

This subsection addresses monitoring and controlling aquatic plants already found in the Lake. Many allied activities can inhibit or prevent future nuisance aquatic plant growth, which, in turn, helps avoid adverse effects related to many in-lake control alternatives. A number of factors create a lake environment conducive to "excessive" plant growth, both in terms of EWM and native plants. For example, poor water quality with high phosphorus content (which can result from both external sources and in-lake processes such as internal loading or diminished phosphorus sequestration) provides the critical building blocks that all plants need to thrive and eventually reach what is perceived as nuisance levels. Consequently, implementing recommendations to improve water quality must be integral to any comprehensive aquatic plant management plan. Thus, many of the issues of concern discussed previously under "Water Quality" are also priorities for aquatic plant management. Recommendations related to these factors are included in Chapter 3 of this report.

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[135] *At present, no chemical herbicide is known to effectively treat starry stonewort.*

[136] *In recent years, it has become evident that EWM and native (or northern) water milfoil have hybridized. The resulting diverse hybrid strains cannot be reliably identified based on physical appearance alone. This makes identification and selection of the appropriate control method problematic.*

[137] *Glomski, L. M., 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*, Volume 48, pp. 12-14, 2010.*

[138] *LaRue, E. A., et. al., "Hybrid Watermilfoil Lineages are More Invasive and Less Sensitive to a Commonly Used Herbicide than Their Exotic Parent (Eurasian Watermilfoil),"* Evolutionary Applications, *Volume 6, pp. 462-471, 2013.*

Table 2.14
Summary of Aquatic Plant Chemical Control Treatments Applied to Silver Lake

		Algal Control		Macrophyte Control						
Year	**Total Acres Treated**	Copper Sulfate (pounds)	Cutrine or Cutrine-Plus (gallons)	Sodium Aresenite (pounds)	2,4-D (gallons)	2,4-D (pounds)	Fluridone (pounds)	Diquat (gallons)	Endothall (pounds)	Aquathol (pounds)
1950	--	--	--	108	--	--	--	--	--	--
1951-1973	--	--	--	--	--	--	--	--	--	--
1974	0.4	7	--	--	--	--	--	--	100	--
1975-1980	--	--	--	--	--	--	--	--	--	--
1981	0.8	--	3.1	--	--	--	--	--	--	--
1982	1.9	--	9	--	--	--	--	--	--	--
1983	--	--	--	--	--	--	--	--	--	--
1984	2.4	--	7	--	--	--	--	--	--	10
1985	1.4	--	7.5	--	--	--	--	--	--	5
1986	3.9	--	10	--	--	--	--	1	--	5
1987	2.6	--	--	--	--	--	--	--	--	--
1988	3	--	--	--	--	1.5	--	2.5	--	--
1989	1.5	--	--	--	--	--	--	--	--	--
1990	2.5	--	2.2	--	--	--	--	1.2	--	1.2
1991	0.8	--	2	--	--	--	--	1	--	1
1992	1.5	--	1.5	--	--	--	--	1.5	--	1.5
1993-2000	--	--	--	--	--	--	--	--	--	--
2001	3.9	--	--	--	--	--	265	--	--	--
2002-2006	--	--	--	--	--	--	--	--	--	--
2007	5.25	--	--	--	--	550	--	--	--	--
2008	0.31	--	--	--	--	30	--	--	--	--
2009	--	--	--	--	--	--	--	--	--	--
2010	0.33	--	--	--	--	35	--	--	--	--
2011-2012	--	--	--	--	--	--	--	--	--	--
2013	4.09	--	--	--	--	445	--	--	--	--
2014	5.85	--	--	--	12.5	600	--	--	--	--
2015-2017	--	--	--	--	--	--	--	--	--	--
Total	42.43	7	42.3	108	12.5	1,661.5	265	7.2	100	23.7

Note: Gallons represent liquid forms of chemical and pounds represent the granular form. Navigate and DMA 4-EVM were the types of 2,4-D herbicides used for macrophyte control, with Navigate having the unit of pounds and DMA 4-IVM as gallons.

Source: Wisconsin Department of Natural Resources and SEWRPC

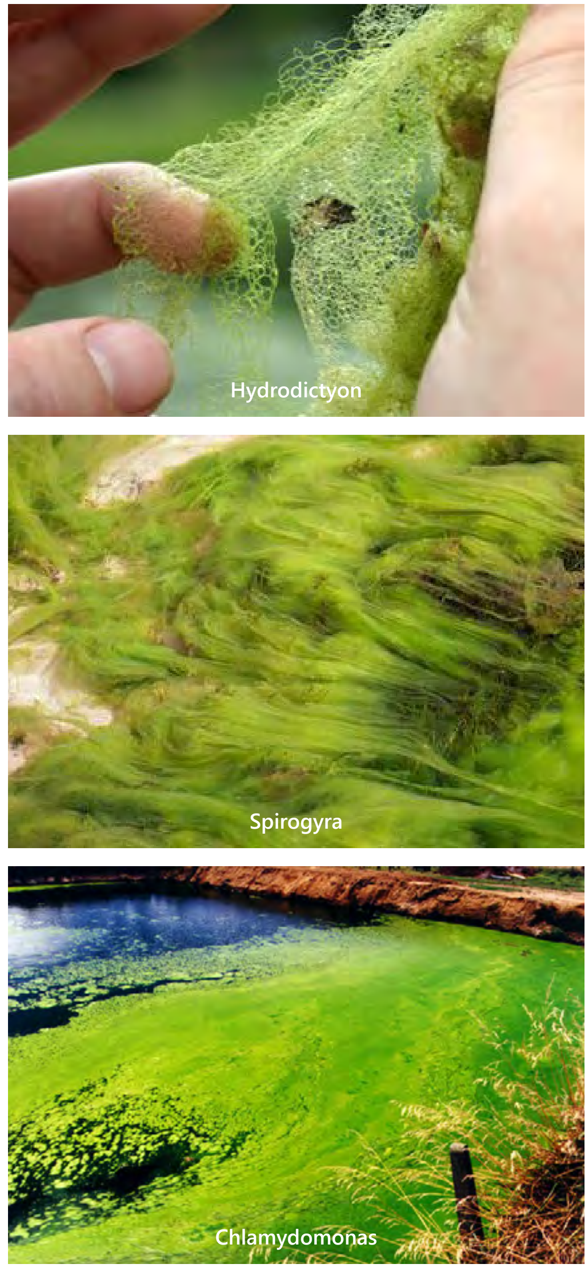
Lake users should be vigilant regarding new invasive species or re-infestations of invasive species already found within the Lake and should proactively manage the very real threat of such species colonizing the Lake. Many additional aquatic invasive species threaten lakes but are not known to be present in Southeastern Wisconsin (e.g., hydrilla (*Hydrilla verticillata*) or, if found in Southeastern Wisconsin, are not found in Silver Lake (e.g., yellow floating heart (*Nymphoides peltata*). Such species can harm Lake ecology. Therefore, ways to protect Silver Lake against new nonnative species are discussed in Chapter 3 of this report.

2.7 CYANOBACTERIA AND FLOATING ALGAE

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 forms of free-floating algae exist including single-cell, colonial, and filamentous algae (see Figure 2.50). Most algae strains are beneficial to lakes when present in moderate levels. However, the presence of toxic blue-green algal strains (also called cyanobacteria) and excessive growth patterns should be considered issues of concern (see Figure 2.51). 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 signifies phosphorus enrichment or pollution.

Algae populations are quantified by abundance and composition. Suspended algal abundance is estimated by measuring lake-water chlorophyll-*a* concentration. High concentrations are often associated with green-colored water. Samples also can be examined to determine if the algae are toxic or nontoxic. Chlorophyll-*a* measurements have been taken in Silver Lake, as discussed in the "Water Quality" section of this report. Recent chlorophyll-*a* concentrations are well below eutrophic levels, suggesting few, if any, algal blooms. Recommendations for continuing water quality measurements such as chlorophyll-*a* are set forth in Chapter 3 of this report.

Figure 2.50
Common Types of Non-Toxic Algae



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

2.8 RECREATION

Silver Lake is a multi-purpose waterbody that provides significant ecological values and serves a variety of human needs and desires. Water-based recreation is an important component of the value the Lake provides. Active recreation includes boating, waterskiing, tubing, swimming, and fishing during summer, and cross-country skiing, snowmobiling, and ice fishing during winter. The Lake is used year-round as a visual amenity with walking, bird watching, and picnicking being popular passive recreational uses of this waterbody. The Lake's location within easy travel distance of the metropolitan Milwaukee underscores its recreational value and popularity. Essentially all Lake residents and users want to ensure that Silver Lake 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, and wildlife) because each topic influences recreational use on the Lake.

As discussed in the "Potential Impacts of Boating" subsection below, water disturbance associated with boating can greatly accelerate shoreline erosion, can disrupt aquatic plant communities, and can suspend lakebed sediments. For example, as shown in Figure 2.52, lakebed disruption from boat traffic is plainly visible within Silver Lake's shallower areas (i.e., where water is less than 10 feet deep). Lake residents have expressed particular concern about certain high-power boats (e.g., bladder boats, also known as wake boats).[139] Bladder boats have become much more popular during recent years.[140]

[139] *Wake boats are a type of inboard watercraft specially designed to increase wave height for certain water sports (i.e., wakeboarding and wake-surfing). To accomplish this, the hull is shaped to produce large wakes and many have a hydrofoil device and/or built-in ballast tanks to displace more water to help create larger waves.*

[140] *Smith, Marlena and Erin Jarvie,* Wakeboarding in Michigan: Impacts and Best Practices, *Michigan Chapter, North American Lake Management Society, Fall 2015.*

Potential Impacts of Boating

Boat wakes have been shown to erode shorelines,[141] scour and disrupt the bottom sediments of a lake,[142] damage aquatic vegetation and disrupt faunal communities,[143] and temporarily decrease water clarity.[144] However, boat wake energy is event-dependent and is influenced by the vessel length, water depth, channel shape and size, and boat speed.[145] Wakes are most destructive in shallow and narrow waterways because wake energy does not have the opportunity to dissipate over distance.[146] Although boat wakes are periodic disturbances, in comparison to wind waves, they can be a significant source of erosive wave force due to their longer wave period and greater wave height.[147] Even small recreational vessels within 500 feet of the shoreline are capable of producing wakes that can cause shoreline erosion and increased waterbody turbidity.[148]

Shoreline conditions can also affect boat wave-induced water quality interactions within a lake. For example, armored shorelines can protect natural shorelines which can thereby prevent shoreline sediments from eroding into the lake. However, armoring potentially can increase lake-bottom sediment resuspension or erosion along other shoreline reaches through waver reflection/refraction. This is particularly prevalent along reaches armored with artificial materials such as concrete, masonry, steel, or steeply sloped riprap. Hence, protecting and promoting natural shorelines and/or properly (i.e., gently) sloped riprap can help absorb wave energy as opposed to reflecting it back into and across the lake. Such actions can in turn help improve water quality.[149] Although vegetated shorelines can effectively attenuate waves in certain settings, the ability to attenuate wave energy is not infinite.

Figure 2.51
Examples of Toxic Algae

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

[141] *Bilkovic, D., M. Mitchell, J. Davis, E. Andrews, A. King, P. Mason, J. Herman, N. Tahvildari, and J. Davis,* Review of boat wake wave impacts on shoreline erosion and potential solutions for the Chesapeake Bay, *STAC Publication Number 17-002, Edgewater, MD. 68 pp, 2017.*

[142] *Asplund, Timothy R. (Wisconsin Department of Natural Resources),* The Effects of Motorized Watercraft on Aquatic Ecosystems, *PUBL-SS-948-00, University of Wisconsin– Madison, Water Chemistry Program, March 17, 2000.*

[143] *Asplund, Timothy R., and Cook, Chad M.,* Effects of Motor Boats on Submerged Aquatic Macrophytes, Lake and Reservoir Management, *Volume 13, Number 1, 1-12, 1997.*

[144] *U. S. Army Corps of Engineers (USACE),* Cumulative impacts of recreational boating on the Fox River - Chain O' Lakes area in Lake and McHenry Counties, Illinois: Final Environmental Impact Statement, *Environmental and Social Analysis Branch, U.S. Army Corps of Engineers, Chicago, Illinois,. 194 p., 1994; Asplund, T. R.,* Impacts of motorized watercraft on water quality in Wisconsin lakes, *Wisconsin Department of Natural Resources Bureau of Research, Madison, Wisconsin, publication number. PUBL-RS-920-96. 46 p., 1996.*

[145] *Bilkovic, D., M. Mitchell, J. Davis, E. Andrews, A. King, P. Mason, J. Herman, N. Tahvildari, and J. Davis, 2017, op. cit.*

[146] *Ibid.*

[147] *Houser, C., "Relative Importance of Vessel-Generated and Wind Waves to Salt Marsh Rrosion in a Restricted Fetch Environment,"* Journal of Coastal Research *Volume 262: 230-240, 2010.*

[148] *Bilkovic, D., M. Mitchell, J. Davis, E. Andrews, A. King, P. Mason, J. Herman, N. Tahvildari, and J. Davis, 2017, op. cit.*

[149] *Heather Harwood, "Protecting Water Quality and Resuspension Caused by Wakeboard Boats,"* Lake Line *Volume 37, Number 3, Fall 2017.*

Figure 2.52
Boat-Induced Bottom Scarring of Silver Lake: 2018

Note: Propeller scarring is visible as thin straight lines on bottom sediments.

Source: Google Earth Pro, Copyright 2018

Artificially intense wave action can exceed the ability for natural shorelines to absorb energy and remain stable. Frequent exposure to powerboat wakes is a prime example of artificial wave action.[150] Several SLPRD members have expressed concern regarding erosion along the western shoreline of Silver Lake from boating activity, because, as described in the "Lake Shoreline Conditions" subsection above, this stretch of shoreline is not armored. Although there is a greater proportion of fallen or downed trees along this shoreline, information is not currently available to quantify the rate at which this shoreline is eroding. Typically, this could be done by comparing aerial imagery over multiple years, but this procedure proved to be inconclusive on account of resolution limitations of older imagery and the relatively modest rate of potential shoreline recession.

Since wake boats are designed to purposely produce larger wakes than standard hull designs, their operation creates more potential for erosion on shorelines compared to other motorboats of similar size and operating speed.[151] Ballast-laden wake boats are capable of producing wave heights and frequencies that may exceed those produced during the most intense summer thunderstorms and/or high winds for the majority of inland lakes in Southeastern Wisconsin.[152,153,154] In addition, due to the specific wake boat design criteria, the stern of such boats is lowered using water ballast. Therefore, the propeller runs deeper in the water compared to other motorboats,[155] causing wake boats to have greater potential to disrupt lake-bottom sediment. Even if the propeller does not come in direct contact with the bottom sediments, propeller turbulence can reach as deep as 10 feet below the water surface.[156] Propeller scarring of lake-bottom sediment in Silver Lake's shallow areas is plainly visible on aerial photography (see Figures 2.52). Greater bottom-sediment disruption increases lake water turbidity and resuspends phosphorus from the lake bed, both of which can decrease perceived water quality within Silver Lake.[157]

The deeper running propellers of wake boats also have a greater chance to uproot and/or fragment aquatic vegetation.[158] Since most native aquatic plants do not reproduce by fragmentation, increased fragmentation does not promote desirable native plant reproduction. Conversely, increased fragmentation of invasive EWM, which does reproduce via fragmentation, can promote spread of this problematic species. In addition, there also is an increased potential for transporting and introducing new invasive species to new waterbodies via water pumped from wakeboat ballast tanks. For example, quagga mussel (*Dreissena bugensis*) larvae, fish pathogens, or invasive plant fragments have been known to be introduced to new locations via water pumped from ship ballast tanks.

Several best management practice recommendations to reduce the potential impacts of wake boats to Silver Lake are included in Chapter 3.

Silver Lake Public Access

Public access to Silver Lake is provided by a public boat launch located at the northeastern end of the Lake (Figure 2.53). Vehicle parking is provided across the street (Figure 2.54) from the launch itself. Signage (Figure 2.55) illustrating pertinent aspects of the Lake boating ordinance is provided at the launch site. The Lake is considered to provide adequate public access as established pursuant to standards set forth in Chapter NR 1 of the *Wisconsin Administrative Code*.

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[150] *Bilkovic, D., M. Mitchell, J. Davis, E. Andrews, A. King, P. Mason, J. Herman, N. Tahvildari, and J. Davis, 2017, op. cit.*

[151] *Smith and Jarvie, 2015 op. cit. and Asplund, 2000 op. cit.*

[152] *Bilkovic, D., M. Mitchell, J. Davis, E. Andrews, A. King, P. Mason, J. Herman, N. Tahvildari, and J. Davis, 2017, op. cit.*

[153] *Sawyer County promulgated a rule during 2018 creating a 700-foot buffer from the shore specifically for boats creating enhanced wakes. See more information at www.cola-wi.org/news?offset=1553543436576.*

[154] *Bilkovic, D., M. Mitchell, J. Davis, E. Andrews, A. King, P. Mason, J. Herman, N. Tahvildari, and J. Davis, 2017, op. cit.*

[155] *Doug Keller, "Low-Speed Boating… Managing the Wave,"* Lake Line *Volume. 37 Number. 3, 2017.*

[156] *Ibid.*

[157] *Harwood, 2017, op cit.*

[158] *Keller, 2017, op. cit.*

While visiting the Lake to collect data during summer 2016, Commission staff occasionally visited the public launch area. On certain occasions, boat trailers, tow vehicles, or other vehicles were parked on grassy areas and other locations not intended for vehicle traffic. The Commission suggests that this area be be policed and that parking be limited to the available paved and marked locations. More suggestions regarding this facet are provided in Chapter 3.

Figure 2.53
Silver Lake Public Boat Landing: 2018

Source: SEWRPC

Figure 2.54
Silver Lake Public Boat Landing Parking Access Drive: 2018

Source: SEWRPC

Silver Lake Boat Counts

To help characterize recreational use intensity, a watercraft census (i.e., a boat count along the Lake's shoreline) was completed by Commission staff during summer 2015. Four hundred and sixty-four watercraft were counted during the census, either moored or stored on land in the shoreland areas around the Lake (see Table 2.15 for additional details). About 40 percent of all watercraft were motorized, with powerboats and pontoon boats comprising the most common types, while 60 percent of all docked or moored boats were non-motorized (e.g., rowboats, kayaks, canoes, sailboats, and pedal-boats/paddleboats). The number of moored or docked boats would generally suggest that about nine to 23 watercraft would be found on Silver Lake during high-use periods.[159]

Another way to assess the degree of recreational boat use on a lake is through direct counts of boats actually in use at a given time. During 2106, Commission staff counted the numbers and types of watercraft in use on Silver Lake during typical summer weekdays and weekends. Survey results are summarized in Tables 2.16 and 2.17. These surveys revealed as many as 13 watercraft in use on weekdays and 21 on weekends. Not surprisingly, fishing and low-speed cruising were the most popular weekday morning activities (a situation possibly related to local boating ordinances requiring no-wake from 7:00 pm to 10:00 am). The most popular afternoon activities, weekdays or weekends, involved personal watercraft and other high-speed power boating activities. Swimming from piers, boats, and rafts was also a very popular activity on both weekdays and weekends.

Boating Pressure on Silver Lake

A study completed in Michigan attempted to quantify desirable boat traffic intensity on an array of lakes used for a variety of purposes. That study, which covered a wide variety of boat types, recreational uses, and lake characteristics, concluded that 10 to 15 acres of useable lake open water area provides a reasonable

[159] *At any given time, between about 2 percent and 5 percent of the total number of watercraft docked and moored around a lake will typically be active on a lake.*

and conservative average maximum desirable boating density.[160,161] Use rates above this threshold are considered to negatively influence public safety, environmental conditions, and the ability of a lake to host a variety of recreational pursuits. High-speed watercraft require more space, necessitating boat densities less than the low end of the range. The suggested density for a particular lake is:

Minimum desirable acreage per boat = 10 acres + (5 acres x (high-speed boat count/ total boat count))

Figure 2.55
Silver Lake Boating Ordinance Signage at Public Boat Launch: 2018

Source: SEWRPC

The 2016 Commission recreational survey suggests that the highest boat use occurs, unsurprisingly, on weekends. Most boats in use during peak periods were capable of high-speed operation; however, most were not being operated at high speed. If one assumes that ten percent of the boats could potentially be operating at high speed during the day, the formula set forth above suggests that 12 to 13 or more acres of useable open water should be available per boat. Given that roughly 67 useable acres are available for boating in Silver Lake, no more than 5 to 6 boats should be present on the lake at any one time to avoid use problems (see Figure 2.56). The number of boats actually observed on Silver Lake (Tables 2.16 and 2.17) are more than double to triple the Lake's suggested safe capacity during heavy use periods.[162] This means that the potential for use conflict, safety concerns, and environmental degradation is much higher than desirable during some weekends, holidays, and some weekdays. To help mitigate this concern, boating ordinances and regulations should be reviewed and, if necessary, modified. Such ordinances and regulations should be conscientiously enforced to help reduce the potential for problems related to boat overcrowding during periods of peak boat traffic. Additional details regarding this recommendation are presented in Chapter 3.

Recreational Activities In/On Silver Lake

As part of the 2016 boat count, Commission staff also evaluated the ways people were using the Lake (see Tables 2.16 and 2.17). The most popular weekday recreational activity was fishing. Swimming and low speed cruising were amongst the most popular weekend activities at Silver Lake. High-speed cruising, personal watercraft use, and skiing/wakeboarding/tubing were more popular during the late afternoon during both weekdays and on weekends. The high number of users hosted by Silver Lake make lake-user conflict likely.

Some recreational use types are not always compatible with other use types. For example, using a particular area for fishing and swimming is unlikely to be compatible with high-speed boating. Chapter 3 recommendations encourage compromise between potentially conflicting use types. The goal is to allow all recreational use types to experience a satisfying experience.

[160] *"Useable lake area" is the size of the open water area that is at least 100 feet from the shoreline.*

[161] *Progressive AE,* Four Township Recreational Carrying Capacity Study, Pine Lake, Upper Crooked Lake, Gull Lake, Sherman Lake*, Study prepared for Four Township Water Resources Council, Inc. and the Townships of Prairieville, Barry, Richland, and Ross, May 2001.*

[162] *The reader should note that actual "useable acreage" is less than used in the formula since high speed boat operation is prohibited within 150 feet of the shoreline. This would further decrease the number of boats that use the Lake without creating use-conflict or safety concerns.*

Table 2.15
Watercraft Docked or Moored on Silver Lake: 2015[a]

Type of Watercraft										
Powerboat	Fishing Boat	Pontoon Boat	Personal Watercraft	Canoe	Sailboat	Kayak	Paddle Boat	Rowboat	Paddle Board	Total
53	7	102	31	32	8	109	85	20	17	464

[a] *Including trailered watercraft and watercraft on land observable during survey.*

Source: SEWRPC

Boating and In-Lake Ordinances

The Town of West Bend posts boating and in-Lake ordinances for Silver Lake at the launch site and on its website.[163] These ordinances conform to State of Wisconsin boating and water safety laws pursuant to Chapter 30 of the *Wisconsin Statutes*. These ordinances provide for water traffic lanes, speed restrictions and hours of operation, and other safety laws.

Rule promulgation and enforcement attempt to promote safe, fair, and sustainable use of the Lake by a wide user spectrum. Rules commonly are put in place to promote public safety, prevent inadvertent damage to the Lake's shoreline, and discourage behaviors that diminish overall enjoyment of the Lake (e.g., speed limits, navigation patterns and time periods, excessive noise). Rules can also address factors that help protect lake health and shoreline infrastructure. Rules are often put in place that govern wake generation, high water conditions, agitation of shallow-water bottom sediment, disruption of aquatic plants, and wildlife disturbance. Since lake conditions and use types/intensity continually evolve, lake rules require periodic review and updating. Recommendations are made in Chapter 3.

2.9 FISH AND WILDLIFE

Life cycles of many species of aquatic terrestrial species include Silver Lake. Consequently, actions that effect aquatic and terrestrial wildlife are issues of concern. Therefore, Lake and watershed management actions that protect or enhance fish and wildlife are of interest to Lake managers. As part of this study, Commission staff identified several issues that could affect aquatic and terrestrial wildlife. Examples of these issues are listed below.

- Fishing was identified as a primary recreational use of the Lake, as was verified by the 2016 recreational survey (see "Recreational Activities In/On Silver Lake" section)
- A healthy and varied fish population is present in the Lake
- Critical species habitats are located within the Lake's watershed (see Maps 2.10 and 2.12)
- The Lake's watershed likely supports a significant waterfowl population including mallards, wood duck, and blue-winged teal, particularly during the migration seasons
- The Lake's watershed supports support both small and large mammals, including furbearers and game animals

Fishery Surveys

The WDNR lists largemouth bass and panfish as abundant in Silver Lake and smallmouth bass and northern pike as present.

[163] *Silver Lake's boating/lake use ordinance may be found at the following URL: townofwestbend.com/uploads/ckfiles/files/Silver%20Lake%20Boating%20Regulations.pdf.*

Table 2.16
Silver Lake Recreational Survey: Weekdays Summer 2016

Category	Observation	Time and Date						
		6:00 a.m. to 8:00 a.m.	8:00 a.m. to 10:00 a.m.		10:00 a.m. to Noon	2:00 p.m. to 4:00 p.m.		4:00 p.m. to 6:00 p.m.
		July 12	July 8	August 31	August 11	June 27	July 22	July 19
Watercrafts Observed on Silver Lake								
Type of Watercraft (number in use)	Powerboats	0	1	0	2	1	6	2
	Pontoon Boat	0	1	0	1	0	2	2
	Fishing Boat	2	2	0	0	1	1	0
	Kayak/Canoe	0	1	0	0	2	0	3
	Personal Watercraft	0	0	0	1	0	3	0
	Sailboat/Wind Board	0	0	0	0	0	0	0
	Row Boat/Paddle Boat	0	2	0	0	0	1	0
Activity of Watercraft (number engaged)	Motorized Cruise/Pleasure Low Speed	0	2	0	2	1	1	1
	High Speed Cruising	0	0	0	0	0	5	2
	Skiing/Tubing/Wake Boarding	0	0	0	1	0	5	1
	Fishing	2	2	0	1	1	1	0
	Rowing/Paddling/Pedaling	0	3	0	0	2	1	3
	Sailing/Windsurfing	0	0	0	0	0	0	0
	On Water	2	7	0	4	4	13	7
Recreational Activities Observed on Silver Lake								
Activity (average number of people)	Park Goer	0	0	0	0	0	0	0
	Beach Swimming	0	0	0	0	0	0	1
	Pier/Boat/Raft Swimming	0	0	0	0	8	23	0
	Canoeing/Kayaking	0	1	0	0	2	0	2
	Personal Watercraft	0	0	0	1	0	4	0
	Skiing/Wake Boarding/Tubing	0	0	0	0	0	10	2
	Rowing/Pedaling	0	2	0	0	0	1	1
	Fishing from Boats	3	3	0	2	0	0	0
	Fishing from Shore	0	0	0	2	0	0	1
	Low-Speed Cruising	0	2	0	4	3	0	2
	High-Speed Cruising	0	0	0	0	0	9	8

Source: SEWRPC

Table 2.17
Silver Lake Recreational Survey: Weekends Summer 2016

Category	Observation	Time and Date		
		Noon to 2:00 p.m.	4:00 p.m. to 6:00 p.m.	
		August 28	August 14	September 4
Watercrafts Observed on Silver Lake				
Type of Watercraft (number in use)	Powerboats	6	11	5
	Pontoon Boat	3	6	8
	Fishing Boat	1	1	0
	Kayak/Canoe	2	1	0
	Personal Watercraft	1	2	5
	Sailboat/Wind Board	0	0	0
	Row Boat/Paddle Boat	0	0	0
Activity of Watercraft (number engaged)	Motorized Cruise/Pleasure Low Speed	5	4	8
	High Speed Cruising	2	8	6
	Skiing/Tubing/Wake Boarding	2	1	2
	Fishing	1	1	0
	Rowing/Paddling/Pedaling	2	1	0
	Sailing/Windsurfing	0	0	0
	On Water			2
Recreational Activities Observed on Silver Lake				
Activity (average number of people)	Park Goer	0	0	0
	Beach Swimming	0	0	3
	Pier/Boat/Raft Swimming	10	11	0
	Canoeing/Kayaking	0	0	0
	Personal Watercraft	2	2	10
	Skiing/Wake Boarding/Tubing	0	2	7
	Rowing/Pedaling	3	0	1
	Fishing from Boats	2	1	0
	Fishing from Shore	0	0	0
	Low-Speed Cruising	21	12	39
	High-Speed Cruising	9	21	4

Source: SEWRPC

The WDNR completed a fyke net/electrofishing fishery survey at Silver Lake during spring 2007. [164] Twelve fish species were captured (see Table 2.18). Bluegills were found to be the most abundant fish species while largemouth bass were the most abundant predator. Bass were reported to have a fairly good size structure but grew below the State average. Bluegill were generally small, had poor size structure, and grew slowly. Other species captured included northern pike, walleye, bluegill, pumpkinseed, black crappie, and rock bass. Anecdotal information indicated that pike were abundant in the Lake but grew slowly. Walleye ranged in size from 10.7 inches to 22.7 inches; the walleye were thought to be likely from past private stocking by the SLPRD. Overall, the 2007 report concluded that Silver Lake's 2007 fish community was fairly typical for a relatively infertile lake, especially a lake with such a small watershed.

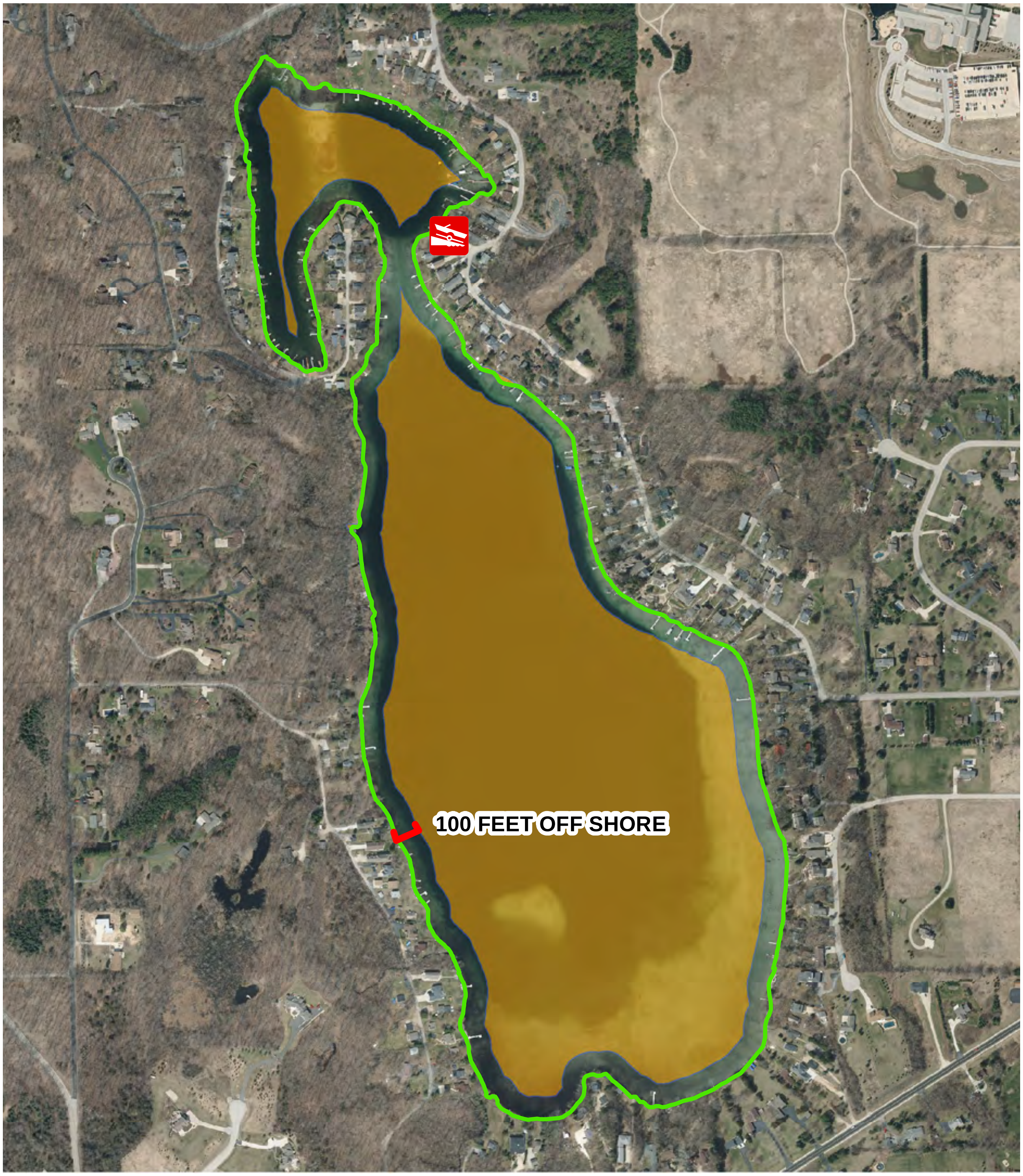
The WDNR concluded with the following observations:

- The Lake's bluegill consists of high numbers of small individuals. Bluegill populations such as those in lakes like Silver Lake are rarely controlled by largemouth bass.

- Walleye may never naturally reproduce in Silver Lake, a situation possibly explained by its infertility and inability to support enough zooplankton to sustain walleye fry (walleye fry feed primarily on zooplankton).

[164] *Nelson, John E.,* Silver Lake, Washington County (WBIC36200) Comprehensive Fish Survey 2007, *Wisconsin Department of Natural Resources, 2007.*

Figure 2.56
Silver Lake's Useable Boating Area



BOAT LAUNCH

USABLE BOATING AREA 100' OFF SHORELINE OF ENTIRE PERIMETER OF LAKE

SILVER LAKE SHORELINE

Date of Photography: April 2015

Source: SEWRPC

- Silver Lake has good to excellent largemouth bass habitat.

- The Lake's northern pike population is highly variable with the Lake being able to sustain a fairly high density of this species with an occasional large pike. However, trophy size pike would be unlikely.

The 2007 WDNR report concluded that the Lake's greatest fishery management challenge was reducing the number of bluegill present so that their growth rate could improve. Walleye stocking was mentioned as one way to improve bluegill population structure. The WDNR recommended that 35 fingerling walleye be stocked per acre with fish introduced by boat over deep water to reduce initial predation that otherwise occurs when fingerling-size fish are stocked in shallow water. Since the majority of pike caught during the survey were in the 20 inch to 21 inch range, it was felt that reducing or eliminating the 26-inch minimum size limit for northern pike may be warranted.

