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Community Assistance Planning Report Number 302 (2nd Edition)

LAKE MANAGEMENT PLAN UPDATE FOR MARY AND ELIZABETH LAKES
KENOSHA COUNTY, WISCONSIN

Chapter 1

BACKGROUND INFORMATION, PROJECT SCOPE, AND PLAN INTENT

Mary and Elizabeth Lakes ("the Lakes") are centerpieces of the Village of Twin Lakes ("Village") and the surrounding area. Recognizing the Lakes' great value to the local community, action has been taken over the years to balance the Lakes' long-term lake health with ongoing lake-user enjoyment. For example, the Village and the Twin Lakes Protection and Rehabilitation Lake District ("District") worked with the Southeastern Wisconsin Regional Planning Commission ("SEWRPC" or "the Commission") to prepare a comprehensive lake management plan.[1] This study, published in 2009:

- Evaluated important natural resource features influencing the Lakes' character
- Examined Lake user impressions, goals, and desires
- Reviewed human actions and how these actions may influence the Lakes' health
- Evaluated ways humans enjoy the Lake

Using this information, strategies and tactics were recommended to help promote human interaction and enjoyment of the Lakes while protecting them from undue human-induced deterioration. The Village

[1]*SEWRPC Community Assistance Planning Report Number 302,* A Lake Management Plan for Elizabeth Lake and Lake Mary, Kenosha County, Wisconsin*, 2009.*

followed up with action, consistent with plan recommendations. Over time, lake-user concerns and interests may change in reaction to new threats, changing desires, emerging issues, and enhanced awareness. The Commission's most recent management plan addressing the Lakes was completed over 14 years ago.

During early 2017, the Village contacted the Commission to discuss ice damage and water level concerns. To assist the Village and District, Commission staff evaluated available hydrologic information as well as potential causative agents for ice damage, presenting findings at the July 2017 annual meeting of the District. The Commissions' spring-summer 2017 limited study focused on two issues: water level history/change within the Lakes and possible agents contributing to ice damage along shorelines. This study revealed the following.

- Lake elevations fluctuate but appear to be trending higher over time.
- Water levels in the Lakes appear to be controlled by features other than the outlet dam.
    - During low runoff periods, the Lakes' water levels are higher than water levels immediately upstream of the outlet dam, revealing that something between the dam and the Lakes controls dry weather lake water elevations.
    - During high runoff periods, the outlet dam may submerge with water levels controlled by a downstream channel feature.
    - Potential channel obstructions are apparent upstream (vegetation constriction) and downstream (possible debris remaining after dam demolition) from the outlet dam.
- Flood elevations identified by the Federal Emergency Management Agency (FEMA) flood insurance study are not in agreement with measured Lake elevations. For example, the weir elevation of the new dam (793.5 feet above National Geodetic Vertical Datum, 1929 adjustment) is equivalent to the 10-percent-annual-probability (10-year recurrence interval) flood elevation.
- Ice damage can result from freeze-thaw cycling, wind push, and ice expansion. Insufficient information was available to identify primary causes for ice damage on the Lakes.

The conversation at the 2017 annual meeting also touched on the following topics.

- Controversy exists regarding flow capacity of the new versus old dam. A study comparing the flow capacity of each would be beneficial.

- The Richmond Hunting Club was ordered to remove a dam downstream of the Lake outlet dam. Although the visible part of the dam was removed, uncertainty remains if submerged fill was removed and if such fill could influence spillway capacity.

- The outlet dam can only be accessed by a private road through property owned by the Richmond Hunting Club. To facilitate hunting, the Richmond Hunting Club places significant restrictions on access to the dam via the private road.

- The Elizabeth Lake Nature Preserve (owned by McHenry County, Illinois) prohibits access to the outlet dam through the lake outlet channel and also prohibits modification to the vegetation and debris in and along this watercourse. Although this stance appears consistent with options available to landowners through Illinois law, given the outlet channel's tendency to block is high, and since high water could harm lake health and infrastructure, the Village and McHenry County need to discuss this issue, with possible involvement of Federal and State agencies.

- The Village had continuous water level records available on digital media. However, the stability of the sensor array was questionable since it was not firmly anchored, casting doubt on the validity of this water level information.

- Ice damage seemed to be most severe during mild winters. January thaw-type weather was thought to be particularly damaging. It should be noted that lake residents hypothesize that higher winter water levels were accentuating ice damage along their shorelines.

- Some expressed concern about perceived water quality deterioration and nuisance-level aquatic plants.

On October 5, 2017, the Commission submitted a scope of work to the Village that proposed the following tasks:

- Evaluate Historical Weather Conditions
- Amend Lake Water Elevation Database
- Assist Twin Lakes with Lake Management Grant Development (no charge)

On November 15, 2017, the Village and District asked the Commission's to expand the scope to include updating additional lake planning elements presented in the first edition of CAPR Number 302. The Village and District wished to update several topics presented in the 2009 lake plan. The Village and District were particularly interested in adding the following topics to the proposed scope of services.

- Update the 2009 lake water quality evaluation
- Model sediment and pollutant loads contributed to the two lakes from their watersheds
- Review and summarize the history of water level control and management on the Lakes, including review and analysis of water elevation gages installed by the United States Geological Survey (USGS)
- Continued and/or expanded volunteer winter ice damage reporting for two more winters
- Discuss alternate Lake level operating ranges and water level control strategies

Given the general concern regarding aquatic plants, the perceived need expressed by some Lake users for active plant management, and that aquatic plant populations have not been studied in detail for over a decade, the Commission also recommended that the Village and District complete an aquatic plant point-intercept study in both Lakes. However, the Village told us that they had completed an aquatic plant inventory relatively recently and were not interested in completing another aquatic plant survey. The final scope of work for the lake management plan update included the following elements.

- Assist Twin Lakes with Lake Management Grant Development (no charge to the Village)

- Data Compilation and Analysis
    - Evaluate Historical Weather Conditions
    - Amend Lake Water Elevation Database
    - Update Lake Water Quality Database
    - Evaluate Factors Influencing Runoff Water Quality and Quantity
    - Examine Water Level Control Policies and Infrastructure
    - Complete an on-the-water survey with lake residents
    - Evaluate Data and Develop Recommendations
- Field Work - Examine Key Elements
- Communication – Attend Meetings, Provide Updates, Prepare Report

The Commission's final scope of work was used to help prepare a successful Wisconsin Department of Natural Resources (WDNR) lake planning grant application.[2,3] As was discussed in SEWRPC's scope of work, much of this work specifically relied upon technical work completed by, and records available from, the Village, the Village's engineer (Town and Country Engineering), Lake residents, the USGS, and the Save our Shorelines Lake resident group's consultant (Emmons and Olivier Resources (EOR), Incorporated, formerly Montgomery Associates Resource Solutions).[4]

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[2]*SEWRPC Staff Memorandum,* Scope of Work to be Performed by SEWRPC for a Water Level and Ice Damage Study of Lakes Mary and Elizabeth*, November 29, 2017.*

[3]*Wisconsin Administrative Code NR 190,* Lake Management Planning Grants*, 2000.*

[4]*Montgomery Associates Resource Solutions was acquired by EOR during 2020.*

This plan update is divided into three chapters. Chapter One provides background information and summarizes the plan's purpose, general study goals, and objectives. Chapter Two addresses issues of concern identified by Lake users and examines information relevant to understanding the nature and cause of these concerns. Using the information presented in Chapters One and Two, Chapter Three recommends concepts to address identified concerns, evaluates the relative importance of these activities, and briefly discusses implementation concepts and logistics.

This plan complements previous plans, programs, and ongoing management actions that focus on the Lakes and their watersheds. As such, the new plan expands upon and updates the First Edition of SEWRPC Community Assistance Planning Report (CAPR) Number 302. This Second Edition of CAPR 302 is not intended be a comprehensive review of every issue facing the Lakes. Instead, much of this plan update focuses on issues unknown at the publishing date of the First Edition or that have gained prominence since that time. The reader should refer to the First Edition of CAPR 302 for topics not addressed in this plan.

The Second Edition of CAPR 302 represents the continuing commitments of government agencies, municipalities, and citizens to sustainably balance human needs and desires with 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 design and execute approaches that help address Lake user concerns and help protect long-term Lake health. By using concepts outlined in this plan, results will be achieved that help enrich and preserve the public's enjoyment of the Lake. The plan's recommendations are appropriate and technically feasible lake management measures that help preserve or enhance the Lakes' health, recreational value, and overall community and riparian landowner value. Preserving or enhancing these elements allows the Lake to sustainably provide safe, varied, and enjoyable recreational opportunities.

This planning program was funded in part by the Village and, in part, through a Chapter NR 190 Lake Management Planning grant awarded to the Village and administered by the WDNR.

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LAKE MANAGEMENT PLAN UPDATE FOR MARY AND ELIZABETH LAKES
KENOSHA COUNTY, WISCONSIN

Chapter 2

INVENTORY FINDINGS AND RELEVANCE TO LAKE MANAGEMENT

Chapter Two presents data and interpretations relevant to understanding the dynamics and overall health of Lake Mary and Elizabeth Lake ("Lakes").[1] This includes study of both in-Lake processes as well as the land areas providing runoff to the Lakes ("watershed"). The project study area for the plan update includes Lake Mary and Elizabeth Lake, together with their watershed and groundwatershed (the area where infiltrating surface water feeds groundwater flow systems that sustain the Lake) (see Map 2.1). This plan evaluates the overall health of the Lakes, situations that concern lake users, and conditions that could contribute to water quality and/or quantity problems. Concepts that help the Village of Twin Lakes ("Village"), the Twin Lakes Protection & Rehabilitation Lake District ("District) and their project partners address specific concerns are subsequently presented in Chapter Three.

2.1 INTRODUCTION

Lakes are treasured community centerpieces, valuable economic assets, and critical ecological features. Unfortunately, human activity often diminishes the quality of benefits provided by lakes. Lake health may be perceived to suffer, the tangible quality of recreational experiences may decline, and lakes may no longer be able to adequately fulfill human needs and desires. Such changes often stimulate community concern and calls for action. Observed changes may portend new, or sometimes more serious, lake-use and ecological challenges.

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[1] *Lake Mary is sometimes referred to as Marie Lake, especially in older documents.*

Continuing change within areas of the Lakes, and the area tributary to them, sustains a range of questions or concerns within this lake-centered community. Examples of concerns include recreational use conflicts, siltation and sedimentation (especially of bays and adjacent to wetland areas), excessively high lake water surface elevations, shoreline ice damage, protection of environmentally valuable areas, and excessively abundant aquatic plant growth in the shallower portions of the lake basins. In addition, present and future urban-density development within the areas tributary to the Lakes is perceived to have impacted, or has the potential to impact, the Lakes and their ecosystems. Some also express concern over variable water quality and potential contamination of lake waters by nonpoint source pollution, especially from stormwater runoff.

2.2 LAKE AND WATERSHED PHYSIOGRAPHY

The condition and overall health of a waterbody is directly related to the natural features and human-induced changes found within the area draining to the waterbody. The assemblage of unique natural features and processes, and human influences upon them, can be collectively referred to as physiography. This section describes the physiography of the Lakes and their watersheds, including the shape and arrangement of landscape features, the composition and arrangement of soil and rock, tributary stream characteristics, Lake basin morphology, how water moves through the area, and how humans influence and manipulate the landscape, and potential pollutant sources.

Additional details of some of the topics examined as part of this characterization process are presented below.

- **The location and extent of a lake's watershed.** Before characterizing watershed features, the size and location of the watershed must be quantified. The watershed delineation process involves carefully examining land surface elevation data, mapping the area from which surface-water runoff eventually flows on the land surface to the waterbody of interest. This analysis determines whether potential pollutant sources threaten runoff quality entering a waterbody. For example, if a pollution source is near a waterbody but outside its watershed, contaminated surface runoff from that source would not reach the waterbody, and, therefore, may not be an issue of concern in terms of water quality.

- **The location and extent of a lake's groundwatershed.** Three sources of water feed most lakes: surface-water runoff, precipitation directly upon the open water surface, and groundwater discharging through springs and/or seeps along a lake's shoreline or bottom. The geographical extent of the area contributing groundwater to lakes can differ from the area contributing runoff to lakes. Water table elevation maps are used to define the area where infiltrating precipitation ultimately contributes water to a lake or tributaries feeding a lake. Groundwater sustains lake elevation and stream flow during dry weather.

- **Natural resource factors.** The arrangement and composition of soil and rock, land slope and elevation, climatic variables, vegetation, and other factors reveal much of a lake's overall character and its water supply. Therefore, it is important to understand the topography, geology, hydrology, vegetation, and climate prevailing in a lake's watershed.

- **Existing land use.** The type, extent, and location of land use practices in a lake's watershed can help predict the type and amount of pollutants reaching a lake. Models estimate total pollutant loads entering a waterbody, evaluate the relative contribution of certain land uses or areas, and predict consequences of land use change. After pollutant sources are quantified, management efforts can focus on areas and/or land-use practices that generate higher pollutant loads. For example, if phosphorus is an important waterbody management concern, and if cultivated crop areas are predicted to be the primary source of phosphorus to a water body, pollution reduction efforts should likely begin with activities that reduce the amount of phosphorus carried by agricultural runoff from cultivated fields.

- **Historical land use.** Awareness of historical land use change can provide context for understanding causes for past waterbody health issues, particularly when considered with contemporaneous water quality monitoring data or well-documented oral or written accounts. For example, if a long-term lake property owner remembers or recorded periods of overly abundant aquatic plant growth, intense algal blooms, or low or high-water levels, those conditions can be correlated with historical land use changes to examine if something changed to cause the issue in question (e.g., increases in impermeable surfaces or installation of stormwater infrastructure associated with urban development). This information can provide insight into how a waterbody may react to future changes and situations.

- **Future planned land use types and distribution**—Planned land use changes can help estimate future watershed conditions. This can help lake managers estimate the potential type, magnitude, and source of future pollution issues and target areas where future active or pre-emptive management can protect long-term waterbody health.

- **The nature and location of discrete pollutant sources (if applicable)**—Many human activities contribute pollutants to waterbodies. Many potential pollutant sources are stringently regulated. However, some may continue to be significant pollution sources. An example is private onsite wastewater treatment systems ("POWTS"), commonly known as septic systems. POWTS can be a significant source of phosphorus when not improperly designed or maintained and are usually a substantial source of chloride.[2] Consequently, it is important to investigate whether POWTS exist within a watershed. Another example is urban stormwater runoff, especially from areas constructed before the advent of mandated modern stormwater management practices in the early 1990s. Urban stormwater runoff can contribute significant pollutants, sediment, and nutrient loads to waterbodies.

Watershed Extent and Characteristics

Both Lake Mary and Elizabeth Lake are elongated along a northeast-southwest axis and lie adjacent to one another. Most of the Lakes' acreage is located within the Village of Twin Lakes, Wisconsin (see Map 2.1). Lake Mary lies within U.S. Public Land Survey Sections 20, 21, and 28, Township 1 North, Range 19 East. Elizabeth Lake, located immediately south of Lake Mary, lies primarily within U.S. Public Land Survey Sections 28, 29, 32, and 33, Township 1 North, Range 19 East. A small portion of Elizabeth Lake, fringing wetlands, the Lake's outlet, and lake water level control weir are located in Sections 2 and 3 of Township 46 North, Range 8 East in McHenry County, Illinois.

According to Commission estimates from recent aerial orthophotography, the Lakes cover a combined 1,086 acres with Lake Mary (333 acres) at roughly half the size of Elizabeth Lake (753 acres). For the purposes of this study, the acreage of Elizabeth Lake included the side channels and bays located along the western and southern shorelines of the Lake to the outlet dam. The Lakes are located within a total watershed of 7,524 acres, including the lake acreage. While topographic mapping suggests that 6,438 acres of this watershed drains to the Lakes, a 2004 Twin Lakes stormwater management plan identifies two internally

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[2] *Water discharged to most septic systems using an on-site treatment and dispersal process ultimately enters the local environment. Pollutants carried by this water must be given time to be treated by the septic system before reaching groundwater or surface water. Systems that rapidly pass wastewater may not provide adequate treatment to remove pathogen, nutrients, and/or harmful compounds before effluent reaches surface water or groundwater. Some recalcitrant, conservative, or persistent pollutants may pass through even well-designed septic systems and will ultimately enter surface water and/or groundwater. An example of one such pollutant is chloride. Since most humans use much salt, elevated chloride concentrations often indicate human influence.*

drained areas of 659 and 30 acres; these areas do not typically contribute surface runoff to the Lakes.[3,4] Consequently the Lakes have a contributing watershed, i.e., not including the lakes themselves or internally drained areas, of 5,749 acres (see Table 2.1). To aid watershed evaluation, the Lakes' watershed was subdivided into discrete subbasins with the internally drained areas noted (see Map 2.1).

A narrow, generally low-lying, isthmus separates the two lake basins. A small, shallow channel crosses the isthmus, allowing water to flow between the two lake basins. The Lakes' water elevations are similar. Although the elevations of the Lakes vary in response to weather, water most commonly flows from Lake Mary to Elizabeth Lake. Some residents report that after heavy precipitation, the flow direction in the channel connecting the two lakes may reverse, with water flowing from Elizabeth Lake into Lake Mary. This may relate to the fact that while storm sewers and ditches discharge to both Lakes, no significant streams and a very small watershed feeds Lake Mary. A moderately large watershed and several small streams feed Elizabeth Lake including two named streams (Elizabeth Springs Creek entering from the east near the state line and Smallwood Creek entering Elizabeth Lake's southeast corner). Water leaves the Lakes by flowing south through an extensive wetland complex. The outlet stream is wholly in Illinois and is named the Elizabeth Lake Drain. Outflow from Elizabeth Lake, and under most conditions from Lake Mary, is controlled by a spillway in a dam located in McHenry County, Illinois.[5] The Elizabeth Lake Drain joins Nippersink Creek downstream of the Village of Richmond, Illinois. From there, Nippersink Creek merges with the Fox River. The Fox River is tributary to the Illinois River which is in turn tributary to the Mississippi River and the Gulf of Mexico.

Essentially all shoreline well suited for residential land uses around both lakes has been developed. Lake Mary abuts the commercial heart of the Village of Twin Lakes and many businesses are located near the Lake in this area. On account of high demand for lakefront parcels, most lots are relatively narrow. Shoreland parcels along long stretches of the Lakes' shoreline are only slightly above the Lakes' water-surface

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[3] *Earth Tech, Inc.,* Stormwater Management Plan Prepared for the Village of Twin Lakes, Wisconsin*, 2004*.

[4] *Water in these internally drained areas generally accumulates and exits via evaporation or by seepage into the Earth and contribution to groundwater flow systems. Such occurrences often occur naturally, especially in areas of irregular topography, but can also be created by human interventions such as placing fill across swales to facilitate roadway construction and not installing a culvert to transmit runoff downstream. Only under prolonged periods of excessively high precipitation would these areas ever contribute surface water runoff to the Lakes.*

[5] *Although not inspected by Commission staff as part of this study, a small, low weir reportedly exists at the Lake Mary outlet. Although normally submerged, local accounts suggest that this low weir can cause Lake Mary to be up to a foot higher than Elizabeth Lake during extreme dry weather.*

elevation. These low-lying parcels are particularly common along the Lakes' western shorelines. In some areas, channels were dug through riparian marshlands and other low-lying areas to create additional buildable lots with direct water access. The spoil from channel excavation was commonly used as fill on the adjoining lots. Such activity occurred many years ago before the advent of many of the laws now protecting wetlands and waterways. Several of the excavated channels appear to parallel the original course of several of the Lakes' natural tributaries. These channels are protected/reinforced with sheet piling and have become the route through which runoff is carried to the Lakes in many instances. Fortunate for the Lakes' health, long stretches of shoreline, particularly along the western and southern shorelines of Elizabeth Lake, remain undeveloped riparian wetland.

Topography

The Lakes are found near the center of a broad northeast-southwest trending valley. From a regional perspective, land-surface elevations gradually rise northwest and southeast of the Lakes. Land surface elevations are generally higher east of the Lakes. About 200 feet of topographic relief are found in the Lakes' watershed, with land surface elevations ranging from roughly 795 feet above National Geodetic Vertical Datum, 1929 adjustment (NGVD 29) along the Lakes' shorelines to elevations of almost 1000 feet above NGVD 29 along the crests of prominent hills east of Elizabeth Lake near the state line (see Map 2.2 and Table 2.2).

Approximately 56.1 percent of the topographical watershed (including internally drained areas) has slopes less than 6.0 percent (see Map 2.3 and Table 2.3). Some areas of the watershed are essentially flat while other areas exhibit erratic, often isolated, steeply sloping relic landforms related to glacial activity. Topographically flat areas near the Lakes likely represent extinct portions of the Lakes beyond their modern shorelines. Attesting to the erratic topography in the Lakes' watershed, some of the steepest slopes in the watershed are directly adjacent to some of its flattest areas. An example is found near the isthmus separating the two lakes. Furthermore, steeply sloping lands (land with slopes greater than 20 percent) occupy only 1.3 percent of the Lakes' topographical watershed which reduces the risk of high runoff sediment loads.[6]

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[6] *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. In steeply sloping areas, eroded sediment is more effectively transported to lakes, streams, and wetland. Once sediment reaches large waterbodies, 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. An example is phosphorus, a nutrient often triggering lake eutrophication, is often attached to fine sediments such as silt and clay and can therefore be found in elevated concentrations in turbid water.*

Weather and Climate

Weather and climate describe the same parameters: atmospheric temperature, precipitation, humidity, wind speed, cloud cover, and other conditions. However, weather and climate are not synonymous. The term "weather" generally describes conditions over short periods of time (e.g., minutes, hours, days, weeks). In contrast, the term "climate" describes long-term weather averages, and typically considers time periods of decades or longer. Long periods of weather data are used to describe climate and allow changing climate to be noted. Weather conditions have been recorded in Southeastern Wisconsin for well over 100 years. For example, air temperature, precipitation, snowfall, and snow depth data has been collected at the Waukesha Water Works since 1893. Monthly maximum, minimum, and average temperatures as well as average precipitation recorded at Pell Lake during the time between 1991 and 2020 are presented in Table 2.4. Pell Lake is located less than four miles west-northwest of the Village of Twin Lakes and offers a reasonable estimate of conditions at the Village of Twin Lakes.

Climate is a dynamic Earth feature that has changed many times over the Earth's history. Wisconsin climate data is based on weather observations that extend back at most only about 180 years. "Long-term" precipitation and temperature trends are often based on records spanning a few decades (generally from about the 1970s or 1980s to the present). The available data suggests that Wisconsin's climate is changing.[7] Many aspects of the landscape's water resource asset base respond to climate and can serve as indicators of climate change at various temporal and spatial scales. Historical data analysis demonstrates that water resources are intimately linked to local and regional climate conditions. Long-term records of lake water levels, lake-ice duration, groundwater levels, and stream baseflow are correlated with long-term trends in atmospheric temperature and precipitation.[8]

The Wisconsin Initiative on Climate Change Impacts ("WICCI") concludes that projected future climate change will affect Wisconsin's water resource quantity and quality.[9] However, WICCI also found clear evidence, from analysis of past and probable future climate trends, that various geographic regions of Wisconsin will respond differently to climate change (see Figure 2.1). These differences reflect local

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

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

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

variations in land use, soil type, groundwater characteristics, all of which influence the amount of precipitation that exits an area as runoff, infiltration, or evapotranspiration. This illustrates the importance of including existing and future land use conditions as part of the watershed protection plan strategy.

Ongoing and future climate change may alter runoff (volume and timing), distribution and intensity of rainfall over time, and whether precipitation falls as rain or snow, each of which affects water's movement through the water cycle. As shown in Figure 2.2, water entering the landscape arrives as precipitation (rain and snowfall) that either falls directly on waterbodies; runs off the land surface and enters streams, river, wetlands, and lakes; or percolates through the soil, recharging groundwater that flows underground and re-emerges as springs, seeps, or human well discharge, all which can feed lakes, wetlands, and streams. Even without climate change, when elements of the hydrologic cycle change, surface-water and groundwater systems, and the way they interact, may change. For example, intense groundwater pumping and consumptive use can reduce or completely deplete flow to springs and seeps feeding streams, wetlands, ponds, and lakes. Climate change may expose the vulnerabilities of water supplies within a given natural system or human community. This vulnerability is commonly proportional to how significantly humans have altered the hydrologic cycle. Water supply vulnerability is often most plainly evident during protracted dry weather. Similarly, flooding and infrastructure failure caused by increased runoff volumes and speed are most evident during extremely wet weather.

The WICCI Water Resources Working Group ("WRWG") incorporated WICCI's 1980-2055 temperature, precipitation (including occurrence of events), and changes in snowfall projection to evaluate potential hydrologic process and resource impacts.[10] This team of experts identified and prioritized the most serious potential water resource problems related to anticipated climate change and proposed strategic adaptation strategies to address those impacts across the State of Wisconsin (see below). The WRWG offers the following guidance to help local communities develop adaptation strategies:[11]

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

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

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

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

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

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

To evaluate climatic trends in the Twin Lakes area, Table 2.5 contrasts Pell Lake monthly average weather data from 1991 through 2020 to weather data collected during the past 15 years (2006 through 2020). Overall, this comparison reveals that the local climate is becoming increasingly warmer and wetter compared to the previous 15 years. Much of the additional precipitation is falling outside of the normal growing season. Commission staff compiled precipitation records from weather stations in Beloit and Union

Grove illustrating trends in total annual precipitation and the number of one-inch rainfall events (see Figures 2.3 and 2.4). Ice cover records from Geneva and Delvan lakes in Walworth County, Friess and Little Friess lakes in Washington County, Rock Lake in Rock County, as well as Lake Mendota and Lake Monona in Dane County demonstrate that the length of winter lake ice cover is decreasing and that the last ice leaves earlier in the spring (see Figure 2.5). Hence, these reductions in ice cover are also likely occurring in Twin Lakes. Changing precipitation and ice cover patterns can impact runoff, shoreline erosion, dam operation, and aquatic plant growth. Such insight should be integrated into water resource management planning and infrastructure design.

Geology and Soils

Kenosha County was entirely covered with glacial ice until roughly 15,000 to 19,000 years ago. These glaciers flowed generally south and west out of the Lake Michigan Basin. Further to the west in Walworth County, these glaciers met ice spreading south and east out of the Green Bay/Lake Winnebago lowlands. The two lobes of glacial ice converged and formed the prominent northeast-southwest trending ridges of the Kettle Interlobate Moraine (commonly referred to as the “Kettle Moraine”). A series of later glacial advance did not extend as far as the Kettle Moraine. These later advances created ridges at their maximal extent (i.e., terminal moraines) that roughly parallel Lake Michigan’s shoreline. The last glacial ice left Kenosha County approximately 15,000 years ago.

Earlier glacial advances deposited sandy sediments now identified as the New Berlin Member of the Holy Hill Formation. While exposed at the surface in the western quarter of Kenosha County, in areas farther to the east, the Holy Hill formation is buried by more recently deposited clay and silt rich sediment of the Oak Creek Formation. Although earlier glacial activity deposited sediment in Kenosha County, it is buried by Holy Hill and Oak Creek Formation throughout the County. Glacial meltwater deposited sands, gravels, silts, and clays, some of which are now exposed at the surface, and in other areas buried by more recent glacial advances and modern waterborne sediment.[12]

Glaciers transported vast quantities of unsorted sediment (diamicton) 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. This water

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

flows 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 become buried. When the buried ice block melts, an irregular land surface marked by conspicuous steep-walled depressions ("kettles") results. Many Wisconsin lakes occupy kettles.

Lake Mary and Elizabeth Lake are situated just beyond the maximal western extent of the glacier depositing Oak Creek Formation till. As such, sorted sandy and gravelly sediment associated with glacial meltwater blankets extensive areas to the west of the Fox River. Higher areas, not buried by meltwater sediment, allow older glacial till of the New Berlin Member of the Holy Hill Formation to remain exposed at the surface in isolated areas. Available data suggests that surface sediments to the north and west of the Lakes are composed of sand and gravel outwash deposited as the Oak Creek glacier melted while sediment along the east shoreline of the Lakes is composed of older sandy, silty glacial till of the New Berlin Member of the Holy Hill Formation. The orientation and topography of the prominent valley in which the Lakes are situated suggests that it may have been formed by erosion induced by glacial meltwater. The isolated steep-sided hills may represent relic areas not eroded by meltwater. The Lakes themselves may be kettle lakes formed when large ice blocks carried by glacial ice were buried and subsequently melted.

Silurian-age dolomitic bedrock of the Racine and Waukesha Formations underlies the entire watershed. The bedrock surface slopes to the southeast with no prominent bedrock valleys or prominences noted on existing mapping. As such, bedrock is most deeply buried under the eastern edge of the watershed near the state line where surface elevations are highest and bedrock elevations are lowest (see Map 2.4 and Table 2.6). In this area, up to 300 to 350 feet of unconsolidated sediment buries the bedrock surface. In contrast, in the comparatively low elevation areas along the western shoreline of Lake Mary and northwestern shoreline of Elizabeth Lake, only 100 to 150 feet of unconsolidated sediment lie on the bedrock surface.[13,14,15]

Soil is the uppermost layer of terrestrial sediment and results from weathering and biological activity. The type of soil underlying an area depends on several factors including landscape position and slope, parent material, hydrology, and the types of plants and animals present. Soils to the east of Lake Mary and Elizabeth Lake belong to the Miami Association. Miami Association soils are generally well drained and have subsoil consisting of silty clay loam and clay loam, with parent materials being loamy or sandy glacial till with a modest veneer of loess (wind-deposited silt). Miami Association soils formed under hardwood forest cover. Soils to the west of Lake Mary belong to the Casco-Rodman Association while soils to the west of Elizabeth Lake belong to the Fox-Casco Association. They are generally rolling and occupy lands on ridges and hills. Both Fox-Casco and Casco-Rodman Association soils are well drained to excessively well drained with clay loam, silty clay loam, or gravelly clay loam subsoil. Parent materials typically consist of a thin layer of loess resting upon stratified sand and gravel glacial outwash or stream terrace deposits. Rodman-Casco soils generally have less topsoil and are coarser grained and more droughty. Both the Fox-Casco and Casco-Rodman Associations form under hardwood forest canopies and have steep slopes in some areas.[16] Wetlands soils fringing the Lakes are not mapped on available soil surveys but probably would belong to the Houghton-Palms Association. Houghton-Palms Association soils are poorly drained, are rich in decomposed or partly decomposed water tolerant plant remains and are typically level.

Hydrologic soils groups indicate the amount of runoff from bare soil following prolonged wetting.[17] Soils with high permeability rates, such as sandy and/or gravelly soils, generally generate less runoff than soils with low permeability rates, such as soils with over 40 percent clay. High permeability soils generate less

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[13] *Peters, R. M., Preliminary Bedrock Geologic Map of Kenosha County, Wisconsin, Wisconsin Geological and Natural History Survey, Open-File Report 2004-13A, 2004.*

[14] *Peters, R. M., Preliminary Bedrock Topography Map of Kenosha County, Wisconsin, Wisconsin Geological and Natural History Survey, Open-File Report 2004-13B, 2004.*

[15] *Peters, R. M., Preliminary Depth to Bedrock Map of Kenosha County, Wisconsin, Wisconsin, Geological and Natural History Survey, Open-File Report 2004-13C, 2004.*

[16] *Link, Ernest G and Owen R. Demo,* Soil Survey of Kenosha and Racine Counties, Wisconsin*, United States Department of Agriculture, 1970.*

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

runoff because the water quickly moves to lower soil layers rather than saturating the upper layer and moving over the land surface to topographically lower areas as runoff, as occurs in low permeability soils. Soils are placed into four broad classes (A, B, C, and D) indicating how well the soils drain well and consequently the amount of runoff that can be expected from soil. Class A are well-drained soils with the lowest runoff potential and class D are poorly drained soils with the greatest runoff potential. Soil permeability can also vary depending on the water table elevation. To account for this, certain soils have dual hydrologic group designations, such as A/D, that indicates the amount of runoff expected if the soil is drained or undrained.[18] Nearly two-thirds of the Twin Lakes watershed (including most upland areas) is covered by soils in the B hydrologic soil group, indicating that these soils are generally well-drained silty or loamy soils that yield a moderate amount of runoff (see Map 2.5 and Table 2.7). The areas around the Lakes are generally covered by soils in the A/D and B/D groups, indicating these soils have low to moderate runoff when drained and very high runoff when undrained. Just over six percent of the watershed is covered by soils in the C and C/D groups which are generally poorly drained soils in low-lying wetland areas.

Pre-Settlement Vegetation

Before European-settlement radically altered the Midwestern landscape, oak savanna covered over two-thirds of the land draining to the Lakes (see Map 2.6 and Table 2.8).[19] A substantial swath of prairie was found near the western periphery of the watershed. Prairie vegetation was the second most dominant vegetative community, covering about one-eighth of the Lakes' watershed. Wetlands covered roughly nine percent of the watershed in areas where they remain today (e.g., the southern shores of Elizabeth Lake and a portion of the western shore of Lake Mary). Oak forest was common around the northern half of Lake Mary and in the far western portion of the watershed, an area covering roughly nine percent of the watershed.

After European settlement, native vegetation throughout the watershed was largely removed and supplanted by vegetation associated with agricultural or urban land uses, although some pockets of native vegetation remain. Today's vegetation has been manipulated to support human wants and needs, with large portions of the watershed devoted to agricultural and residential uses.

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

[19] *Oak savanna is a lightly wooded grassland where fire resistant oaks and prairie plants dominate.*

Surface Water Resources

General Concepts and Management Principles

All water found in Wisconsin's waterbodies and aquifers ultimately originated 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 into the atmosphere. Precipitation that does not run off and does not evaporate soaks into the ground. This infiltrating water replenishes groundwater supplies. Groundwater ultimately feeds such features as aquifers, springs, seeps, and water supply wells. Waterbody water sources include:

- **Precipitation** falling directly upon the surface of waterbodies can be a significant water source to expansive features such as lakes and wetlands. Precipitation falling directly upon streams and rivers is not typically a significant contributor to a stream or river's total water budget.

- **Surface runoff** (or overland flow) is runoff from precipitation or snowmelt that travels over the land surface to a waterbody. Surface runoff is the primary source of water to most waterbodies during wet weather.

- **Interflow** is lateral movement of water through unsaturated sediment. Interflow delivers precipitation or snowmelt sourced water to streams before it enters groundwater.

- **Hyporheic flow** is stream flow within stream bed materials paralleling the general direction of stream flow. Hyporheic flow commonly persists even when visible stream flow ceases. Hyporheic flow initiates and sustains 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. Water infiltrating the land surface replenishes groundwater supplies.

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 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 water delivered to a waterbody over the year.

The following sections examine factors component to understanding where Mary and Elizabeth Lakes water comes from, how water behaves while in the Lakes, and how water ultimately leaves the Lakes.

Lake Mary and Elizabeth Lake

The Lakes and their tributaries receive water from surface-water and groundwater sources. Two named streams, several small unnamed streams and ditches, broad wetlands, ponds, and reservoirs also occupy lands draining to the Lakes. Lake Mary and Elizabeth Lake and their contributing watershed form a major headwater of Nippersink Creek, the largest single tributary of the Fox River, and a highly valued watercourse in Illinois. This section provides information regarding hydrology, morphometry, general characteristics, and management issues specifically related to Lake Mary and Elizabeth Lake.

Origin

Lake Mary and Elizabeth Lake, along with most other prominent natural waterbodies in the local area, formed after glaciers withdrew from southwestern Kenosha County about 15,000 to 17,000 years ago. As glacial ice melted, vast amounts of sediment were released. Glacial meltwater deposited materials in some areas and eroded sediments in other locations. The valley in which the Lakes is situated likely was created by glacial meltwater eroding sediment near the maximal extent of the most recent glacier reaching southwestern Kenosha County. The Lakes' basins may represent depressions created when chunks of ice broke away from the main body of the glacier, were carried away, were buried in sediment, and later melted.

Morphometry

Several morphologic and hydrologic parameters are used to examine the influence human activity can potentially have on a lake, including those described below.

- **Watershed/lake area ratio** contrasts the open-water area of a lake with the area from which it receives surface-water runoff. Lakes with higher ratios (i.e., large watersheds versus lake size) are considered more vulnerable to human influence and more prone to water quality problems. As a rule of thumb, lakes with a watershed/lake ratio greater than 10:1 often experience some water quality issues.[20] Nevertheless, the way a watershed is used can greatly influence the type and amount of

[20]*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.*

pollutants carried to the Lake. The average watershed/lake area ratio for Wisconsin drainage lakes like the Twin Lakes is 88:1.[21]

Lake Mary receives surface-water runoff from a 566-acre contributing watershed located entirely in Kenosha County. Lake Mary's watershed/lake area ratio is approximately 1.7:1, indicating that the lake acreage is less than half the contributing watershed acreage.

Elizabeth Lake's open-water area measures 753 acres.[22,23] Elizabeth Lake receives water from Lake Mary through a short channel connecting the Lakes. In addition to the runoff it receives that first passes through Lake Mary, Elizabeth Lake receives direct runoff from another 2,845.5 acres in Kenosha and Walworth Counties, Wisconsin and the remaining 2,337 acres located in McHenry County, Illinois[24]. The water quality of runoff entering Elizabeth Lake from Lake Mary benefits from sediment settlement and biogeochemical processes occurring in Lake Mary. This means that the quality of water contributed to Elizabeth Lake from the Lake Mary outlet should be much better than the water quality of typical direct runoff. Therefore, the watershed-to-lake ratio for Elizabeth Lake should consider the surface area of Lake Mary and the watershed contributing to Lake Mary. Without Lake Mary and its watershed, Elizabeth Lake's watershed to lake area ratio is approximately 6.8:1. Even when Lake Mary and its watershed are included, Elizabeth Lake's watershed/lake area ratio is only 8.1. Both Lakes exhibit small watershed/lake area ratios suggesting that both Lakes are less vulnerable to human influence and land use than many of the lakes in the Region.

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[21] Ibid.

[22] *For the purpose of this study, the side channels and bay connected to Elizabeth Lake were considered part of the lake. Approximately 688 acres of Elizabeth Lake are in Wisconsin while 65 acres are in Illinois.*

[23] *In a 2009 plan, the Commission estimated that the Lakes' combined open water area was 953 acres while the WDNR currently estimates the Lakes to cover 1,052 acres. Lake surface area estimates commonly vary. This variability often relates to the methods used to measure lake size, season, prevailing weather, vegetation, and shoreline condition. For example, if aerial imagery is used to estimate lake area, the apparent area of open water may change when viewed from above on account of trees and infringing shoreline vegetation. This can cause the lake to appear larger during dormant seasons. Furthermore, shoreline vegetation changes (e.g. expansion or recession of cattails) could change apparent open water area. The water surface elevation of many lakes responds to precipitation patterns. In such a case, apparent open water lake area may appear larger during wet weather and smaller during drought.*

[24] *According to the Village of Twin Lakes' stormwater management plan, approximately 609 acres of the lands sloping toward Elizabeth Lake in Wisconsin are internally drained. It is not known if any of the lands sloping toward Elizabeth Lake in Illinois are internally drained.*

- **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 on account of the greater length of shoreline available for development. Based upon 1960 mapping completed by the Wisconsin Conservation Department (the forerunner of the WDNR), Lake Mary has a shoreline development factor of 1.41 while Elizabeth Lake's shoreline development factor is similar at 1.55. This means that both lakes have half again as much area as a perfectly round lake, a fact owing to their oblong shapes. The shoreline development factor does not include the canals excavated into riparian wetlands that enable additional lots to gain lake access. Therefore, the relatively low shoreline development factors belie the higher human impact potential on the Lakes.

- **Lake depth** significantly affects the water quality and biology of lakes. Deep lakes (water depths over 20 feet) tend to stratify, a condition that inhibits mixing of a 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 foster anoxic water at depth and geochemical reactions that release nutrients to the water column and degrade water quality. Based upon 1960 Wisconsin Conservation Department bathymetry information, Lake Mary's known maximum depth is 33 feet while Elizabeth Lake's known maximum depth is 32 feet. While neither Lake is particularly deep for their size, both are deep enough to regularly stratify. Therefore, both Lakes' deep-water areas are vulnerable to oxygen depletion during summer. The ramifications of this phenomenon are discussed in Section 2.5, "Water Quality."

Lake Mary's deeper water basins are found in a relatively narrow, elongated, northeast-southwest trending area (see Map 2.7). A prominent shoal extending to the northeast from the Point Road area at the southwest corner of the Lake bisects this area. Expansive gently sloping shallow-water areas flank Lake Mary's eastern and western shorelines while deeper water lies closer to shore at the northeast and southwest ends of the Lake.

Like Lake Mary, deep-water portions of Elizabeth Lake are in a northeast-southwest trending area in the northern half of the Lake (see Map 2.7). Unlike Lake Mary, water depths along Elizabeth Lake's eastern and northeastern shorelines increase relatively rapidly. Elizabeth Lake's western and southern shorelines are flanked by extensive shallow water areas that often abut riparian wetlands. The southern portion of the Lake has broad expanses of very shallow water. Historically, this area may or may not have been open water, depending on weather conditions. It was depicted as open water in 19th century maps. However, the 1861 plat map of the Town of Randall shows a straight roadway completely crossing Elizabeth Lake a short distance north the Illinois border (see Figure 2.6).[25] The depiction of this roadway coincides with a light-colored near straight trace visible on the Lake bottom in modern aerial photographs. Local residents identify this feature as a corduroy road.[26]

- **Lake volume.** Based upon available bathymetric data, Lake Mary has a total volume of 1,870 acre-feet and a computed mean depth of slightly less than six feet while Elizabeth Lake has a total volume of 7,191 acre-feet and a computed mean depth of ten feet.[27] Graphs relating each Lake's depth to its volume and bottom area at a particular depth are presented in Figures 2.7 and 2.8. Slightly more than one third of the surface area of each Lake is underlain by water less than five feet deep.

- **Retention time** refers to the average length of time needed to replace the lake's entire water volume.[28] In general, lakes with larger watershed/lake area ratios have shorter retention times. Retention time is significant because it can help determine how quickly some pollution problems can be resolved. For example, if retention times are short, dissolved pollutants may quickly flush from a lake. In such cases, management efforts may focus on ongoing pollutant and nutrient loads contributed to the lake from the watershed. In contrast, lakes with long retention times tend to

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[25] *The names of the Lakes are reversed in the 1861 plat map.*

[26] *Corduroy roads were a frontier-expedient method of running roadways across wetlands. They consist of logs placed side by side orthogonal to the roadway and often covered with gravel or another material to form a surface capable of bearing traffic.*

[27] *The most recent bathymetric data known to be available from public sources was collected during the 1960s. These maps were published in the following reports: Wisconsin Department of Natural Resources,* Marie Lake, Kenosha County, Wisconsin, *Lake Use Report Number FX-17, 1970 and Wisconsin Department of Natural Resources,* Elizabeth Lake, Kenosha County, Wisconsin, *Lake Use Report Number FX-7, 1969.*

[28] *The terms "flushing rate" and "hydraulic residence time" are also commonly used to describe the amount of time natural water sources require to completely replace one lake volume. Flushing rate is the mathematical 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).*

accumulate nutrients and pollutants. These can eventually become concentrated in bottom sediments. In this case, in addition to preventing ongoing external pollution, it also may be necessary to employ in-lake water quality management efforts. Based on previous water balance studies and lake volume estimates, both Lakes have an average retention time that is about 22 to 23 months.[29] Both are significantly longer than typical Wisconsin inland lakes, which have retention times of about 11 months, a situation likely related to the comparatively small watersheds of both Lake Mary and Elizabeth Lake.

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 surface and water added by direct precipitation and runoff to a lake changes, influencing retention time.[30] For example, long hot, dry weather periods can increase retention time, while long periods of cool, wet weather could decrease retention time.

<u>Water Budgets</u>

Lake Mary has no mapped tributaries but receives runoff from 566.2 acres via a network of small drainageways that includes ditches, natural intermittent streams, and storm sewers. Lake water drains from Lake Mary through a short channel discharging to Elizabeth Lake. Some long-term lake-area residents state that the channel delivering Lake Mary's outflow to Elizabeth Lake occasionally ceases to flow or even reverses flow direction for short periods of time after heavy rainfall.

Given what is known of the local area, and water table elevation contours, Lake Mary likely receives groundwater via modest springs and seeps along its east and west shorelines.[31] The likely source of this groundwater is infiltration under nearby topographically higher areas to the east and west of the Lake. The Lake also loses water to the local groundwater flow systems in some areas. Based upon mapped groundwater elevation contours, Lake water seeps into Lake Mary's bed and shoreline along its northern end, contributing flow to the headwaters of Bassett Creek. Furthermore, under most conditions, Lake Mary's

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[29] *The evaporation rate reported in the 2009 lake management plan may have been overestimated meaning that the lake residence time should actually be somewhat longer than the 1.85 years reported in the plan.*

[30]*In the Twin Lakes area, the amount of precipitation falling on a waterbody's surface is slightly more than two 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.*

[31]*Southeastern Wisconsin Regional Planning Commission,* Groundwater Resources of Southeastern Wisconsin*, Technical Report Number 37, 2002.*

water likely seeps into the bed and shoreline at the south end of Lake Mary, seeping through the isthmus separating the two lakes as groundwater, and ultimately contributing water through springs and seeps located along Elizabeth Lake's northern shoreline.

Considering the information now available, Lake Mary may be best labelled a seepage lake, or, less likely, a drained lake. The WDNR classifies Lake Mary as a deep headwater lake, a classification consistent with observed conditions and interpretations. To protect fish and aquatic life in deep headwater lakes, *Chapter NR 102.06* sets a phosphorus criterion of 20 micrograms per liter for deep headwater lakes such as Lake Mary.

Elizabeth Lake receives runoff from approximately 6,081.7 acres, including the acreage of Lake Mary and its direct tributary lands.[32] Unlike Lake Mary, Elizabeth Lake receives water from several modest-sized perennial tributary streams including Smallwood Creek, Elizabeth Springs Creek, the outlet from Lake Mary, and four mapped unnamed streams. Given what is known of the local area, and water table elevation contours,[33] Elizabeth Lake likely receives groundwater via modest springs and seeps along its east, north, and west shorelines. The source of this groundwater is water seeping from Lake Mary and precipitation seeping into the ground under nearby topographically higher areas east and west of the Lake. The Lake also loses water to the local groundwater flow systems in some areas. Based upon mapped groundwater elevation contours, Lake water seeps into limited portions of Elizabeth Lake's bed and shoreline along its southwestern end, reemerging as seep and spring flow within wetlands flanking the headwaters of the Elizabeth Lake Drain in Illinois.

Considering the information now available, Elizabeth Lake would be best defined as a drainage lake, although, given the apparently intermittent nature of most Lake tributaries, it may at times have conditions similar to a seepage lake. The WDNR classifies Elizabeth Lake as a deep lowland lake, a classification generally consistent with observed conditions. To protect fish and aquatic life in lakes, *Chapter NR 102.06* sets a phosphorus criterion of 30 micrograms per liter for deep drainage lakes such as Elizabeth Lake.

Commission staff refined the water budget for both lakes using weather, stream gaging station, and other data gathered by others. This included estimating groundwater contributions to the Lake's water budget

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[32] *It is not currently known if any portion of Elizabeth Lake's watershed in Illinois is internally drained.*

[33] *Southeastern Wisconsin Regional Planning Commission,* Groundwater Resources of Southeastern Wisconsin*, Technical Report Number 37, 2002.*

using over 50 years of USGS gaging station data collected on Nippersink Creek downstream of the Lakes. The USGS data was also used to estimate the amount of water yielded by the Nippersink watershed for dry, average, and wet weather conditions. These USGS data, along with watershed acreage estimates, allowed the Commission to estimate the amount of water contributed to each lake by groundwater and surface-water runoff. Similarly, local precipitation records and evaporation values allowed water fluxes to and from the Lake's open water surface to be estimated. Based upon outlet flow conditions reported by Twin Lakes-area residents, our water budget assumes that the Lakes behave in an overall hydrologic sense as seepage lakes. Seepage lakes are often supported by, and contribute to, local groundwater flow systems. For this reason, the Commission's simulation assumed that groundwater inflow and outflow were the same for average and wet conditions. Furthermore, to simplify calculations, we assumed that lake water surface elevations, and hence lake volumes, do not change from year to year.[34]

Following the approach described in the previous paragraph, the amount of water flowing into and out of each lake through each hydrologic element was estimated. Table 2.9 summarizes the percentage of the Lakes' inflows and outflows related with various components of the hydrologic cycle for dry, normal, and wet weather conditions. Our amended water budget suggests that Lake Mary receives 2,340 acre-feet of water during a typical year. During extremely dry years, as little as 1,243 acre-feet of water enters Lake Mary, while during extremely wet years, 3,596 acre-feet enters Lake Mary. Similarly, for Elizabeth Lake, 8,421 acre-feet of water enter the Lake during a typical year. During extremely dry years, as little as 3,902 acre-feet enter the Lake, while during extremely wet years, 14,591 acre-feet enter Elizabeth Lake. Precipitation and groundwater combine to form the largest source of water to both Lakes in all but the wettest years. During extremely heavy runoff periods, stormwater reaching the Lakes from their watersheds is the primary source of water to the Lakes. Similarly, most water leaves the Lakes via evaporation and seepage to groundwater except during the heaviest runoff periods. During wet weather or heavy snowmelt, surface-water outlet channels carry the most flow out of the Lakes.

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[34] *Lake Mary's and Elizabeth Lake's water elevation do fluctuate to some degree in response to several factors. Rainfall variations appear to cause up to six inches of water surface elevation in Lake Mary. Elizabeth Lake's water elevation also fluctuates almost one foot in response to precipitation, but other factors, such as blockage in the Elizabeth Lake's outlet channel appear to be more significant. In any case, water level fluctuations are relatively small and, in the most extreme cases, change lake volume by less than 10 percent.*

Lake Water Elevations

In their natural states, the elevations of both Lakes were controlled by the elevations of the beds and conditions of outlet channels. Water levels would undoubtedly vary with changing weather conditions, with the Lakes falling during dry weather and rising during wet weather. In addition to these changes, multiple channel factors would influence lake water surface elevations. Examples of such factors include the type and density of vegetation growing in and along the outlet channels, fallen trees impinging on the channel, accumulated flotsam, and beaver activity.

The original government survey dating to January 1833 suggests that the channel connecting Lake Mary and Elizabeth Lake is a natural feature, with water draining from Lake Mary to Elizabeth Lake which in turn discharged to the waterway now known as the Elizabeth Lake Drain. The actual elevations of the Lakes is not possible to ascertain. After European settlement, humans modified streams connected to the Lakes, causing changes that could reduce water levels within the Lakes. An example is ditching of the Elizabeth Lake Drain and deepening of the channel connecting the Lakes. As is extremely common in Southeastern Wisconsin, dams were built to retain water within the Lakes, possibly to elevations similar to pre-settlement conditions.

Lake Mary

The water level of Lake Mary has been a matter of controversy for over 100 years. A decision made on August 2, 1933, by the Wisconsin Public Service Commission, describes dissatisfaction with changing water levels in Lake Mary.[35] According to the document, before 1886 the channel connecting the two lakes was not navigable except during high water. Around 1886, a "large steam launch was forced through the channel." The brief contends that propeller of this vessel essentially deepened the channel, causing the water level of Lake Mary to fall to artificially low levels. In reaction to this, a log and earth dam was built across the channel in 1886. A concrete dam replaced the log and earth dam in 1896. The 1896 dam was replaced in 1932 with a dam with a larger roller on the crest to facilitate portaging. This roller fitted to the new dam was claimed to hold water levels in Lake Mary excessively high and was ordered to be removed during periods of high water. The Lake Mary dam was last inspected in 1978.

Very little additional information is available regarding the Lake Mary dam. As part of a 2018 shoreline inspection, Commission staff may have observed a submerged concrete structure just upstream of the Lake

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[35] *Public Service Commission of Wisconsin,* Opinions and Decisions of the Public Service Commission of Wisconsin, Volume IV, May 5, 1933 to October 26, 1933*, Docket Number 2-WP-108, pages 898 and 899, 1935,*

Mary outlet channel. Therefore, with the present-day elevation of Elizabeth Lake, the submerged weirlike structure in Lake Mary likely does not influence water levels in Lake Mary. Instead, the Elizabeth Lake outlet dam largely controls the elevation of Lake Mary. Since water commonly flows out of Lake Mary to Elizabeth Lake, Lake Mary's water levels are generally slightly higher than Elizabeth Lake's water elevation, with the possible exception of after extreme precipitation events when flow in the outlet channel reportedly reverses. Residents claim that roughly two feet of soft "muck" sediment has accumulated in the channel connecting the Lakes; this suggests that flow velocities in the channel are extremely low.

Another dam was identified on the north end of Lake Mary, a location with no known outlet stream. The 1970 lake use report includes a figure labelling a spillway near the intersection of County Trunk Highway EW and Barry Road.[36] No dam is visible at this location in historical aerial photographs. However, the lake use report labels a Wisconsin Conservation Department benchmark on the west side of a spillway, and an elevation of 793.9 feet as the elevation of the outlet or spillway.[37] The purpose of this dam, if it existed, is unknown. However, since the lake use report identified the channel connecting the two lakes as the lake outlet, and a dam existing on this channel, it is possible that this depiction is an error and is indeed referring to a dam on the channel connecting the two lakes. Both the Lake Mary and Elizabeth Lake lake-use report clearly depict a dam structure just downstream of Park Drive and describes this dam as "a small concrete spillway on the outlet stream serves to maintain the level of Marie Lake 0.6 above the normal water level of Elizabeth Lake downstream". This conclusion seems to be confirmed by the known Lake Mary outlet dam label having identical benchmark and spillway elevations included in the Elizabeth Lake lake-use report. A dam is not visible on the channel connecting the two lakes on any available historical aerial photograph.

The surface water elevation of Lake Mary was reported as 793.95 feet above mean sea level during either May 1960 or July 1966 and water level fluctuations were reported as "minimal".[38] Lake Mary water elevation data has been consistently collected since at least 1992. According to the 2009 Lake Management Plan, water levels in Lake Mary varied between 793.2 and 795.1 feet NGVD-29 between the years 1992 and 2000,

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[36]*Wisconsin Department of Natural Resources,* Marie Lake, Kenosha County, Wisconsin*, Lake Use Report Number FX-17, 1970.*

[37]*No datum was mentioned but presumably it is referenced to mean sea level.*

[38] *Wisconsin Department of Natural Resources,* Marie Lake, Kenosha County, Wisconsin*, Lake Use Report Number FX-17, 1970*

representing 1.9 feet of water level variation of the period.[39] This included periods of very wet and dry weather. Starting in late 2019, and concluding in late 2021, the USGS monitored water elevations in Lake Mary. Lake Mary's water elevations varied between 793.84 and 794.58, representing a much smaller variation of water levels than those measured between the years 1992 and 2000 (see Figure 2.9). During the 2019 through 2021 time period, the area experienced very wet weather at the beginning of measurement, and dry weather at the end of the period of measurement. The recent measurements suggest that dry-weather lake water surface elevations are higher than in the past while wet-weather water elevations are lower. Therefore, since Lake Mary's water elevations are largely controlled by the elevation of Elizabeth Lake, the better maintained channel connecting Elizabeth Lake and the outlet dam and/or the newly reconstructed Elizabeth Lake outlet configuration appear to be better able to hold desired water levels.

Some residents report occasional flow direction reversal in the channel connecting the two lakes, with water backing up into Lake Mary from Elizabeth Lake during intense precipitation. Available data collected between 2019 and 2021 reveals that water levels in Lake Mary are consistently higher than those in Elizabeth Lake. During periods when water levels rapidly rise, the elevation in the two lakes come close to being equivalent. Given that the new dam appears to better pass large flow events, it is possible that the reported channel flow reversal phenomenon may now be less likely to occur.

Elizabeth Lake

The south end of Elizabeth Lake has an indistinct shoreline. Wetlands flank the open water area of the Lake in this area, making it difficult to exactly identify where the "end" of the Lake may be. Indeed, this extensive marshland likely represents a portion of Elizabeth Lake nearing extinction. The marshland can expand and contract on account of weather, plant management, wildlife interactions with wetlands plants, and other factors.

