MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

REQUEST FOR PROPOSALS - ENGINEERING AND CONSULTING SERVICES

Minnehaha Creek Watershed District

Project overview

Background

The Minnehaha Creek Watershed District (MCWD) is requesting proposals from qualified firms to conduct a feasibility study that identifies innovative, cost-effective, and technically sound options to reduce phosphorus export from stormwater runoff within the Downtown Management Unit (DMU) of the Long Lake Creek Subwatershed.

This work will draw from the Long Lake Creek Partnership Roadmap (“Roadmap”, Appendix A), an MCWD-led initiative in partnership with the cities of Long Lake, Orono, and Medina, and Long Lake Waters Association, which identified and prioritized water quality improvement opportunities throughout the Long Lake Creek subwatershed. The DMU, which encompasses 518 acres and represents the western drainage area of Long Lake, was identified as the largest contributor of phosphorus load to Long Lake per unit area, largely due to it having the highest concentration of impervious surface and insufficient stormwater treatment infrastructure.

The Roadmap recommended Holbrook Park as a priority regional treatment project within the DMU. MCWD would like to expand the feasibility focus to include other areas of downtown Long Lake to support a coordinated stormwater strategy and identify multi-benefit and cost-effective opportunities within Long Lake’s urban corridor. The feasibility study will analyze various project areas for technical feasibility, including engineering and regulatory feasibility, as well as produce cost and benefit estimates.

For the purposes of this feasibility study, MCWD will administer the consulting contract. City of Long Lake (City) staff will participate in the review of final deliverables. In this RFP, MCWD and the City are collectively referred to as “project partners”.

Issues to solve

- Excess nutrients: Phosphorus concentrations in runoff from the DMU average 300 µg/L—three times the State standard for streams.
- Runoff volume: The DMU produces four times the runoff volume per unit area compared to other management units in the subwatershed.
- Lack of stormwater treatment: Key areas within the DMU lack sufficient stormwater capture or treatment mechanisms.

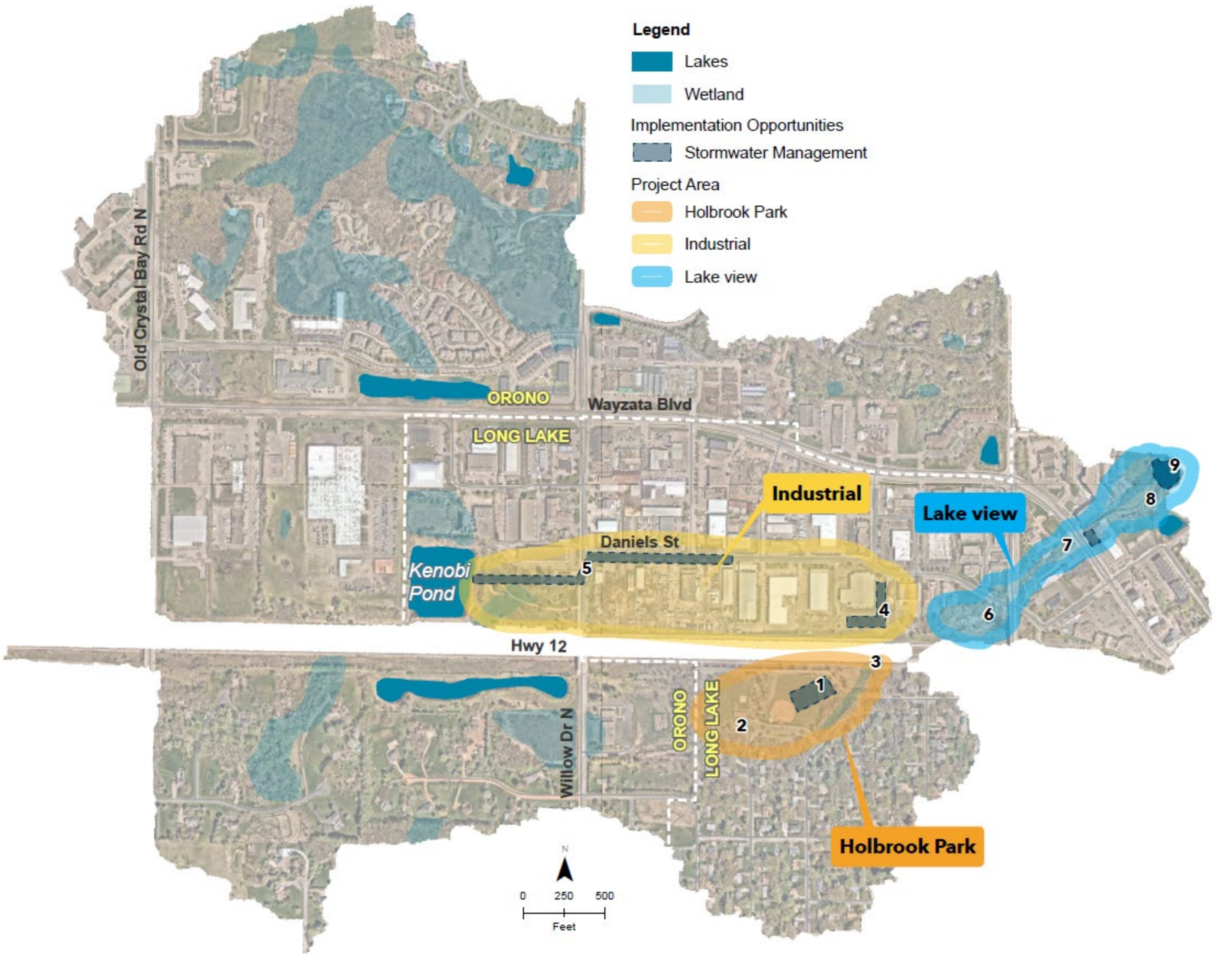
Goals

- Evaluate and recommend stormwater treatment practices that reduce phosphorus export and runoff volume.
- Develop a clear, actionable understanding of site constraints and opportunities at key locations.
- Identify and evaluate project concepts that are innovative, feasible, cost-effective, and supported by data and modeling.
- Align proposed project alternatives with regional water quality goals, potential future redevelopment plans, and MCWD's collaborative planning framework.

Project areas

The feasibility study should investigate specific project areas identified in the Roadmap, as well as additional areas identified through site-walks and knowledge from City staff. See the table and project map for the description and location of each project site.

Project Areas	Feasibility Focus	Notes
Holbrook Park area	1. Holbrook Park (DT01) 2. Adjacent south and southeast ravines 3. Highway 12 ROW basin NE of Holbrook Park	Roadmap recommended regional stormwater treatment underneath ballpark, although it may not be cost-effective due to elevations. Ravine and ROW basins may have substantial capacity
Industrial corridor	4. Long Lake Public Works facility (DT02) 5. Daniels Street (DT04)	Roadmap recommended subsurface infiltration at public works and rerouting storm sewer from Daniels Street toward Kenobi Pond during future reconstruction. City indicated no planned street reconstruction of Daniels Street in the near future.
Lake view corridor	6. Retention basin south of City Hall 7. Stream channel leading from City Hall to Nelson Lakeside Park 8. Nelson Lakeside Park filtration basins 9. Nelson Lakeside Park North Pond (DT03) and South Pond	Roadmap considered North Pond expansion/retrofit. North and South Ponds are maintained by MCWD. Filtration basins, owned and maintained by City, may be underperforming and require maintenance.