Table 2.18
Silver Lake Fish Survey: 2007

Species Collected	Average Length (inches)
Black Crappie	6.85
Bluegill	4.25
Brown Bullhead	NA
Green Sunfish	NA
Largemouth Bass	10.6
Northern Pike	20.5
Pumpkinseed	5.5
Rock Bass	6.05
Walleye	16.8
White Sucker	NA
Yellow Bullhead	NA
Yellow Perch	NA

Source: Wisconsin Department of Natural Resources

The WDNR again employed electrofishing and fyke net sampling during spring 2015 to evaluate Silver Lake's fishery.[165] Fyke netting targeted spawning northern pike and walleye after ice out. Total catch and catch rates for both species were low suggesting low density populations. Northern pike size structure was below average, a condition suggesting heavy harvest of adults or slow growth. The walleye size structure suggested good growth potential. Due to lack of adequate habitat, especially for northern pike, WDNR fisheries biologists felt that stocking both species would be needed to improve adult populations. Electrofishing targeted primarily largemouth bass and bluegill, although other species were caught with the boom shocker. The Lake provides ample spawning habitat for both largemouth bass and bluegill, and although bass size structure dropped off at the minimum size limit (indicating harvest of this species), the distribution of bass year classes reflects a strong population. In 2014, an experimental daily bag limit of 15 panfish, but only 5 of any one species, was placed on Silver Lake as part of an attempt to control bluegill size structure. The results of this plan will be evaluated in 2021.

Fishery Management Practices

Fish have been stocked in Silver Lake over the years for a variety of reasons. Rainbow trout were stocked in the Lake as early as the 1950s and walleyes have been stocked in the Lake since at least 1963.[166] More recent fish stocking records are summarized in Table 2.19. Over the past 25 years, walleye, yellow perch, and rainbow trout have been stocked into Silver Lake. WDNR concludes in its reports that Silver Lake has a typical fish population for a clear, spring-fed lake, suggesting that ongoing management practices are maintaining a viable fishery. Consequently, implementing ever evolving practices and recommendations is important. Furthermore, providing information and constructive feedback to fish and wildlife managers can help management programs evolve with actual on-the-ground conditions.

Healthy fish, bird, amphibian, reptile, and mammal populations are promoted by a number of in-lake and watershed-driven factors, including the following examples.

- Good water quality

- Reliable water supplies

- Water levels that vary within natural ranges

- Diverse plant and animal types and species mixes not monopolized by invasive species

[165] *Motl, Travis (WDNR), email to Dale Buser (SEWRPC), March 16, 2020.*

[166] *Wisconsin Department of Natural Resources,* Lake Use Report No. ML-8*, 1973, op. cit.*

- Adequate space, unfettered migration, and access to adjacent population gene pools

- A patchwork of habitat types, with sufficient diversity to assure access to all life-cycle critical habitat types

- Desirable population levels.

Fish and wildlife populations can be maintained or even enhanced by implementing "best management practices" (BMPs). The importance of maintaining Lake water levels, enhancing water quality, and judiciously managing aquatic plants, all of which are very important to maintaining or enhancing fish and wildlife populations, were discussed previously in this chapter. Therefore, the following section focuses on maintaining and expanding habitat, identifying key management decisions, and using BMPs and targeted strategies to enhance aquatic and terrestrial wildlife populations. Relevant concepts are briefly discussed below.

Table 2.19
Fish Stocked in Silver Lake: 1984-2019

Year	Species Stocked	Number Stocked	Age Class
1984	Walleye	495	Yearling
2004	Walleye	1,900	Large Fingerling
2004	Yellow Perch	1,000	Yearling
2008	Walleye	5,600	Small/Large Fingerling
2009	Walleye	1,210	Yearling
2010	Walleye	4,320	Small Fingerling
2011	Walleye	300	Yearling
2011	Yellow Perch	877	Yearling
2012	Walleye	3,170	Small Fingerling
2014	Rainbow Trout	405	Large Fingerling
2014	Walleye	615	Large Fingerling
2014	Yellow Perch	435	Adult
2015	Yellow Perch	607	Yearling
2016	Walleye	1,360	Large Fingerling
2016	Yellow Perch	606	Yearling
2017	Walleye	4,091	Large Fingerling
2019	Walleye	1,770	Large Fingerling

Source: Wisconsin Department of Natural Resources

Fishery Protection and Enhancement

Aquatic best management practices refer to activities that homeowners and resource managers can participate. Examples include catch and release fishing and fish stocking; both are intended to improve the Lake's fishery. To determine which fishery management practices may be most effective, it is important to know the following aspects of the Lake's history and condition. Fishery-related examples are provided below.

- **Fish population and size structure.** The WDNR completes studies examining the species, populations, and sizes of the fish in a lake. This information helps identify issues that may confront fish population. For example, if low numbers of juvenile fish are found, fish may not be successfully reproducing, a situation suggesting that habitat projects may be valuable. Similarly, if abundant juveniles are found but few large adult fish are present, over-harvest may be a factor and catch-and-release fishing should be promoted.

- **Fish stocking history.** To evaluate the information found in fish population studies, it is important to know how many fish of different sizes have been stocked. For example, if only stocked fish are captured, it is likely that no natural spawning occurs in the lake, meaning that the lake's fishery is depends entirely on fish stocking. Therefore, a management recommendation may be to continue fish stocking or identify and rectify impediments to natural reproduction. Common examples of the latter include construction of artificial spawning reefs and restoring access to important tributary areas by rectifying infrastructure that impedes fish migration.

Habitat Types and Interconnection

Wildlife needs large, well connected swaths of suitable landscape. Suitable landscape need not be completely natural but do need to provide for the needs of the species of interest. For example, whitetail deer do not need virgin forest to survive and instead may find a patchwork of woodlands and open fields more suitable. Consequently, understanding habitat needs of species of interest and protecting and expanding such areas the protection and expansion of natural habitat is crucial if wildlife populations are to be maintained or enhanced.

Open space natural areas can be classified as either wetlands or uplands. Each is briefly described below.

- **Wetlands** are defined by their hydrology, hydric soils, and presence of wetland plants. Many types of wetlands exist causing vegetation and appearance to vary greatly. For example, wetlands are often occupied by the prototypical cattail and bulrush vegetation that comes to many people's minds. However, the vegetation covering other wetland types can be dominated by sedges, brush, and/or trees. Most wildlife, both aquatic and terrestrial, relies upon, or is associated with, wetlands for at least a part of their lives. This includes crustaceans, mollusks, aquatic insects, fish, amphibians, reptiles, mammals (e.g., deer, muskrats, beavers), and birds (e.g., resident species such as turkeys and raptors and migrant waterfowl and songbirds).

- **Uplands** are areas outside the borders of wetlands, floodplains, and waterbodies. They are often characterized by drier, more stable soils. Uplands vegetative communities vary greatly (e.g., prairies, oak savannas, mesic hardwood woodlands). Uplands also provide sites for many critical wildlife life functions including breeding, nesting, resting, and feeding sites. Upland habitat types also offer refuge from predators for many upland game and nongame species. Unlike wetlands, the dry and stable soils make uplands more desirable for urban development and largely do not enjoy protection under most conservation-themed ordinances. Therefore, uplands can be more challenging to protect.

The dynamic interactions and exchanges between wetlands and uplands are key to the health of many terrestrial organisms. Many animals and insects depend upon both uplands and wetlands to complete their entire life cycle. For example, amphibians such as toads and salamanders live most of their lives in upland areas but depend upon wetlands for breeding. Consequently, if ecological connections between uplands and wetlands are severed (e.g., a road is constructed or a fence is erected) critical migration corridors may become dangerous or impossible to cross. This denies upland amphibians access to wetland breeding areas and will ultimately cause the populations of these animals to decline. In fact, habitat fragmentation has been cited as a primary global cause of decreasing wildlife populations.[167] Therefore, protecting and enhancing undeveloped upland and wetland is only part of the picture. Interconnection between intact habitat areas must also be maintained or enhanced, underscoring the importance of environmental corridor protection.

Aquatic Habitat Protection and Enhancement

Aquatic habitat enhancement generally refers to encouraging native aquatic plant (particularly pondweed) growth within a lake, as these plants provide food, shelter, and spawning areas for fish. Additionally, aquatic habitat enhancement also involves protecting wetlands) as well as encouraging the presence of fallen trees and other woody structure along the shorelines. Such features are common in natural lake environments and provide critical refuge and feeding areas for fish and other aquatic organisms, basking areas for amphibians, and substrate for periphyton.

To help ascertain the state of the aquatic habitat within the Lake, Commission staff completed an aquatic plant survey (see "Aquatic Plant Management" section) and a shoreline assessment in the summer of 2015 (see "Shoreline Maintenance" subsection). The results of the aquatic plant survey revealed that Silver Lake has very good plant diversity, with several different pondweed species.[168] Subsequent surveys have confirmed good species diversity (see Table 2.13). However, the shoreline assessment concluded there very little woody structure is present in most nearshore areas around the Lake. These conclusions indicate that while the current aquatic plant community should be maintained, riparian and near-shore projects should be implemented to increase natural shoreline vegetation and woody structure in shallow near-shore areas. Recommendations related to both are presented in Chapter 3.

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[167] *Fahrig, Lenore, "Effects of Habitat Fragmentation on Biodiversity",* Annual Review of Ecology, Evolution, and Systematics*, Volume 34, pp. 487-515, 2003.*

[168] *Pondweed species are important to lake ecology. For example, they provide excellent feeding and shelter opportunities to many aquatic organisms.*

Terrestrial Best Management Practices

The way people manage their land can significantly affect terrestrial wildlife populations. Turtles, for example, oftentimes travel considerable distances from their home lakes and rivers to uplands areas where they lay eggs. If pathways to suitable habitats are blocked by fences, buildings, walls, large stretches of pavement, or other impediments, or if these pathways are dangerous on account of pets, lawn equipment, traffic, or other hazards, turtles will not have the opportunity to nest or the new hatchlings may not be able to safely return to their home waterbody.

Many conservation organizations publish best management practices that homeowners, landowners, and resource managers can follow to help preserve or enhance wildlife populations. Although some best management practices are species- or animal-type specific (e.g., spaying or neutering to reduce control feral cat populations), many recommendations can benefit all wildlife. In general, wildlife enhancement best management practices target either agricultural or residential land uses. Agricultural measures commonly encourage habitat enhancement such as planting cover crops, establishing buffers, retiring marginal agricultural land and converting it to grassland or forest, allowing fallen trees to naturally decompose where practical, and restoring natural hydrology by disrupting artificial drainage infrastructure (e.g., buried tiles, ditches). Residential measures tend to focus on practices that landowners can install to provide habitat, such as installing a rain garden or avoiding nonnative plants in landscaping plans and preventing introduction of nonnative insects. Some recommendations are of course applicable to both types of landowners. For example, indiscriminately, carelessly, or wantonly killing native wildlife, particularly nongame amphibians, reptiles, and birds, must be discouraged to the maximum extent possible.

Sharing best management practice principles with the general public helps foster a culture encouraging wildlife populations without major targeted investment. Consequently, measures that often help increase acceptance and use of best management practices are included in Chapter 3 recommendations.

LAKE MANAGEMENT RECOMMENDATIONS AND PLAN IMPLEMENTATION 3

Credit: SEWRPC Staff

3.1 INTRODUCTION

Silver Lake is a valuable recreational resource to Lake residents and visitors, contributes to the local economy, enhances quality of life in the local area, and is an important ecological asset. This chapter discusses various management approaches that help maintain and enhance the Lake's health, is value to the community, and its latent ecological value.

Recommendations provided in this chapter are based upon data, analyses, and interpretations presented in Chapter 2. The recommendations cover an array of topics, all have been identified as important by Lake managers, Lake residents, and/or Lake users. While it may not be logistically feasible to immediately implement every recommendation, all have long-term value. In recognition of this limitation, and to promote efficient plan implementation, the importance and significance of each recommendation is identified to help prioritize execution sequence. Nevertheless, all recommendations should eventually be addressed, subject to possible modification based on analysis of new data (e.g., land use changes, new invasive species, aquatic plant community dynamics, water-quality fluctuation), project logistics, regulation, and possibly other factors.

Most of the approaches discussed in this chapter rely upon effective collaboration between the Silver Lake Protection and Rehabilitation District (SLPRD) and various project partners. Examples of primary project partners includes the Town of West Bend (the Town), the Silver Lake Sanitary District, and Silver Lake residents. However, other partners such as the Wisconsin Department of Natural Resources (WDNR), developers, landowners, land trusts, and other nearby municipalities are likely very important and necessary to ensure the long-term health of Silver Lake. Therefore, those interested in protecting and enhancing Silver Lake's overall health are strongly encouraged to continuously seek common ground and identify allied projects and partnerships that further the recommendations contained of this plan.

As a planning document, this chapter provides concept-level activity descriptions that may be undertaken to help protect and enhance Silver Lake. The full logistical and design details needed to implement most recommendations will need to be considered and developed in the future when the individual recommendations are implemented. It is important to note that these project concepts are not detailed technical specifications;

they are instead presented to provide stakeholders and decision makers with ideas about the types and nature of projects to pursue. In summary, this chapter provides context for understanding what needs to be done and helps readers picture how such efforts may appear. This type of information is often invaluable for coalition building, grant funding requests, and preliminary project design work.

To help implement this plan, recommendations are organized by the issues of concern identified in Chapter 2 (Table 2.1). A table lists and prioritizes all recommendation (Table 3.1). The priority levels were developed in collaboration with the SLPRD and the WDNR, the practicality and scale of action needed, and by contrasting the relative benefit provided by each recommendation. For example, concepts that concomitantly benefit both Silver Lake's surface-water and groundwater resources should be ranked higher than those solely benefitting either surface water or groundwater (see Map 3.1). Some recommendations apply to many goal but are more or less important in each application. Therefore, a certain activity may be assigned a high priority since it extremely important to achieving one goal and a lower priority in another section where it is less important to achieving another goal. Various figures and maps are included indicating where recommendations should be implemented, helping current and future Silver Lake managers target management efforts.

3.2 LAKE WATER SUPPLY RECOMMENDATIONS

All waterbodies gain and lose water, however, the processes by which individual lakes and streams gain or lose water widely differ. Rain and snow are the sources of all water naturally supplied to the Region's waterbodies. Although all water bodies are fed by a combination of runoff, tributary streams, and groundwater, all these water sources ultimately depend upon water originally supplied by precipitation. Waterbodies naturally lose water in several ways including evaporation, plant transpiration, outflow, and infiltration into waterbody beds and banks. When water inflow and outflow are not balanced, water elevations and flows fluctuate. If water supply is less than water demand, lake elevations can fall and stream flows can be reduced or eliminated. During wet weather or snowmelt, lake elevations and stream flow volumes generally increase.

Human activity modifies natural hydrology. Two human activities significantly affect Southeastern Wisconsin's hydrology. Each is summarized below.

- Artificial impermeable surfaces and most stormwater conveyance infrastructure hasten runoff, increase runoff volume, and discourage groundwater recharge. This typically increases the volume of water reaching lakes and rivers through runoff during wet weather, increases runoff intensity, and decreases flow to waterbodies during dry weather.

- Pumping water from water-supply wells and dewatering activity alters natural groundwater flow patterns. If most extracted groundwater is returned to groundwater at the point of withdrawal after use, overall impact may be minimal.[169] However, when water is either consumptively used (e.g., evaporated) or exported from the local groundwater flow system (e.g., carried away by sewers that discharge beyond the immediate groundwatershed boundary), groundwater elevations may fall and the flow of springs and seeps feeding surface-water features can be reduced or eliminated.

Unmitigated human-induced change is generally detrimental to waterbody health. Therefore, management actions should be taken to counter the effects of human activity. Because of its small surface watershed size, and because the Lake's groundwatershed is much larger than the surface watershed, Silver Lake's water supply depends primarily on groundwater. Therefore, many of the proposed concepts recommended to protect the Lake's water supply focus upon groundwater-related issues.

➤ **Recommendation 1.1: Continue to monitor Silver Lake's water level and weather conditions**
The Lake's elevation is influenced by several factors including precipitation, evaporation, wind and other weather conditions, the elevation and condition of the outlet dam weir, obstructions in the outlet channel between the Lake and the outlet dam, and the volume of groundwater discharging to the Lake.

[169] *An example of return flow pertains to rural residential settings. Rural residences are commonly served by a private well and a privately owned wastewater treatment system relying upon soil absorption. Much of the water pumped from the well finds its way to the soil adsorption system and from there ultimately reenters groundwater.*

Table 3.1
Silver Lake Management Plan Recommendation Summary

Recommendation Number	Description	Priority
	3.2: Lake Water Supply Recommendations	
1.1	Continue to monitor Silver Lake's water level and weather conditions	Medium
1.2	Maintain and inspect outlet dam and keep operational records	High
1.3	Enhance stormwater runoff detention and treatment wherever feasible	High
1.4	Protect the Lake's groundwater supply	High
1.5	Monitor groundwater conditions	Medium
1.6	Enforce existing ordinances and protect sensitive parcels	High
1.7	Identify unprotected parcels in high groundwater recharge potential areas	High
	3.3: Lake Water Quality and Pollutant Load Reduction Recommendations	
2.1	Continue monitoring Lake water quality	High
2.2	Protect and enhance existing wetlands, buffers, and floodplains	High
2.3	Reassure that engineered stormwater detention and conveyance systems are adequately maintained	High
2.4	Enhance existing and planned stormwater management infrastructure	High
2.5	Stringently enforce construction site erosion control and stormwater management ordinances	High
2.6	Promote rural land management practices that reduce soil erosion and nutrient export	Medium
2.7	Reduce pollutant loads from residential areas	High
2.8	Collect leaves and yard waste	High
2.9	Promote a healthy and robust aquatic plant community	High
	3.4: Nearshore Sedimentation and Shoreland Maintenance Recommendations	
3.1	Reduce runoff-related nutrient and sediment loads	High
3.2	Monitor shoreline erosion and nearshore sediment accumulation	Medium
3.3	Protect, enhance, and expand nearshore emergent vegetation	Medium
3.4	Strictly enforce the local boating ordinances	High
3.5	Encourage removal and/or enhancement of "hard" shoreline protective structures	High/Low
3.6	Encourage "soft" or "natural" shoreline protection	Medium
3.7	Enforce construction-related ordinances	High
	3.5: Aquatic Plant Management Recommendations	
4.1	Protect and promote native plant community	High
4.2	Manually remove nuisance plants in select nearshore areas	Medium
4.3	Hand-pull or use diver-assisted suction harvesting (DASH) to help control EWM, starry stonewort, and/or other invasive plants	Low
4.4	Consider herbicides to control new invasive species	Medium
4.5	Prevent invasive species introduction/re introduction	High
4.6	Periodically re-evaluate the Lake's aquatic plant management plan	High
4.7	Continue to work with WDNR to manage starry stonewort, fund experimental management strategies, and publicize results	High
	3.6: Cyanobacteria and Floating Algae Recommendations	
5.1	Control external phosphorus loading	High
5.2	Monitor algal abundance	Low/High
5.3	Notify Lake users of potentially unhealthy conditions	High
5.4	Promote a healthy native aquatic plant community	High
	3.7: Recreational Use Recommendations	
6.1	Conscientiously operate the public boat launch	High
6.2	Continue to participate in the Clean Boats, Clean Waters Program	High
6.3	Encourage safe boating practices and manage boat traffic pressure	High
6.4	Evaluate measures to avoid excessive boat traffic	High/Low
6.5	Stringently enforce recreational ordinances	High/Low
6.6	Reduce powerboat induced shoreline erosion	Medium
6.7	Dissipate wave energy using shoreline BMPs	Medium

Table continued on next page.

Table 3.1 (Continued)

Recommendation Number	Description	Priority
	3.8: Fish and Wildlife Recommendations	
7.1	Support WDNR fishery management endeavors	High
7.2	Protect fish habitat and vulnerable fish	Medium
7.3	Identify and remove fish passage barriers	Low
7.4	Improve in-Lake and nearshore aquatic habitat	Medium
7.5	Promote shoreline buffers	Medium
7.6	Maintain or enhance water quality	Low
7.7	Preserve, connect, and expand wetland and terrestrial wildlife habitat	Medium
7.8	Incorporate upland conservation and restoration targets into management and policy decisions	High
7.9	Limit development in environmental corridors	High
7.10	Protect and preserve WDNR-designated critical habitat areas	High
7.11	Protect ecological value and function of buffer, wetland, woodland, and floodplain areas	Medium
7.12	Adopt best management practices to improve wildlife habitat	Medium
7.13	Monitor fish and wildlife populations	Medium
	3.9: Plan Implementation Recommendations	
8.1	Establish a land conservancy	Low
8.2	Pursue promulgation of a groundwater protection ordinance	High
8.3	Pursue Modification of the Town of West Bend's R-1R Rural Residential District	High
8.4	Protect groundwater recharge, critical species habitats, and natural areas with existing ordinances	High
8.5	Revise C-1 District boundaries to reflect updated Wisconsin Wetland Inventory boundaries	High
8.6	Enhance relationships with local governmental units	High
8.7	Track planned and ongoing watershed activity	High
8.8	Increase ordinance awareness and regularly update ordinances	High
8.9	Solicit funding from grants and other sources.	High
8.10	Encourage Lake users to actively participate in future management efforts	Medium
8.11	Reinforce local Lake management knowledge	Medium
8.12	Continue to reinforce stakeholder inclusivity and transparency.	High
8.13	Foster and monitor communications with future Lake managers	High
8.14	Develop an action plan highlighting action items, timelines, goals, and responsible parties	High
8.15	Actively publicize and promote this plan	High

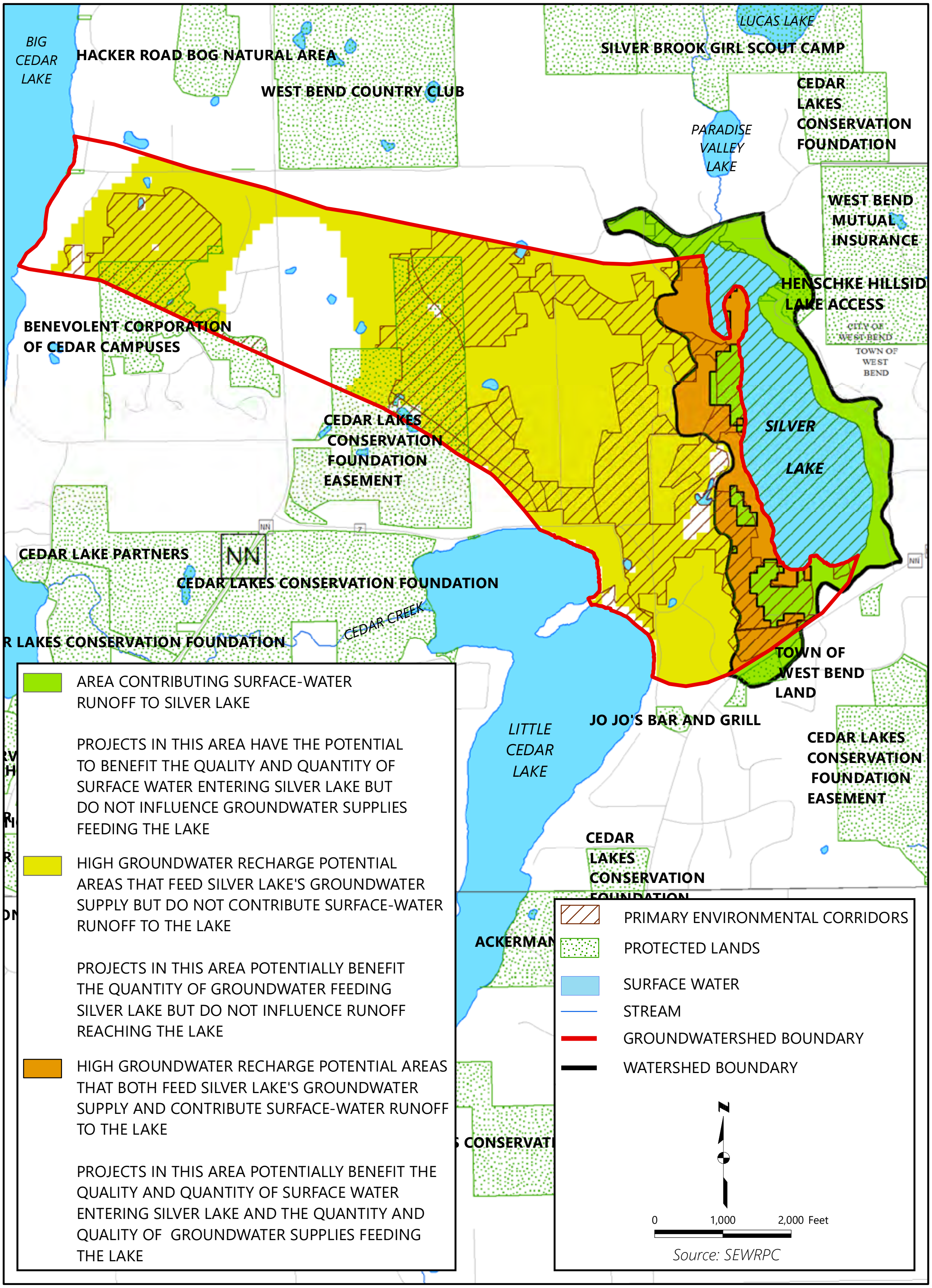
Source: SEWRPC

Variations in these factors cause Lake water levels fluctuate. Recording on-the-ground local information relating these factors helps monitor human and environmental stressors on the Lake's water supply. The availability of long-term information may affect future ordinance develop and design/operation of water management infrastructure. This recommendation should be assigned a medium priority.

At a minimum, the SLPRD should continue to manually measure and record daily precipitation and the Lake water levels whenever the monitoring point is not frozen. The SLPRD could install automated water level recording equipment to reduce labor demands and could post resultant digital data to its website in essentially real time. Electronic water level monitoring equipment is widely available with the hardware associated with simpler devices can costs less than $1000. Monitoring additional weather conditions and noting lake appearance would also be beneficial (e.g., record wind speed, wind direction, water and air temperature, ice conditions, wave action).

In addition to monitoring and recording data, the SLPRD may wish to refine the relationship between the elevation of the Lake at the current point of measurement at the south end of the Lake and the weir near Paradise Drive. The difference in elevation changes depending upon transient obstruction, the presence of aquatic plants, debris accumulation, and other factors. Furthermore, the stage/discharge relationship presented in this report should be reviewed and refined to assure accuracy over the full range of flow. A second monitoring point near the outlet dam would help assure that accuracy of the outlet flow calculation. Continuous outflow information is very useful data to have available when examining many lake management strategies and may be interesting and useful to recreational boaters and Lake residents.

Map 3.1
Upland Areas Contributing to Silver Lake's Water Supply



➤ **Recommendation 1.2: Maintain and inspect outlet dam and keep operational records**

The WDNR classifies the Lake outlet dam as a small low-hazard structure. As such, periodic inspections by a professional engineer are not required. Nevertheless, the SLPRD is responsible for assuring proper dam operation and maintenance. This includes clearing debris and repairing defective components. In recognition of this, the SLPRD should institute a policy that requires its staff to complete formal inspections of dam operating characteristics and condition. Records of operational details, cleaning, maintenance, and any other actions SLPRD and its partners or contractors undertake, should be formally recorded and the records should be retained indefinitely. This recommendation is assigned a high priority.

➤ **Recommendation 1.3: Enhance stormwater runoff detention and treatment wherever feasible**

The most fundamental way of detaining and treating stormwater is by installing green infrastructure and/or stormwater BMPs in the area contributing runoff to the Lake. Larger-scale public works projects are often employed to manage stormwater from entire neighborhoods. Common examples include stormwater detention ponds, infiltration basins, grassed swales, and other stormwater infrastructure specifically designed and carefully located to slow runoff, improve water quality, and promote infiltration.[170] Smaller-scale practices installed by many landowners can also significantly affect runoff volume and quality. Examples homeowner-scale practices include managing turf and other areas to increase soil permeability, directing stormwater to areas of permeable soil and favorable topography, reducing or minimizing the extent of impermeable surfaces, and redirecting downspouts and other runoff away from storm sewers and into raingardens. Such initiatives can be promoted by active educational outreach, providing instructions and supplies to property owners, and/or through subsidies. Some practices and projects, especially those completed on publicly owned property, may qualify for cost sharing through the WDNR's Healthy Lakes initiative.[171] This recommendation is assigned a high priority.

➤ **Recommendation 1.4: Protect the Lake's groundwater supply**

The Lake's groundwater supply is vital to Lake health. To help protect the quantity and quality of groundwater discharging to the Lake, primary attention needs to take place in the Lake's groundwatershed, an area found primarily to the west of the Lake (see Map 3.1). Care must be taken in this area to avoid diminishing groundwater recharge, guard against excessive groundwater export, and maintain high groundwater quality. Nevertheless, large-scale groundwater extraction in areas beyond the groundwatershed can also influence the amount of groundwater entering the Lake or the amount of lake water infiltrating into the Lake bottom and must be carefully examined. Actions that can help protect the Lake's water supply include the following examples:

- Encourage high-quality stormwater infiltration in the Lake's groundwatershed as an integral part of all new stormwater infrastructure.
- Consider retrofitting existing stormwater conveyance systems throughout the Lake's groundwatershed to promote high-quality stormwater infiltration.
- Preserve or enhance natural landscape features throughout the groundwatershed that promote groundwater recharge (e.g., topographically closed depressions). Emphasis should be placed on areas identified as having high groundwater recharge potential (see Maps 2.14 and 3.1).
- Discourage widespread agricultural drainage enhancements in areas within the groundwatershed with high groundwater recharge potential.
- Avoid unnecessary or excessive expanses of impermeable surfaces in any area contributing water to the Lake.
- Discourage water supply systems in the groundwatershed that rely on private water supply wells yet discharge wastewater to distant treatment plants.

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[170] *Rain gardens are depressions that retain water, are vegetated with native plants, and help water infiltrate into the ground rather than enter the Lake through surface runoff. Rain gardens can help reduce erosion and the volume of unfiltered pollution entering a waterbody and can also help augment baseflow to waterbodies.*

[171] *Visit the Healthy Lakes program website for more information on best practices: healthylakeswi.com/.*

- Carefully evaluate activities within the groundwatershed and near the Lake that require long-term dewatering (e.g., quarry operations) if effluent water discharges to surface-water features draining to areas beyond the groundwatershed.

- Carefully examine new groundwater demands within the Lake's groundwatershed and nearby areas. Examples include high capacity wells or increased withdrawals at existing wells, clusters of smaller wells, or quarry dewatering. Such activities can influence groundwater flow directions and velocities and can change the amount of groundwater entering or leaving the Lake.

- Minimize use of sodium chloride reliant deicers and water softening agents.

- Expeditiously remediate identified groundwater contamination issues within the groundwatershed.

Some progressive Southeastern Wisconsin municipalities have already promulgated ordinances designed to protect groundwater quality and quantity.[172] The SLPRD could actively call for local municipalities to follow this lead. A groundwater protection ordinance can incorporate many of the example actions listed above. Overall, protecting the Lake's groundwater supply is assigned a high priority.

➤ Recommendation 1.5: Monitor groundwater conditions

Groundwater is a largely unseen but vital resource supporting Silver Lake. To provide insight on the health of this resource, the SLPRD should consider instituting a groundwater monitoring regimen. Lake elevation monitoring provides valuable insight regarding the amount of groundwater entering the Lake, underscoring the importance of Lake-elevation monitoring. Groundwater elevations could also be measured at key points throughout the groundwatershed. Such points could include water wells, ponds, streams, and wetlands. Devices are now available to allow convenient real-time data collection.[173] Furthermore, the SLPRD should consider periodically collecting water quality data from the prominent springs feeding the southwestern corner of the Lake. Samples were collected at this location in the late 1970s and during 2018 as part of the current study. Groundwater monitoring is assigned a medium priority.

➤ Recommendation 1.6: Enforce existing ordinances and protect sensitive parcels

Regulations already exist that help protect areas that influence the Lake's water supply. For example, existing ordinances already protect wetlands, floodplains, and areas of steeply sloping terrain. Parcels already acquired or otherwise protected for conservation purposes should be retained and enhanced as practical (see Map 3.1). Enhancement can include features and strategies that promote groundwater recharge. Consider supporting initiatives that promote parcel enhancement and protection of additional acreage in the area contributing water to Silver Lake. (e.g., Cedar Lakes Conservation Foundation (CLCF), Ozaukee-Washington Land Trust (OWLT)). Furthermore, the SLPRD should actively support initiatives that promote soil health on agricultural parcels in the Lake's groundwatershed. Healthy soils generally absorb more water which in turn increases the proportion off precipitation contributing to groundwater recharge.[174] These recommendations should be assigned a high priority.