An open water channel extends from the open water portion of the Lake downstream into Illinois. Portions of this stream channel are extremely straight in historical aerial photographs, suggesting that they were ditched at some point in the past. Where the marshland narrows, a road crosses the stream. Where the roadway crosses the stream, an outlet dam was built to control the elevation of Elizabeth Lake. This dam, located in Illinois a little less than a half mile downstream of Elizabeth Lake, crosses a natural area with luxuriant wetland vegetation and known beaver and muskrat activity. The channel is not considered

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[39] *SEWRPC CAPR No. 302,* A Lake Management Plan for Elizabeth Lake and Lake Mary, Kenosha County, Wisconsin: Volume One, Inventory Findings*, July 2009*.

navigable under Illinois law and cannot, therefore, be lawfully entered. The channel's configuration and location make it prone to debris jams and beaver damming.

Water levels in Elizabeth Lake have been a matter of contention for many years, including complaints of excessively high water and excessive water level variation. The outlet dam has been perceived by some to be largely responsible for these issues. The Elizabeth Lake outlet dam was recently reconstructed. partially in response to this perception. During public meetings held during 2017 and 2018, Commission staff presented other factors that seem to be likely causes for water level issues. Perhaps the most important finding was the presence of debris jams and beaver dams between Elizabeth Lake and the dam site. When debris jams and/or beaver dams impede flow, the dam itself no longer controls the level of Elizabeth Lake. After jams and dams were removed in the channel, the Lake's level remained in a more acceptable range and overall elevation. However, given the private ownership of the channel, negotiating entrance and work in the channel can be complicated.

At the time of the 2017/2018 meetings mentioned above, no good source of water elevation data was available to judge the efficiency of water conveyance along the channel connecting Elizabeth Lake and the outlet dam site. As part of Commission recommendations, accurate water level data began to be collected in the Lake and at the dam site. The Village commissioned the United States Geological Survey to install two water elevation gaging stations, one in the Lake, and the other just upstream of the outlet dam. These gages have been collecting water elevation at both locations for over 5 years (see Figure 2.9). These data were used to produce a third graph depicting the difference of water level between the Lake and the dam site (see Figure 2.10). If the dam actually controls Lake water elevations, the difference in elevation between the Lake gage and the dam site gage would be zero.

As can be seen from Figure 2.10, jams and dams in the outlet channel influence the water level in Elizabeth Lake most of the time. The magnitude of this influence seems to be greatest during the summer during both 2019 and 2020, seemingly after large runoff events. Starting in 2021, large runoff events did not occur, and the magnitude of the channel backwater effect oscillated between a high of roughly six inches and a low of roughly an inch. Whatever the case, the dam has not controlled the water level of Elizabeth Lake from the summer of 2021 through the winter of 2023/2024. Instead, channel blockages influenced the water level.

Other Surface-Water Features

Mary and Elizabeth Lakes are the dominant water resource features in the Twin Lakes area. Nevertheless, the surrounding uplands are interspersed with ponds, small lakes, small/ephemeral watercourses, and wetlands, many of which are interconnected. Smaller water resource features and their floodplains provide extremely important stormwater detention, water quality enhancement, and ecological functions. Elizabeth Lake receives water from several modest-sized perennial tributary streams including Smallwood Creek, Elizabeth Springs Creek, the outlet from Lake Mary, and four significant mapped unnamed streams. Six of the seven mapped tributaries are first-order streams. Elizabeth Springs Creek is a second-order stream, while the Elizabeth Lake Drain leaves the Lake as a third-order stream.[40] No mapped perennial streams contribute water to Lake Mary.

Historical soil maps identify intermittent drainageways flowing toward the lakes.[41] The channels of most unmapped intermittent drainageways become indistinct near Elizabeth Lake (see Map 2.8). The largest intermittent drainageway feeds Lake Mary through a channel excavated into wetlands along the Lake's western shoreline. This artificial channel likely follows the original trace of a natural intermittent drainageway. Historical soil survey mapping also depicts small intermittent drainageways leading to Lake Mary from the uplands east of the lake. Many of these intermittent drainageways now likely continue to flow underground through storm sewers and still discharge to Lake Mary. The Village of Twin Lakes maps eight storm sewer outfalls discharging to Lake Mary. Most are found along Lake Mary's eastern and northern shorelines (see Map 2.9). Other, privately owned, undocumented, storm sewers also lead to Lake Mary. For example, lake residents estimated that roughly ten such private storm sewers are found on the isthmus separating Lake Mary from Elizabeth Lake and were likely installed roughly 100 years ago.

The mouths of some streams were ditched to provide additional lake access via canals from otherwise off-lake lots. These canals are primarily found along the Lake's western shoreline. Excavated canals form the mouth of some natural tributary streams. Additionally, some streams and many ephemeral drainage ways were redirected to flow underground, discharging to the Lake via storm sewer outfalls (see Map 2.8). As is

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[40] *Stream order refers to a stream classification concept developed by Arthur Strahler and Robert Horton during the 1940s and 1950s. Headwater perennial tributaries are assigned a stream order of 1 and are labelled first-order streams. When two first-order streams converge, a second-order stream is formed, when two second-order streams converge, a third-order stream is formed, and so on. When a lesser order stream converges with a higher order stream, the larger stream's order remains unchanged.*

[41] *Link, Ernest G and Owen R. Demo,* Soil Survey of Kenosha and Racine Counties, Wisconsin, *op. cit*.

the case with Lake Mary, numerous small private storm sewers are likely to convey modest quantities of runoff to the Lake.

Groundwater Resources

General Principles and Importance

Groundwater is a dynamic, vital resource yet it is not visible for casual observation except where it discharges to surface water (e.g., springs and seeps). Precipitation falling in the local area is the ultimate source of essentially all Southeastern Wisconsin's groundwater. Water held in moist sediment above the water table (the "vadose zone") can either return to the atmosphere via evapotranspiration or may move to aquifers if additional percolation increases soil moisture. Water that percolates into the land surface or into the bed of a waterbody and does not quickly return to the surface via evapotranspiration or by re-entering waterbodies, and ultimately reaches subsurface areas of saturation, is termed groundwater. The water elevation in the shallowest laterally extensive saturated strata is commonly referred to as the "water table"[42]

Even though groundwater is largely invisible, it is vitally important to the Region's ecology and human inhabitants. The amount of groundwater available to wells and discharging to seeps and springs, as well as its ability to help moderate floods and support natural resource features, is controlled by a plethora of natural and human-induced factors such as precipitation, topography, soil permeability and structure, land use, potable water supply, and the water-bearing properties of sediments. Balancing growing human demands with long-term sustainability and ecosystem health necessitates careful, enlightened groundwater resource planning and management.

Private and public water supplies throughout inland portions of Southeastern Wisconsin depend entirely upon groundwater making it a natural resource crucial to modern human habitation. In general, the Region's groundwater supplies adequately support growing human populations, agricultural demands, commerce, and diverse industrial uses. However, overexploitation and attendant water shortages may occur in areas of concentrated development, intensive landscape manipulation, inconducive geology, and/or intense human water demand. In addition to providing potable water for human needs, groundwater systems help attenuate runoff volumes, reducing flood risks along lake and stream corridors.

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[42] *In some instances, saturated areas are created by water accumulating on impermeable layers buried in the subsurface. Such saturated areas can be underlain by unsaturated sediment and are termed "perched" water table aquifers.*

In addition to providing for human needs and desires, groundwater is vital to terrestrial and aquatic ecosystem health. Groundwater is often the only natural source of water to surface-water features during dry weather and is therefore critical to healthy stream ecology. Groundwater modulates flood, fair-weather, and drought stream flows by detaining water during wet weather and gradually releasing it to surface water features over extended time periods. Reduced flow volumes during wet weather help reduce erosion in uplands along watercourses, thereby contributing to improved water quality and ecosystem health.

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. Groundwater-derived baseflow sustains waterbodies allowing them to maintain a diverse assemblage of plants and animals and enable them to provide unique ecological functions. Since groundwater is a key component of most surface-water features' water supplies, protecting groundwater is a key component to protecting waterbody health.

Aquifers

Groundwater is stored and moves in pore spaces and fractures found in unconsolidated sediment and bedrock.[43] Groundwater recharge, movement, and discharge are controlled by a variety of factors including precipitation, topography, soil or rock permeability and structure, land use, and the lithology and water-bearing properties of sediments and bedrock units. Unconsolidated sediment and bedrock units with significant interconnected porosity and/or fracturing can supply useable amounts of water over prolonged periods and are referred to as "aquifers." Three aquifers underlie the Twin Lakes watershed, as summarized below in order of increasing depth from the land surface.

- **Sand and gravel aquifer**. This aquifer consists of porous, coarse-grained, sand and gravel; materials primarily deposited by glacial action. Its thickness and properties vary widely. Nevertheless, it is an important water supply aquifer in portions of western Kenosha County. Roughly 100 to 300 feet of

[43] *A common local myth suggests that groundwater is derived from underground rivers flowing from northern Wisconsin (e.g., Lake Superior). Although a few small caves are found in Southeastern Wisconsin, they are not significant contributors to overall groundwater flow and do not extend appreciable distances and are not conduits for underground rivers.*

unconsolidated sediment overlay bedrock in most areas near Twin Lakes.[44] According to well driller logs, some layers of sand and gravel can be sufficiently porous to be considered an aquifer. Sand and gravel lenses in unconsolidated sediment continue to be used for water supply purposes, with new wells installed in the past 10 years. The sand and gravel aquifer is commonly in good hydraulic communication with the underlying Silurian dolomite aquifer.

Water in the sand and gravel aquifer originates as precipitation infiltrating in upland areas or seeping into the beds and banks of water features. The sand and gravel aquifer supplies the water discharging from most local springs and seeps. Therefore, the sand and gravel aquifer is very important to sustaining water elevations and flows in local lakes and streams during dry weather. The sand and gravel aquifer is highly vulnerable to contamination and over exploitation. Much of the water feeding this shallow aquifer infiltrates the land surface in the immediate area. Water quality and quantity can therefore be significantly influenced by local land use change.

- **Silurian dolomite (Niagara) aquifer**. Water in this aquifer is stored and moves primarily in bedrock fractures. Essentially all of the water found in this aquifer is derived from local precipitation that either falls upon exposed bedrock or infiltrates from the surface through porous glacial sediment. Although its water-bearing characteristics and thickness vary widely, it underlies essentially all of Kenosha County, is relatively easy to access at a reasonable cost, and is therefore a very important potable 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 sometimes referred to as the "Niagara Aquifer".

- **Sandstone aquifer.** The sandstone aquifer is deeply buried and is hydraulically isolated from the sand and gravel and Silurian dolomite aquifers by a thick layer of relatively impermeable shale bedrock. 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. Since a thick layer of low permeability shale overlies the sandstone aquifer over the entire Twin Lakes watershed, much of the water found in the sandstone aquifer below the Twin Lakes watershed infiltrates farther to the west. For this reason, the sandstone aquifer is less vulnerable to pollutant sources located in the Twin Lakes watershed. The sandstone aquifer is an important public and industrial water supply, but because of

[44] *Peters, R. M., Preliminary Depth to Bedrock Map of Kenosha County, Wisconsin, Wisconsin* op. cit., *2004.*

the cost of establishing deep wells, is not commonly used for residential water supplies in most of Southeastern Wisconsin.

Flow Direction and Interaction with Surface-Water Features

Groundwater recharge/discharge systems occur on many spatial and time scales. Long regional recharge/discharge relationships and short localized flow paths can both potentially contribute to a water body's overall water budget. The directions and origins of regional groundwater flow paths may differ from the area feeding surface-water runoff to a waterbody. Therefore, some groundwater feeding a waterbody may originate in distant areas and/or outside the waterbody's watershed. The relationship between short- and long-distance flow paths is illustrated in Figure 2.11.

Smaller-scale shallow, local groundwater flow paths commonly approximate surface-water flow paths. However, to estimate the direction of more regionally extensive flow systems, groundwater elevations measured in water supply or monitoring wells should be consulted. Since water normally moves perpendicular to elevation contours, groundwater flow directions can be predicted. When performing such analyses, the locations and elevations of streams, ponds, and lakes must be considered. This relationship can be used to predict if a surface water body is fed by groundwater, recharges groundwater, or has little interaction with groundwater. By combining these data, maps can identify land areas contributing recharge to groundwater systems feeding waterbodies. Such areas help sustain lake levels and stream flows during dry weather.

In most instances, water table elevation contours are a subdued reflection of surface topography. Topographically higher lands are commonly groundwater recharge areas whereas most major lakes, rivers and wetlands are groundwater discharge areas. The Commission mapped estimated water table groundwater elevations throughout the Region.[45] These water table elevation contours help identify groundwater flow direction and the land area contributing water to lakes and streams.

As illustrated in Figure 2.11, groundwater and surface-water systems are interconnected. Surface runoff and interflow are most important during storms or snowmelt. Their contributions are typically combined into a single term called direct runoff. Groundwater, on the other hand, sustains waterbodies during dry periods and is usually a substantial component of the total water volume reaching a waterbody over an entire year.

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

Groundwater seeps through a waterbody's bed and/or banks and influences stream flow. When water table elevations are higher than the adjacent waterbody, water seeps from the waterbody's bed or banks and into the lake or stream, adding to stream flow or sustaining lake elevation (see Figure 2.12, "Gaining Stream"). Conversely, a waterbody will recharge groundwater flow systems when water table elevations are lower than the waterbody's elevation. In such instances, water seeps through the bed or banks into the underlying groundwater system (see Figure 2.12, "Losing Stream"). Streams can have both gaining and losing reaches and the extent and location of these reaches may change based upon prevailing conditions. In the absence of contributions from runoff or human discharge points, or depletions caused by human withdrawals or evapotranspiration, streamflow increase along gaining reaches and decrease along losing reaches.

The rate at which water flows between a stream and an adjacent groundwater flow system is influenced by the hydraulic gradient between the waterbody and the water bearing strata as well as the hydraulic conductivity of geologic materials located at the groundwater/surface-water interface. For instance, clayey sediment tend to reduce flow between a stream and underlying sediments compared to a sandy or gravelly sediment. Losing stream reaches can occur under conditions in which the underlying sediments are fully saturated or when the sediments are unsaturated. A losing stream reach underlain by an unsaturated zone is said to be disconnected from the underlying groundwater flow system. Some stream reaches are ephemeral (that is, they periodically cease flowing), and, consequently, interchange of water between the stream and underlying groundwater flow system may periodically cease. Since precipitation rates, evapotranspiration, water table elevations, and human-induced hydrologic stressors vary with time, a particular stream reach can switch between gaining and losing conditions from one period to another.

By combining groundwater recharge potential, groundwater flow direction, and waterbody elevation data, a broad understanding of the interconnected nature of surface water and groundwater resources can be surmised. Maps can be prepared identifying land areas more conducive to groundwater recharge feeding certain water resource features, and therefore representing superior areas to protect baseflow to waterbodies and water supplies. Such maps help illustrate the subsurface routes groundwater follows through a landscape and whether waterbodies gain or lose water to the groundwater flow system. This information helps resource managers plan where work should be focused. For example, such information can help resource managers identify priority parcels where action can be taken to maintain or enhance the landscape's ability to provide groundwater recharge. Furthermore, this information can help identify areas where stormwater management features can best contribute to groundwater recharge.

Groundwater Recharge

Groundwater supplies are replenished by precipitation or runoff soaking into the ground and entering aquifers. Water that infiltrates the land surface and enters aquifers is often referred to as "groundwater recharge." Although precipitation is the ultimate source of essentially all groundwater recharge, groundwater recharge is not uniform across the landscape, does not always occur at the point where precipitation initially strikes the Earth, and does not necessarily occur throughout the year. For example, relatively flat undeveloped areas underlain by layers of granular permeable mineral soil typically contribute more water to groundwater recharge and are therefore identified as having high or very high groundwater recharge potential. In contrast, hilly areas underlain with low permeability soil (e.g., clay) and drained by storm sewers commonly contribute less water to groundwater recharge and are typically classified as having low recharge potential. Runoff leaving areas less conducive to groundwater recharge can still contribute to groundwater recharge at locations farther downstream. Most groundwater recharge typically occurs during periods of low natural water demand (i.e., when plants are dormant) and/or during periods of abundant precipitation or snowmelt. Small summer rains contribute little to groundwater recharge even on the best sites because growing plants draw water from the soil and higher temperatures increase evaporation.

Evaluating groundwater recharge potential helps identify areas most important to sustainable groundwater supplies. The Commission evaluated groundwater recharge potential throughout Southeastern Wisconsin.[46] Groundwater recharge potential data can help planners locate areas that should not be covered with impervious surfaces and/or where infiltration basins would be most effective.

Development's Effects on Groundwater

Groundwater supplies are commonly vulnerable to unintended, human-induced, depletion and degradation. Humans deplete groundwater flow systems in two primary ways. The first is by actively pumping water from aquifers which reduces, or in extreme cases eliminates, natural groundwater discharge through springs and seeps. The second is by reducing groundwater recharge through land use changes that modify vegetation, decrease soil permeability, increase impervious cover, and/or hasten runoff. These two groundwater depletion factors typically occur simultaneously in urbanized areas. Human activity can also introduce substances into groundwater that compromise its quality and diminish its value as a potable water source or as a water supply to natural waterbodies. Common examples of contaminants introduced by human activity include salts, metals, petroleum constituents, and organic substances.

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

Since groundwater-dependent waterbodies typically respond slowly to change, diminished groundwater contributions to the Lakes may only be noticeable over extended lengths of time. This situation illustrates the need for ongoing vigilance and pre-emptive monitoring. Consequently, practices that protect the amount and quality of water feeding groundwater systems tributary to the Lakes must be integral to overall planning efforts addressing the Lakes.

Despite laws mandating runoff infiltration, as practical, in new developments, new land development typically reduces the landscape's ability to absorb water and supply groundwater recharge.[47] 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 amounts of water, but can negatively impact nearby surface water resources, and are generally more vulnerable to contamination than deep 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.[48] When high-capacity wells are planned in shallow aquifers, the Commission's regional water supply plan recommends studies to evaluate potential negative effects.[49] The plan also calls for installing systems enhancing infiltration of high-quality water when studies predict a potentially significant reduction in baseflow to surface-water features.

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

[48] *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).*

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

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

- Development density and location
- The amount of pumped water exported from the groundwatershed
- Aquifer properties and the characteristics of existing water resource features

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.

Most urbanized areas developed before approximately 1990 route stormwater runoff directly to surface water; this situation discourages groundwater recharge in broad upland areas. Beginning in 1990, *Wisconsin Administrative Code Chapter NR 151, "Runoff Management"* code requirements call to detain/infiltrate runoff from new development where practicable. Nevertheless, most development still reduces groundwater recharge compared to pre-development conditions.

Groundwater recharge can be reduced in many ways, including the following examples.

- Hastening stormwater runoff by channeling water through pipes or straightening streams.
- Disrupting native vegetation and reducing soil's ability to absorb water (e.g., soil compaction, disrupted soil structure).
- Ditching, tiling, and otherwise draining areas where ponding is prevalent or that are wet.
- Preventing floodwater from spreading out on floodplains. This can occur when fill is placed or when streams are ditched.

- Changing soil structure in ways that reduce soil permeability. Examples include compaction, intensive tilling, and soil salinization.

- Increasing the amount of impervious land cover.

All these issues reduce stormwater infiltration, increase runoff, increase downstream flooding, and threaten groundwater supplies.

If sanitary sewers are installed in areas served by private water supply wells, water formerly re-entering shallow aquifers from wastewater dispersal is often conveyed to discharge points outside of the watershed. This situation can also reduce the volume of groundwater discharging to local seeps, springs, lakes, streams, or wetlands. Development and land management activities need to consider groundwater recharge and actions to protect and enhance recharge should be a priority. Some communities have passed groundwater ordinances to protect precious resource elements and help assure groundwater supplies are sustainable in the long term.[50]

As is obvious from the preceding discussion, 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. A well-publicized example of unsustainable groundwater use is extraction from the deep sandstone aquifer. Water levels in the deep sandstone aquifer once rose above the ground surface meaning that water in drilled wells discharged to the surface without pumping in many areas. The quality and abundance of this resource made it a prime target for high volume wells. Heavy withdrawals throughout the region caused this aquifer's water levels to decline hundreds of feet since the 1800s, as shown in Figure 2.13, "Figure A."

In much of the Region, including the Twin Lakes watershed, water movement between the shallow sand and gravel and dolomite aquifer and the deep sandstone aquifer is limited by the low permeability

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[50] The Village of Richfield in Washington County passed a groundwater protection ordinance over 10 years ago and uses the ordinance as a tool to regulate development that is consistent with long-term sustainability. More information about Richfield's groundwater ordinance can be found at the following website: www.richfieldwi.gov/index.aspx?NID=300.

Maquoketa shale aquitard. This aquitard forms a relatively impermeable barrier between direct surface recharge and the deep sandstone aquifer. As a result, local groundwater recharge to the sandstone aquifer has been much less than the water volume extracted by pumping, resulting in progressively lower water levels in the deep sandstone aquifer. The drawdowns of the deep aquifer are indicative of a water budget deficit and are the combined result of pumping primarily in southeastern Wisconsin and northeastern Illinois. In contrast, drawdowns in the shallow aquifer throughout the Region are much smaller (see Figure 2.13, "Figure B") despite that nearly twice the amount of water is extracted from it compared to the sandstone aquifer. The reason for the lesser drawdown is that the shallow aquifer receives recharge from precipitation and is also often hydraulically linked directly to surface-water features.

Stormwater Runoff

Human activity generally diminishes a landscape's ability to detain and absorb runoff. In turn, the amount of precipitation leaving the land surface as stormwater runoff increases, runoff leaves a watershed more quickly, and groundwater recharge volumes decrease (see Figure 2.14). This is largely related to human development's propensity to cover natural soils with impervious surfaces such as roofs and pavement. This activity, along with human-induced soil compaction and vegetation changes, reduces the volume of stormwater detained on the land surface, lessens natural soil permeability, and compromises the ability of vegetation to absorb precipitation.

Human landscape influences commonly cause runoff to be delivered to waterbodies more quickly. Runoff is hastened by a variety of human activities including installing landcovers that rapidly shed and convey water, grading areas to eliminate temporary ponding, ditching sinuous streams to shorten stream channel length, installing drainage tiles in wet areas, removing streamside vegetation and in-channel features that increase channel roughness and slow runoff speed, compromising the ability of floodwaters to spread onto floodplains, and installing storm sewer systems that rely upon buried pipes or lined channels. All these examples promote stormwater runoff and snowmelt to be quickly and directly conveyed to lakes and streams, increasing runoff volumes and decreasing runoff detention times. This is the root cause of human-influenced waterbodies exhibiting "flashy" hydrographs – a situation where stormwater runoff levels and flow volumes change quickly and more radically than under natural conditions in reaction to precipitation or snowmelt (see Figure 2.15).

Historically, human influence has almost always increased the volume of water transmitted by waterbodies during high-runoff periods and diminished dry-weather flow. These changes have a great potential to negatively influence waterbody hydrology and health as well as overall ecological health. For examples, human-induced changes often:

- Increase flood elevations
- Destabilize waterbody beds and banks
- Diminish the diversity and human-perceived value of aquatic organism communities
- Threaten the overall health and sustainability of a variety of aquatic, riparian, and terrestrial ecological communities
- Compromise overall waterbody and riparian function and value,
- Exacerbate water navigability and safety concerns, and
- Threaten infrastructure integrity or shorten its lifespan.

To help mitigate the negative effects associated with human land use, modern stormwater regulations mandate positive action to dampen the negative influence of human-induced change on watershed hydrology.[51,52,53] Impervious surfaces draining to engineered storm sewer systems are an excellent example of a common feature influencing runoff quality, quantity, and timing. Directly connected impervious surfaces increase runoff volume and velocity during and directly after rainfall events. Many studies link increased impervious land surface areas 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

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

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

[53] *Wang, L., J. Lyons, P. Kanehl, R. Bannerman, and E. Emmons 200*0, "Watershed Urbanization and Changes in Fish Communities in Southeastern Wisconsin Streams", *Journal of the American Water Resources Association,* 36:5(1173-1187).

streams with more than 12 percent watershed impervious surface consistently have poor fish communities.[54] Consequently, reducing impervious land cover, or installing purpose-built features 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. Recommendations on how to mitigate runoff intensity while increasing groundwater recharge and stream baseflow are provided in chapter 3.

Waterbody Depletion

Unmanaged groundwater extraction and/or human-induced groundwater recharge reduction can adversely affect the quality and quantity of potable water supplies and habitat sustaining desirable organisms. One of the most visible effects is reduced dry-weather flow volumes in streams and lower surface-water elevations in lakes, a process called waterbody depletion. Depletion stems from reduced discharge from springs and seeps feeding waterbodies and affects lakes, ponds, streams, rivers, and wetlands.

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 factors (e.g., weather patterns and climate change) 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:

- When considered alone, individual water extraction points may not noticeably change surface-water and/or groundwater conditions. However, focused pumping, well clusters, unfavorable aquifer properties, and/or other factors can combine to significantly decrease groundwater discharge to surface-water features.

- Diminished groundwater discharge may be most evident within certain waterbodies or may be pervasive throughout the area.

[54] *Wang, L., J. Lyons, and P. Kanehl 2001, Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spatial Scales.* Environmental Managemen*t, 28(2):255-266.*

- Basin-wide development typically occurs over decades. Therefore, resulting cumulative depletion effects may only begin to slowly manifest themselves after decades. Such slow rates of change may be difficult to notice by casual observation.

- Depletion effects may persist after groundwater withdrawals end and/or recharge is restored. Aquifers take time to recover from long-term stress. In some aquifers, maximum depletion may occur after pumping stops. Natural water levels and flow patterns may take decades or centuries to recover or, in some instances, may never fully recover.

- Depletion can affect water quality in surface-water features and/or aquifers. For example, groundwater discharge sustains dry-weather habitat for fish and other aquatic organisms in many streams. Groundwater moderates seasonal temperature fluctuations, cooling stream temperatures in summer and warming stream temperatures in winter. Reduced groundwater discharge can diminish temperature moderation.

- Distance, aquifer properties, and the nature of recharge reduction and/or withdrawal affect depletion timing and intensity.

- Reduced groundwater discharge may be most pronounced in certain waterbodies or waterbody segments or may be pervasive throughout the watershed.

Management Tools – Plans and Models

The Commission developed a water supply system plan for the Southeastern Wisconsin Region that considers existing water demands, future development, sustainability, and protection of natural resource features.[55] This plan is the third component of the Commission's regional water supply planning program. The other two elements were a groundwater resource inventory and a regional groundwater model.[56,57] The regional aquifer simulation model predicts water levels in the deep and shallow aquifers under historical, current, and planned conditions and allows the effects of different groundwater management alternatives on surface water resources to be simulated. Furthermore, the model provides a framework within which

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[55]Ibid.

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

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

more-detailed “inset” models may be developed to investigate site-specific groundwater-related questions, including the possible effects of wells on surface-water resources. In summary, the model allows the following questions to be addressed:

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

While the resolution of the regional groundwater models was considered sufficient and valid to compare differences in alternative plans, it may not be sufficiently fine to predict site-specific impacts or may not be able to resolve differences in impact between nearby surface-water or groundwater features.[58] Simulating conditions over a relatively small area such as the Twin Lakes watershed would likely require a refined inset model that includes more detailed site-specific hydrogeological data and smaller model cell size. As noted previously, in cases where development of high-capacity wells in the shallow aquifer could negatively affect surface water resources, the Commission regional water supply plan recommends conducting detailed site-specific studies to evaluate potential negative effects and installing enhanced rainfall infiltration systems in areas where such studies indicate a potential significant reduction in baseflow to surface waters.

One of the most accessible and easily applied tools developed as part of the Commission’s water supply planning effort is the groundwater recharge potential map. This tool is derived from a soil-water balance recharge model covering Southeastern Wisconsin. Understanding groundwater recharge potential and its distribution over the landscape are key to making informed land use decisions, decisions that jointly consider human and environmental needs. Unlike the regional groundwater model discussed above, groundwater recharge potential maps are plotted at a significantly smaller grid size (about 100 feet on a side) and can therefore be directly employed for local planning purposes. Therefore, the Commission’s groundwater recharge potential maps can be directly used to identify and protect areas that contribute the most to shallow water supply wells and the baseflow of the lakes, streams, springs, seeps, and wetlands in

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[58] Since the average grid cell size of the groundwater simulation model is over one-quarter square mile (about 2,500 feet on a side), the results from this regional modeling effort are not sufficiently detailed to estimate the impact of groundwater withdrawal on a site-specific basis. In other words, the Twin Lakes watershed is too small to use the regional model for local groundwater supply planning purposes.

the Twin Lakes watershed. Actively using these maps as part of land use planning and development decisions can tangibly contribute to the goals of sustainable groundwater use and a healthy natural environment. As an example, 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.[59] 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.

In summary, sustainable groundwater supplies provide a reliable source of high-quality water that supports both short-term and long-term human needs and desires as well as ecological health. Human needs and desires include supporting existing and new residences and commerce, avoiding undue negative influence on existing wells and natural groundwater discharge areas, protecting groundwater-dependent natural resource features, and protecting water quality.

Conditions in the Twin Lakes Area

Groundwater supplies nearly all the water needed by residences and industry within and near the Twin Lakes watershed. Groundwater is a critical component of the Lakes' overall water supply, providing cool, clean water to the Lakes and their tributaries, maintaining surface water elevations and stream baseflow during dry periods, and sustaining the ecology of the Lakes and their connected water resource features. Unrestricted development and groundwater exploitation can imperil community water supplies, flood modulation, and ecosystem health. To help understand where problems may exist and where management efforts can best be applied to groundwater supplies feeding Lake Mary and Elizabeth Lake, Commission staff examined groundwater elevation contours and groundwater recharge potential in the surrounding area.[60] This inventory was not confined to the surface-water watershed, as was the case for the other inventories completed as part of this study, since groundwater flow paths may extend beyond the area contributing surface-water runoff to the Lakes.

Water table elevation contours underlying the portion of Southeastern Wisconsin near Lake Mary and Elizabeth Lake area are shown in Map 2.10 and Table 2.10. Depth to groundwater varies considerably across the landscape. In and near waterbodies and wetlands, groundwater is generally found near the land surface.

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

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

In contrast, under prominent uplands, the water table can be up to 70 feet below the land surface.[61] The Lakes lie in a shallow trough in local water table contours. This means that groundwater from shallow aquifers discharges to the Lakes, helping sustain water levels and discharge over the outlet dam. Based upon groundwater contour lines, springs and seeps along or near the Lakes' northwestern and southeastern shorelines likely contribute groundwater to the Lakes. The northern end of Lake Mary and the southern end of Elizabeth Lake likely lose water to the groundwater flow system. Lake water infiltrating into the shoreline and Lake bottom near the north end of Lake Mary likely reemerges as springs and seeps in the headwaters of Bassett Creek. Similarly, Lake water infiltrating into the shorelines and Lake bottom near the south end of Elizabeth Lake likely contributes flow to the Elizabeth Lake Drain in Illinois.

Groundwater feeding both Lakes originates as precipitation and surface water infiltrating through the ground surface over an area much larger than the area contributing surface-water runoff. The portion of Southeastern Wisconsin where infiltrating precipitation and surface water may ultimately discharge to the Lakes is illustrated in Map 2.11 and Table 2.11. The area recharging shallow aquifers supplying groundwater to the Lakes extends up to about 4.5 miles to the northwest and up to about 1.5 miles to the southeast. Land in this area has varying water infiltration capacity and ability to recharge groundwater supplies. While broad portions of the Lakes' groundwatershed are underlain by areas having high groundwater recharge potential, areas west of the Lakes also have significant acreages identified as having very high groundwater recharge potential. Consequently, springs and seeps along the northwestern shorelines of both Lakes likely contribute the most groundwater to the Lakes. Smaller springs and seeps also likely occur along the southeastern shorelines of both Lakes.

A water budget was completed for both lakes as part of a 1993 study.[62] This study reported that groundwater is a dominant feature in both Lake's hydrology. The Commission's 2009 lake management plan reported that groundwater was the source of over a quarter of the Lake Mary annual water supply and over a fifth of Lake Elizabeth's annual water supply. Furthermore, on an annual basis, more water leaves the Lakes via groundwater than flows over the Lake outlet dam.[63] The water budget constructed for this study

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[61] *The depth to groundwater for a particular area can be estimated by subtracting plotted water table elevations from surface elevation values.*

[62] *Discovery Group, Ltd., Madison, Wisconsin and Blue Water Science, St. Paul, Minnesota,* Lake Management Plan, Twin Lakes Protective and Rehabilitation District, Twin Lakes, Wisconsin*, Revised February 18, 1993.*

[63] *SEWRPC Community Assistance Planning Report Number 302*, op. cit.

indicated that groundwater contributes 30% of the water supply for Lake Mary and 52% of Elizabeth Lake's water supply (see Table 2.9).

Numerous water supply wells have been drilled throughout the area contributing groundwater to the Lakes. Well clusters center on highly developed areas such as within the Village of Twin Lakes and near prominent lakes. Some of these wells are permitted as high-capacity wells, wells that have the capacity to withdraw more than 100,000 gallons of water per day. High-capacity wells typically serve schools, apartment buildings, mining concerns, golf courses, and other needs. All wells, as well as other human-induced groundwater withdrawals such as construction and quarry dewatering, divert groundwater from natural discharge points and therefore can reduce the flow of springs, seeps, and streams. Therefore, human groundwater demand should be considered as part of lake management planning.

The more densely populated portions of the Twin Lakes groundwatershed are either presently served, or are planned to be served, by public sewers (see Map 2.12). Essentially all wastewater discharged to public sanitary sewers in the Twin Lakes groundwatershed is exported from the area contributing groundwater to Mary and Elizabeth Lakes. Since much of the water discharged to sanitary sewers originates as groundwater drawn within the Twin Lakes groundwatershed, residential and commercial water use in areas served by public wastewater collection systems represents a significant net artificial demand placed upon the groundwater flow system feeding Mary and Elizabeth Lakes, decreasing the volume of groundwater discharging to the Lakes and their tributaries. The Village of Twin Lakes wastewater treatment plant discharges up to 750,000 gallons of treated effluent per day, representing an equivalent net reduction of water discharged to the Lakes. This is equivalent to slightly more than one cubic foot per second.

Since the Lakes water surface elevations are not known to be excessively low during dry weather, groundwater pumping and impervious surfaces apparently have not yet unduly reduced baseflow to the Lakes. Nevertheless, since groundwater flow systems react only slowly to change, decreased baseflow may only be noticeable with time, and vigilance is warranted. Consequently, to maintain groundwater baseflow to the Lakes and their tributary waterbodies, high-priority groundwater recharge areas should be identified for protection and watershed-wide practices that enhance recharge should be initiated. Recommendations to detain runoff and enhance groundwater recharge are provided in Chapter 3.

2.3 LAKE SHORELINES

Shoreline Evaluation

Commission staff were guided on a shoreline survey of both Lake Mary and Elizabeth Lake on September 11, 2018. The guides were two lake residents, one who resided on Lake Mary and another who resided on Elizabeth Lake. Each guide donated their time and use of their boat to complete the survey with Commission staff. Commission staff along with their guides completed a loop of each lake looking for areas of interest such as point source runoff and shoreline damage. When conducting the survey of the shoreline for Lake Mary, the crew started at 334 Indian Point Road and proceeded to follow the shoreline counterclockwise around the lake. Additionally, when the shoreline survey was conducted on Elizabeth Lake, the crew began at 110 Cobblestone Court and proceeded in a counterclockwise direction following the shoreline. The guide, both of whom had lived on the lake for some time, narrated the survey explaining things about the lake and shoreline that Commission staff may otherwise not have known.

On Lake Mary, 30 of these "points of interest" were located and described (see Map 2.9 and Appendix A). On Elizabeth Lake, 48 of these "points of interest" were documented (see Map 2.8 and Appendix B). To further identify points of interest, the Commission took photographs as well and videoed the shoreline using a GoPro camera.

Of the total 78 points of interest documented on the Twin Lakes, 19 are sources of direct stormwater runoff into the lake. Lake Mary has 14 of these sources of stormwater runoff and Elizabeth Lake has five. Of the 19 sources of stormwater runoff into the Twin Lakes, 10 are pipes/culverts that output water directly into the lake. Lake Mary has 9 out of the 10 pipes located at point numbers: 3, 4, 6, 7, 11, 13, 17, 20, and 26. During the survey the Commission staff were unable to identify what fed into each of the pipes. Of the pipes/culverts seen on Lake Mary, six correspond with known locations of stormwater drainage as outlined in the Village of Twin Lakes' 2004 Stormwater Management Plan.[64] The sources of stormwater runoff that goes directly into the Lakes are a variety of pipes, culverts lake access points, or street endings. Stormwater runoff can also be a source of external sediment and nutrient loading into the Lakes. As stormwater travels over the landscape, it can pick up a variety of nutrients and pollutants, then in the cases of direct point sources for stormwater, directly deposit those nutrients and pollution into the lake.

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[64] *See chapter 5 of the Village of Twin Lakes' 2004 Stormwater Management planed prepared by Earth Tech for the Village. Note that the date used in the plan for locations of the stormwater drainage piper is from 1996-1997.*

Several of the points of interest were those of a historical nature as described by the guides that went onto the lakes with Commission staff. One of those is Elizabeth Lakes' point 20 which is located at an area that was historically used to harvest ice. Prior to modern refrigeration, ice would be harvested in the winter using horses to pull large blocks of ice to ice houses where the blocks would be packed in straw and sawdust to preserve them to be utilized later in the warmer summer months. Areas of ice harvesting were often located in shallower areas of the lake to ensure that if the ice broke and a person or horse fell through, that the fall would not be fatal.

Overall, Commission staff saw very few sections of developed shoreline that did not have some type of shoreline protection. Most shoreline areas had some sort of shoreline protection in the form of a seawall or rip rap. The sea walls seen varied from poured concrete, to wooden structures, to cobblestone boathouse foundation extensions and corrugated metal paneling. Additionally, as is common in Southeastern Wisconsin, both Lake Mary and Elizabeth Lake have association piers that provide homeowners who do not own lakefront property access to the lakes.

Winter Ice Damage

Shoreline ice damage can be caused by several things such as freeze-thaw cycling, wind push, and ice expansion. The ice on frozen lakes often expands towards the shoreline as it continues to freeze. The ice can expand with force up to many tons per square foot. That amount of force can move objects in its path including seawalls, rip rap, shoreline soils, permanent docks and a variety of other shoreline structures. Ice sheets can often get blown into shore by strong winds or pushed into the shore by currents within a lake, near inlets and near outlets.[65] "Weak ice" or ice that is not very thick or has not had consistent freezes poses less of a threat to the shoreline since as it pushes into shore, instead of damaging or breaking parts of the shoreline, the ice will break on impact. When lake water levels are lower, ice sheets not only push into the shoreline but can undermine the bank and any structure by pushing underneath causing buckling and heaving. Additionally, when lake levels are lower, ice can freeze into the lake bottom near the shore in shallow areas and cause erosion by pulling back sediment as the ice retreats during melt and spring thaw.[66] In 2017, the Village, District, and lake residents expressed concern for damage caused by winter ice on Lake Mary and Elizabeth Lake. However, little data was available for the Commission to use to analyze potential

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[65] *dnr.wisconsin.gov/topic/Waterways/shoreline/info-erosion.html*

[66] *Information from phone interview on January 26, 2024 with Robert Livingston, a long-time lake resident. Mr. Livingston owns a landscaping company that has worked extensively on shoreline restoration and shoreline protection on the Twin Lakes for over 30 years.*

causes for ice damage on the Twin Lakes. Thus, in 2018 a survey with several questions was sent out by Jennifer Frederick (former, Village Administrator) to gather general information about ice on the two lakes.[67] The Commission wanted to obtain more frequent and spatially extensive data to better understand the timing, locations, and extent of the ice damage. The Commission hoped to use that information along with weather data to examine what conditions (water levels, wind direction, period in the lake ice "life cycle") contributed to ice damage on the lakes. In 2020, the survey was revised, and the Commission made calendars with simple yes/no questions that people could fill out each day with the hope that with enough people filling it out, a better data set could be created and thus analyzed.

The calendars consisted of six yes or no questions to be answered each day with accompanying pictures of ice conditions submitted to the Commission by Twin Lakes residents. The respondents were instructed to answer "Yes" to "new or worsening" impacts, so a dock damaged on January 1st would not have a "Yes" for every following day if there was no further damage. This was done to hopefully better pinpoint when impacts were occurring. The respondents were also encouraged to take additional pictures of ice impacts. There were six conditions that the residents were asked to observe: OW = Open Water gap between ice and shore, SP = Shoreline Piling of Ice, IP = Ice Pushing against structure or wall, IF = Ice Fisherman/shanties visible, SB = Shoreline Buckling/Other Damage, and RO = Rocks Overturned by ice (see Figure 2.16).

The first calendar survey was sent out on December 12, 2019, and was distributed to lake volunteers by the Village administrator, in part through a District steering council meeting on January 11th, 2020. This practice was continued in 2021, with the calendar distributed on December 9th, 2020, as well as 2022, with the calendars distributed on December 20, 2021. The collection effort was likely hampered by the onset of Covid-19. Overall, a total of 17 properties gave information about ice conditions and damage (see Map 2.13 and Table 2.12). Through the four survey years, 10 residents returned the surveys, and an additional 12 residents informed the Commission via email correspondence of ice damage to their shoreline. Several residents responded to multiple years. Many respondents submitted pictures and used the margins of the calendars to add their own notes.

Winter of 2018

In winter of 2018, a total of 5 residents responded to the call for ice damage information. Three properties on Elizabeth Lake and one property on Lake Mary responded to the survey sent out. One property owner on Elizabeth Lake reached out via email correspondence.

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[67] *Jennifer Frederick was the Village Administrator for the Village of Twin Lakes, Wisconsin in 2018.*

The result of the survey reported that in mid to late December 2017, Elizabeth Lake had frozen over completely but was not stable all over. Throughout January and February, the ice receded and advanced along Elizabeth Lake's shoreline several times with fluctuating temperatures causing melting and refreezing in areas. 1148 Lucille Avenue saw displaced soil behind the rip rap on several occasions in January. In February, the eastern shoreline near Lakeshore Drive had a seawall destroyed due to high water undermining its base. In a nearby area, steppingstones were displaced due to the formation of a berm (an embankment constructed to help control the flow of water). The Lucille Avenue Beach had ice pushed up onto the shore in early February. In early March of 2018, it was reported that there was some ice push into the western shoreline of Elizabeth Lake. March 24, 2018 there was still a floating ice sheet on the lake but by March 31st the lake was completely open water.

In late spring 2018 a single report about damage that occurred on the southern shore of Lake Mary during the winter showed photos of a concrete seawall with extensive damage (see Figure 2.17, "Winter 2018: 2045 E Lakeshore Drive").

Winter of 2020

In winter of 2020, one property (2045 E Lakeshore Drive) responded to the calendar survey regarding lake conditions and ice damage for Elizabeth Lake. Additionally, five property owners relayed information on shoreline damage via email correspondence.

Winter of 2020 was a dynamic winter, with several melts and freezes in January alone. On January 16th it was reported that there was open water in the center of the lake but later refroze and caused ice buckling nearshore (2045 E Lakeshore Drive) less than a week later. Ice fishermen were on and off the lake periodically through the end of January as ice conditions varied. On February 2nd there were high temperatures and thawing of the top layer of ice on Lake Elizabeth. The ice refroze and was stable enough to support snowmobiles by February 8th. The end of February brought lots of ice noise and patches of open water nearshore. March 1st saw shoreline buckling, ice push and rocks overturned by the ice (see Figure 2.17, "Winter 2020: Near 2045 E Lakeshore Drive"). Strong winds in the first week of March pushed ice to the north end of the lake and by March 11th Elizabeth Lake was completely open water.

Several property owners on Elizabeth Lake gave accounts of how their properties faired over winter of 2020 via email correspondence. One property owner (1613 Mt Moriah) on the north end of the lake indicated in their correspondence, that it was "a disastrous winter" for their shoreline and explained that they had $1100 of damage to their shoreline. However, a property owner located on the western shoreline of the lake (1122 Lucille Ave) reported that their shoreline held back the ice and had no damage to their shoreline.

Three property owners, all located on the southern end of Lake Mary, wrote in their correspondence about their shoreline. One property (1616 Mount Moriah) reported that high water had been over the rocks along their shoreline and that the water has "always been kind of high." Additionally, that property indicated that come spring, "any yard in this cove that is 25ft from shoreline is surely soggy." Another property owner (325 Indian Point Road) also indicated high water levels causing soggy property, even in summer. This owner also explained that there was shoreline heaving and deterioration on their property after the past winter. The property at 300 Indian Point Road reported that they had no damage to their shoreline but credited that to having had their shoreline professionally done two years prior.

Winter of 2021

The Commission received a couple responses for the winter of 2021 ice damage survey for Elizabeth Lake. One from the west side (2308 Haerle Avenue) and one from the east side (2045 E Lakeshore Drive). Elizabeth Lake froze over completely at the end of December 2020. By the first week of January lightweight ice fishing tents were up and ice skaters were enjoying the frozen lake. In mid-February some shoreline buckling was reported on both sides of Elizabeth Lake. February 22nd through the 26th a large thaw was reported in the survey causing a lot of slushy ice in areas.

Throughout the winter of 2021, ice fishermen were consistently on Elizabeth Lake with their ice shacks. It was reported that all permanent ice shacks were off the lake by March 4th. Ice began to extensively thaw during the second week of March, with one survey saying that the ice was very dark, slushy near shore and unstable that week. One survey repose detail how a nearby property on the eastern shoreline (340 Kriwel Avenue) has part of their steel seawall hanging off the rest of the wall along with some berm formation. Elizabeth Lake had full open water by March 14th. One property owner made comment that the ice "went out peacefully this year" (see Figure 2.17, "Winter 2021: Winter Ice Goes Out Peacefully").

Winter of 2022

In 2022 the Commission received two calendar survey responses and eight correspondences regarding ice conditions and damages. General feedback that the Commission received from lake residents was that the winter of 2022 was particularly bad for shoreline damage (see Figure 2.17, "Winter 2022: Dog on Shoreline Damage"). One respondent reported that they had extensive damage to their shoreline from winter of 2022 and had to have their shoreline redone (see Figure 2.17, "Winter 2022: Shoreline Push"). Additionally, they explained that their neighbors lost several feet of shoreline. One group of neighbors on the west shoreline of Elizabeth Lake on Haerle Avenue all received major shoreline damage from the winter. It was reported that there was a 2-foot bump reaching from the southern part of 2350 Haerle Avenue through nearly half of 2358 Haerle Avenue (see Figure 2.17, "Winter 2022: 2332 Haerle Avenue"). The property owner of 267 West Park Drive stated that they had previously had damage to their flagstone shoreline which created a tripping hazard. So, in 2002 they installed artificial turf. The property owner explained that in winter of 2022 the turf moved and wrinkled from the movement of the ground beneath it; the owners received an estimate that it would be $2,000 to repair the damage.

Respondents reported that Elizabeth Lake froze and thawed nearly a half dozen times before January 1st of 2022. However, they then reported that Elizabeth Lake was fully frozen by January 10th. Ice fishermen were spotted on the lake not too long after the final freeze. Mid-January of 2022 brought shoreline piling of ice in several areas of the lake. Additionally, by the end of January shoreline buckling and ice pushes were occurring nearly daily. Through all of February shoreline buckling, shoreline piling, and ice push were prevalent (see Figure 2.17, "Winter 2022: Ice Buckling"). One respondent reported that the shoreline buckling and the damage it causes was particularly bad during the second half of February on Elizabeth Lake. Elizabeth Lake had a period of melting the first week of March but did not have full ice-off until March 15th.

2.4 HUMAN USE AND OCCUPATION

Water pollution problems, and the ultimate solutions to those problems, are primarily a function of the human activities within the tributary area of a waterbody and of the ability of the underlying natural resource base to sustain those activities. This is especially true in the area directly tributary to a lake because lakes are highly vulnerable to human activities within their direct tributary area. Accordingly, the human uses and occupations within the area tributary to a lake are important considerations in lake water quality management.

Historical Land Use

Knowledge of historical urban growth and development patterns can help correlate waterbody changes to human influences and can also help predict future changes. Urban growth within the Wisconsin portion of the Twin Lakes watershed is summarized on Map 2.14 and Table 2.13. As of 1900, urbanized areas were confined to 3.7 acres at the north end of Lake Mary, an area identified as "Twin Lake Station" on 1893 United States Geological Survey topographic maps and that remains the heart of today's Village of Twin Lakes. However, the 1893 maps show that a few residences were already scattered along the eastern shorelines of both Lakes. Urbanized areas accounted for less than 0.05 percent of the watershed as of 1900 growing to 15.6 percent of the Lakes' watershed by 2010. Growth over this period was not evenly paced. Instead, urban growth was particularly rapid between 1920 and 1963 and once again between 2000 and 2010. By 1970, nearly the entire non-wetland shoreline of both Lakes was developed into urban land use. Since this time, most urban growth is occurring near the Lakes, although a few developments are set well away from the Lakes.

2015 and Planned Land Use

The Commission's 2015 land use estimates for the Wisconsin portion of the Lakes watershed were combined with 2013 land use estimates from McHenry County, Illinois to characterize existing land use for the entire area draining to the Lakes. Commission staff mapped this combined land use (see Map 2.15 and Table 2.14). Agricultural lands occupy 44.2 percent of lands draining to the Lakes and are the dominant land use. Agricultural lands generally occupy large blocks of upland areas well away from the Lakes. Natural, semi-natural, unmanaged, and park lands occupy almost 30 percent of the watershed, with woodland areas accounting for almost half of this total. Demonstrating the growth of residential development in the area, single-family residential occupies 17.5 percent of the area draining to the Lakes while roadways occupy 6.3 percent. Streams and ponds occupy slightly less than one percent of the watershed. The balance of the watershed is occupied by a variety of urban activities. These activities include airports, commercial areas, governmental and institutional facilities, industrial areas, and multi-family housing. None occupies more than 0.5 percent of the watershed.

Planned land use estimates that 2,025 acres of cultivated agricultural lands will be converted to single-family residential, commercial, and industrial uses (see Table 2.15). Most of these changes are anticipated to occur between US Hwy 12 and Richmond Road in the western portion of the watershed as well between Wilmot Road and Illinois Hwy 173 in the southeastern portion of the watershed (see Map 2.16). Changing land use will likely affect the Twin Lakes watershed in several ways, an example of which includes the mass of various pollutant types entering the Lakes. For example, primary pollutants from rural uses are sediment and nutrients (from fertilizer runoff and soil erosion) while pollutants from urban uses are more likely to include metals (e.g., copper and zinc). As the urban uses continue to develop within the watershed, sediment and nutrient loads may decrease while contaminant loads, such as heavy metals, may increase.

Political Jurisdictions

The Twin Lakes watershed extends across the Illinois/Wisconsin state line and includes portions of Kenosha and Walworth Counties, Wisconsin and McHenry County, Illinois. The total watershed includes seven municipalities including the Villages of Genoa City and Twin Lakes, Wisconsin; the Village of Spring Grove, Illinois; the Towns of Bloomfield and Randall, Wisconsin; and the Towns of Burton and Richmond, Illinois (see Map 2.17 and Table 2.16). The Village of Twin Lakes surrounds Lake Mary and Elizabeth Lake's entire Wisconsin shoreline and is the municipality with the greatest acreage of the Lakes' watershed (2,262 acres, 35 percent of the total). Other municipalities with large areas draining into the Twin Lakes include the Town of Richmond (1,809 acres or 28 percent of the Lake's watershed and includes all Illinois Lakes shoreline) and the Town of Randall (1,635 acres or 25 percent of the Lakes' watershed). The remaining municipalities occupy the remaining 12 percent of the Lakes' watershed. The Village of Spring Grove is the largest of these municipalities followed in descending order by the Village of Genoa City, the Town of Bloomfield, and the Town of Burton.

Sewer Service Area

The extent of adopted sanitary sewer service areas are shown on Map 2.12 and tabulated on Table 2.17. These sewer service areas have been delineated through a local sewer service area planning process. For Wisconsin municipalities, communities, assisted by the Commission, define a public sewer service area boundary consistent with local land use plans and development objectives. Sewer service area plans include detailed maps of environmentally significant areas within the sewer service area. Following plan adoption by the designated agency managing the wastewater collection and/or treatment system, the Commission evaluates adopting local sewer service area plans. 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.

No wastewater treatment plants discharge to waterbodies within the Twin Lakes watershed. Slightly less than half (46 percent) of the land draining to the Lakes is not within a sanitary sewer planning area. About 40 percent of the land draining to the Lakes is within the Village of Twin Lakes sewer service area while about nine percent of the Lakes' watershed is in the facility planning area of Richmond. The remaining watershed areas are within the sewer service areas of the Village of Genoa City, the Pell Lake Sanitary District, and the facility planning areas of Spring Grove. The Village of Twin Lakes sewer service area treatment plant discharges up to 750,000 gallons of treated effluent to Bassett Creek northeast of the watershed while the Village of Genoa City sewer service area discharges to North Branch Nippersink Creek. Neither contributes water to the Twin Lakes.

Natural Resource Elements

Natural resources elements are features integral to Southeastern Wisconsin's landscape that provide many human needs and desires and are vital to environmental health. Since environmental provisioning of human needs and desires and ecology are dependent upon a network of abiotic and biotic relationships, deterioration, or removal of one important relationship, may cause damage throughout the entire network. For example, draining a wetland can eliminate an area's ability to supply important fish reproduction, nursery, and refuge functions, may compromise upland wildlife habitat value, can interrupt important groundwater recharge/discharge relationships, and can inhibit natural runoff filtration and floodwater storage. This loss in ecosystem function may further affect groundwater supply for domestic, municipal, and industrial use or its contribution to low flows in streams and rivers. Preserving natural resource elements not only improves local environmental quality but also sustains and possibly enhances aquatic, avian, and terrestrial wildlife populations across the Region.

Floodplains

Section 87.30 *Wisconsin Statutes* requires that counties, cities, and villages adopt floodplain zoning to preserve floodwater conveyance and storage capacity and prevent new flood-damage-prone development in flood hazard areas. The minimum standards that such ordinances must meet are set forth in Chapter NR 116 *Wisconsin Administrative Code*, "Wisconsin's Floodplain Management Program". These regulations govern filling and development within regulatory floodplains, defined as areas having a one-percent annual probability of flooding.[68] As required under Chapter NR 116, local floodland zoning regulations must prohibit nearly all development within the floodway, the portion of the floodplain with actively flowing water conveying the one-percent-annual-probability flood flow. Local regulations must also restrict filling and development within the flood fringe, that portion of the floodplain located beyond the floodway inundated during the one-percent-annual-probability flood and detaining floodwater for later release. Filling within the flood fringe reduces floodwater storage capacity and may increase downstream flood flows and flood depths/elevations.

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

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[68] *The one-percent annual flood probability is oftentimes referred to as "the one-hundred year flood event." This does not mean that such a flood will happen once in a century. Instead, such a flood has a one-percent probability to recur each year.*

reconstruction, remodeling, conversion and repair of such nonconforming structures—with the overall intent of lessening public responsibilities generated by continued and expanded development of land and structures inherently incompatible with natural floodplains; and 3) lessen potential danger to life, safety, health, and welfare of persons whose lands are subject to the hazards of floods.

Although dry much of the time, floodplains are vital to water body function and health. During intense runoff (e.g., during heavy or sustained rainfall or snowmelt), lakes and stream water elevations rise. Floodplains help convey, detain, and treat runoff and often promote groundwater recharge. Areas abutting lakes and streams with a one-percent chance of flooding any particular year are often referred to as "100-year floodplains." Approximately 1367 acres of the Twin Lakes watershed are currently mapped as 100-year floodplains (see Map 2.18). All mapped floodplain acreage either overlays the open-water surface of Mary and Elizabeth Lakes or is found in wetlands abutting the Lakes. Other flood-prone areas likely exist in the watershed but are currently unmapped. An example includes the wetlands found in tributary stream headwaters east of Elizabeth Lake.