Considerations

- If the consultant identifies additional opportunities within the project areas above that could address the DMU's issues and reach the stated goals, these may also be evaluated along with those identified above.
- Land Ownership and Access: Some locations are on public land; others may require coordination with private property owners or depend on redevelopment timing.
- Regulatory Requirements: The study must consider local, state and federal stormwater and wetland regulations.
- Maintenance: Maintenance capacity for City staff and MCWD staff is limited; project alternatives should consider maintenance effort and cost in determining feasibility and recommendations of projects.
- Orono stormwater pond retrofit: The Kenobi Pond, located just west of Daniels Street in the Industrial corridor, is managed by the City of Orono, and is undergoing maintenance in the coming months. Additional coordination with the City of Orono is required if project recommendations include the use of Kenobi Pond's stormwater capacity.
- Localized issues, such as flooding, pipe clogging, and access should be considered. Known issues will be provided to the consultant team.

Scope of work

The final negotiated scope of work may include, but may not be limited to, the components listed below.

1. **Kickoff and discovery:** Hold a kickoff meeting with project partners and conduct a discovery phase to review all relevant existing information, including through discussions with both project partners.
2. **Project identification and evaluation:** Assess and evaluate the project concepts described above and identify any additional project opportunities. Conduct a comparative analysis of all identified concepts—new and existing—and provide recommendations on which project(s) merit advancement to feasibility-level design based on their potential impact, feasibility, and alignment with project goals.
3. **Landscape architecture and engineering:** Feasibility-level design and engineering of the identified site areas, including schematic designs, with sufficient detail to 1) identify any technical or other barriers to project implementation, 2) produce several viable design alternatives based on the concepts identified in the Roadmap, and 3) select a project(s) to serve as the technical and procedural basis to advance into full project design.
4. **Permitting scan:** Based on the feasibility-level design and engineering, identify required and any potential permitting challenges.
5. **Operations and maintenance (O&M)**: Based on feasibility-level design and engineering, identify O&M and capital replacement requirements, costs, schedules, and anticipated maintenance responsibility (i.e., City, MCWD, other).
6. **Project costs and benefits:** Based on feasibility-level design and engineering, produce cost estimates and cost-benefit analyses. For each project opportunity, ease of design and construction and procuring potential funding (e.g., grants) should also be documented to assist the project partners in deciding which project(s) to advance.

Additional tasks may be proposed by the consultant if deemed necessary to support the feasibility analysis—such as collecting supplemental stormwater data, conducting pond surveys, or performing desktop-level environmental reviews. The work is expected to be completed within six months after the execution of a contract.

Instructions to proposers

Informational meeting

An informational meeting will be held on **Thursday, June 26th, at 10:00 AM** (15320 Minnetonka Blvd, Minnetonka, MN 55345) to answer any questions about the project or process. At this time, MCWD staff will present a summary of the project and will provide a description of the desired products. **Please RSVP** and submit any questions via email in advance of the meeting to rbaker@minnehahacreek.org **by Tuesday, June 24th at 4:00 PM**.

Proposal submittal deadline

Please submit electronic copies of proposals by email to Rachel Baker, Planner-Project Manager, at rbaker@minnehahacreek.org and Michael Hayman, Director of Project Planning, at mhayman@minnehahacreek.org no later than **4:00pm on Wednesday, July 16th, 2025**.

Proposal contents

Each proposal should include the following items:

1. **Cover Letter:** Include a primary point of contact and contact information.
2. **Project understanding:** Describe your understanding of the scope of work, the approach to be taken, and your vision for the feasibility study. Identify any additional information the project partners will need to supply or obtain to enhance your understanding of the project and successfully complete the work, and any issues you anticipate in performing the work.
3. **Qualifications and experience:** Provide an overview of the firm(s), project team members, and qualifications, with particular attention paid to the role, experience, and expertise of each proposed team member. Include descriptions of projects undertaken by the firm(s) and team members similar in nature to the one being proposed.
4. **Approach and Methodology:** Provide a detailed description of your approach to the scope of work contained in this RFP, including how you will build in check points to coordinate with MCWD and City of Long Lake staff. Include a detailed scope of work with descriptions of all anticipated tasks and deliverables, and any supplemental tasks not described in the RFP.
5. **Budget, schedule, and level of effort:** Provide a spreadsheet showing:
    a. Tasks with associated team members, hours, schedule, and budget
    b. Overall cost proposal
    c. Overall schedule with major milestones and client check-ins
6. **References:** Provide three recent references for your proposed principal team members, including names, addresses, and phone numbers.
7. **Partner resources:** Provide a list of resources, expectations, and requirements which the consultant expects from the project partners in order to complete the project as proposed.
8. **Subcontracting:** If the primary contractor intends to use any subcontractors, submit the subcontracted firms' information and provide an overview of the proposed subcontracted team members.

Proposal evaluation and consultant selection

Evaluation criteria

Methodology

- **Project Understanding:** Does the proposal make it clear that the consultant fully understands the project's scope, goals, and technical requirements?

- **Completeness and Specificity:** How fully does the proposal explain what the consultant will do to develop the required deliverables?
- **Identification of Needs:** Does the proposal carefully consider what resources will be required to complete the tasks, including staff time, additional technical information, etc.?
- **Innovation:** Does the approach incorporate modern or cutting-edge techniques and analysis consistent with a technically sound product, where appropriate and requested in the RFP?

Experience

- **Company Experience:** What other similar projects has the consultant performed that are directly related to the proposed work (evaluated via the proposer's submittal materials)?
- **Staff Experience:** What qualifications and work experience do the proposed staff members or subcontractors bring to the project?
- **Area Knowledge:** Does the company or any of the project team have specific knowledge about the project area that would aid in the study?

Cost

- **Fee structure:** The proposal must clearly outline the fees and costs to complete all aspects of this project. Include hourly rates for each project team member along with hours for each task. The final fee structure and contract price are subject to negotiation.

Consultant selection

Interviews

Interviews will be conducted at the option of MCWD. Proposers selected for interviews will be contacted within two weeks of proposal submittal deadline.

Selection criteria

A selection committee composed of MCWD staff will evaluate proposals and interview results (if conducted) to recommend a consultant to the MCWD Board of Managers for approval.

Scope adjustments

The project partners reserve the right to negotiate modifications to the selected consultant’s proposed scope of work and budget, prior to awarding a contract.

MCWD Board contract approval

The MCWD Board of Managers will approve the final negotiated scope of work and budget and authorize the execution of a contract (see Appendix D, MCWD Professional Service Agreement Template).

Disclosures

Non-binding:

The District reserves the right to accept or reject any or all responses, in part or in whole, and to waive any minor informalities, as deemed in the District’s best interests. In determining the most advantageous proposal, the District reserves the right to consider matters such as, but not limited to, consistency with the District's watershed management plan goals, and the quality and completeness of the consultant's completed projects similar to the proposed project. This RFP does not obligate the respondent to enter into a contract with the District, nor does it obligate the District to enter into a relationship with any entity that responds, or limit the District's right to enter into a contract with any entity that does not respond, to this RFP. The District also reserves the right, in its sole discretion, to cancel this RFP at any time for any reason. Each respondent is solely responsible for all costs that it incurs to respond to this RFP and, if selected, to engage in the process including, but not limited to, costs associated with preparing a response or participating in any interviews, presentations or negotiations related to this RFP.

Right to modify, suspend, and waive:

The District reserves the right to:

- Modify and/or suspend any or all elements of this RFP;
- Request additional information or clarification from any or all respondents;
- Allow one or more respondents to correct errors or omissions or otherwise alter or supplement a proposal;
- Waive any unintentional defects as to form or content of the RFP or any response submitted.