➤ Recommendation 1.7: Identify unprotected parcels in high groundwater recharge potential areas

Much of Silver Lake's groundwatershed is presently undeveloped. While large swaths of land already enjoy protection, future urbanization in remaining areas, particularly the areas with high groundwater recharge potential between the Cedar Lakes and Silver Lake, could reduce the amount of groundwater reaching Silver Lake (see Map 3.1). For this reason, the SLPRD should closely monitor development in the areas identified in Map 3.2 and should call for formal protocol that limit the extent of impermeable surfaces, actively require infiltration of high-quality stormwater, and mandate study of the effects of

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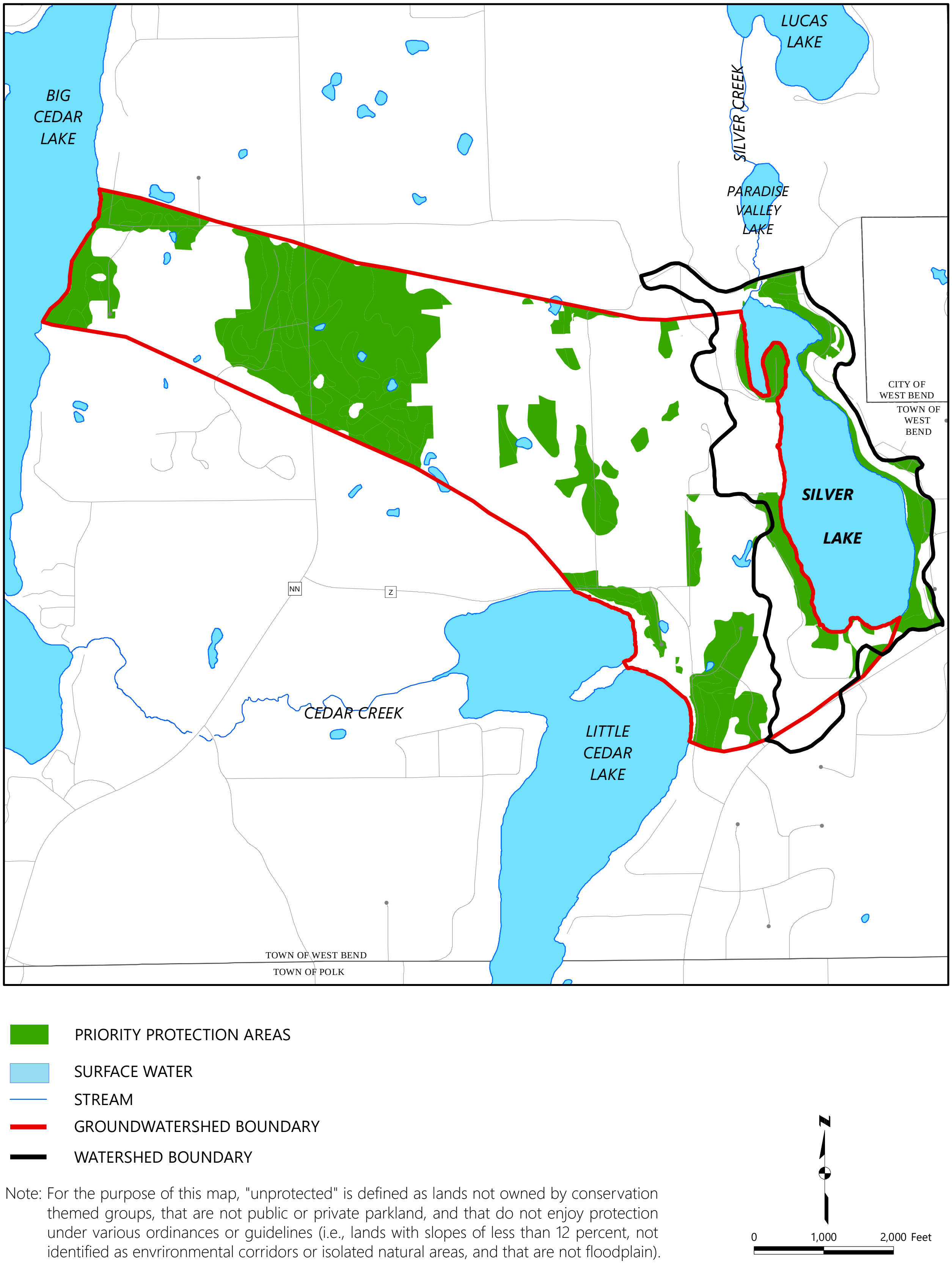
[172] *The Village of Richfield, also in Washington County, actively promotes actions that safeguard its groundwater supplies for the benefit of its residents and environment. For more information, the reader may visit the Village of Richfield's groundwater protection webpage: www.richfieldwi.gov/300/Groundwater-Protection.*

[173] *Many firms market devices to monitor water elevation and quality. An example is Wellntel, a firm based in Southeastern Wisconsin (www.wellntel.com). This is not an endorsement of the goods or services provided by this firm but is instead provided to help the reader grasp the concept of remote monitoring.*

[174] *This ten-minute video graphically demonstrates how soil health benefits hydrology: youtu.be/5rbSWey0pOg. We encourage anyone interested in soil health to visit this website and contact County land conservation or local NRCS/FSA staff.*

Map 3.2
Unprotected Land Tracts in the Area Contributing Water to Silver Lake



Note: For the purpose of this map, "unprotected" is defined as lands not owned by conservation themed groups, that are not public or private parkland, and that do not enjoy protection under various ordinances or guidelines (i.e., lands with slopes of less than 12 percent, not identified as envrironmental corridors or isolated natural areas, and that are not floodplain).

Source: Natural Resources Conservation Service and SEWRPC the proposed development on local groundwater hydrology. The Town of West Bend would be the most logical municipality to carry such programs forward. Similar regulations are already in place in the Village of Richfield in southern Washington County. This recommendation is assigned a high priority.

3.3 LAKE WATER QUALITY AND POLLUTANT LOAD REDUCTION RECOMMENDATIONS

Available water quality data reveals that Silver Lake is only moderately fertile (i.e., mesotrophic). However, since many Lake residents express concern about various water quality-related issues (e.g., watershed pollution sources, excessive aquatic plant growth, algal growth) pre-emptive water quality management action is warranted. Fortunately, the Lake's water quality is not presently known to be poor enough or changing rapidly enough to warrant aggressive, immediate management actions (e.g., alum treatment, flow diversion, intense biological manipulation).

The management strategies recommended in this section help lake managers maintain or improve Silver Lake's relatively good water quality. The core strategy is reducing the mass of nutrients, sediment, and pollutants reaching the Lake. This initiative focuses upon the area contributing surface-water runoff to the Lake. Actions to protect groundwater quality were discussed Section 3.2.

➤ **Recommendation 2.1: Continue monitoring Lake water quality**

Regularly scheduled, consistent water quality monitoring for key parameters allows the Lake's water quality to be contrasted to reference points such as other lakes and water quality standards. Such data helps lake managers identify trends, pollutant sources, and corrective strategies. For this reason, continued or expanded water quality monitoring is assigned a high priority.

While Silver Lake's water quality database extends back roughly 50 years, large data gaps punctuate this record. Many of these gaps can be prevented in the future by relatively low-cost volunteer initiatives. The Wisconsin Citizen Lake Monitoring Network (CLMN) and other groups provides training and guidance on monitoring lake health.[175]

Most lake monitoring programs include water quality evaluation at a point over the deepest portion of the lake (often referred to as the "deep-hole site"). Water quality monitoring should continue at Silver Lake's deep hole site, but sampling should occur more often and more consistently. Field water quality monitoring should occur throughout the open water season (preferably every 10 to 14 days) and should include evaluation of water clarity using a secchi disk as well as measuring temperature, oxygen, and optionally conductivity profiles. Laboratory samples should be collected at least four times per year (two weeks after ice off and during the last two weeks of June, July, and August). Laboratory samples should be analyzed for basic lake water quality parameters including total phosphorus, total nitrogen, and chlorophyll-*a*. All monitoring activities should be periodically reviewed and revised when warranted by data trends, changing interests, and other factors.

Expanding monitoring efforts to include supplemental measurements of phosphorus and chloride as well as supplemental temperature/oxygen/conductivity profiles (e.g., during summer nights, fall, winter) should also be considered. These supplemental measurements often provide new Lake chemistry insight. For example, oxygen profiles collected during both midsummer days and nights can help evaluate diurnal oxygen swings and may reveal the presence of daytime oxygen super saturation and pre-dawn oxygen deficiency. Sampling phosphorus at both the Lake's surface and deepwater area can help determine the role of internal phosphorus loading to the Lake's nutrient budget.

Chloride should also be monitored at least once per year to gauge if concentrations are increasing over time to levels that could cause damage to the Lake's ecosystem. Monitoring chloride concentrations allows the rate of concentration increase over time to be quantified. This will help discern the overall impact of cultural influence on the Lake and to evaluate if chloride concentrations are approaching levels that could foster negative changes in the Lake's ecosystem. As previously noted in Chapter 2, Silver Lake

[175] *More information regarding the CLMN may be found at the following website: www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/clmn/default.aspx.*

is currently being monitoring for chloride as part of the Commission's Regional Chloride Study within Southeastern Wisconsin. As part of this effort, the Commission will likely monitor Silver Lake's chloride concentrations for at least one more year.

➤ **Recommendation 2.2: Protect and enhance existing wetlands, buffers, and floodplains**
This recommendation is assigned a high priority. Examples of ways this recommendation could be implemented include are listed below.

- Adopt protective development standards and limitations in Commission-delineated environmental corridors. These revisions could be stipulated through various Town and County zoning ordinances. Protection could be expanded to help protect critical upland habitat and groundwater recharge areas. See "Local Ordinances" subsection within Section 3.9, "Plan Implementation Recommendations" for more detail.

- Stringently enforce shoreland setback requirements and construction site erosion control, drainage, and stormwater management ordinances.[176]

- Control spread, and, when possible, eradicate invasive species. Many invasive plant species are already threatening, Wisconsin wetlands, woodlands, and aquatic environments.[177]

- Encourage shoreline best management practices (BMPs) and enhance shoreline buffers.[178] The Commission recommends that 75 percent of Silver Lake's shoreline be occupied by buffer areas. This would mean that at a least ten foot wide buffer strip would need to be established along an additional 1.0 mile of shoreland area (36.5 percent of the Lake's total shoreline, see Figure 3.1). This program should also encourage creating rain gardens, disconnecting roof and driveway drains, and constructing bioswales or buffers, especially on riparian parcels. The ten-foot minimum buffer width is consistent with WDNR's "Healthy Lakes" grant program. This grant program could potentially fund some of these efforts, particularly in areas of along developed lakeshores.[179]

- Provide shoreland property owners with information describing the benefits of nearshore and terrestrial buffers. Encourage landowners to protect existing buffers. Enhance, restore, or create buffers in favorable areas where they are highly degraded or absent. Educational resources could include installation instructions, typical costs, construction material sources, and a list of local contractors providing this service. Such programs are most productive if accompanied by an incentive program that helps share installation cost.

- Partner with the CLCF, the OWLT, or similar organizations to actively protect wetlands and uplands within key areas. Protection can be obtained through fee simple purchase, conservation easements, and/or deed restrictions. Maps 3.1 and 3.2 identify priority areas for protection. These areas would include lands adjacent to lands already in protected ownership (e.g., CLCF or OWLT-owned lands), primary environmental corridors, high or very high groundwater recharge potential, and/or lands with less than 12 percent slopes. Protected parcels can be enhanced to improve habitat, filtering, and hydrologic functions. To maintain or enhance ecological value, invasive species control should also be considered important.

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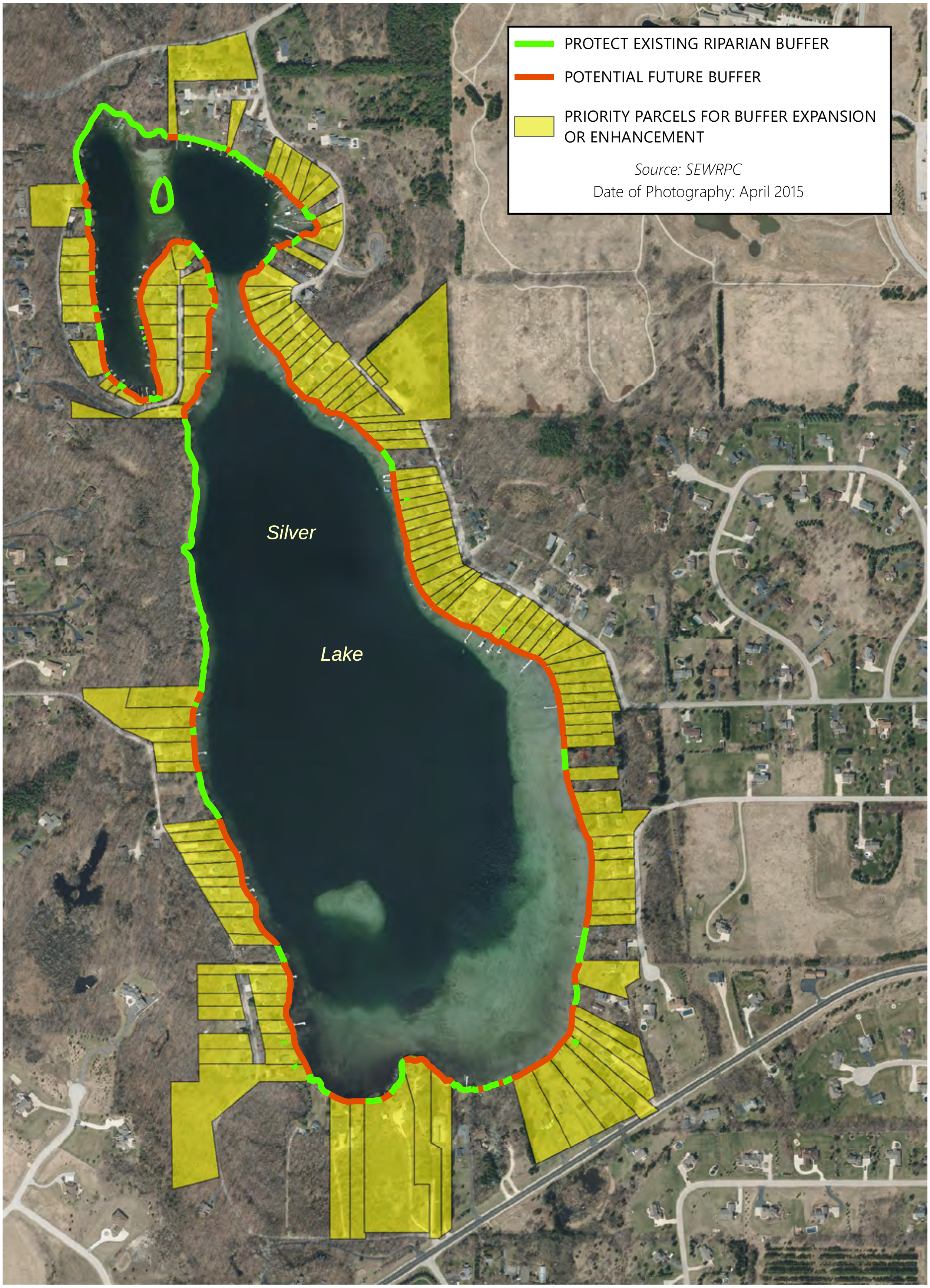
[176] *Ordinances are sometimes overlooked and/or poorly understood. Stakeholders can increase the positive impact of existing ordinances by educating the regulated community and reporting infractions when education fails to provide results.*

[177] *Common wetland invasive plant species are described on the WDNR's website at the following URL: dnr.wi.gov/topic/Invasives/documents/wetland_species.pdf.*

[178] *The Wisconsin Healthy Lakes Initiative maintains an excellent website describing a broad array of practices that can be employed to protect and maintain lake health. The reader is encouraged to visit the program website found at the following URL: healthylakeswi.com/best-practices/.*

[179] *More information regarding the Healthy Lakes program may be found at the following website: healthylakeswi.com*

Figure 3.1
Silver Lake Shoreline Buffer Recommendations: 2020



- Runoff speed and stormwater volume should be reduced whenever possible. Runoff should be detained and/or infiltrated when practical. Many opportunities exist to achieve this goal. Areas with opportunity are highlighted on Map 3.1). While none are large scale, widespread application of small-scale practices can have profound results. For example, widespread adoption of environmentally friendly residential stormwater practices could significantly alter stormwater runoff patterns and quality. A simple example of a residential practice consistent with this recommendation is disconnecting rooftop downspout and driveway drains allowing water to infiltrate or filter through vegetation. Another example includes revamping roadside runoff patterns to reduce direct runoff into waterbodies. Ditch turnouts and ditch checks are examples of practices that can help public and private roadway managers can use to achieve this goal. Example design guidance is provided in Appendix C. Roadway practices obviously require active participation by the Town of West Bend, private road owners, and adjacent landowners. The SLPRD and others interested in Lake health should actively promote the benefits and needs of such action to roadway managers and the general public.

➤ **Recommendation 2.3: Reassure that engineered stormwater detention and conveyance systems are adequately maintained**

Over the past several decades, many stormwater management systems have included design elements that help modulate runoff rates and improve water quality. These systems often require maintenance. For example, stormwater detention ponds eventually fill will sediment, can become overrun with invasive species, and become choked with debris. Therefore, stormwater basin maintenance includes managing aquatic plants, removing and disposing of flotsam or jetsam, ensuring adequate water depth to settle and store pollutants, and actively and aggressively managing excess sediment. Specifications associated with the design of stormwater detention basins and maintenance requirements ensure that basins are functioning properly.[180] It is important to remember that stormwater detention basins occasionally require dredging to maintain characteristics that protect the Lake. The frequency of dredging is highly variable and depends upon the design of the basin and the characteristics of the contributing watershed. Regulatory entities should require stormwater basins be regularly inspected in a manner consistent with current practices. Stormwater basin owners must know the importance of meeting these requirements through educational outreach, helping ensure continued proper functioning of the ponds. Coordinating with municipalities and neighborhood associations can play an important role. This recommendation is assigned a high priority.

➤ **Recommendation 2.4: Enhance existing and planned stormwater management infrastructure**

Stormwater runoff quality can often be improved by retrofitting current infrastructure. This is often most conveniently done when existing infrastructure needs repair or replacement. For example, straight roadside ditches and swales that feed directly into a waterbody can be regraded to gently and gradually disperse water into vegetated upland and wetland areas. This change helps trap sediment and nutrients that would previously have been discharged directly into the Lake or streams leading to the Lake.

Regulations already require new development to detain runoff and improve runoff water quality. The municipality issuing the permit governing development may require additional actions that help safeguard surface water and groundwater in the Silver Lake area.[181] For example, new development could be required to infiltrate high-quality runoff, extend detention times, spread floodwater, and use features such as grassed swales to convey stormwater. In certain instances, runoff from older development could be redirected into newly designed infrastructure to extend benefits to larger swaths of the watershed. This recommendation is assigned a high priority.

[180] *Technical standards for designing and maintaining wet detention basins and other stormwater management practices can be found at the following URL: dnr.wi.gov/topic/stormwater/standards/postconst_standards.html.*

[181] *The Town of West Bend promulgated a stormwater/erosion control ordinance during 2016. A copy of this ordinance may be found at the Town's website (townofwestbend.com/zoning-information). Washington County has been designated the authority to enforce this ordinance.*

➤ **Recommendation 2.5: Stringently enforce construction site erosion control and stormwater management ordinances**

This recommendation should be assigned a high priority throughout the area contributing stormwater runoff to the Lake (the Lake's watershed, see Map 3.1) The Town of West Bend's stormwater/erosion control ordinance became effective in 2016. The Town of West Bend designated Washington County's Land and Water Conservation Division of the Planning and Parks Department as the entity tasked with administering and enforcing the provisions of this ordinance. The SLPRD and others interested in Lake health can assist Washington County with administering and enforcing this ordinance. Examples of ways this could be achieved includes educating those affected by this ordinance and by documenting and reporting suspicioned ordinance violations.[182] Related information is provided in Section 3.9, "Plan Implementation".

➤ **Recommendation 2.6: Promote rural land management practices that reduce soil erosion and nutrient export**

Even though the area immediately surrounding Silver Lake is highly urbanized, portions of the area contributing runoff to the Lake remain rural in nature. Woodlands set back from the riparian area occupy roughly half of the undeveloped land in the Lake's watershed. No land in the Lake-direct watershed is used for agricultural purposes, a situation that is highly unusual in Southeastern Wisconsin. For this reason, soil health initiatives and other production agriculture practices that form the backbone of many water quality improvement endeavors are not applicable to Silver Lake. However, forestry management practices can influence not only habitat value, but also runoff quantity/quality over appreciable areas of the Lake's watershed and are therefore important to protect the Lake's water quality.

Monitoring and actively managing woodlands throughout the Lake's watershed should be considered a medium priority. Perhaps the most serious threat to many Southeastern Wisconsin woodlands is the combined problem of disease and insects that destroy the native tree canopy and invasive plants such as buckthorn (common buckthorn, *Rhamnus cathartica*, and glossy buckthorn, *Frangula alnus*) that inhibit or prevent native tree regeneration. Introduced pests already attack many native trees such as ash, elm, butternut, and oak species in Washington County. New pests are on the horizon that target black walnut, beech, other oaks, and other tree species. Existing woodlands should be kept free of invasive plant species and actions should be taken to prepare the woodland for the arrival of pests. For example, increasing the diversity of tree species through careful stand management and or planting can help assure that complete canopy loss does not occur in the future. State programs are available to assist woodland owners with stand management, tax implications, and professional forestry advice.

➤ **Recommendation 2.7: Reduce pollutant loads from residential areas**

Residential areas, especially waterfront properties, can contribute appreciable pollutant loads to lakes and streams. Not only are waterfront properties commonly densely populated and heavily influenced by human activity, but their location also reduces the chance that pollutants emanating from these areas can be intercepted before entering waterbodies.

While many residential activities can contribute sediment, nutrients, and other pollutants to waterbodies, privately owned wastewater treatment systems (POWTS), winter deicing, and landscaping activities are perhaps the most common examples. However, since the Lake watershed's wastewater disposal needs are largely provided by the City of West Bend's system, POWTS are not likely an important ongoing contributor to Silver Lake's overall ongoing pollutant load but may have been a significant source in the past.

The dense road network in the Silver Lake watershed may be a significant source of sediment and other pollutants to the Lake. Concepts that help reduce sediment and pollutant loads from roadways were presented in Recommendation 2.2. In addition to these actions, reducing the mass of chloride-based road deicing salt applied to roadways can help reduce chloride loads to the Lake.[183]

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[182] *The type of infraction, time, specific location (address if possible), observer name, photographs, runoff patterns, and other relevant information should be immediately recorded.*

[183] *Pavement deicing can be made more efficient in several ways, an action reducing the amount of salt applied during a winter season. Many organizations, including the Commission, are studying the impact of chloride on the environment and methods that can be taken to reduce the effect of road deicing on water quality. Sources of information abound on the internet. For example, the WDNR discusses road deicing at the following URL: dnr.wi.gov/wnrmag/2010/02/salt.htm.*

Intensely "manicured" landscapes, an aesthetic favored by many property owners, often utilize more fertilizer and pesticides on a per-acre basis than agricultural lands. Given that many of the Region's waterbodies are ringed by residential properties, and that runoff from these properties often drains directly to waterbodies, the collective load to lakes and streams can by quite high. Furthermore, some property owners burn leaves and brush near the water's edge allowing nutrients contained in ash to easily enter waterbodies. Actions that can help alleviate these loads include the following examples.

- Establish or enhance shoreline buffers (see Recommendation 2.2)
- Direct Lake-direct runoff through buffers and rain gardens
- Encourage stormwater infiltration through appropriate lawn care
- Avoid pollutant leaks and spills in and around homes
- Prohibit burning and disposal of yard waste near lake and stream shorelines
- Minimize chloride-based deicer use

Communicating best management practices and engaging in a campaign to encourage their use (e.g., offering to pick up grass clipping or leaves as discussed in Recommendation 2.8) will incrementally reduce water quality problems. Mitigating residential area pollutant loads is assigned a high priority, especially given the direct impact that shoreline residents, who have a vested interest in Lake health, can have on Silver Lake's water quality.

➤ Recommendation 2.8: Collect leaves and yard waste

A study completed in Dane County in the Lake Wingra watershed demonstrated that leaves can be a principal contributor to total external phosphorus loading to lakes in urban settings.[184] Within the Lake Wingra watershed, residential use contributed nearly 60 percent of total phosphorus to the lake, the highest percentage of all urban land use. Furthermore, of the residential land uses, streets and lawns accounted for 65 percent of the total phosphorus loading. Residential streets yielded the largest total phosphorus loading, especially during autumn. On average, about 55 percent of the total annual residential phosphorus loading was delivered to Lake Wingra during autumn. In some situations, over 70 percent of the annual residential phosphorus loading occurred during autumn. Street-sourced phosphorus was primarily related to curbside and street leaf litter. As vehicle traffic rolled over leaves, the crushed leaf structure accentuated phosphorus leaching during wet weather, creating a nutrient-laden "tea" of sorts. Runoff then washed the leaf litter and the "nutrient tea" into storm sewers and eventually into receiving water bodies. Additional studies demonstrated that the leaves of certain species of trees (e.g., sugar maple *Acer saccharum,* silver maple *Acer saccharinum*) are especially phosphorus rich, while the shed leaves of other species contain comparatively little phosphorus.[185]

The Lake Wingra study underscores the importance of carefully managing leaves deposited on residential streets, providing opportunity to significantly reduce a typically large external phosphorus load. Leaf collection is especially important in residential areas that drain toward the Lake. Stockpiling leaves in the street where they may be crushed and washed into the Lake or burning leaves in shoreline and ditch areas can create situations where strong phosphorus pulses are delivered to the Lake by late autumn rains.

The Town of West Bend does not provide curbside leaf pickup but does maintain a site where residents can bring leaves, grass clippings, and other yard waste. The location and hours of operation are posted on the Town's website (townofwestbend.com/services/town-services). To reduce phosphorus loads contributed by leaves and landscaping activity, watershed residents should be encouraged to either use leaves as

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[184] *Roger Bannerman of the U.S. Geological Survey described the findings of the Lake Wingra study in his presentation entitled* "Urban Phosphorus Loads: Identifying Sources and Evaluating Controls." *This presentation may be viewed at the following URL: fyi.extension.wisc.edu/nrwebinars/urban-phosphorus-loads-identifying-sources-and-evaluating-controls.*

[185] *Cohen, William F. and G. Fred Lee, "Leaves as Source of Phosphorus,"* Environmental Science and Technology, *Volume 7, Number 9, September 1973.*

mulch well away from the water's edge or take advantage of Town's yard waste collection and leaf disposal program. Because it is relatively simple to implement, this action should be assigned high priority.

➤ **Recommendation 2.9: Promote a healthy and robust aquatic plant community**
Aquatic plants compete with algae and undesirable plant species for nutrients. Aquatic plants also help dissipate wave energy and cover the Lake bottom, reducing the potential for sediment resuspension and associated phosphorus reintroduction into the water column. Preserving and promoting healthy native aquatic plant communities enhances in-lake phosphorus sequestration. Muskgrass, a plant species abundant in Silver Lake, is key to this process and should be preserved and promoted whenever and wherever practical. Maintaining or improving water clarity and actively managing invasive aquatic plant competition are key to assuring continued robust muskgrass growth. Additional information regarding aquatic plant management is provided in Section 3.5, "Aquatic Plant Management." This recommendation is assigned high priority.

3.4 NEARSHORE SEDIMENTATION AND SHORELAND MAINTENANCE RECOMMENDATIONS

As was discussed in Chapter 2, sediment appears to be accumulating along shoreline areas, a situation that could restrict future recreational use. Several potential sediment sources were identified including natural marl formation, stormwater runoff, accumulated aquatic plant remains, terrestrial leaf and miscellaneous plant litter, shoreline erosion, and lake-bottom sediment disturbed and redistributed by recreational boat traffic. Given the variety of sediment sources that may contribute to this issue, a variety of management concepts are recommended. Examples follow.

➤ **Recommendation 3.1: Reduce runoff-related nutrient and sediment loads**
Humans manipulate the landscape to suit their needs. One facet of this issue involves the way water is conveyed away from developed areas. As part of such drainage improvement schemes, drainage ways are deepened, straightened, and are often made to run across the landscape in ways that benefit human land use. For example, drainage ways commonly are relocated and straightened to parallel roads and property lines. Furthermore, considerable effort is expended to reduce the extent and duration of wet spots. To achieve these goals, low areas are filled or artificially drained, drainage ways are converted to ditches or buried storm sewers, and conveyance routes often discharge directly to major surface-water features. All these activities tend to increase the ability of stormwater to erode and carry sediment, nutrients, and pollutants directly to lakes and streams. Once at the discharge point, sediment tends to accumulate and nutrients fuel luxuriant plant growth, both of which can cause nearshore areas to become shallower and weedier over time. This recommendation is assigned high priority.

Several methods can be employed to reduce the sediment, nutrient, and pollutant loads delivered to the Lake in direct runoff. Reduced loads improves Lake-water quality. Therefore, most of the recommendations discussed in Section 3.3 also benefit nearshore sedimentation. Even though Silver Lake has a small area contributing surface water to the Lake, certain nearshore areas are more prone to be affected by concentrated sediment-laden, nutrient-rich runoff (e.g., areas where roadside ditches, storm drains, or direct drainage from roadways enter the Lake). Several of the approaches described in the Recommendations 2.2, 2.3, 2.4, 2.5 are particularly relevant.

Even though the most visually apparent sediment accumulations may be related to concentrated stormwater discharge points, small improvements to modest loads over broad expanses of the shoreline can also have a significant influence on nearshore sedimentation. For this reason, lakeshore property owners should be encouraged to carefully follow the recommendations suggested in Section 3.3 with emphasis placed on Recommendations 2.2, 2.6, 2.7, and 2.8.

➤ **Recommendation 3.2: Monitor shoreline erosion and nearshore sediment accumulation**
The SLPRD expressed interest in estimating shoreline recession rates and in-lake sediment thickness. Data available at the present time does not allow changes to be quantified. To pursue this goal, the SLPRD should periodically carefully measure shoreline location and Lake bottom elevation. If the SLPRD continues to desire information regarding shoreline erosion and Lake sedimentation, the Commission suggests that these efforts be assigned a medium priority.

Perhaps the easiest method to achieve this goal would be to establish measuring points (e.g., metal stakes driven securely into the earth) on the shoreline in key areas and precisely measure the distance from the measuring point to the water's edge during periods of equivalent Lake water elevation. Measurements would need be collected only once per year and are likely to be best made during time periods when vegetation is less likely to obscure the water's edge (i.e., early spring). Measuring stations should be established wherever interest warrants (for example, the sedge-vegetated undeveloped western shoreline).

Several methods could be used to quantify nearshore sedimentation rates. The simplest approach would use a technique similar to that used to measure shoreline location. Measuring point locating stakes would be driven at spots at least 50 feet from the Lake forming the base of a line. Secondary stakes would be driven near the lakeshore forming lines in the direction of interest. Water depth would be measured at five to 10 spots set distances from the measuring stake.[186] Lake water levels will be recorded at the existing gage when water depths are measured. To determine lakebed elevation, water depth will be subtracted from lake elevation. Locations suspected of experiencing shoreline erosion or external sediment loading would be prime candidates for measurement. Measurements should be taken at least once per year during the same time of the year. Several measurements spaced over the open-water season would be desirable to help evaluate seasonal variation.

Sediment cores could also be collected to evaluate sedimentation rates. This is usually a complex procedure completed by environmental professionals. Retrieved sediment cores are segmented and various techniques are used to determine the age of each segment. Such an approach is typically expensive and only determines rates at one location. For these reasons, determining sedimentation rates by sediment core analysis is not likely a practical alternative for Silver Lake at this time.

➤ **Recommendation 3.3: Protect, enhance, and expand nearshore emergent vegetation**

Emergent vegetation helps disperse wave energy before it reaches the Lake's shoreline. Bulrush is an example of emergent vegetation which can add considerable ecological value to the Lake. Floating leaf vegetation such as water lily may also provide wave energy attenuation value. Protecting remaining emergent vegetation around the Lake should be considered a <u>high priority</u>. Enhancing and expanding nearshore emergent vegetation should be a <u>medium priority</u>.

➤ **Recommendation 3.4: Strictly enforce the local boating ordinances**

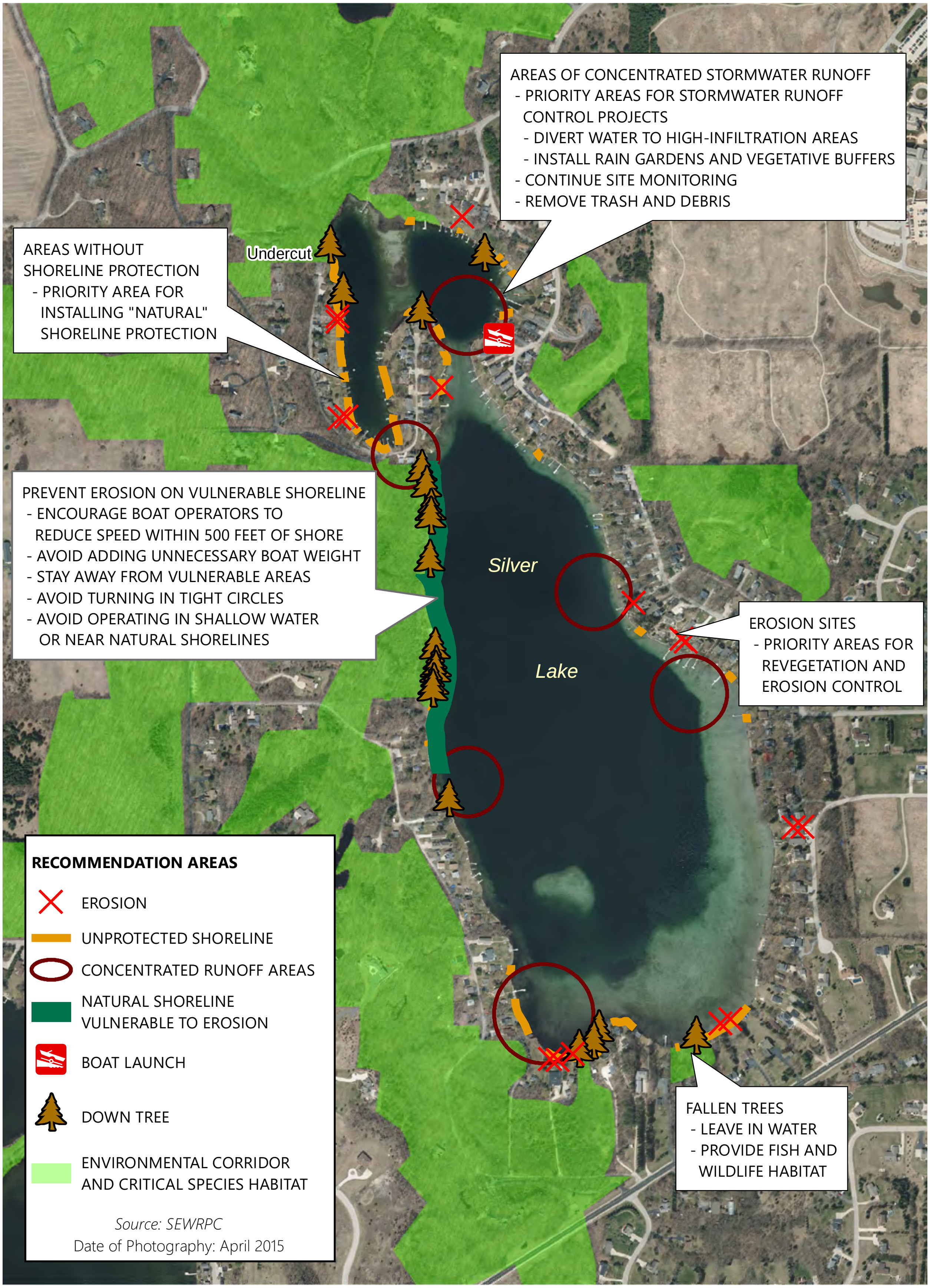
Based upon information supplied by the SLPRD, the Lake's undeveloped western shoreline appears particularly vulnerable to shoreline erosion caused by motorboat induced waves (see Figure 3.2). In general, boat speed and shoreline proximity influence the amount of energy transferred by boat wakes to Lake shorelines. The existing boating ordinance calls for slow no wake speed within the entire kettle area at the north end of the Lake and within 150 feet of the Lake's shoreline. High speed operation is only permitted between late morning and late afternoon. Furthermore, boat speeds when operating at high speed is limited to 35 miles per hour. These regulations, while primarily crafted to promote safe boating, also provide some protection to shorelines, and therefore should be strictly enforced. The SLPRD should also consider supplementing or revising ordinances that enhance lake-bottom and shoreline protection (see Section 3.7, "Recreational Use Recommendations" for more detail). This recommendation is assigned <u>high priority</u>.