Wetlands

Historically, wetlands were commonly considered wastelands, areas presenting obstacles to agricultural production and development. Private concerns and governmental institutions supported widespread wetland draining and filling. Wetlands continued to be drained and filled until scientific research revealed their great value as productive and biologically diverse ecosystems and provide functions critical to a plethora of human needs and desires.[69] Regulations now severely restrict wetland filling and draining.

Wetlands are best known for their broad variety of plant life. Wetland plants are varied in their growth habit, with submerged, floating-leaf, emergent, and terrestrial forbs and grasses intermixed with woody trees and shrubs. Many of these plants only grow in wetlands. Many wildlife species rely on, or are associated with, wetlands for at least part of their lives. This includes various crustaceans, mollusks, and other aquatic insect larvae and adults; fishes, including forage fish and important gamefish species like trout, northern pike, and largemouth bass; amphibians; reptiles; mammals including deer; resident bird species like turkeys as well as migrants like sandhill or whooping cranes and various ducks and geese. Thus, wetlands help maintain biologically diverse communities that provide tremendous ecological and economic value.

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

The term "ecosystem services" refers to any of the benefits that ecosystems—both natural and semi-natural—provide humans.[70] In other words, ecosystem functions are classified by their abilities to provide goods and services satisfying human needs,[71] either directly or indirectly. Examples of ecosystem services provided by wetland include floodwater detention lessening flood severity in downstream areas; nutrient, sediment and pollutant processing and retention that improves downstream water quality; aquatic organism, bird, amphibian, and terrestrial wildlife breeding, nursery, feeding, and refuge, and human recreational opportunities. The economic value of wetland-derived ecosystem services exceeds those provided by lakes, streams, forests, and grasslands and is second only to the value provided by coastal estuaries.[72] Society gains a great deal from wetland conservation. Therefore, it is essential to incorporate active wetland conservation and restoration 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 onto themselves. For regulatory purposes, the State of Wisconsin basically defines wetlands as areas where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation and which has soils indicative of wet conditions. Three specific characteristics are evaluated when a wetland determination is made including:

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

These characteristics severely limit and complicate urban development, as wetland area have permanent or transient high water tables and soils that are commonly highly compressible, unstable, have high shrink-

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[70] *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.*

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

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

swell potential, and exhibit low bearing capacity. Development in wetlands often results in flooding, wet basements, unstable foundations, failing pavement, and failing sanitary sewer and water lines. Significant and costly onsite preparation and maintenance costs are associated with developing wetland soils. This is particularly the case with roads, foundations, and public utilities.

Delineated wetlands currently occupy approximately 567 acres, or about 7.5 percent of the entire Twin Lakes watershed.[73] About 308.5 acres of wetland are found in the Illinois portion of the watershed while 258.9 acres lie in the Wisconsin portion. The most wetlands flank the southwestern shoreline of Lake Mary and the northeastern corner and the southern end of Elizabeth Lake. A patchwork of small to modest-sized wetlands are found well away from the Lakes, most lying to the southeast of Elizabeth Lake, and most within the State of Illinois. Very little wetland acreage is found in the remainder of the watershed (see Map 2.19). The wetlands in the watershed vary by habitat type and vegetative composition, with emergent/wet meadow, scrub/shrub, and aquatic beds as most common types in the Wisconsin portion of the watershed (see Table 2.18 and Map 2.20).

Wetland areas have been both gained and lost over the past decades. Between 2005 and 2015, 37.3 acres of wetland were restored or created and 15.9 acres were lost, for a net gain of 21.4 acres of wetland, in the Wisconsin portion of the watershed (see Map 2.21). The Illinois portion of the watershed contains more wetland acreage than the Wisconsin portion despite its smaller overall size.

Uplands

Upland habitat occupies areas not identified as wetland or aquatic habitat. Compared to wetland habitat, upland habitat is usually topographically higher, are farther from open water, have deeper depths to groundwater, and commonly have drier, less organic-rich soil. The most ecologically productive upland habitat typically remains in a natural or seminatural state. Many exceptions and gray areas exist within this broad generalization of uplands, as can be seen within the Twin Lakes watershed. For example, upland habitat can be difficult to differentiate from wetland habitat because uplands and wetlands are intertwined and form a complex mosaic across the landscape. It is precisely this landscape variety and the linkages between these unique community types that provides the critical habitats to sustain healthy and diverse aquatic and terrestrial wildlife.

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[73] *These acres were calculated using the 2005 Advanced Identification Wetlands as a source and may not reflect current conditions.*

The upland habitat dominated by natural and seminatural vegetation in the Wisconsin portion of the Twin Lakes watershed is shown in Map 2.22 and summarized in Table 2.19. Within the watershed, this habitat type is mostly comprised of woodlands, brush, and grassland. As most of this land was cultivated in the 1940s, a portion of these woodlands are forest regrowth. Grassland areas may be under active management as pastureland or enrolled in a soil conservation program. Finally, even though highly modified and manipulated to achieve human goals, residential and other developed land use types can provide pockets of valuable habitat to a wide variety of plants and animals. Common examples include the purposeful planting and arrangement of mast producing shrubs and trees and plants attractive to pollinators to benefit wildlife.

Like wetlands ecosystems, upland habitats also provide a broad variety of ecosystem services. Although the economic value of their ecosystem services is not as large as wetland ecosystems, these areas provide important services worth protecting. Upland habitat feeds and shelters a wide array of wildlife, helps filter pollutants from runoff improving water quality, provides condition favorable for groundwater recharges and slows runoff both which help downstream flooding, improves air quality, reduces erosion and enhances soil health, and provide humans recreation, tourism, and education opportunities.

An important contrast between upland and wetland habitat is that the upland soils generally pose fewer challenges to urban development and are generally not offered regulatory protection. Therefore, construction and ongoing maintenance costs are generally reasonable and do not impede site development, making these areas highly desirable for urban development. Since uplands are not protected and offer attractive development opportunities, it is important to incorporate upland conservation and restoration targets as part of this plan to guide management and policy decisions regarding the use and preservation of such ecosystems.

Natural Resource Planning Features

The Commission has studied the distribution of natural resource elements in Southeastern Wisconsin for decades, labelling, ranking, and mapping important natural resource elements. This section describes the nature and location of natural resource planning features in Wisconsin. Natural resource planning features are not mapped in Illinois.

Primary Environmental Corridors

Primary environmental corridors ("PECs") encompass natural resource and natural resource-related elements known to provide important services to humans, plant and animal communities, and overall landscape ecologic health. By definition, PECs are at least 400 acres in size, two miles in length, and 200 feet in width.[74] As of 2010, PECs cover 1,476 acres of the Wisconsin portion of the total watershed (28.4 percent), including Lake Mary itself and the Wisconsin portion of Elizabeth Lake (see Map 2.23 and Table 2.20).[75] These PECs represent a composite of the best remaining natural resource elements (lake, streams, woodlands, wetlands, and wildlife habitat areas) in the Twin Lakes watershed. Thus, the Lakes and their associated shorelands are part of the highest quality natural resources within the watershed, highlighting the importance of managing nearshore areas to protect their quality and integrity.

Secondary Environmental Corridors

Secondary environmental corridors ("SECs") often abut primary environmental corridors and are at least 100 acres in size and one-mile long. In 2010, SECs encompassed about 53 acres, or about 1.0 percent, of the Wisconsin portion of the watershed near the watershed's eastern periphery (see Map 2.23). Secondary environmental corridors are remnant resources that have been reduced in size compared to the larger PECs described above due to land development for intensive urban or agriculture purposes. Nevertheless, SECs help preserve ecosystem function by facilitating surface-water drainage and groundwater recharge, maintaining pockets of natural resource features, as well as providing corridors for wildlife movement and seed dispersal.

Isolated Natural Resource Areas

Natural resource features physically separated from environmental corridors by intensive urban or agricultural land uses have also been identified. These pockets of natural resource areas, which are at least five acres in size, are referred to as isolated natural resource areas. Widely scattered throughout the watershed, isolated natural resource areas cover about 113 acres of the Wisconsin portion of the watershed as of 2010 (see Map 2.23). Isolated natural resource features occupy about 2.1 percent of the Wisconsin portion of the total watershed.

Natural Areas and Critical Species Habitat Sites

Natural areas, as defined by the Wisconsin Natural Areas Preservation Council, are tracts of land or water so little modified by human activity, or sufficiently recovered from the effects of such activity, that they

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

[75] *The Commission defines primary environmental corridors for the Southeastern Wisconsin Region. These PECs include lakes and rivers when they meet the size criteria necessary. The calculated acreages do not include the Illinois portion of Elizabeth Lake as the Commission does not define corridors within Illinois.*

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. Indeed, some of the highest quality natural areas in Southeastern Wisconsin are wetland complexes that have maintained adequate or undisturbed linkages (i.e., landscape connectivity) to upland habitat. This is consistent with research findings in other areas of the Midwest.[76]

Natural areas have been identified for the seven-county Southeastern Wisconsin Region in SEWRPC Planning Report No. 42, "*A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*," published in September 1997 and amended in 2010. This plan, developed to assist Federal, State, and local units and agencies of government, and nongovernmental organizations, helps planners and resource managers give environmentally sound land use advice. This advice includes suggestions for acquiring priority properties, managing public lands, and locating development in areas that will help protect and preserve the natural resource base of the Region.

Identified natural areas are 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).

Classifying an area into one of these categories requires 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 human disturbance such as logging, grazing, water level changes, and pollution; how frequently the plant and animal communities occur within the Region; the presence of unique natural features within the area; the size of the area; and the educational value. The Twin Lakes watershed contains one natural area of countywide or regional significance (NA-2): the 256-acre Elizabeth Lake Lowlands located astride the state line along the southwestern shore of Elizabeth Lake (see Map 2.24).

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

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. Sensitive areas have special biological, geological, ecological, or archaeological significance, "offering critical or unique fish and wildlife habitat, including seasonal or life-stage requirements, or offering water quality or erosion control benefits of the body of water". Wisconsin law mandates special protection of these "sensitive areas" or "Critical Habitat Designation" areas, which comprise approximately eighty percent of the plants and animals on the state's endangered and threatened species list. Critical habitat designation helps waterfront owners 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 work will not harm sensitive resources. The only critical habitat area within the Twin Lakes watershed is 17.7-acre Hamilton Woods, located near the eastern shoreline of Elizabeth Lake (see Map 2.24).

2.5 WATER QUALITY

Actual and perceived water quality are generally high priority concerns to lake and stream resource managers, residents, and Lake users. Concern is often expressed that pollutants entering the Twin Lakes from various sources have or could degrade water quality over time. The water quality information presented in this section can help interested parties better understand the current and historical conditions, trends, and dynamics of the Twin Lakes. By interpreting and applying this information, management strategies can target issues that have the highest likelihood of protecting the long-term health of these water bodies.

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

Water quality metrics commonly respond in reaction to water quality changes. For example, nutrients from eroded topsoil and common fertilizers can cause a lake's phosphorus concentrations to increase. Increased phosphorus concentrations fuel algal growth. Increased algal abundance causes lake water to become cloudier, diminishing water clarity. Finally, chlorophyll-*a* concentrations (a measure of algae content) increase. In addition to water clarity, phosphorus, chlorophyll-*a*, and DO values, a number of other parameters can also help determine the "general health" of a lake. For example, the abundance of the bacteria *Escherichia coli*, commonly known as *E. coli*, is often measured as an indicator if lake water is safe for swimming while chloride concentrations are an indicator of overall human-induced pollution entering a lake.[77] Key water-quality indices must be regularly measured over long periods of time to develop a water quality maintenance and improvement program. This allows lake managers to establish baselines and identify trends.

Water Temperature and Dissolved Oxygen

Seasonal air temperature fluctuation and varying amounts of sunshine influence lake temperatures, causing waters to mix and stratify seasonally. In spring and fall, most lakes are well mixed and therefore are the same temperature from the water surface to the lake bottom. In summer, surface water warms and becomes more buoyant than underlying cooler water. In deeper lakes (e.g., 20 feet or deeper) a distinct warm upper layer (referred to as the lake's "epilimnion") and a separate colder deep layer ("hypolimnion") form, a condition which causes the lake to be considered "stratified" (see Figure 2.18). The temperature change between the epilimnion and hypolimnion is generally abrupt occurring in a relatively narrow depth band referred to as the "thermocline." Lakes can also weakly stratify in winter since water is most dense at 39 degrees Fahrenheit. Since water freezes at 32 degrees Fahrenheit, the warmest water in lakes during midwinter (aside from areas influenced by groundwater seepage, springs, and surface-water inputs) can often be found near the lake bottom in the deepest portions of the lake.

Temperature and oxygen concentration profiles were assembled from data spanning over 40 years in Lake Mary with a much less comprehensive data set in Lake Elizabeth. Temperature and oxygen concentration profiles suggest that the Twin Lakes stratify every year and remain stratified throughout the summer (see Figure 2.19 and Figure 2.20) The location and thickness of the thermocline vary month-to-month and year-to-year. However, the summer thermocline is generally around 10 feet thick and is found somewhere

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

between 15 and 25 feet below the Lakes' surfaces. As summer progresses, the epilimnion thickens and the thermocline is generally found deeper in the Lakes. Summertime epilimnion temperatures in both Lakes fluctuate between 70 to 85 degrees Fahrenheit while hypolimnion temperatures are between 55 to 70 degrees Fahrenheit. Temperature profiles have not noticeably changed in either Lake over the period of available record.

A reliable oxygen supply is vital to desirable aquatic organisms and the overall lake health. In general, oxygen concentrations should remain above 5.0 mg/l to support a healthy fishery in most of the Region's inland lakes.[78,79] Epilimnion dissolved oxygen concentrations in the summer range between 7 to 12 mg/l, which are generally sufficient to support desirable aquatic life throughout the year (see Figure 2.21 and Figure 2.22). When the Lakes stratify, water in the deepest portion of the Lakes is unable to obtain oxygen from the atmosphere or from most of the Lake's aquatic plants. Organic matter from the biologically active epilimnion continues to settle into the hypolimnion where it decomposes, a process that consumes oxygen. For this reason, oxygen concentrations drastically decline through the thermocline during summer stratification. With hypolimnetic dissolved concentrations at or near 0 mg/l, the Lakes' deepest areas become hypoxic (low oxygen) or anoxic (no oxygen) and are therefore not habitable to fish during much of summer.

Lakes with high fertility are most prone to have hypoxic or anoxic hypolimnia. Relatedly, lakes with anoxic hypolimnia are most prone to supporting geochemical reactions that release phosphorus from lake-bottom sediments, the nutrient that limits lake plant and algal growth in most of the Region's lakes. Therefore, a self-reinforcing feedback loop can develop where fertile lakes are made even more fertile through lake-bottom phosphorus release ("internal loading"). Similarly, reducing external nutrient loads can reduce lake fertility which in turn can decrease the temporal and spatial extent of anoxia and thereby reduce internal loading. The depth where anoxic water is found during mid- to late-summer in Lake Mary has remained relatively unchanged throughout the period of record, indicating stable nutrient loading conditions. Lake Elizabeth's dissolved oxygen profiles are too sparsely collected to discern a trend.

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

[79] *Oxygen dissolves into water. Cooler water is capable of holding more oxygen than warm water. Oxygen saturation is calculated by comparing the oxygen concentration at a particular temperature to the theoretical oxygen saturation value for that temperature. Generally, oxygen saturation values should remain between 90 and 110 percent best support healthy fisheries.*

Specific Conductance

Specific conductance is a measure of the ability of a liquid, such as lake water, to conduct electricity, standardized at a specific temperature (25°C). This ability is greatly dependent on the concentration of dissolved solids in the water: as the amount of dissolved solids increases, the specific conductance increases. Specific conductance is often useful as an indication of possible pollution of a lake's waters. Freshwater lakes, especially those in watersheds overlaying carbonate formations like dolomite, commonly have a specific conductance in the range of 10 to 1,000 microSiemens per centimeter (µS/cm). Specific conductance measurements exceeding 1,000 µS/cm may be an indication of surface pollutants, particularly road salt and other de-icing agents.[80] During periods of thermal stratification, specific conductance can dramatically increase at the lake bottom due to an accumulation of dissolved materials trapped in the hypolimnion. Such a condition can lead to a significant concentration gradient, with higher conductance measurements in the deeper waters and lower conductance measurements in the surface waters; these gradients are a consequence of the "internal loading" phenomenon described previously.

Figure 2.23 shows specific conductance profiles by lake depth for the Twin Lakes. As in the previous planning studies, surface to bottom conductivity gradients can be observed during the summer period. Although the relative levels of conductance were within the normal range for lakes in Southeastern Wisconsin,[81] such gradients were interpreted at the time to be an indication that Lakes do experience some degree of internal loading. Additionally, the specific conductance increases noted in the CAPR 302 have continued, with Lake Mary surface measurements of 570 µS/cm @ 25ºC in 1991, 630 in 1997, 673 in 2004, 781 in 2016, and 813 in 2022. Specific conductivity has been measured less frequently on Lake Elizabeth, but it is likely that a similar increase would be observed if measurements were conducted. These specific conductance increases are consistent with the elevated chloride concentrations observed in the Lakes, as discussed below.

Chloride

Chloride is a "conservative pollutant" meaning that natural processes (other than evaporation) typically do not detain or remove it from water. Humans use chloride bearing materials for a multitude of purposes, such as road salt, water softening, industrial processes, agricultural nutrients and pesticides, pharmaceuticals, petroleum products, and a host of other substances in common use by modern society. As such, chloride concentrations are normally associated with human-derived pollutant concentrations and

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[80] *Deborah Chapman,* Water Quality Assessments*, 2nd Edition, E&FN Spon, 1996.*

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

are, therefore, a good indicator of the overall level of human activity/potential impact and possibly the overall health of a water body. The most important anthropogenic source of chlorides to the Twin Lakes is believed to be the salts used on roads for winter snow and ice control.[82]

Under natural conditions, surface water in Southeastern Wisconsin contains very low concentrations of chloride. Studies completed in Waukesha County lakes during the early 1900s reported concentrations of three to four mg/l of chloride; in fact, lakes in Southeastern Wisconsin had the lowest levels of chlorides statewide.[83] Most Wisconsin lakes saw little increase in chloride concentrations until the 1960s, but a rapid increase thereafter. The first recorded measurements of chloride in Elizabeth Lake and Lake Mary were in 1966, with concentrations of 9.3 and 8.7 mg/l, respectively.

By the mid-1990s, chloride concentrations in the Lakes rose to 46 mg/l in Elizabeth Lake and 76 mg/l in Lake Mary. The most recent chloride measurements in the Lakes indicate a concentration of 75.6 mg/l in Elizabeth Lake in 2012 and 123 mg/l in Lake Mary in 2018. Chloride continues to accumulate in both Lakes at steady rates (see Figure 2.24) While the recent concentrations reported within the Lakes are below the WDNR standards of 395 mg/l for chronic toxicity and 757 mg/l for acute toxicity (see Table 2.23) established to protect fish and aquatic life, the increasing accumulation of chloride represents a decline in water quality that will be challenging to reverse. The increasingly saltier environment influences the capacity of the Lakes to support native flora and fauna, as invasive species may be more tolerant of high chloride conditions. For example, reed canary grass, a common invasive species of wetland and riparian settings, is well-adapted to saltier environments.[84] Similarly, Eurasian water milfoil can survive levels of industrial and salt pollution that eliminates native aquatic plants.[85] 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

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[82] *The major sources of chlorides to lakes in Southeastern Wisconsin include both road salt applications during winter months and salts discharged from water softeners. This latter is of lesser importance to the Twin Lake, as such waters are conveyed to the public sewage treatment facility and the effluent therefrom is discharged to Bassett Creek and North Branch Nippersink Creek outside of the Twin Lakes watershed.*

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

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

[85] *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, *144: 263-266, 1993*.

concentrations that are lethal to native fish species.[86] Progressively higher chloride concentration may increasingly favor undesirable changes to the Lake's flora and fauna until chronic conditions become toxic to most aquatic life at 395 mg/l. 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 the Lakes.

pH and Acidity

The acidity of water is measured using the pH scale. The pH scale is a logarithmic measure of hydrogen ion (H+) concentration on a scale of 0 to 14 Standard Units (SU), with 7.0 indicating neutrality. Water with pH values lower than 7.0 SU has higher hydrogen ions concentrations and is more acidic, while water with pH values higher than 7.0 SU has lower hydrogen ion concentrations and is less acidic. Since the scale is logarithmic, each 1.0 pH change reflects a tenfold change in hydrogen ion concentration, e.g., a pH of 4 is ten times more acidic than a pH of 5 and a hundred times more acidic that a pH of 6. In Wisconsin lakes, pH can range anywhere from 4.5 in some acid-bog lakes to 8.4 in hard water, marl lakes.[87]

Many chemical and biological processes are affected by pH, as are the solubility and availability of many substances. Different organisms can tolerate different ranges of pH, with most preferring ranges between about 6.5 and 8.0 SU. Although moderately acidic (slightly below a pH of 7) does not usually harm fish, as pH drops to 6.5 or lower, some species can be adversely affected, especially during spawning. For example, at a pH of 6.5, walleye spawning can be inhibited; at a pH of 5.8, lake trout spawning is inhibited; and at a pH of 5.5, smallmouth bass disappear.[88] As pH continues lower, walleye, northern pike and other popular sport fishes gradually disappear and a pH of 3.0 is toxic to all fish.[89] In addition, many metals are more soluble in water with low pH than they are in water with high pH. Thus, toxicity of many substances for fish and other aquatic organisms can be affected by pH. Under low pH conditions, toxic metals, such as

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[86] *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.*

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

[88] Ibid.

[89] Ibid.

aluminum, zinc and mercury, can be released from lake sediment if present. At a pH of 5.0, aluminum is at its most poisonous, precipitating onto the gills of the fish in the form of aluminum hydroxide.[90]

Lakes have natural and man-made sources of acidity. Peat-bog lakes are naturally acidic due to the natural release of organic acids during decomposition; many such lakes are without fish[91]. Because of diffusion of carbon dioxide into water and associated chemical reactions, rainfall (in areas that are not impacted by air pollution) has a pH of about 5.6 SU; the pH of rainfall in areas where air quality is affected by oxides of nitrogen or sulfur tends to be lower. The mineral content of the soil and bedrock underlying a waterbody also has a strong influence on the waterbody's pH. Lakes with carbonate bedrock, such as the Twin Lakes and most other lakes in Southeastern Wisconsin, tend to be alkaline with a pH between 8.0 and 9.0 SU.[92] Pollutants contained in discharges from point sources and in stormwater runoff can also affect a waterbody's pH. Further, photosynthesis by aquatic plants, phytoplankton, and algae can cause pH variations both on a daily and seasonal basis.

Both lakes are alkaline with mean pH measurements of 8.2 SU, which is well within the range for warmwater fish and aquatic life. Lake Mary appears to be becoming slightly less alkaline, with summer surface pH decreasing from 8.7 SU in 1995 to 8.6 SU in 2023 and seeing values as low as 6.48 SU in 2016 (see Figure 2.25). The Lake Mary summer pH profiles clearly show the pH gradient created by the thermocline, an effect similar to that reflected in the summer profiles for conductivity, oxygen, and percent oxygen saturation. In summer, photosynthesis increases both dissolved oxygen concentrations and pH as algae and plants remove carbon dioxide from the water, raising pH, while oxygen is released as a byproduct of the photosynthetic reactions. Elizabeth Lake has much less pH data available so robust trends by season or over time could not be established.

Alkalinity and Hardness

Alkalinity is a measure of the capacity of a lake to absorb and neutralize acids, known as "buffering". The alkalinity of a lake depends on the levels of bicarbonate, carbonate, and hydroxide ions present in the water. Lakes in Southeastern Wisconsin typically have a high alkalinity, with an average concentration of 173 mg/l

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

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

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

expressed as calcium carbonate ($CaCO_3$), because of the deposits of limestone and dolomite that make up much of the bedrock underlying many of the lakes and their associated tributary areas.[93] In contrast, water hardness is a measure of the multivalent metallic ion concentrations, such as those of calcium and magnesium, present in a lake. Hardness is usually reported as an equivalent concentration of calcium carbonate, measured in mg/l. If a lake receives groundwater through rock layers containing calcite and dolomite (both are limestone materials), the lake's alkalinity and hardness will be high. Soft water lakes have calcium carbonate levels less than 60 mg/l; hard water lakes contain levels over 120 mg/l.

The Twin Lakes may be classified as hard-water alkaline lakes, with average alkalinities of 183 and 187 mg/l and average hardness of 231 and 247 mg/l for Elizabeth Lake and Lake Mary, respectively. These alkalinities are within the normal range of lakes in Southeastern Wisconsin.[94] Total alkalinity and hardness in the Twin Lakes are generally stable, with slight declines in alkalinity in more recent sampling in Lake Mary (see Figure 2.26 and 2.27, respectively). Since the Twin Lakes have high alkalinity and because pH does not regularly fall below 7 stu, the Lakes are not considered to be susceptible to the harmful effects of acidic deposition.

Nutrients, Sediment, and Water Clarity

The most prevalent pollutants to waterbodies include sediment and nutrients, both of which have natural sources and sources attributable to human activity. Sediment and nutrient loads can greatly increase when humans disturb land cover and runoff patterns through activities such as tilling and construction, both of which typically loosen soil, increase runoff and in turn allow soil to more easily erode and eventually enter streams and lakes. Phosphorus is a key nutrient for aquatic plants and algae, with the availability of phosphorus often limiting their growth and abundance. On the other hand, high phosphorus concentrations can promote heavy algal growth, which reduces water clarity and can eventually lower lake dissolved oxygen concentrations through increased decomposition. Sources of phosphorus can vary across a watershed, with agricultural fertilizers and animal manure as the predominant phosphorus sources in rural areas while stormwater discharge and onsite wastewater treatment systems contribute phosphorus in urban areas. There are no waters impaired by phosphorus or sediment within the Wisconsin portion of the Twin Lakes tributary area.

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[93] Ibid.

[94] Ibid.

Water Clarity

One of the three major determinants of trophic status is water clarity. Water clarity, or transparency, provides an indication of overall water quality—the greater the clarity, the better the water quality. Clarity may decrease because of turbidity caused by:

- High concentrations of small, aquatic organisms, such as algae and zooplankton
- Suspended sediment and/or inorganic particles
- Color caused by high concentrations of dissolved organic substances (e.g., tannins that stain water of bog lakes in northern Wisconsin)

In most Southeastern Wisconsin lakes, water clarity is influenced by the abundance of algae and suspended sediment. Water clarity generally varies throughout the year as algal populations increase and decrease in response to changes in lake temperature, sunlight, and nutrient availability. Clarity is measured using a Secchi disk, a black-and-white, eight-inch-diameter disk. This disk is lowered into the water until it is no longer visible, at which point the depth is recorded, and then it is raised until visible again, when depth is recorded again. The average of these depths is called the "secchi depth." Mean growing season water clarity via secchi depths is slightly higher in Lake Mary (8.3 feet) than in Elizabeth Lake (6.7 feet); however, water clarity has only been measured twice in Elizabeth Lake since 2010 so the information is limited (see Figure 2.28). Water clarity has remained stable in Lake Mary over the past three decades while trends for Elizabeth Lake cannot be established due to limited data availability.

Additionally, many lakes in the Southeastern Wisconsin Region have populations of non-native Zebra mussels (*Dreissena polymorpha*). These non-native mussels are prolific filter feeders and thus can improve water clarity by removing particulate matter through filter-feeding. The WDNR verified the presence of zebra mussels in both Lakes in the early 2000s. Zebra mussels may be influencing water clarity in the Lakes, but that hypothesis has not been directly tested. Continued monitoring of water clarity will be an important part of any future water quality assessments.

Chlorophyll-a

Chlorophyll-*a,* a photosynthetic pigment whose abundance is used to indicate algal biomass, is the most reliable metric of a lake's trophic status. Algae is an important and healthy part of lake ecosystems. Algae is a foundational component of lake food chains and produces oxygen in the same way as rooted plants.

Many kinds of algae exist, from single-cell, colonial, and filamentous algae to cyanobacteria. Most algae strains are beneficial to lakes when present in moderate levels. However, the presence of toxic strains, as well as excessive growth patterns, should be considered issues of concern. As with aquatic plants, algae grows faster in the presence of abundant phosphorus (particularly in stagnant areas). Consequently, when toxic or high volumes of algae begin to grow in a lake, it often is a sign of phosphorus enrichment or pollution.

Algae populations are quantified by abundance and composition and can be examined to determine if the algae present are toxin-forming. Suspended algal abundance is estimated by measuring the chlorophyll-*a* concentration in the water column, with high concentrations associated with green-colored water. Concentrations of chlorophyll-*a* have decreased in both Lakes over time, indicating reduced algal abundance, with Lake Mary having slightly lower chlorophyll-*a* concentrations than Elizabeth Lake (see Figure 2.29). Since 1990, mean growing season chlorophyll-*a* concentrations are 5.5 and 6.8 µg/l for Lake Mary and Lake Elizabeth, respectively, which are far below the 27 µg/l threshold above which aquatic life impairment can occur and algae blooms are more prevalent.

Phosphorus

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

Two forms of phosphorus are commonly sampled in surface waters: total phosphorus and dissolved phosphorus. Total phosphorus consists of all the phosphorus contained in material dissolved or suspended in water. Dissolved phosphorus consists of the phosphorus contained in material dissolved in water. In both these types, phosphorus may be present in a variety of chemical forms. However, as the degree of eutrophication in freshwater systems correlates more strongly with total phosphorus concentration than with dissolved phosphorus concentration, the State's water quality criteria are expressed in terms of total phosphorus. Thus, water quality sampling tends to focus on assessing total phosphorus concentrations rather than dissolved phosphorus concentrations.

Total phosphorus in the Lakes have remained relatively steady the mid-1990s, as shown in Figure 2.30. Concentrations are slightly lower in Lake Mary than in Lake Elizabeth, with average growing season (June through September) surface water concentrations 0.019 and 0.022 mg/l, respectively. This phosphorus concentration is below the aquatic life impairment threshold of 0.030 mg/l for deep headwater and deep lowland drainage lakes mandated by the administrative code (see Table 2.21).[95,96] Samples collected during the growing season at depths 20 feet and below in both Lakes have greater total phosphorus concentrations (means of 0.04 and 0.04 mg/l for Lake Mary and Lake Elizabeth, respectively) than surface water samples.

Large discrepancies between surface and deep-water phosphorus concentrations, as exhibited in the Twin Lakes, are a potential indicator of internal loading. Internal loading refers to the release of phosphorus stored in a lake's bottom sediment that occurs under low oxygen conditions associated with lake stratification. Phosphorus is typically not particularly soluble and often adheres to particles that settle to the 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 plant remains and lake-bottom sediment to dissolve into the water column. This allows phosphorus that is otherwise trapped in deep lake-bottom sediment to be released into lake water. This released phosphorus can mix into the water column during the next turnover period fueling plant and algae growth. In most lakes, phosphorus is the nutrient controlling overall plant and algal growth, and additional phosphorus can lead to increased plant and algal growth. If internal loading is a primary component of a lake's phosphorus budget, water quality management may focus on in-lake phosphorus management efforts in addition to preventing polluted runoff from entering the lake. Commission staff were unable to determine whether internal loading is a significant portion of the Lakes' phosphorus cycling as there were not enough recent spring surface and deep water total phosphorus samples to compare with summer samples.

Nitrogen

Surface waters contain a variety of nitrogen compounds that are nutrients for plants and algae. Typically, only a small number of forms of nitrogen are examined and reported in water quality sampling. Total nitrogen includes all of the nitrogen in dissolved or particulate form in the water, excluding all gaseous forms of nitrogen. Total nitrogen is a composite of several different compounds that vary in their availability to algae and aquatic plants and in their toxicity to aquatic organisms. Many nitrogen-containing organic

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[95] *Wisconsin Department of Natural Resources, Wisconsin 2020 Consolidated Assessment and Listing Methodology (WisCALM) Clean Water Act Section 303(d) and 305(b) Integrated Reporting, April 2019.*

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

compounds, such as amino acids, nucleic acids, and proteins that commonly occur in natural and polluted waters are included in total nitrogen. Common inorganic constituents of total nitrogen include ammonia, nitrate, and nitrite. These are the forms that most commonly support algal and plant growth. Nitrate (NO_3^-) can be toxic to humans at high concentrations (WDNR drinking water limit is 10 mg/l of nitrate as nitrogen). Nitrate concentrations in the Lakes have not been measured since the mid-1970s, at which time the mean concentrations (0.18 and 0.21 mg/l of nitrate as nitrogen in Lake Mary and Lake Elizabeth, respectively) were far below toxic levels.

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

Occasionally, nitrogen acts as the limiting nutrient for algal and plant growth in freshwater systems, typically when phosphorus concentrations are very high. In general, when the ratio of total nitrogen (N) to total phosphorus (P) concentrations is 15:1 or greater, the availability of phosphorus limits algal growth. Conversely, when this proportion is less than 10:1, nitrogen concentrations limit plant growth. Ratios between 15:1 and 10:1 are considered transitional.[97] Spring turnover nitrogen concentrations have not been measured since 1974 in either Lake, so Commission staff were unable to assess limitations on nutrient availability. However, phosphorus is generally the limiting nutrient within most Southeastern Wisconsin lakes and would likely be for the Twin Lakes as well. Although data is limited, summer nitrogen concentrations appear to have declined over time in Lake Mary from a high of 1.1 mg/l in 1974 to 0.7 mg/l in 2017. Growing season total nitrogen concentrations were last measured in Elizabeth Lake in 1974 with a concentration of 1.04 mg/l (see Figure 2.31). As the presumed limiting nutrient in the Lakes, phosphorus should be the major focus of nutrient loading and algae bloom management decisions.

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

Trophic State Index

Lake biological productivity is referred to in terms of "trophic state." Low productivity lakes with few nutrients, algae, and plants are in an oligotrophic state; lakes with moderate nutrients and productivity are in a mesotrophic state; and lakes with excessive nutrients and productivity are in a eutrophic state. Wisconsin trophic state index (WTSI) equations are used to convert measurements of summer water clarity, measured using a Secchi disk; chlorophyll-*a*, a measure of algae abundance; and total phosphorus concentrations to a common unit used to assess the overall productivity and thus trophic state throughout Wisconsin[98]. WTSI values based upon chlorophyll-a are considered the most reliable estimators of lake trophic state as this is the most direct measurement of algal abundance. This common unit allows lake-specific information to be compared to other lakes.[99] WTSI values are used to determine the trophic state of a lake, either oligotrophic, mesotrophic, or oligotrophic (see Figure 2.32).

Commission staff calculated the trophic status of Elizabeth Lake and Lake Mary using summer (defined as June 1st to September 15th) surface measurements of these three parameters collected at the deepest point in these Lakes (see Figures 2.33 and 2.34, respectively). Both Elizabeth Lake and Lake Mary border on mesotrophic and eutrophic conditions, with both lakes indicating more common mesotrophic conditions within the past decade. Lake Mary has slightly lower TSI values than Lake Elizabeth, indicating more mesotrophic conditions.

2.6 WATERSHED POLLUTANT LOADING

The most prevalent pollutants to lakes include sediment and nutrients, both of which have natural sources and sources that are attributable to human activity. Sediment and nutrients contribute to lake aging. Sediment and nutrient loads can greatly increase when humans disturb land cover and runoff patterns through activities such as tilling and construction, both of which typically loosen soil, increase runoff and in turn allow soil to more easily erode and eventually enter streams and lakes. In contrast, heavy metals, detergents, oils, and fertilizers were not common in the watershed under natural conditions and are essentially completely attributable to human activity.

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

[99] *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.*

Different human land use types contribute different types of pollution to water bodies. For example, phosphorus sources in rural areas may be correlated with agricultural fertilizers and animal waste delivered to waterbodies through overland runoff. In contrast, in urban areas, phosphorus from lawn fertilizers, clippings and leaves from ornamental plantings, and cleaning agents are often quickly conveyed to water bodies with little opportunity for attenuation. In 2010, the State of Wisconsin placed restrictions on the sale of some phosphorus-containing cleaning agents.[100] The State has also adopted a turf management standard limiting the application of lawn fertilizers containing phosphorus within the State,[101] potentially acting to reduce the amount of phosphorus discharged from urban settings. In both rural and urban areas, poorly maintained or failing onsite wastewater treatment systems have been found to contribute phosphorus to surface-water features.

Urban leaf litter can also be a substantial source of phosphorus pollution, particularly in urban sections of the watershed. A study conducted in the Lake Wingra watershed in Dane County indicates that 55 percent of the total annual residential phosphorus loading occurs during autumn, largely attributable to curbside and street-area leaf litter.[102] Leaves crushed by vehicular traffic leach greater amounts of phosphorus, particularly during wet weather. Runoff then washes the leached phosphorus into the stormwater drainage system and eventually into surface waters. Effectively managing leaves on residential streets during the fall can help reduce the phosphorus loading from urban areas within the Twin Lakes watershed.

Simulated Nonpoint Source Loads

The Commission simulated nonpoint source pollutant loads for suspended solids (sediment) and total phosphorus to the Twin Lakes using three land-use based models. One simulation used the USEPA Spreadsheet Tool for Estimating Pollutant Load (STEPL) model, another used the Wisconsin Lake Model Spreadsheet (WiLMS version 3.3.18) and third used the WDNR's Pollutant Load Ratio Estimation Tool

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

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

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

(PRESTO-Lite). These three models assume that a given land use type emits a set rate of pollutants on an annual basis.

PRESTO-Lite is a statewide tool that compares phosphorus loads from point and nonpoint sources within a watershed to output an annual average load. The comparison that comes from PRESTO-Lite can be used as a screening tool for municipal and industrial dischargers to aid in determining eligibility for adaptive management as part of NR 217.18, *Wisconsin Administrative Code*. PRESTO-Lite performs three functions: delineates a watershed to the point of interest, estimates the nonpoint source loading in that watershed, and aggregates the point source loading data in that watershed. According to the PRESTO-Lite outputs, nonpoint sources contribute 37 pounds of total phosphorus and 960 pounds of total phosphorus are contributed to Lake Mary and Elizabeth Lake, respectively, each year. There are no reported point sources within the Twin Lakes watershed. However, it should be noted that the watershed boundary delineated by PRESTO-Lite differs than the boundary delineated by Commission staff. Additionally, PRESTO-Lite does not take into account internally drained areas within the watershed that do not contribute pollutant loads via surface runoff to the Lakes. Consequently, the PRESTO-Lite model may not provide most accurate estimate of the nonpoint source loads to the Lakes.

To estimate how much pollutant loading could be reduced via best management practices (BMPs) within the Twin Lakes' watershed, the STEPL model was utilized in this study.[103] STEPL employs simple algorithms to calculate nutrient and sediment loads from different land uses and the load reductions that would result from the implementation of various BMPs. The annual nutrient loading was calculated based on the runoff volume and the pollutant concentrations in the runoff water as influenced by factors such as the land use distribution and management practices. The annual sediment load (sheet and rill erosion only) is calculated based on the Universal Soil Loss Equation and the sediment delivery ratio. The sediment and pollutant load reductions that result from the implementation of BMPs are computed using generalized BMP efficiencies. Commission staff initialized the STEPL model using the US EPA parameters defined for the Nippersink Creek Watershed and updated the watershed BMP coverage using estimates of 50 percent conservation tillage and 5 to 10 percent no-till usage as provided by Kenosha County Public Works & Development Services staff.[104]

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

[104] *Personal communication between Mark Jenks, Kenosha County Public Works & Development Services, and Commission staff (Justin Poinsatte), on February 16th, 2024.*

Without any BMPs implemented, Commission staff estimate an annual load of 5,366 pounds of phosphorus, 24,425 pounds of nitrogen, and 1,984 tons of sediment to the Twin Lakes from the watershed. Under the current estimated BMP coverage, the model outputs an estimated annual load of 4,459 pounds of phosphorus, 22,194 pounds of nitrogen, and 494 tons of sediment. Thus, the BMPs already implemented in the watershed are reducing nonpoint source pollutant loads by 16.9 percent for phosphorus, 9.1 percent for nitrogen, and 24.9 percent for sediment compared to modeled conditions without any BMPs implemented. Even with the BMPs implemented, agricultural lands still account for 67.7 percent of the phosphorus loads, 60.7 percent of the nitrogen loads, and 86.1 percent of the sediment loads to the Lake (see Table 2.22). Subbasin TL-2 in the northwestern portion of the watershed had the highest modeled total phosphorus, nitrogen, and sediment loading per acre within the watershed (see Maps 2.26, 2.27, and 2.28 as well as Table 2.23), followed by subbasins TL-1 and TL-3.

Commission staff also estimated phosphorus loading to the Lakes using WiLMS, which incorporates land use, hydrologic, and watershed area information to simulate the total flux of phosphorus during a typical year.[105] The WiLMS model produces a range of probable phosphorus load values (low, most likely, and high). The USGS has found that models tend to over-predict loading for calcareous lakes and would suggest that the low range values for WiLMS may better portray conditions in the watershed. Therefore, the low range values were also used to estimate water quality of the Lakes. Load estimates from WiLMS 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 are designed for reservoirs, some for deep lakes, while others are general lake models. The Canfield-Bachmann 1981 natural lake model was utilized to model Lake Mary and Lake Elizabeth total phosphorus concentrations based on the WiLMS-derived total phosphorus loading. The model predicted total phosphorus concentrations for Lake Elizabeth to be 0.061 mg/l. Actual measured concentrations have been measured at 0.022 mg/l. For Lake Mary, the predicted value is 0.032 mg/l using the same model. Actual observed summer value of phosphorus in Lake Mary is 0.019 mg/l. These discrepancies may be due to the known over-prediction of these models in hard-water lakes as well as the lakes' summer stratification trapping higher phosphorus concentrations in colder, deeper water.

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

This section concludes Chapter 2, which provided an inventory of the Lakes' watershed, shoreline, water quality, and pollutant loading conditions. Chapter 3 will provide recommendations on monitoring and management techniques, programs and policies, and funding opportunities to help maintain and enhance the aquatic habitat and recreational enjoyment of the Twin Lakes.

Community Assistance Planning Report Number 302 (2nd Edition)

LAKE MANAGEMENT PLAN UPDATE FOR MARY AND ELIZABETH LAKES
KENOSHA COUNTY, WISCONSIN

Chapter 2

INVENTORY FINDINGS AND RELEVANCE TO LAKE MANAGEMENT

TABLES

Table 2.1
Watershed Acreages: Lake, Watershed, and Subbasin Acreages

Defined Area	Acres
Lake Mary	333.0
Elizabeth Lake	753.0
Wisconsin	688.0
Illinois	65.0
Total Watershed[a]	7,524.0
Wisconsin	5,181.0
Illinois	2,343.0
Topographical Watershed[b]	6,438.0
Contributing Watershed[c]	5,749.0
Total Watershed Subbasins	
TL-1[d]	899.2
TL-2	647.7
TL-3	655.5
TL-4	1,100.6
TL-5	832.9
TL-6[e]	2,615.0
TL-7[f]	83.7
ID-1[g]	659.1
ID-2[g]	30.0

[a] *The Twin Lakes and all areas that could contribute surface runoff to the Lakes, including internally drained areas.*

[b] *All areas that topography suggests could contribute runoff to the Twin Lakes; does not include lake acreage.*

[c] *All areas typically contributing surface runoff to the Twin Lakes; does not include lake acreage or internally drained areas.*

[d] *Includes 333 acres of Lake Mary. TL-1 is 566.2 acres without the lake included.*

[e] *Includes 746.6 acres of Elizabeth Lake. TL-6 is 1,868.4 acres without the lake included.*

[f] *Includes 6.4 acres of Elizabeth Lake channel to outlet dam. TL-7 is 77.4 acres without the lake channel included.*

[g] *ID-1 and ID-2 are internally drained areas that do not contribute surface runoff to the Lakes under typical conditions.*

Source: SEWRPC

Table 2.2
Generalized Elevation of the Twin Lakes' Watershed

Elevation (feet)	State	Acres of Watershed	Percent of Watershed
	Illinois	2333.90	31.0
825	Wisconsin	2867.46	38.1
875	Wisconsin	2086.17	27.7
925	Wisconsin	195.87	2.6
975	Wisconsin	40.32	0.5

Source: Wisconsin Geological and Natural History Survey and SEWRPC

Table 2.3
Soil Slopes of the Twin Lakes' Watershed

Slope	State	Acres of Watershed	Percent of Watershed
0-6 Percent	Illinois	304.5	4.7
7-12 Percent	Illinois	4.0	0.1
7-12 Percent	Illinois	211.9	3.3
13-19 Percent	Illinois	160.4	2.5
20 Percent or Greater	Illinois	29.8	0.5
		2,269.0	35.2
0-6 Percent	Wisconsin	3,311.3	51.4
7-12 Percent	Wisconsin	459.3	7.1
13-19 Percent	Wisconsin	345.5	5.4
20 Percent or Greater	Wisconsin	52.9	0.8
	Wisconsin Total	4,169.0	64.8
	Topographical Watershed Total	6,438.0	100.0

Source: Wisconsin Geological and Natural History Survey and SEWRPC

Table 2.4
Pell Lake Monthly Weather Summary: 1991-2020

Month	Maximum Temperature (°F)	Minimum Temperature (°F)	Average Temperature (°F)	Precipitation (inches)
January	29.0	12.6	20.8	1.71
February	32.5	14.4	23.4	1.50
March	44.4	25.0	34.7	2.20
April	57.0	34.8	45.9	3.36
May	68.6	45.7	57.1	4.28
June	78.1	55.7	66.9	4.73
July	81.9	59.2	70.6	4.39
August	80.2	56.9	68.6	3.88
September	73.2	50.2	61.7	3.64
October	60.9	39.0	50.0	2.89
November	46.4	28.6	37.5	2.33
December	35.0	19.6	27.3	1.64

Source: NOAA and SEWRPC

Table 2.5
Pell Lake Climatic Comparison: 1991-2020 V 2006-2020

Month	Maximum Temperature (°F)	Minimum Temperature (°F)	Average Temperature (°F)	Precipitation (inches)
January	1.1	2.5	1.8	-0.06
February	-1.2	-0.5	-0.8	0.13
March	0.2	-0.1	0.1	0.28
April	-0.4	0.1	-0.2	0.29
May	-0.1	0.6	0.3	-0.05
June	0.0	0.4	0.2	0.18
July	0.4	0.7	0.5	-0.03
August	-0.2	0.3	0.0	0.33
September	0.8	0.3	0.6	-0.08
October	-0.2	0.2	-0.1	0.51
November	0.9	0.4	0.6	-0.23
December	0.2	1.4	0.8	0.57

Source: NOAA and SEWRPC

Table 2.6
Depth to Bedrock in the Twin Lakes' Watershed

Depth (feet)	State	Acres of Watershed	Percent of Watershed
N/A	Illinois	2,333.9	31.0
150-200	Wisconsin	3,369.9	44.8
200-250	Wisconsin	767.2	10.2
250-300	Wisconsin	51.0	0.7
Water	Wisconsin	1,001.8	13.3

Source: Wisconsin Geological and Natural History Survey and SEWRPC

Table 2.7
Hydrological Soil Groups of the Twin Lakes' Watershed

Hydrological Soil Group	State	Acres of Watershed	Percent of Watershed
A	Illinois	0.0	0.0
A/D	Illinois	219.1	2.9
B	Illinois	1,343.7	17.9
B/D	Illinois	413.0	5.5
C	Illinois	209.9	2.8
C/D	Illinois	79.5	1.1
Undefined	Illinois	68.7	0.9
	Illinois Total	2,333.9	31.0
A	Wisconsin	0.0	0.0
A/D	Wisconsin	186.4	2.5
B	Wisconsin	3,250.3	43.2
B/D	Wisconsin	501.3	6.7
C	Wisconsin	45.4	0.6
C/D	Wisconsin	141.5	1.9
Undefined	Wisconsin	1065.0	14.2
	Wisconsin Total	5,189.8	69.0
	Watershed Total	7,523.7	100.0

Source: SEWRPC

Table 2.8a
Pre-Settlement Vegetation of the Twin Lakes' Watershed

Pre-Settlement Vegetation	State	Acres of Watershed	Percent of Watershed
Wetland	Illinois	238.72	3.7%
Oak Savanna	Illinois	1929.82	29.8%
Lakes, Rivers, and Streams	Illinois	165.36	2.6%
Wetland	Wisconsin	328.69	5.1%
Prairie	Wisconsin	798.73	12.3%
Oak Forest	Wisconsin	587.11	9.1%
Oak Savanna	Wisconsin	2547.09	39.3%
Lakes, Rivers, and Streams	Wisconsin	928.20	14.3%
Total Acres		7523.72	
Current Areas Less Lakes		6480.00	

Source: ILDNR and SEWRPC

Table 2.8b
Pre-Settlement Vegetation of the Twin Lakes' Watershed

Pre-settlement Vegetation	State	Acres of Watershed	Percent of Watershed
Wetland	Illinois	560.77	8.7
Oak Savanna	Illinois	1658.01	25.6
Prairie	Illinois	43.24	0.7
Lakes, Rivers, and Streams	Illinois	71.89	1.1
Wetland	Wisconsin	328.69	5.1
Prairie	Wisconsin	798.73	12.3
Oak Forest	Wisconsin	587.11	9.1
Oak Savanna	Wisconsin	2547.09	39.3
Lakes, Rivers, and Streams	Wisconsin	928.20	14.3
Total Acres		7523.72	
Current Areas Less Lakes		6480.00	

Source: NRCS and SEWRPC

Table 2.9
Amended Hydrologic Budget for the Twin Lakes

Groundwater Recharge	**Lake Mary**			**Elizabeth Lake**		
	Very Dry Weather	Normal Weather	Very Wet Weather	Very Dry Weather	Normal Weather	Very Wet Weather
Inflows (per cent)						
Incident precipitation to lake surface	66%	62%	58%	36%	29%	24%
Runoff from tributary land area	5%	21%	31%	12%	39%	52%
Groundwater Inflow	30%	17%	11%	52%	25%	15%
Inflow from Lake Mary	--	--	--	0%	6%	9%
Total	100%	100%	100%	100%	100%	100%
Outflows (per cent)						
Evaporation from lake surface	96%	54%	37%	70%	26%	15%
Groundwater Outflow	0%	29%	52%	0%	49%	70%
Outflow	4%	17%	11%	30%	25%	15%
Total	100%	100%	100%	100%	100%	100%

Source: SEWRPC, USGS, WDNR

Table 2.10
Depth to Groundwater in the Twin Lakes' Watershed

Depth (feet)	State	Acres of Watershed	Percent of Watershed
N/A	Illinois	2333.9	31.0
0-25	Wisconsin	847.8	11.3
25-50	Wisconsin	2566.2	34.1
50+	Wisconsin	774.0	10.3
Water	Wisconsin	1001.8	13.3

Source: Wisconsin Geological and Natural History Survey and SEWRPC

Table 2.11
Potential Water Recharge for the Twin Lakes' Watershed

Potential for Water Recharge	State	Acres of Watershed	Percent of Watershed
N/A	Illinois	2,333.9	31.0
N/A	Wisconsin	51.7	0.7
High	Wisconsin	1,959.9	26.1
Moderate	Wisconsin	1,582.6	21.0
Undefined	Wisconsin	1,255.8	16.7
Very High	Wisconsin	339.8	4.5

Source: Wisconsin Geological and Natural History Survey and SEWRPC

Table 2.12
Twin Lakes' Winter Shoreline and Ice Conditions Respondents

Point	Address	Lake	Years of Response
1	2045 East Lakeshore Drive	Elizabeth	2018, 2020, 2021, 2022
2	207 West Park Drive	Elizabeth	2018
3	260 West Park Drive	Mary	2018
4	267 West Park Drive	Elizabeth	2022
5	1613 Mount Moriah Drive	Mary	2020
6	1616 Mount Moriah Drive	Elizabeth	2020
7	321 Indian Point Road	Mary	2022
8	325 Indian Point Road	Mary	2020
9	300 Indian Point Road	Mary	2020
10	1148 Lucille Avenue	Elizabeth	2018
11	1122 Lucille Avenue	Elizabeth	2022
12	1116 Lucille Avenue	Elizabeth	2018
13	2308 Haerle Avenue	Elizabeth	2021, 2022
14	2332 Haerle Avenue	Elizabeth	2022
15	2350 Haerle Avenue	Elizabeth	2022
16	2354 Haerle Avenue	Elizabeth	2022
17	2358 Haerle Avenue	Elizabeth	2022

Source: SEWRPC

Table 2.13
Historic Urban Growth in the Twin Lakes' Watershed: 1850-2010

Year	State	Acres of Watershed	Percent of Watershed	Cumulative Acres	Acres per Year
	Illinois	2,333.9	31.021	N/A	N/A
1900	Wisconsin	3.7	0.049	4	N/A
1920	Wisconsin	37.5	0.498	41	1.9
1950	Wisconsin	357.1	4.746	398	11.9
1963	Wisconsin	305.0	4.053	703	23.5
1970	Wisconsin	57.1	0.760	760	8.2
1975	Wisconsin	42.5	0.565	803	8.5
1980	Wisconsin	8.3	0.110	811	1.7
1990	Wisconsin	37.8	0.502	849	3.8
1995	Wisconsin	11.4	0.152	860	2.3
2000	Wisconsin	32.1	0.426	892	6.4
2010	Wisconsin	122.5	1.628	1,015	12.2
OUT	Wisconsin	4,174.9	55.490	N/A	N/A

Source: SEWRPC

Table 2.14
Land Use in the Twin Lakes' Watershed

	Watershed Subbasin Area (acres)								
Land Use Categories[a]	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	Internally Drained (Small)	Internally Drained (Large)
Agricultural	0	0	0	333.8	372.1	187.7	0.2	0	0
Airport	0	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	5.3	0.4	0	0	0
Governmental and Institutional	0	0	0	0	1.0	0	0	0	0
Industrial	0	0	0	0	0	0	0	0	0
Multi - Family Residential	0	0	0	0	0	0	0	0	0
Open Lands	0	0	0	35.0	34.4	21.7	4.9	0	0
Other Transportation, Communication, and Utilities	0	0	0	0	0	0	0	0	0
Recreational	0	0	0	0	10.4	56.2	10.5	0	0
Single - Family Residential	0	0	0	26.9	174.6	107.1	0.0	0	0
Streets and Highways	0	0	0	17.4	43.1	23.4	0.0	0	0
Surface Water	0	0	0	5.1	2.8	6.5	0.9	0	0
Wetlands	0	0	0	67.8	41.5	137.6	53.3	0	0
Woodlands	0	0	0	151.1	139.9	164.0	9.5	0	0
Illinois Subtotal	0	0	0	637.0	825.1	704.6	79.3	0	0
Agricultural	57.1	423.8	517.8	237.0	0	258.7	0	13.3	456.2
Airport	0	0	14.1	0	0	0	0	0	0
Commercial	13.6	1.1	8.8	0	0	0.1	0	0	0
Governmental and Institutional	17.5	5.4	0	0	0	0	0	0	0
Industrial	7.2	0	0	0	0	2.4	0	0	0.2
Multi - Family Residential	17.9	0	0	0	0	1.6	0	0	0
Open Lands	25.9	33.8	27.7	36.1	0	89.1	0	0	65.1
Other Transportation, Communication, and Utilities	1.4	0	0	0	0	0.5	0	0	4.3
Recreational	6.0	19.8	18.0	5.5	0	17.1	0	9.2	0.6
Single - Family Residential	247.5	79.3	17.0	40.1	0	340.8	0	3.9	83.0
Streets and Highways	84.9	51.3	24.6	15.9	0	100.2	0	3.7	40.7
Surface Water	3.7	1.1	0.3	0.9	0	7.1	0	0	0.3
Wetlands	22.7	15.0	11.9	35.7	0	165.7	0	0	1.4
Woodlands	60.7	10.5	8.7	84.7	0	169.8	0	0	1.7
Wisconsin Subtotal	565.9	641.0	648.8	455.7	0	1,153.1	0	30.1	653.4
Total	565.9	641.0	648.8	1,092.7	825.07	1,857.7	79.3	30.1	653.4

[a] *Parking included in associated use.*

Source: SEWRPC

Table 2.15
Planned Land Use for the WI Portion of the Twin Lakes' Watershed

Land Use Categories[a]	Acres	Percent
Urban		
Residential		
Single-Family - Rural Density	145	1.9
Single-Family - Suburban Density	528	7.0
Single-Family - Low Density	975	13.0
Single-Family - Medium Density	793	10.5
Single-Family - High Density	0	0.0
Multi-Family	22	0.3
Commercial	133	1.8
Industrial	280	3.7
Governmental and Institutional	78	1.0
Transportation, Communication, and Utilities	764	10.2
Recreational	75	1.0
Subtotal	3793	50.4
Rural		
Agricultural	1008	13.4
Other Open Lands	369	4.9
Wetlands	572	7.6
Woodlands	669	8.9
Water	1113	14.8
Extractive	0	0.0
Landfill	0	0.0
Subtotal	3731	49.6
Total	7524	100.0

[a] *Parking included in associated use.*

Source: SEWRPC

Table 2.16
Civil Divisions in the Twin Lakes Watershed: 2020

Municipality	State	Acres	Percent
Town of Burton	Illinois	14.4	0.2
Town of Richmond[a]	Illinois	1,844.6	24.5
Village of Spring Grove	Illinois	474.9	6.3
Town of Bloomfield	Wisconsin	24.4	0.3
Town of Randall	Wisconsin	1,634.8	21.7
Village of Genoa City	Wisconsin	256.7	3.4
Village of Twin Lakes[b]	Wisconsin	3,274.0	43.5
	Total	7,523.7	100.0

[a] *The calculated acreage for the Town of Richmond includes 65 acres of Elizabeth Lake.*

[b] *The calculated acreage for the Village of Twin Lakes includes all 333 acres of Lake Mary and 688 acres of Elizabeth Lake.*

Source: SEWRPC

Table 2.17
Sanitary Sewer Service Areas of the Twin Lakes Watershed

Treatment Plant	Sanitary Sewer Area	Total Acreage of Sanitary Area	Subbasin (acres)								
			TL-1	TL-2	TL-3	TL-4	TL-5	TL-6	TL-7	Internally Drained (ID-1)	Internally Drained (ID-2)
Wisconsin											
Village of Twin Lakes	Twin Lakes	3,580.6	0.1	324.9	42.2	64.8	0	1,806.2	0	420.8	22.4
Pell Lake Sanitary District No. 1	Powers-Benedict-Tombeau Lakes	44.7	0.0	42.6	2.1	0	0	0	0	0	0
Village of Genoa City	Genoa City	147.6	0.0	0	147.6	0	0	0	0	0	0
Illinois											
Spring Grove FPA	Spring Grove FPA	145.6	0.0	0	0	0	145.6	0	0	0	0
Richmond FPA	Richmond FPA	644.9	0.0	0	0	0	105.4	455.9	83.7	0	0
	Total	4,563.4	0.1	367.5	191.9	64.8	251.0	2,262.1	83.7	420.8	22.4

Source: SEWRPC

Table 2.18
Wetland Cover Types in the Twin Lakes' Watershed

Wetland Cover Type	Acres of Watershed	Percent of Wetlands in Watershed
Aquatic bed	106.7	23.7
Emergent/wet meadow	144.8	32.2
Filled/drained wetland	6.7	1.5
Flats/unvegetated wet soil	12.3	2.7
Forested	49.7	11.0
Open water	11.0	2.4
Scrub/shrub	118.6	26.4
Total	449.7	100.0

Source: Wisconsin Geologic and Natural History Survey and SEWRPC

Table 2.19
Upland Cover Types in the Twin Lakes' Watershed

Upland Cover Type	Acres of Watershed	Percent of Watershed
Deciduous	419.574	5.577
Grassland	65.719	0.873
Mixed	5.214	0.069
Out	6969.359	92.632
Upland Brush	43.574	0.579
Upland Conifer	20.282	0.270
Total	7523.72	100

Source: SEWRPC

Table 2.20
Environmental Corridors in the Twin Lakes' Watershed

Corridor Type	State	Acres	Percent of Watershed
N/A	Illinois	2,333.9	31.0
Not in Environmental Corridor	Wisconsin	3,548.0	47.2
Primary Environmental Corridor	Wisconsin	1,475.9	19.6
Secondary Environmental Corridor	Wisconsin	53.3	0.7
Isolated Natural Resource Area	Wisconsin	112.6	1.5

Source: SEWRPC

Table 2.21
Lake Water Quality Parameter Descriptions, Typical Values, and Regulatory Limits

Parameter	Description	Southeastern Wisconsin Values[a]		Regulatory Limit or Guideline	Elizabeth Lake Values		Lake Mary Values	
		Median	Range		Mean	Range	Mean	Range
Chloride (mg/L)	Low concentrations (e.g., < 5 mg/L) naturally occur in lakes due to natural weathering of bedrock and soils. Human activities increase concentrations (e.g., road salts, wastewater, water softener regeneration) and can affect certain plants and animals. Chloride remains in solution once in the environment and **can serve as an excellent indicator of other pollutants.**	41	18-260	Acute toxicity[b,c] 757 Chronic toxicity[b,c] 395	30.8[d]	6.2-75.6	44	9.3-123
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]	6.78[f]	1.74-14.1[f]	5.54	0.8-14.8
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]	8.5[g]	0.2-16.3	8.7	0.1-17.9

Table continued on next page.