Any substantial change in a requirement of the RFP will be disseminated in writing to all parties that have given written notice to the District of an interest in preparing a response.

Disclosure and Disclaimer:

This RFP is for informational purposes only. Any action taken by the District in response to proposals made pursuant to this RFP, or in making any selection or failing or refusing to make any selection, is without liability or obligation on the part of the District or any of its officers, employees or advisors. This RFP is being provided by the District without any warranty or representation, expressed or implied, as to its content, accuracy or completeness. Any reliance on the information contained in this RFP, or on any communications with District officials, employees or advisors, is at the consultant's own risk. Prospective consultants must rely exclusively on their own investigations, interpretations and analysis in connection with this matter. This RFP is made subject to correction of errors, omissions, or withdrawal without notice.

The District will handle proposals and related submittals in accordance with the Minnesota Data Practices Act, Minnesota Statutes §13.591, subdivision 3(b).

Appendix

A. Long Lake Creek Partnership Roadmap

B. Long Lake Creek Subwatershed Assessment: Technical Report

C. Stantec 01-24-23 Memo: Long Lake Subwatershed Assessment

D. MCWD Professional Service Agreement Template

Appendix A

Long Lake Creek Partnership Roadmap

MINNEHAHA CREEK
WATERSHED DISTRICT

JANUARY 23, 2023 DRAFT

LONG LAKE CREEK ROADMAP

CONTENTS

Exective Summary	3
Introduction	5
Roadmap Development	7
Findings & Recommendations	9
Wolsfeld Management Unit	11
Holy Name Management Unit	16
Downtown Management Unit	21
Long Lake Direct Management Unit	26
Long Lake Creek Management Unit	31
Implementation Plan Summary	36
Appendix	41

EXECUTIVE SUMMARY

Since 2018, the Cities of Long Lake, Medina, and Orono; Long Lake Waters Association (LLWA); and Minnehaha Creek Watershed District (MCWD or District) have been working together towards a common goal of improving water quality within the Long Lake Creek (LLC) Subwatershed. The partners aim to restore five impaired lakes in the system to meet state water quality standards, providing fishable and swimmable lakes that underpin the quality of life in their communities.

To support this effort, the MCWD has led the development of a science-driven implementation roadmap. This involved first conducting a subwatershed assessment to identify the water resource issues, the drivers causing the issues, and implementation strategies to address them. From there, the MCWD worked with the partners to identify project opportunities, evaluated their cost-effectiveness, and developed an implementation strategy and project recommendations to achieve the water quality goals.

Of a total 59 projects evaluated, 34 are recommended for advancement based on their high cost-effectiveness and feasibility to implement. The Roadmap categorizes these projects into short, mid, and long-term priorities based on the following implementation strategy:

1. **Regional Treatment:** Prioritize implementation of regional treatment projects in the near-term for the largest water quality improvement
2. **Landscape Projects:** Implement additional projects on the landscape as opportunities and capacity allow to further reduce external nutrient loading
3. **Internal Load Management:** Address internal nutrient loading from the lake sediments once sufficient progress is made to reduce external nutrient sources

Enhancement and addition of regional treatment is recommended as the first priority because these projects can treat a large drainage area while more dispersed, localized treatment is implemented over time. Two regional treatment projects have been identified as top priorities for near-term implementation:

1. **County Rd 6 Pond:** Retrofit of an existing MCWD-owned pond with a filter bench to enhance treatment of the two large northern tributaries to Long Lake.
2. **Holbrook Park:** Regional stormwater management in a Long Lake-owned park to treat a large portion of the downtown area, which produces the highest runoff volume and nutrient loading per unit area.

If completed in total, these 34 projects are estimated to achieve the reductions required for Wolsfeld Lake, Long Lake, and Tanager Lake to meet water quality standards. Achieving water quality standards for Holy Name Lake and School Lake may require biological management within those systems, the load reductions for which are difficult to estimate and will require ongoing monitoring. The total cost for implementing this suite of projects is estimated at $10.5 million.

Each of the partners has an important role to play in executing this strategy. The cities, to achieve the load reductions assigned by the state, have the responsibility to implement projects and best practices on the landscape. As such, the pace and scale of implementation will be largely driven by each city. The MCWD will provide technical and financial support to cities for implementation of projects on the landscape through its new Land & Water Partnership program. The MCWD will also lead the implementation of projects to address internal loading and retrofits to existing MCWD-owned ponds. The LLWA will support the implementation of capital projects by continuing to build awareness and support in the community. The LLWA can also build community capacity for local action such as the implementation of residential best practices.

Based on discussions with the cities, it is assumed that implementation will be largely dependent on funding support from grants or other sources. Projects that are identified in this Roadmap will be strong candidates for a variety of state and regional grant programs as well as MCWD's new Land & Water Partnership program. The District will continue to coordinate with the partners and provide recommendations for the funding strategy with the goal of leveraging the maximum amount of external funding.

This Roadmap provides a data-driven strategy and suite of projects that could be implemented to restore the five impaired lakes in this system. Undoubtedly, there will be projects in the Roadmap that will not be implemented, and there will be new opportunities that will arise. Therefore, it will be important for the partners to continue to coordinate and remain adaptive as they work together toward achieving their shared water quality goals. The MCWD plans to continue convening the partners, at least annually, to maintain a shared strategy and set of priorities for the partnership to advance.

Restoration of these impaired lakes will require long-term commitment and investment by the partners. By working together to establish a shared implementation strategy and prioritize the highest impact and most cost-effective projects, the partners will be able to leverage each other's resources, build community support, and have greater success in securing grant funding to support the work.

INTRODUCTION

PURPOSE

The Cities of Long Lake, Medina, and Orono; Long Lake Waters Association (LLWA); and Minnehaha Creek Watershed District (MCWD or District) have agreed to work together towards a common goal of improving water quality within the Long Lake Creek (LLC) Subwatershed. The partners aim to restore five impaired lakes in the system to meet state water quality standards, providing fishable and swimmable lakes that underpin the quality of life in their surrounding communities.

To support this effort, the District has led the development of a science driven "implementation roadmap" that identifies the highest-impact and most feasible projects to achieve this vision. By working together to develop and follow a shared implementation plan, the partners will be able to leverage each other's resources and have greater success at securing grant funding to support the work.

BACKGROUND

Five lakes within the LLC Subwatershed are impaired for excess nutrients: Holy Name, School, Wolsfeld, Long, and Tanager. In 2014, the MN Pollution Control Agency (MPCA) completed the Upper Minnehaha Creek Watershed Total Maximum Daily Load (TMDL) Study which set pollutant reduction goals needed to meet water quality standards so that each lake is suitable for recreational use and can support aquatic life. The TMDL assigned load reduction requirements to the cities of Medina, Orono, and Long Lake that must be met as part of the cities' Municipal Separate Stormsewer System (MS4) permits.

In 2016, the three cities adopted resolutions to work together to pursue grant funding and implement projects to improve water quality and address TMDL requirements (Attachment A). The cities recognized that taking a coordinated and collaborative approach could increase their chances of success. In parallel LLWA, a non-profit entity composed of residents throughout the Long Lake Creek Subwatershed, formed to protect and enhance water quality within the subwatershed.

Between 2016 and 2018, the cities and LLWA began to engage the District in efforts to manage carp in Long Lake to improve water quality. As a regional unit of government spanning the three cities, the District assumed the role of convener to help coordinate and guide the efforts of the partnership. The group agreed that a holistic and data-driven approach was needed in order to identify and pursue the most cost-effective projects to improve water quality.