➤ **Recommendation 3.5: Encourage removal and/or enhancement of "hard" shoreline protective structures**

Most natural shorelines dissipate wave energy. Lakeshore property owners commonly remove fallen trees, emergent vegetation, and shoreline vegetation to facilitate viewing and accessing the lake. When natural wave energy dissipation features are removed, shorelines commonly begin to erode. In the past, a common reaction to eroding shorelines was installing concrete walls, revetments, steel sheet piling, or other hard shoreline protection structures. Even though these approaches may check shoreline erosion, they routinely require maintenance, reflect wave energy back into the Lake increasing wave energy striking other shorelines, and provide very little habitat value. While hard shoreline protection may truly

[186] *Perhaps the trickiest part of measuring lake-bottom depth is the flocculent nature of some lake bottoms. In some instances, lake-bottom sediment is so soft that it is difficult to tell where water ends and sediment begins. To help alleviate this concern, the probe used to measure water depth should be fitted with a disc that can buoy the measuring probe when sediment is soft. Every attempt should be made to assure the measuring technique is consistent across all measuring sites and events.*

Figure 3.2
Shoreline Recommendations For Silver Lake: 2018



be needed in a few highly vulnerable areas, it can be fully or partially supplanted or supplemented with other approaches that emulate nature in many areas.

Since hard shoreline infrastructure typically provides little habitat value and does not dissipate wave energy, the length of hard shoreline protection should be minimized. Riparian landowners should be encouraged to repair or remove failing hard shoreline protection structures. Hard infrastructure should only be maintained where it is truly needed to protect shorelines from active erosion. Hard shoreline protection structures used to "tidy up" the water's edge should be targeted for removal or naturalization (see Recommendation 3.6). Removing and repairing shoreline protection structures may require engineering and technical construction expertise, consequently, the WDNR and shoreline restoration experts should be consulted and integrated into the process. Since this is a voluntary program focused primarily on private landowners, communication and education and grant-based cost-share or donation–based programs are key elements to effective implementation.

Most shorelines altered by human activity can benefit from installation of "soft" or "nature-like" shoreline protection elements. Such elements can also often help hard armored shorelines dissipate wave energy. For example, emergent vegetation, floating leaf aquatic plants, large woody structure, and randomly placed stones (as opposed to formal revetments and walls) can by established immediately lakeward of an armored shoreline (see Recommendation 3.3). Furthermore, portions of shoreline areas abutting armored segments may provide opportunity for establishing buffers that help improve runoff water quality (see Recommendation 2.2). As an added benefit for residential properties, naturalized shorelines often deter geese from entering lakeshore lawns.

Repairing or removing failing shoreline protection and protecting actively eroding shorelines should be assigned high priority. Taking action to naturalize armored shorelines, while beneficial to the Lake's overall health, are optional and are therefore assigned a low priority.

➤ **Recommendation 3.6: Encourage "soft" or "natural" shoreline protection**
Incorporating natural shoreline protection should focus on areas where little to no shoreline protection exists or where erosion is actively taking place (see Figure 3.2). Natural shoreline protection elements also tend to deter nuisance geese from congregating along shorelines and can enhance waterbody water quality by filtering runoff. Funding may be available through WDNR's "Healthy Lakes" program.[187] This recommendation is assigned a medium priority.

➤ **Recommendation 3.7: Encourage construction-related ordinances**
Existing ordinances govern the size and location of buildings around the Lake, stormwater management, and erosion control measures. These ordinances help protect the Lake and its shoreline. Stormwater and erosion control ordinances are also integral to protecting the Lake's water quality and are therefore discussed in Recommendation 2.5. Rule enforcement is discussed in Section 3.9, "Plan Implementation." This recommendation is assigned high priority.

Selective dredging has occurred in nearshore portions of the Lake. Reducing sediment delivery to the Lake helps prolong the useful life of the water-depth benefits generated by dredging.

3.5 AQUATIC PLANT MANAGEMENT RECOMMENDATIONS

The individual recommendations presented below, which collectively constitute the recommended aquatic plant management plan, balance the following three major goals.

- Maintain or enhance Lake navigation
- Protect the Lake's native aquatic plant community
- Control Eurasian watermilfoil (EWM) and starry stonewort populations

[187] *The WDNR has several resources available at its shoreland property owner information webpage: dnr.wi.gov/topic/shorelandzoning/.*

Plan provisions also help ensure that current Lake recreational uses (e.g., swimming, boating, fishing) are maintained to the greatest extent practical. Plan recommendations described in this section consider common, State-approved, aquatic plant management alternatives including manual, biological, physical, chemical, and mechanical measures. These descriptions help Lake managers better understand the nature, type, and scope of aquatic plant management plan recommendations (see Figure 3.3). Nevertheless, aquatic plant management activities must address conditions present at the time of treatment and must not be overly reliant on or blindly follow descriptions and maps contained in this plan. The Lake's aquatic plant management plan should be re-evaluated in three to five years (at the end of the five-year permitting cycle) or at any other time when new data becomes available. This helps Lake managers better gage the effectiveness of the aquatic plant management plan and promptly refine it as needed.

The most effective aquatic plant management strategies rely on combinations of methods and techniques that help control invasive and nuisance aquatic plants yet protect native plant community health and diversity. A "silver bullet" single-minded strategy rarely produces the most efficient, most reliable, or best overall result. To preserve recreational uses while sustaining Lake health, the following aquatic plant management concepts are recommended.

➤ **Recommendation 4.1: Protect and promote native plant community**

Silver Lake supports a diverse array of native aquatic plant species. This plant community is integral to the Lake's ecosystem, provides excellent fish and wildlife habitat, and benefits overall Lake health. Muskgrass is particularly beneficial to Lake health. Muskgrass is an important component of the marl formation process, a process that removes phosphorus from Lake water. To promote Lake health, the native aquatic plant community should be protected and, as practical, enhanced by carefully implementing aquatic plant management. Concepts that protect and promote the Lake's native aquatic plant community are listed below and are assigned <u>high priority</u>.

- Avoid disrupting or denuding the Lake-bottom sediment. Similar to weedy species found in lawns and gardens, invasive aquatic species (EWM in particular) thrive on disturbed sediment and areas without competing vegetation. For this reason, care should be taken to judiciously and sensitively remove vegetation, especially from problem areas.

- EWM and other invasive species can reproduce from plant fragments. Power boats navigating through plant beds chop vegetation creating innumerable plant fragments. Consider limiting recreational boating through shallow invasive plant (especially EWM) control areas to reduce the spread of this hard to manage invasive plant.

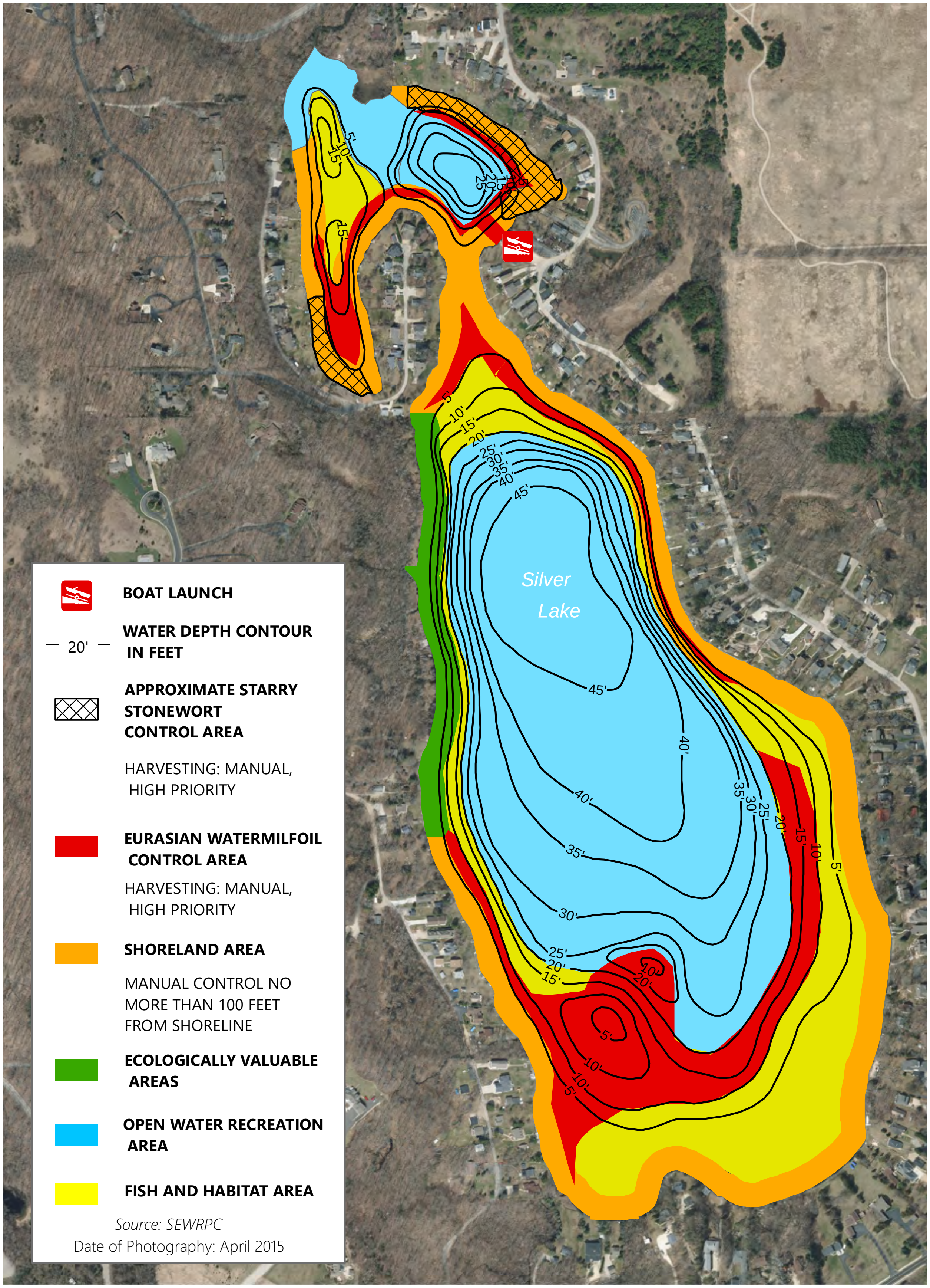
- Take advantage of many invasive plant species tendency and competitive advantage of growing in very early spring. Implement control methods as early as practical in the spring to help minimize damage to native aquatic plant communities.

- Implement recommendations highlighted in Section 3.3, "Lake Water Quality and Pollutant Load Reduction Recommendations." Water quality profoundly affects plant community health. Several conditions (e.g., nutrient and sediment loads delivered to the Lake) can promote plant growth, leading to nuisance levels of certain aquatic plants and shifts in species composition. For example, excessive water-borne nutrients can increase the abundance of free-floating algae, a situation decreasing water clarity. Increased suspended sediment loads can also decrease water clarity. Decreased water clarity diminishes the depth to which aquatic plants can populate the Lake. This can be especially damaging to muskgrass since reducing the extent of muskgrass in a lake can lead to increased phosphorus concentrations, a self-reinforcing loop incrementally diminishing water clarity over time. Accordingly, efforts to improve water quality, which typically correspond with overall Lake and its watershed integrity and health, can also help reduce nuisance aquatic plant growth.

➤ **Recommendation 4.2: Manually remove nuisance plants in select nearshore areas**

"Manual removal" is defined as aquatic plants control using human hands or hand-held non-powered tools. Manual removal is typically employed in areas inaccessible to large-scale management work. Such personalized work typically forms the transition between shoreland owner preferences and public-policy driven action on the main body of a lake.

Figure 3.3
Silver Lake Aquatic Plant Management Recommendation Summary: 2020



Riparian landowners need not obtain a permit for manually removing aquatic plants if their work is confined to no more than 30 feet of their own shoreline and does not extend more than 100 feet into the Lake. All resulting plant waste must be removed from the lake (see Figure 3.3).[188] The 30–foot stretch of shoreline must integrate recreational use areas such as a piers or docks. A permit *is* required if the SLPRD or other groups not owning the property in question actively complete work.[189]

Shoreline-resident-focused educational campaigns should actively promote the value of native plants, explain the relationship between algae and plants (i.e., more algae will grow if fewer plants remain), teach basic aquatic plant identification, and advise allowable action to legally to "clean up" shorelines.[190] This recommendation is assigned a medium priority.

- **Recommendation 4.3: Hand-pull or use diver-assisted suction harvesting (DASH) to help control EWM, starry stonewort, and/or other invasive plants**

Hand-pulling could be used to help control invasives in small areas where large-scale control approaches are not feasibly employed. For example, EWM could be pulled in shallows along the southern and eastern shorelines (see Figure 3.3). EWM populations in this area are sparse enough that this effort could be undertaken by volunteers. No permit is needed for hand-pulling if the effort specially targets non-native plants (in the case of Silver Lake, EWM and starry stonewort) and as long as all pulled plants are removed from the Lake. Starry stonewort could also be managed in a similar way. If done properly, hand pulling will remove some of starry stonewort's reproductive bulbils from the Lake, thereby reducing the "seed bank" for future growth. However, the size and dispersal of bulbils makes complete removal unlikely. Before actively participating in such work, residents must understand the need to prevent extensive loss of native plants, must comprehend the importance of aquatic plants to the Lake's fish and wildlife, and must be able to identify native aquatic plants. Volunteer training helps ensure that this plant management technique does not adversely affect local wildlife and fisheries, desirable aquatic plant communities, aesthetics, shoreline protection, and/or water quality.

In addition to hand pulling, a DASH contractor could be considered to control invasives in offshore areas. This activity requires an NR 109 permit. This measure may help ensure that EWM does not displace native communities in deeper water areas. Suction harvesting is feasible for certain select starry stonewort infestations or if the population decreases to a manageable size. Suction harvesting may occur in intermixed beds of starry stonewort and EWM; however, suction harvesting equipment should not be used in starry stonewort beds then be moved to monotypic EWM beds without thorough cleaning. If not properly cleaned, harvesting equipment may transport starry stonewort to new areas within the Lake. Because of the small-scale nature, labor intensity, and/or cost of these approaches, this recommendation is assigned a low priority.

- **Recommendation 4.4: Consider herbicides to control new invasive species**

Large-scale chemical treatment is not part of the recommended aquatic plant management plan for a variety of reasons (see the "Chemical Measures" section in Chapter 2 for further detail). Nevertheless, the SLPRD may want to consider a rapid response chemical treatment for Chapter NR 40 prohibited species (e.g., hydrilla, *Hydrilla verticillata)*, if such a species were to appear in the Lake in the future. This recommendation is assigned a medium priority.

- **Recommendation 4.5: Prevent invasive species introduction/re-introduction**

Invasive species are a constant and widespread threat to all Southeastern Wisconsin waterbodies. Preventing new introduction is crucial to maintaining healthy lakes and streams. For example, hydrilla is just one of many potential new invasive species that could create future management problems.[191] The

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[188] *The manual removal area limitation for nearshore aquatic plants applies to shorelines where native plants are present. The removal area limitation does not apply to nearshore areas populated solely with nonnative and invasive plants.*

[189] *If a lake district or other group wants to remove invasive species along lake shorelines, a permit is necessary under Wisconsin Administrative Code Chapter NR* 109 Aquatic Plants: Introduction, Manual Removal and Mechanical Control Regulations*. The permit is required since aquatic plant removal is not being completed by the shoreline property owner.*

[190] *Commission and WDNR staff could help review any documents developed for such a campaign.*

[191] *The WDNR's website posts information describing invasive species and their threats. For example, pictures of regulated aquatic invasive species can be found at the following website: dnr.wi.gov/topic/Invasives/documents/NR40Aquatics.pdf.*

WDNR considers hydrilla "the most troublesome invasive in Wisconsin. It outcompetes native vegetation, acts as a breeding ground for mosquitoes, and destroys fish and wildlife.[192] Because hydrilla resembles elodea (a native plant) when casually observed, it could easily be overlooked. To help reduce the threat of introducing new invasives, the following recommendations are given a high priority:

- Underscore the critical role that Lake residents and users play to prevent the spread of invasive species.
- Continue participating in the Clean Boats Clean Waters program, a State program targeting invasive species prevention and proactively encouraging Lake users to clean boats and equipment before launching.[193]
- Target launch sites for focused aquatic plant control. Boat launches are important portals for new invasive species.
- Take immediate action to evaluate and eradicate newly-identified invasive species. If a new alien species infestation is found in the Lake, eradication efforts should be promptly evaluated, and, if possible, immediately employed to help prevent establishment. The WDNR has special funds that can assist early eradication efforts, particularly aquatic plants (Table 3.1). To help achieve this goal, active citizen monitoring for new invasive species is highly recommended. The Wisconsin Citizen Lake Monitoring Network (CLMN) provides training to help citizens participate in these efforts.
- Encourage riparian owners to recognize invasive species and remove them from their shoreline. For example, isolated stands of purple loosestrife can be removed where they occur through cutting, bagging, and applying herbicide to cut stems.

➤ **Recommendation 4.6: Periodically re-evaluate the Lake's aquatic plant management plan**
Lake aquatic plant communities evolve over time. This evolution results from many natural and human-induced influences including lake aging, changing water quality, climatic variation, active plant management actions, changing recreational pressures, and introducing new native and/or non-native animal and plant species. Since Lake and plant condition change over time, what may have been an appropriate action in the past may no longer be a valid approach in the present or future. For this reason, the Lake's aquatic plant management plan must be regularly reevaluated and updated to help reinforce actions that promote overall Lake health. Updating the aquatic plant management plan typically requires completing a new point-intercept survey every five years and thoughtful re-examination of aquatic plant species composition and abundance. This recommendation is assigned a high priority.

➤ **Recommendation 4.7: Continue to work with WDNR to manage starry stonewort, fund experimental management strategies, and publicize results**
Silver Lake is one of only a few Wisconsin lakes where starry stonewort (*Nitellopsis obtusa*) has been observed. After confirming its presence and completing a meander survey to quantify its distribution and quantity, the SLPRD applied for a Rapid Response Grant (AIRR-190-16) to attempt to eradicate the population. The SLPRD, the WDNR, and the Washington County Aquatic Invasive Species Coordinator developed a management strategy that included preventing spread of starry stonewort and educating Lake users and others of the presence and problems posed by starry stonewort in Silver Lake. The Rapid Response Grant allowed the SLPRD to move forward with a DASH control experiment. During the DASH treatment, the Washington County AIS Coordinator, with help from WDNR, continued to rake and monitor starry stonewort and flagged locations overlooked by the suction harvester using buoys. A post-treatment survey found that 90 percent of the starry stonewort population was eliminated. Additionally, the AIS Coordinator installed a Clean Boats Clean Waters station at the public launch which included a cleaning station and signs to inform Lake users of threats posed by aquatic invasive species and their spread. To supplement this Lake-specific educational endeavor, the WDNR and Washington County completed educational outreach throughout Washington County.

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[192] *More information regarding hydrilla may be found at the following URL: dnr.wi.gov/topic/Invasives/fact/Hydrilla.html.*

[193] *More information about the WDNR's Clean Boats Clean Waters program can be found at the following URL: dnr.wi.gov/lakes/cbcw.*

Washington County completed pointintercept and meander surveys during 2016 and spring of 2017 to monitor starry stonewort populations after DASH treatment. These surveys revealed that starry stonewort was still present in Silver Lake with scattered populations around the east side of the northeast kettle near the boat launch. More recently, a 2018 survey showed that starry stonewort continues to expand within parts of the northern kettle, particularly within and around docks/piers. Hence, continued data sharing and coordination of management activities with WDNR staff are essential to manage this invasive plant within Silver Lake. This situation needs to continue to be closely monitored.

The SLPRD should continue to apply for WDNR Aquatic Invasive Species Control grants, cooperate with the WDNR, work with the Washington County Invasive Species Coordinator to monitor and manage starry stonewort in the Lake, and actively collaborate with studies that are attempting to define effective management strategies for this new pest. This recommendation is assigned a high priority.

3.6 CYANOBACTERIA AND FLOATING ALGAE RECOMMENDATIONS

Algae is an important and healthy component of aquatic ecosystems. Algae are primary building blocks of waterbody food chains and produce oxygen in the same way as rooted plants. Many forms of algae exist, ranging from free-floating microscopic algae to filamentous algae and cyanobacteria. Most algal strains benefit lakes when moderately abundant. However, the presence of overabundant algae, or toxic strains, should be considered issues of concern. As with aquatic plants, algae generally grow more prolifically in the presence of abundant dissolved phosphorus (particularly in stagnant areas). Consequently, when overly abundant and/or toxic algae are noted in a lake, phosphorus enrichment is likely a primary causal agent.

Excessive or toxic algal growth are currently not known to be issues of widespread concern in Silver Lake, although some concerns have been expressed regarding algal levels in the north kettle. To maintain healthy algae populations, this section focuses upon monitoring algal abundance, preparing Lake residents to respond if algae growth becomes excessive of if toxic strains appear, and preventing excessive or toxic algal growth.

➤ **Recommendation 5.1: Control external phosphorus loading**
Silver Lake's algal growth is limited by available phosphorus. Several concepts that help control phosphorus concentrations in the Lake are discussed in the Section 3.3, "Lake Water Quality and Pollutant Load Reduction Recommendations." Related issues are discussed in Section 3.5, "Aquatic Plant Management Recommendations" and Section 3.8, "Fish and Wildlife Recommendations." From the perspective of controlling Lake algal abundance, following the recommendations presented in these sections should be assigned a high priority.

➤ **Recommendation 5.2: Monitor algal abundance**
Suspended algal abundance can be quantified by measuring chlorophyll-*a* concentrations, as was described in the Section 3.3 "Lake Water Quality and Pollutant Load Reduction Recommendations." If large amounts of suspended or floating algae are found in the future (e.g., "pea soup" green water, mats of filamentous algae), samples should be collected to allow algal types, particularly toxic strains of cyanobacteria, to be identified. Given that Silver Lake is not known to experience algal problems, this can be considered a low priority at present. However, if algae become abundant, or if toxic strains are suspicioned to be present, this recommendation should be elevated to high priority.

➤ **Recommendation 5.3: Notify Lake users of potentially unhealthy conditions**
If data or observations suggest an algal bloom, warn residents to stay out of the water. This should be considered a high priority unless testing positively confirms the absence of toxic algae. Therefore, methods should be developed to rapidly communicate water conditions not conducive to body contact. The following rule-of-thumb precautions may prove useful:

- Choose recreational areas that do not have noticeably green water, as wind can concentrate cyanobacteria blooms into near-shore areas. Do not boat, swim, water ski, or engage in other water-based recreation in or through water that looks "pea soup," green or like blue paint, or that has a scum layer or puffy blobs floating on the surface. People can be exposed through inhalation and need not touch contaminated water.

- Do not let children play with scum layers, even from shore.
- Always offer fresh, clean drinking water to pets. Do not let pets swim in or drink lake water experiencing algal blooms or noticeably green water.
- Always take a shower after significant contact with any surface water (whether a cyanobacteria bloom appears to be present—surface water may contain other potentially harmful bacteria and viruses).
- After swimming, pets should be immediately washed before they self-groom.
- Avoid swallowing untreated surface water—it may contain pathogens other than cyanobacteria that could make you ill.

The U.S. EPA Office of Water offers a suite of materials to help states and communities protect public health during harmful cyanobacteria algal blooms.[194] Some types of cyanobacteria can release toxic chemicals into water. Public health officials and outdoor water recreation managers can use EPA's online resources to develop monitoring programs and communicate evolving health risks to the public.

➤ Recommendation 5.4: Promote a healthy native aquatic plant community

The Lake's native aquatic plant community directly competes with algae and cyanobacteria for essential nutrients such as phosphorus. If the native plant community's demand for phosphorus declines, more phosphorus is available to fuel growth of algae and cyanobacteria. Healthy native plant communities can be promoted by implementing recommendations provided in Section 3.5, "Aquatic Plant Management Recommendations." This recommendation is assigned a high priority.

Implementing the above recommendations will help prevent overabundant algae and cyanobacteria in Silver Lake without precluding or significantly inhibiting Lake use. However, should excessive or greatly increased algal growth or cyanobacteria blooms occur in the future, or should toxic algae be identified, the following Lake management concepts may prove beneficial and are provided for reference only. None are recommended to be implemented currently.

- **In-Lake treatments** – Floating algae use dissolved or suspended nutrients to fuel growth. If water-column nutrient levels are reduced, the abundance of algae can be controlled. Water quality enhancement recommendations presented in Section 3.3, "Lake Water Quality and Pollutant Load Reduction Recommendations" could be considered to help control algae. Supplemental activities not recommended for overall Lake water quality management, but which could be considered as short-term interim solutions to counter severe algae problems include the following examples.
  - **Alum treatments** – Alum treatment involves dispensing a chemical (alum: hydrated potassium aluminum sulfate) throughout a lake. This chemical forms a flocculent solid that sinks, carrying algae and other solids to the lake bottom, allowing water to clear and rooted aquatic plants to grow at greater depth. Additional rooted aquatic plants compete with algae for nutrients and can help clarify lake water in the longer term. Alum-bound phosphorus precipitated to the lake bottom does not become soluble under anoxic water conditions and can help form a cap to reduce internal phosphorus loading. These effects can help lower lake water phosphorus concentrations, and, therefore, reduce algal blooms.
  - **Hypolimnetic withdrawal and on-shore treatment** – Some of the phosphorus available to fuel warm-season algal growth is released from Lake bottom sediment during summer, is available to fuel algal growth when conditions are right and is returned to the Lake bottom where it remains available to fuel future algal growth. At least some of this stored phosphorus is likely a legacy from the time period where heavy phosphorus loads were directed to the Lake from lakeshore property wastewater treatment systems. Since the Lake has a finite capacity to flush pollutants downstream, actions to actively and permanently remove phosphorus from the Lake can help decrease future nutrient levels. Hypolimnetic withdrawal and on-shore treatment would use pumps or gravity to

[194] *The USEPA cyanobacteria website is www.epa.gov/cyanohabs.*

remove nutrient-rich waters from deep within the Lake during the summer, treat the water on shore or in wetlands, and then allow the treated water to pass downstream or re-enter the Lake. This approach can be designed at a variety of scales, with the most intensive approaches yielding the quickest results. Less costly low-intensity approaches can operate essentially indefinitely and lead to incremental water quality improvement over decades.

- **Aeration** – This process involves pumping air deep into a lake to disrupt stratification and limit the extent of anoxic conditions. This in turn reduces internal loading (i.e., the release of phosphorus from deep sediments) and may reduce the severity of algal blooms during mixing periods. This method has produced mixed results in various lakes throughout Wisconsin and appears to be most successful in smaller water bodies such as ponds. If not properly designed or operated, aeration can increase nutrient levels and intensify and/or prolong algal blooms.

- **Manual removal** – Manually removing algae using suction devices has recently been tested within the Region. This measure, though legal, is currently in the early stages of use. Additionally, "skimming" algae has been tried by lake managers with little success. Consequently, it would be necessary to further investigate these measures prior to implementation.

All the above measures are commonly implemented only when algal blooms become so troublesome that recreational use is impaired.

3.7 RECREATIONAL USE RECOMMENDATIONS

Silver Lake is utilized for a wide variety of recreational activities including swimming, kayaking, water-skiing, pleasure boating, and fishing. Maintaining, and as possible enhancing, the quality of these uses should be considered a priority. This includes reducing the potential for Lake-use conflict and safety concerns. The following concepts are recommended to protect all lake uses.

➤ **Recommendation 6.1: Conscientiously operate the public boat launch**
Police the area for litter, misuse, and/or overuse. Continue to prominently post lake-use regulations and information that Lake users can use to better understand the threats facing the Lake. Continue to provide material to clean boats (see Recommendation 6.2). Monitor vehicle parking and strictly limit vehicle and trailer parking to designated parking spots within the launch area parking lot. Consider issuing citations for parking on grassy areas and other inappropriate locations. Evaluate use fee (see Recommendation 6.4). This concepts in this recommendation are assigned <u>high priority</u>.

➤ **Recommendation 6.2: Continue to participate in the Clean Boats, Clean Waters program**
The SLPRD should support activities that provide boaters with cleaning equipment to help avoid transport of invasive species to new water bodies. Furthermore, support assignment of inspection staff to the Silver Lake boat launch. This recommendation is assigned a <u>high priority</u>. More information regarding the Clean Boats, Clean Waters Program may be found at www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/cbcw/default.aspx.

➤ **Recommendation 6.3: Encourage safe boating practices and manage boat traffic pressure**
Silver Lake is a popular natural resource feature providing the community space for a variety of recreational pursuits. Action must be taken to balance recreational opportunity with sustainable Lake health, public safety, and other human desires. For example, the demand for recreational powerboating must be balanced against the needs of those engaging in more passive activities such as fishing, swimming, sail boating, paddle boating, and viewing the Lake and its wildlife. Furthermore, overall Lake use must consider the overall ecological health of the Lake. The SLRPD should review and revise boating ordinances, regulations, and fees to help address boat safety, boat traffic volume, and multi-use recreational quality. Boat traffic volume and potentially boat speed/wake generation are priority issues (see Recommendation 6.4 for more detail). Overall, this recommendation is assigned a <u>high priority</u>.

➤ **Recommendation 6.4: Evaluate measures to avoid excessive boat traffic**

Based upon data collected during summer 2016, Silver Lake's boat traffic volume occasionally exceeds its calculated sustainable capacity during peak use periods (e.g., warm summer weekends and holidays). Excessive boat traffic causes recreational use conflicts, can create potentially unsafe conditions, and can damage the Lake's ecology and overall health. The SLPRD may wish to collect more data and should pursue measures that help reduce peak boat traffic volumes. This recommendation is assigned a high priority for summer weekends and holidays and a low priority on typical weekdays and off-season weekends.

Common economic theory suggests that boating demand can be reduced if cost increases. Cost can include the price paid to launch a boat or other factors such as convenience (see *Wisconsin Administrative Code* NR 1, Natural Resources Board Policies, for more information. NR 1.91, Public Boating Access Standards, describes permissible fee structures in detail). Certain changes can be made that both benefit the long-term health of the Lake and may place negative pressure on demand. Examples of such changes include the following:

- Promulgate an ordinance to allow temporary closure of boat launch facilities when the parking lot area is full. Such an ordinance recently went into place at nearby Big Cedar Lake. At a minimum, parking should be strictly restricted to designated parking spaces. Funding should be provided to staff the launch with an attendant so that the launch can be reopened when parking spaces become available.

- Review water-based recreation ordinances and modify as necessary. Stringently enforce the regulations, especially during summer holidays and weekends. Consider expanding water patrol activity. Grants are available help communities revise and develop ordinances and sponsor water patrols.

- Increase the current base boat launch fee as allowable under state law.

- Consider launch fee surcharges, particularly on weekends and holidays,[195] such as the following:

  - Twenty per cent surcharge for toilet facilities. Potentially also apply to weekday rates to enhance revenue available to fund weekend/holiday launch attendants.

  - Large boat surcharges on weekends. An attendant would need to be on site for effective application.

  - Have an attendant on duty during all summer weekends and holidays. The attendant's primary duty would be to implement Clean Boats, Clean Waters watercraft inspections and distribute literature to help lake users understand invasive species issues. A surcharge of 20 per cent may be charged when an attendant is on duty. The attendant can also be responsible for identifying and collecting large boat launch surcharges.

➤ **Recommendation 6.5: Stringently enforce recreational ordinances**

Stringent boating ordinance enforcement should be considered a low priority on most weekdays, but a high priority on summer weekends and holidays. The SLPRD should review existing ordinances to examine if they provide sufficient protection or are compatible with current lake use and condition. As Lake conditions and Lake use evolve, ordinances must keep pace with change and thus require amendment. Regular ordinance review and revision should be considered an integral part of ordinance enforcement and should be assigned a high priority.

[195] *Launch fee surcharge guidance is provided at the following WDNR-sponsored URL: dnr.wi.gov/AID/documents/LaunchFees/InlandWatersFacilitiesMaxLaunchFees.pdf.*

➤ **Recommendation 6.6: Reduce powerboat-induced shoreline erosion**

Several ordinances are already enforced that are designed to protect shoreline and shallow areas around the Lake. Feedback from the SLPRD, comments from other lake groups in the Region, and information gathered as part of this study suggests that additional guidance may be needed to address wakeboat operation on the Lake. To help minimize the ecological and environmental impacts of wake boats/surf boats, the SLPRD should encourage boat operators to take the following actions:

- Avoid high speed operation within 500 feet of Lake shorelines
- Avoid unnecessary ballast water or adding other extra weight to boats
- Operate boats at speeds equal to or less than slow-no-wake in water less than 10 feet deep
- Avoid operating wake boats in shallow water or near natural shorelines
- Avoid turning boats in tight circles as this increases wave height and frequency
- Seek deeper water to minimize contact with vegetation
- Encourage boats to operate outside EWM control areas to reduce fragmentation and spread of this invasive species (see Figure 3.3)
- Adopt practices to preclude transport of aquatic invasive species. This includes draining water from, drying, and decontaminating all parts of the boat that come into contact with lake water

These practices may be best promoted by educational outreach, placing appropriate navigation buoys, and be posting signs and literature at the boat launch. This recommendation is assigned a medium priority.

➤ **Recommendation 6.7: Dissipate wave energy using shoreline BMPs**

As described in Section 3.4, "Nearshore Sedimentation and Shoreland Maintenance Recommendations," shoreline residents can play a key role to reduce shoreline and nearshore habitat damage created by human lake-based recreational activity. The waves created by some powerboats can greatly exceed the maximum size of waves created under natural conditions on smaller lakes such as Silver Lake. Additionally, unlike large natural storm-drive storm events, human recreational activity can take place nearly every day throughout the prime boating season. This recommendation is assigned a medium priority. The following example BMPs help dissipate wave energy along lake shorelines:

- Design shoreline protection structures to minimize reflected wave energy. This can be best achieved by dissipating wave energy. A large variety of methods promote this goal. For example, the SLPRD should promote natural surfaces in new structures and retrofitting existing hard structures with randomly placed rounded glacial stone or large woody structure, both which would be placed in shallow water immediately offshore.
- Install bioengineered shorelines that use native plants for protection.
- Maintain or expand the extent and density of nearshore submergent and emergent aquatic vegetation.
- Construct fish sticks or fish habitat structures in the nearshore area.
- Retain or place large woody structure along shorelines wherever practical.

In general, management efforts must focus on sustaining the Lake's health which in turns sustains high quality, diverse recreational use. This general principal should guide future management decision, including efforts undertaken to implement this plan.