Table 2.21 Continued

Parameter	Description	Southeastern Wisconsin Values[a]		Regulatory Limit or Guideline	Elizabeth Lake Values		Lake Mary Values	
		Median	Range		Mean	Range	Mean	Range
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 drainage lake such as Pewaukee 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]	22f	5-100[f]	19	0-83
Water Clarity (feet)	Measured with a Secchi disk (a ballasted black-and-white, eight-inch-diameter plate), which is lowered into the water until a depth is reached at which the disk is no longer visible. It can be affected by physical factors, such as suspended particles or water color, and by various biologic factors, including seasonal variations in planktonic algal populations living in a lake. **Measurements less than five feet are considered indicative of poor water clarity and eutrophic lake conditions**.	4.6	3-12	10.9[h]	6.67	3.25-15.25[f]	8.34	2.3-28.9f
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]	32-82.0	--[g]	32-82.5

[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) for Chlor-a, for total phosphorus; for water clarity, values based on combined east and west basins annual average.*

Table 2.21 Continued

[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

Table 2.22
Simulated Pollutant Annual Loading in the Twin Lakes' Watershed

Subbasin	Phosphorus (pounds per year)			Nitrogen (pounds per year)	Sediment (tons per year)
	STEPL	WiLMS	PRESTO-Lite	STEPL	STEPL
TL-1	346	NA	37	2,080	74
TL-2	1,089	NA		6,012	247
TL-3	616	NA		2,645	288
TL-4	738	NA		3,207	327
TL-5	618	NA		2,849	229
TL-6	1,040	NA		5,329	322
TL-7	12	NA		71	2
Total	4,459	NA		22,194	1,490

Note: The boundaries of the subbasins within the Twin Lakes' watershed differ in acreage and extent between the PRESTO-Lite boundaries and those used by the Commission for the STEPL analysis.

Source: Wisconsin Geologic and Natural History Survey and SEWRPC

Table 2.23
Simulated Pollutant Annual Loading Per Acre in the Twin Lakes' Watershed

	Phosphorus (pounds per acre)			Nitrogen (pounds per acre)	Sediment (tons per acre)
Subbasin	STEPL	WiLMS	PRESTO-Lite	STEPL	STEPL
TL-1	0.6	NA	0.1	3.7	0.1
TL-2	1.7	NA		9.4	0.4
TL-3	0.9	NA		4.1	0.4
TL-4	0.7	NA		2.9	0.3
TL-5	0.7	NA		3.4	0.3
TL-6	0.6	NA		2.8	0.2
TL-7	0.1	NA		0.9	0.0
Average	0.8			3.9	0.2

Note: The boundaries of the subbasins within the Twin Lakes' watershed differ in acreage and extent between the PRESTO-Lite boundaries and those used by the Commission for the STEPL analysis.

Source: Wisconsin Geologic and Natural History Survey and SEWRPC

Community Assistance Planning Report Number 302 (2nd Edition)

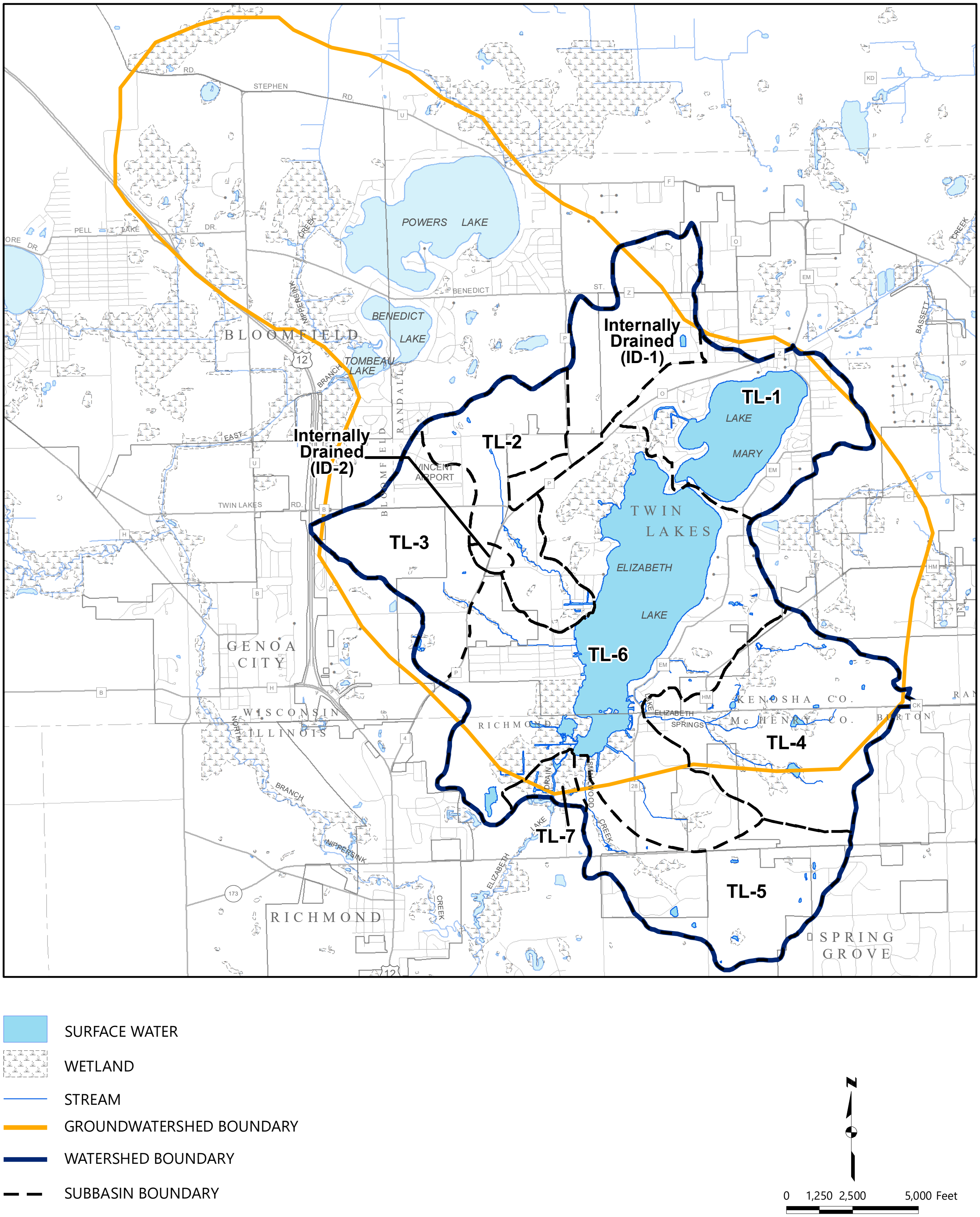
LAKE MANAGEMENT PLAN UPDATE FOR MARY AND ELIZABETH LAKES
KENOSHA COUNTY, WISCONSIN

Chapter 2

INVENTORY FINDINGS AND RELEVANCE TO LAKE MANAGEMENT

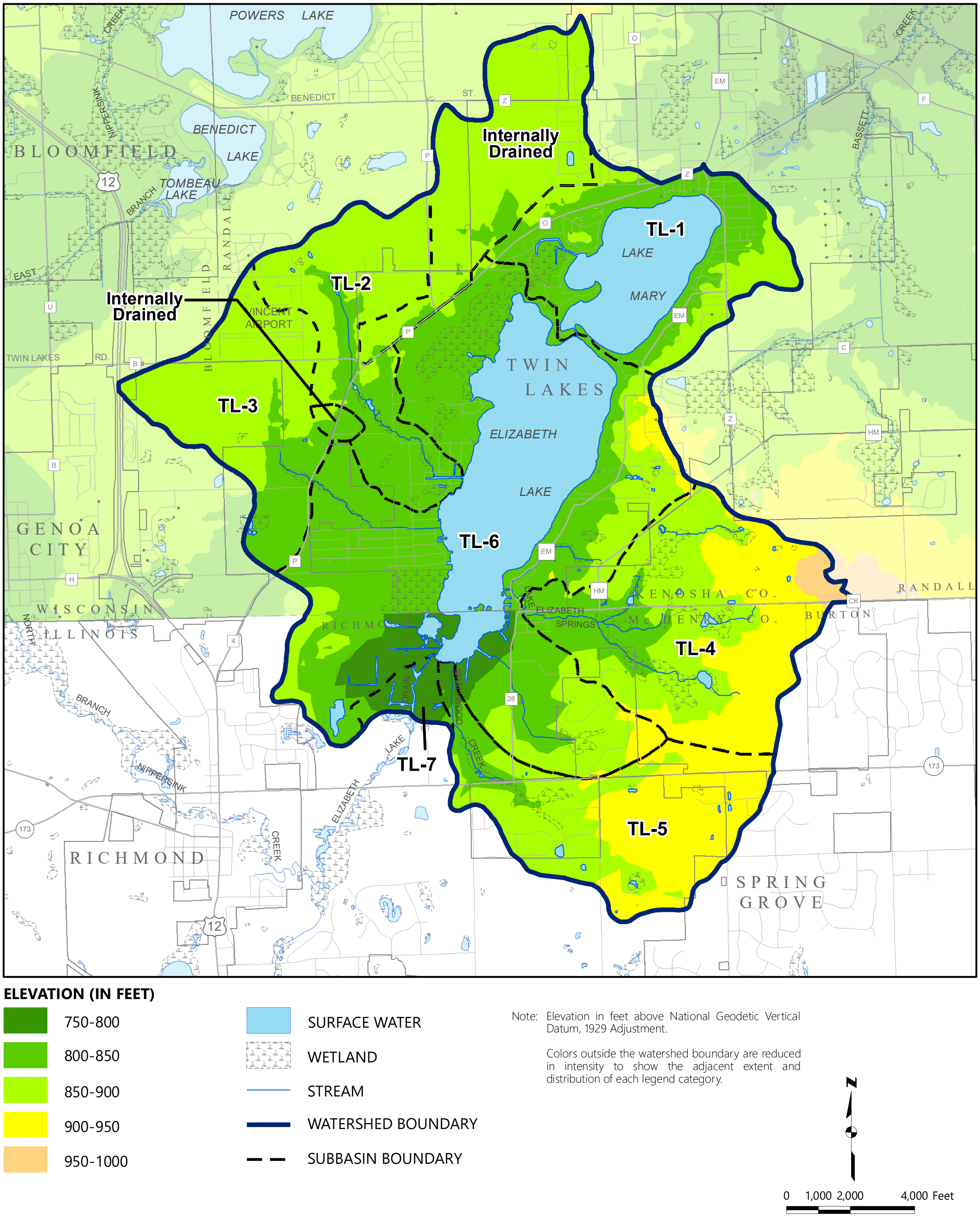
MAPS

Map 2.1
Watershed and Groundwatershed for the Twin Lakes



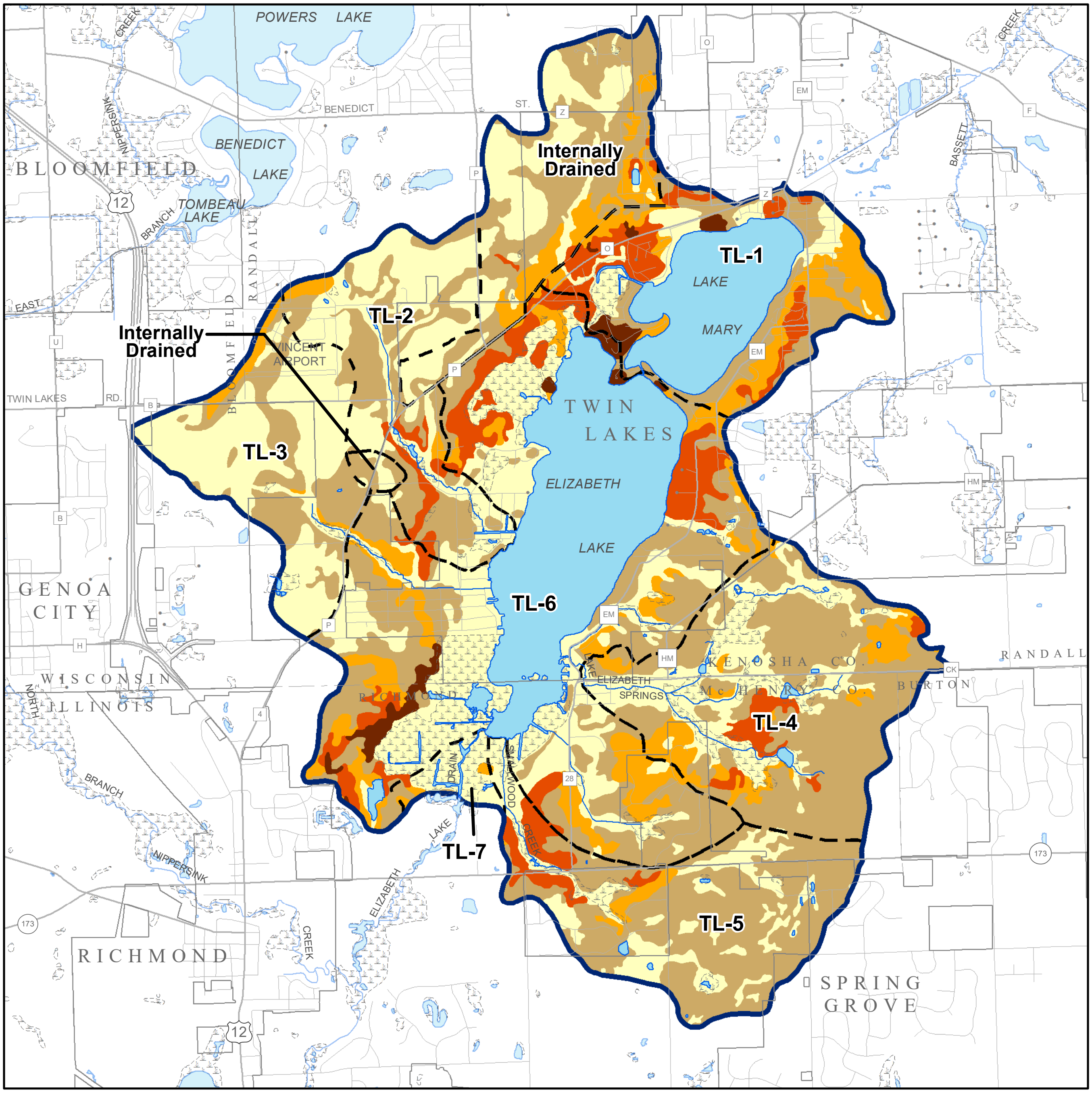
Source: Wisconsin Geological and Natural History Survey, Illinois State Water Survey, and SEWRPC

Map 2.2
Topographic and Physiographic Characteristics Within the Twin Lakes Study Area



Source: Southeastern Wisconsin Regional Planning Commission

Map 2.3
Soil Slopes Within the Twin Lakes Study Area



SOILS HAVING SLOPES RANGING FROM 0 TO 6 PERCENT

SOILS HAVING SLOPES RANGING FROM GREATER THAN 2 TO 6 PERCENT

SOILS HAVING SLOPES RANGING FROM GREATER THAN 6 TO 12 PERCENT

SOILS HAVING SLOPES RANGING FROM GREATER THAN 12 TO 20 PERCENT

SOILS HAVING SLOPES OF GREATER THAN 20 PERCENT

SURFACE WATER

WETLAND

STREAM

WATERSHED BOUNDARY

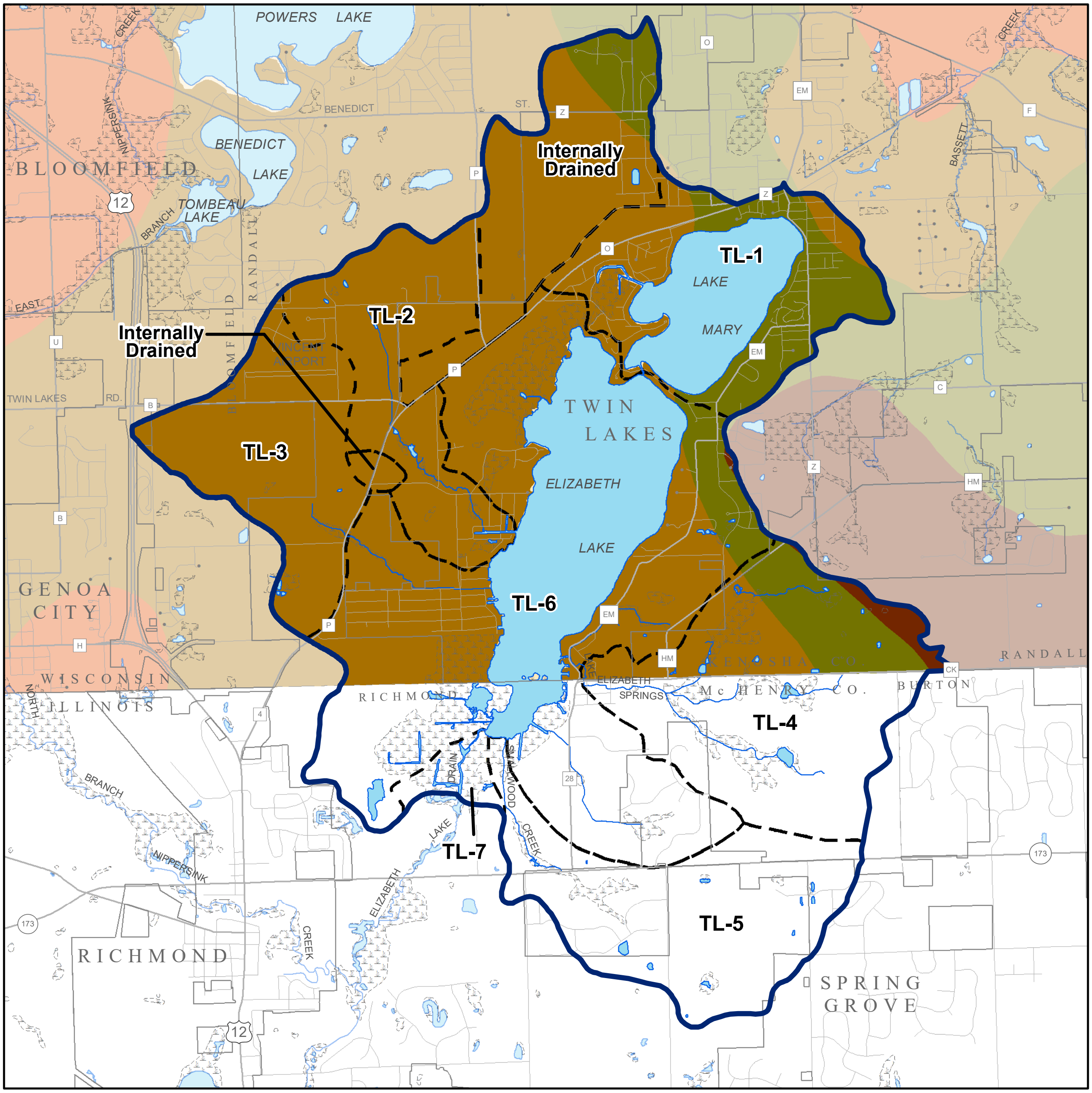
SUBBASIN BOUNDARY

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

0 1,000 2,000 4,000 Feet

Source: Natural Resources Conservation Service and SEWRPC

Map 2.4
Depth to Bedrock Within the Twin Lakes Study Area



DEPTH TO BEDROCK (IN FEET)

- 100-150
- 150-200
- 200-250
- 250-400

- SURFACE WATER
- WETLAND
- STREAM
- WATERSHED BOUNDARY
- SUBBASIN BOUNDARY

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

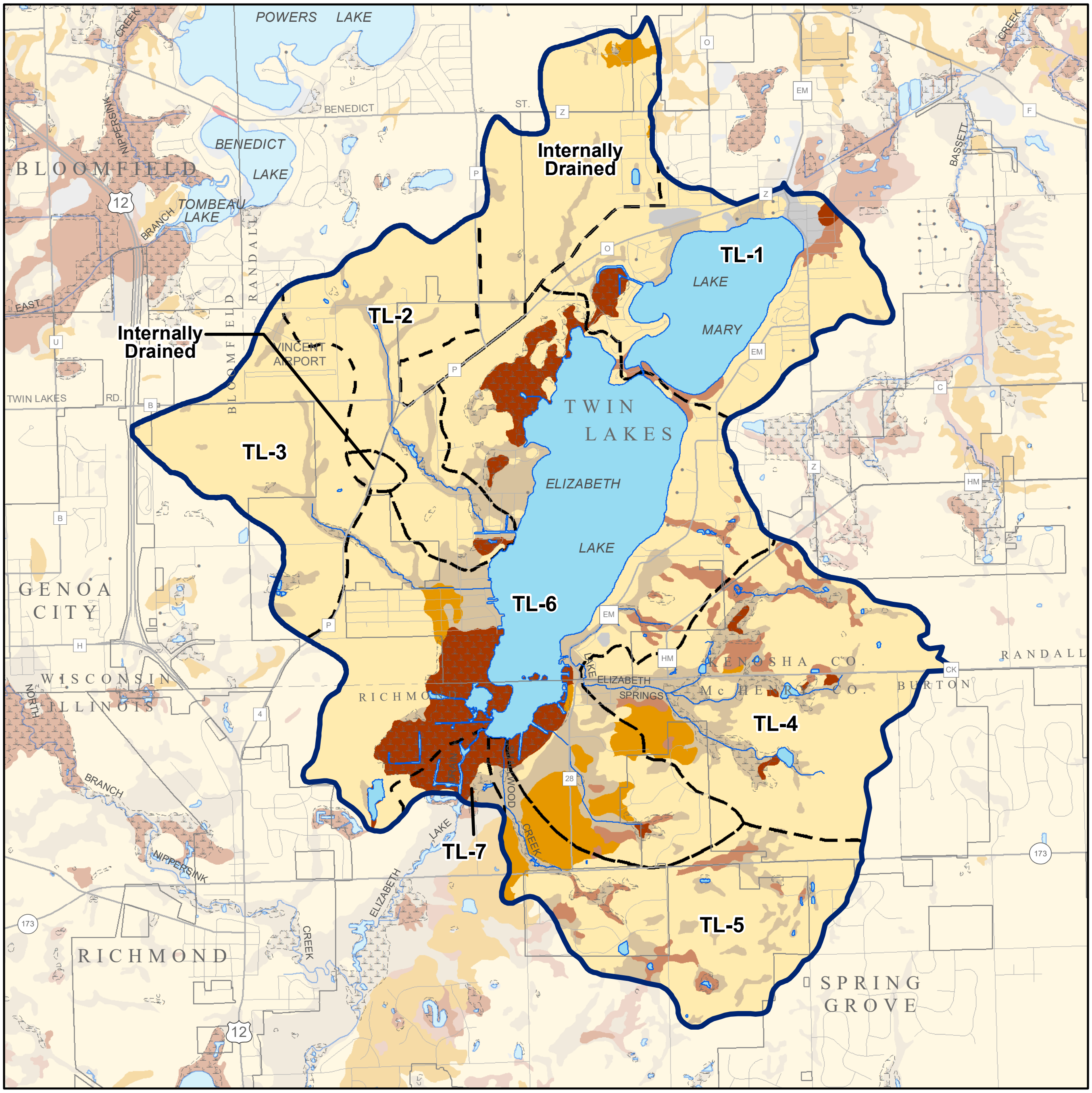
Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

N

0 1,000 2,000 4,000 Feet

Source: Wisconsin Geological Natural History Survey and Southeastern Wisconsin Regional Planning Commission

Map 2.5
Hydrologic Soil Groups Within the Twin Lakes Study Area



GROUP A: WELL-DRAINED SOILS

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

GROUP B: MODERATELY DRAINED SOILS

GROUP C: POORLY DRAINED SOILS

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

GROUPS C/D AND D: VERY POORLY DRAINED SOILS; POORLY DRAINED SOIL/VERY POORLY DRAINED SOIL (POORLY DRAINED IF WATER TABLE IS LOWERED THROUGH PROVISION OF A DRAINAGE SYSTEM. VERY POORLY DRAINED IF WATER TABLE IS NOT LOWERED.)

HYDROLOGIC SOIL GROUP NOT DETERMINED

SURFACE WATER

WETLAND

STREAM

WATERSHED BOUNDARY

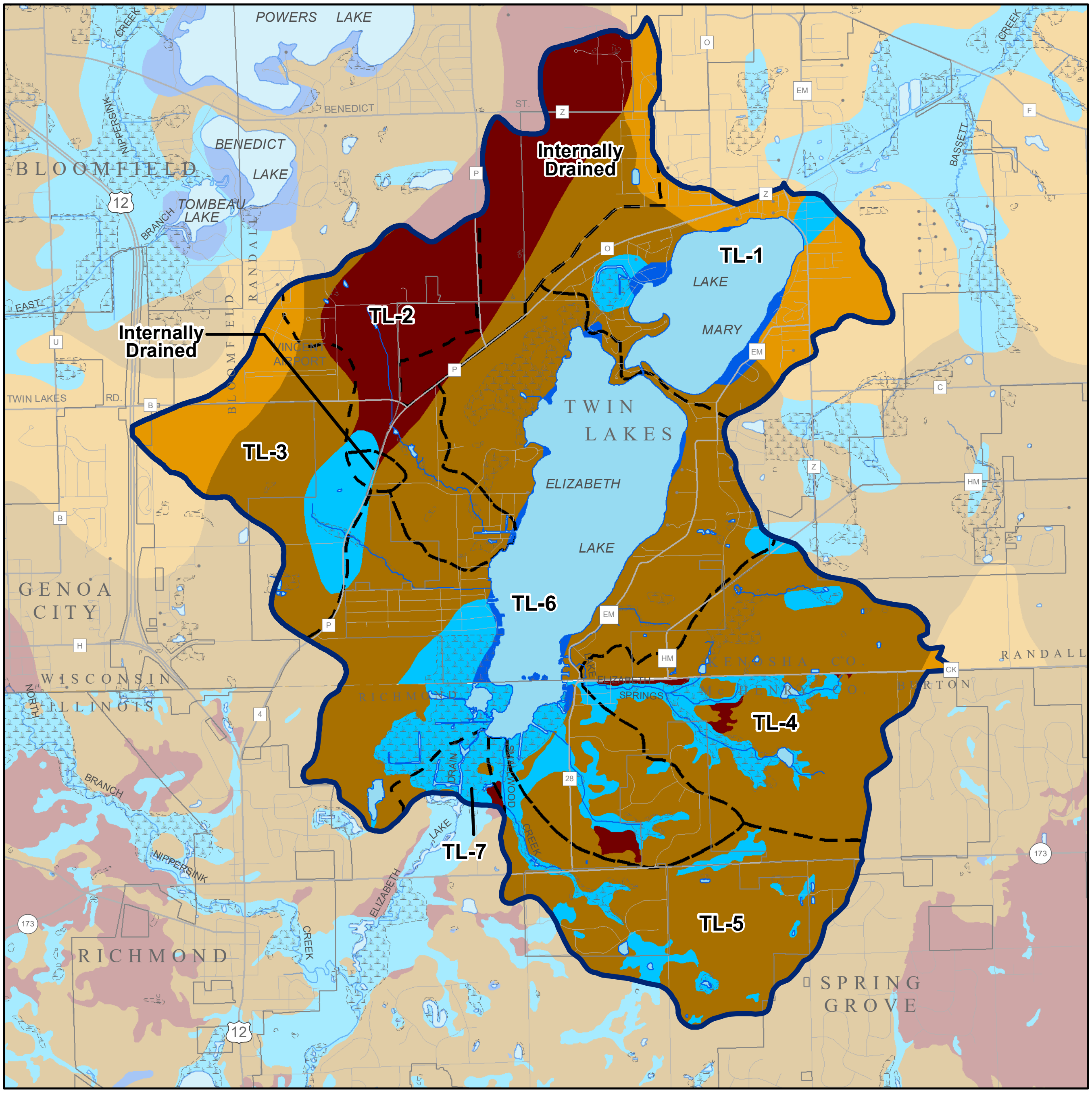
SUBBASIN BOUNDARY

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

0 1,000 2,000 4,000 Feet

Source: Natural Resources Conservation Service and Southeastern Wisconsin Regional Planning Commission

Map 2.6
Presettlement Vegetation Within the Twin Lakes Study Area: 1836



PRESETTLEMENT VEGETATION TYPES

- PRAIRIE
- OAK SAVANNA
- OAK FOREST
- WETLAND
- LAKES, RIVERS, OR STREAMS
- SURFACE WATER
- WETLAND
- STREAM
- WATERSHED BOUNDARY
- SUBBASIN BOUNDARY

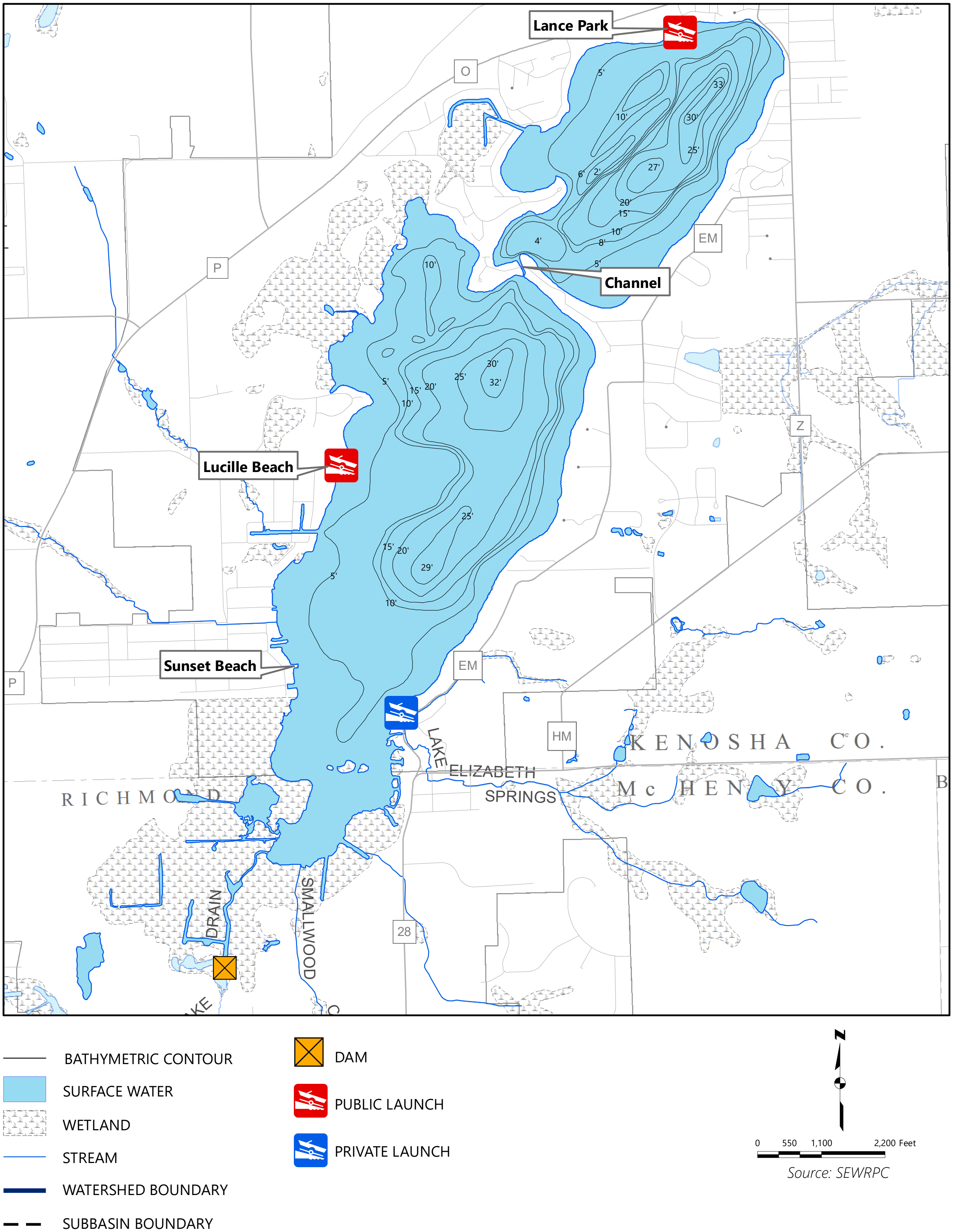
Note: Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

N

0 1,000 2,000 4,000 Feet

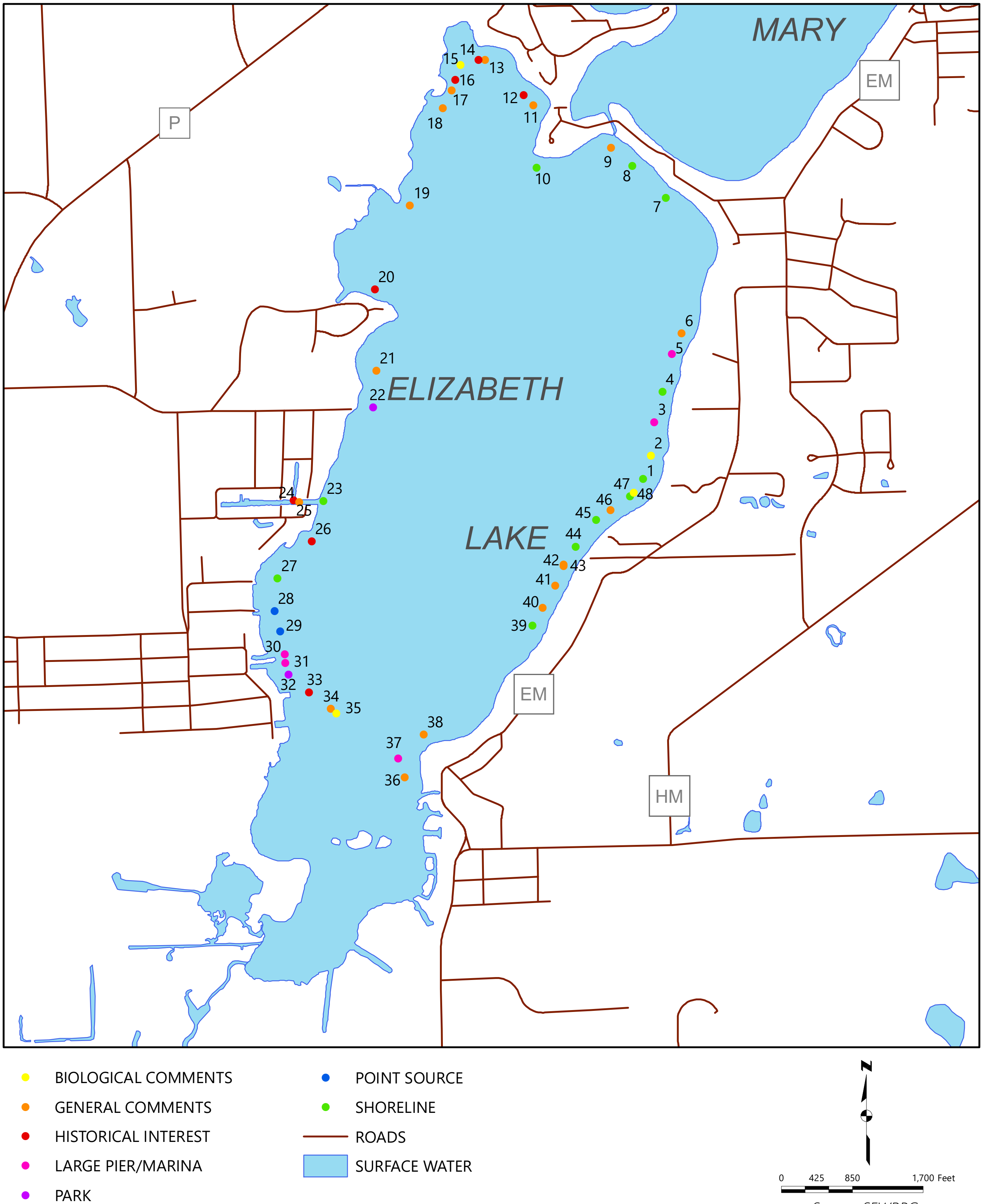
Source: Natural Resources Conservation Service and Southeastern Wisconsin Regional Planning Commission

Map 2.7
Bathymetry Contours for Lake Mary and Elizabeth Lake



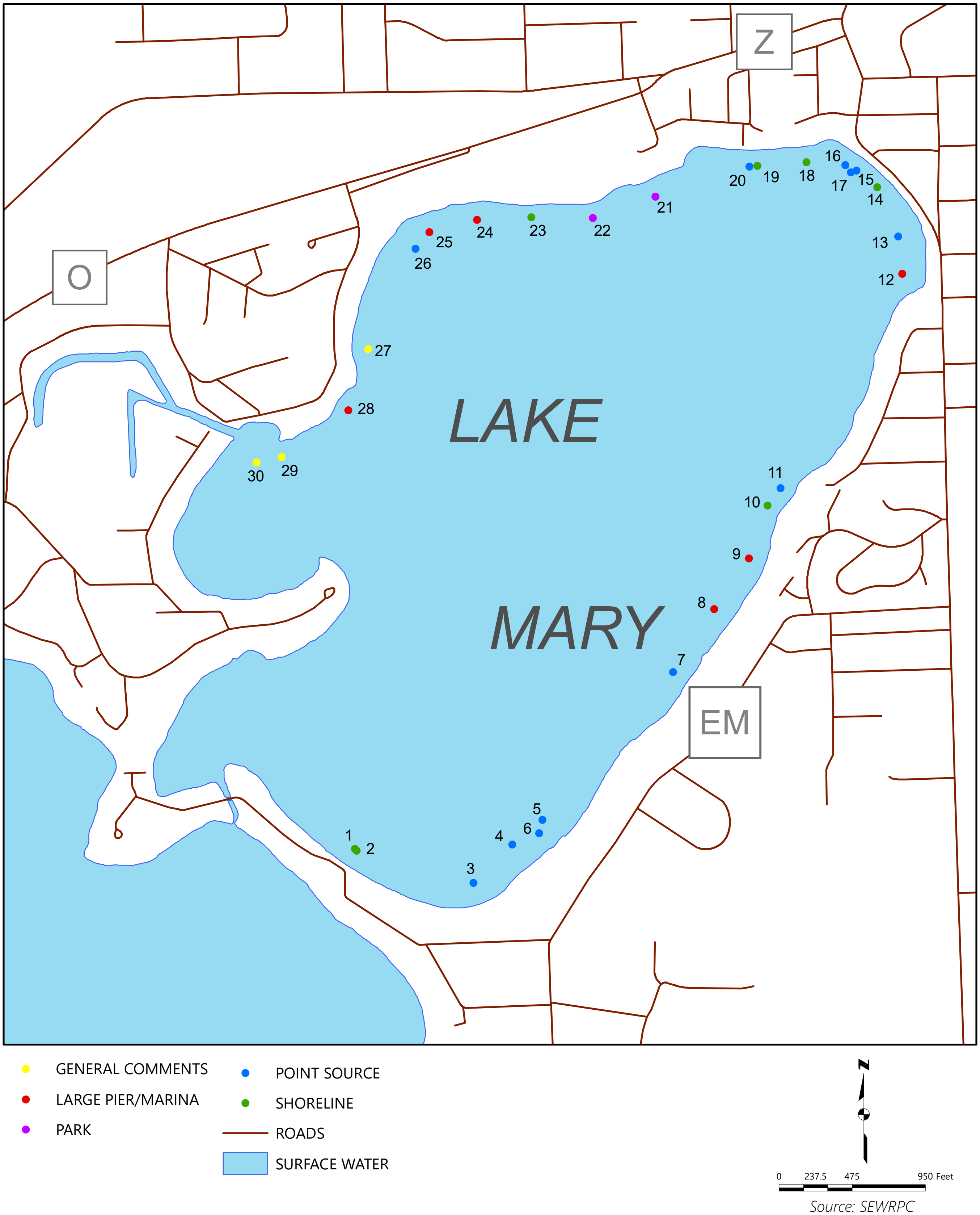
Source: SEWRPC

Map 2.8
Lake Elizabeth Shoreline Survey Points of Interest



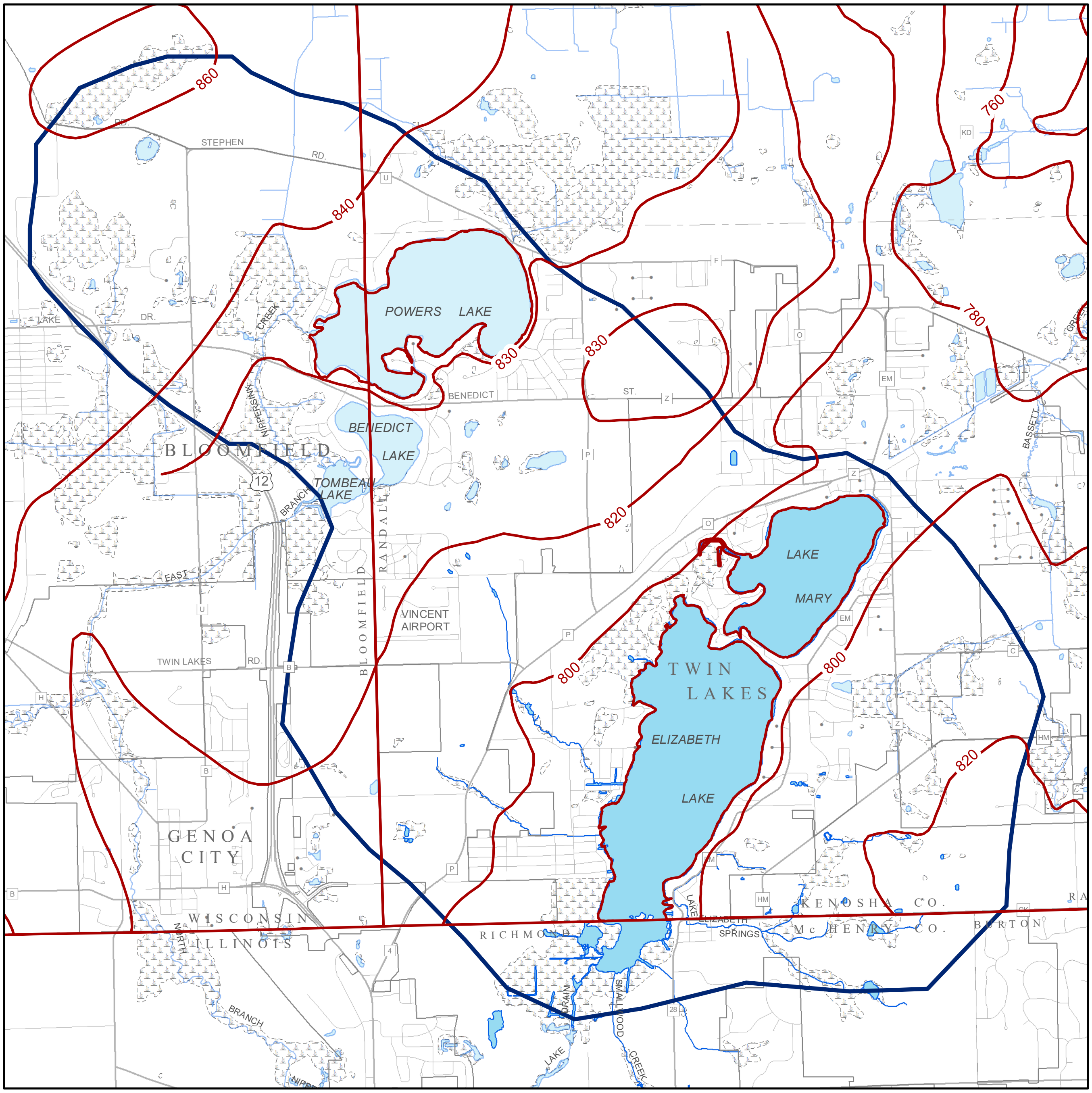
Source: SEWRPC

Map 2.9
Mary Lake Shoreline Survey Points of Interest



Source: SEWRPC

Map 2.10
Groundwater Elevation Contours Within the Twin Lakes Groundwatershed



WATER TABLE CONTOUR ELEVATION

SURFACE WATER

WETLAND

STREAM

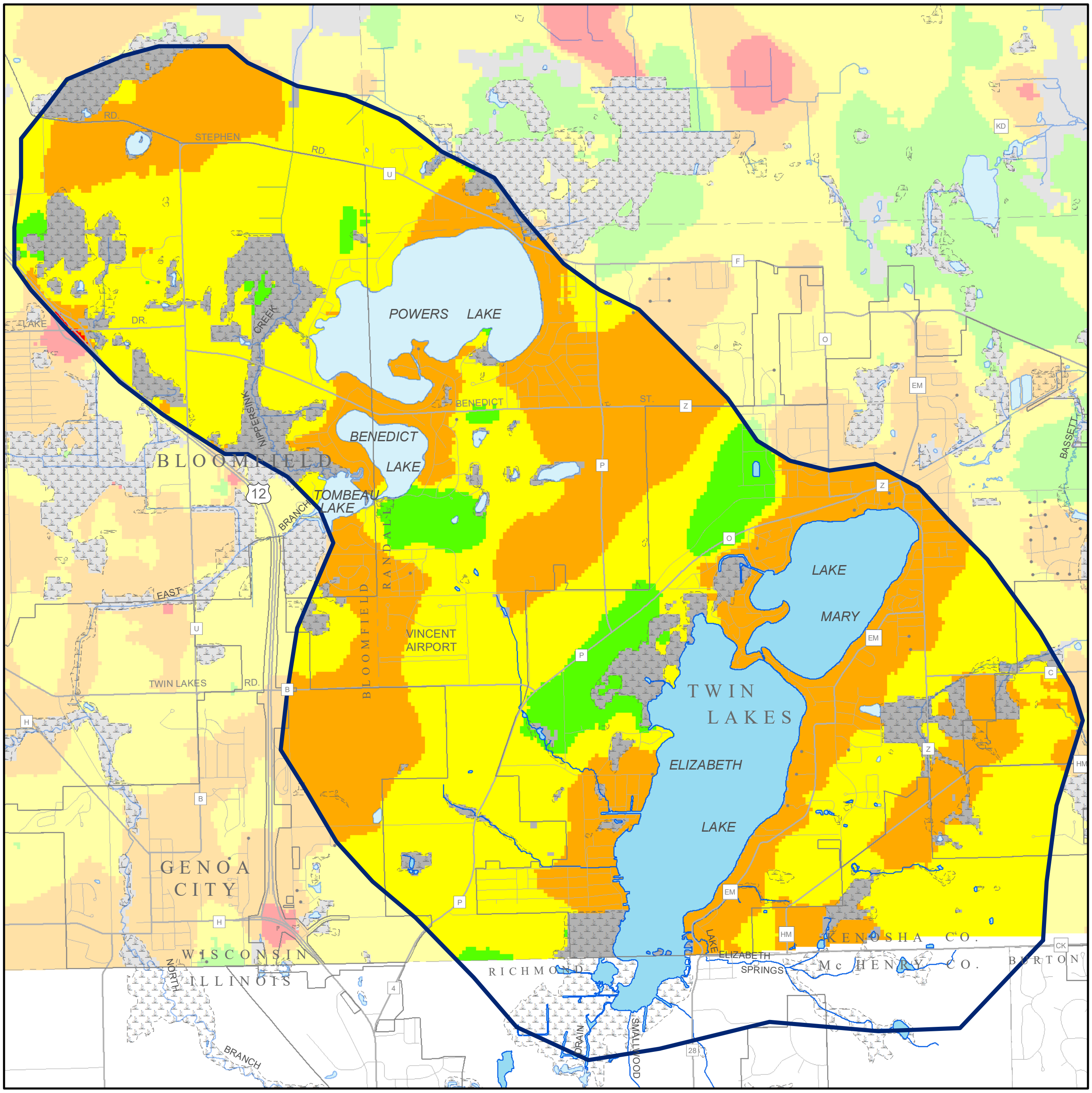
GROUNDWATERSHED BOUNDARY

N

0 1,125 2,250 4,500 Feet

Source: Wisconsin Geological and Natural History Survey, Illinois State Water Survey, and SEWRPC

Map 2.11
Groundwater Recharge Potential Within the Twin Lakes Groundwatershed



VERY HIGH

HIGH

MODERATE

LOW

UNDEFINED

SURFACE WATER

WETLAND

STREAM

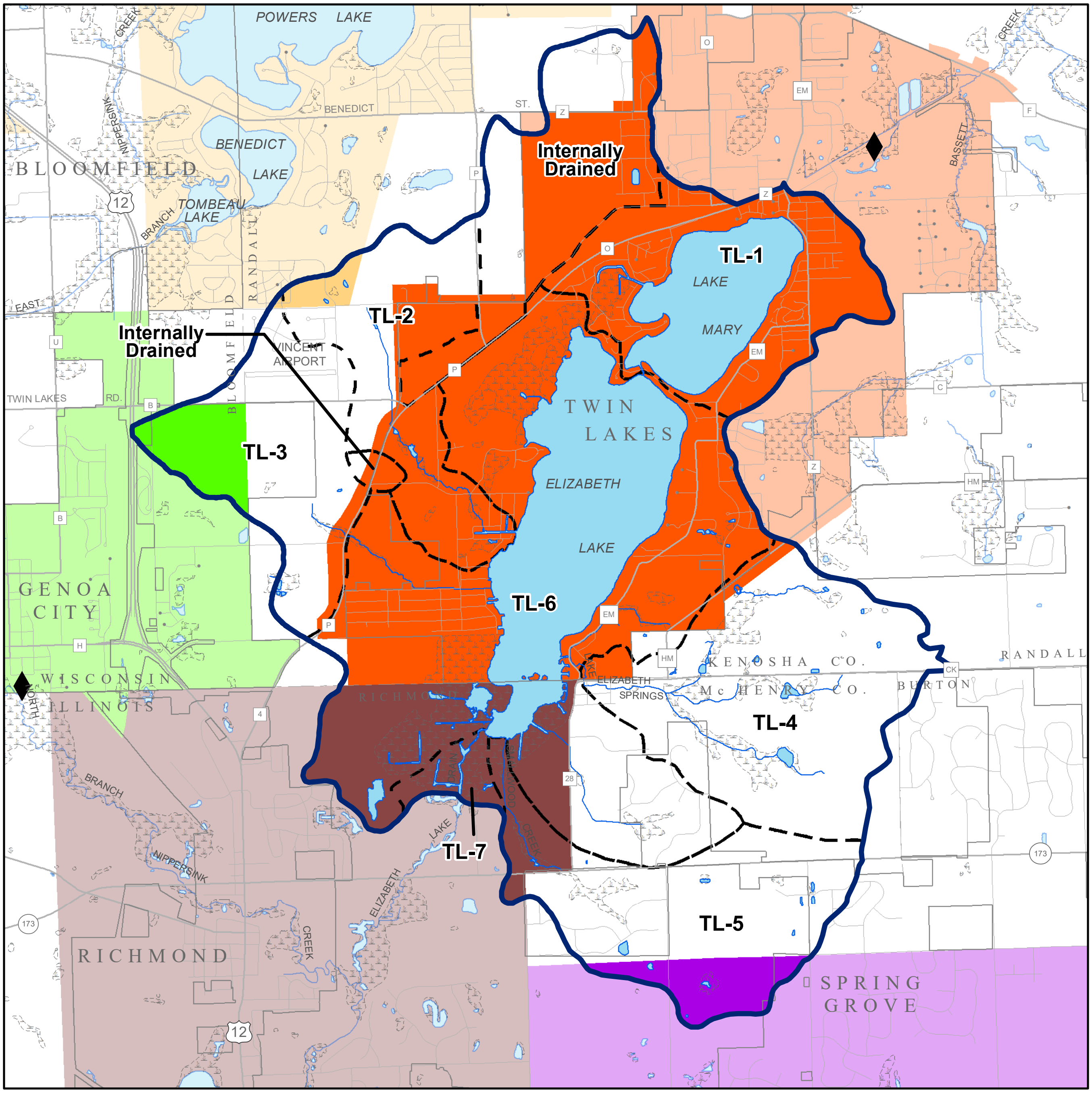
GROUNDWATERSHED BOUNDARY

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

0 1,050 2,100 4,200 Feet

Source: Wisconsin Geological and Natural History Survey and Southeastern Wisconsin Regional Planning Commission