In 2018, with the support of the partners, the District obtained a $112,000 Accelerated Implementation Grant from the Board of Soil and Water Resources (BWSR). Through this grant, the District served as the technical and planning lead to conduct a subwatershed assessment, identify cost-effective projects and strategies to improve water quality, and develop a clear and actionable roadmap to guide implementation.

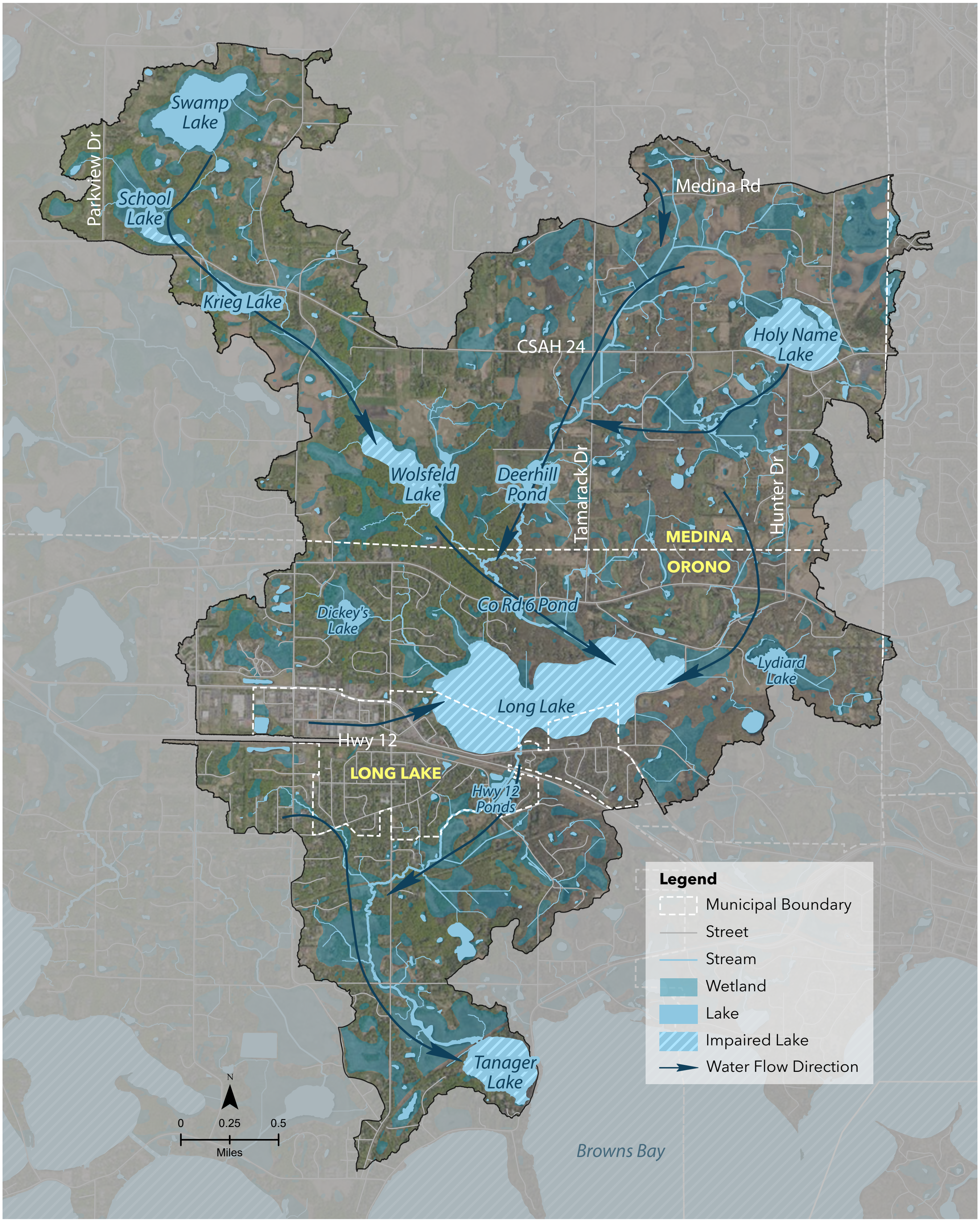
CITY OF LONG LAKE

LLWA LONG LAKE WATERS ASSOCIATION
Three Cities · Seven Lakes · One Watershed

CITY OF MEDINA

MINNEHAHA CREEK WATERSHED DISTRICT

ORONO THE LAKESHORE CITY



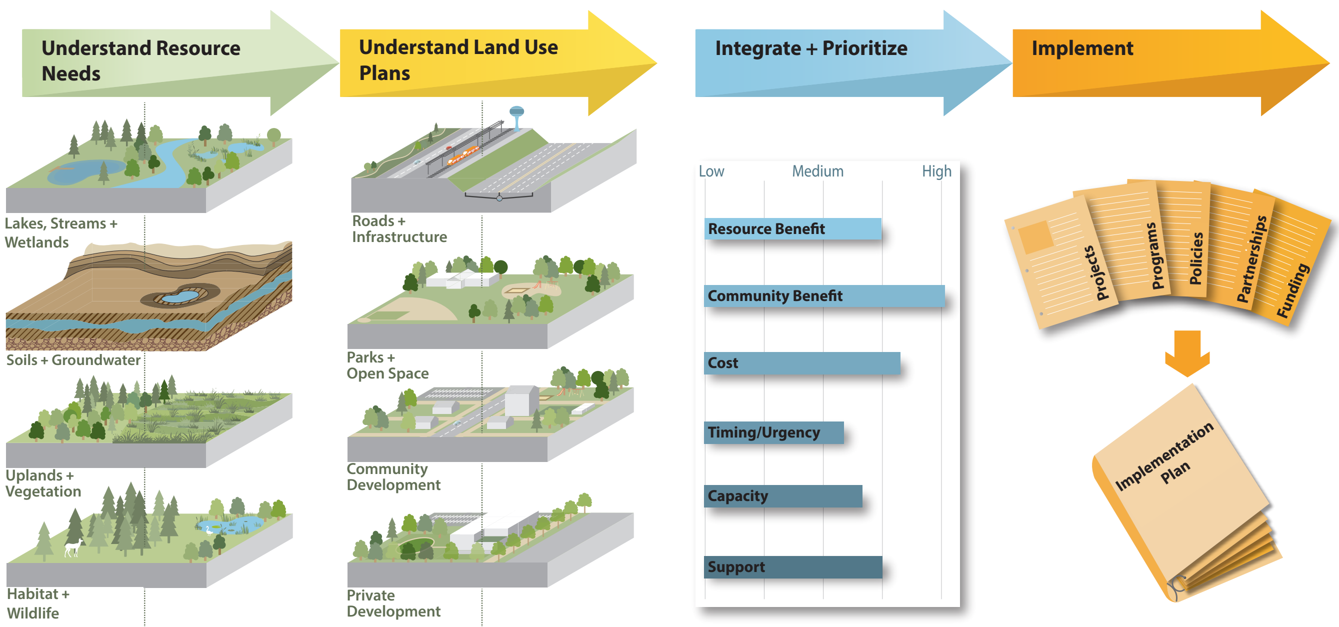
Subwatershed overview map

ROADMAP DEVELOPMENT

APPROACH

To develop the implementation roadmap, the District followed a 4-step approach:

1. Understand Resource Needs: Complete a natural resource assessment to understand issues and drivers of poor water quality
2. Understand Land Use Plans: Incorporate land use plans to identify opportunities for water quality improvement projects
3. Integrate + Prioritize: Integrate land use and natural resource understanding to evaluate and prioritize projects
4. Implementation Plan: Develop a plan that describes projects, roles, timelines, and funding sources



The following page summarizes work completed in each of these four steps. The subsequent sections describe the findings and recommendations from this process, first broken down by management unit, and then summarized in the Implementation Plan Summary section. Additional detail on the methodology, data, and findings from the subwatershed assessment can be found in the accompanying Technical Report.