3.8 FISH AND WILDLIFE RECOMMENDATIONS

Fish and wildlife populations depend upon the Lake's health. The presence of abundant and diverse native fish and wildlife increases the Lake's recreational use, aesthetic appeal, overall enjoyment by humans, and the integrity of the Lake ecosystem. To enhance fish and wildlife within Silver Lake and its watershed, the following management concepts are offered.

➤ **Recommendation 7.1: Support WNDR fishery management endeavors**
The WDNR concludes that Silver Lake's fish population is largely healthy but angling quality could be improved through careful management action. These actions include suppressing the Lake's overly abundant small bluegill population, stocking walleye to prey upon bluegill and expand angling opportunity and modifying the way the Lake's abundant yet slow growing northern pike population is managed. Carefully following and supporting WDNR fishery advice should be assigned a high priority. In conformance with this recommendation, the SLPRD and Lake users are encouraged to actively participate in fishery management by providing input and feedback as described below:

- Attempt to fully comprehend fishery information.
- Actively participate in WDNR planning processes and support suggested management recommendations.
- Provide the WDNR with information useful to fishery management strategies. For example, report observed spawning areas, creel surveys, angler pressure, baitfish and prey abundance, and other conditions.

➤ **Recommendation 7.2: Protect fish habitat and vulnerable fish**
The SLPRD, Lake users, and shoreland property owners should strive to protect valuable fish habitat and avoid disturbing vulnerable fish. Fish require a variety of habitats to successively complete life-cycle critical functions. For example, the locations where fish breed may be very different than the locations where they feed. Fish entering shallow water may become quite vulnerable to harm at certain points during the year. While the types of habitat vary by season and with fish species, a few types of habitat are clearly related to preserving populations of popular fish. For example, protecting gravelly shallows helps maintain suitable bass and bluegill spawning areas, while seasonally flooded stands of stiff vegetation are important to spawning northern pike. Overall fisheries can be protected by limiting high-speed boating and other disruptive activities in such areas during spawning periods. WDNR fisheries staff can help SLPRD identify the locations of these areas and the timing of protective measures. This should be considered a medium priority.

➤ **Recommendation 7.3: Identify and remove fish passage barriers**
Even intermittent streams, which flow only flow seasonally or during wet weather, can provide fish passage and two-way access to spawning and nursery grounds. Streams and ditches connected to the Lake flow through wetlands which may be critical feeding, breeding, and spawning habitat for many fish species, including northern pike. Barriers to fish and aquatic organisms are often categorized by permanence. Barriers that occasionally block passage and which may be temporary in nature include examples such as debris jams, sediment and railroad ballast accumulations, and channel overgrowth by invasive plants. Examples of permanent barriers include culverts that are perched, too narrow, or too long and dams. These barriers vary greatly in their ease of removal. Barrier removal can be prioritized along a single reach by contrasting the amount, type, and quality of potentially accessible habitat, ease of removal, landowner cooperation, and cost. Ozaukee County's Fish Passage Program is well developed and a good resource when establishing a fish passage program.[196]

[196] *More information about the Ozaukee County Fish Passage Program may be found at the following URL: www.co.ozaukee.wi.us/619/Fish-Passage.*

Silver Lake has no significant tributaries but is the headwater to Silver Creek, a stream that could provide lithophyllic spawning habitat now unavailable to the Lake's fish population.[197] While fish may be able to migrate downstream to access Silver Creek, the outlet dam is likely a complete barrier to upstream fish migration. This means that any Silver Lake resident fish migrating downstream are unlikely to return to the Lake and any young-of-the-year fish that may hatch downstream of the dam are unable to reach the Lake. Relatively simple techniques are readily available to improve the ability to pass upstream over the outlet dam structure. Identifying, prioritizing, and ultimately removing fish passage barriers should be considered a low priority.

➤ Recommendation 7.4: Improve in-Lake and nearshore aquatic habitat

Typical landscaping practices often simplify shoreline complexity. Fallen trees, emergent vegetation, and brushy nearshore vegetation are commonly cleared to improve lake visibility and access. These elements often provide cover for aquatic organisms, basking areas for birds and amphibians, anchor points for periphyton, and other habitat elements desired and/or needed by lake-dependent animals. Given the high value and intense use associated with lakeshore property, completely naturalizing shorelines is generally impractical. However, actions can be taken to improve the ecological function of most lakeshore landscaping practices. Practices that promote in-Lake and/or nearshore habitat value include the following examples. All are assigned a medium priority from a habitat improvement perspective.

- **Restore nearshore large woody structure.** This activity focuses on retaining or adding fallen trees in nearshore areas and installation of engineered woody structure sometimes referred to as "fish sticks."[198] Since large woody structure also promotes shoreline stability, it was also component to actions called for in Recommendations 3.5 and 6.7.

- **Preserve native aquatic plants and associated habitat.** Native aquatic plant communities provide countless benefits to fish and wildlife. Therefore, care for native aquatic plants and habitat they provide is important. To achieve this goal, the SLPRD should promote proper implementation of the aquatic plant management plan described in Recommendation 5.4 and Section 3.5, "Aquatic Plant Management Recommendations," especially as they relate to avoiding inadvertently damaging the native aquatic plant community. Furthermore, as explained in Section 3.7, "Recreational Use Recommendations," action to reduce boat-induced disruption of native aquatic plants, riparian wetlands, and lake-bottom sediments are highly desirable.

➤ Recommendation 7.5: Promote shoreline buffers

The vegetative communities along the Lake's shoreline have been simplified through traditional landscaping practices, a situation that reduces its habitat value for aquatic organisms. Buffers are also component to several other recommendations including the Recommendation 2.2, 2.7, 3.5, and 3.6. Implementing this recommendation could include outreach, education, or incentive-based programs, and, from a fishery and wildlife management perspective, should be assigned a medium priority.

➤ Recommendation 7.6: Maintain or enhance water quality

Healthy fish and wildlife populations depend upon a healthy Lake ecosystem. The SLPRD should promote actions listed throughout Chapter 3 that promote water quality. Mitigating water quality stress on aquatic life increases the quality and extent of areas desirable to baitfish and gamefish. The primary issue in this category relevant to most local lakes is low oxygen and supersaturated oxygen concentrations during some seasons at certain depths. The water quality recommendations discussed earlier in this chapter call for measures that may help improve the Lake's oxygen conditions. Other stressors may develop in the future (e.g., new invasive species and other water quality concerns) and such changes should be carefully monitored for their impact on aquatic life. Since water quality is not currently known to be

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[197] *Walleyes and white suckers are common examples of fish that favor spawning sites in stony flowing streams. The Lake's walleye population is currently entirely dependent upon stocking and could potentially benefit from access to suitable spawning habitat. Furthermore, the reportedly slow-growing nature of the Lake's northern pike population may attest to low forage fish populations. The Lake's population of white suckers, a favorite food of northern pike, could possibly be bolstered by improving fish passage between Silver Creek and Silver Lake.*

[198] *The WDNR provides information on the role of woody structures and fish sticks projects at the following URL: dnr.wi.gov/topic/fishing/outreach/fishsticks.html.*

detrimental to the Lake's target fishery, this recommendation is given a low priority from a fishery and wildlife management perspective.

- **Recommendation 7.7: Preserve, connect, and expand wetland and terrestrial wildlife habitat**
  Many recommendations presented earlier in Chapter 3 rely upon practices that concomitantly preserve or enhance fish and wildlife habitat. Examples include recommendations mentioned in Recommendation 1.6, 2.2, 2.6, 2.7, 3.1, and 3.3. Given that fish and wildlife populations in the Lake and its watershed are generally thought to be heathy, these recommendations as they relate to fish and wildlife habitat are given a medium priority.

- **Recommendation 7.8: Incorporate upland conservation and restoration targets into management and policy decisions**
  Upland areas provide a wide range of ecosystem services but are often among the first targeted for urban development. Taking positive action to protect and restore upland habitat should be assigned a high priority.

- **Recommendation 7.9: Limit development in environmental corridors**
  Continue to carefully control and limit development in Commission-delineated primary environmental corridors (see Map 3.1). This recommendation is assigned a high priority.

- **Recommendation 7.10: Protect and preserve WDNR-designated critical habitat areas**
  Critical species habitats are essential for protecting rare native species, including those on the Wisconsin's endangered and threatened species list (see Maps 2.11 and 2.12). This recommendation is assigned a high priority.

- **Recommendation 7.11: Protect ecological value and function of buffer, wetland, woodland, and floodplain areas**
  Many natural areas in Southeastern Wisconsin have undergone radical change during past decades, often to the detriment of local ecological integrity and fish and wildlife abundance. Aside from direct human landscape manipulation, invasive plants, imported insects, and introduced disease put additional pressure upon the ecological integrity of natural areas. The SLPRD should encourage natural areas be monitored for degradation and should promote actions that help protect and restore native vegetation. While dozens of invasive plant species exist,[199] some of the most common include reed grass (*Phragmites australis*), purple loosestrife (*Lythrum salicaria*), garlic mustard (*Alliaria petiolate*), teasel (*Dipsacus* spp.), common buckthorn (*Rhamnus cathartica*), glossy buckthorn (*Frangula alnus*), and tatarian honeysuckle (*Lonicera tatarica)*. These species quickly spread and displace native plants that help treat polluted water and provide valuable habitat. Consequently, a visual survey of appropriate watershed and shoreline locations is recommended to determine these plants may pose a current or potential problem. If it is found to be an issue, the landowner should be strongly encouraged to eradicate the infestation.

  Woodlands cover large portions of the Silver Lake watershed and warrant special attention. Woodland management practices are discussed in Recommendation 2.6. The SLPRD should encourage woodland owners to research State programs that provide technical and financial assistance covering topics such as forestry management, tax implications, and professional forestry advice. Furthermore, woodland owners should be encouraged to join, and attend events sponsored by, the Wisconsin Woodland Owners' Association.[200] This recommendation is assigned a medium priority.

- **Recommendation 7.12: Adopt best management practices to improve wildlife habitat**
  Best management practice acceptance and employment can be voluntarily fostered through outreach, educational programs, and financial incentives targeted at privately-owned parcels of particular interest. Publicly owned and protected parcels often provide ideal sites to demonstrate practices of interest and should be standard bearers for the initiatives promoted by the SLPRD. Some special interest non-governmental organizations ("NGOs", e.g., CLCF, OWLT, Pheasants Forever, Ducks Unlimited, Trout

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[199] *Readers are encouraged to visit the WDNR's invasive species website for more information: dnr.wi.gov/topic/Invasives.*

[200] *More information regarding the Wisconsin Woodland Owners' Association may be found at the following URL: wisconsinwoodlands.org.*

Unlimited) foster habitat improvement projects and collaborate with landowners to install beneficial projects. As part of implementing this element, a list of best management practices, benefits of such practices, available financial incentives, and relevant NGOs should be compiled and provided to landowners. This recommendation is assigned medium priority.

➤ **Recommendation 7.13: Monitor fish and wildlife populations**

Tracking fish and wildlife diversity and abundance helps future Lake managers detect change. Consequently, continued fish population assessments and periodic recording of the types of animals found in and on the Lake and within its watershed is assigned a medium priority. Monitoring data can be gleaned from government agency reports and staff, non-governmental organizations (e.g., Audubon Society), and from volunteers around the Lake and throughout the watershed. A plethora programs are sponsored to encourage citizen involvement in this endeavor.[201] Most programs host a website making reporting information relatively easy. Some provide equipment. A few examples, and links to their websites, are provided below.

- The Wisconsin Turtle Conservation Program: wiatri.net/inventory/witurtles
- The Wisconsin Frog and Toad Survey: wiatri.net/inventory/FrogToadSurvey
- Wisconsin Bumble Bee Brigade: wiatri.net/inventory/bbb
- Snapshot Wisconsin: dnr.wi.gov/topic/research/projects/snapshot/
- Operation Deer Watch: dnr.wi.gov/topic/wildlifehabitat/summerdeer.html
- Wisconsin Phenological Society: sites.uwm.edu/wisconsin-phenological-society
- Cedar Lake Conservation Foundation (Wildlife Monitoring): www.conservecedarlakes.org/see

3.9 PLAN IMPLEMENTATION RECOMMENDATIONS

Without a formal implementation plan, confusion and common free-rider behavior commonly causes plan recommendations to go uncompleted. Therefore, a central goal for any lake protection group and plan is answering the need to coordinate and schedule plan components. This can include providing technical guidance to project partners, collaboratively developing a workplan that assigns tasks to specific individuals who then become responsible for executing specific tasks, and developing tangible goals and quantifiable metrics to measure progress and relative success over time. Developing an action plan with timelines, goals, and identified responsible parties is a significant step toward plan implementation. Target metrics can help implementing agencies and funders gauge progress over time and often help motivate participants, ensuring that the plan is carried through in the long term. Some recommendations can be best achieved using regulatory authority while others involve proactively implementing new, oftentimes voluntary, management efforts. Both are discussed in this section.

Regulations

Relative to this plan, regulatory implementation refers to maintaining and improving water quality, water quantity, habitat value, and fish and wildlife populations using local, State, and Federal rules and laws. Several regulations already govern activities within the area contributing runoff and groundwater to Silver Lake, including zoning and floodplain ordinances, boating and in-Lake ordinances, angling and hunting regulations, and State regulations related to water quality. These regulations already help protect the Lake by mitigating pollution, preventing or limiting development, protecting fish and wildlife, and encouraging use of best management practices.

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[201] *Scores of citizen-based monitoring programs are active in Wisconsin. The WDNR and the University of Wisconsin-Extension hosts a directory of such programs. Those interested in citizen-based monitoring opportunities are strongly encouraged to visit the directory website: wiatri.net/cbm/whoswho/.*

Local Ordinances

Zoning ordinances dictate where development can take place, the form of development allowed, and the technical standards that need to be met for development to proceed. Consequently, zoning can be a particularly effective tool to protect buffers, wetlands, uplands, and shorelands if environmental goals are integrated into ordinance development, formulation, and enforcement. Environmental corridors can be integrated into conservancy zoning district regulations to help determine where development is permitted and not permitted, and to determine the extent of development allowed. Based upon a review of the Town of West Bend comprehensive 2025 land use plan and recent updated zoning ordinance as summarized in Chapter 2, the following zoning ordinance-based concepts are offered.

➤ Recommendation 8.1: Establish a land conservancy

A land conservancy could be established to protect habitat, stormwater conveyance/detention/treatment, groundwater recharge areas, and other natural resource assets important to Silver Lake. Lands targeted for conservation would focus upon primary environmental corridors, secondary environmental corridors, and isolated natural areas, especially where they overlay high groundwater recharge potential areas (see Map 3.1). Alternately, the SLPRD could partner with existing land conservation organizations already active in the area (e.g., the CLCF (www.conservecedarlakes.org) and the OWLT (owlt.org)).

Land must not necessarily be purchased and set aside to be protected. Other initiatives such as conservation easements and purchase of development rights can achieve this recommendation's goals but normally at lower cost. This recommendation is assigned a low priority.

➤ Recommendation 8.2: Pursue promulgation of a groundwater protection ordinance

Groundwater protection ordinances aim to balance human groundwater withdrawal with the benefits provided by natural groundwater discharge patterns. More simply put, groundwater protection ordinances attempt to sustain natural water resource features fed by groundwater. Since groundwater is Silver Lake's dominant water source, protecting local groundwater resources from overexploitation and degradation protects the health of Silver Lake. The Town of West Bend would normally be the entity responsible for promulgating and enforcing a groundwater protection ordinance. The SLPRD and Town of West Bend residents should advance this idea to the Town of West Bend board. Wisconsin municipalities already enforce such ordinances. For example, the Village of Richfield in southern Washington County developed a groundwater protection ordinance to reduce the impacts of new development on existing wells, infrastructure, and natural resource assets. The ordinance aims to:

- Maintain adequate water supply for human needs and desires
- Support recreational and water supply uses
- Retain natural flora and fauna abundance and diversity
- Protect groundwater recharge
- Maintain stream baseflows and/or water levels in local lakes, ponds and wetlands[202]

This recommendation is assigned a high priority.

➤ Recommendation 8.3: Pursue modification of the Town of West Bend's R-1R Rural Residential District

The SLPRD and Town of West Bend residents should request that the Town of West Bend modify or update the Town's R-1R Rural Residential District code. The code currently does not meet standards for cluster subdivision design for residential development outside urban service areas. More specifically, it does not meet recommendation 1.4 in VISION 2050, Volume 3, page 16)[203] of no more than one dwelling unit per five acres. Furthermore, the Town's R-1R standard does not currently meet development guidelines considered compatible with environmental corridors and isolated natural resource areas (i.e., Table K, VISION 2050, Volume 3, page 211). This recommendation is assigned a high priority.

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[202] *More information may be found on the Village's website at www.richfieldwi.gov/index.aspx?NID=300.*

[203] *SEWRPC,* Vision 2050, A Regional Land Use and Transportation Plan for Southeastern Wisconsin*, July 2017.*

➤ Recommendation 8.4: Protect groundwater recharge, critical species habitats, and natural areas with existing ordinances

Update the existing natural environmental and cultural features identified and mapped within the existing Town of West Bend ordinance (Section 4.0, part E (1) "Design Process and Standards for Conservation Developments," pages 25-26). The new features should include protection of high and very high groundwater recharge areas (Maps 2.14 and 3.1) and mapped critical species habitats and natural areas (Maps 2.11 and 2.12) identified under the natural areas plan and plan updates. It is also recommended that the Town of West Bend remove "Class I, II, III wildlife habitat areas identified by SEWRPC" from the existing ordinance within Section 4.0, Section 4.0, part E (1) "Design Process and Standards for Conservation Developments." This recommendation is assigned a high priority.

➤ Recommendation 8.5: Revise C-1 District boundaries to reflect updated Wisconsin Wetland Inventory boundaries

The Town of West Bend should periodically reassure that its C-1 District zoning map boundaries align with current Wisconsin Wetlands Inventory boundaries. This is assigned a high priority.

In addition to general zoning, shoreland zoning, construction site erosion control, and stormwater management ordinances help protect natural resource features. Shoreland zoning, for example, primarily administered by Washington County, follows State standards to set minimum building setbacks around navigable waters.[204] Furthermore, stormwater management and construction erosion control ordinances help limit the negative effect that property development often has on water pollution, flooding, habitat value and integrity, and other important resource values.

Several important recommendations made under this plan relate to municipal or county ordinance enforcement (e.g., shoreline setbacks, zoning, construction site erosion control, drainage, and boating). Such agencies often have limited resources at their disposal to assure rules are respected and properly applied. Consequently, the following recommendations, directed toward local citizens and management groups, and are made to help responsible entities better monitor and enforce existing regulations.

➤ Recommendation 8.6: Enhance relationships with local government units

Plan implementation depends upon open communication and trust. Both are enhanced by interpersonal familiarity. To encourage communication and trust, the SLPRD should maintain and enhance relationships with Washington County and Town of West Bend administrators and law enforcement officers. Regular active communication with other organizations such as the CLCF, the OWLT, and the WDNR should also be pursued. This no-cost initiative helps build open relationships facilitating efficient communication and collaboration whenever needed. This recommendation is assigned a high priority.

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[204] *The Wisconsin Legislature significantly changed shoreland zoning laws in the 2011, 2013, and 2015 legislative sessions. These changes have generally resulted in a more limited role for the WDNR and counties, and a greater role by the State legislature to directly establish shoreland standards. Of particular importance are 2011 Wisconsin Act 167, 2013 Wisconsin Act 80, 2015 Wisconsin Act 55, 2015 Wisconsin. Act 167, and 2015 Wisconsin. Act 391. Previously, county ordinances were required to meet minimum standards set by the WDNR, but counties could enact stricter standards. That began to change with the 2011 Wisconsin Act 170, which prevented counties from adopting stricter standards than those published in* Wisconsin Administrative Code *Chapter NR 115 "Wisconsin's Shoreland Protection Program" for nonconforming structures and substandard lots. Since 2011, the trend to enhance the role of the State legislature in the development of shoreland zoning has continued. For example, some of the more stringent standards adopted by counties, such as setbacks in excess of 75 feet, are no longer valid. Currently, under 2015 Wis. Act 55, a shoreland zoning ordinance may not regulate a matter more restrictively than it is regulated by a State shoreland-zoning standard unless the matter is not regulated by a standard in* Wisconsin Administrative Code *Chapter NR 115 "Wisconsin's Shoreland Protection Program." Examples of unregulated matters may involve wetland setbacks, bluff setbacks, development density, and stormwater standards. In addition, under 2015 Act 55, a local shoreland zoning ordinance may not require establishing or expanding vegetative buffers on already developed land through mitigation; counties must allow property owners to establish 35-foot wide "viewing corridors" within each 100 feet of shoreland buffer zone and allow multiple viewing corridors to run consecutively in cases where shorelines run in excess of 100 feet. Whereas the impervious surfaces standard remains at no more than 15 percent of the lot area, sidewalks, public roadways, and areas where runoff is treated by a device or system or is discharged to an internally drained pervious area, must not be included in the calculation of impervious surface. Additionally, exceptions exist to the 15 percent standard for highly developed areas. Additional legislation relative to shoreland zoning enacted after the 2015-2017 state budget legislation includes Act 41 which addresses town shoreland zoning authority relative to county authority (effective date: July 3, 2015) and Act 167 which codifies and revises current Wisconsin Department of Natural Resources shoreland zoning standards.*

➤ **Recommendation 8.7: Track planned and ongoing watershed activity**
The SLPRD, Lake users, and Lake residents should stay abreast of activities within the watershed (e.g., construction, filling, erosion) that could potentially affect the Lake. As part of this effort, participants should create, maintain, and share adequate records (e.g., notes, photographs) and, when appropriate, judiciously notify relevant regulatory entities. This recommendation is assigned a high priority.

➤ **Recommendation 8.8: Increase ordinance awareness and regularly update ordinances**
Regulations are of little value if they are unknown, unenforced, or obsolete. As part of this recommendation, the SLPRD should help inform watershed residents of the existence of various ordinances and how they help protect the Lake. This helps ensure that residents know why these rules are important, that permits are required for almost all significant grading or construction, and that such permits offer opportunities to regulate activities that could harm the health of the Lake and its watershed. The SLPRD should also monitor the continued relevance of ordinances and call for revision as conditions evolve. This recommendation is assigned a high priority.

State Regulations

The State Legislature requires the WDNR to develop performance standards for controlling nonpoint source pollution from agricultural and nonagricultural land and from transportation facilities.[205] The resulting performance standards, found in *Wisconsin Administrative Code* Chapter NR 151, "Runoff Management," establish requirements for best management practices. Similar regulations cover construction sites, wetland protective areas, and buffer standards.

Water quality objectives are presented in *Wisconsin Administrative Code* Chapter NR 102, "Water Quality Standards for Wisconsin Surface Waters." These rules set water quality standards promoting healthy aquatic ecosystems and public waterbody use and enjoyment. Some standards applicable to Silver Lake include the following.

- Dissolved oxygen greater than or equal to 5.0 mg/L
- pH between 6.0 and 9.0 SU
- Fecal coliform geometric mean less than or equal to 200 colonies per 100 milliliters, single sample maximum less than or equal to 400 colonies per 100 milliliters
- Total phosphorus (summer epilimnion) 30 µg/L (or 0.030 mg/L)
- Chloride acute toxicity 757 mg/L, chronic toxicity 395 mg/L

The rule further stipulates maximum temperatures for each month, with the highest standards applying to July and August when the following maxima apply: ambient water temperature of less than or equal to 77°F, sublethal water temperature of less than or equal to 80°F for one week or less, and acute water temperature of less than or equal to 87°F for one day or less.

The regulations described set standards to maintain the health of Silver Lake and the resources within its watershed. However, even though developers, residents, and Lake users are legally obligated to adhere to the ordinances, limited resources within enforcement bodies at State, County, and municipal government

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[205] *State performance standards are set forth in* Wisconsin Administrative Code *Chapter NR 151 "Runoff Management." Additional code chapters related to the State nonpoint source pollution control program include* Wisconsin Administrative Code *Chapter NR 152* Model "*Ordinances for Construction Site Erosion Control and Storm Water Management." This Chapter was amended in 2018 in response to 2013 Wisconsin Act 20, see WDNR Guidance #3800-2014-3,* Implementation of 2013 Wisconsin Act 20 for Construction Site Erosion Control and Stormwater Management *published during October 2014,* Wisconsin Administrative Code *Chapters NR 153 "Runoff Management Grant Program," NR 154 "Best Management Practices, Technical Standards and Cost-Share Conditions," NR 155 "Urban Nonpoint Source Water Pollution Abatement and Storm Water Management Grant Program," and Chapter ATCP 50 "Soil and Water Resource Management". These chapters of the* Wisconsin Administrative Code *became effective in October 2002.* Wisconsin Administrative Code *Chapters NR 120 "Priority Watershed and Priority Lake Program" and NR 243 "Animal Feeding Operations" were repealed and recreated in October 2002.*

can make the task of ensuring compliance difficult. Consequently, several methods to enhance ordinance adherence and plan implementation are described below.

Proactive Management

In addition to continued and enhanced regulatory enforcement, several plan recommendations seek to proactively improve Lake and watershed conditions without the threat of regulatory enforcement. A variety of challenges can limit the ability of Lake residents and the SLPRD to implement certain management efforts recommended in this plan. Examples of such challenges are listed below.

- Lack of adequate funding. The cost associated with plan recommendations may be intimidating.

- Institutional cooperation and capacity. Institutional capacity refers to assets available through agencies, universities, schools, service groups, volunteers, and non-governmental organizations that can be used to implement projects. These assets can be defined in terms of knowledge, know how, labor, equipment, and other resources.

- The Silver Lake Protection and Rehabilitation District, a Chapter 33, *Wisconsin Statutes,* public inland lake protection and rehabilitation district, is dedicated to the protection of Silver Lake. Lake districts are considered "special purpose units of government" and are a taxing body. They also have some capabilities to regulate lake use (e.g., boating ordinances, sewage management).[206] In contrast, lake associations are voluntary groups where both membership and dues payment are voluntary. However, because, unlike a district, they are not a government body, they can act more quickly on some issues.

- Volunteers – To increase advocacy, learning opportunities, and the volunteer base for labor intensive and/or wide-ranging projects (e.g., hand pulling or wetland invasive species monitoring), it is desirable to reach a broad stakeholder group. This group should include members of the SLPRD, the Silver Lake Sanitary District, Lake users and residents, the general public, conservation-themed organizations, schools, and agencies with an interest in the water resources of the Silver Lake and its watershed. The planning process for Silver Lake reveals that many stakeholders have strong connections to the Lake. However, participants in the planning process were almost entirely composed of lakeshore or near-lakeshore residents. To increase the advocacy and volunteer base for projects, volunteers must be drawn from well beyond Lake shoreline properties.

Since these factors commonly hinder local citizens and management groups from effectively achieving executing Lake management objectives, the following suggestions are offered to enhance project execution.

➤ **Recommendation 8.9: Solicit funding from grants and other sources**

Apply for grants, when available, to support program implementation, including those recommended as part of this plan. To be effective, this process requires coordination, creativity, and investment of stakeholder time. Table 3.2 provides an example list of grant opportunities that can potentially be used to implement plan recommendations. This is recommended as a high priority.

➤ **Recommendation 8.10: Encourage Lake users to actively participate in future management efforts**

Not only does Lake user involvement help assure community support, but also supplements the donor and volunteer pool working toward improving the Lake. Broad-based resident engagement on future efforts benefits the Lake, but also benefits the economic value of resident's properties. This recommendation is assigned a medium priority.

➤ **Recommendation 8.11: Reinforce local Lake management knowledge**

The goal of this recommendation is to build a small cadre of local experts well versed in the most important issues facing the Lake. To help achieve this goal, encourage key lake community members to attend meetings, conferences, and/or training programs. This helps build local lake management knowledge and enhances the SLPRD's institutional knowledge and capacity. Some examples of capacity-building events are the Wisconsin Lakes Conference (which targets local lake managers) and the "Lake Leaders"

[206] *For more information visit wisconsinlakes.org or contact Eric Olson at eolson@uwsp.edu.*

Table 3.2
Example WDNR Grant Programs Supporting Lake Management Activities

Category	Program	Grant Program	Maximum Grant Award	Minimum Grantee Match (percent)	Application Due Date
Water	Surface Water Grants	Aquatic Invasive Species (AIS) Prevention and Control	Clean Boats, Clean Waters: **$24,000**	25	November 1
			Established Population Control: **$150,000**	25	November 1
			Early Detection and Response: **$25,000**	25	Year-Round
			Research and Development annual funding limit: **$500,000**	25	November 1
		Surface Water Education	**$5,000** per project **$50,000** per waterbody	33	November 1
		Surface Water Plan	**$10,000**	33	November 1
		Comprehensive Management Plan	**$25,000**	33	November 1
		County Lake Grant	**$50,000**	33	November 1
		Ordinance Development	**$50,000**	25	November 1
		Management Plan Implementation	Lakes: **$200,000** Rivers: **$50,000**	25	November 1
		Healthy Lakes & Rivers	**$1,000** per practice **$25,000** per waterbody	25	November 1
		Surface Water Restoration	Lakes: **$50,000** Rivers: **$25,000**	25	November 1
		Land Acquisition and Easement	Lakes: **$200,000** Rivers: **$50,000**	25	November 1
	Citizen-Based Monitoring Partnership Program	--	**$5,000**	None	Spring
	Targeted Runoff Management	--	Small-Scale: **$225,000**	30	May 15
			Large-Scale: **$600,000**	30	May 15
	Urban Nonpoint Source & Stormwater Management	--	Planning: **$85,000** Property Acquisition: **$50,000** Construction: $**150,000**	50	May 15
Conservation and Wildlife	Knowles-Nelson Stewardship Program	Habitat Areas	--	50	March 1
		Natural Areas	--	50	March 1
		Streambank Protection	--	50	March 1
		State Trails	--	50	March 1
Boating	Boat Enforcement Patrol	--	Up to **75% reimbursement**	None	Various
	Boating Infrastructure Grant	--	Up to **$200,000 per state**	50	June 1
Recreation	Knowles-Nelson Stewardship Program	Acquisition and Development of Local Parks	--	50	May 1
		Acquisition of Development Rights	--	50	May 1
		Urban Green Space	--	50	May 1
		Urban Rivers	--	50	May 1
	Sport Fish Restoration	Boat Access	Varies annually	25	February 1
		Fishing Pier	Varies annually	25	October 1

Note: This table incorporates information from NR 193, which was made effective on June 1st, 2020. More information regarding these example grant programs may be found online at the following address: dnr.wi.gov/aid/grants.html. Additional federal, state, and local grant opportunities are available. Eligibility varies for each grant program.

Source: Wisconsin Department of Natural Resources and SEWRPC

training program (which teaches the basics of lake management and provides ongoing resources to lake managers).[207] Both of these are hosted by the University of Wisconsin-Extension. Additionally, in-person and on-line courses, workshops, training, regional summits, and general meetings are also extremely valuable. An example would be to conduct a workshop for riparian homeowners on vegetative buffer strip development and installation. Attendance at these events should include follow-up documents/meetings to help assure that the lessons learned are communicated to the larger Lake group. This recommendation is assigned a medium priority.

- **Recommendation 8.12: Continue to reinforce stakeholder inclusivity and transparency**
  If stakeholders do not fully understand or trust the aims and goals of a project, excess energy can be unproductively devoted to conflict, a result that benefits no one. Inclusivity/transparency efforts should be implemented through public meetings, social media, newsletters, email, questionnaires, and any other mechanism that helps disperse and gather a full suite of information and builds consensus. In this way, a broad array of data and viewpoints can be identified and considered. This in turn allows conflict to be discussed, addressed, and mitigated before finalizing plans and implementing projects. This recommendation is assigned a high priority.

- **Recommendation 8.13: Foster and monitor communications with future Lake managers**
  Successfully implementing a lake management plan requires long-term commitment and dedication. This means that those leading initiatives today may not be the same individuals completing the initiative. Furthermore, some initiatives may carry on indefinitely (e.g., water quality monitoring, aquatic plant management). For this reason, leaders must conscientiously integrate next-generation leadership into implementation efforts.

  To maintain positive momentum, the SLPRD should foster and monitor efforts to communicate concerns, goals, actions, and achievements to future Lake managers. Institutional knowledge is a powerful tool that should be preserved indefinitely whenever possible. Actions associated with this are sometimes embedded in organization bylaws and policies (e.g., recording meeting minutes). Open communication helps further increase the capacity of Lake management entities. This may take the form of periodic meetings, internet websites, social media, newsletters, emails, reports and any number of other means that help compile and report actions, plans, successes, and lessons learned. These records should be kept for future generations of lake leaders. This recommendation is assigned a high priority.

- **Recommendation 8.14: Develop an action plan highlighting action items, timelines, goals, and responsibly parties**
  A written action plan, developed collaboratively with project partners, helps ensure that plan recommendations are implemented in a timely, comprehensive, transparent, and effective manner. Additionally, an action plan can help ensure that all responsible parties are held accountable for their portions of the plan's implementation. This recommendation is assigned a high priority.

- **Recommendation 8.15: Actively publicize and promote this plan**
  As a final note, a major recommendation to promote implementation of this plan is educating Lake residents, users, and governing bodies regarding the content of this plan. A campaign to communicate the relevant information in the plan should, therefore, be given a high priority.

3.10 SUMMARY AND CONCLUSIONS

The future is expected to bring tangible change to Silver Lake and its watershed. Projections suggest that some undeveloped land today will give way to urban residential land use. It is critical that proactive measures be actively pursued that lay the groundwork for effectively deal with, and benefit from, future change. Working relationships with appropriate local, county, and State entities need to be nurtured now and in the future. These actions help assure that action is expeditiously taken to protect and/or enhance the value of critical natural areas, reduce human influence and pressure on the Lake and its watershed, and instill attitudes among current and future residents that foster cooperation and coordination of effort on many levels.