Map 2.12
Adopted Sanitary Sewer Service Areas Within the Twin Lakes Study Area: March 2018



PELL LAKE SANITARY DISTRICT NO. 1

VILLAGE OF GENOA CITY

VILLAGE OF TWIN LAKES

RICHMOND FACILITY PLANNING AREA

SPRING GROVE FACILITY PLANNING AREA

SEWERAGE TREATMENT PLANT

SURFACE WATER

STREAM

WATERSHED BOUNDARY

SUBBASIN BOUNDARY

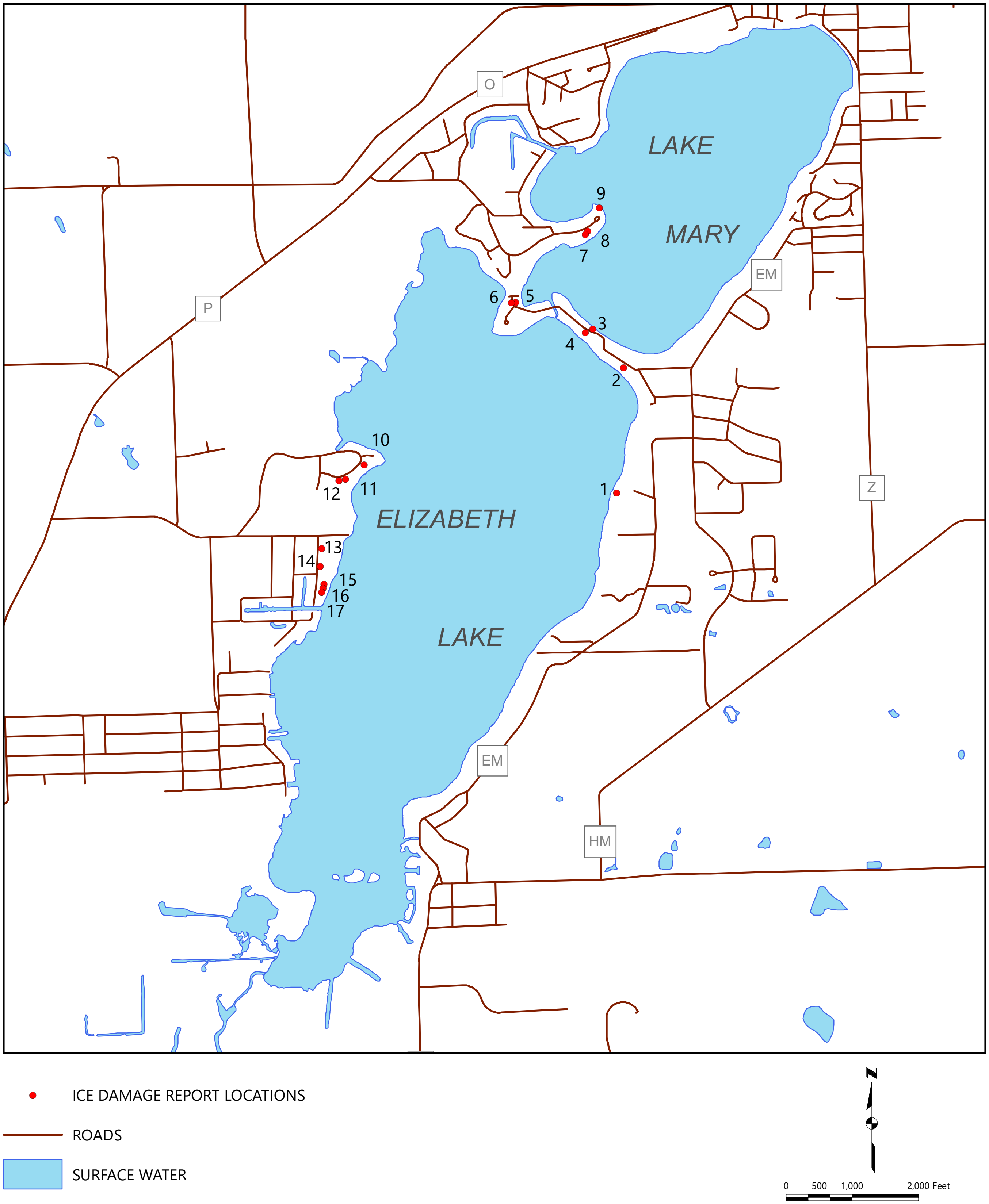
Note: Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

N

0 1,000 2,000 4,000 Feet

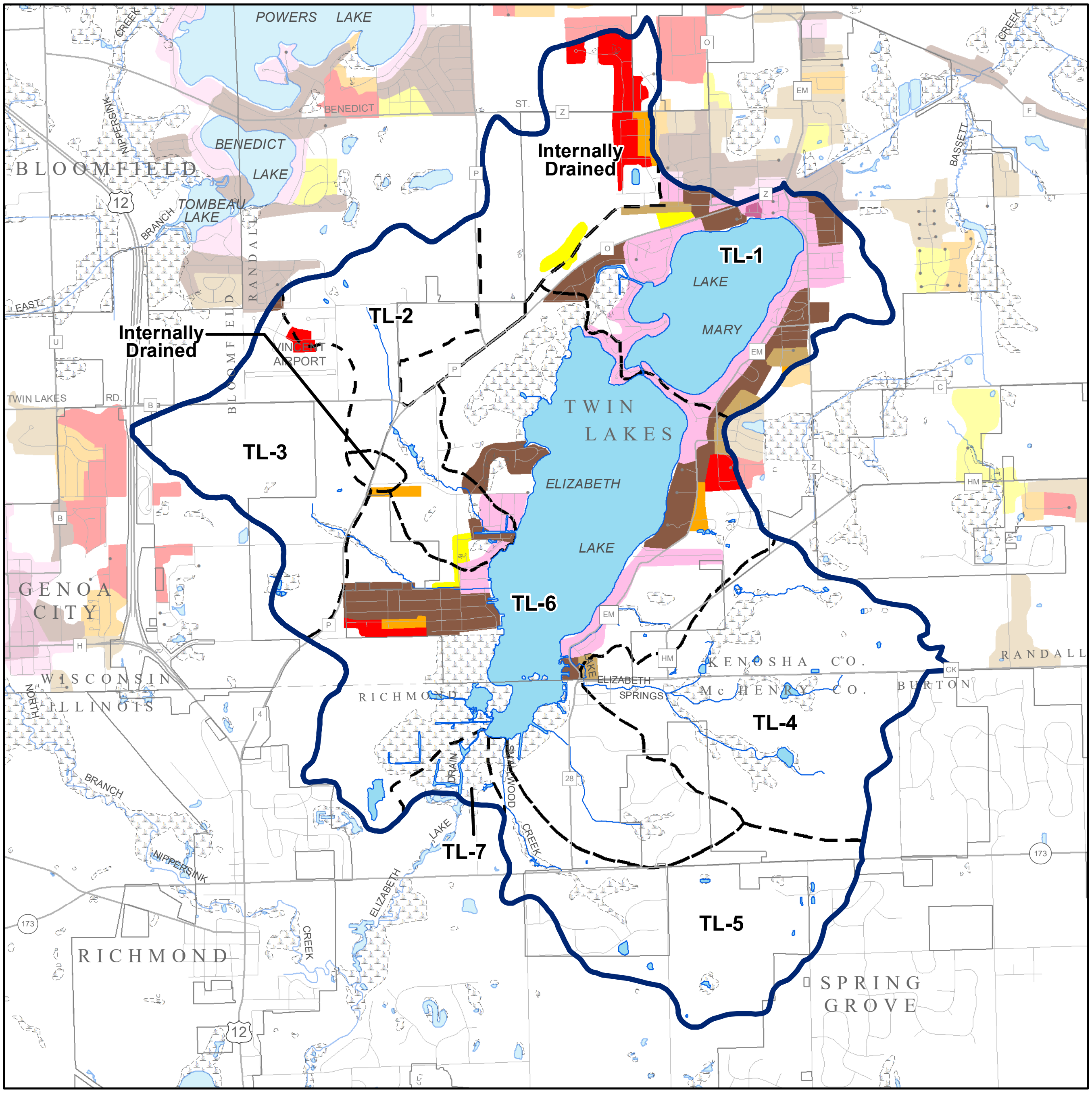
Source: Chicago Metropolitan Agency for Planning and Southeastern Wisconsin Regional Planning Commission

Map 2.13
Locations of Reported Conditions of Shorelines



Source: SEWRPC

Map 2.14
Historical Urban Growth Within the Twin Lakes Study Area: 1850-2010



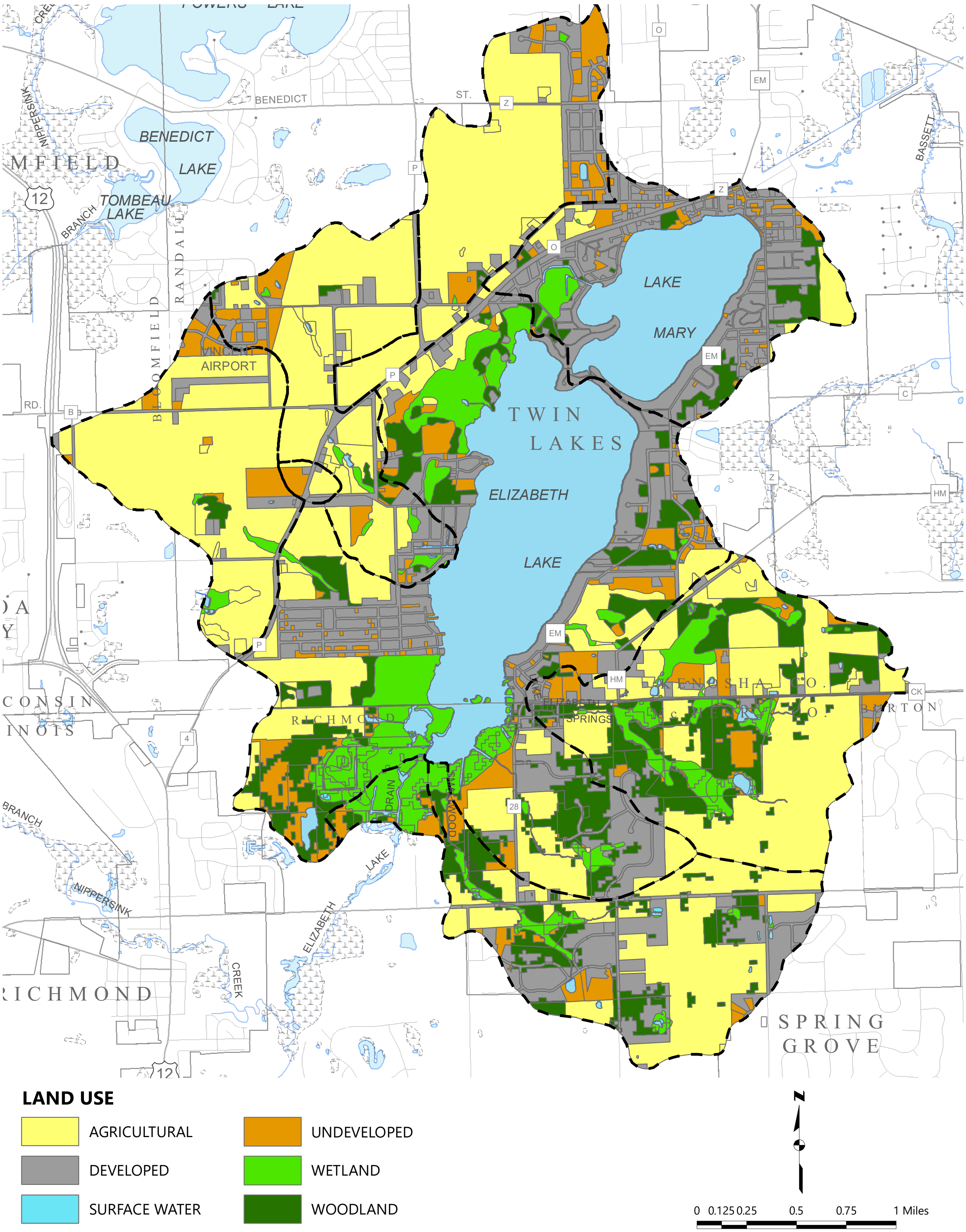
	BEFORE 1900		2001-2010
	1901-1950		SURFACE WATER
	1951-1970		WETLAND
	1970-1980		STREAM
	1981-1990		WATERSHED BOUNDARY
	1991-2000		SUBBASIN BOUNDARY

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

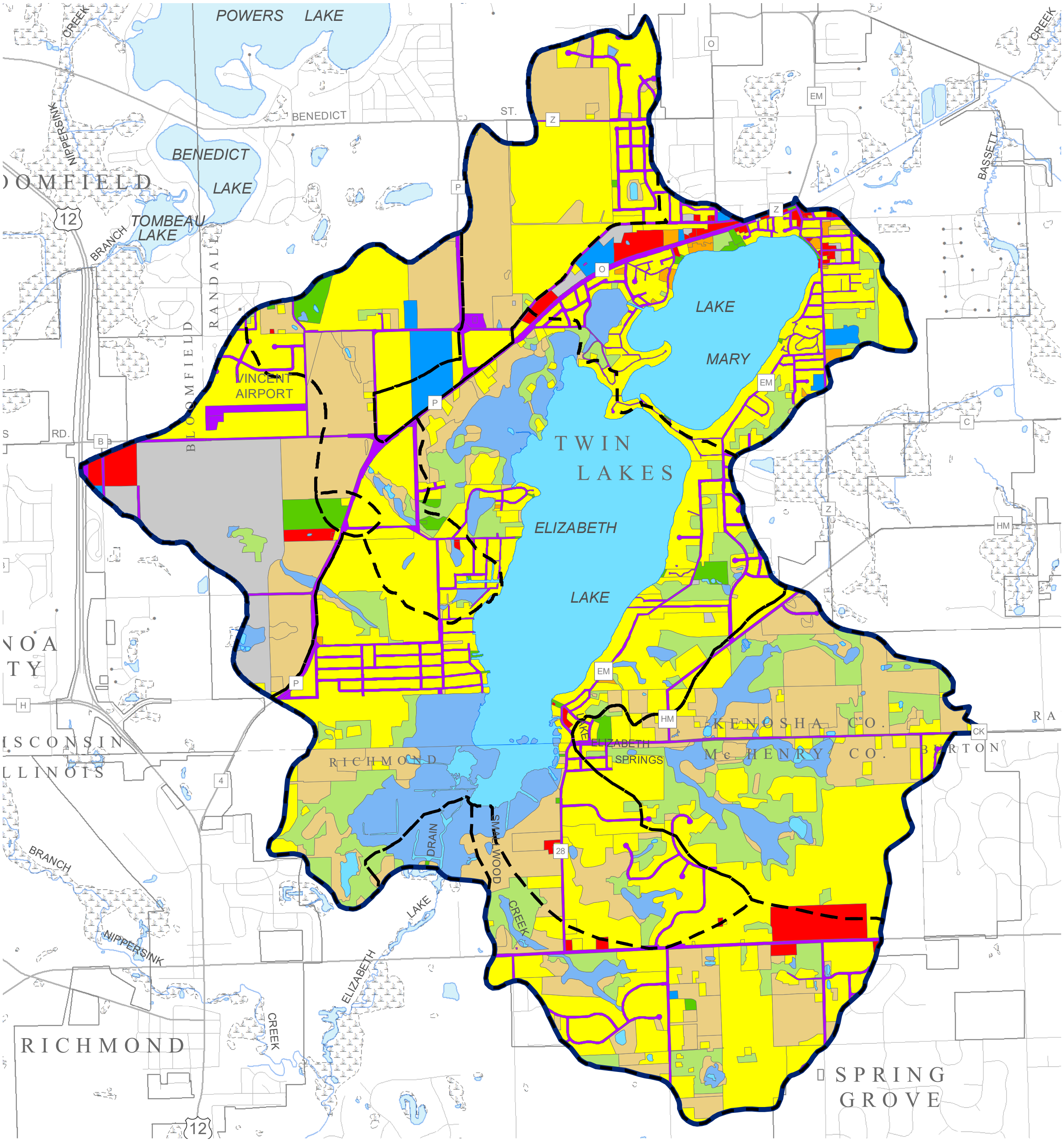
0 1,000 2,000 4,000 Feet

Source: Southeastern Wisconsin Regional Planning Commission

Map 2.15
2015 Wisconsin and 2013 Illinois Generalized Land Use for the Twin Lakes Watershed



Map 2.16
Planned Land Use for Twin Lakes Watershed



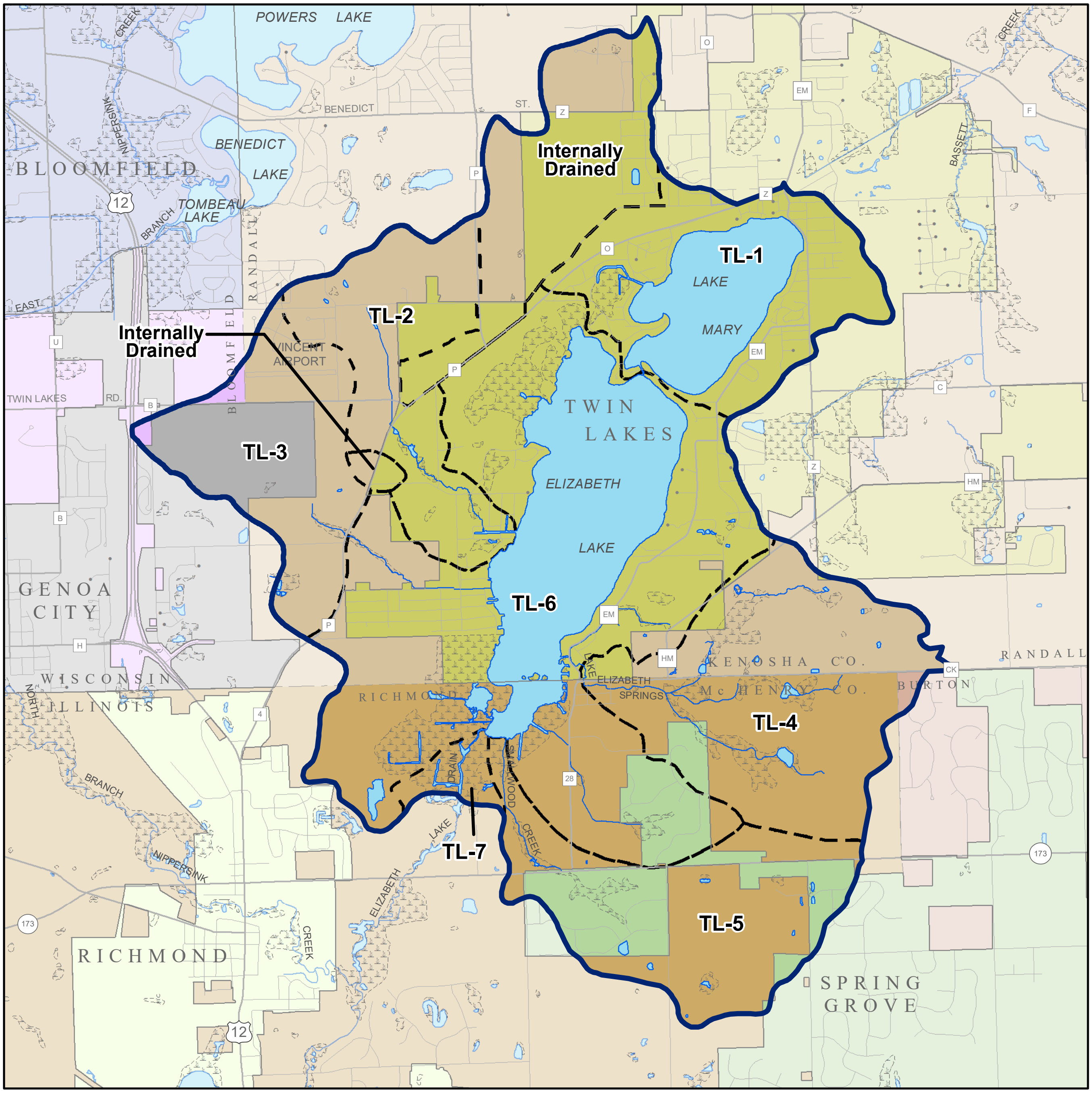
SINGLE-FAMILY RESIDENTIAL	GOVERNMENT AND INSTITUTIONAL
MULTI-FAMILY RESIDENTIAL	RECREATION
COMMERCIAL	WETLANDS
INDUSTRIAL	WOODLANDS
TRANSPORTATION, COMMUNICATIONS, AND UTILITIES	AGRICULTURAL, UNUSED, AND OTHER OPEN LANDS
EXTRACTIVE AND LANDFILL	SURFACE WATER

WETLAND
STREAM
WATERSHED BOUNDARY

N

0 0.1 0.2 0.4 0.6 Miles

Map 2.17
Civil Divisions Within the Twin Lakes Study Area



TOWN OF BLOOMFIELD	VILLAGE OF GENOA CITY
TOWN OF BURTON	VILLAGE OF RICHMOND
TOWN OF RANDALL	VILLAGE OF SPRING GROVE
TOWN OF RICHMOND	VILLAGE OF TWIN LAKES

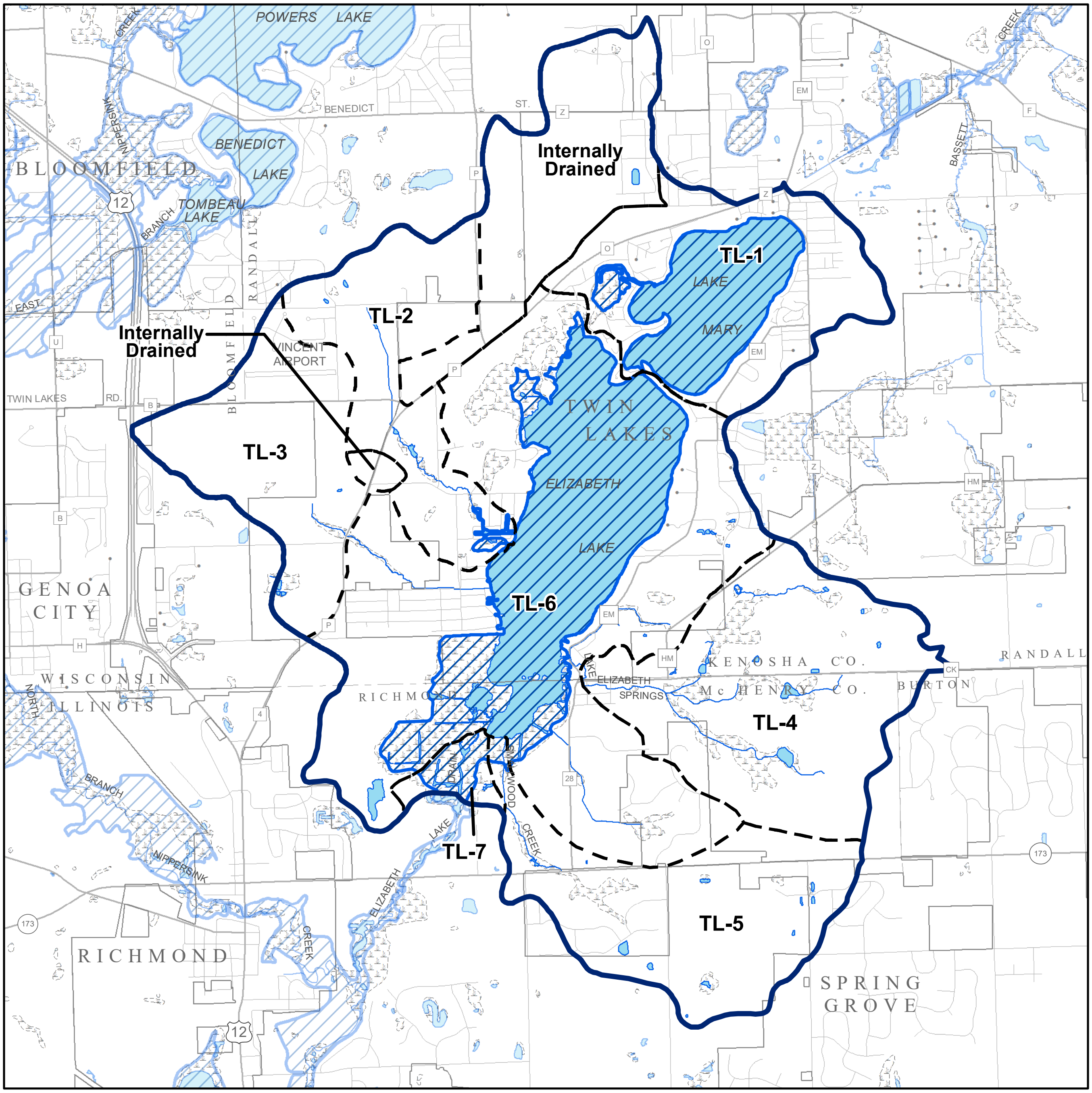
SURFACE WATER
STREAM
WATERSHED BOUNDARY
SUBBASIN BOUNDARY

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

0 1,000 2,000 4,000 Feet

Source: Southeastern Wisconsin Regional Planning Commission

Map 2.18
Floodplains Within the Twin Lakes Study Area



ONE-PERCENT-ANNUAL-PROBABILITY (100-YEAR RECURRENCE INTERVAL) FLOODPLAIN (FEMA FIS: KENOSHA, SEPTEMBER 2017, MCHENRY, JUNE 2018, WALWORTH, MARCH 2013)

SURFACE WATER

WETLAND

STREAM

WATERSHED BOUNDARY

SUBBASIN BOUNDARY

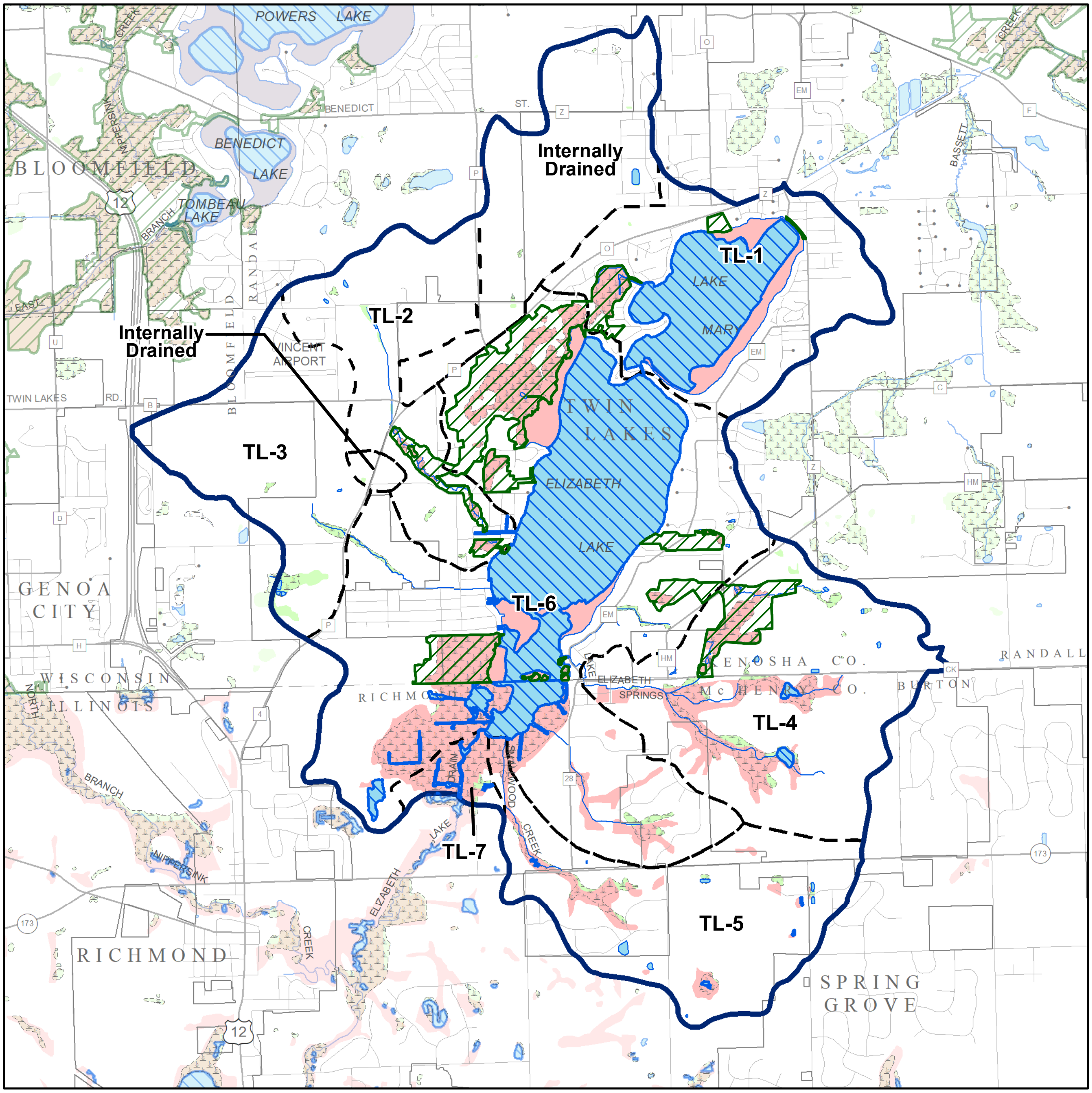
Note: Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

N

0 1,000 2,000 4,000 Feet

Source: Federal Emergency Management Agency and SEWRPC

Map 2.19
Advance Identification (ADID) Wetlands Within the Twin Lakes Study Area: 2005



PRIMARY ENVRIRONMENTAL CORRIDOR
ADID LAKES AND PONDS
ADID WETLANDS
WETLANDS OUTSIDE OF PRIMARY ENVIRONMENTAL CORRIDORS
SURFACE WATER
WETLAND
STREAM
WATERSHED BOUNDARY
SUBBASIN BOUNDARY

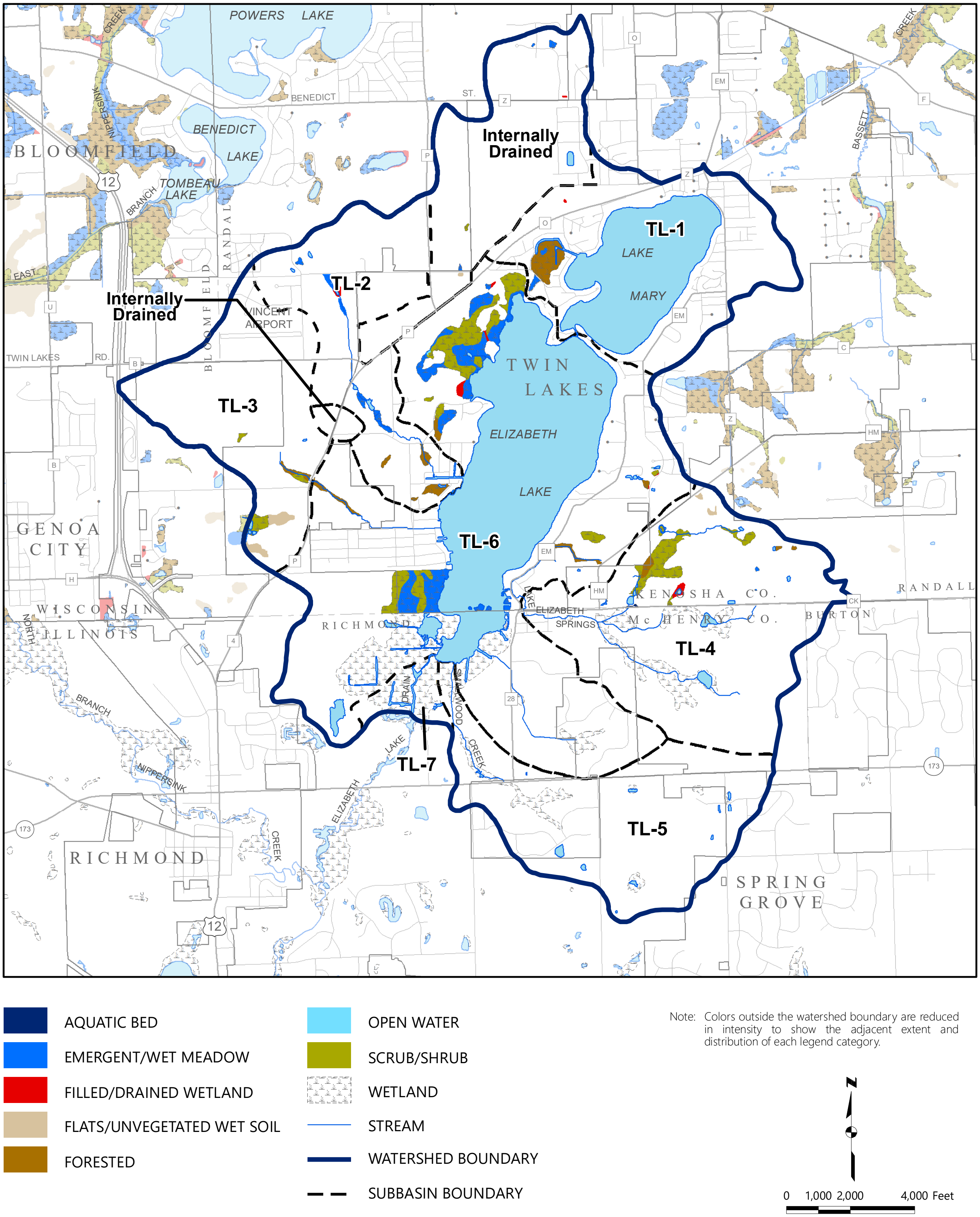
Note: Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

N

0 1,000 2,000 4,000 Feet

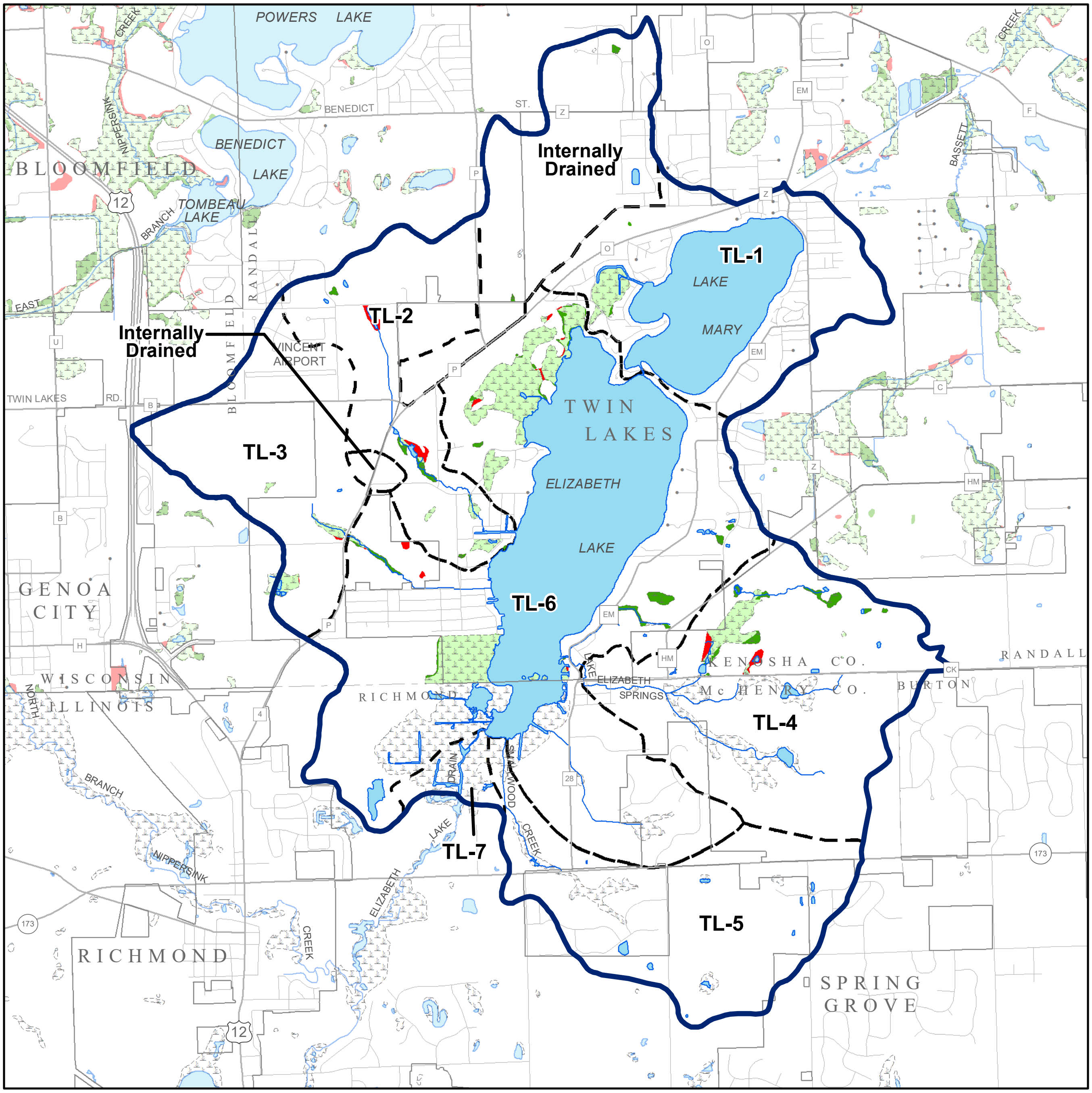
Source: National Wetlands Inventory, Illinois, Department of Natutal Resources, and Southeastern Wisconsin Regional Planning Commission

Map 2.20
Wetland Cover Types Within the Twin Lakes Study Area: 2010



Source: Southeastern Wisconsin Regional Planning Commission

Map 2.21
Wetland Gains or Losses Within the Twin Lakes Study Area: 2000-2015



WETLANDS

WETLAND LOSSES

WETLAND GAINS

SURFACE WATER

WETLAND

STREAM

WATERSHED BOUNDARY

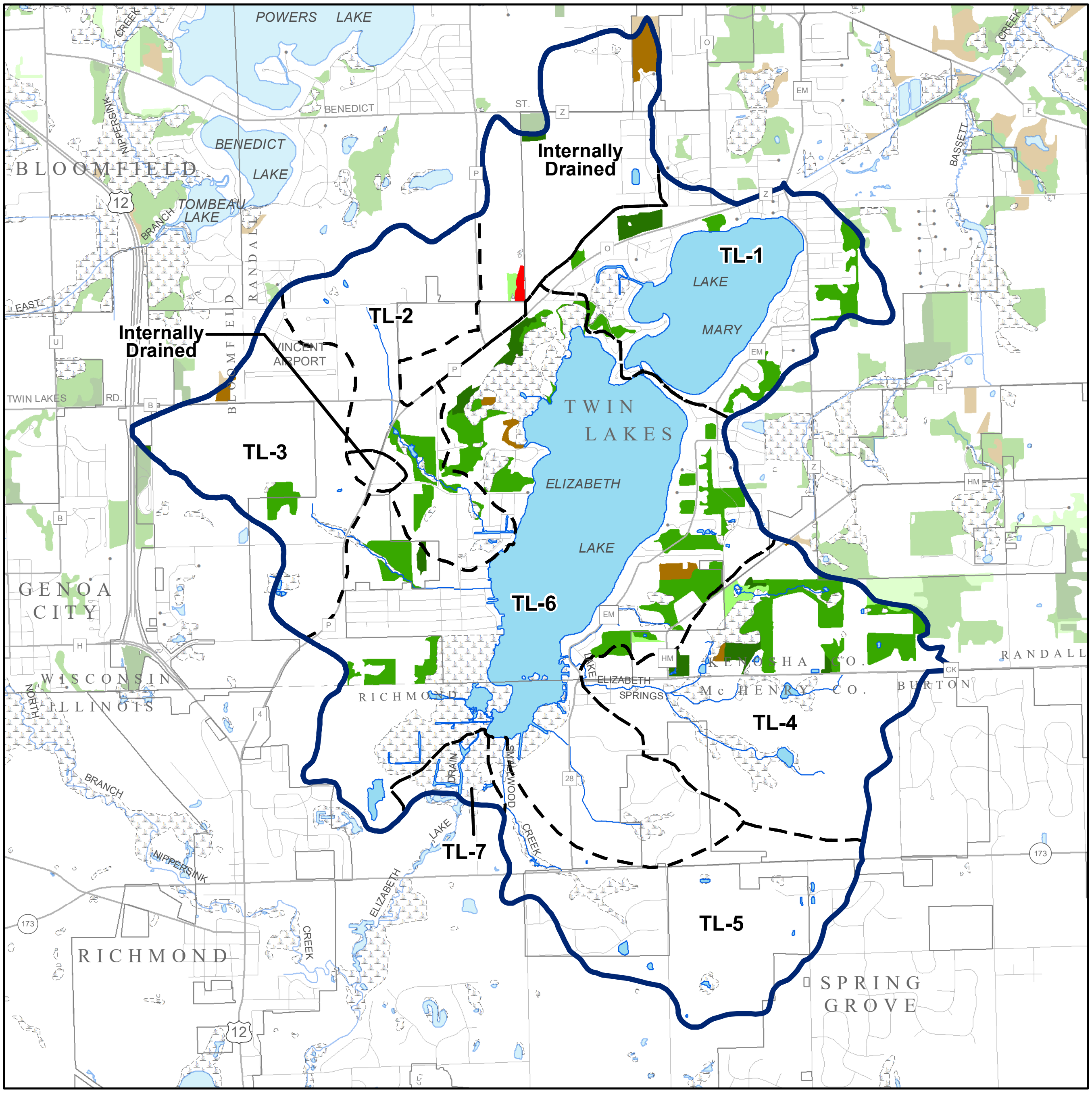
SUBBASIN BOUNDARY

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

0 1,000 2,000 4,000 Feet

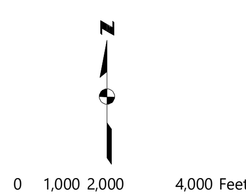
Source: Southeastern Wisconsin Regional Planning Commission

Map 2.22
Upland Cover Types Within the Twin Lakes Study Area: 2005



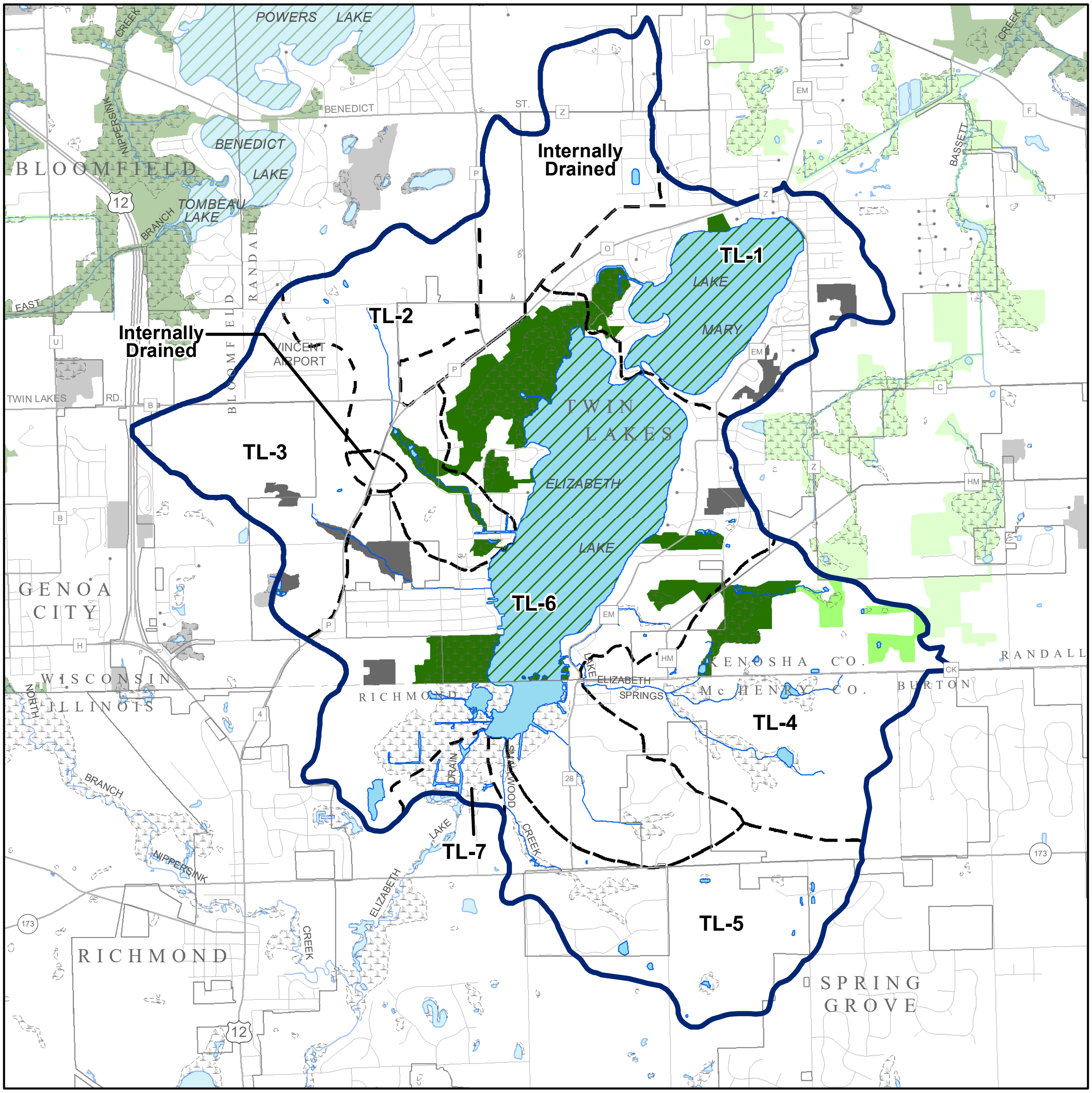
UPLAND BRUSH	SURFACE WATER
UPLAND CONIFER	WETLAND
DECIDUOUS	STREAM
GRASSLAND	WATERSHED BOUNDARY
MIXED	SUBBASIN BOUNDARY

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



Source: Southeastern Wisconsin Regional Planning Commission

Map 2.23
Environmental Corridors Within the Twin Lakes Study Area: 2010



PRIMARY ENVRIRONMENTAL CORRIDOR

SECONDARY ENVIRONMENTAL CORRIDOR

ISOLATED NATURAL RESOURCE AREA

SURFACE WATER

WETLAND

STREAM

WATERSHED BOUNDARY

SUBBASIN BOUNDARY

Note: Water bodies that are included in environmental corridors and isolated natural resource areas are shown with a hatched pattern.

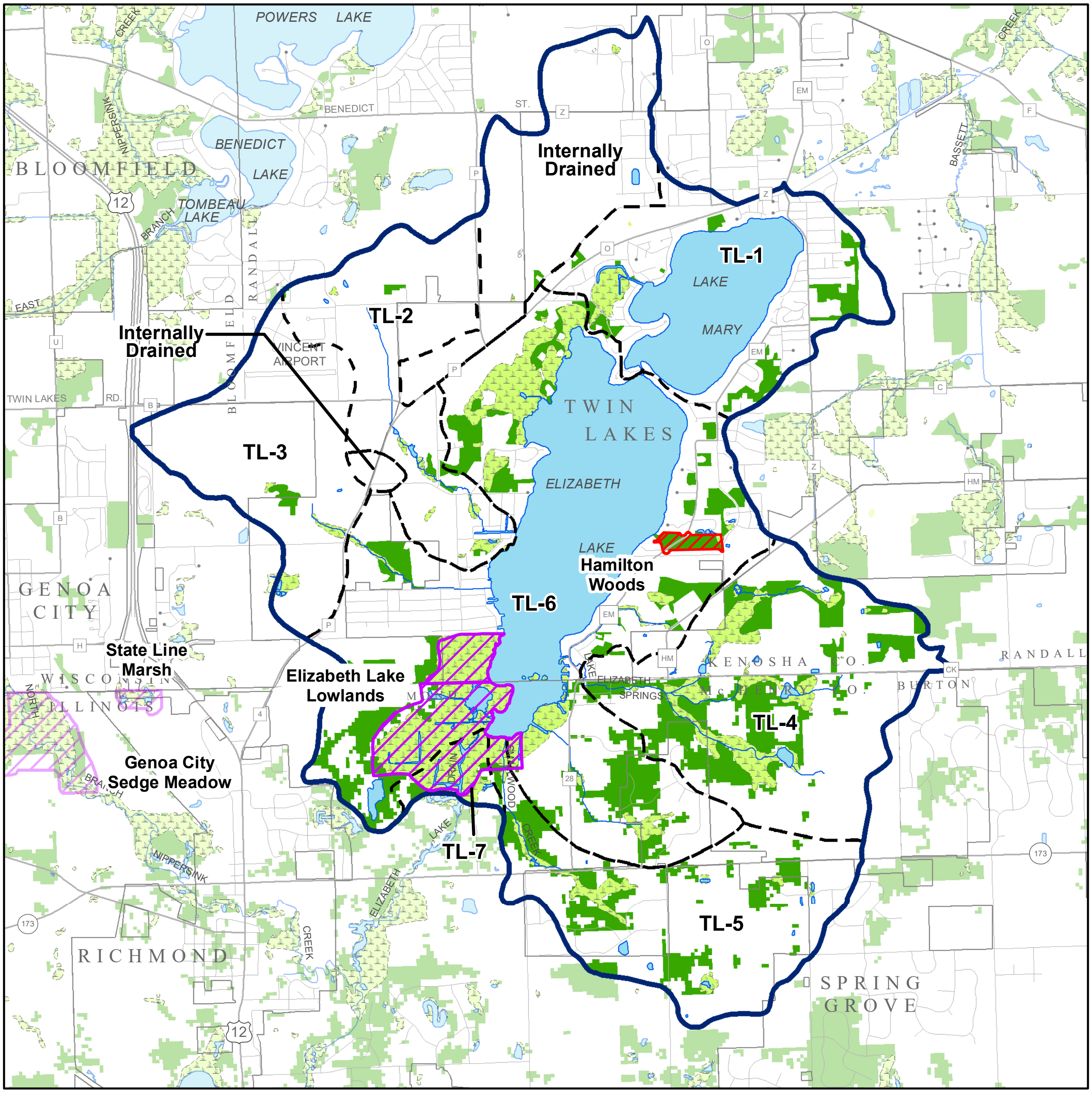
Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

N

0 1,000 2,000 4,000 Feet

Source: Southeastern Wisconsin Regional Planning Commission

Map 2.24
Natural Areas, Critical Species Habitat Sites, Woodlands, and Wetlands Within the Twin Lakes Study Area



NATURAL AREA
CRITICAL SPECIES HABITAT SITE
WOODLAND
WETLAND
SURFACE WATER
WETLAND
STREAM
WATERSHED BOUNDARY
SUBBASIN BOUNDARY

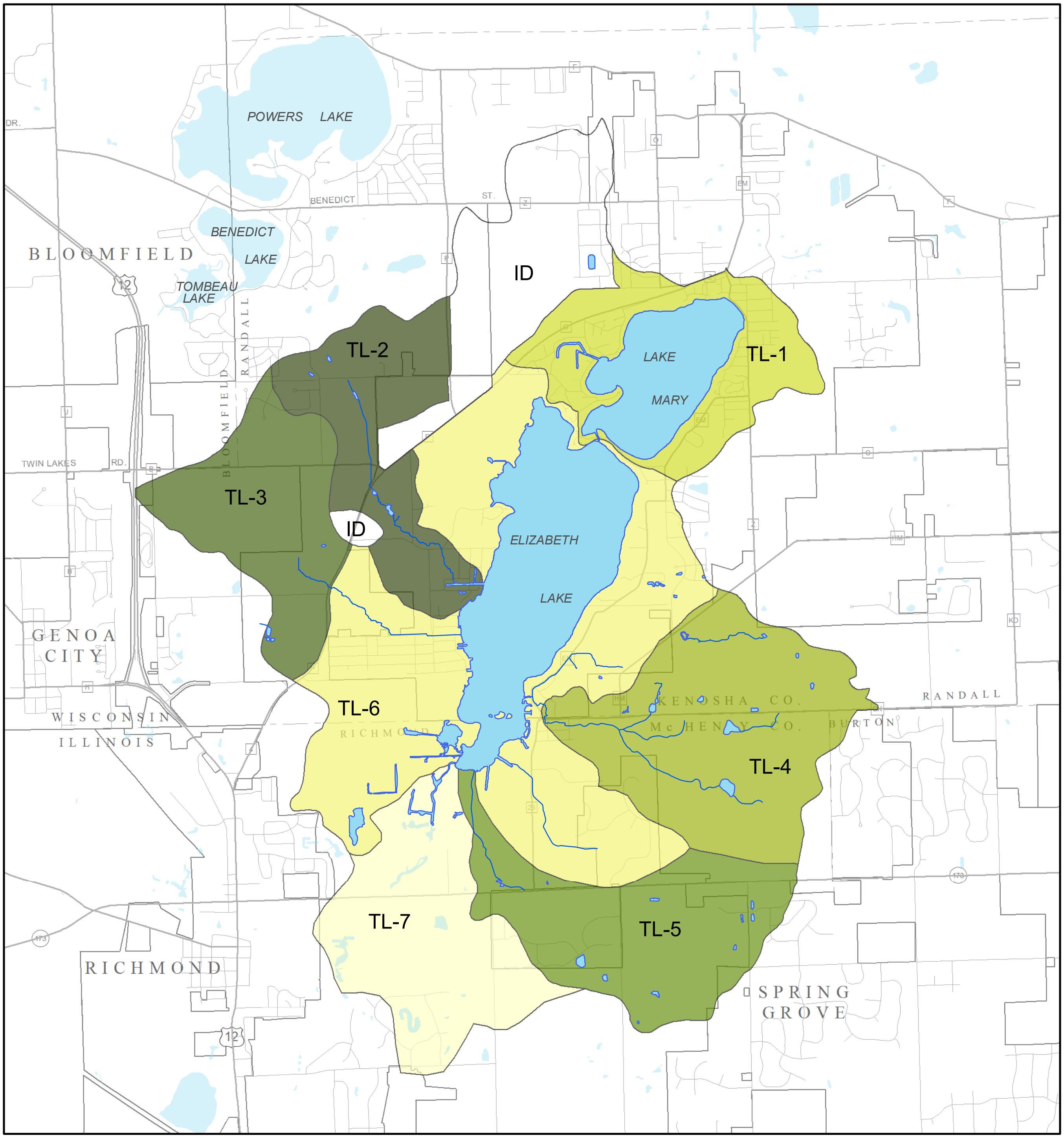
Note: Colors outside the watershed boundary are reduced in intensity to show the adjacent extent and distribution of each legend category.