UNDERSTANDING RESOURCE NEEDS

The first step in solving a water quality issue is understanding the underlying drivers of the problem. To diagnose the drivers of the impairments in the Long Lake Creek system, the MCWD conducted a subwatershed assessment that involved intensive water quality monitoring, analysis of in-lake conditions, ecological health assessments, and watershed modeling.

UNDERSTANDING LAND USE PLANS

Water quality improvements are often most cost-effective when integrated with land use changes such as redevelopment, road reconstruction, or park improvements. To identify opportunities to integrate projects that address major drivers of water quality into these land use changes, MCWD held work sessions with each partner to discuss local knowledge and land use plans. This included review and discussion of the following:

- City capital improvement plans
- Anticipated development/redevelopment
- Priorities and problem areas
- Existing stormwater treatment
- Landowner relationships

INTEGRATION + PRIORITIZATION

Based on the subwatershed assessment and city input, a suite of potential projects were identified, and a preliminary engineering analysis was conducted to develop load reduction and cost estimates to prioritize opportunities.

Projects were then categorized into short, mid, and long-range priorities based on the following:

- Prioritization of the most cost-effective projects
- Consideration of project feasibility, complexity, land ownership, and dependency on other projects/development
- Watershed management best practice of reducing upstream/external nutrient loads before managing internal loads for greater longevity and cost-effectiveness
- Assumption that implementation is primarily grant-dependent, and cities require time to allocate funds to match grants

IMPLEMENTATION PLANNING

To support the cities in project planning and implementation, the District developed recommendations for the implementation strategy, priority projects, roles, timelines, and funding sources.

OVERVIEW

MANAGEMENT APPROACH

MCWD's approach for managing water resources includes characterizing issues, identifying causes (drivers), and outlining management strategies to achieve measurable change towards identified goals.

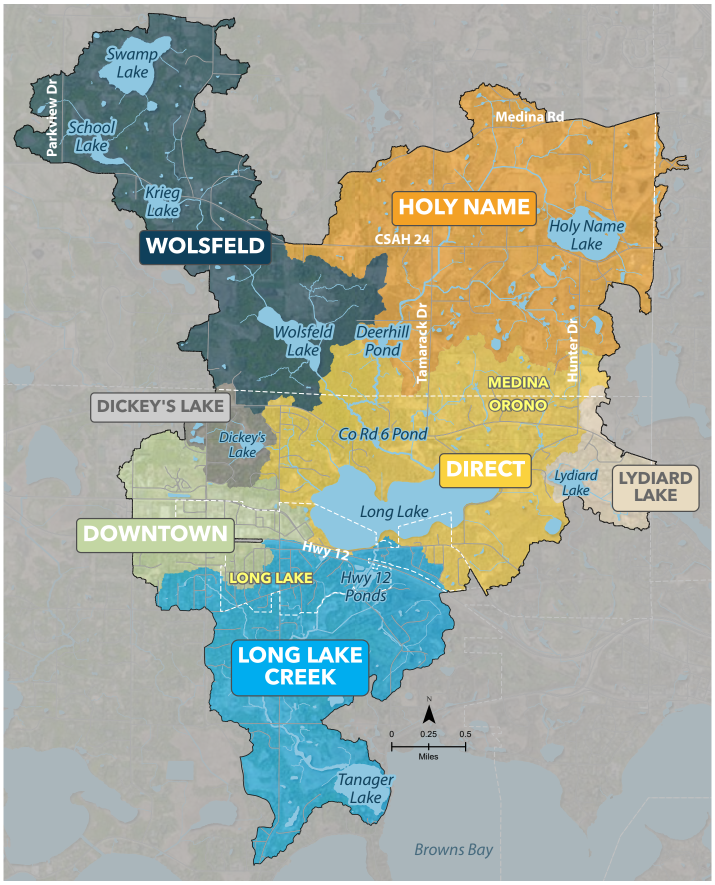
Typically, the underlying driver of in-lake issues such as degraded ecology, poor water quality, or excess flooding is caused by the introduction of human induced landscape change such as increased development or agricultural practices. Over time, many of the in-lake issues caused by land use change become drivers. For example, watershed phosphorus sources slowly increase phosphorus sediment release (internal phosphorus loading), which creates a positive feedback loop that further degrades water quality. Another example involves common carp. Common carp thrive in poor water quality systems, which means that degraded systems are more susceptible to carp establishment. However, their introduction can further degrade lake ecosystems.

Therefore, MCWD prioritizes projects that address the root cause of lake or stream degradation, which is typically excess runoff or nutrient loading from watershed sources. In-lake restoration such as alum treatments, biological manipulation, or stream restoration typically occur after the underlying issues are addressed to ensure any in-lake or stream restorations are successful.

MANAGEMENT UNITS

To facilitate the assessment, the 11.9 square mile subwatershed was broken into smaller management units (MUs) based on how water flows through the system and the unique landscape conditions and land uses present in each unit (see figure). The assessment focused primarily on the upper portion of the subwatershed, which drains to Long Lake. In 2011, MCWD completed a comprehensive study for the lower portion (Long Lake Creek MU) which took a similar approach to diagnose drivers of poor water quality and identify and prioritize projects. The findings from that study are incorporated into this Roadmap.

Dickey's Lake and Lydiard Lake were not included in the assessment since both have small drainage areas and are currently meeting water quality standards. Lydiard Lake is also a landlocked basin. Improvements to these systems would likely yield small benefits relative to the cost of the management activity.