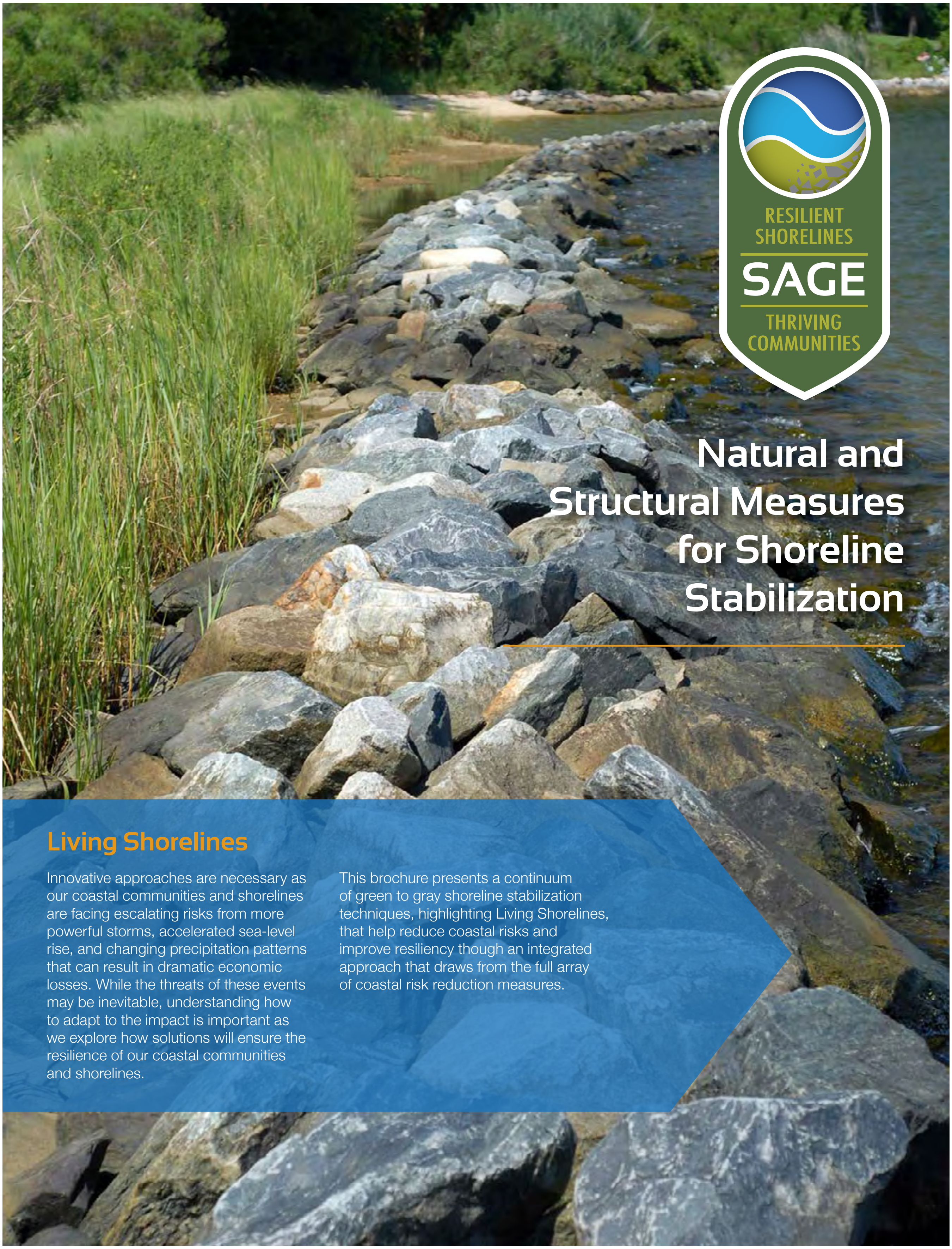
[207] *More information regarding the upcoming Wisconsin Lakes conference may be found at www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/convention/default.aspx. The Lake Leaders program is described at www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/lakeleaders/default.aspx.*

As a final point, this plan is not a comprehensive user manual or bible. Instead, the concepts and recommendations in Chapter 3 are intended to stimulate ideas and action. The recommendations and concepts are provided as a starting point to address concerns identified by Lake residents and users. Successful plan implementation requires vigilance, cooperation, and enthusiasm, not only from local management groups, but also from State and regional agencies, Washington County, the Town of West Bend, and the residents of areas contributing surface-water and groundwater to the Lake. The recommended measures help provide water quality, biological, and habitat protection needed to maintain or enhance the natural beauty, recreational potential, ecological value and ambience of Silver Lake and its watershed.

APPENDICES

NATURAL AND STRUCTURAL MEASURES FOR SHORELINE STABILIZATION

APPENDIX A



RESILIENT SHORELINES
SAGE
THRIVING COMMUNITIES

Natural and Structural Measures for Shoreline Stabilization

Living Shorelines

Innovative approaches are necessary as our coastal communities and shorelines are facing escalating risks from more powerful storms, accelerated sea-level rise, and changing precipitation patterns that can result in dramatic economic losses. While the threats of these events may be inevitable, understanding how to adapt to the impact is important as we explore how solutions will ensure the resilience of our coastal communities and shorelines.

This brochure presents a continuum of green to gray shoreline stabilization techniques, highlighting Living Shorelines, that help reduce coastal risks and improve resiliency though an integrated approach that draws from the full array of coastal risk reduction measures.

Coastal Risk Reduction and Living Shorelines

Coastal Risk Reduction

Coastal systems typically include both natural habitats and man-made structural features. The relationships and interactions among these features are important variables in determining coastal vulnerability, reliability, risk and resilience.

Coastal risk reduction can be achieved through several approaches, which may be used in combination with each other. Options for coastal risk reduction include:

- Natural or nature-based measures: Natural features are created through the action of physical, biological, geologic, and chemical processes operating in nature, and include marshes, dunes and oyster reefs. Nature-based features are created by human design, engineering, and construction to mimic nature. A living shoreline is an example of a nature-based feature.
- Structural measures: Structural measures include sea walls, groins and breakwaters. These features reduce coastal risks by decreasing shoreline erosion, wave damage, and flooding.
- Non-structural measures: Includes modifications in public policy, management practices, regulatory policy and pricing policy (e.g., structure acquisitions or relocations, flood proofing of structures, implementing flood warning systems, flood preparedness planning, establishment of land use regulations, emergency response plans).

The types of risk reduction measures employed depend upon the geophysical setting, the desired level of risk reduction, objectives, cost, reliability, and other factors.

SAGE – Systems Approach to Geomorphic Engineering

USACE and NOAA recognize the value of an integrated approach to risk reduction through the incorporation of natural and nature-based features in addition to non-structural and structural measures to improve social, economic, and ecosystem resilience. To promote this approach, USACE and NOAA have engaged partners and stakeholders in a community of practice called SAGE, or a Systems Approach to Geomorphic Engineering. This community of practice provides a forum to discuss science and policy that can support and advance a systems approach to implementing risk reduction measures that both sustain a healthy environment and create a resilient shoreline.

SAGE promotes a hybrid engineering approach that integrates soft or 'green' natural and nature-based measures, with hard or 'gray' structural ones at the landscape scale. These stabilization solutions include "living shoreline" approaches which integrate living components, such as plantings, with structural techniques, such as seawalls or breakwaters.

Living Shorelines achieve multiple goals, such as:

- Stabilizing the shoreline and reducing current rates of shoreline erosion and storm damage;
- Providing ecosystem services (such as habitat for fish and other aquatic species) and increasing flood storage capacity; and
- Maintaining connections between land and water ecosystems to enhance resilience.

In order to determine the most appropriate shoreline protection technique, several site-specific conditions must be assessed. The following coastal conditions, along with other factors, are used to determine the combinations of green and gray solutions for a particular shoreline.

REACH: A longshore segment of a shoreline where influences and impacts, such as wind direction, wave energy, littoral transport, etc. mutually interact.

RESILIENCE: The ability to avoid, minimize, withstand, and recover from the effects of adversity, whether natural or man made, under all circumstances of use. This definition also applies to engineering (i), ecological (ii), and community resilience (iii).

FETCH: A cross shore distance along open water over which wind blows to generate waves. For any given shore, there may be several fetch distances depending on predominant wind direction.

PHYSICAL CONDITIONS: The slope of the foreshore or beach face, a geologic condition or bathymetry offshore.

TIDAL RANGE: The vertical difference between high tide and low tide.

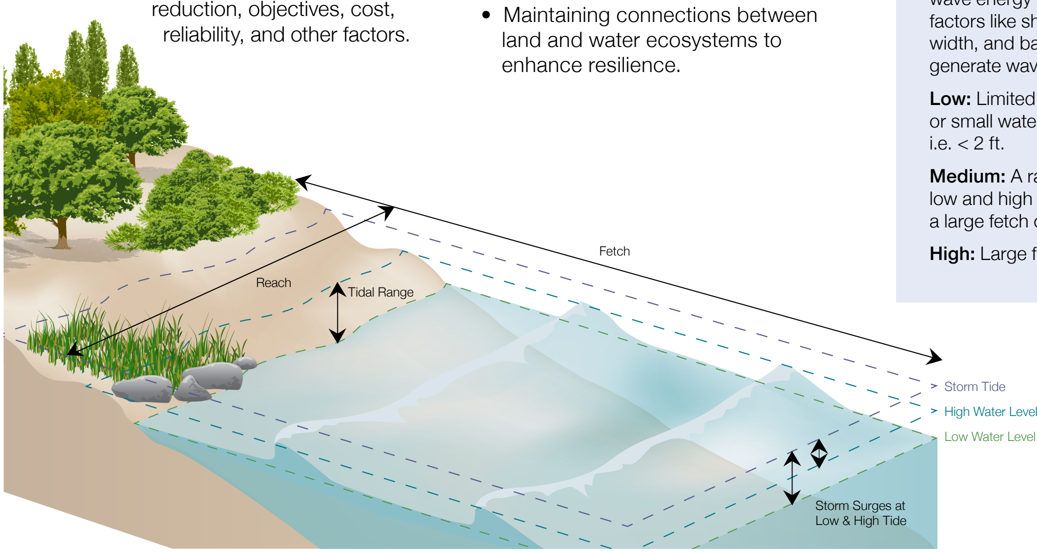
STORM SURGE: The resulting temporary rise in sea level due to the action of wind stress on the water surface and low atmospheric pressure created during storms which can cause coastal flooding. Surge is the difference from expected tide level. Storm tide is the total water level.

WAVE ENERGY: Wave energy is related to wave height and describes the force a wave is likely to have on a shoreline. Different environments will have lower or higher wave energy depending on environmental factors like shore orientation, wind, channel width, and bathymetry. Boat wakes can also generate waves.

Low: Limited fetch in a sheltered, shallow or small water body (estuary, river, bay) i.e. < 2 ft.

Medium: A range that combines elements of low and high energy (e.g., shallow water with a large fetch or partially sheltered) i.e. 2 - 5 ft.

High: Large fetch, deep water (open ocean).



2

HOW GREEN OR GRAY SHOULD YOUR SHORELINE SOLUTION BE?

GREEN - SOFTER TECHNIQUES

Small Waves | Small Fetch | Gentle Slope | Sheltered Coast

LIVING SHORELINE

VEGETATION ONLY

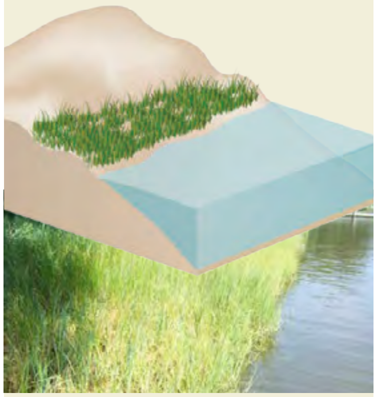


Photo Credit: Maryland Department of Natural Resources - Shoreline Conservation Service

Roots hold soil in place to reduce erosion. Provides a buffer to upland areas and breaks small waves.

Suitable For

Low wave energy environments.

Material Options

- Native plants*

Benefits

- Dissipates wave energy
- Slows inland water transfer
- Increases natural storm water infiltration
- Provides habitat and ecosystem services
- Minimal impact to natural community and ecosystem processes
- Maintains aquatic/terrestrial interface and connectivity
- Flood water storage

Disadvantages

- No storm surge reduction ability
- No high water protection
- Appropriate in limited situations
- Uncertainty of successful vegetation growth and competition with invasive

Initial Construction: ●
Operations & Maintenance: ●

EDGING

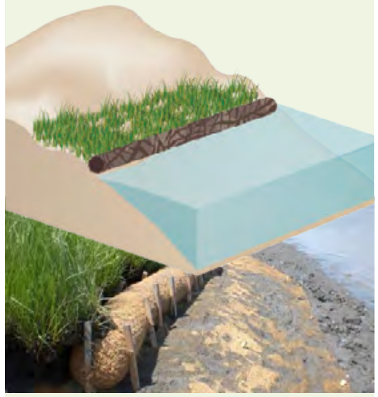


Photo Credit: Partnership for Delaware Estuary

Structure to hold the toe of existing or vegetated slope in place. Protects against shoreline erosion.

Suitable For

Most areas except high wave energy environments.

Vegetation* Base with Material Options

(low wave only, temporary)

- "Snow" fencing
- Erosion control blankets
- Geotextile tubes
- Living reef (oyster/mussel)
- Rock gabion baskets

Benefits

- Dissipates wave energy
- Slows inland water transfer
- Provides habitat and ecosystem services
- Increases natural storm water infiltration
- Toe protection helps prevent wetland edge loss

Disadvantages

- No high water protection
- Uncertainty of successful vegetation growth and competition with invasive

Initial Construction: ●●
Operations & Maintenance: ●

SILLS

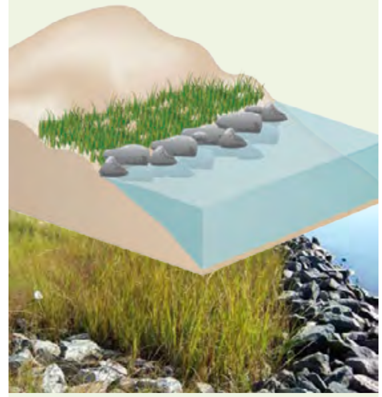


Photo Credit: Maryland Department of Natural Resources - Shoreline Conservation Service

Parallel to existing or vegetated shoreline, reduces wave energy and prevents erosion. A gapped approach would allow habitat connectivity, greater tidal exchange, and better waterfront access.

Suitable For

Most areas except high wave energy environments.

Vegetation* Base with Material Options

- Stone
- Sand breakwaters
- Living reef (oyster/mussel)
- Rock gabion baskets

Benefits

- Provides habitat and ecosystem services
- Dissipates wave energy
- Slows inland water transfer
- Provides habitat and ecosystem services
- Increases natural storm water infiltration
- Toe protection helps prevent wetland edge loss

Disadvantages

- Require more land area
- No high water protection
- Uncertainty of successful vegetation growth and competition with invasive

Initial Construction: ●●
Operations & Maintenance: ●

CONTINUED ON NEXT PAGE

* Native plants and materials must be appropriate for current salinity and site conditions.

Initial Construction: ● = up to $1000 per linear foot, ●● = $1001 - $2000 per linear foot, ●●● = $2001 - $5000 per linear foot, ●●●● = $5001 - $10,000 per linear foot
Operations and Maintenance (yearly for a 50 year project life): ● = up to $100 per linear foot, ●● = $101 - $500 per linear foot, ●●● = over $500 per linear foot

HOW GREEN OR GRAY SHOULD YOUR SHORELINE SOLUTION BE?

GREEN - SOFTER TECHNIQUES

Small Waves | Small Fetch | Gentle Slope | Sheltered Coast

LIVING SHORELINE

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BEACH NOURISHMENT ONLY

Photo Credit: USACE New York District Public Affairs

Large volume of sand added from outside source to an eroding beach. Widens the beach and moves the shoreline seaward.

Suitable For

Low-lying oceanfront areas with existing sources of sand and sediment.

Material Options

- Sand

Benefits

- Expands usable beach area
- Lower environmental impact than hard structures
- Flexible strategy
- Redesigned with relative ease
- Provides habitat and ecosystem services

Disadvantages

- Requires continual sand resources for renourishment
- No high water protection
- Appropriate in limited situations
- Possible impacts to regional sediment transport

Initial Construction: ●●●
Operations & Maintenance: ●●

BEACH NOURISHMENT & VEGETATION ON DUNE

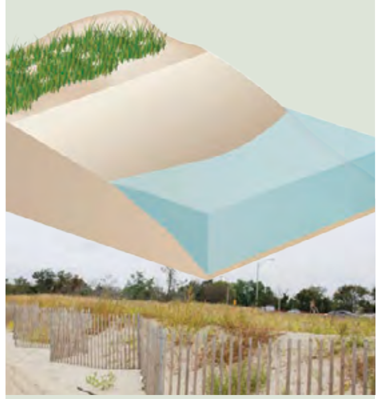

Photo Credit: USACE New York District Public Affairs

Helps anchor sand and provide a buffer to protect inland area from waves, flooding and erosion.

Suitable For

Low-lying oceanfront areas with existing sources of sand and sediment.

Material Options

Sand with vegetation
Can also strengthen dunes with:

- Geotextile tubes
- Rocky core

Benefits

- Expands usable beach area
- Lower environmental impact
- Flexible strategy
- Redesigned with relative ease
- Vegetation strengthens dunes and increases their resilience to storm events
- Provides habitat and ecosystem services

Disadvantages

- Requires continual sand resources for renourishment
- No high water protection
- Appropriate in limited situations
- Possible impacts to regional sediment transport

Initial Construction: ●●●
Operations & Maintenance: ●●

Initial Construction: ● = up to $1000 per linear foot, ●● = $1001 - $2000 per linear foot, ●●● = $2001 - $5000 per linear foot, ●●●● = $5001 - $10,000 per linear foot 4
Operations and Maintenance (yearly for a 50 year project life): ● = up to $100 per linear foot, ●● = $101 - $500 per linear foot, ●●● = over $500 per linear foot

HOW GREEN OR GRAY SHOULD YOUR SHORELINE SOLUTION BE?

GRAY - HARDER TECHNIQUES

Large Waves | Large Fetch | Steep Slope | Open Coast

COASTAL STRUCTURE

BREAKWATER

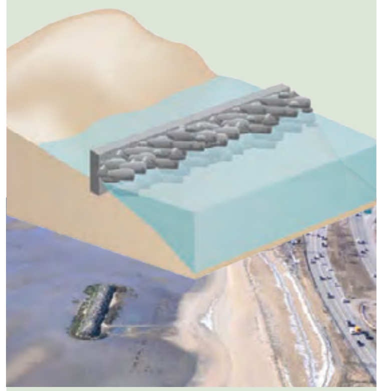

Photo Credit: USACE New York District Public Affairs

Offshore structures intended to break waves, reducing the force of wave action and encourages sediment accretion. Can be floating or fixed to the ocean floor, attached to shore or not, and continuous or segmented. A gapped approach would allow habitat connectivity, greater tidal exchange, and better waterfront access.

Suitable For

Most areas except high wave energy environments often in conjunction with marinas.

Material Options

- Grout-filled fabric bags
- Armorstone
- Pre-cast concrete blocks
- Living reef (oyster/mussel) if low wave environment
- Wood
- Rock†

Benefits

- Reduces wave force and height
- Stabilizes wetland
- Can function like reef
- Economical in shallow areas
- Limited storm surge flood level reduction

Disadvantages

- Expensive in deep water
- Can reduce water circulation (minimized if floating breakwater is applied)
- Can create navigational hazard
- Require more land area
- Uncertainty of successful vegetation growth and competition with invasive
- No high water protection
- Can reduce water circulation
- Can create navigation hazard

GROIN

Photo Credit: USACE New York District Public Affairs

Perpendicular, projecting from shoreline. Intercept water flow and sand moving parallel to the shoreline to prevent beach erosion and break waves. Retain sand placed on beach.

Suitable For

Coordination with beach nourishment.

Material Options

- Concrete/stone rubble†
- Timber
- Metal sheet piles

Benefits

- Protection from wave forces
- Methods and materials are adaptable
- Can be combined with beach nourishment projects to extend their life

Disadvantages

- Erosion of adjacent sites
- Can be detrimental to shoreline ecosystem (e.g. replaces native substrate with rock and reduces natural habitat availability)
- No high water protection

† Rock/stone needs to be appropriately sized for site specific wave energy.

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GRAY CAN BE GREENER: e.g., 'Living Breakwater' using oysters to colonize rocks or 'Greenwall/Biowall' using vegetation, alternative forms and materials

Breakwater — Initial Construction: ●●●● Operations & Maintenance: ●●●

Groin — Initial Construction: ●●● Operations & Maintenance: ●●

Initial Construction: ● = up to $1000 per linear foot, ●● = $1001 - $2000 per linear foot, ●●● = $2001 - $5000 per linear foot, ●●●● = $5001 - $10,000 per linear foot
Operations and Maintenance (yearly for a 50 year project life): ● = up to $100 per linear foot, ●● = $101 - $500 per linear foot, ●●● = over $500 per linear foot

HOW GREEN OR GRAY SHOULD YOUR SHORELINE SOLUTION BE?

GRAY - HARDER TECHNIQUES

Large Waves | Large Fetch | Steep Slope | Open Coast

COASTAL STRUCTURE

CONTINUED FROM LAST PAGE

REVETMENT

Photo Credit: Maryland Department of Natural Resources - Shoreline Conservation Service

Lays over the slope of a shoreline. Protects slope from erosion and waves.

Suitable For

Sites with pre-existing hardened shoreline structures.

Material Options

- Stone rubble‡
- Concrete blocks
- Cast concrete slabs
- Sand/concrete filled bags
- Rock-filled gabion basket

Benefits

- Mitigates wave action
- Little maintenance
- Indefinite lifespan
- Minimizes adjacent site impact

Disadvantages

- No major flood protection
- Require more land area
- Loss of intertidal habitat
- Erosion of adjacent unreinforced sites
- Require more land area
- No high water protection
- Prevents upland from being a sediment source to the system

‡ Rock/stone needs to be appropriately sized for site specific wave energy.

BULKHEAD

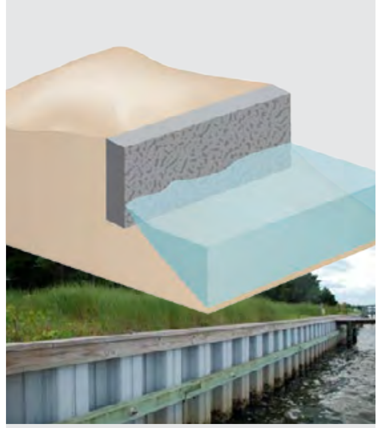


Photo Credit: North Carolina Department of Environment and Natural Resources

Parallel to the shoreline, vertical retaining wall. Intended to hold soil in place and allow for a stable shoreline.

Suitable For

High energy settings and sites with pre-existing hardened shoreline structures. Accommodates working water fronts (eg: docking for ships and ferries).

Material Options

- Steel sheet piles
- Timber
- Concrete
- Composite carbon fibers
- Gabions

Benefits

- Moderates wave action
- Manages tide level fluctuation
- Long lifespan
- Simple repair

Disadvantages

- No major flood protection
- Erosion of seaward seabed
- Erosion of adjacent unreinforced sites
- Loss of intertidal habitat
- May be damaged from overtopping oceanfront storm waves
- Prevents upland from being a sediment source to the system
- Induces wave reflection

SEAWALL

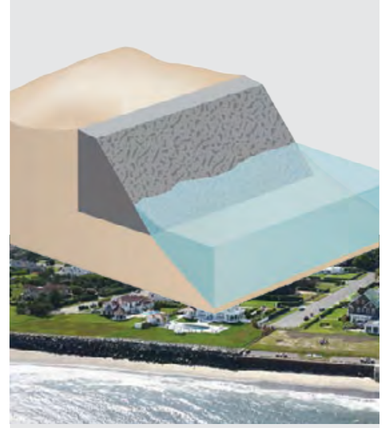


Photo Credit: USACE New York District Public Affairs

Parallel to shoreline, vertical or sloped wall. Soil on one side of wall is the same elevation as water on the other. Absorbs and limits impacts of large waves and directs flow away from land.

Suitable For

Areas highly vulnerable to storm surge and wave forces.

Material Options

- Stone
- Rock
- Concrete
- Steel/vinyl sheets
- Steel sheet piles

Benefits

- Prevents storm surge flooding
- Resists strong wave forces
- Shoreline stabilization behind structure
- Low maintenance costs
- Less space intensive horizontally than other techniques (e.g. vegetation only)

Disadvantages

- Erosion of seaward seabed
- Disrupt sediment transport leading to beach erosion
- Higher up-front costs
- Visually obstructive
- Loss of intertidal zone
- Prevents upland from being a sediment source to the system
- May be damaged from overtopping oceanfront storm waves

GRAY CAN BE GREENER: e.g., 'Living Breakwater' using oysters to colonize rocks or 'Greenwall/Biowall' using vegetation, alternative forms and materials

	Revetment	Bulkhead	Seawall
Initial Construction:	●●●●	●●●	●●●●
Operations & Maintenance:	●●	●●	●●●

Initial Construction: ● = up to $1000 per linear foot, ●● = $1001 - $2000 per linear foot, ●●● = $2001 - $5000 per linear foot, ●●●● = $5001 - $10,000 per linear foot

Operations and Maintenance (yearly for a 50 year project life): ● = up to $100 per linear foot, ●● = $101 - $500 per linear foot, ●●● = over $500 per linear foot

Is a Living Shoreline a Good Fit for What I Need?

Living Shorelines achieve multiple goals such as:

- Stabilizing the shoreline and reducing current rates of shoreline erosion and storm damage
- Providing ecosystem services, such as habitat for fish and other aquatic species and increasing flood storage capacity
- Maintaining connections between land and water ecosystems to enhance resilience

Site-specific conditions will influence your choice of shoreline protection technique (ex: wave energy level, fetch lengths, rate and pattern of erosion, etc). Here are some additional factors to keep in mind as you consider Living Shorelines.

WHAT ARE THE BENEFITS?

- Erosion control and shore stabilization.
- Restored and enhanced habitat which supports fish and wildlife populations.
- Increased property values.
- Enhanced community enjoyment.
- Opportunities for education.
- Improved public access to waterfront through recreational activities such as fishing, boating and birding. Can be used to satisfy zoning and permitting requirement for waterfront development projects.
- Complemented natural shoreline dynamics & movement; increased resilience and absorption of wave energy, storm surge and floodwaters; and an adaptive tool for preparation of sea level rise.
- Improved water quality from settling or trapping sediment (e.g. once established, a marsh can filter surface water runoff or oysters can provide coastal water filtration).

WHAT ARE SOME CHALLENGES?

- Uncertainty in risk because of lack of experience of techniques.
- Public funds are often tied to government permit compliance.
- Permitting processes can be lengthy and challenging. The existing regulatory process is centered on traditional "gray" or "hard" techniques. Regulators and project sponsors alike are learning how to design living shorelines projects. Talk with someone about your state's permitting process or to hear about their experiences.
- It takes time to develop and test new shoreline protection methods.
- There may be land ownership constraints. Consider where federal and state jurisdiction for the water body starts and ends.
- In urban environments, there is limited land (bulkheads may seem like the only option), a variety of upland uses (industrial past use may have left legacy contaminants) and high velocity waters.
- The overall sediment system needs to be taken into account to protect neighboring properties from experiencing starved down drift shorelines or other consequences as a result of a project.
- Lack of public awareness of performance and benefits of living shorelines.
- Not all techniques have the same level of performance or success monitoring. Less practiced techniques may require more monitoring.

WHAT INFLUENCES COST?

- The materials chosen for the project influence cost.
- Including green techniques can be cheaper than traditional gray techniques.
- Sometimes it's possible to install the project yourself, other times you will need help from a professional.
- Long term maintenance is required as any landscape project (e.g. replanting may be needed after a storm).

HOW TO FIND OUT MORE

If you have a Living Shorelines permitting question, contact your state's office of Environmental Protection, Conservation or Natural Resources, your coastal zone manager such as your state's Department of State, as well as your local U.S. Army Corps of Engineers (USACE) district office.

If you would like science or engineering advice, or to talk to people who have experience studying or constructing living shorelines, reach out to some of the following: your local universities, your City's Department of Planning and Department of Parks, Sea Grant Chapter, Littoral Society, The Nature Conservancy, The Trust for Public Land, The Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), USACE, engineering firms and other organizations that focus on your local waterfront.

These and other websites are good references to learn more about Living Shorelines:

SAGE
www.SAGEcoast.org

NOAA Restoration
www.habitat.noaa.gov/livingshorelines

USACE Engineer Research Development Center, Engineering with Nature
el.erdc.usace.army.mil/ewn

USACE North Atlantic Division, National Planning Center of Expertise for Coastal Storm Damage Reduction
www.nad.usace.army.mil/About/NationalCentersofExpertise/CoastalStormDamageReduction(Planning).aspx

Virginia Institute of Marine Science (VIMS) Center for Coastal Resources Management
ccrm.vims.edu/livingshorelines/index.html

Coasts, Oceans, Ports & Rivers Institute (COPRI)
www.mycopri.org/livingshorelines

The Nature Conservancy
www.nature.org/ourinitiatives/habitats/oceanscoasts/howwework/helping-oceans-adapt-to-climate-change.xml

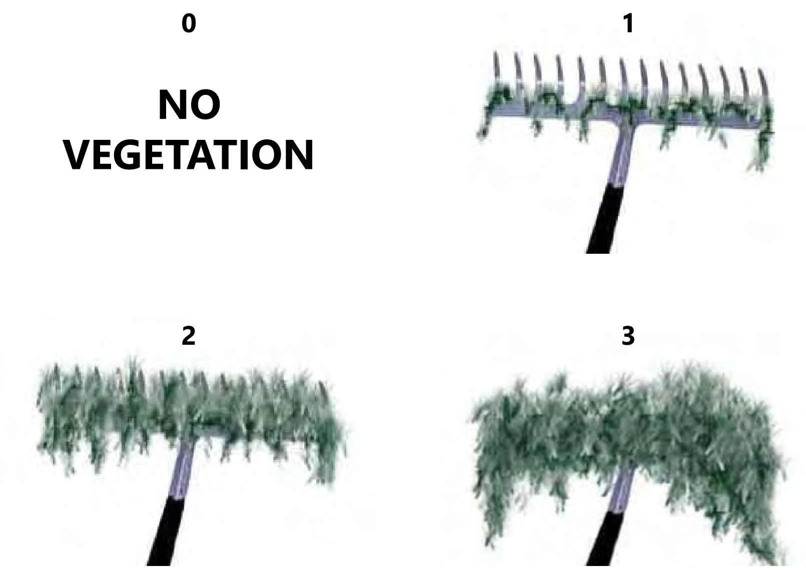
US Army Corps of Engineers®

Developed with support and funding from SAGE, NOAA and USACE; February 2015

APPENDIX B

LAKE AQUATIC PLANT SPECIES DETAILS

Figure B.1
Rake Fullness Ratings



Source: Wisconsin Department of Natural Resources and SEWRPC

SOURCES OF INFORMATION:

Borman, S., Korth, R., & Temte, J. (2014). Through the Looking Glass: A Field Guide to Aquatic Plants, Second Edition. Stevens Point, WI, USA: Wisconsin Lakes Partnership.

Robert W. Freckman Herbarium: wisplants.uwsp.edu

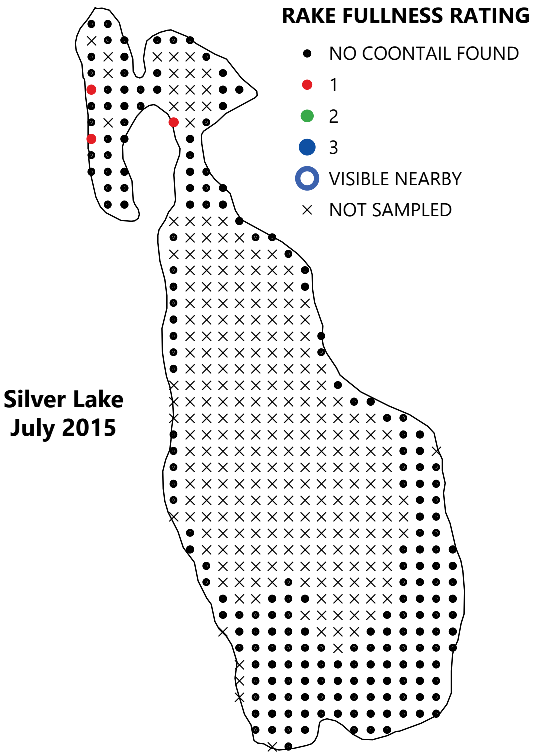
Skawinski, P. M. (2014). Aquatic Plants of the Upper Midwest: A Photographic Field Guide to Our Underwater Forests, Second Edition. Wausau, Wisconsin, USA: Self-Published.