N

0 1,000 2,000 4,000 Feet

Source: Illinois Department of Natural Resources, National Wetland Inventory, and Southeastern Wisconsin Regional Planning Commission

Map 2.25
STEPL Simulated Phosphorus Loading into the Twin Lakes with BMPs

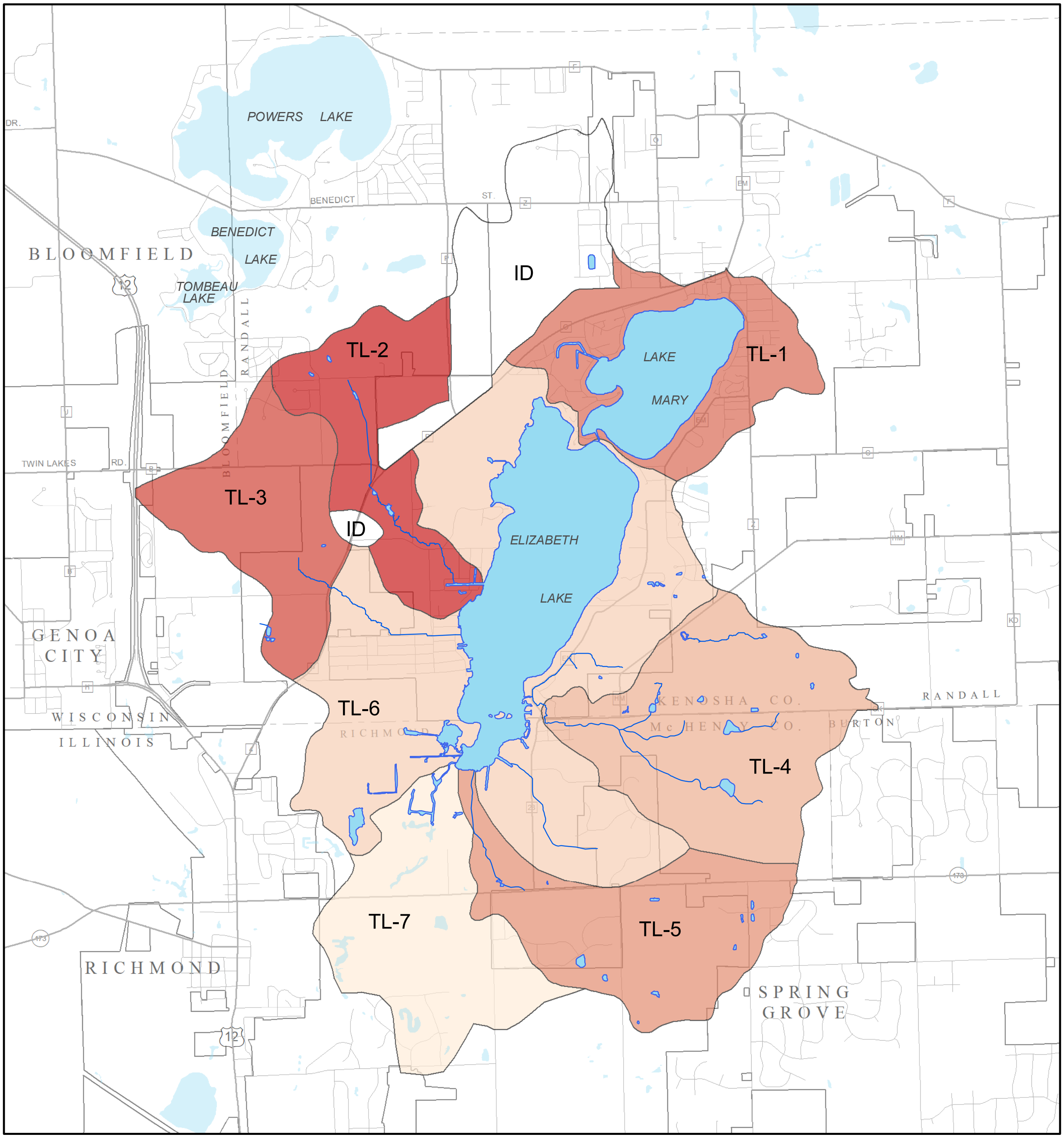


Subbasins

- 0 lbs per acre (Internally Draining)
- 0.15 lbs per acre
- 0.56 lbs per acre
- 0.61 lbs per acre
- 0.68 lbs per acre
- 0.75 lbs per acre
- 0.95 lbs per acre
- 1.69 lbs per acre
- Surface Water

Source: SEWRPC

Map 2.26
STEPL Simulated Nitrogen Loading into the Twin Lakes with BMPs



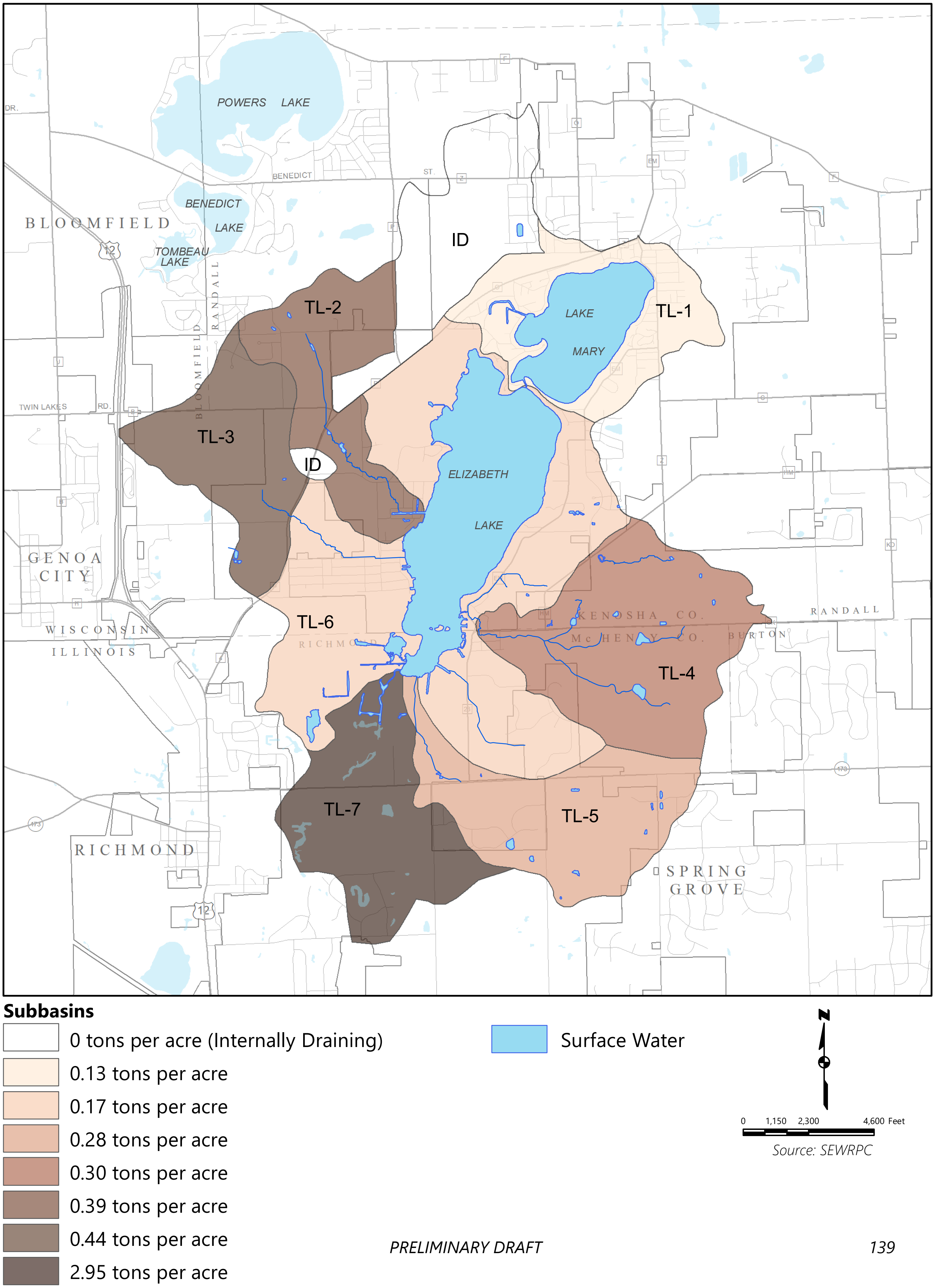
Subbasins

- 0 lbs per acre (Internally Draining)
- 0.865809295656894
- 2.84714060366717
- 2.94631404926016
- 3.4438714753995
- 3.66050496910687
- 4.07579320514433
- 9.35955023609959
- Surface Water

0 1,200 2,400 4,800 Feet

Source: SEWRPC

Map 2.27
STEPL Simulated Sediment Loading into the Twin Lakes with BMPs



Source: SEWRPC

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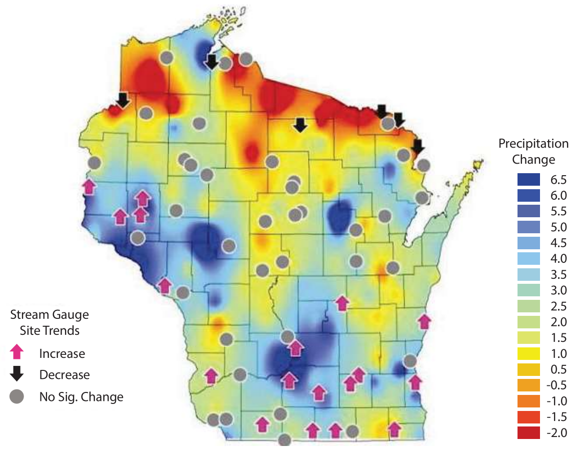
LAKE MANAGEMENT PLAN UPDATE FOR MARY AND ELIZABETH LAKES
KENOSHA COUNTY, WISCONSIN

Chapter 2

INVENTORY FINDINGS AND RELEVANCE TO LAKE MANAGEMENT

FIGURES

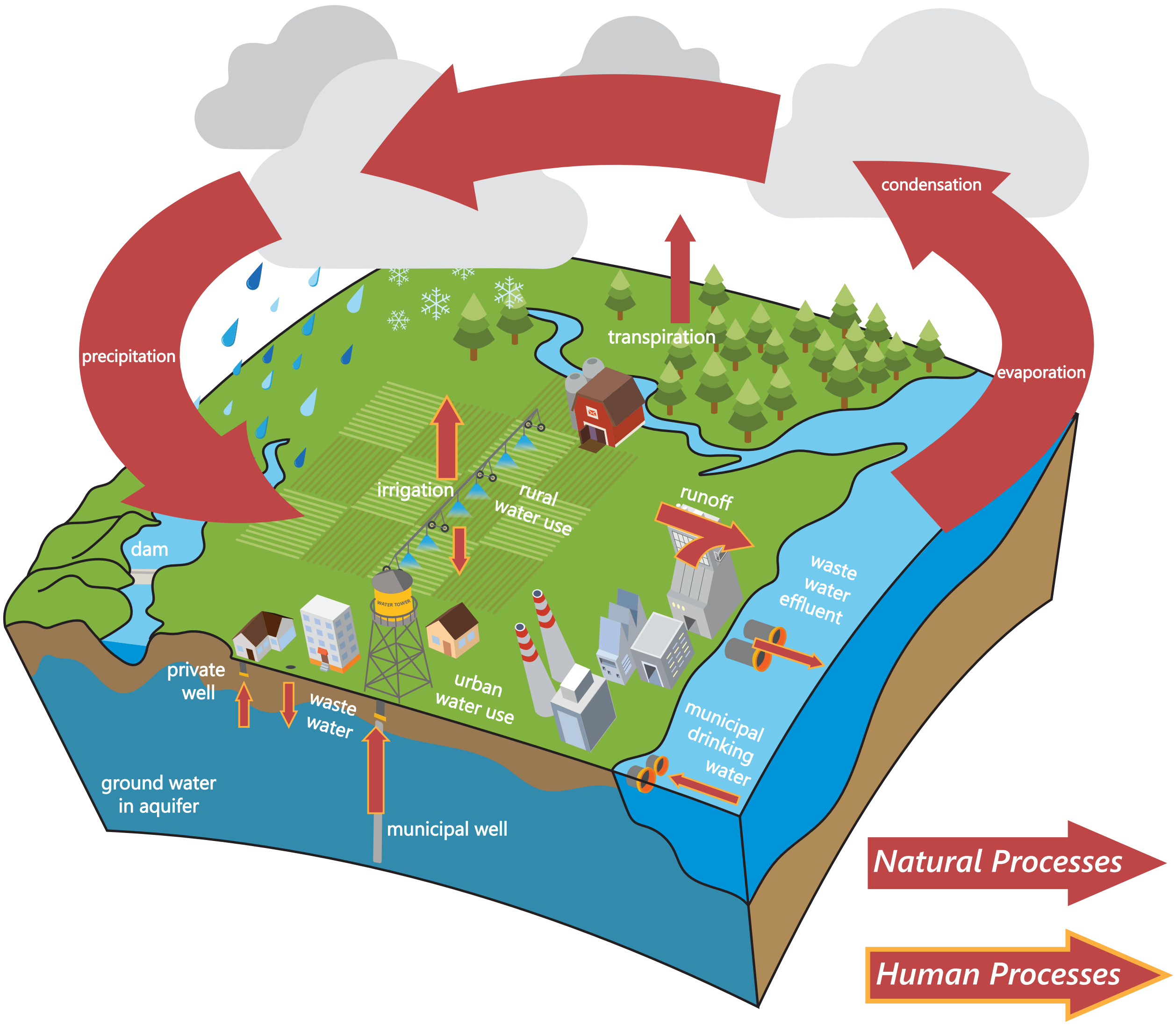
Figure 2.1
River Baseflow and Precipitation Change in Wisconsin: 1960-2006



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

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

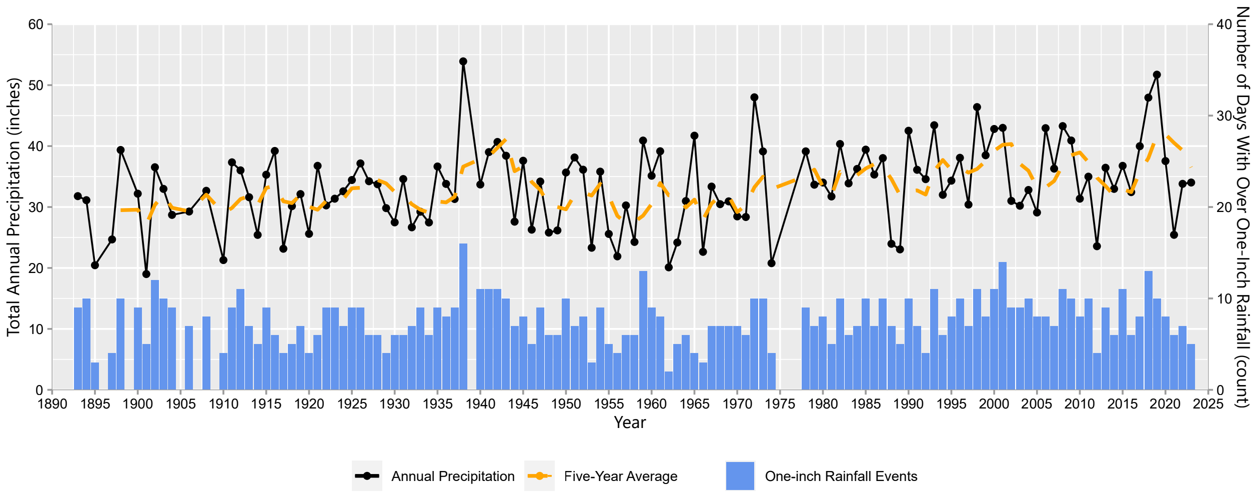
Figure 2.2
Human Influence on Hydrologic Cycle



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

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

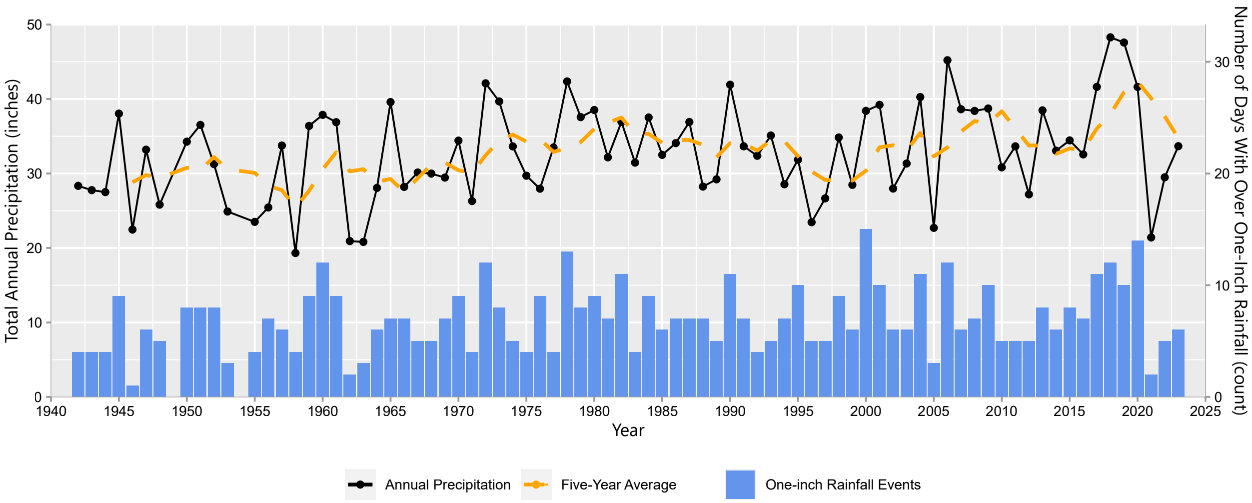
Figure 2.3
Beloit Total Annual Precipitation and One-Inch Rainfall Events: 1893 - 2023



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

Source: NOAA and SEWRPC

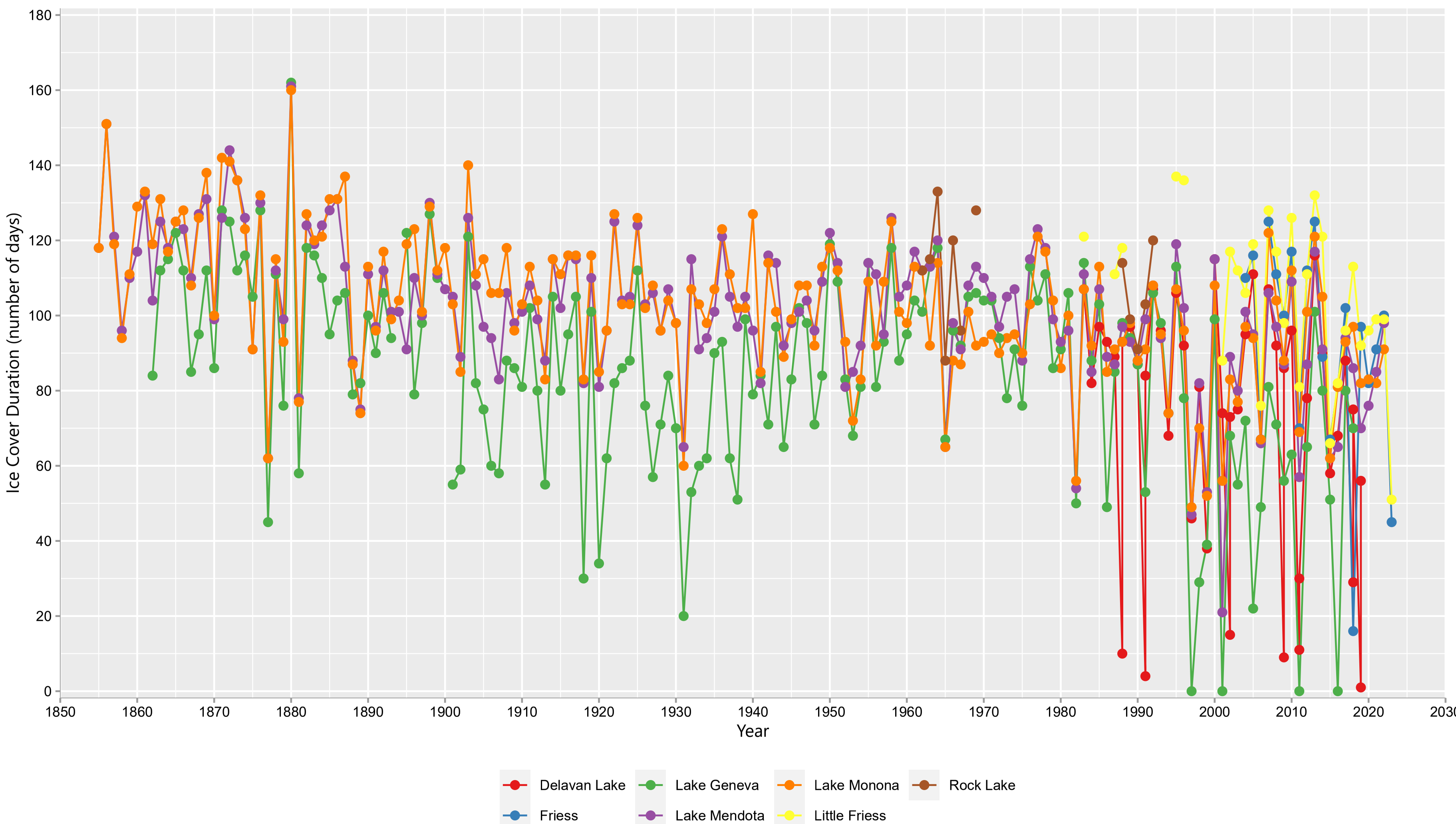
Figure 2.4
Union Grove Total Annual Precipitation and One-Inch Rainfall Events: 1942 - 2023



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

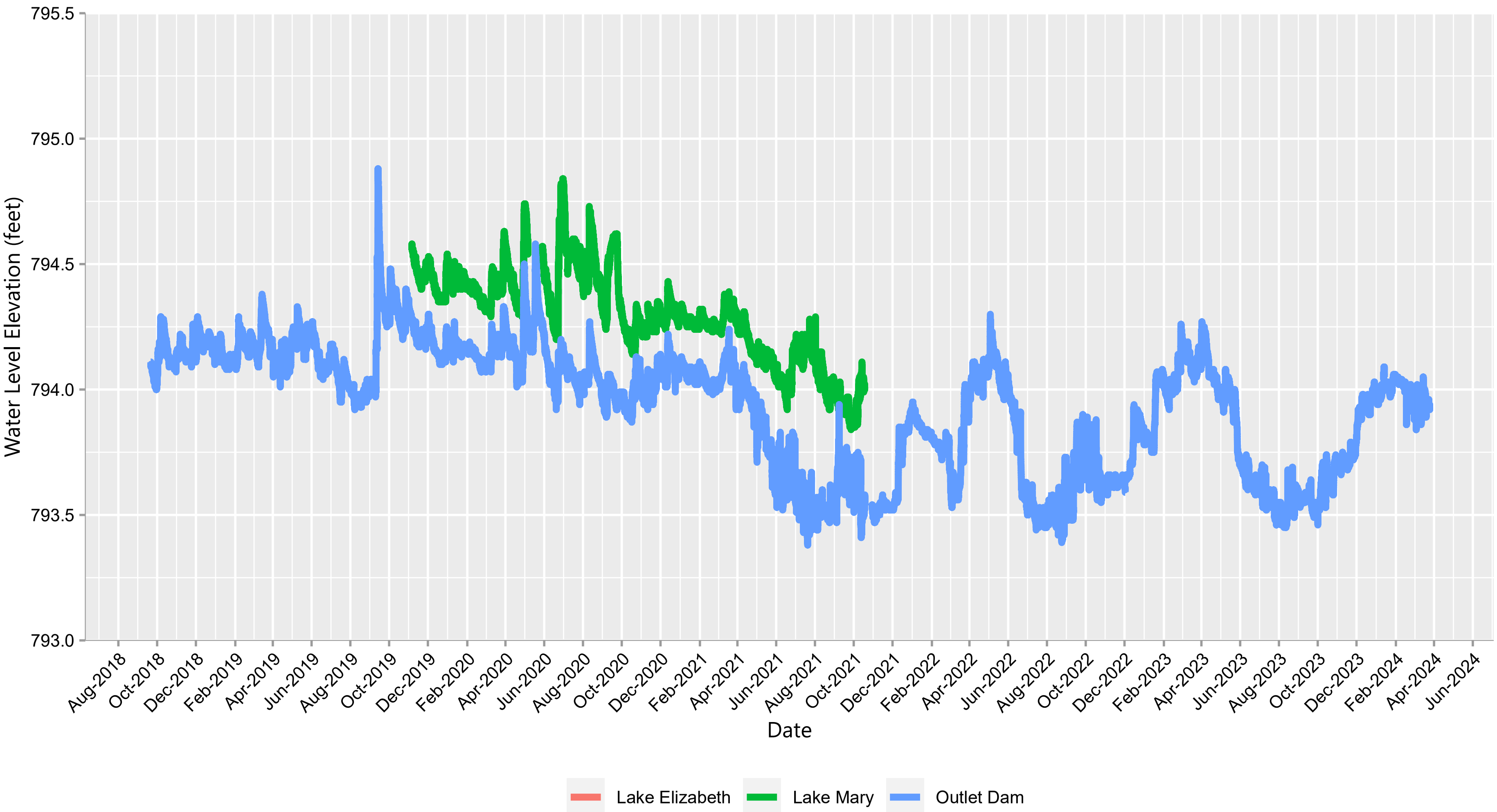
Source: NOAA and SEWRPC

Figure 2.5
Ice Cover Duration on Southern Wisconsin Lakes: 1855-2024



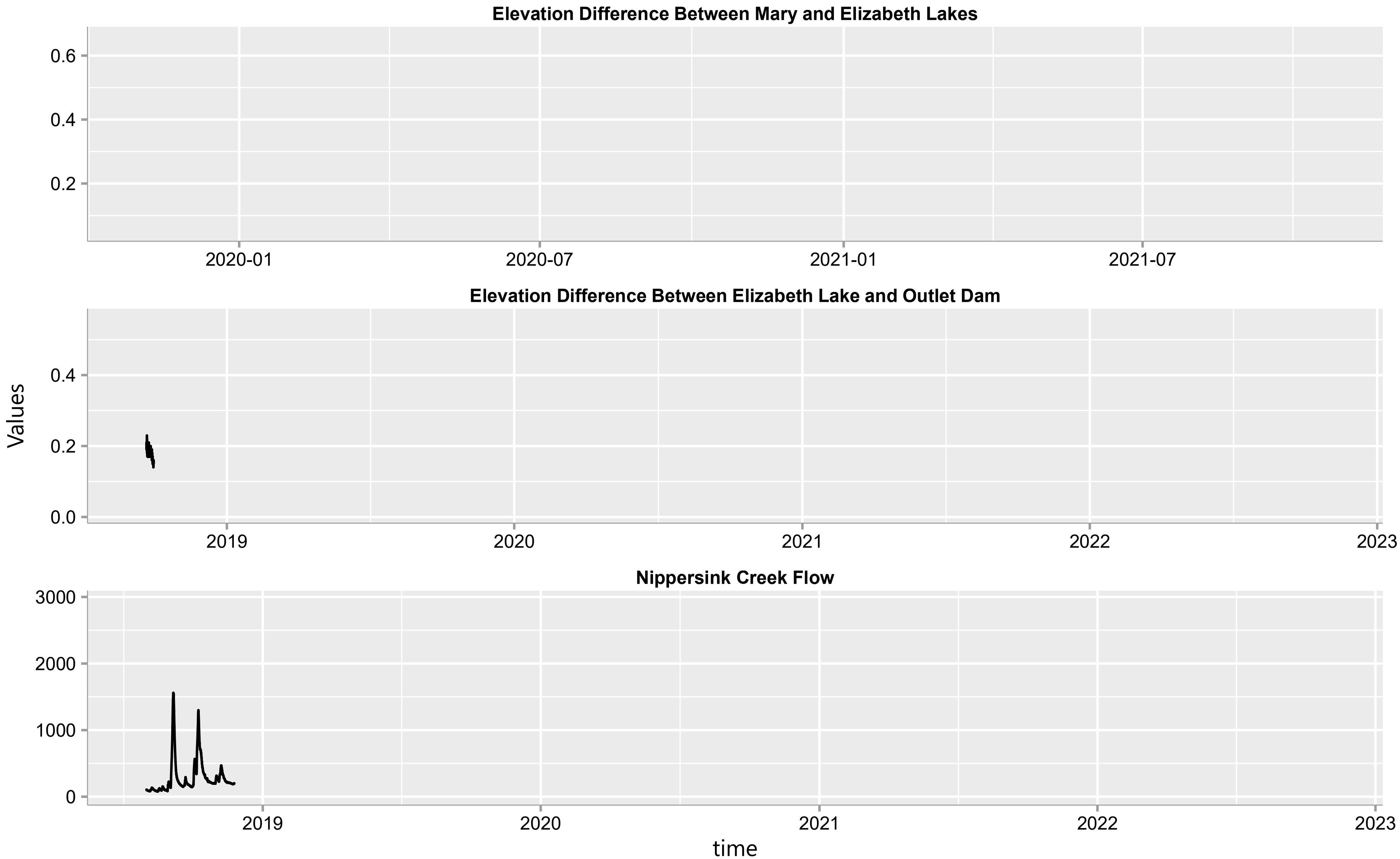
Source: EPA, Delavan Lake Sanitary District, Friess Lake Advancement Association, and SEWRPC

Figure 2.9
Water Level Elevations in Lake Mary, Elizabeth Lake, and at Outlet Dam: 2018-2024



Source: USGS and SEWRPC

Figure 2.10
Nippersink Creek Flow and Elevations Differences Between Lake Mary, Elizabeth Lake, and the Outlet Dam: 2018-2022



Source: USGS and SEWRPC

Figure 2.11
Regional vs. Local Groundwater Flow Paths

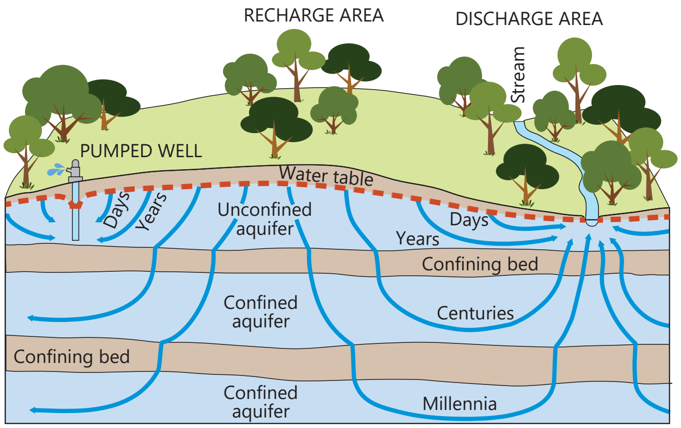
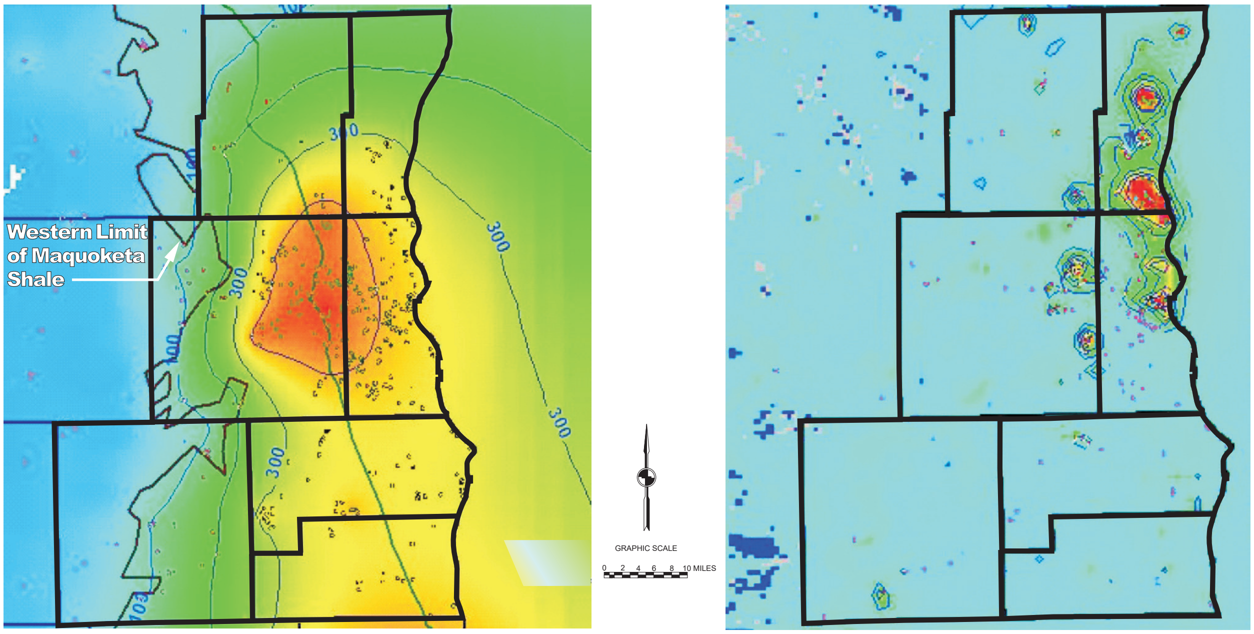


Figure 2.13
Simulated Groundwater Drawdowns for the Region

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

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



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

Figure 2.14
Effect of Impervious Surfaces on Hydrology

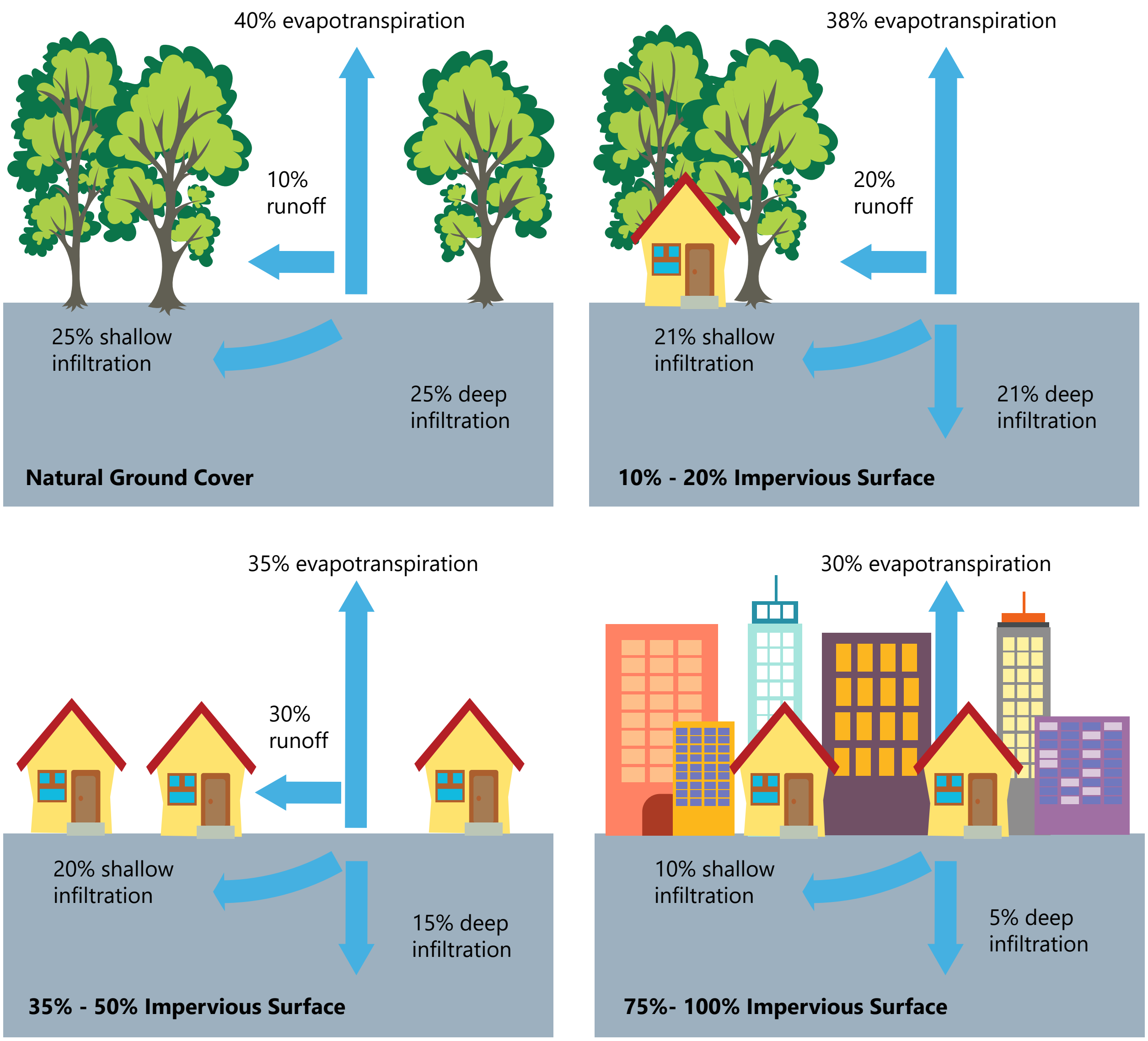
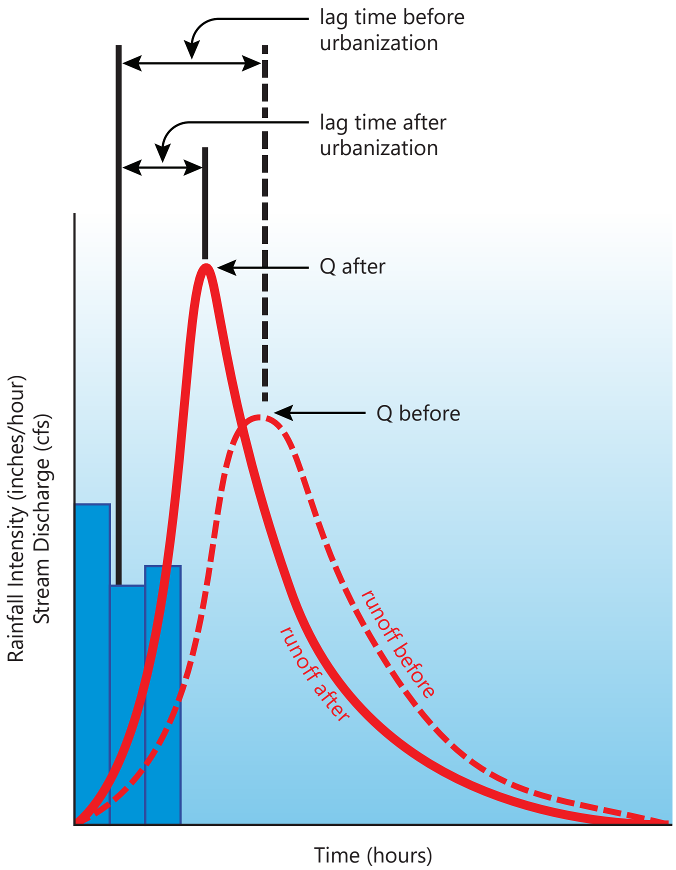


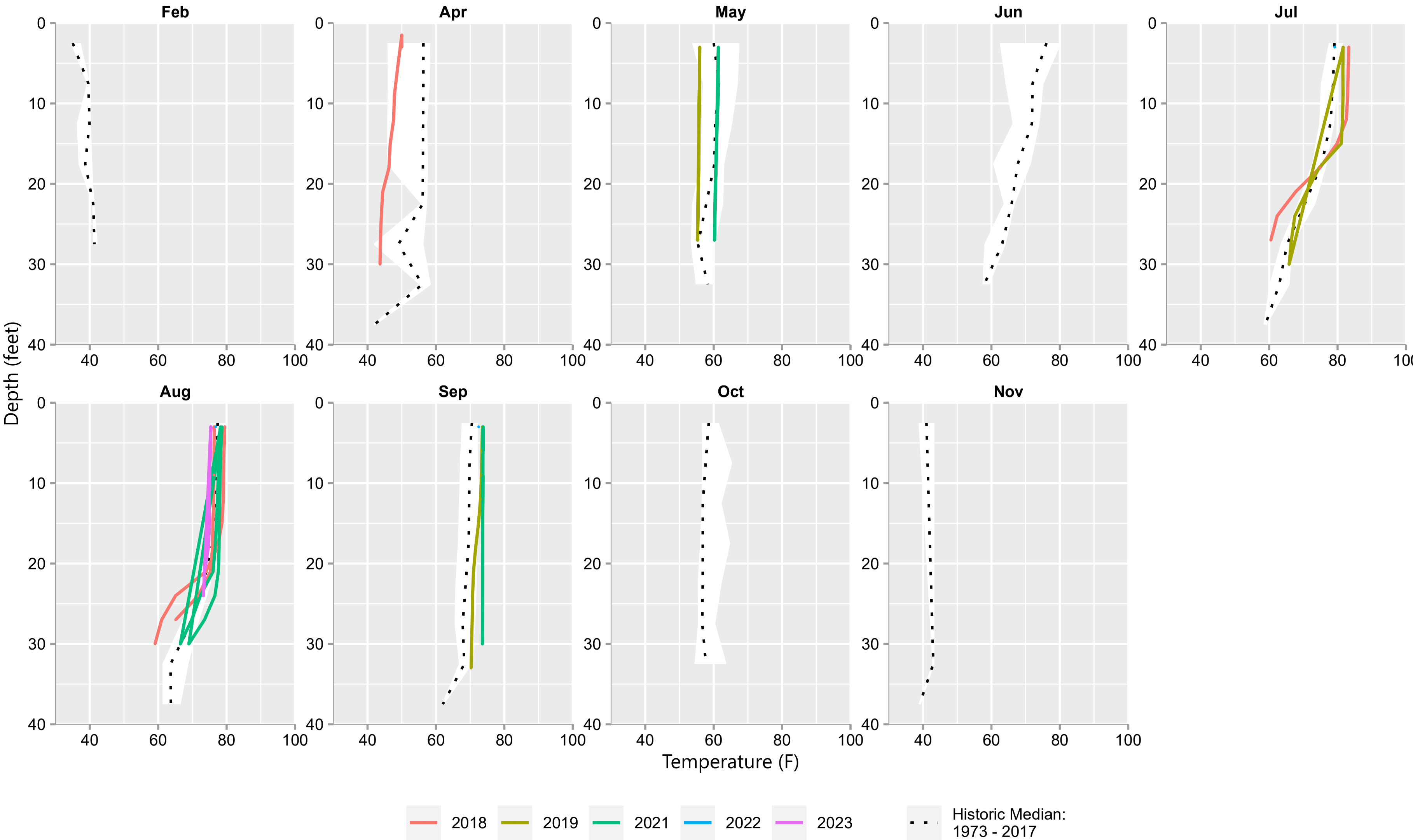
Figure 2.15
Stream Hydrographs Before and After Urbanization



Note: The lag time is the time it takes to reach peak flow for the watershed since the highest rainfall intensity. Q is the stream flow discharge.

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

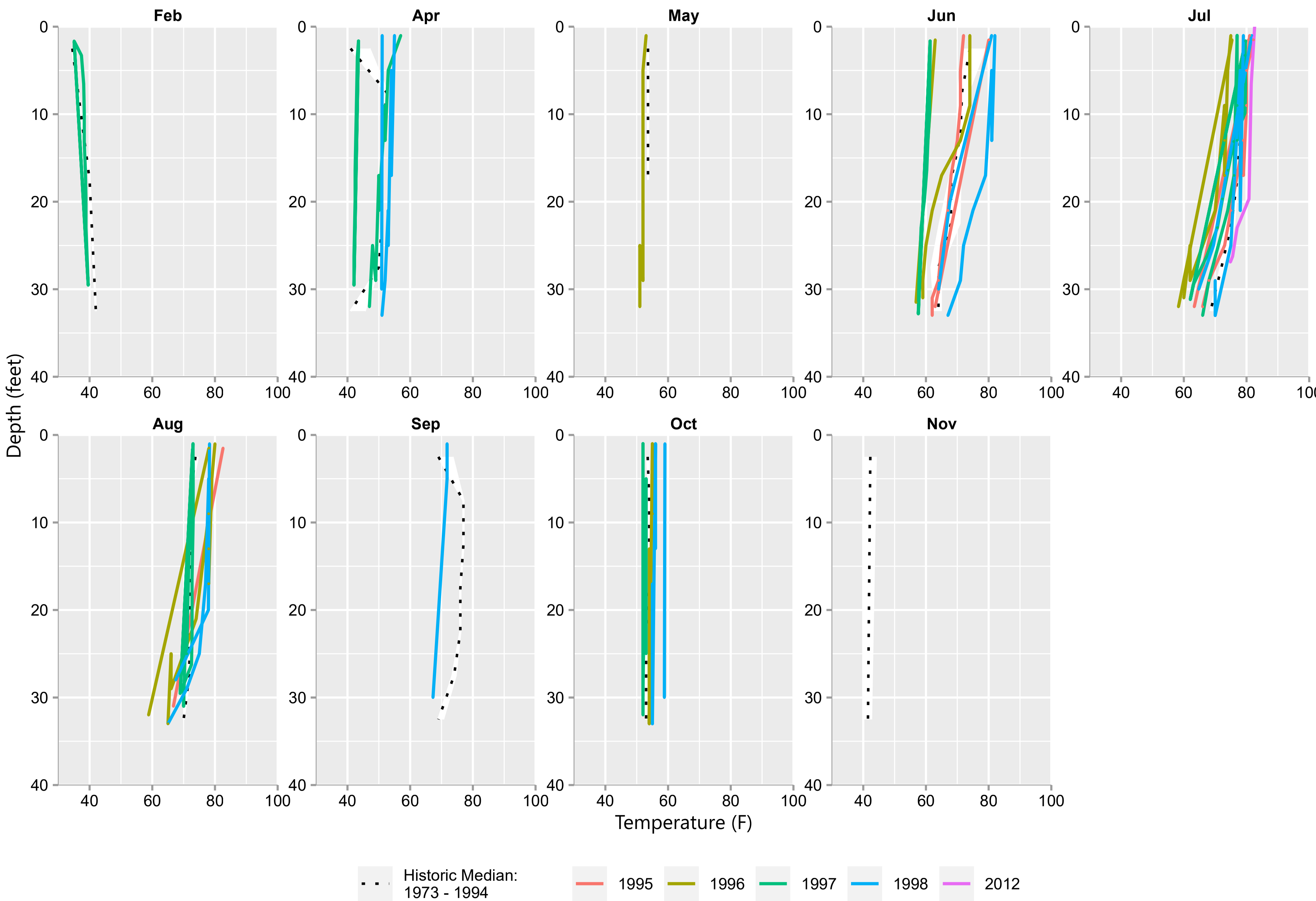
Figure 2.19
Lake Mary Water Temperature Profiles from 1973 to 2023



Note: The white ribbon indicates the lower 25 percent and upper 75 percent quantiles of the historic range.

Source: Wisconsin Department of Natural Resources and SEWRPC

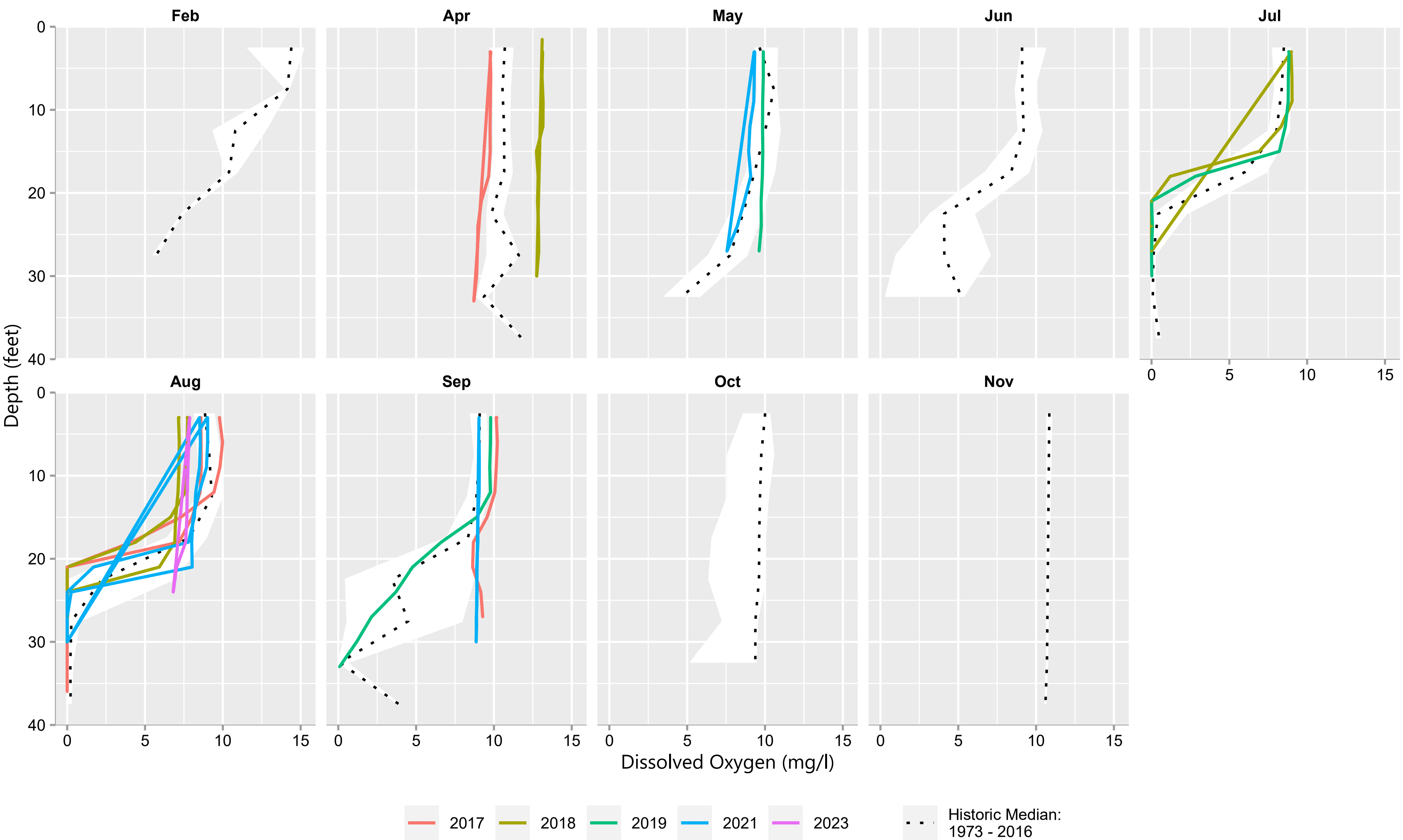
Figure 2.20
Elizabeth Lake Water Temperature Profiles from 1973 to 2012



Note: The white ribbon indicates the lower 25 percent and upper 75 percent quantiles of the historic range.

Source: Wisconsin Department of Natural Resources and SEWRPC

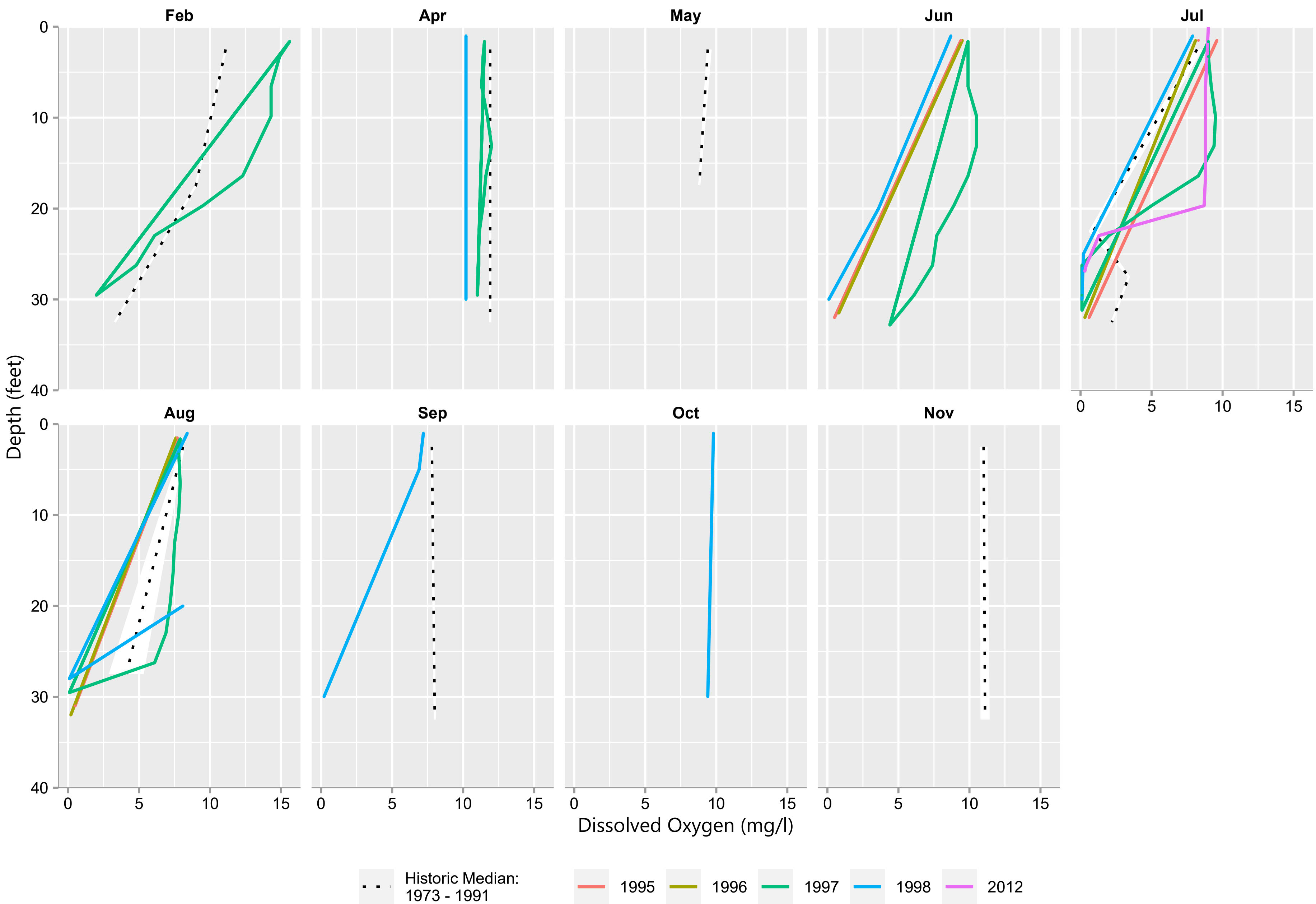
Figure 2.20
Lake Mary Dissolved Oxygen Profiles from 1973 to 2023



Note: The white ribbon indicates the lower 25 percent and upper 75 percent quantiles of the historic range.