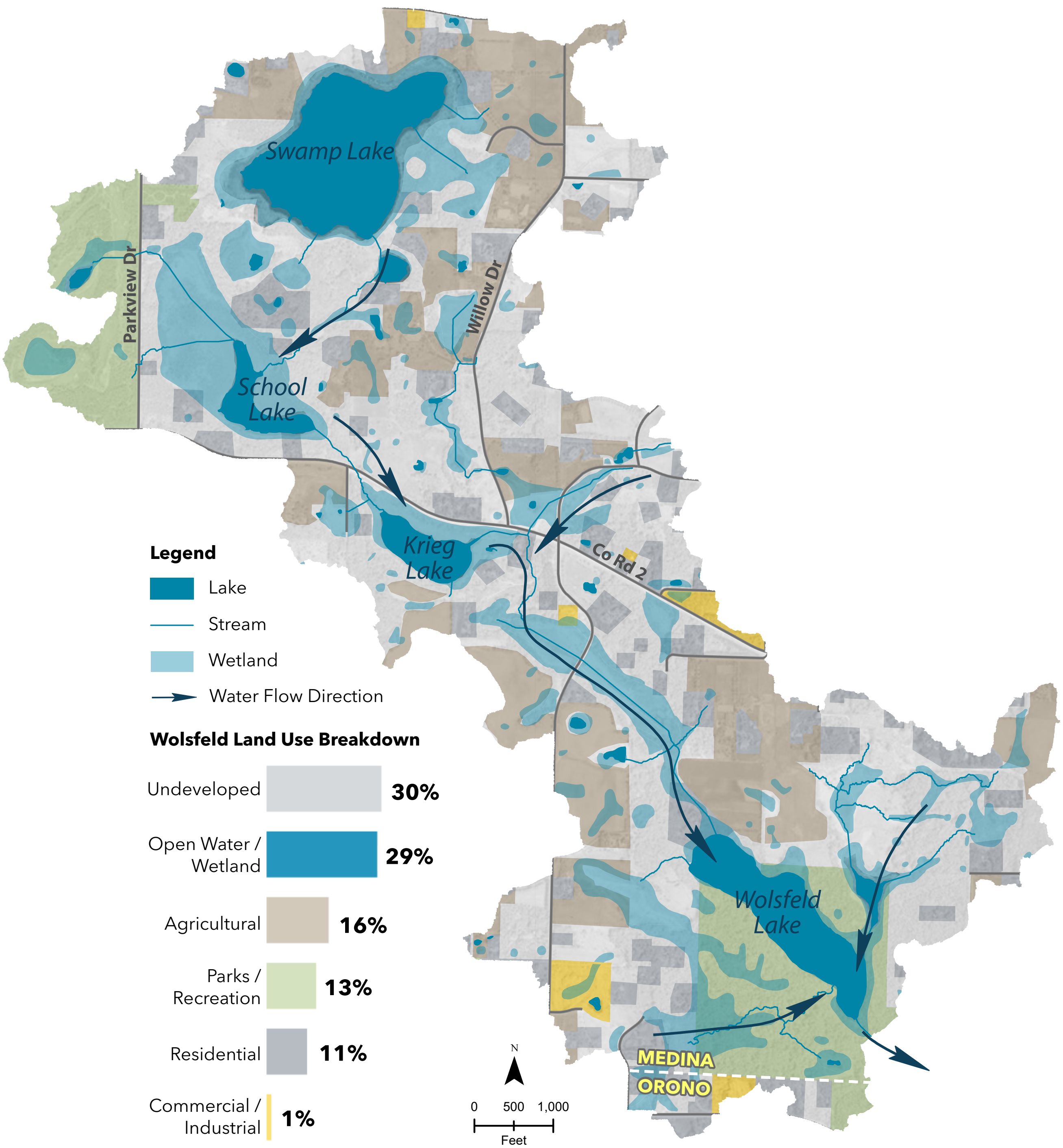


Management Units

The remainder of this section is organized by management unit, each split into the following three subsections:

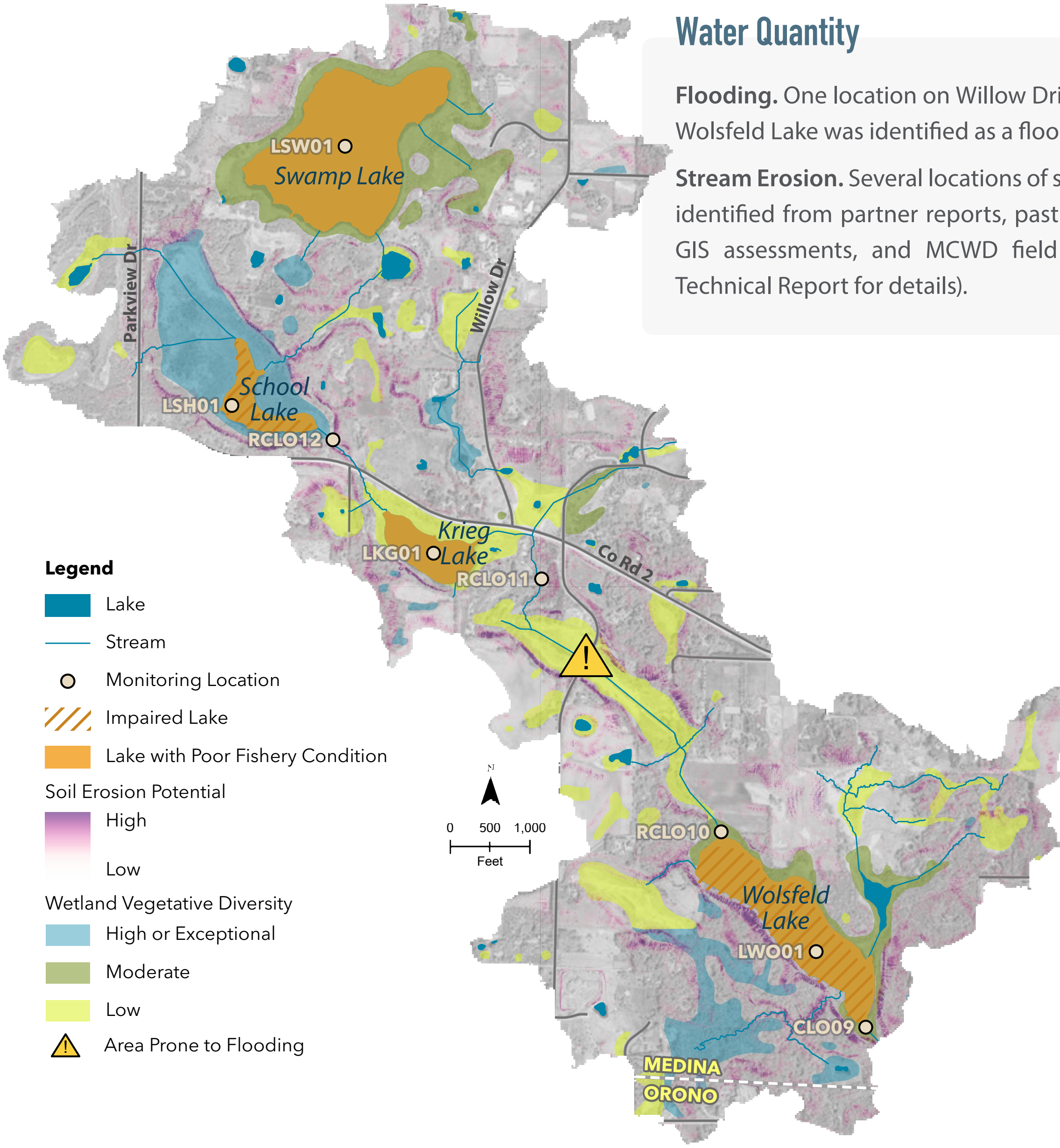
- **Issues**: Water resource issues are organized by water quality, water quantity, and ecological integrity. Condition information was compiled from community input, watershed modeling, historic water quality sampling, vegetation sampling, and fisheries sampling.
- **Drivers**: This section is organized by the two categories of underlying drivers that cause water resource issues: watershed-based drivers and in-lake drivers. Drivers were identified based on modeling, historic water quality sampling, field investigations, sediment sampling, wetland surveys, lake vegetation surveys, and fisheries sampling.
- **Strategies & Opportunities**: Management strategies and project opportunities are also organized into watershed and in-lake strategies. All projects are in the concept phase and require further feasibility assessment and engineering design. This section includes a table summarizing project opportunities and the associated costs and water quality benefits.

WOLSFELD MANAGEMENT UNIT



The Wolsfeld Management Unit (MU) encompasses 1,670 acres and represents the northwest drainage area of the subwatershed. It is located primarily in the City of Medina and includes a small portion of the City of Orono. It includes the impaired School and Wolsfeld Lakes as well as Krieg Lake and a large wetland referred to as Swamp Lake. Land use is primarily undeveloped, agricultural, and low-density residential. The MU includes two large natural and scientific preserve areas. The arrows on the map above represent the MU's drainage pathway.

ISSUES



Water Quantity

Flooding. One location on Willow Drive just upstream of Wolsfeld Lake was identified as a flood prone area.