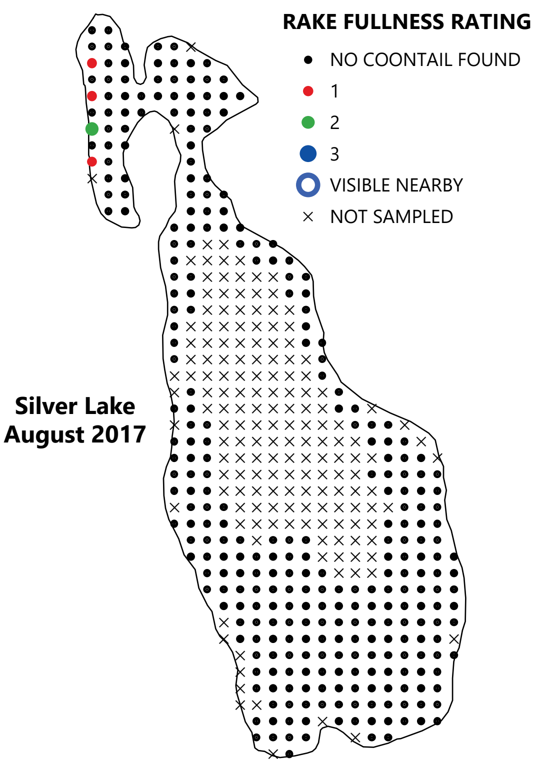
University of Michigan Herbarium: michiganflora.net/home.aspx

UW-System WisFlora. 2016. wisflora.herbarium.wisc.edu/index.php

Native

COONTAIL
Ceratophyllum demersum





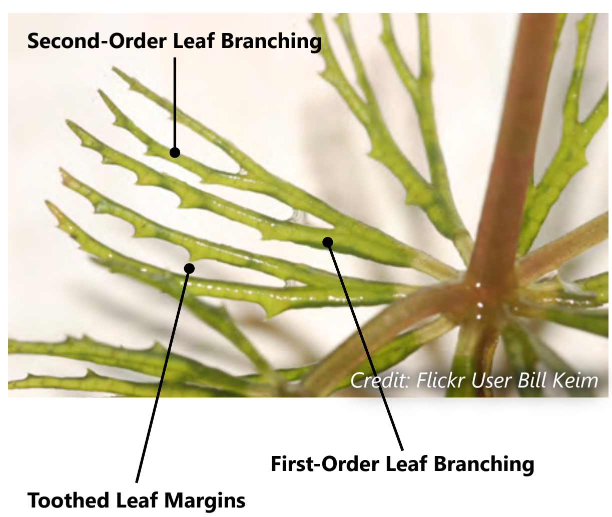
Identifying Features

- Often bushy near tips of branches, giving the raccoon tail-like appearance (“coontail”)
- Whorled leaves with one to two orders of
- branching and small teeth on their margins
- Flowers (rare) small and produced in leaf axils

Coontail is similar to spiny hornwort (C. echinatum) and muskgrass (Chara spp.), but spiny hornwort has some leaves with three to four orders of branching, and coontail does not produce the distinct garlic-like odor of muskgrass when crushed

Ecology

- Common in lakes and streams, both shallow and deep
- Tolerates poor water quality (high nutrients, chemical pollutants) and disturbed conditions
- Stores energy as oils, which can produce slicks on the water surface when plants decay
- Anchors to the substrate with pale, modified leaves rather than roots
- Eaten by waterfowl, turtles, carp, and muskrat

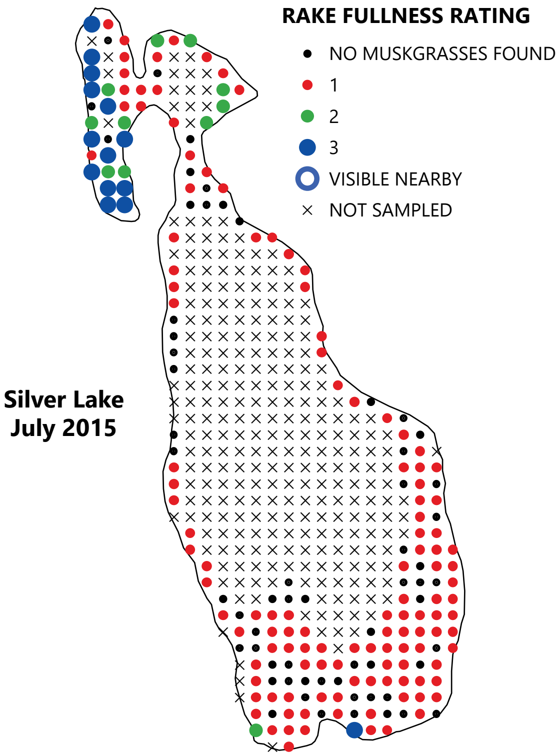


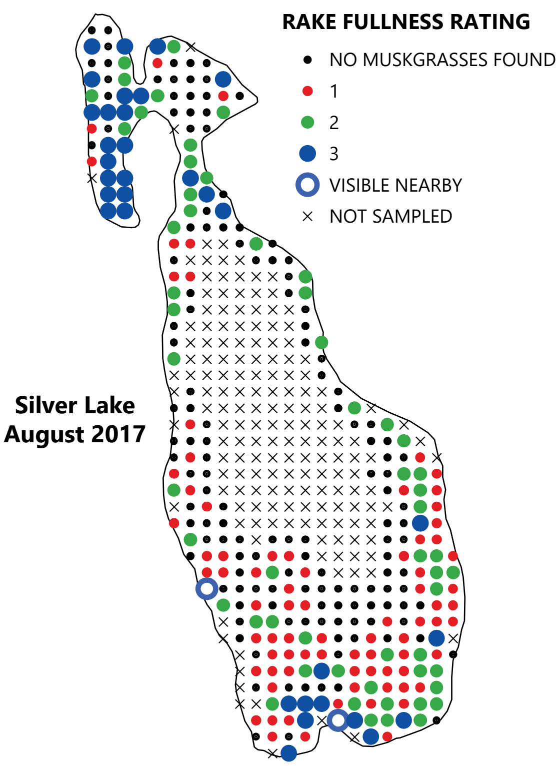
Native

MUSKGRASSES

Chara spp.

Credit: Flickr User Jeremy Halls





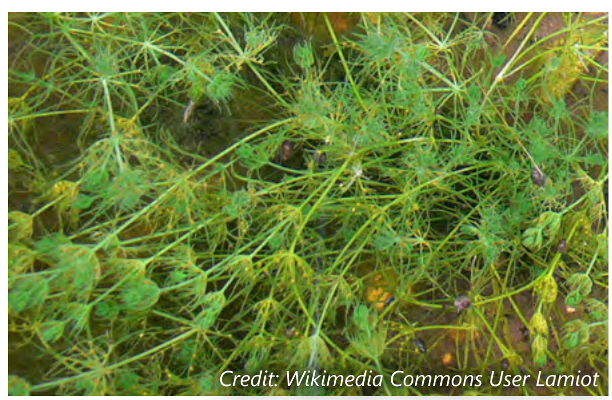
Identifying Features

- Leaf-like, ridged side branches develop in whorls of six or more
- Often encrusted with calcium carbonate, which appears white upon drying (see photo below)
- Yellow reproductive structures develop along the whorled branches in summer
- Emits a garlic-like odor when crushed

Stoneworts (*Nitella* spp.) are similar large algae, but their branches are smooth rather than ridged and more delicate

Ecology

- Found in shallow or deep water over marl or silt, often growing in large colonies in hard water
- Overwinters as rhizoids (cells modified to act as roots) or fragments
- Stabilizes bottom sediments, often among the first species to colonize open areas
- Food for waterfowl and excellent habitat for small fish



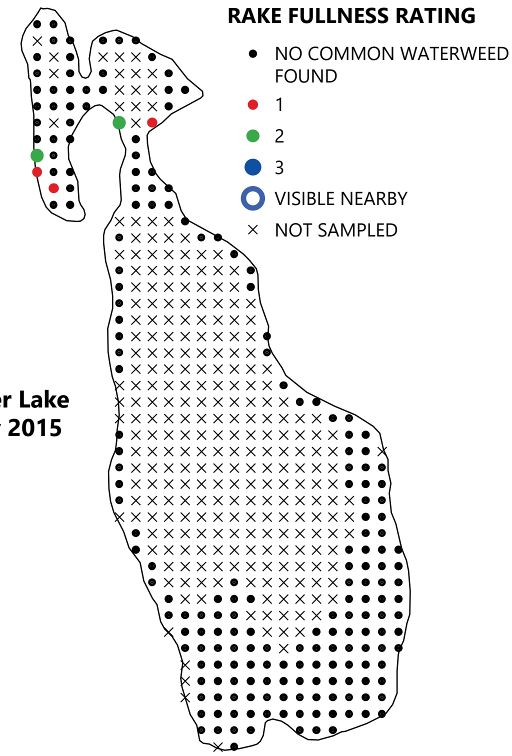
Credit: Wikimedia Commons User Lamiot

Native

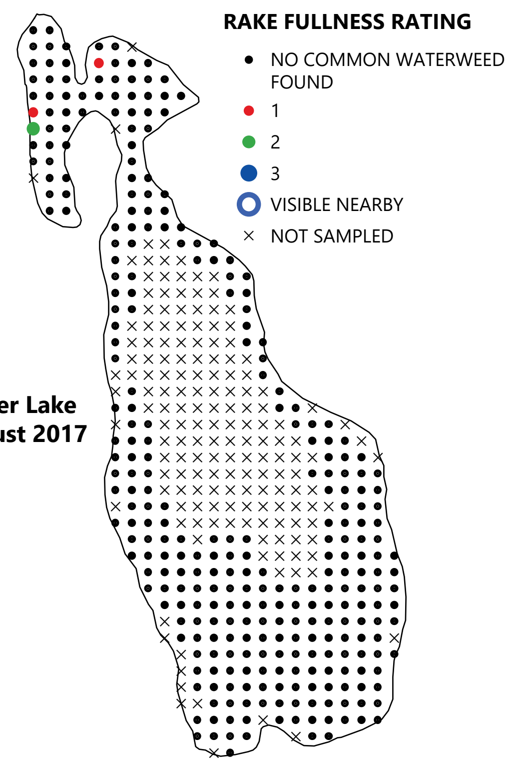
COMMON WATERWEED

Elodea canadensis

Credit: Flickr User Corey Raimond



Silver Lake July 2015



Silver Lake August 2017

Identifying Features

- Slender stems, occasionally rooting
- Leaves lance-shaped, in whorls of three (rarely two or four), 6.0 to 17 mm long and averaging 2.0 mm wide
- When present, tiny male and female flowers on separate plants (females more common), raised to the surface on thread-like stalks

Ecology

- Found in lakes and streams over soft substrates tolerating pollution, eutrophication and disturbed conditions
- Often overwinters under the ice
- Produces seeds only rarely, spreading primarily via stem fragments
- Provides food for muskrat and waterfowl
- Habitat for fish or invertebrates, although dense stands can obstruct fish movement

Credit: Wikimedia Commons User Christian Fischer

Nonnative/ Exotic

PURPLE LOOSESTRIFE

Lythrum salicaria

Credit: Wikimedia Commons User Liz West

Identifying Features

- Terrestrial or semi-aquatic, emergent forb
- Stems often angled with four, five, or more sides, and growing one to two meters tall
- Flowers deep pink or purple, six-parted, 12 to 25 mm wide, and in groups
- Leaves lance-like, four to 11 cm long and either opposite or in whorls of three

Purple loosestrife, if small, is similar to winged loosestrife (Lythrum alatum), but winged loosestrife differs in having leaves generally smaller (<5.0 cm long), leaves mostly alternate (only lower leaves opposite), and flowers mostly held singly in the leaf axils rather than in pairs or groups

Ecology/Control

- Found in shallows, along shores, and in wet to moist meadows and prairies
- Invasive and continues to escape from ornamental plantings
- Galerucella beetles have been successfully used to control purple loosestrife. Plants may also be dug or pulled when small, but they subsequently should be placed in a landfill or burned. Several herbicides are effective, but application near water may require permits and aquatic-use formulas

Credit: Wikimedia Commons User Liz West

Credit: Paul Skawinski

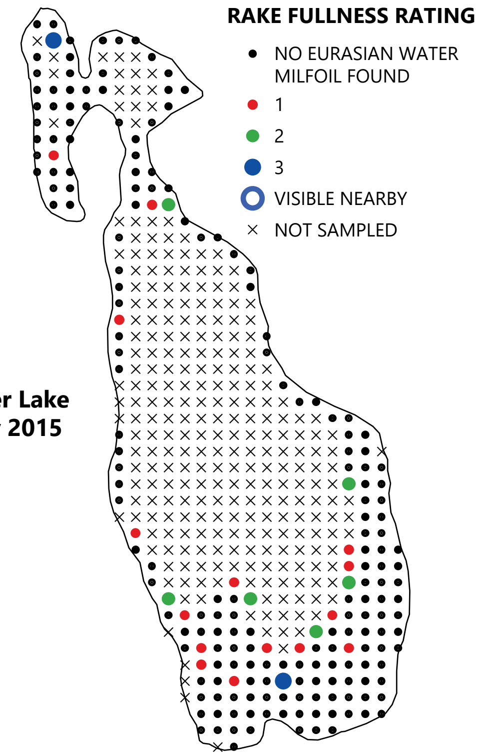
Credit: Consortium of Wisconsin Herbaria

Nonnative/ Exotic

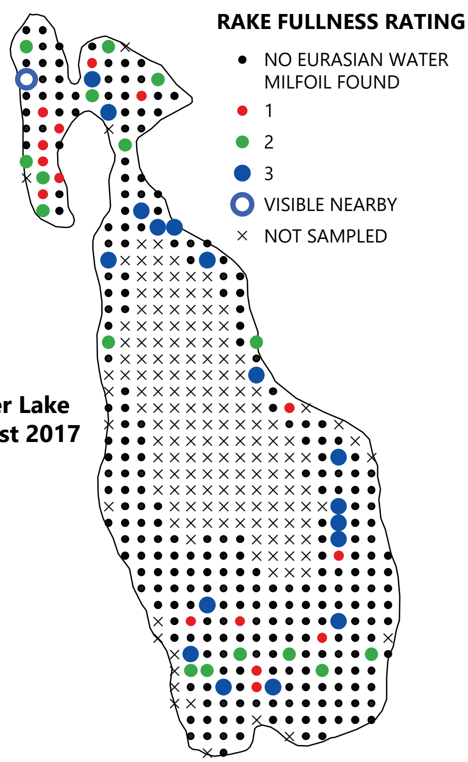
EURASIAN WATERMILFOIL

Myriophyllum spicatum

Credit: Paul Skawinski



Silver Lake July 2015



Silver Lake August 2017

Identifying Features

- Stems spaghetti-like, often pinkish, growing long with many branches near the water surface
- Leaves with 12 to 21 pairs of leaflets
- Produces no winter buds (turions)

Eurasian watermilfoil is similar to northern watermilfoil (*M. sibiricum*). However, northern watermilfoil has five to 12 pairs of leaflets per leaf and stouter white or pale brown stems

Ecology

- Hybridizes with northern (native) watermilfoil, resulting in plants with intermediate characteristics
- Invasive, growing quickly, forming canopies, and getting a head-start in spring due to an ability to grow in cool water
- Grows from root stalks and stem fragments in both lakes and streams, shallow and deep; tolerates disturbed conditions
- Provides some forage to waterfowl, but supports fewer aquatic invertebrates than mixed stands of aquatic vegetation

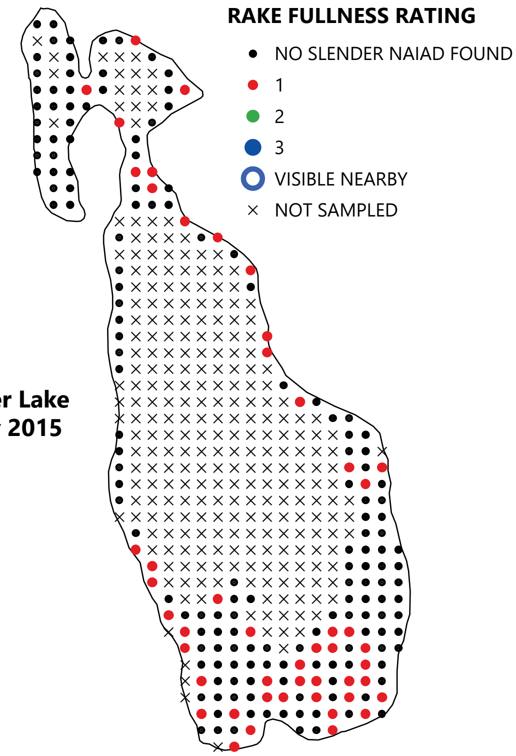
Credit: Paul Skawinski

Native

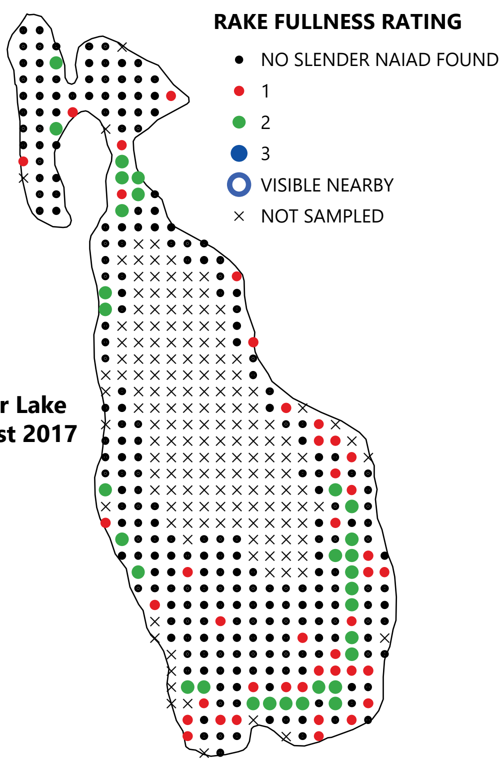
BUSHY PONDWEED OR SLENDER NAIAD

Najas flexilis

Credit: Flickr User Tab Tannery



Silver Lake July 2015



Silver Lake August 2017

Identifying Features

- Leaves narrow (0.4 to 1.0 mm) and pointed with broader bases where they attach to the stem and finely serrated margins
- Flowers, when present, tiny and located in leaf axils
- Variable size and spacing of leaves, as well as compactness of plant, depending on growing conditions

Two other Najas occur in southeastern Wisconsin. Southern naiad (N. guadalupensis) has wider leaves (to 2.0 mm). Spiny naiad (N. marina) has coarsely toothed leaves with spines along the midvein below

Ecology

- In lakes and streams, shallow and deep, often in association with wild celery
- One of the most important forages of waterfowl
- An annual plant that completely dies back in fall and regenerates from seeds each spring; also spreading by stem fragments during the growing season

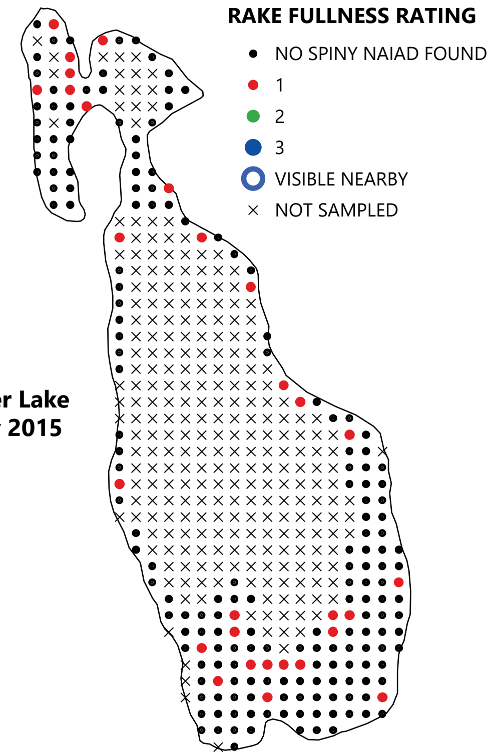
Credit: Wikimedia Commons User Robert H. Mohlenbrock

Nonnative/ Exotic

SPINY NAIAD

Najas marina


Credit: Wikimedia Commons User Pascale Guinchard



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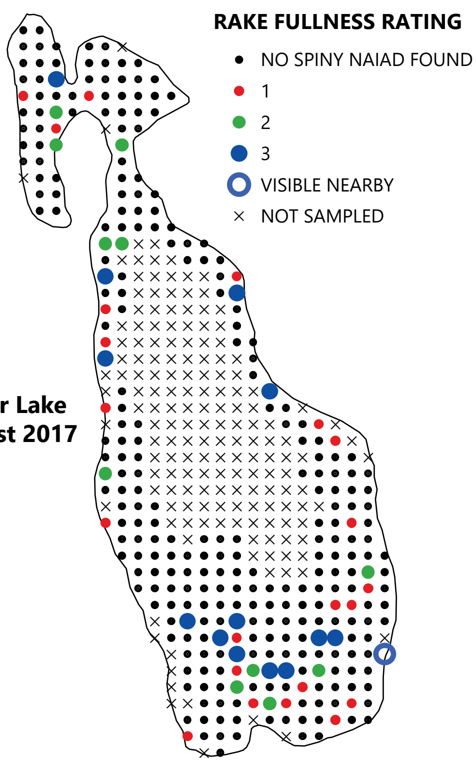


Silver Lake August 2017

Identifying Features

- Stems stiff and spiny, often branching many times
- Leaves stiff, 1.0 to 4.0 mm thick, with coarse teeth along the margins and midvein on the underside

Spiny naiad is quite distinct from other naiads due to its larger, coarsely toothed leaves and the irregularly pitted surface of its fruits. Spiny naiad is presumably introduced in Wisconsin, but it is considered native in other states, including Minnesota

Ecology

- Alkaline lakes, water quality ranging from good to poor
- An annual, regenerating from seed each year
- Occurs as separate male and female plants
- Capable of growing aggressively

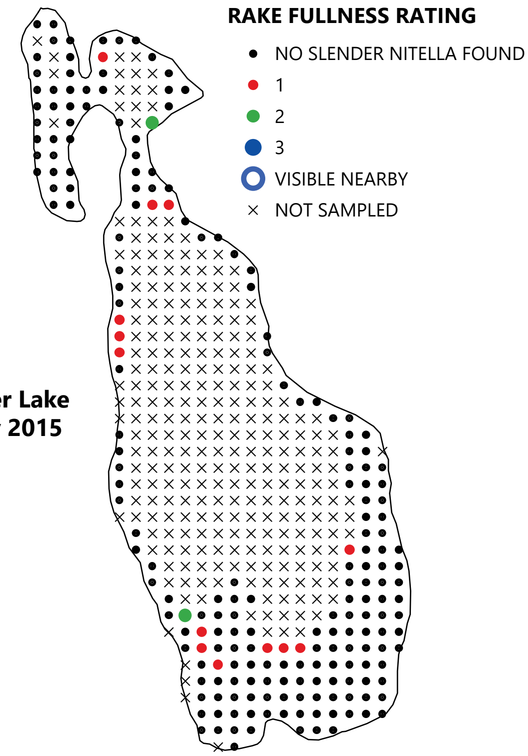

Credit: Wikimedia Commons User Kristian Peters

Native

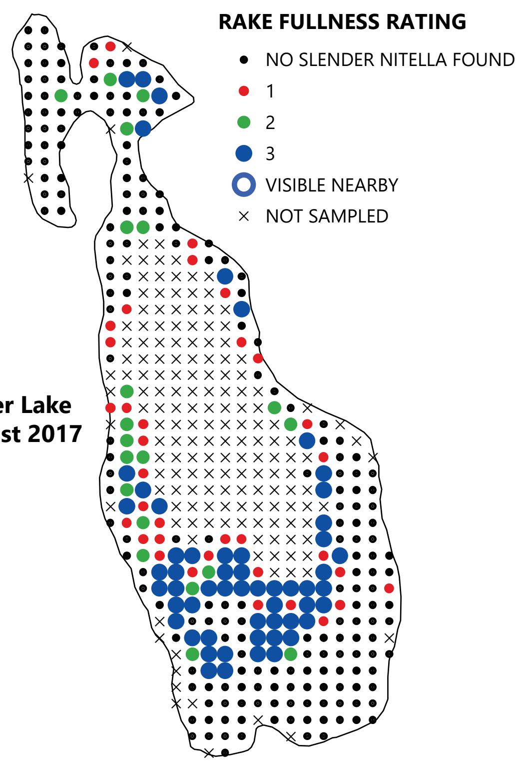
NITELLAS OR STONEWORTS

Nitella spp.

Credit: Wikimedia Commons User Show_ryu



Silver Lake July 2015



Silver Lake August 2017

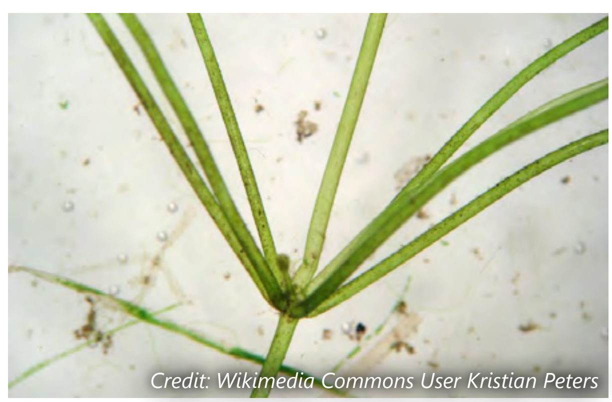
Identifying Features

- Stems and leaf-like side branches delicate and smooth, side branches arranged in whorls
- Bright green
- Reproductive structures developing along the whorled branches

Muskgrasses (*Chara* spp.) are large algae similar to stoneworts (*Nitella* spp.), but their branches are ridged and more robust than those of stoneworts. Another similar group of algae, *Nitellopsis* spp., differ from stoneworts by having whorls of side branches that are at more acute angles to the main stem and star-shaped, pale bulbils that, when present, are near where side branches meet the main stem

Ecology

- Often found in deep lake waters over soft sediments
- Overwinters as rhizoids (cells modified to act as roots) or fragments
- Habitat for invertebrates, creating foraging opportunities for fish
- Sometimes browsed upon by waterfowl



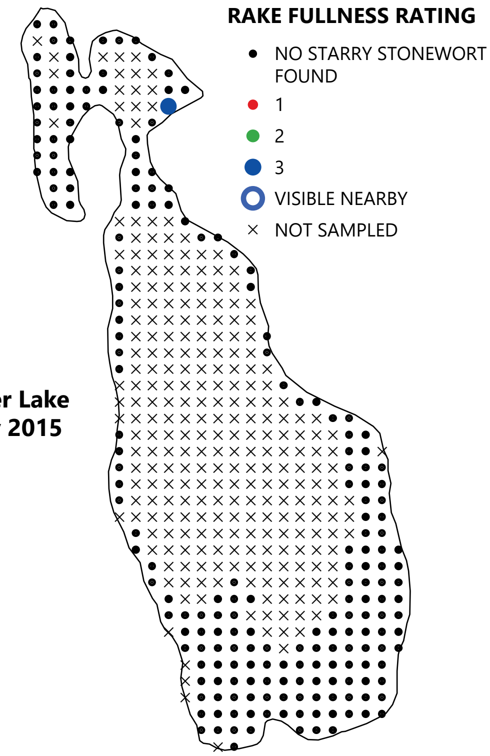
Credit: Wikimedia Commons User Kristian Peters

Nonnative/ Exotic

STARRY STONEWORT

Nitellopsis obtusa

Credit: Paul Skawinski



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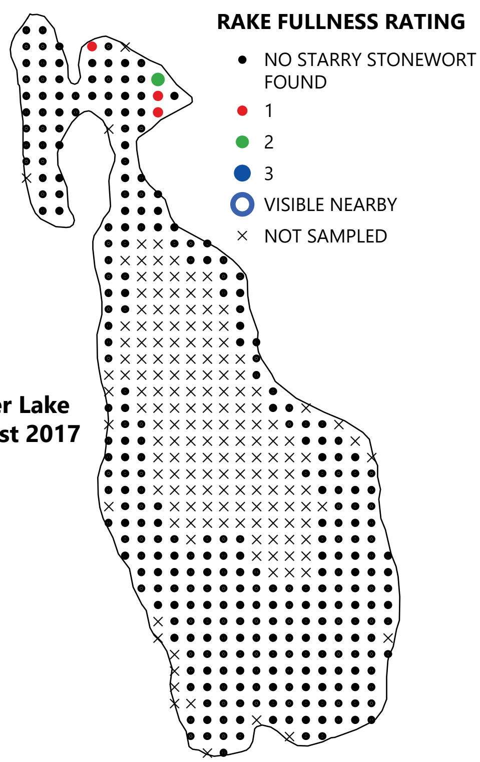


Silver Lake August 2017

Identifying Features

- Stems and leaf-like side branches smooth, side branches arranged in whorls of 4-6 branchlets
- More robust than other members of family
- Distinctive star-shaped bulbils

Ecology

- Alkaline lakes
- Typically annual, but can act like perennial during mild winters
- Occurs as separate male and female plants—currently, only male exists in U.S.
- Can form dense mats and grow over two meters tall

Credit: SEWRPC Staff

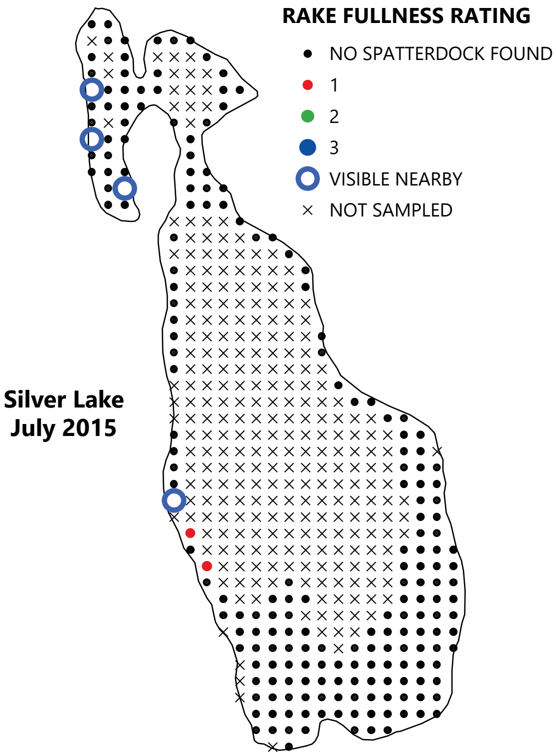
Credit: Paul Skawinski

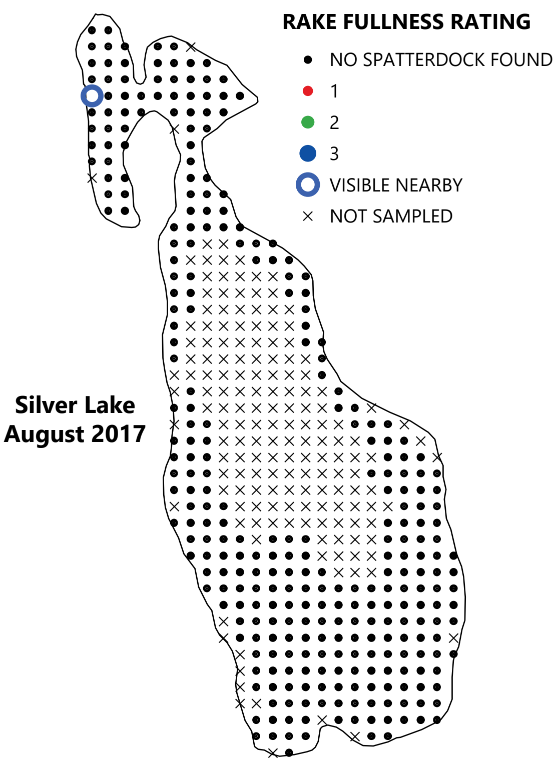
Native

SPATTERDOCK

Nuphar variegata

Credit: Wikimedia Commons User Cephas





Identifying Features

- Leaf stalks winged in cross-section
- Most leaves floating on the water surface, heart-shaped, and notched, with rounded lobes at the base
- Yellow flowers, 2.5 to 5.0 cm wide, often with maroon patches at the bases of the sepals (petal-like structures) when viewed from above

Unlike spatterdock, the similar yellow pond lily (Nuphar advena) has leaf stalks that are not winged in cross-section, leaves that more often emerge above the water surface, and leaf lobes that are more pointed. Spatterdock is superficially similar to water lilies (Nymphea spp.), but it has yellow versus white flowers and leaves somewhat heart-shaped versus round. American lotus (Nelumbo lutea) is also similar, but its leaves are round and un-notched, and its flowers are much larger

Ecology

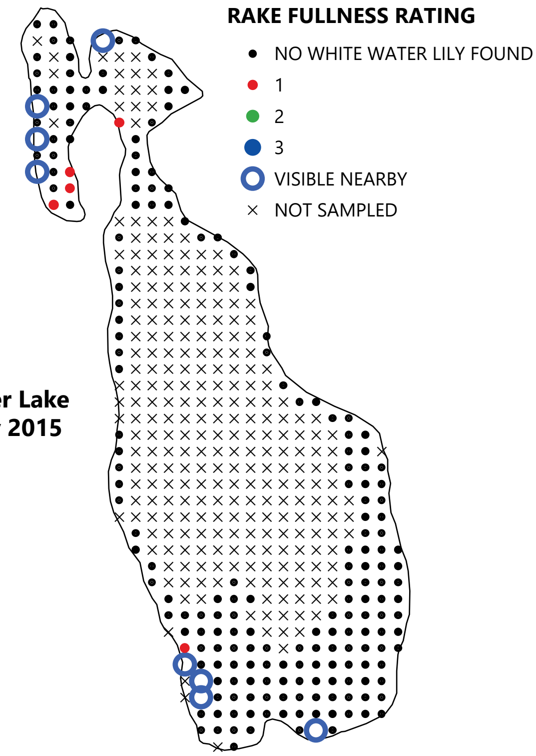
- In sun or shade and mucky sediments in shallows and along the margins of ponds, lakes, and slow-moving streams
- Overwinters as a perennial rhizome
- Flowers opening during the day, closing at night, and with the odor of fermented fruit
- Buffers shorelines
- Provides food for waterfowl (seeds), deer (leaves and flowers), and muskrat, beaver, and porcupine (rhizomes)
- Habitat for fish and aquatic invertebrates

Credit: Flickr User Jason Hollinger

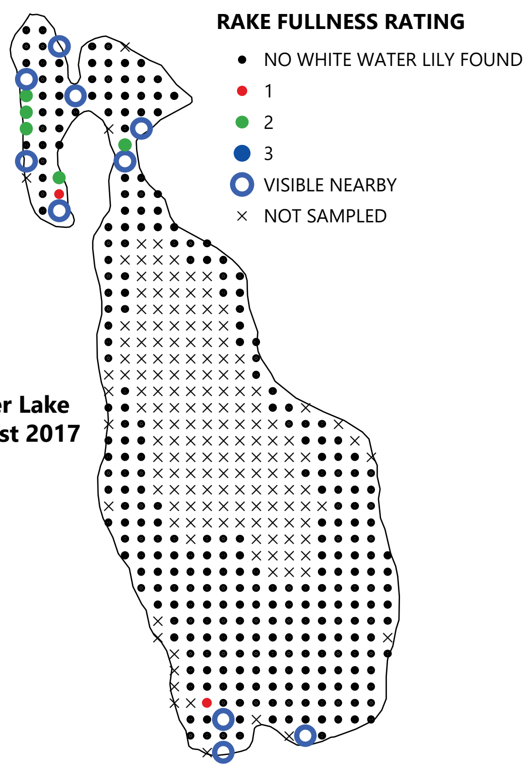
Native

WHITE WATER LILY
Nymphaea odorata

Credit: Flickr User Ryan Hodnett



Silver Lake July 2015



Silver Lake August 2017

Identifying Features

- Leaf stalks round in cross-section with four large air passages
- Floating leaves round (four to 12 inches wide under favorable conditions), *with a notch* from the outside to the center, and reddish-purple underneath
- Flowers white with a yellow center, three to nine inches wide

Pond lilies (*Nuphar* spp.) are superficially similar, but have yellow flowers and leaves somewhat heart-shaped. American lotus (*Nelumbo lutea*) is also similar, but its leaves are unnotched

Ecology

- Found in shallow waters over soft sediments
- Leaves and flowers emerge from rhizomes
- Flowers opening during the day, closing at night
- Seeds consumed by waterfowl, rhizomes consumed by mammals

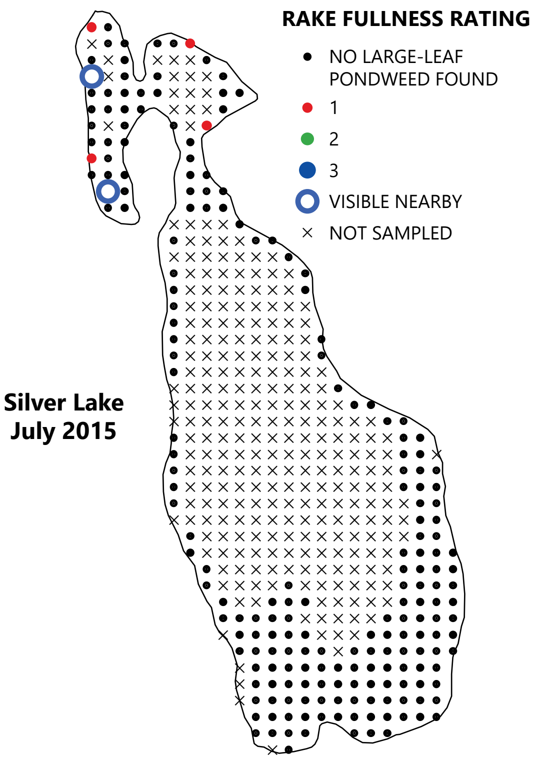
Credit: Wikimedia Commons User Kurt Stüber

Native

LARGE-LEAF PONDWEED

Potamogeton amplifolious

Credit: Wikimedia Commons User Edward G. Voss



Note: Large-leaf pondweed was not found or identified during the 2017 aquatic plant survey.