Source: Wisconsin Department of Natural Resources and SEWRPC

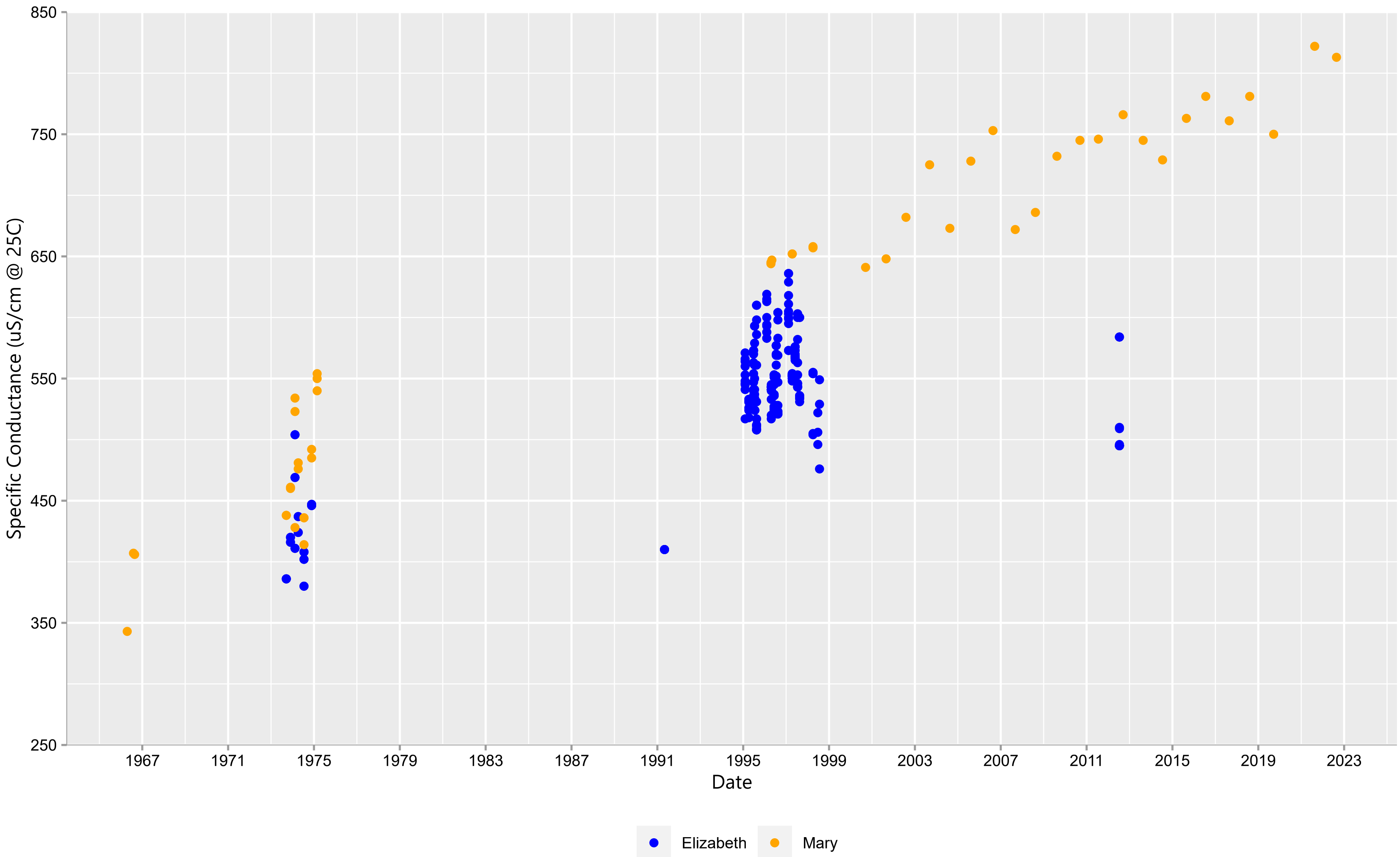
Figure 2.22
Elizabeth Lake Dissolved Oxygen Profiles from 1973 to 2012



Note: The white ribbon indicates the lower 25 percent and upper 75 percent quantiles of the historic range.

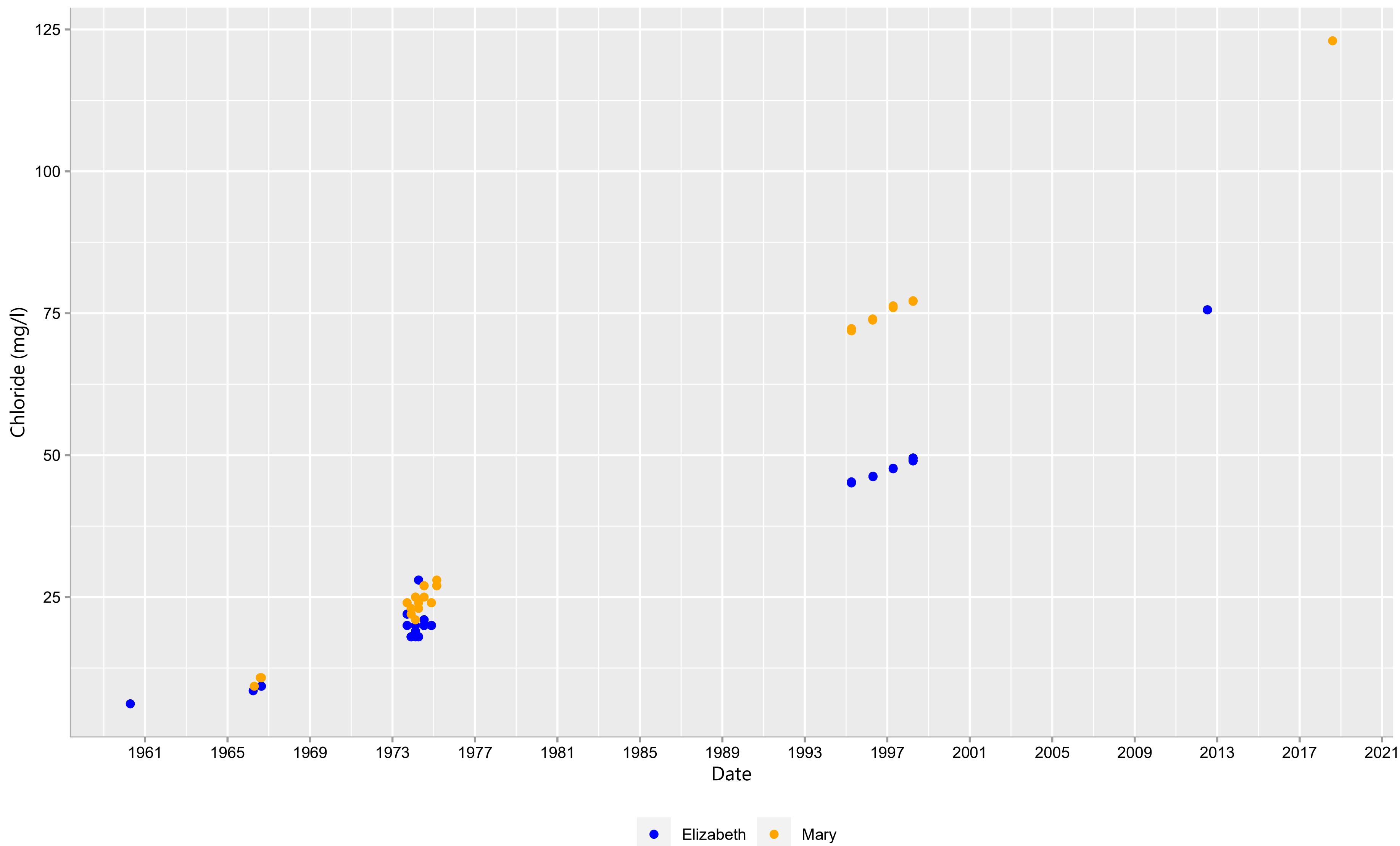
Source: Wisconsin Department of Natural Resources and SEWRPC

Figure 2.23
Lake Mary and Elizabeth Lake Specific Conductance Over Time: 1966-2022



Source: WDNR,USGS,NARS_WQX,WDNR Lake Use Report, and SEWRPC

Figure 2.24
Lake Mary and Elizabeth Lake Chloride Over Time: 1960-2018

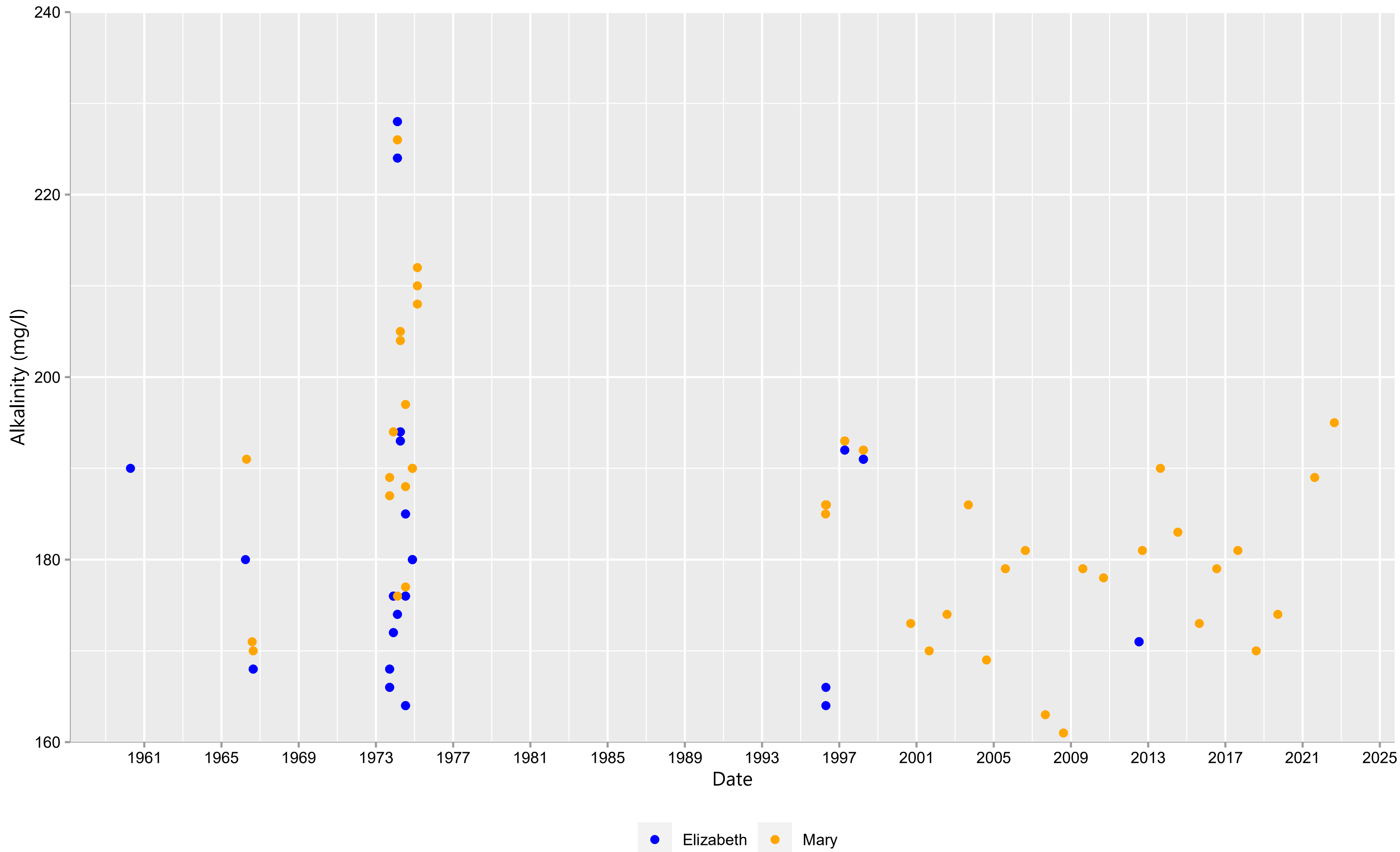


Source: WDNR,USGS,NARS_WQX,WDNR Lake Use Report, and SEWRPC

Figure 2.25
Lake Mary and Elizabeth Lake pH Over Time: 1960-2023

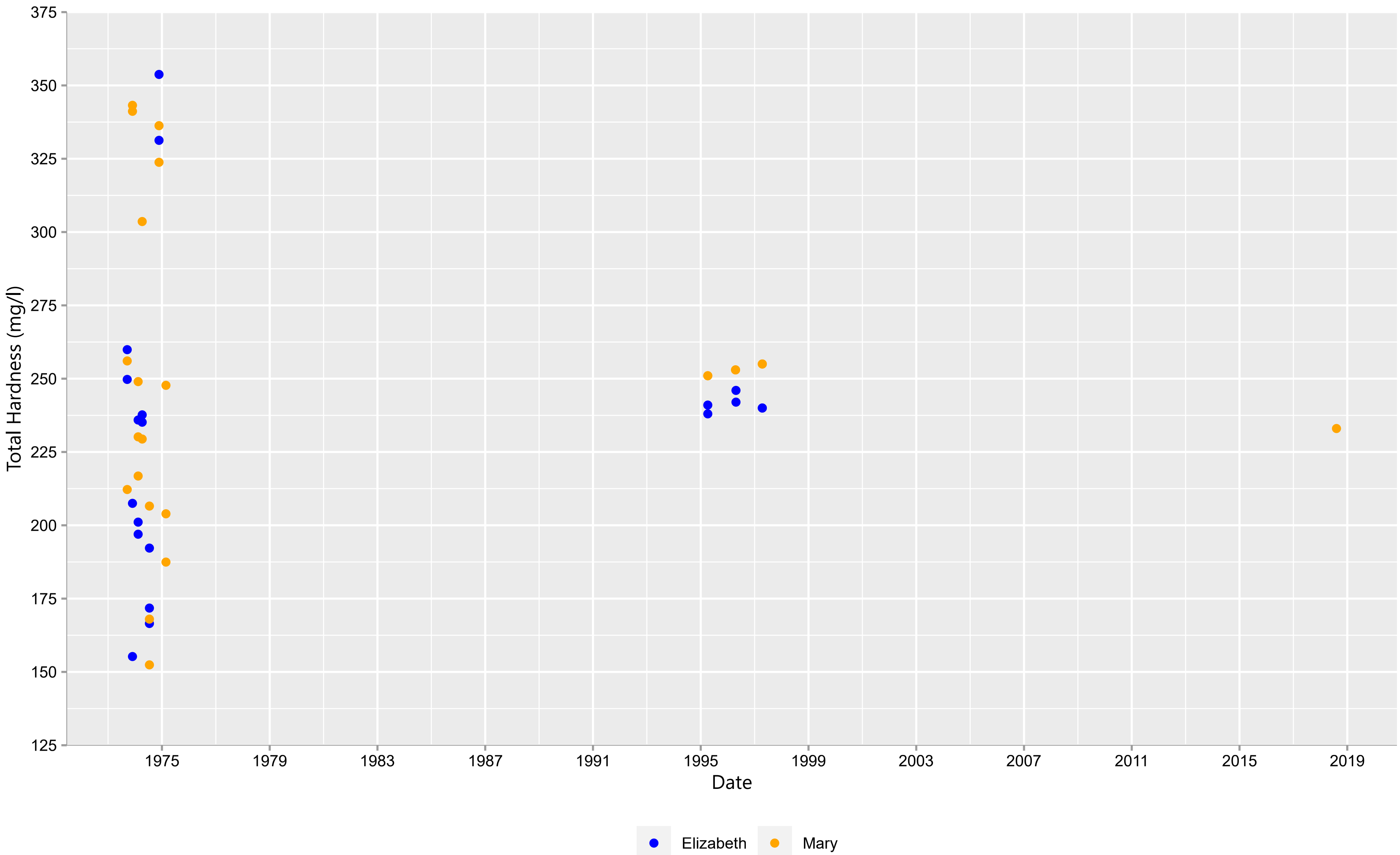
Source: WDNR,USGS,NARS_WQX,WDNR Lake Use Report, and SEWRPC

Figure 2.26
Lake Mary and Elizabeth Lake Alkalinity Over Time: 1960-2022



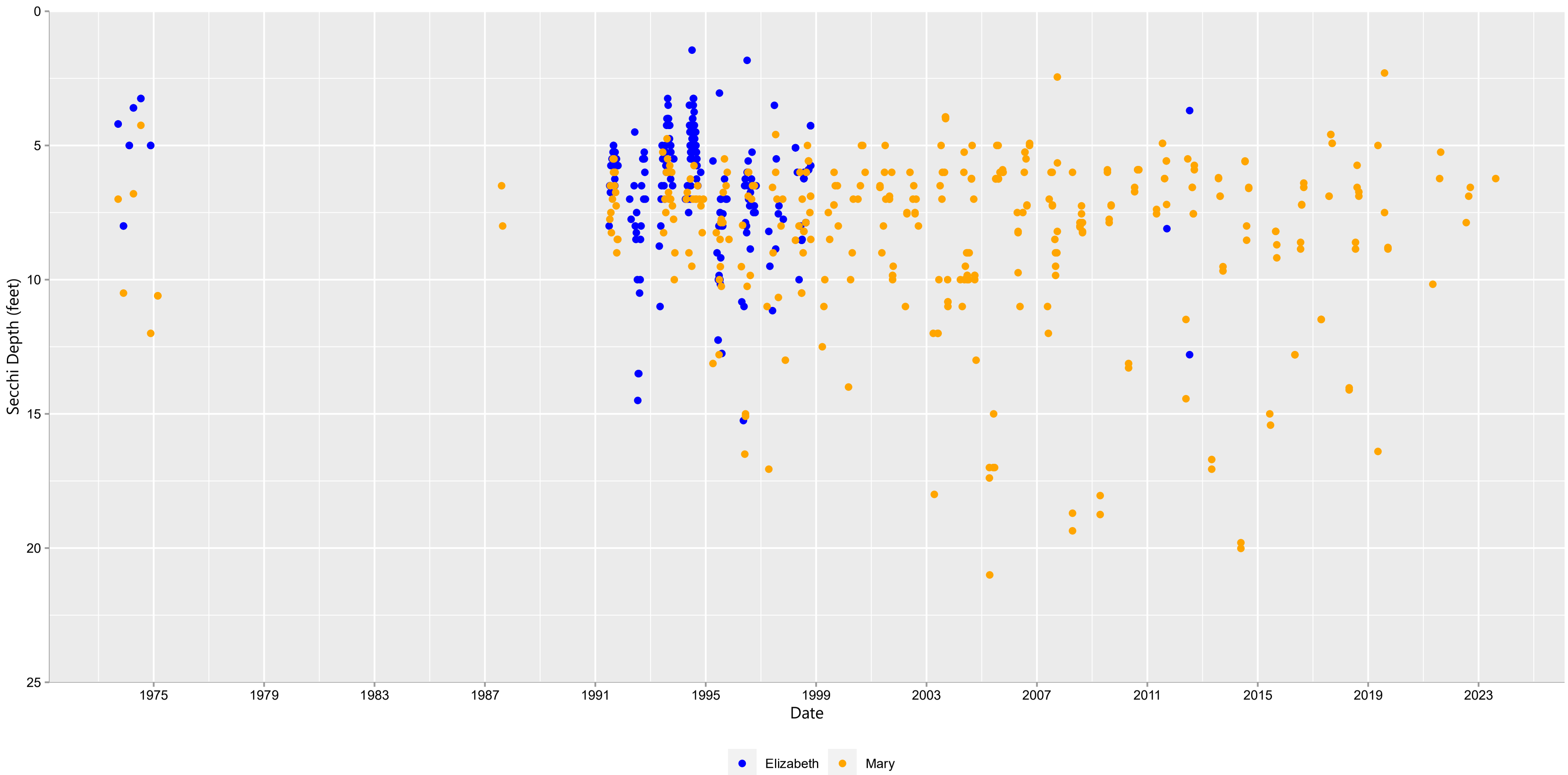
Source: WDNR,WDNR Lake Use Report, and SEWRPC

Figure 2.27
Lake Mary and Elizabeth Lake Total Hardness Over Time: 1973-2018



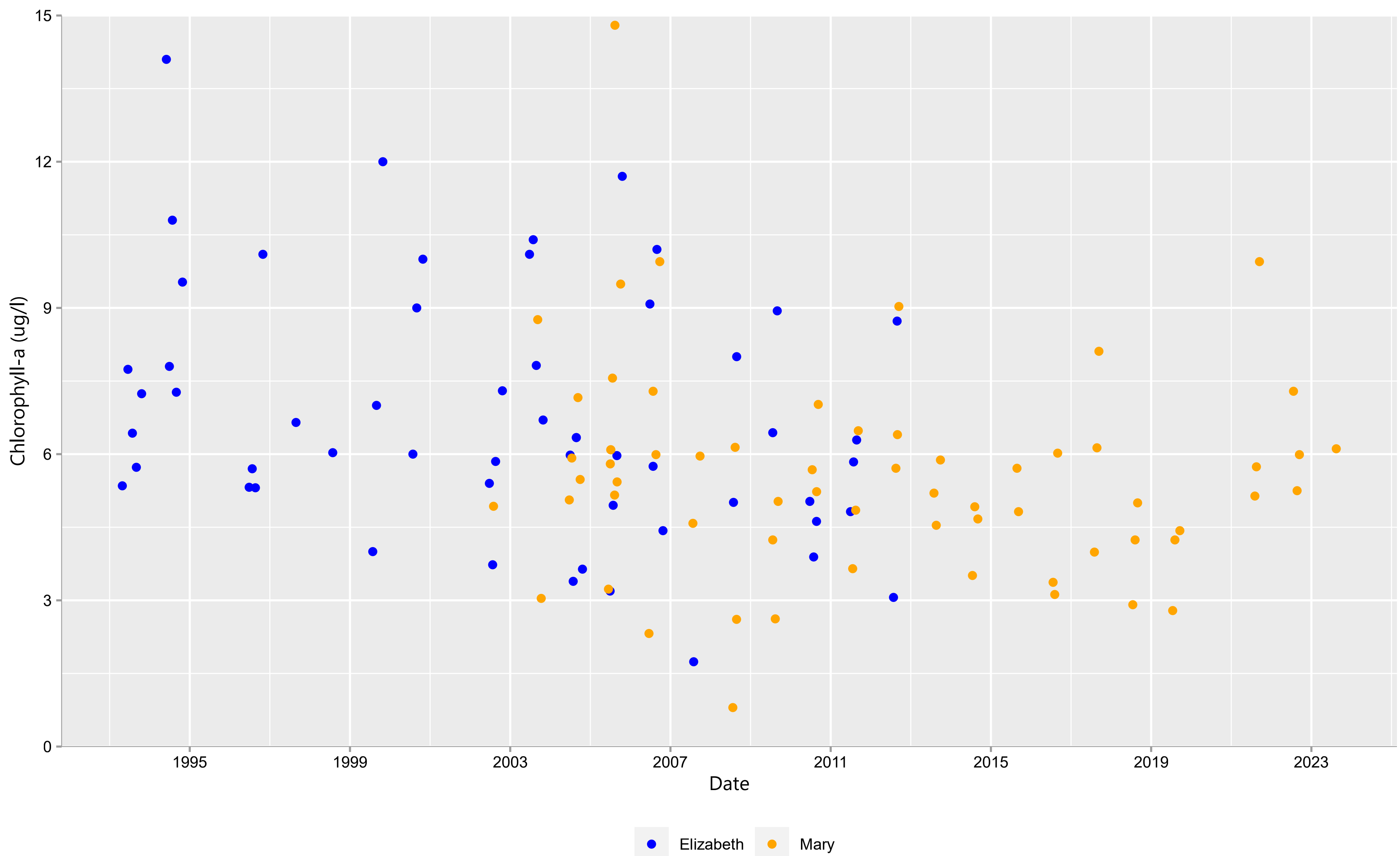
Source: WDNR,USGS, and SEWRPC

Figure 2.28
Lake Mary and Elizabeth Lake Water Clarity Over Time: 1973-2023



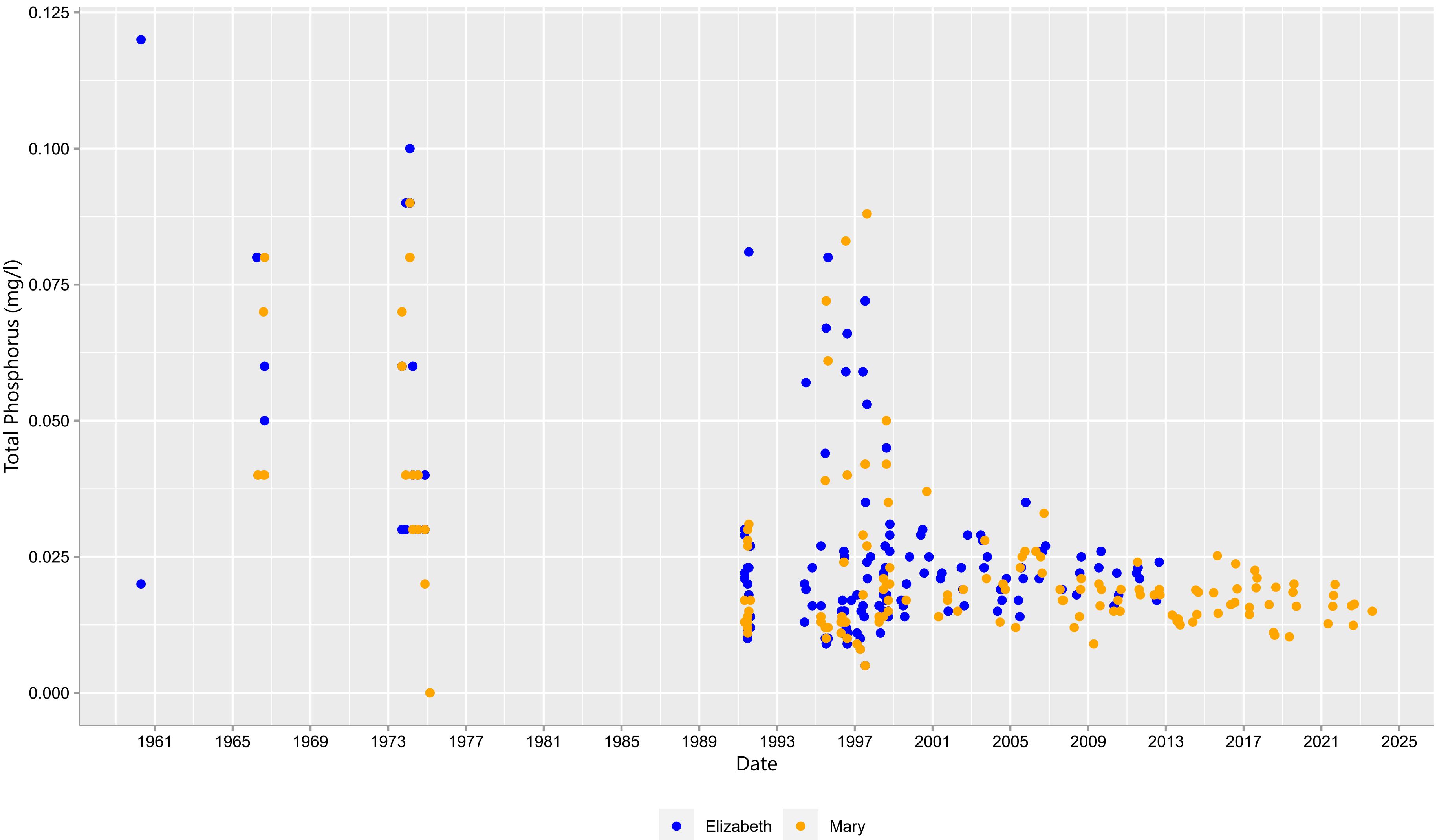
Source: WDNR,USGS,NALMS,NARS_WQX, and SEWRPC

Figure 2.29
Lake Mary and Elizabeth Lake Chlorophyll Over Time: 1993-2023



Source: WDNR, and SEWRPC

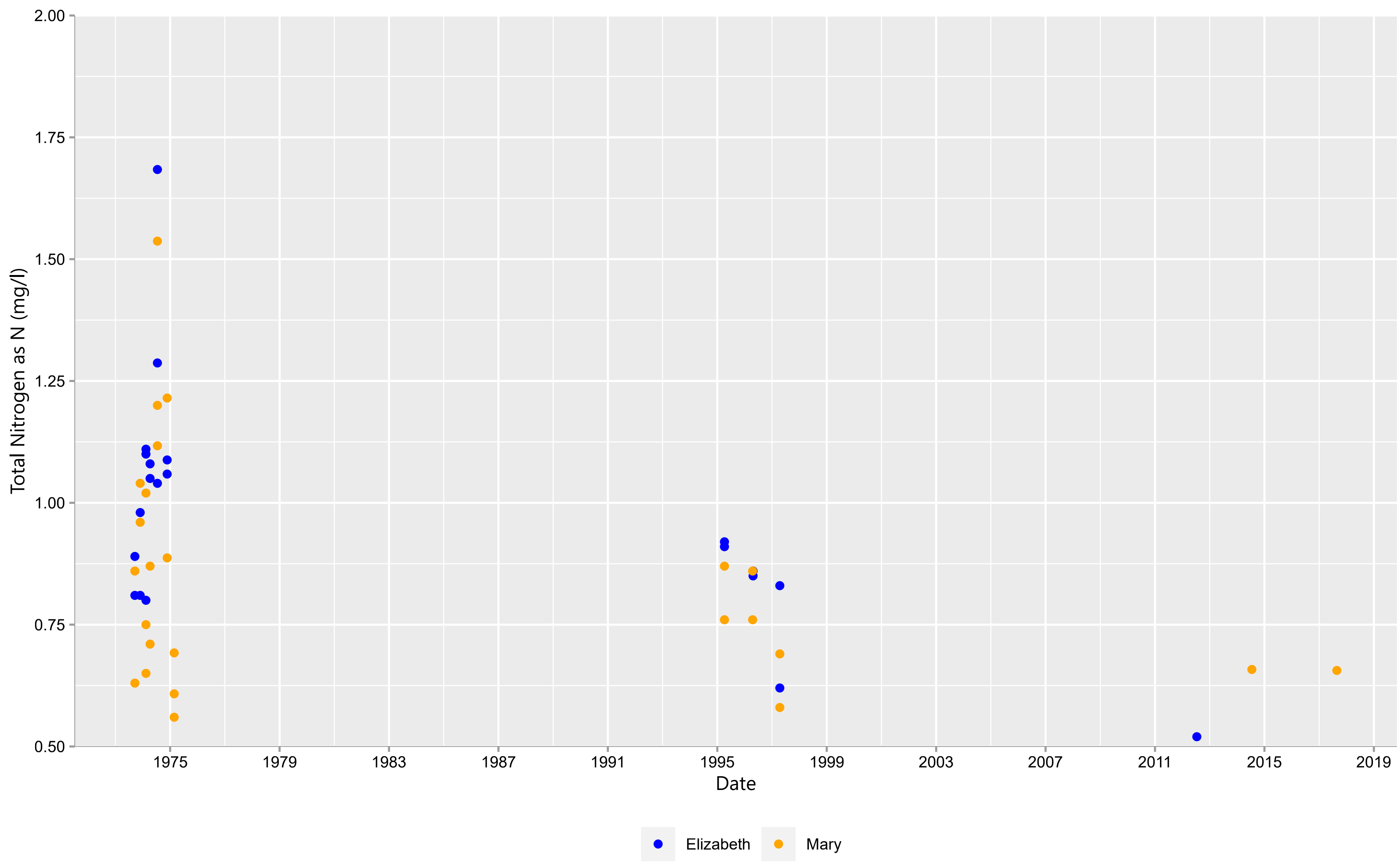
Figure 2.30
Lake Mary and Elizabeth Lake Total Phosphorus Over Time: 1960-2023



Note: Measurements recorded as total and dissolved phosphate in WDNR Lake Use Reports for the Twin Lakes are presumed to be phosphate as phosphorus.

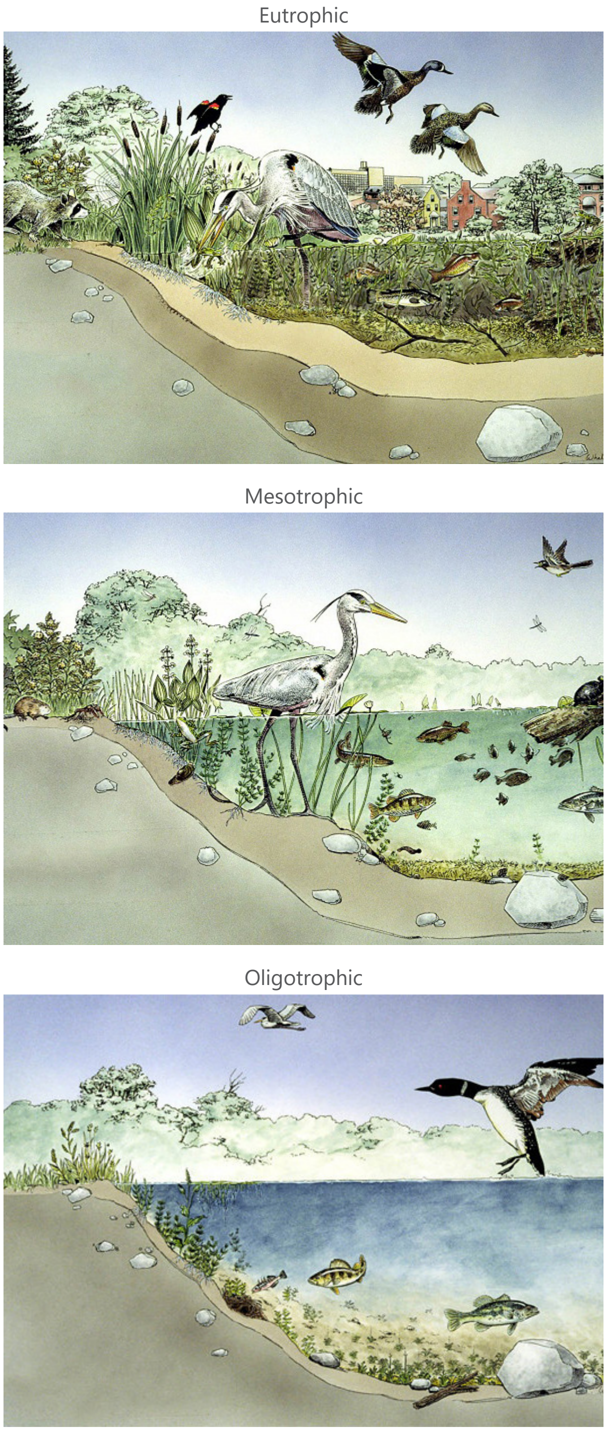
Source: WDNR,USGS,WDNR Lake Use Report, and SEWRPC

Figure 2.31
Lake Mary and Elizabeth Lake Total Nitrogen Over Time: 1973-2017



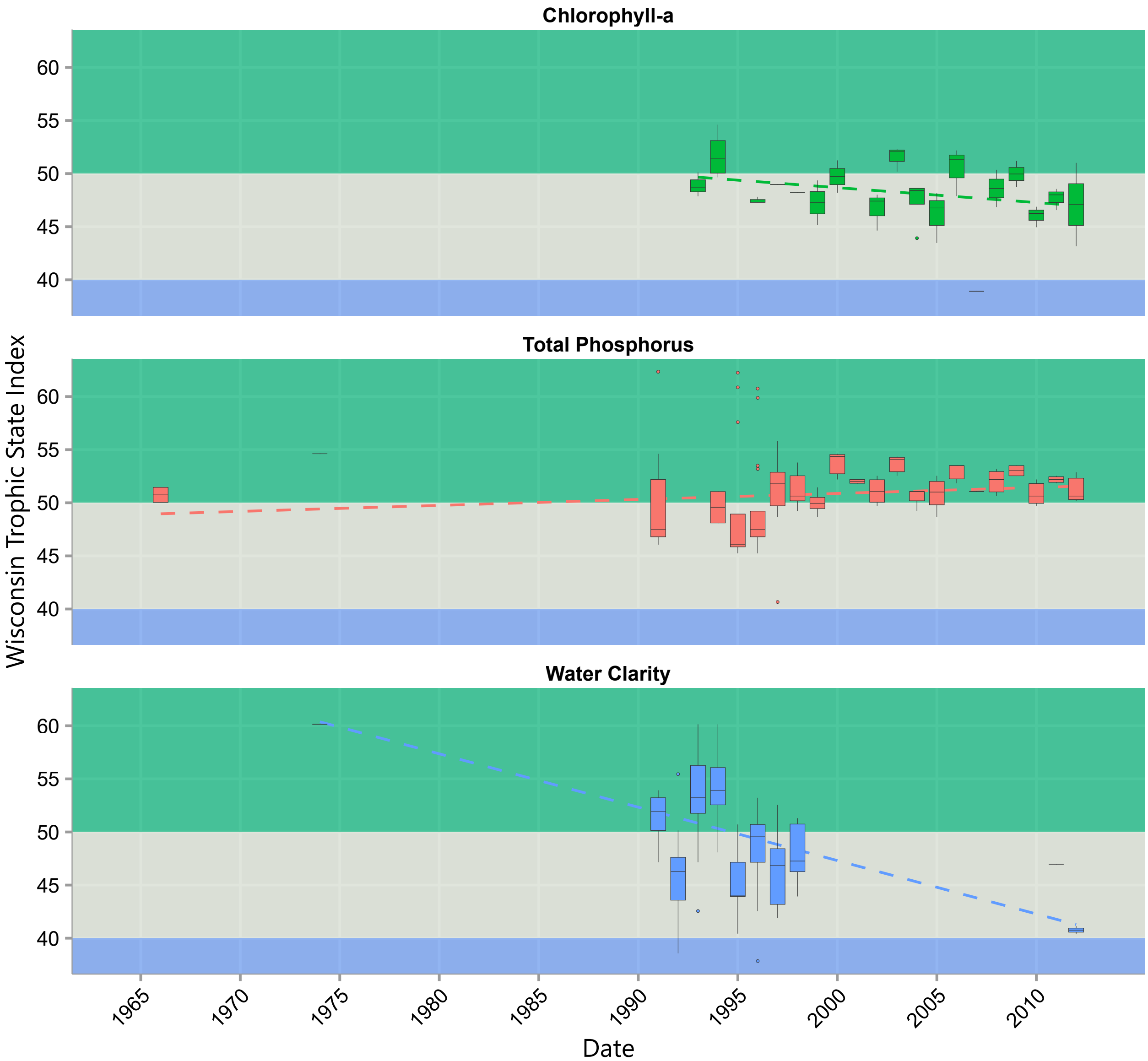
Source: WDNR,USGS, and SEWRPC

Figure 2.32
Comparison of Lake Trophic Status



Source: UW-Extension Lakes Program and SEWRPC

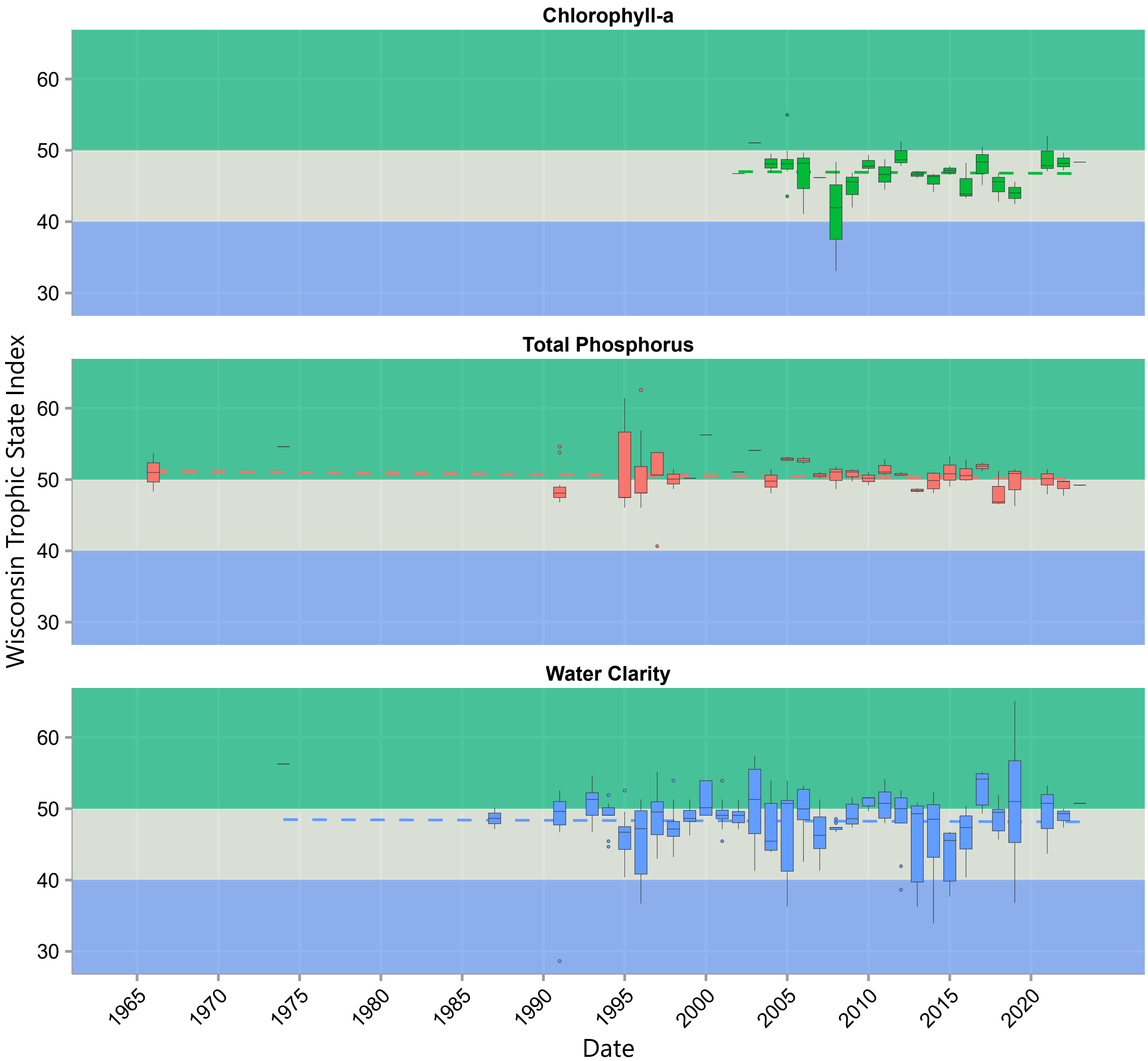
Figure 2.33
Lake Elizabeth Trophic State: 1966-2012



Note: Trophic state calculated usnig only shallow water samples collected between June 1st and September 15th.

Source: WDNR,USGS,NARS_WQX,WDNR Lake Use Report, and SEWRPC

Figure 2.34
Lake Mary Trophic State: 1966-2023



Note: Trophic state calculated usnig only shallow water samples collected between June 1st and September 15th.

Source: WDNR,USGS,NARS_WQX,WDNR Lake Use Report, and SEWRPC

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DIM/TMS/JPP/nkk
4/3/2024, 7/9/2024

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LAKE MANAGEMENT PLAN UPDATE FOR MARY AND ELIZABETH LAKES
KENOSHA COUNTY, WISCONSIN

Chapter 3

MANAGEMENT RECOMMENDATIONS AND PLAN IMPLEMENTATION

3.1 INTRODUCTION

The Twin Lakes are valuable resources to lake residents and visitors, contribute to the economy and quality of living in the local area, and are important features to the overall hydrology and ecology of the watershed. This chapter provides actionable suggestions that help maintain and enhance the health of the Lakes and encourage their continued enjoyment. The resultant recommendations are listed in Table 3.1 and are based upon the interests and priorities of lake users, analysis of available data, practicality, and the potential for successful implementation. Implementing these recommendations helps maintain and enhance the health of the Lake and improves its ability to provide short- and long-term benefit to the overall community.

The recommendations made in this chapter cover a wide range of programs and seek to address a broad array of factors and conditions that significantly influence the health, aesthetics, and recreational use of the Twin Lakes. Since the plan addresses a wide scope of issues, it may not be feasible to implement every recommendation in the immediate future. To promote efficient plan implementation, the relative importance and significance of each recommendation is noted to help Lake managers prioritize plan elements. Nevertheless, all recommendations should eventually be addressed, subject to possible revision based on analysis of yet-to-be collected data (e.g., future aquatic plant surveys and water quality monitoring results), project logistics, and/or changing/unforeseen conditions.

Those responsible for Lake planning and management should actively conceptualize, seek, and promote projects and partnerships that enable the recommendations of the plan to be implemented. The measures presented in this chapter focus primarily on those that can be implemented through collaboration between local organizations, watershed property owners, and others who have a vested interest in the long-term health of Lake Mary, Elizabeth Lake, and the watershed. Examples include riparian property owners, the Village of Twin Lakes, the Twin Lakes Protection and Rehabilitation Lake District (District), Kenosha County, the Wisconsin Department of Natural Resources (WDNR), and the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS). Collaborative partnerships formed among other potential stakeholders, such as agricultural producers, non-governmental organizations (e.g., Kenosha/Racine Land Trust (SENO K/RLT) and Geneva Lakes Conservancy), developers, wastewater treatment plants (e.g., Twin Lakes Sewer Plant, Village of Twin Lakes Sewer Division), and other watershed municipalities (i.e., Town of Burton, IL; Town of Richmond, IL; Village of Spring Grove, IL; Town of Bloomfield, WI; Town of Randall, WI; & Village of Genoa City, WI), can help promote efficient, affordable, and sustainable actions to assure the long-term ecological health of the Twin Lakes.

As a planning document, this chapter provides concept-level descriptions of activities that may be undertaken to help protect and enhance the Twin Lakes and their watersheds. It is important to note that plan recommendations provide stakeholders and implementing entities with guidance regarding the type and nature of projects to pursue to meet plan goals. These recommendations and project suggestions do not constitute detailed technical specifications. The full logistical and design details needed to implement most recommendations must be more fully developed in the future when individual recommendations are implemented. Grants are often available to develop concepts into actionable design drawings and plans.

In summary, this chapter provides those implementing the plan the ability to:

- Better understand plan element context and what needs to be done
- Judge the relative importance of plan elements
- Better comprehend plan intent
- Envision what various plan elements may look like

Such concepts can be invaluable for building coalitions and partnerships, writing competitive and meaningful grant requests, and initiating project design work.

3.2 HYDROLOGY, WATER QUANTITY, AND WATER RESOURCES INFRASTRUCTURE

Management plans that call upon practices that preserve, enhance, or naturalize watershed runoff, consider natural resource features and limitations, and promote thoughtfully engineered water resource infrastructure can benefit waterbody and watershed health and resilience in many ways. Such plans help managers choose alternative courses of action that slow runoff, detain stormwater, promote stormwater infiltration, sustain groundwater supplies, protect and enhance habitat value, and benefit recreational pursuits. A few examples of benefits accruing from such practices are listed below:

- Stormwater runoff intensity is reduced. This can reduce watercourse bed and bank erosion, lower sediment/nutrient loads, preserve topsoil integrity, foster soil water storage and groundwater recharge, protect infrastructure, and improve aquatic habitat value.

- Favorable soil moisture conditions are prolonged. This positively affects plant health and crop yields, especially during drier summers. Furthermore, less stormwater leaves the landscape as runoff, reducing downstream flooding and soil erosion.

- Groundwater recharge potential is maintained helping assure groundwater continues to flow at natural groundwater discharge points such as springs and seeps. Furthermore, maintaining groundwater recharge potential helps maintain aquifer water levels that assure reliable potable water supplies for human needs.

- Stream flow volumes are modulated and water quality is improved. Peak runoff volumes and flood elevations are reduced, dry-weather flows are increased, summer water temperatures are cooler, and winter water temperatures are sometimes slightly higher.

- Waterbody ecology is benefitted. Aquatic habitat health is promoted by the factors listed above allowing the waterbody to better reach its latent ecological potential.

- Recreational opportunities are maintained or increased. Healthy aquatic habitat supports more abundant and diverse native plants and animals.

Management strategies addressing the Lakes' water supply and water elevation/storage volume should identify opportunities, quantify changes, and evolve over time. Data collected by systematic monitoring helps lake managers make decisions consistent with current conditions and trends. The following recommendations suggest practical strategies to protect and enhance the Lakes' water supply and generate data needed to gage ongoing conditions.

- **Recommendation 1.1: Continue to monitor Twin Lakes' water-surface elevation**

  The Lakes' water surface elevation is influenced by several factors including precipitation, evaporation, wind, and various other weather conditions; the elevation and condition of the outlet dam; obstructions in the outlet channel; and the volume of water entering the Lakes from their watersheds and groundwater. Variations in these factors cause the Lakes' water levels to fluctuate. Recording Lake-specific information relating to these factors helps monitor human and environmental stressors on the Lakes' water supply. Detailed knowledge of the Lakes' elevation allows the Lakes' hydrology to be better understood and changes noted. The availability of information collected consistently over long periods of time is useful for future ordinance and technical guidance development, may help gage the impact of continued development and management activity, and can help with design and operation of water management infrastructure such as dam gates. Due to concerns over the Lakes' elevation, this recommendation is assigned as a high priority.

- **Recommendation 1.2: Quantify surface water outflow**

  The amount of water leaving the Lakes through the dam outlet works provides valuable information about the Lakes and watershed hydrology. Quantifying outlet flow over extended periods of time will help with future management decisions and may be valuable to future management actions such as aquatic plant management. The amount of water leaving through the dam outlet works can be easily estimated using water elevation data collected as part of Recommendation 1.1, noting the position of operable gates, and applying relatively simple published empirical relationships. Automated water level data collection would enrich this data set and could be used to post real-time outlet flow graphs. This recommendation should be considered a high priority.

- **Recommendation 1.3: Establish monitoring program for Twin Lakes' outflow to the dam**

  Village representatives and lake property owners shared that the channel leading to the dam becomes blocked or narrowed by debris, often from beaver dams.[1] Commission staff were told that beaver

[1] *Phone call communication between Robert Livingston and Commission staff on January 26th, 2024.*

trapping has been actively occurring. It would be beneficial for the Village or District to collaborate with McHenry County, Illinois to establish a program to monitor the condition of the channel to ensure it stays unblocked. This monitoring could be in the form of regular in-person visits, trail cameras, or regular drone surveillance. If monitoring determines that flow is impeded, then appropriate action should be taken to remove this impediment. This monitoring and action to remove impediments should be considered a high priority.

- **Recommendation 1.4: Institute groundwater monitoring**

Groundwater recharge within the Twin Lakes watershed supplies water to the shallow aquifers, which, in turn, provides baseflow to the Lakes and Nippersink Creek. Baseflow is essential to maintaining the hydrology, instream habitat, and overall health of the Lakes, particularly during dry weather.[2] Groundwater discharge points, such as seeps and springs, are sources of cool, unadulterated water to The Twin Lakes. Groundwater discharge points may help sustain coolwater fish species and bolster the Lakes' water quality. Therefore, maintaining or enhancing groundwater recharge is a crucial part of any plan that hopes to maintain or improve water quality and instream habitat conditions within the watershed. Methods to accomplish this are discussed in a subsequent subsection.

Groundwater is not visible to casual observation and changes often go unnoticed until critical thresholds are reached (e.g., a well goes dry, a stream or pond dries up). Changes to groundwater flow systems are often subtle and may occur over decades. To ascertain subtle change, the Village or District should consider initiating a groundwater monitoring program in the Lakes' groundwatershed. Groundwater elevations can be monitored in appropriately selected water supply wells and/or in purpose-built shallow monitoring wells. Ideally, measurements would be collected at least once a month into perpetuity. Relatively inexpensive automated measuring devices are also commercially available. Groundwater elevation data should be permanently recorded and a brief annual "water year" summary should be made discussing thoughts regarding measured water levels.[3] This initiative should be assigned a medium priority.

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[2] *Atypically dry weather may occur more frequently as climate change occurs.*

[3] *An example of a recent biannual groundwater report for the Village of Richfield in Washington County can be found at the following URL: wi-richfield2.civicplus.com/DocumentCenter/View/2539/Village-of-Richfield-Board-Presentation-2021.*

Detaining Runoff and Enhancing Infiltration

Human-induced change to watershed hydrology is most often detrimental to waterbody health and sustainability. Therefore, management actions in the area contributing water to the Twin Lakes should attempt to reduce the impact of human-induced change on waterbody hydrology. To maintain waterbody health and provide sustainable potable water sources, action should be taken to counteract human activity that compromises sustainable, high quality, water supplies. In general, management actions should aim to slow and detain runoff, maintain or increase groundwater recharge, and control the volume of groundwater extracted from systems feeding the Twin Lakes. Examples of such approaches are described in the following paragraphs.

Detaining Runoff

Agricultural pursuits and urban development involve manipulating the natural landscape in ways that usually increase runoff volume and speed and decrease groundwater infiltration. Actions can be taken to detain and more slowly release surface runoff to better approximate natural rainfall/runoff patterns. When water is detained, runoff intensity and downstream flood elevations are reduced, natural streams are less likely to excessively erode their beds and banks, and physical and biological processes reduce pollutant and sediment loads. Examples of methods to protect or increase stormwater detention follow.

- **Recommendation 1.5: Maintain or enhance conditions slowing stormwater runoff**

  Human activity modifies drainage basin hydrology and profoundly affects the amount and timing of water reaching waterbodies. In general, human activity decreases a landscape's ability to detain and absorb precipitation, hastens runoff speed, increases peak and total runoff volume, and discourages water infiltration into soils. These changes increase surface runoff intensity and the overall volume of stormwater runoff reaching lakes and rivers during wet weather and decrease flow to waterbodies during dry weather. Increased wet-weather runoff intensity and volumes increase soil erosion, destabilize natural stream channels, increase downstream flood elevations, and increase sediment and nutrient loads to waterbodies. A few common examples of human activities promoting these consequences include creating impermeable or less permeable surfaces (e.g., roofs, parking lots, roadways, compacted soil areas), ditching natural streams, conveying stormwater over or through smooth impermeable surfaces or pipes, filling low areas, artificially draining closed depressions and wet areas, and eliminating native vegetative cover in favor of crops, lawns, and other manicured landscaping features.

  Actions increasing runoff volume generally decrease the amount of water absorbed by soils, decrease water available to plants over dry portions of the growing season, and decrease the volume of water contributed to groundwater systems. Consequently, human activity often disrupts natural soil moisture regimens as well as groundwater flow directions and discharge patterns. Groundwater is the sole source of potable water in the Twin Lakes' watershed. If most pumped groundwater is returned to groundwater after use (e.g., soil absorption fields associated with septic systems), overall impact to groundwater flow systems may be minimal. However, when water is either consumptively used (e.g., evaporated) or exported from the local groundwater flow system (e.g., carried by sanitary sewers to discharge points outside of the groundwatershed), groundwater elevations may fall and discharge to, and flow in, surface-water features can be reduced or eliminated. This recommendation is assigned to be a medium priority.

- **Recommendation 1.6: Protect remaining landscape features that detain storm water**

Many natural landscape features detain runoff. Examples of such features include wetlands, floodplains, and closed depressions. Efforts should focus on protecting and enhancing natural stormwater detention areas. Such features should be protected throughout the watershed. This activity should be assigned a low priority.

- **Recommendation 1.7: Retire marginally productive cropland and/or restore features that detain runoff**

Historically, cropland was expanded into areas where soil moisture regimens were not naturally conducive to agricultural production. To facilitate agriculture, these areas were ditched, graded, and subsurface drainage tiles were installed. In many instances, the practices were successful with the drained cropland now providing additional productive and profitable agricultural land. In other instances, the newly drained land was not successfully converted to good cropland and was either abandoned or provides marginal crop yields and economic returns. These less-than-successful drainage projects should be scrutinized for restoration of natural hydrology and habitat. This can include disrupting drain tile networks, completing ditch plugs and fills, and enhancing landscape features that naturally hold runoff (e.g., closed depressions, wetlands). Because of the large acreage of public land already withdrawn from agricultural production available for restoration projects, this recommendation should be assigned a low priority.

- **Recommendation 1.8: Replace rural detention capacity lost on account of human activity with engineered infrastructure**

If the capacity of existing and restored natural features remains insufficient to achieve desired goals, stormwater can be detained in purpose-built artificial structures (e.g., agricultural sedimentation basins, stormwater detention basins, ditch checks, swales). Given the amount of publicly and privately held land restoration opportunities available in the watershed, this recommendation should be assigned a low priority.

➤ Recommendation 1.9: Expand urban stormwater detention infrastructure

Artificial stormwater detention features should be installed to service new developments or retrofitted to infrastructure in developed areas. With careful and holistic planning, it can sometimes be feasible to build detention features as part of new development that also serve existing development. The recommendation should be assigned a medium priority as part of greenfield development or planned infrastructure replacement projects in legacy development. Homeowner-scale projects that help detain stormwater (e.g., downspout disconnection from storm sewers, rain gardens, promoting soil health in turfgrass areas) should also be assigned a low priority. In most instances, large stand-alone projects in existing high-value development areas should be assigned a low priority.

Enhancing Infiltration

Traditional urban development increases impervious surface area and decreases overall landscape permeability. Without deliberate engineering to promote infiltration of stormwater and meltwater runoff, development reduces the volume of water infiltrating into soils and feeding shallow aquifers. Reduced infiltration reduces groundwater supplies which in turn decreases stream baseflow. Decreased baseflow reduces dry weather flow that can lead to substantial loss in stream depth, increased water temperatures, loss of critical fish and other aquatic organism habitat, increased potential for summer fish kills caused by low dissolved oxygen concentrations, and loss or degradation of desirable fish species.