Stream Erosion. Several locations of stream erosion were identified from partner reports, past diagnostic studies, GIS assessments, and MCWD field assessments. (see Technical Report for details).

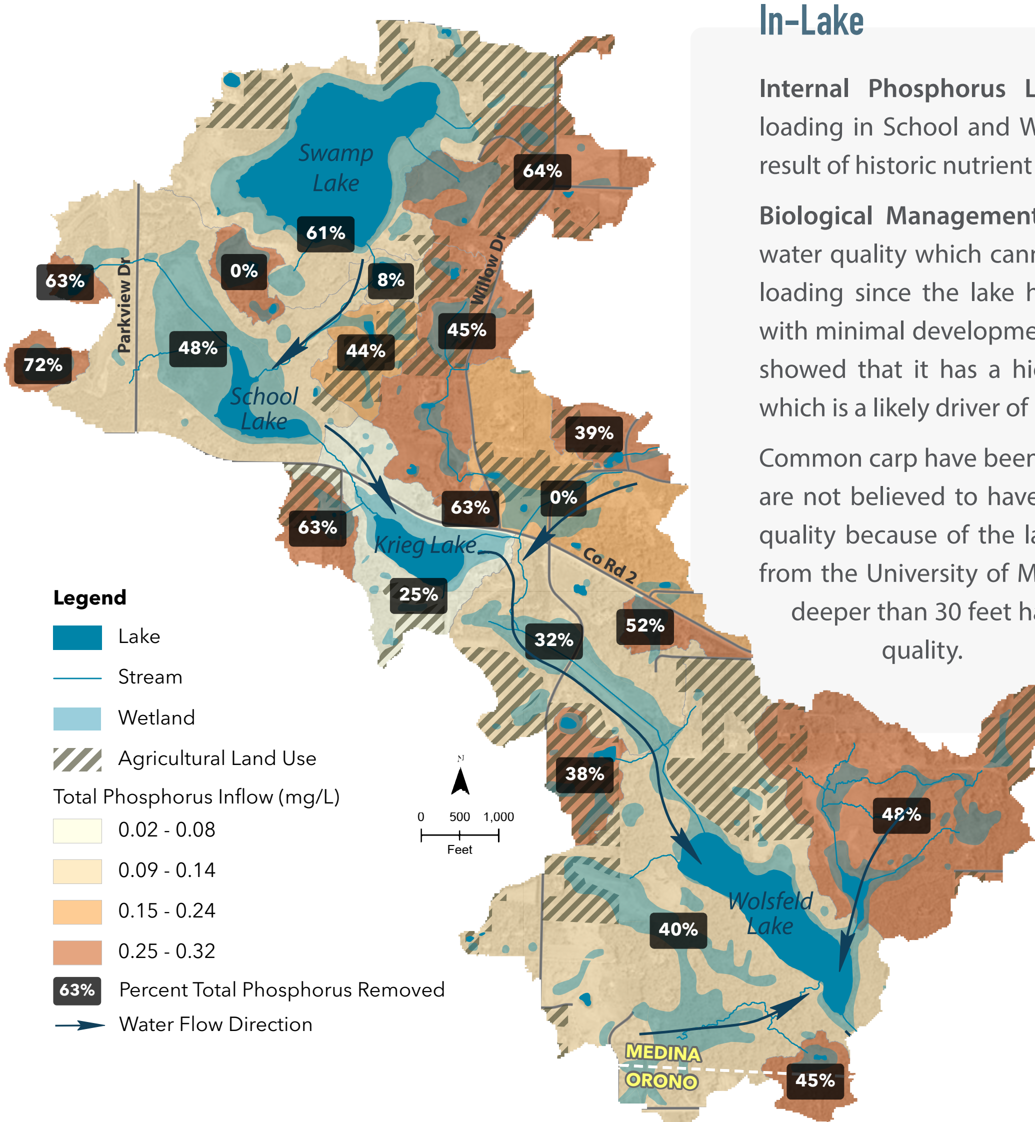
Ecological Integrity

Wetlands. 74 percent of wetlands have low or moderate vegetation diversity based on MCWD's functional assessment of wetlands.

Lakes. All lakes in this MU have poor or impaired fisheries and submerged aquatic vegetation (SAV) populations, based on low species diversity and/or dominance of vegetation/fish that thrive in poor water quality conditions.

Water Quality

Excess Nutrients. All four lakes within the MU (Swamp, School, Krieg, and Wolsfeld Lake) have excess phosphorus concentrations, which leads to poor clarity and summer algal blooms. Currently, School and Wolsfeld Lake are listed on the State of Minnesota impaired waters.



In-Lake

Internal Phosphorus Loading. Internal phosphorus loading in School and Wolsfeld Lakes is very high as a result of historic nutrient loading to both lakes.

Biological Management. Swamp Lake has very poor water quality which cannot be explained by watershed loading since the lake has a very small drainage area with minimal development. Fish surveys in Swamp Lake showed that it has a high biomass of black bullhead, which is a likely driver of poor water quality.

Common carp have been observed in Wolsfeld Lake but are not believed to have a significant impact on water quality because of the lake's depth. Based on research from the University of Minnesota, carp present in lakes deeper than 30 feet have little to no impact on water quality.

Watershed

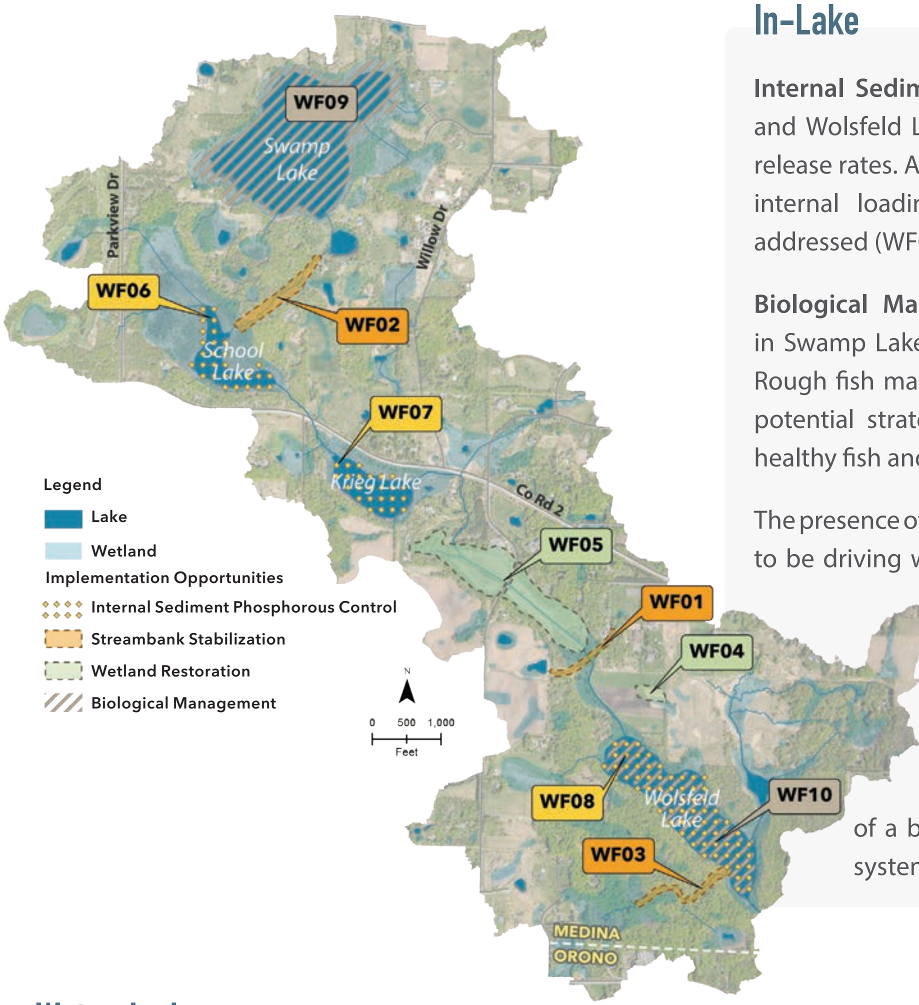
Erosion. Stream channel erosion is one of the greatest issues in this MU. Erosion is caused by natural geologic conditions, including steep slopes and erodible soil types.