Identifying Features

- When produced, floating leaves 2-23 cm long *with 27-49 veins* and petiole longer than leaf blade
- Submersed leaves large and sickle-shaped, 4-7 cm wide, 8-20 cm long, *with more than 19 veins*, and folded upwards along the sides
- White stipules up to 12 cm long

Large-leaf pondweed may be distinguished from Illinois pondweed (*P. illinoensis*) by the greater number of veins on submersed and floating leaves.

Ecology

- Soft substrate, shallow and deep lakes
- Emerges in spring from buds formed along rhizomes
- Provides food for waterfowl, muskrat, beaver, and deer
- Provides habitat and/or food for fish, muskrat, waterfowl, and insects

Credit: Paul Skawinski

Native

FRIES’ PONDWEED
Potamogeton friesii

Credit: Flickr User Lliam Rooney

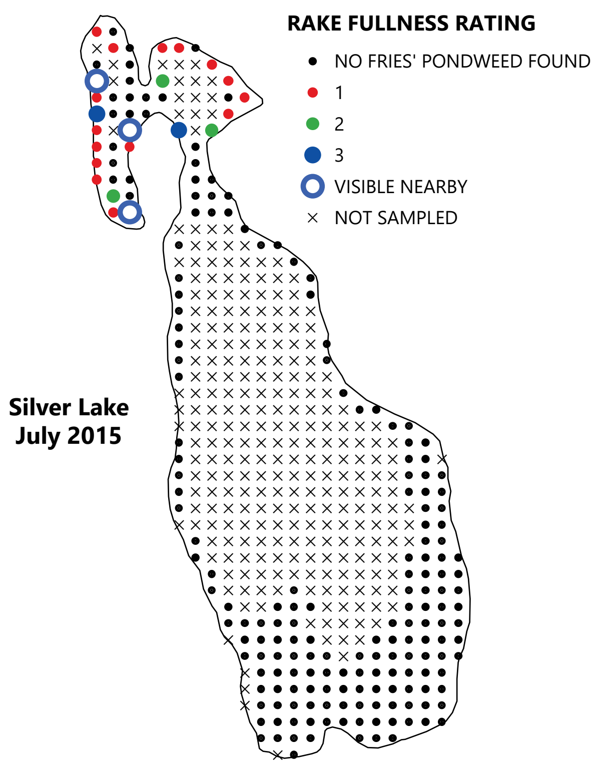
Identifying Features

- Slender stems slightly compressed
- Submerged leaves linear with no petiole, one row of lacunar cells on each side of midvein, and 5-7 veins
- Tip of leaf rounded with short bristle
- Winter bud fan shaped and in two planes, with inner leaves at 90 degrees from outer leaves

Fries’ pondweed is similar to other narrow-leaved pondweeds such as small pondweed (*P. pusillis*) and stiff pondweed (*P. strictifolius*) but other narrow pondweeds do not create a fan shaped winter bud

Ecology

- Common in calcareous lakes and slow-moving streams
- Overwinters largely as winter buds (turions)
- Provides food for waterfowl,
- Provides habitat for fish and aquatic invertebrates



Note: Fries’ pondweed was not found or identified during the 2017 aquatic plant survey.

Credit: Flickr User Brenton Butterfield

Native

VARIABLE PONDWEED

Potamogeton gramineus

Credit: Wikimedia Commons User Tristan He

Identifying Features

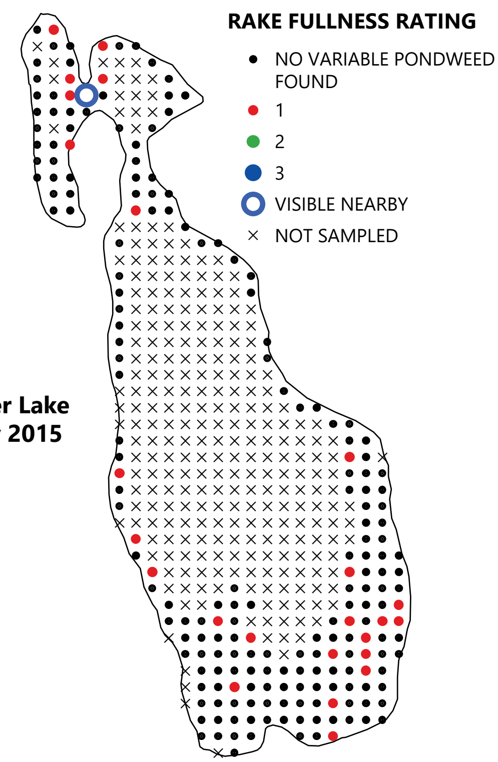
- Often heavily branched
- Submerged leaves narrow to lance-shaped, with three to seven veins, smooth margins, without stalks, but the blade tapering to the stem
- Floating leaves with 11 to 19 veins and a slender stalk that is usually longer than the blade
- Often covered with calcium carbonate in hard water

Variable pondweed is similar to Illinois pondweed (*P. illinoensis*), but Illinois pondweed has submerged leaves with nine to 19 veins

Ecology

- Shallow to deep water, often with muskgrass, wild celery, and/or slender naiad; requires more natural areas that receive little disturbance
- Overwinters as rhizomes or winter buds (turions)
- Provides food for waterfowl, muskrat, deer, and beaver
- Provides habitat for fish and aquatic invertebrates

Silver Lake
July 2015



Note: Variable pondweed was not found or identified during the 2017 aquatic plant survey.

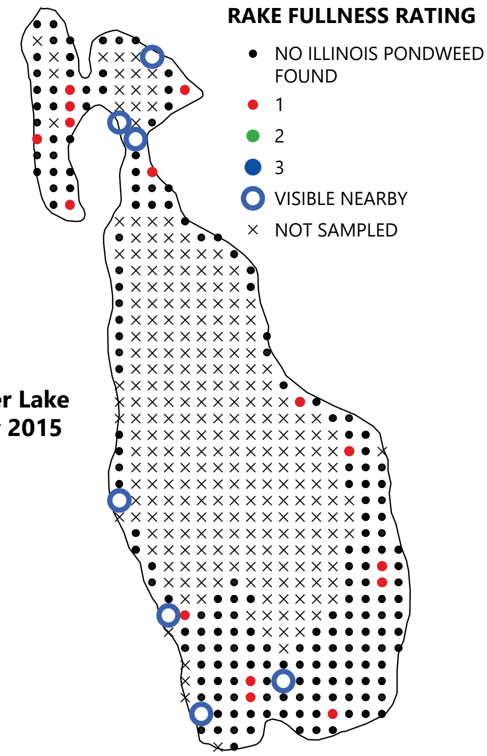
Credit: Flickr User Jason Hollinger

Native

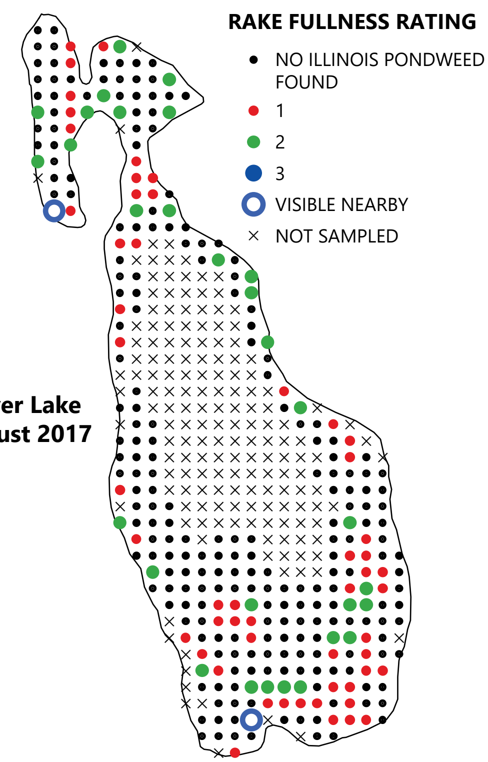
ILLINOIS PONDWEED

Potamogeton illinoensis

Credit: Flickr User Dick Culbert



Silver Lake July 2015



Silver Lake August 2017

Identifying Features

- Stout stems up to 2.0 m long, often branched
- Submerged leaves with nine to 19 veins (midvein prominent) on short stalks (up to 4.0 cm) or attached directly to the stem
- Floating leaves, if produced, elliptical, with 13 to 29 veins
- Often covered with calcium carbonate in hard water

Variable pondweed (*P. gramineus*) is similar to Illinois pondweed, but differs in having three to seven veins on submerged leaves

Ecology

- Lakes with clear water, shallow or deep, neutral or hard, over soft sediments
- Overwinters as rhizomes or remains green under the ice
- Provides food for waterfowl, muskrat, deer, and beaver
- Provides excellent habitat for fish and aquatic invertebrates

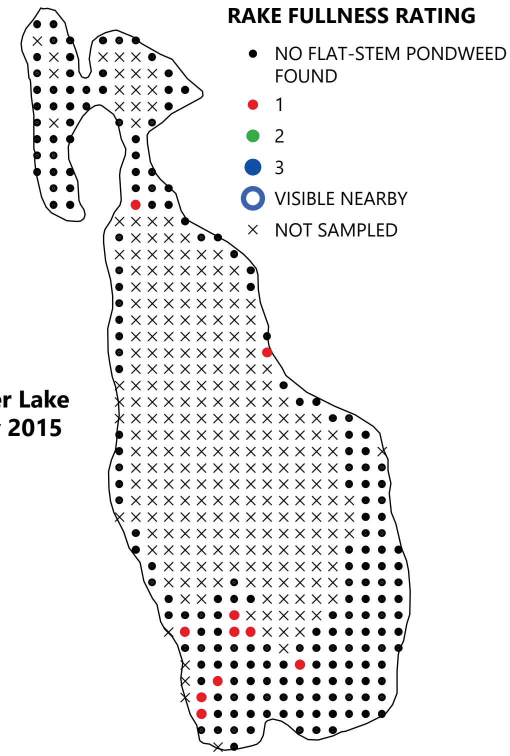
Credit: Flickr User Fernando Arcas

Native

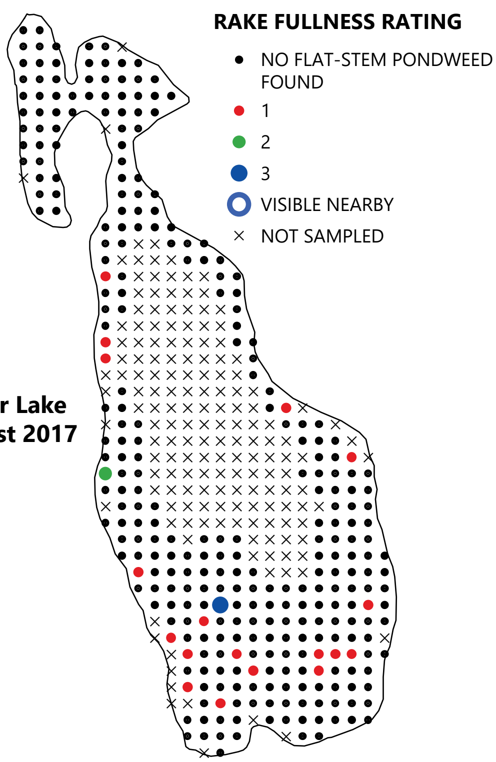
FLAT-STEM PONDWEED

Potamogeton zosteriformis

Credit: Donald Cameron



Silver Lake July 2015



Silver Lake August 2017

Identifying Features

- Stems strongly flattened
- Leaves up to four to eight inches long, pointed, with a prominent midvein and many finer, parallel veins
- Stiff winter buds consisting of tightly packed ascending leaves

Flat-stem pondweed may be confused with yellow stargrass (*Heteranthera dubia*), but the leaves of yellow stargrass lack a prominent midvein.

Ecology

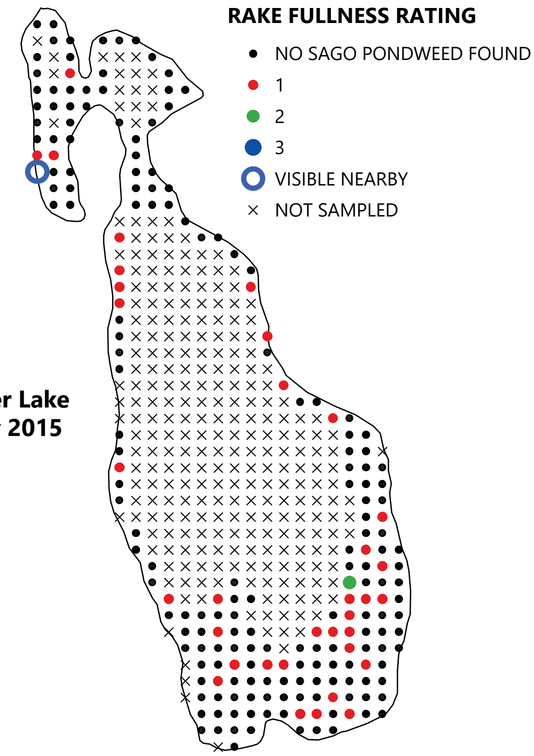
- Found at a variety of depths over soft sediment in lakes and streams
- Overwinters as rhizomes and winter buds
- Has antimicrobial properties
- Provides food for waterfowl, muskrat, beaver, and deer
- Provides cover for fish and aquatic invertebrates

Credit: Donald Cameron

Native

SAGO PONDWEED

Stuckenia pectinata



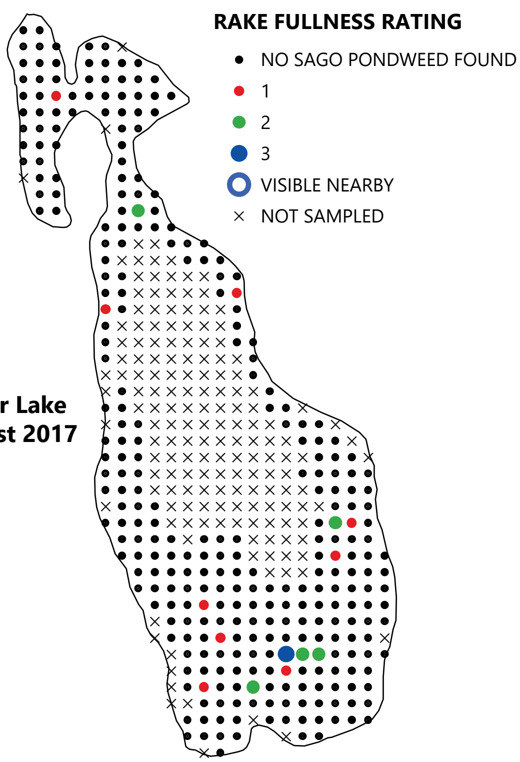
Silver Lake July 2015

Identifying Features

- Stems often *slightly zig-zagged* and forked multiple times, yielding a fan-like form
- Leaves one to four inches long, very thin, and ending in a sharp point
- Whorls of fruits spaced along the stem may appear as beads on a string

Ecology

- Lakes and streams
- Overwinters as rhizomes and starchy tubers
- Tolerates murky water and disturbed conditions
- Provides abundant fruits and tubers, which are an *important food for waterfowl*
- Provides habitat for juvenile fish



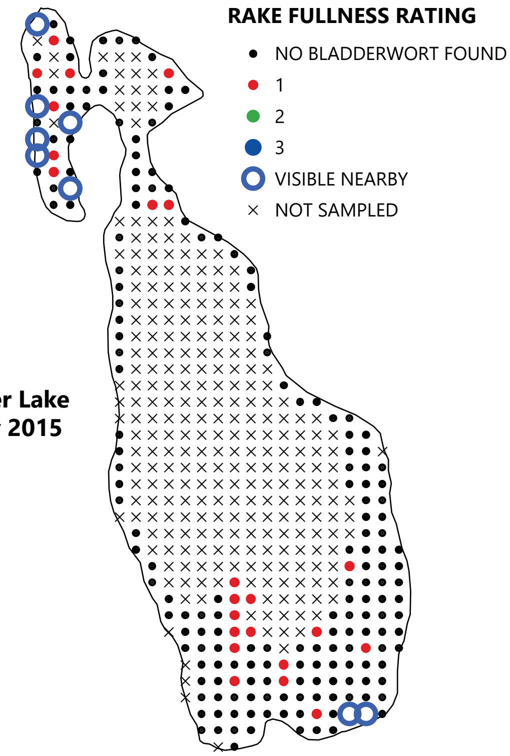
Silver Lake August 2017

Native

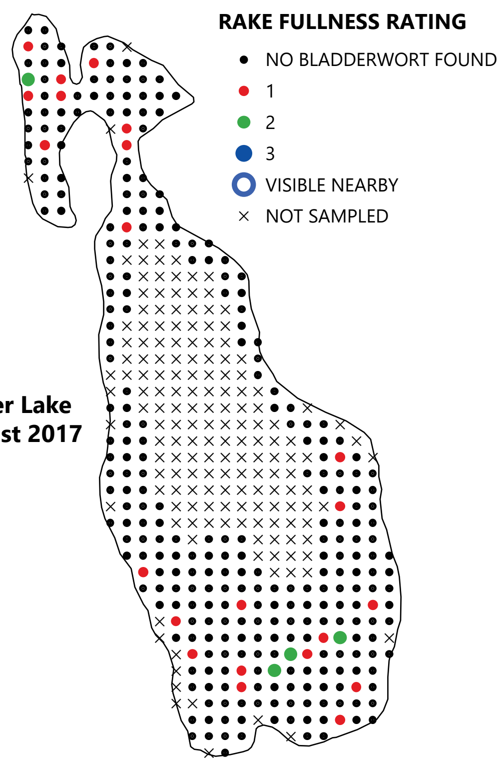
BLADDERWORTS

Utricularia spp.

Credit: Paul Skawinski



Silver Lake
July 2015



Silver Lake
August 2017

Identifying Features

- Flowers snapdragon-like, yellow or purple, held on stalks above the water surface
- *Producing bladders* (small air chambers on the stem) that capture prey and give buoyancy to the stem
- Stems either floating (due to air bladders) or anchored in the substrate; branches finely divided, if floating

Several similar bladderworts occur in southeastern Wisconsin

Ecology

- Most species found in quiet shallows and along shores, but common bladderwort (*Utricularia vulgaris*) sometimes occurring in water several feet deep
- Provides forage and cover for a wide range of aquatic organisms
- Bladders capture and digest prey, including small invertebrates and protozoans

Credit: Flickr User Doug McGrady

Credit: Wikimedia Common User Alex Popovkin

Credit: Wikimedia Commons User Michael Kurz

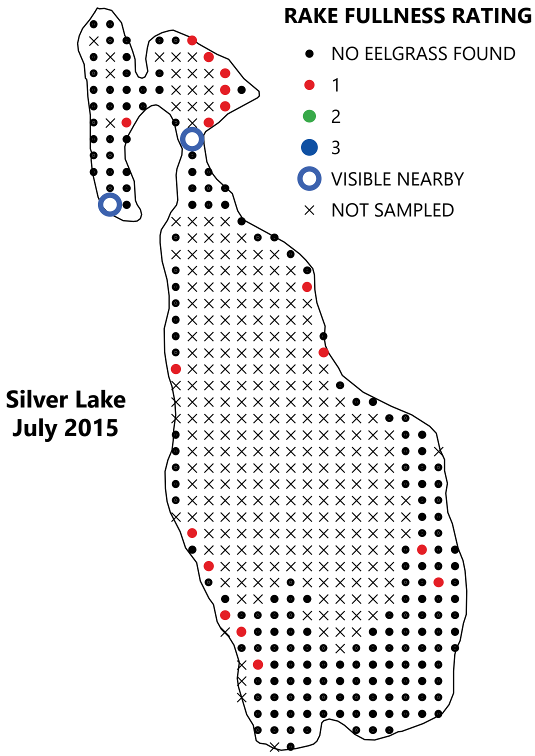
Credit: Paul Skawinski

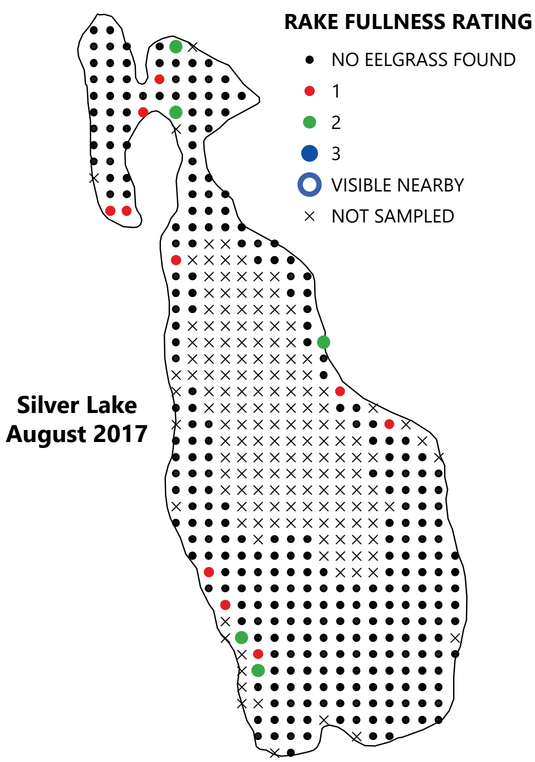
Native

WATER CELERY OR EELGRASS

Vallisneria americana

Credit: Wikimedia Commons User Fredlyfish4





Identifying Features

- Leaves ribbon-like, up to two meters long, with a prominent stripe down the middle, and emerging in clusters along creeping rhizomes
- Male and female flowers on separate plants, female flowers raised to the surface on spiral-coiled stalks

The foliage of eelgrass could be confused with the submersed leaves of bur-reeds (*Sparganium* spp.) or arrowheads (*Sagittaria* spp.), but the leaves of eelgrass are distinguished by their prominent middle stripe. The leaves of ribbon-leaf pondweed (*Potamogeton epihydrus*) are also similar to those of eelgrass, but the leaves of the former are alternately arranged along a stem rather than arising from the plant base

Ecology

- Firm substrates, shallow or deep, in lakes and streams
- Spreads by seed, by creeping rhizomes, and by offsets that break off and float to new locations in the fall
- All portions of the plant consumed by waterfowl; an especially important food source for Canvasback ducks
- Provides habitat for invertebrates and fish

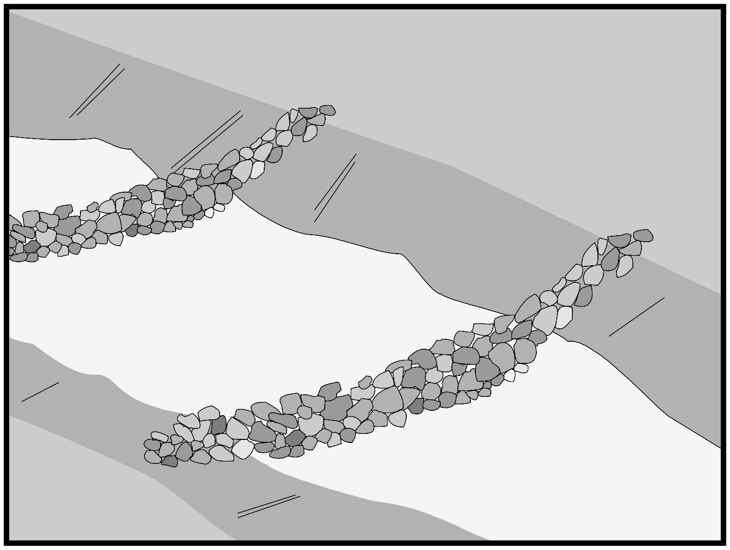
Credit: Wikimedia Commons User Fredlyfish4

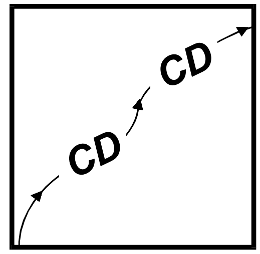
DITCH CHECK/CHECK DAM AND DITCH TURNOUT MANAGEMENT PRACTICES

APPENDIX C

Check Dams

SC-4





Standard Symbol

BMP Objectives

- ● Soil Stabilization
- ● Sediment Control
- ○ Tracking Control
- ○ Wind Erosion Control
- ○ Non-Storm Water Management
- ○ Materials and Waste Management

Definition and Purpose

Check dams reduce scour and channel erosion by reducing flow velocity and encouraging sediment settlement. A check dam is a small device constructed of rock, gravel bags, sandbags, fiber rolls, or other proprietary product placed across a natural or man-made channel or drainage ditch.

Appropriate Applications

- Check dams may be installed:
  - In small open channels that drain 4 ha (10 ac) or less.
  - In steep channels where storm water runoff velocities exceed 1.5 m/s (4.9 ft/sec).
  - During the establishment of grass linings in drainage ditches or channels.
  - In temporary ditches where the short length of service does not warrant establishment of erosion-resistant linings.
- This BMP may be implemented on a project-by-project basis with other BMPs when determined necessary and feasible by the Resident Engineer (RE).

Limitations

- Not to be used in live streams.
- Not appropriate in channels that drain areas greater than 4 ha (10 ac).
- Not to be placed in channels that are already grass lined unless erosion is expected, as installation may damage vegetation.
- Require extensive maintenance following high velocity flows.
- Promotes sediment trapping, which can be re-suspended during subsequent storms or removal of the check dam.

- Not to be constructed from straw bales or silt fence.

Standards and Specifications

- Check dams shall be placed at a distance and height to allow small pools to form behind them. Install the first check dam approximately 5 meters (16 ft) from the outfall device and at regular intervals based on slope gradient and soil type.
- For multiple check dam installation, backwater from downstream check dam shall reach the toe of the upstream dam.
- High flows (typically a 2-year storm or larger) shall safely flow over the check dam without an increase in upstream flooding or damage to the check dam.
- Where grass is used to line ditches, check dams shall be removed when grass has matured sufficiently to protect the ditch or swale.
- Rock shall be placed individually by hand or by mechanical methods (no dumping of rock) to achieve complete ditch or swale coverage.
- Fiber rolls may be used as check dams if approved by the RE or the Construction NPDES Coordinator. Refer to SC-5 "Fiber Rolls."
- Gravel bags may be used as check dams with the following specifications:

Materials

– ***Bag Material:*** Bags shall be either polypropylene, polyethylene or polyamide woven fabric, minimum unit weight 135 g/m2 (four ounces per square yard), mullen burst strength exceeding 2,070 kPa (300 psi) in conformance with the requirements in ASTM designation D3786, and ultraviolet stability exceeding 70% in conformance with the requirements in ASTM designation D4355.

– ***Bag Size:*** Each gravel-filled bag shall have a length of 450 mm (18 in), width of 300 mm (12 in), thickness of 75 mm (3 in), and mass of approximately 15 kg (33 lb). Bag dimensions are nominal, and may vary based on locally available materials. Alternative bag sizes shall be submitted to the RE for approval prior to deployment.

– ***Fill Material:*** Fill material shall be between 10 mm and 20 mm (0.4 and 0.8 inch) in diameter, and shall be clean and free from clay balls, organic matter, and other deleterious materials. The opening of gravel-filled bags shall be secured such that gravel does not escape. Gravel-filled bags shall be between 13 kg and 22 kg (28 and 48 lb) in mass. Fill material is subject to approval by the RE.

Installation

– Install along a level contour.

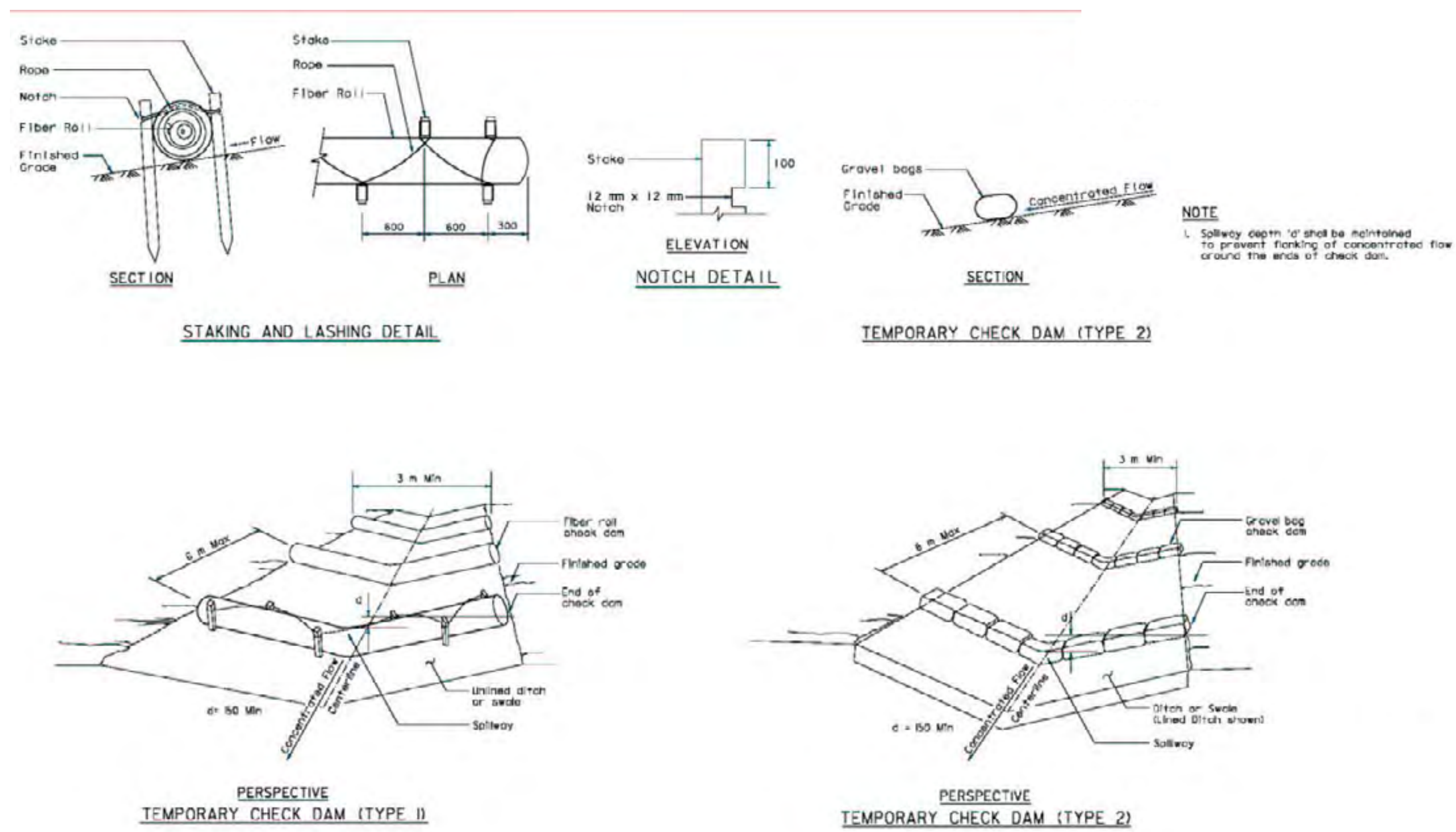
– Tightly abut bags and stack gravel bags using a pyramid approach.

Gravel bags shall not be stacked any higher than 1 meter (3.2 ft).

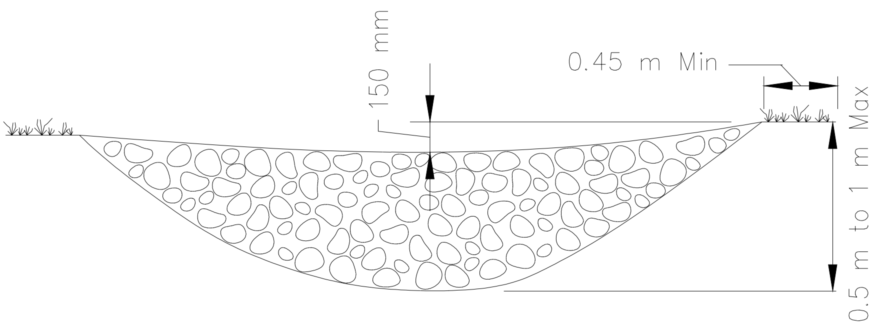
– Upper rows of gravel bags shall overlap joints in lower rows.

Maintenance and Inspection

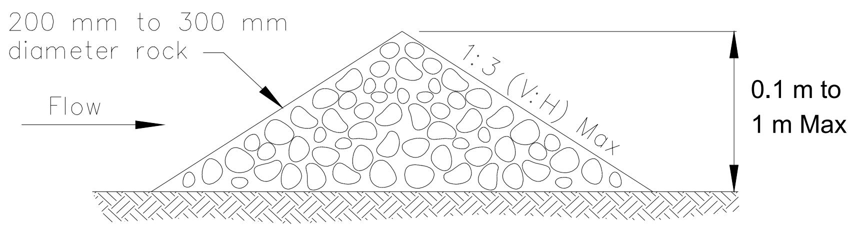
- Inspect check dams after each significant rainfall event. Repair damage as needed or as required by the RE.
- Remove sediment when depth reaches one-third of the check dam height.
- Remove accumulated sediment prior to permanent seeding or soil stabilization.
- Remove check dam and accumulated sediment when check dams are no longer needed or when required by the RE.
- Removed sediment shall be incorporated in the project at locations designated by the RE or disposed of outside the highway right-of-way in conformance with the Standard Specifications.



Stake
Rope
Notch
Fiber Roll
Finished Grade
Flow
SECTION
Stake
Rope
Fiber Roll
600
600
300
PLAN
STAKING AND LASHING DETAIL
Stake
100
12 mm x 12 mm Notch
ELEVATION
NOTCH DETAIL
Gravel bags
Finished Grade
Concentrated Flow
SECTION
TEMPORARY CHECK DAM (TYPE 2)
NOTE
1. Spillway depth 'd' shall be maintained to prevent flanking of concentrated flow around the ends of check dam.
3 m Min
6 m Max
Fiber roll check dam
Finished grade
End of check dam
d
Concentrated Flow
Centerline
Unlined ditch or swale
Spillway
d= 50 Min
PERSPECTIVE
TEMPORARY CHECK DAM (TYPE 1)
3 m Min
6 m Max
Gravel bag check dam
Finished grade
End of check dam
d
Concentrated Flow
Centerline
Ditch or Swale (Lined Ditch shown)
Spillway
d = 150 Min
PERSPECTIVE
TEMPORARY CHECK DAM (TYPE 2)



ELEVATION



TYPICAL ROCK CHECK DAM SECTION

ROCK CHECK DAM
NOT TO SCALE