➤ Recommendation 1.10: Encourage practices that enhance water infiltration

Numerous resources are available that examine how impervious surfaces affect waterbodies and measures that can be taken to offset these effects.[4] 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 driveways between neighbors

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[4] *An example resource may be found at a University of Wisconsin Stevens Point website: www.uwsp.edu/cnr-ap/clue/Documents/Water/ImperviousSurfaces2013.pdf.*

  - Minimize building footprints (i.e., build taller instead of wider or deeper, consistent with local zoning ordinances)
  - Remove unneeded sidewalks and parking areas
- Choose 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
  - Improve soil health
  - Assure that lawn area soils are not compacted
- Maintain and restore shoreline buffers

Municipalities within the Lakes' watershed should incentivize or require developers to implement these techniques on new residential developments as well as install these practices in publicly-owned lands and along roadways. Given the urbanizing lands within the watershed, this recommendation should be considered a high priority.

- **Recommendation 1.11: Protect groundwater supply by preserving high recharge areas**

  In addition to supporting water levels and flows in surface water bodies and sustaining groundwater dependent and unique natural resource elements, groundwater recharge areas are the source of water to all potable and industrial wells in the Twin Lakes watershed. Without sufficient recharge, groundwater elevations fall, a situation that can compromise the utility of existing pumps and wells. This is especially important to the relatively shallow wells commonly used for household water supply. Preserving and enhancing recharge potential within the groundwatershed, especially in the areas identified as having high and very high recharge potential, is essential to protecting groundwater feeding the Lakes and tributaries, groundwater dependent resource features, and water supply wells. Land trusts operating within the Twin Lakes groundwatershed should consider incorporating groundwater recharge potential into their land easement and acquisition selection criteria. High and very high recharge potential sites should not be intensively developed without careful consideration of groundwater recharge changes. Such sites may provide ideal sites to position stormwater infrastructure designed to infiltrate and detain high-quality stormwater.5 As opposed to directly runoff directly to surface water features, Infiltrating stormwater helps reduce peak flows and increases cool, high quality baseflow to waterbodies during dry periods, conditions that generally improve waterbody health. Therefore, protection of groundwater recharge areas should be assigned a high priority.

3.3 WATER QUALITY

Water quality is one of the key parameters used to determine the overall health of a waterbody. The importance of good water quality can hardly be overestimated, as it impacts not only various recreational uses of a lake, but also nearly every facet of the natural balances and relationships that exist in a lake between the myriad of abiotic and biotic elements present. Because of the importance water quality plays in the functioning of a lake ecosystem, careful monitoring of this lake element represents a fundamental management tool.

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

Water Quality Monitoring

Lake Mary has been monitored for water quality since the late 1980s. Elizabeth Lake was previously monitored by a volunteer participating in the UWSP Extension/WDNR Citizen Lake Monitoring Network[6] which provides equipment, training, and covers laboratory expenses for participating lakes to do regular water quality monitoring. This monitoring ceased in 2012. Elizabeth Lake lacks the consistent water quality monitoring necessary to fully assess aspects of the condition and health of this waterbody. Recommendations to continue and enhance these monitoring efforts are described below:

➤ **Recommendation 2.1: Restart water quality monitoring in Elizabeth Lake**

Water quality monitoring is an important tool that helps quantify the Lakes' current condition, helps lake managers decipher longer term change, and allows the factors responsible for change to be identified. Monitoring is integral to management efforts aiming to maintain and improve the health of the Twin Lakes. Therefore, monitoring water quality should be a high priority.

Regular water quality monitoring should be initiated in the lake's "deep hole" site in the middle of each lake. To allow historical data to be contrasted to current conditions, and, thereby, allow trends to be identified, field measurements and water quality samples should continue to be collected at this "deep hole" site at least once during mid-summer and ideally at least monthly during the growing season. At a minimum, water quality should be analyzed for the following parameters:

- Field measurements:
    - Water clarity (i.e., Secchi depth)
    - Temperature (profiled over the water depth range at the deepest portion of each lake)
    - Dissolved oxygen
    - Specific conductance (near-surface sample)
    - pH (near-surface sample)

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[6] *More information regarding the CLMN can be found at the following website: https://www3.uwsp.edu/ cnr-ap/UWEXLakes/Pages/programs/clmn/default.aspx*

- Laboratory measurements:
    - Total phosphorus (near-surface and deep-water samples)
    - Chlorophyll-a (near-surface sample)
    - Total nitrogen (near-surface sample)
    - Total suspended solids[7] (near-surface sample)

Laboratory tests quantify the amount of a substance within a sample under a specific condition at a particular moment in time and provide valuable benchmarks and trend-defining values. Phosphorus, nitrogen, and chlorophyll-*a* analyses are the basic suite of parameters used to determine and track overall lake health and trophic state. These parameters are tested in many Southeastern Wisconsin lakes and are useful to contrast the Lake's health to other waterbodies of interest.

Field measurements are often reasonable surrogates for common laboratory tests. For example, water clarity decreases when total suspended solids and/or chlorophyll-*a* concentrations are high, samples with high concentrations of total suspended solids commonly contain more phosphorus, and water with higher specific conductance commonly contains more salt and, therefore, more chloride. Periodically sampling water and running a targeted array of laboratory and field tests not only provides data for individual points in time but can also allow laboratory results to be correlated with field test results. Once a relationship is established between laboratory and field values, field data can be used as an inexpensive means to estimate the concentrations of key water quality indicators normally quantified using laboratory data. Supplemental temperature/oxygen profiles collected at other times of the year (e.g., other summer dates, nighttime summer, fall, winter) can be helpful. For example, temperature/oxygen profiles collected during midsummer nights, just before sunrise, help evaluate diurnal oxygen saturation swings.

Regular water quality monitoring helps lake managers identify variations in the Lakes' water quality, improves the ability to understand problems and propose solutions and the capacity to track progress

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[7] *Total suspended solids are the measure of the solids in water that can be trapped in a filter and is often used to quantify the transparency (or clarity) of water.*

to achieving the Lakes' water quality goals. Since Lake Mary is regularly monitored and Elizabeth Lake is not currently being monitored, this recommendation is listed as a high priority.

Phosphorus Management

As discussed in Section 2.5, "Water Quality", the Twin Lakes are not currently listed as impaired for total phosphorus and are considered mesotrophic lakes. Consequently, the recommendations in this section will focus on maintaining this status by addressing internal and external phosphorus loads.

- **Recommendation 2.2: Reduce nonpoint source phosphorus loads**

  The Twin Lakes receive substantial sediment and pollutant loads from various sources, including agricultural lands, stormwater, and runoff from shoreline residential parcels. Since neither lake is impaired for total phosphorus, efforts and practices to reduce phosphorus loads should be considered a medium priority. These efforts and practices are discussed in more detail in Section 3.5, "Pollutant and Sediment Sources and Loads." If the water quality monitoring in the Lakes indicates that either lake is trending toward or becomes impaired for total phosphorus, then this recommendation should become a high priority.

- **Recommendation 2.3: Monitor and manage in-Lake phosphorus cycling**

  The available evidence suggests that phosphorus internal loading could be a substantial contributor to total phosphorus in the Lakes. However, Commission staff were unable to estimate the total phosphorus load contributed by internal loading due to lack of the necessary water quality measurements. Actions taken to monitor and reduce internal phosphorus cycling would help maintain the high water quality that the Lakes currently enjoy. As stated in Recommendation 2.1, water quality monitoring on both lakes should occur consistently and should include total phosphorus data collected in both spring and summer at the water's surface and in the deepest areas of each lake. Native aquatic plants, par particularly muskgrass (*Chara* spp.), will utilize available phosphorus and sequester the phosphorus in their tissue. Consequently, minimizing mechanical and chemical disturbance (e.g., scouring from boat traffic, herbicide applications) of native plant communities can help reduce phosphorus concentrations in the Lakes. Given that neither Lake is currently impaired for total phosphorus, these recommendations are a medium priority but should be considered a high priority if monitoring indicates that either Lake is trending toward or becomes impaired.

Chloride Management

Chloride concentrations in the Twin Lakes have increased over time, consistent with many other lakes within Southeastern Wisconsin. As described in Section 2.5, "Water Quality", chloride can have harmful impacts on native plants and animals at even low concentrations and can become lethal at higher concentrations. Chloride is a conservative pollutant meaning that there are no natural processes that will break it down within the Lake. Additionally, removing chloride from waterbodies is prohibitively expensive in most cases. Thus, reduction of chloride inputs is the most effective management strategy to maintain low chloride concentrations in the Lakes.

- **Recommendation 2.4: Reduce salt application by practicing smart salt management**

  Private salt application, such as to parking lots and personal sidewalks, can contribute substantial amounts of chloride to surface waters if the application rates are not properly managed. Similarly, road salt application to public roadways can be a major contributor to surface water chloride loads. Applicators should be encouraged to use salt best management practices, such as calibrating salt spreading equipment; using road salt alternatives, such as pre-treatment and brining, when practicable; and storing materials away from surface waters. Salt applicators should also be encouraged to undergo winter salt certification training, hosted by Wisconsin Salt Wise.[8] This recommendation is a high priority.

- **Recommendation 2.5: Optimize water softeners and upgrade to high-efficiency softener**

  Residential and commercial water softeners have been shown to be a major chloride source, particularly in areas with hard water such as Southeastern Wisconsin.9 Water softeners should be optimized for their water use and hardness levels, which can reduce their chloride discharge by up to 50 percent. Watershed municipalities and their associated wastewater treatment facilities should consider adopting the approach utilized by the City of Waukesha in 2016, which cost-shared water softener optimization with local water conditioning companies. Subsequently, the City's residents only had to pay a nominal copayment to optimize their water softeners. Following the diversion to utilize Lake Michigan water for its drinking water, the City has updated the program to require homeowners to optimize their water

[8] *For a more complete list of salt best management practices and information on the Wisconsin Salt Wise winter salt certification program, see www.wisaltwise.com.*

[9]*A. Overbo, S. Heger, S. Kyser, et al.,* Chloride Concentrations from Water Softeners and Other Domestic, Commercial, Industrial, and Agricultural Sources to Minnesota Waters*, Minnesota Water Quality Association, 2019.*

softeners to meet more stringent water quality standards.10 When water softeners are too old for optimization to have much effect, replacing the old softeners with high-efficiency softeners should be considered to reduce chloride discharge. This recommendation is a medium priority.

- **Recommendation 2.6: Reduce chloride loading from agricultural sources**

  Agricultural lands can also contribute chloride to surface waters, particularly following the application of potassium chloride ("potash") fertilizer. Producers in the watershed should understand how their management may affect chloride concentrations in the Lakes and make efforts to reduce chloride loading through more efficient potash application. Given the urbanizing nature of the watershed, this recommendation should be considered a low priority.

3.4 SHORELINE CONDITIONS

Maintaining shorelines and streambanks can reduce sediment and phosphorus loading associated with erosion and/or runoff into the Lake and its tributaries. Promoting and maintaining native plant communities along shorelines also provides critical habitat for fish and wildlife. The following recommendations address shoreline conditions on the Lakes:

- **Recommendation 3.1: Monitor shoreline erosion and nearshore sediment accumulation**

  The Village and lake front property owners expressed concerns about shoreline erosion occurring during the winter months when ice movement would appear to erode soils and damage shorelines. Data available and collected at the present time does not allow changes to be quantified. To pursue this goal, the Village or District should periodically carefully measure shoreline location and Lake bottom elevation. If the Village and District continue to desire information regarding shoreline erosion and sedimentation in the Lakes, the Commission suggests that these efforts be assigned a high 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 to be collected only once per year and are likely to be best made during time periods when

[10] *For more information on the City of Waukesha's Water Softener Salt Program, see waukesha-wi.gov/1763/Softener-Salt-Program.*

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 Lakes, 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.[11] The Lakes' 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 the Twin Lakes at this time.

- **Recommendation 3.2: 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 little habitat value. These structures are also vulnerable to

[11] 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.

damage by winter ice and can be expensive to repair. Commission staff documented some damaged shoreline structures on both Lake Mary and Elizabeth Lake (see Map 2.Shoreline, Appendix A, and Appendix B). While hard shoreline protection may truly 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 using riprap. A 1996 United States Army Corps of Engineers study provides the following guidance regarding installing riprap that is resistant to ice damage:[12]

- The most severe damage occurs at or below the water level.

- Little damage occurs to riprapped shorelines if the shoreline has a 3:1 slope and the ice slides up the riprap. Damage can still occur if an ice ridge forms and the new ice forces itself between the ridge and the riprap.

- The average diameter of the riprap stone (the D50) should be greater than the maximum ice thickness to avoid the riprap stones being plucked by the ice.

- For riprap with a 3:1 slope, the maximum diameter of the riprap stone used should be two times greater than the maximum ice thickness to avoid ice shove damage. For steeper slopes (e.g., 5:1), the maximum diameter of the riprap stone should be three times greater than the maximum ice thickness.

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

[12] *D.S. Sodhi, S.L. Borland, and J.M. Stanley,* Ice Action on Riprap: Small-Scale Test, *United States Army Corps of Engineers Cold Regions Research & Engineering Laboratory Report 96-12, 1996.*

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. Furthermore, portions of shoreline areas abutting armored segments may provide an opportunity for establishing native plant buffers that help improve runoff water quality and help anchor shorelines with deep root systems as compared to lawn grass. 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 is assigned high priority. Taking action to naturalize armored shorelines, while beneficial to the Lake’s overall health, is optional and is therefore assigned a medium priority.

- **Recommendation 3.3: Protect, enhance, and expand nearshore emergent vegetation**

Emergent vegetation helps disperse wave energy before it reaches the Lakes’ 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 high priority. Enhancing and expanding nearshore emergent vegetation should be a low priority.

- **Recommendation 3.4: 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. 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.[13] This recommendation is assigned a low priority.

- **Recommendation 3.5: Develop an incentivizing program to encourage implementation of shoreline protection recommendations**

[13] *For more information on Healthy Lakes and Rivers Grants visit: https://healthylakeswi.com/grants/*

In addition to the recommendations for shoreline protection made above, there are practices that individual landowners can implement. In this case, it would be beneficial for the Village or District to sponsor some of these programs to encourage property owners to implement them on their shorelines. The Geneva Lake Conservancy in Walworth County has a "Conservation@Home" program that is an education and recognition program for property owners that are striving to make environmentally conscious choices on their property.[14] Additionally the WDNR has a Healthy Lakes and Rivers Grants program that provides funding to implement best practices such as fish sticks, rain gardens, native plantings, and runoff diversions.[15] Sponsoring and/or implementing these programs is a medium priority.

3.5 POLLUTANT AND SEDIMENT SOURCES AND LOADS

The Twin Lakes have relatively good water quality and no significant point sources of pollution in their watersheds. The Commission's pollutant load modeling indicates that agricultural lands are the main contributor of phosphorus and sediment loads to the Twin Lakes under current land uses. Future conversion of agricultural land use to residential development will likely impact the Lake's water quality in several ways, including an overall decrease in sediment loading to the Lake and an increase in the amounts of metal loading. The limited water quality data available suggests that there is a great deal of phosphorus in the bottom sediments that could be released under anoxic conditions (i.e., internal loading); the role recycling of phosphorus may be playing in the Twin Lakes has yet to be determined and will require a separate study.[16] This section addresses programs and practices related to reducing pollutant loads to the Twin Lakes.

Fox River Total Maximum Daily Load (TMDL)

Excessive sediment and nutrient loading can lead to increased algal blooms, oxygen depletion, water clarity issues, and degraded habitat. Algal blooms can be toxic to humans and costly to the local economy. Estimated annual economic losses due to eutrophication in the United States are as follows: recreation ($1 billion), waterfront property value ($0.3 to $2.8 million), recovery of threatened and endangered species ($44 million), and drinking water ($813 million). Due to the impairments of the Fox Illinois River Basin, a Total Maximum Daily Load (TMDL) study for phosphorus and sediment is being developed for the Fox

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[14] See genevalakeconservancy.org/conservationhome for more information.

[15] See healthylakeswi.com/grants for more information.

[16] See Section 2.7, "Pollutant Loads" of this report for a detailed description of phosphorus recycling.

Illinois River basin and its tributaries.[17] A TMDL establishes phosphorus and sediment load reduction goals for the Fox Illinois River basin. This watershed comprises area including the Fox River, the Des Plaines River, Nippersink Creek, North Mill Creek and Channel Lake watersheds. The Twin Lakes's watershed is a part of the North Branch Nippersink Creek basin.

This lake management plan envisions that restoration techniques be applied as a management action within the context of the Fox Illinois River TMDL pollutant load reduction goals as implemented through traditional regulatory actions (such as point source permits) and through voluntary programs (such as implementation of nonpoint source BMPs). Implementation of restoration techniques along with regulatory and voluntary actions would contribute to addressing the numeric or narrative water quality criteria and designated water use objectives for the Twin Lakes and their watershed.

- **Recommendation 4.1: Reduce point sources of stormwater discharge into the Twin Lakes**

  During the 2018 shoreline survey of Lake Mary and Elizabeth Lake, Commission staff noted several pipes and culverts that were directly contributing to runoff into the Lakes. While some of these were mapped in the Village's stormwater management plan, many were not. Pipes and culverts that drain into lakes can carry a variety of pollutants depending on how much and location of the area that is draining into them. Some examples of pollution often found in stormwater include garbage, sediments, herbicides, pesticides, pet waste, bacteria, and nutrients such as nitrogen and phosphorus. Identifying and reducing the number of stormwater discharge pipes that drain directly into Twin Lakes is listed as a low priority.[18]

- **Recommendation 4.2: Implement stormwater management plan wet retention basin recommendations**

  Wet detention basins are depressions constructed to have stormwater directed into, mitigating stormwater runoff into the Lakes. Basins are used to detain stormwater and then allow for the release of stormwater to be at a slower rate. Wet retention basins can reduce pollutants, stormwater runoff rates, and when strategically placed, can prevent or reduce flooding. The Village had a stormwater management plan prepared for them by Earth Tech, Inc. in 2004 which contained recommendations on the construction of wet retention basins at three locations within the Twin Lakes' watershed. The recommendations for the construction of these wet retention basins are detailed in the stormwater

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[17] *For more information or to subscribe for updates regarding the Fox Illinois TMDL study see: dnr.wisconsin.gov/topic/TMDLs/FOXIL.*

[18] *For more information see: dnr.wisconsin.gov/topic/Stormwater/learn_more/whatis.html.*

management plan in greater detail.[19] Since this recommendation has been made in past reports, but not yet been addressed, this recommendation is assigned a low priority.

Agricultural Best Management Practices

Pollutant load modeling presented in this plan identified rural nonpoint sources as main contributors to total phosphorus and sediment pollution in the Twin Lakes. Consequently, utilizing agricultural BMPs and regenerative agriculture techniques are effective measures to reduce nonpoint source pollutants and enhance water quality of the Lakes and Nippersink Creek. Some agricultural producers within the watershed participate in the Kenosha Regenerative Producers Group, a producer-led group dedicated to promoting regenerative agricultural techniques as described in this section.[20] Consequently the following recommendations aim to encourage greater use of these techniques by collaborating and supporting the Kenosha Regenerative Producers Group.

- **Recommendation 4.3: Collaborate with producer-led groups to incentivize use of no-till and conservation tillage practices**

  Removing crop residue through tillage operations leads to soil erosion. When soil is tilled, more soil is exposed to erosive forces, leading to nutrient and sediment laden surface runoff. No-till farming is the practice where the soil is undisturbed except for where the seed is placed in the soil. No-till planters disturb less than 15 percent of the row width.

  No-till benefits are recognized in several areas. By not turning soil over to prepare a seed bed, the soil structure of pores and channels formed throughout the soil surface layers remains intact and does not become compacted. This allows precipitation to effectively infiltrate, which results in less surface runoff and enables agricultural producers to drive on and/or plant their fields in wetter conditions. Utilizing no-till can also increase soil organic matter, which generally has the capacity to absorb and hold more water, and then release it to crops during the growing season. Decaying residue cycles nutrients back into the soil, decreasing reliance on fertilizers.

  However, there are several considerations for no-till that producers should plan to address before adopting the practice. Since the soil is not turned over, undesirable weeds may be harder to control and thus herbicide use may need to be increased; reducing herbicide dependence is one of the reasons that

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[19] *See the Stormwater Management Plan, prepared for the Village of Twin Lakes by Earth Tech, Inc. January 2004.*

[20] *See www.kenoshaproducers.org for more information.*

cover crops are often also utilized in a no-till system. The benefits of no-till are not fully realized until the practice has been in place for several consecutive years. To be effective, no-till must be done as part of a system of crop rotation, nutrient management, and integrated pest management. Managing weeds and the residue resulting from no-till requires the farmer to be committed to changing additional interdependent farming practices as well as renting or purchasing new equipment or modifying existing equipment.

The Village of Twin Lakes and the District should collaborate with the Kenosha Regenerative Producers Group and identify means to encourage and potentially incentivize the use of no-till agriculture within the Twin Lakes watershed. As agricultural land uses were identified as the main nonpoint sources of phosphorus and sediment loading to the Lake, this recommendation is given a medium priority.

- **Recommendation 4.4: Collaborate with producer-led groups to encourage cover crop use**

The establishment of cover crops is the practice of planting grasses, legumes, forbs or other herbaceous plants for seasonal cover and conservation purposes. Common cover crops used in Wisconsin include winter hardy plants such as barley, rye and wheat. Other less common, but also effective cover crops include oats, spring wheat, hairy vetch, red clover, turnips, canola, radishes, and triticale.[21] Cover crops can help reduce phosphorus and sediment loads by reducing erosion and improving infiltration. Cover crops grow and remain during the fallow months when corn and soybean fields would be bare. The use of cover crops for erosion control requires maintaining nearly continuous ground cover to protect the soil against raindrop impact. Having continuous plant cover increases infiltration, reduces flow and runoff across the soil surface, and binds soil particles to plant roots. A cover crop slows the velocity of runoff from rainfall and snowmelt, reducing soil loss due to sheet and rill erosion. Decreased soil loss and runoff translates to reduced transport from farmland of nutrients, pesticides, herbicides, and harmful pathogens associated with manure that degrade the quality of surface waters and could pose a threat to human health. Over time, a cover crop regimen will increase organic matter in the soil, leading to improvements in soil structure, stability, and increased moisture and nutrient holding capacity for plant growth.

Recent findings based on an annual cover crop survey by the USDA Sustainable Agriculture Research and Education program, recommend that a variety of strategies be employed to convince farmers to plant cover crops. Education, sharing new research results, appropriate technical assistance, low-cost

[21] *See UW-Extension website for more information at www.fyi.uwex.edu/covercrop.*

seed, and in some cases, financial incentives will be necessary to encourage more farmers to adopt cover crops.[22] The Village of Twin Lakes and the District should collaborate with the Kenosha Regenerative Producers Group and identify ways to encourage and potentially incentivize the use of cover crops within the Twin Lakes watershed. As agricultural land uses were identified as the main nonpoint sources of phosphorus and sediment loading to the Lake, this recommendation is given a medium priority.

- **Recommendation 4.5: Collaborate with producer-led groups to encourage and implement nutrient management plans**

The goal of a nutrient management plan is to reduce excess nutrient applications to cropland and to thereby reduce nutrient runoff to lakes, streams, and groundwater. Nutrient management plans consider the amounts and types of nutrients, and timing of nutrient application, to obtain desired yields while minimizing the risk of surface water and groundwater contamination. Plans must be prepared by a qualified planner, which may be the farmer or a certified crop adviser. Soil testing is done on each field, so the farmer knows where nutrients are needed and where they are not and considers tillage and residue management practices. Plans help farmers allocate nutrients economically while also helping to ensure they are not over-applying nutrients, which could cause water quality impacts.

The Village of Twin Lakes and the District should collaborate with the Kenosha Regenerative Producers Group and identify means to encourage enrollment of farms within the Twin Lakes watershed under nutrient management plans. As the agricultural lands within the watershed are not in Farmland Preservation or Agricultural Enterprise zones which provides incentives for farmers to sign up for these plans, this recommendation is a low priority.

3.6 PLAN IMPLEMENTATION

The methods to implement this plan vary with recommendation type, with efforts required education and outreach, ordinances and regulations, as well as partnership and collaboration. This section provides recommendations on how to best implement projects and recommendations provided in the management plan through these means.

[22] *The USDA report can be downloaded at www.sare.org/Learning-Center/From-the-Field/North-Central-SAREFrom-the-Field/2015-Cover-Crop-Survey-Analysis.*

Awareness, Education, and Outreach

One of the most effective ways to promote plan implementation is educating lake residents, users, and governing bodies regarding the content of this plan. The following recommendations are intended to increase awareness of the management plan, engage interested parties, and encourage outreach that can lead to potential partnerships and collaboration.

- **Recommendation 5.1: Integrate lake users and residents in future management efforts**

  The aim of this effort is to add to the donor and volunteer base working toward improving the Lake as well as receiving greater community input on lake planning and management decisions. Private donations and volunteer time can be used as cost match for some grants. This recommendation is given a medium priority.

- **Recommendation 5.2: Encourage key players to attend meetings, conferences, and/or training programs to build their lake management knowledge**

  Some examples of capacity-building events are Wisconsin Water Week (which targets local lake managers) and the "Lake Leaders" training program (which teaches the basics of lake management and provides ongoing resources to lake managers). Both are hosted by the University of Wisconsin Extension. Additionally, courses, workshops, on-line training, regional summits, and general meetings can also be used for this purpose. Attendance at these events should include follow-up documents and meetings so that the lessons learned can be shared with the larger lake group. This recommendation is given a medium priority.

- **Recommendation 5.3: Continue to ensure inclusivity and transparency with respect to all Lake management activities**

  If stakeholders do not fully understand the aims and goals of a project, or if they do not trust the process, excess energy can be devoted to conflict, a result that benefits no one. These efforts should be implemented through public meetings and consensus building so that conflicts can be discussed, addressed, and mitigated prior to implementing projects. This recommendation is given a medium priority.

- **Recommendation 5.4: Foster and monitor management efforts to communicate actions and achievements to future lake managers**

  Institutional knowledge is a powerful tool that should be preserved whenever possible. Actions associated with this are sometimes imbedded in organization bylaws (e.g., minutes). Open communication helps increase the capacity of lake management entities. This may take the form of annual meetings, websites, newsletters, emails, reports, and any number of other means that help compile and report action, plans, successes, and lessons learned. These records should be kept for future generations and made publicly accessible. This recommendation is given a medium priority.

- **Recommendation 5.5: Consider installing "This is Our Watershed" and "Adopt a Highway" signage throughout the watershed**

  Such signs should be placed along sub-watershed tributaries and along major transportation routes as a means of raising awareness for environmental concerns. Increased awareness usually leads to increased involvement as more of the general public begins to see themselves as stakeholders in maintaining the quality of the natural resources around them. This is recommended as a low priority.

- **Recommendation 5.6: Establish a "New Lake Resident" welcome package**

  Oftentimes, new residents are unaware of the special responsibilities they now have as property owners in a lake community. New shoreline property owners particularly have a need to be educated and "brought up to speed" on the various programs, rules, activities, and opportunities associated with lakefront ownership. This is recommended as a medium priority.

Ordinances and Regulations

Several important recommendations relate to enforcing current ordinances (e.g., shoreline setbacks, zoning, construction site erosion control, and boating). Public agencies often have limited resources available to monitor compliance and effect enforcement. Consequently, the following recommendations are aimed at local citizens and management groups and are made to enhance the ability of the responsible entities to monitor compliance and enforce regulations.

- **Recommendation 5.7: Actively share this plan and work with municipalities to adopt it by maintaining and enhancing relationships with County, municipal zoning administrators, directors of public works/municipal engineers, and law enforcement officers.**

  This helps build open relationships with responsible entities and facilitates efficient communication and collaboration whenever needed. This should be assigned a high priority.

- **Recommendation 5.8: Keep abreast of activities within the watershed that can affect the Lakes**

  Certain activities (e.g., construction, filling, excessive erosion) could potentially affect the Lakes. This initiative includes maintaining good records (e.g., notes, photographs) and judiciously notifying relevant regulatory entities of problems when deemed appropriate. Given the modest amount of such activity known in the watershed, this is currently assigned a low priority. If flagrant violation of existing ordinances becomes commonplace, this should be assigned a medium priority.

➤ **Recommendation 5.9: Educate watershed residents about relevant ordinances. Update ordinances as necessary to face evolving use problems and threats**

This helps ensure that residents know why rules are important, that permits are required for almost all significant grading or construction, and that such permits offer the opportunity to regulate activities that could harm the Lake. This should be considered a medium priority.

Partnership and Collaboration

Numerous opportunities exist for partnership and collaboration to improve water quality within the watershed. The following recommendations provide ideas and collaboration opportunities intended to inspire further action.

➤ **Recommendation 5.10: Foster open relationships with potential project partners**

Continue to partner with and maintain good relations with volunteer groups, municipalities, and governing bodies, which promotes effective solutions to issues shared. This is recommended as a medium priority.

➤ **Recommendation 5.11: Encourage participation and growth of producer-led groups**

Producer-led watershed groups are a recent innovation that has greatly enhanced the ability to actively promote sustainable agriculture and allied conservation practices in Wisconsin. Producer-led groups sponsor programs that endeavor to improve soil health, water quality, and farm profitability by a variety of means, including the following examples. Some producers within the watershed already participate in the Kenosha Regenerative Producers Group. The following activities are recommended to improve participation and growth of this organization within the Twin Lakes watershed:

- Recruiting producers to apply for and install low-cost conservation BMPs to improve soil and water quality.

- Providing education and outreach (field days, workshops, tours) to area producers about the principles of soil health, soil improvement practices, equipment use, and water quality improvement conservation practices.

- Collectively leasing or buying novel equipment and sharing ideas for modifying existing equipment

- Improving the image of agriculture by showcasing various local producer leaders, outreach activities, farms and/or fields through signage, and being active in the community promoting good farming practices

Encouraging participation with the Kenosha Regenerative Producers Group should be considered a medium priority.

Funding Sources

The following subsection provides a brief description of some of the State and Federal funding sources available to help fund BMPs and other plan recommendations in the watershed:

State

- **Surface Water Grant Program** – State program that offers competitive grants for local governments, Counties, lake districts and other eligible organizations to address a range of surface water issues.[23] There are several subprograms that could be useful for implementing plan recommendations and that the Village, District or Kenosha County could sponsor. These subprograms include:

    - **Surface Water Restoration** – Provides funding to implement shoreline, in-water, and wetland restoration projects that follow appropriate NRCS guidelines as well as funding to develop ordinances that protect surface water resources. Cost-share is up to 75 percent of eligible costs for up to $75,000 for lakes and $50,000 for rivers.

    - **Management Plan Implementation** – Provides funding to implement recommendations in a WDNR-approved surface water management plan. Eligible projects include nonpoint source pollution control, habitat restoration, water quality improvements, landowner incentives, and management staffing. Cost-share is up to 75 percent of eligible costs for up to $200,000 for lakes and $50,000 for rivers.

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[23] *For more information on the WDNR Surface Water Grant program, see www.dnr.wisconsin.gov/aid/SurfaceWater.html and Wisconsin Department of Natural Resources, 2023 DNR Surface Water Grant Application Guide, July 2023: dnr.wisconsin.gov/sites/default/files/topic/Aid/grants/surfacewater/CF0002.pdf.*

- **Healthy Lakes and Rivers** – Provides funding to implement approved best practices for shoreland landowners following technical guidance. Practices include fish sticks, native plantings, water diversions, rain gardens, and rock infiltration. Cost-share is up to 75 percent of eligible costs for up to $25,000.

- **Clean Boats, Clean Waters** – Provides funding to help prevent spread of aquatic invasive species through education and monitoring at boat launches. Eligible costs include supplies, training, and payment to any paid staff or in-kind donations from volunteers. Cost-share is up to 75 percent of eligible costs for up to $4,000 per boat launch.

- **Land Acquisition** – Provides funding to permanently acquire land to protect surface waters. Eligible costs including costs associated with appraisal, land survey fees, title costs, and any historical, cultural, or environmental assessments. Cost-share is up to 75 percent of eligible costs for up to $200,000 for lakes and $50,000 for rivers.

- **Targeted Runoff Management (TRM) Grant Program** - State program that offers competitive grants for local governments for controlling nonpoint source pollution. Grants reimburse costs for agricultural or urban runoff management practices in critical areas with surface water or groundwater quality concerns. The cost-share rate for TRM projects is up to 70 percent of eligible costs.[24]

Federal

- **Environmental Quality Incentives Program (EQIP)** - Federal program that provides financial and technical assistance to implement conservation practices that address resource concerns.[25] Farmers receive flat rate payments for installing and implementing runoff management practices. The following agricultural practices are eligible for cost sharing:

  - Cover crop
  - Critical Area Planting
  - Diversion
  - Fence
  - Field Border
  - Filter Strip
  - Forage and Biomass Planting
  - Grade Stabilization Structure
  - Grassed Waterway
  - Heavy Use Area Protection

[24] *For more information on TRM, see dnr.wisconsin.gov/aid/TargetedRunoff.html.*

[25] *For more information on EQIP, see www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip.*

- Lined Waterway or Outlet
- Livestock Pipeline
- Mulching
- Obstruction Removal
- Prescribed Grazing
- Streambank and Shoreline Protection
- Strip Cropping
- Surface for Water Control
- Subsurface Drain
- Terrace
- Trails and Walkways
- Tree/Shrub Establishment
- Tree/Shrub Site Preparation
- Underground Outlet
- Vegetated Treatment Area
- Water and Sediment Control Basin
- Water Well
- Watering Facility
- Wetland Restoration

- **Conservation Reserve Program (CRP)** - A Federal land conservation program administered by the Farm Service Agency. Farmers enrolled in the program receive a yearly rental payment for environmentally sensitive land that they agree to remove from production. Contracts are 10 to 15 years in length. Eligible practices include buffers for wildlife habitat, wetland buffers, riparian buffers, wetland restoration, filter strips, grass waterways, shelter belts, living snow fences, contour grass strips, and shallow water areas for wildlife.[26]

- **Conservation Reserve Enhancement Program (CREP)** – Joint effort between County, State, and the Federal government that provides funding for practice installation, rental payments, and an installation incentive. Interested parties can enter a 15-year contract or perpetual contract conservation easement. Eligible practices include filter strips, buffer strips, wetland restoration, tall grass prairie and oak savanna restoration, grassed waterway, and permanent native grasses.[27]

- **Agricultural Conservation Easement Program (ACEP)** – Federal program that consolidates three former programs (Wetlands Reserve Program, Grassland Reserve Program, and Farm and Ranchlands Protection Program). Under this program, NRCS provides financial assistance to eligible partners for purchasing Agricultural Land Easements that protect the agricultural use and conservation values of eligible land.[28]

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[26] *For more information on CRP, see www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program.*

[27] *For more information on CREP, see www.datcp.wi.gov/Pages/Programs_Services/CREPLandowners.aspx.*

[28] *For more information on ACEP, see www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/acep.*

- **Conservation Stewardship Program (CSP)** – Federal program that offers funding for participants that take additional steps to improve resource condition. Program provides two types of funding through five-year contracts: 1) annual payments for installing new practices and maintaining existing practices and 2) supplemental payments for adopting a resource-conserving crop rotation.[29]

- **Farmable Wetlands Program (FWP)** – Federal program designed to restore previously farmed wetlands and wetland buffer to improve both vegetation and water flow. The Farm Service Agency runs the program through the Conservation Reserve Program with assistance from other government agencies and local conservation groups.[30]

3.7 SUMMARY

To help implement plan recommendations, Table 3.1 summarizes all recommendations and their priority level. As stated in the introduction, this chapter is intended to stimulate ideas and actions. Therefore, these recommendations should provide a starting point for addressing the issues identified in the Twin Lakes and their watershed. Successfully implementing this plan requires vigilance, cooperation, and enthusiasm, not only from local management groups, but also from State and regional agencies, Kenosha County, municipalities, Lakes' residents and users, and the public. Implementation of the recommended measures will provide the water quality and habitat protection necessary to maintain or establish conditions in the watershed that are suitable for maintaining and improving the natural beauty and ambience of Lake Mary and Elizabeth Lake and their ecosystem.

[29] *For more information on CSP, see www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp.*

[30] *For more information FWP, see www.fsa.usda.gov/programs-and-services/conservation-programs/farmable-wetlands/index.*

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KENOSHA COUNTY, WISCONSIN

Chapter 3

MANAGEMENT RECOMMENDATIONS AND PLAN IMPLEMENTATION

TABLES

Table 3.1
Summary of Recommendations for Twin Lakes

Recommendation Number	Recommendation	Priority
	HYDROLOGY, WATER QUANTITY, AND WATER RESOURCES INFRASTRUCTURE	
1.1	Continue to monitor Twin Lakes' water-surface elevation	High
1.2	Quantify surface water outflow	High
1.3	Institute monitoring program for Twin Lakes' outflow to the dam	High
1.4	Institute groundwater monitoring	Medium
1.5	Maintain or enhance conditions slowing stormwater runoff	Medium
1.6	Protect remaining landscape features that detain storm water	Low
1.7	Retire marginally productive cropland and/or restore features that detain runoff	Low
1.8	Replace rural detention capacity lost on account of human activity with engineered infrastructure	Low
1.9	Expand urban stormwater detention infrastructure	Low
1.10	Encourage practices that enhance water infiltration	High
1.11	Protect groundwater supply by preserving high recharge areas	High
	WATER QUALITY	
2.1	Restart water quality monitoring in the Elizabeth Lake	High
2.2	Reduce nonpoint source phosphorus loads	Medium-High
2.3	Monitor and manage in-lake phosphorus cycling	Medium-High
2.4	Reduce salt application by practicing smart salt management	High
2.5	Optimize water softeners and upgrade to high-efficiency softeners	Medium
2.6	Reduce chloride loading from agricultural sources	Low
	SHORELINE RECCOMENDATIONS	
3.1	Monitor shoreline erosion and nearshore sediment accumulation	High
3.2	Encourage removal and/or enhancement of "hard" shoreline protective structures	Medium-High
3.3	Protect, enhance, and expand nearshore emergent vegetation	Low
3.4	Encourage "soft" or "natural" shoreline protection	Low
3.5	Develop an incentivizing program to encourage implementation of shoreline protection recommendations	Medium
	POLLUTANT AND SEDIMENT SOURCES AND LOADS	
4.1	Reduce point sources of stormwater discharge into the Twin Lakes	Low
4.2	Implement stormwater management plan wet retention basin recommendations	Low
	Agricultural Best Management Practices	
4.3	Collaborate with producer-led groups to incentivize use of no-till and conservation tillage practices	Medium
4.4	Collaborate with producer-led groups to encourage cover crop use	Medium
4.5	Collaborate with producer-led groups to encourage and implement nutrient management plans	Low
	PLAN IMPLEMENTATION	
	Awareness, Education, and Outreach	
5.1	Integrate lake users and residents in future management efforts	Medium
5.2	Encourage key players to attend meetings, conferences, and/or training programs to build their lake management knowledge	Medium
5.3	Continue to ensure inclusivity and transparency with respect to all Lake management activities	Medium
5.4	Foster and monitor management efforts to communicate actions and achievements to future lake managers	Medium
5.5	Consider installing "This is Our Watershed" and "Adopt a Highway" signage throughout the watershed	Low
5.6	Establish a "New Lake Resident" welcome package	Medium
	Ordinances and Regulations	
5.7	Actively share this plan and work with municipalities to adopt it by maintaining and enhancing relationships with County, municipal zoning administrators, directors of public works/municipal engineers, and law enforcement officers.	High
5.8	Keep abreast of activities within the watershed that can affect the Lakes	Low-Medium
5.9	Educate watershed residents about relevant ordinances. Update ordinances as necessary to face evolving use problems and threats	Medium

Table continued on next page.

Table 3.1 (Continued)

Recommendation Number	Recommendation	Priority
	Partnership and Collaboration	
5.10	Foster open relationships with potential project partners	Medium
5.11	Encourage formation and growth of producer-led group covering the watershed	Medium

Note: This summary of recommendations is a compiled list of items the Twin Lakes Protection and Rehabilitation District; the Village of Twin Lakes; the residents of the Twin Lakes' watershed; and riparian owners, working together with volunteers and other nonprofit organizations, could implement to improve the Twin Lakes and their watershed(s).

Source: SEWRPC

APPENDICES

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KENOSHA COUNTY, WISCONSIN

Appendix A

LAKE MARY SHORELINE POINTS OF INTEREST

Table A.1
Lake Mary Shoreline Points of Interest

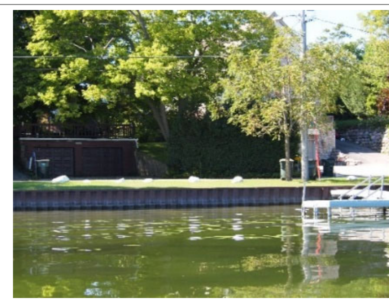
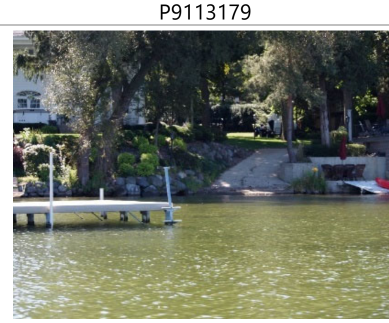
Point	Category	Notes	Photograph at Point
1	Shoreline	Damaged sea wall	
2	Shoreline	A steel sheet sea wall, held up well with no current damage, unsure how long ago it was installed. Potentially had damage previously due to low water levels.	
3	Point Source	Small pipe to the right of white shed	 P9113177
4	Point Source	Pipe coming out of wall	 P9113179
5	Point Source	Eastern shoreline, East Lake shore Drive area. "Driveway/launch" right down into the lake	 P9113180

Table continued on next page.

Table A.1 Continued

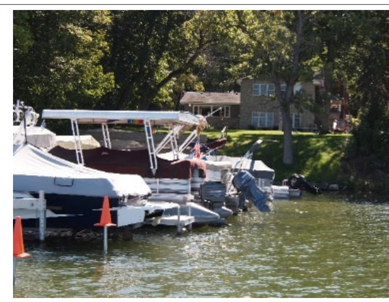
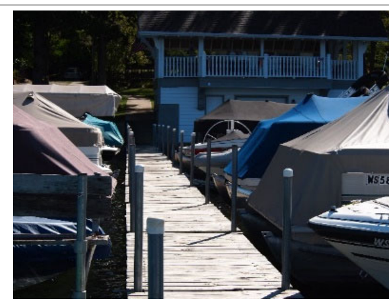
Point	Category	Notes	Photograph at Point
6	Point Source	Pipe or something similar going into lake	 P9113182
7	Point Source	Large drainage pipe in/out of lake (2ft across or bigger by visual estimate)	 P9112112
8	Large Pier/Marina	Subdivision pier, common use by homeowners association on other side of road. Limited public access.	
9	Large Pier/Marina	Another association access/dock	
10	Shoreline	In 2002/2003 along 1500/1600 block on East Lakeshore drive there was severe ice damage when the water was low	

Table continued on next page.

Table A.1 Continued

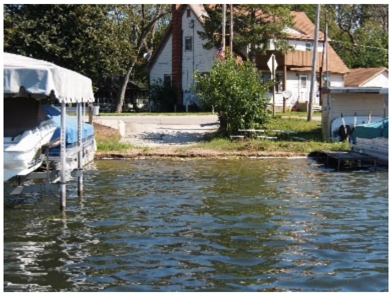
Point	Category	Notes	Photograph at Point
11	Point Source	Culvert/pipe	 P9113254
12	Large Pier/Marina	Sunset Grille Restaurant and Marina, boat slip rentals	
13	Point Source	Under street sewer that drains into the lake.	 P9113300
14	Shoreline	Beach area	
15	Point Source	Street drains right into the water	

Table continued on next page.

Table A.1 Continued

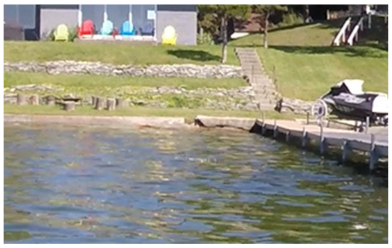
Point	Category	Notes	Photograph at Point
16	Point Source	Snowmobile "launch"	
17	Point Source	Culvert behind water garden that goes right into the lake	 M_point_17.png
18	Shoreline	Seawall still in good shape	
19	Shoreline	Cracked seawall	
20	Point Source	Pipe going into lake	 P9113339

Table continued on next page.

Table A.1 Continued

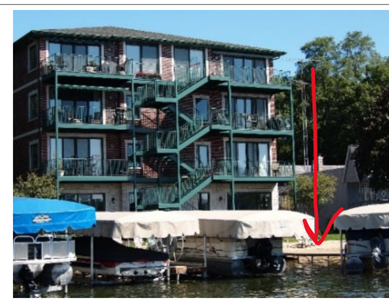
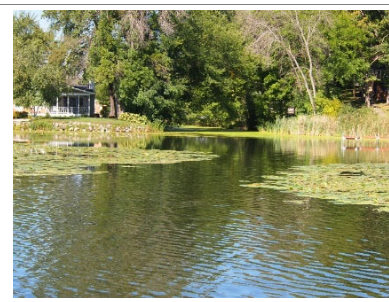
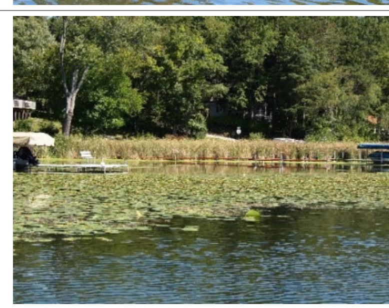
Point	Category	Notes	Photograph at Point
21	Park	Lance Park, where ski show happens. The parking lot designed to drain away from lake but ultimately still ends up in lake, Has a public beach	
22	Park	Still Lance Park - ski show seating area	
23	Shoreline	Natural Shoreline	
24	Large Pier/Marina	Condominium beach	 P9113392
25	Large Pier/Marina	Association Pier	

Table continued on next page.

Table A.1 Continued

Point	Category	Notes	Photograph at Point
26	Point Source	Pipe/culvert - goes way up the hill where there is a farm that used to raise cows and the run off cause an E. Coli issue in this part of the lake. Then the city had them stop raising cows and the E. coli issue is less common now	 P9113402
27	General Comments	This shoreline area gets a lot of wave action from the ski show	
28	Large Pier/Marina	Association boat launch	
29	General Comments	Channel - other side of road has lots of farms which eventually drain to here	
30	General Comments	Much more vegetation, though to be attributed to runoff coming in through the channel (lily pads & cattails) & also thought that this area was dredged 30+ years ago	

Source: SEWRPC

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Appendix B

ELIZABETH LAKE SHORELINE POINTS OF INTEREST

Table B.1
Elizabeth Lake Shoreline Points of Interest

Point	Category	Notes	Photograph at Point
1	Shoreline	When it rains, "the water comes down the street like crazy and it has washed out the concrete pad 3 times."	
2	Biological Comments	This is a "vacant lot" has a creek that empties into the lake, thought by residents of lake to be why the area has more weeds and is shallow. The area near here does not freeze well in the winter.	
3	Large Pier/Marina	Association pier where water runs downhill into the lake and is thought to have been built in the early 1960s.[a]	
4	Shoreline	Property reported moderate shoreline damage at the last meeting	
5	Large Pier/Marina	Association pier/beach	

Table continued on next page.

Table B.1 (Continued)

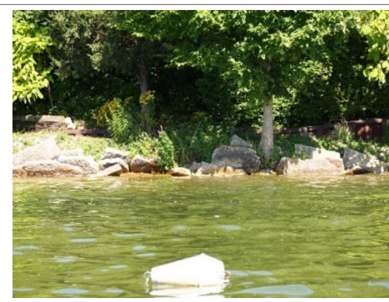
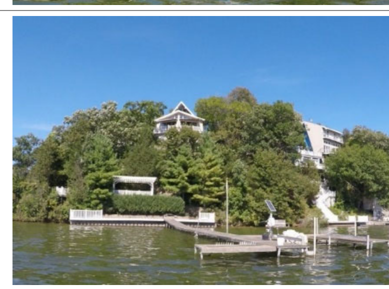
Point	Category	Notes	Photograph at Point
6	General Comments	2029 East Lakeshore Drive said to have a natural draining area.	
7	Shoreline	233 W Park – Property owners second time putting up seawall/riprap.	
8	Shoreline	Sea wall that got pushed/broken by ice (The Commission received email correspondence specific to the property during time of ice damage surveys).	
9	General Comments	The channel to Lake Mary that is about 10ft wide.	
10	Shoreline	Deck uneven from ice movement against wall.	

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Table B.1 (Continued)

Point	Category	Notes	Photograph at Point
11	General Comments	How snowmobiles cross between the two lakes, residents not pleased.	
12	Historical Interest	Supposedly the location where a hotel was where Evinrude developed the outboard motor so he could take his daughters to town to get ice cream, since there were only row boats at the time. Other lakes claim the same thing.	
13	General Comments	Area called the "Boy Scout Island Wetlands"	
14	Historical Interest	The story goes that Mr. Stump[b] developed a lot of the land on this side of the lake and this is a newer house.	
15	Biological Comments	Thought that the wetland area filters some of the water that enters the lake.	
16	Historical Interest	This house was Mr. Stumps house for a very long time.	

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Table B.1 (Continued)

Point	Category	Notes	Photograph at Point
17	General Comments	"Boy Scout Island" - "I could have bought it for $250,000 in 1990" Resident of Elizabeth Lake guide. Noted that he would have had to build not only a bridge but also build sewage lines across the wetlands to get sewage off the island.	Aerial photo?
18	General Comments	People are gradually cutting away cattails near their docks/properties.	
19	General Comments	When driving on Lance Drive you can see this part of the lake from the road.	
20	Historical Interest	Center of ice harvesting area. Areas on the lake were historically harvested for ice blocks during the winter before modern refrigeration.[c]	
21	General Comments	Thought to be the biggest house on the lake. Used to be a camp with two dorms and a central kitchen building. They were trying to find someone to buy it. Now hedge fund manager supposedly owns it and the house was built in the last two years (from at time of survey sept 2018).	
22	Park	Lucille Beach - very shallow launch with lots of plants, thought to be from nutrient runoff from the launch. This is the shoreline that seemingly gets most of the ice push/ice damage. All sandy bottom, very shallow.	

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Table B.1 (Continued)

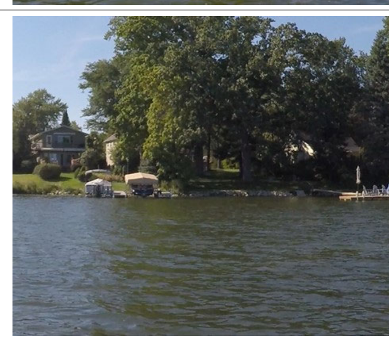
Point	Category	Notes	Photograph at Point
23	Shoreline	Damaged seawall that has been in place a very long time.	
24	Historical Interest	Mr. Stump dug all the channels here.	
25	General Comments	A lake resident that lives in this area of the lake in the channel was at the time taking measurements relative to the seawall for lake level.	
26	Historical Interest	"Turtle Bay" - "Would guess that this bay was dredged over 20 years ago and I can get that exact date"[d]	
27	Shoreline	House tried using logs as ice deterrent but went back to using rocks.	

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Table B.1 (Continued)

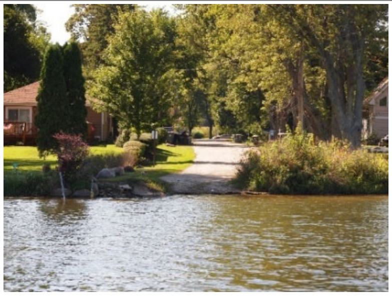
Point	Category	Notes	Photograph at Point
28	Point Source	Dead end of a street - runs right into the lake.	
29	Point Source	Concrete culvert	
30	Large Pier/Marina	Subdivision marina harbor	
31	Large Pier/Marina	Subdivision marina harbor	
32	Park	Sunset Beach – This is where the Village of Twin Lakes has repaired the seawall and will be putting in a lake level gauge.[e]	

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Table B.1 (Continued)

Point	Category	Notes	Photograph at Point
33	Historical Interest	"There was something called a corduroy road. In the 1850s. A corduroy road was the way you rather than building a bridge, you put logs across the swamp. So that's 2ft below where we are now" – Elizabeth Lake resident (referring to lake level)	
34	General Comments	Development stops near the state line between Illinois and Wisconsin.[f]	
35	Biological Comments	This is what keeps McHenry County area clear. This is thought to be a "cleansing area", the pollutants go through these weeds before going down into Illinois. (according to Lake Elizabeth resident)	
36	General Comments	This is where they park the police boat.	
37	Large Pier/Marina	Sand Bar and Island Grill	
38	General Comments	Large, damaged tree	

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Table B.1 (Continued)

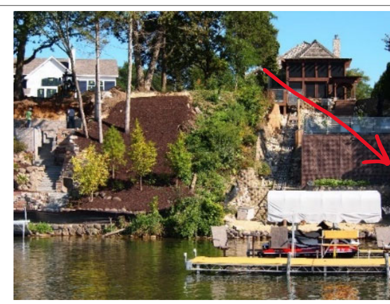
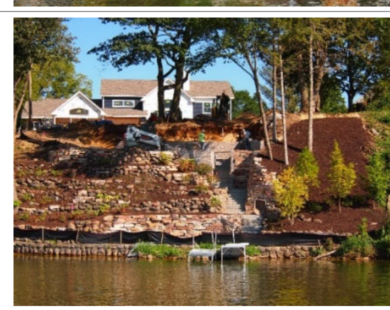
Point	Category	Notes	Photograph at Point
39	Shoreline	Sea wall is tipping	
40	General Comments	High shoreline with a farm field on the other side	
41	General Comments	This is the only commercial property left on the lake and it’s for sale (at time of survey)	
42	General Comments	Elevator/ramp from shoreline up the steep hill to house.	
43	General Comments	New construction	

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Table B.1 (Continued)

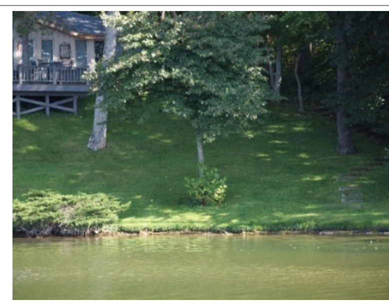
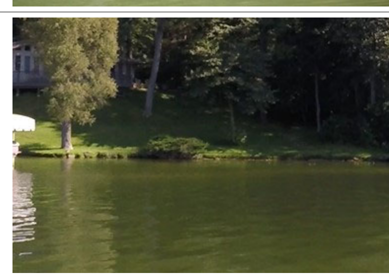
Point	Category	Notes	Photograph at Point
44	Shoreline	Property up for sale - no shoreline protection (344 Blackhawk Trl. $1.79 million)	
45	Shoreline	This seawall has had damage in the past.	
46	General Comments	Large property where the owners recently repaired their boathouse.	
47	Shoreline	Unprotected shoreline	
48	Biological Comments	There are underground springs that come down to the lake through the two boat houses, they are said to be natural springs (according to Elizabeth Lake Resident)	

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Table B.1 (Continued)

[a] *On Elizabeth Lake it is popular for subdivision and neighborhoods to share a large marina or several boat slips which allow for homeowners who do not own frontage on the lake the opportunity to access the lake.*

[b] *"Mr. Stump" was mentioned several times by the two guides that were on the shoreline survey with Commission staff. From what was explained, M. Stump was an earlier settler of the Twin Lakes area, particularly on Elizabeth Lake.*

[c] *Lake Elizabeth historical had many ice houses that would harvest ice during the winter along the shallower parts of the lake.*

[d] *Several areas of the lake were thought to have been dredged but the Commission did not receive historical confirmation of this.*

[e] *Commission staff did not receive further indication that the gauge had been installed or any data from it.*

[f] *Commission staff did not go into the Illinois area of the lake due to Illinois navigation laws and due to the area being quite shallow and dense with plants.*

Source: SEWRPC