Erosion is a contributing factor to flooding at Willow Drive based on field investigation. Tree branches and debris from stream erosion is building up downstream of the wetland at Willow Drive and restricting flow. This is the most likely cause of flooding since there were no other stormwater infrastructure issues observed in the area.

Stormwater Runoff. The Wolsfeld MU has the lowest runoff volume of all the MUs since the amount of impervious area is relatively low. However, phosphorus concentrations are high due to erosion and agricultural stormwater runoff. Agricultural land use is a common cause of elevated nutrient concentrations in stormwater runoff. In addition, bare soils on agricultural land during spring and fall storm events can lead to erosion and suspended sediment issues.

Altered Wetlands. The Wolsfeld MU has a few exceptional wetlands , however, the majority have moderate or low vegetation quality. Field and water quality investigations have shown that altered hydrology and excess nutrient loading is disrupting the wetlands' hydrology and nutrient cycling.

STRATEGIES & OPPORTUNITIES



In-Lake

Internal Sediment Phosphorus Control. School, Krieg, and Wolsfeld Lakes all have high sediment phosphorus release rates. Alum dosing could be completed to reduce internal loading once watershed erosion issues are addressed (WF06, 07, 08).

Biological Management. High nutrient concentration in Swamp Lake appears to be due to biological drivers. Rough fish management and whole lake drawdown are potential strategies that could be explored to restore healthy fish and aquatic vegetation communities (WF09).

The presence of carp in this subwatershed does not appear to be driving water quality issues in the impaired lakes, therefore, carp management has not been prioritized as a near-term strategy. However, since carp appear to be actively recruiting in the subwatershed and migrating to/from Tanager, future management may be considered as part of a broader strategy for the Lake Minnetonka system (WF10).

Watershed

Channel Stabilization. The assessment identified three opportunities to stabilize eroding channels or ravines to reduce nutrient loading (WF01, 02, 03). WF03 is located within the Wolsfeld Woods Scientific and Natural Area, where tree removal is prohibited, which limits the opportunity for a stabilization project. Stormwater Management strategies will focus on agricultural BMPs and areas upstream of eroding channels/ravines. Potential best practices for agricultural properties include alternative tile intakes, buffers, and manure management.

Stormwater Management. Stormwater management for this MU should focus primarily on agricultural best practices (e.g. alternative tile intakes, buffers, manure management) and reducing runoff to eroding channels/ravines.

Over time, some of the agricultural properties within this MU may be converted to rural residential use. This conversion is expected to reduce nutrient loading based on current regulatory standards and may present opportunities for partnership to achieve greater benefit.

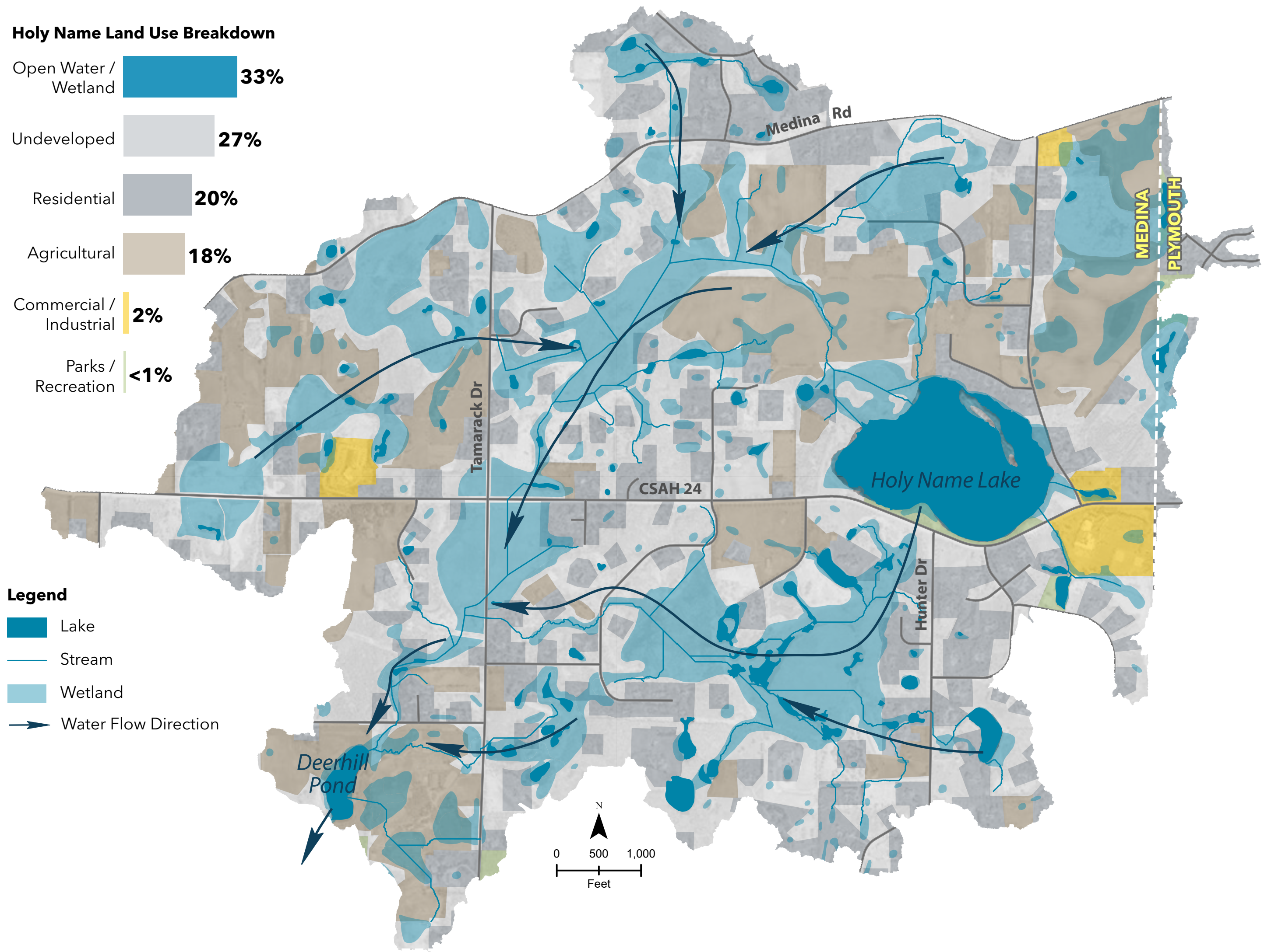
Wetland Restoration. Wetland restoration opportunities for this Roadmap are focused primarily on reducing nutrient loading to impaired lakes. Two opportunities have been identified (WF04, 05) which could involve hydrologic and vegetation restoration. WF04 should also be assessed for potential excavation of nutrient-rich sediment.

IMPLEMENTATION OPPORTUNITIES SUMMARY

WOLSFELD MANAGEMENT UNIT

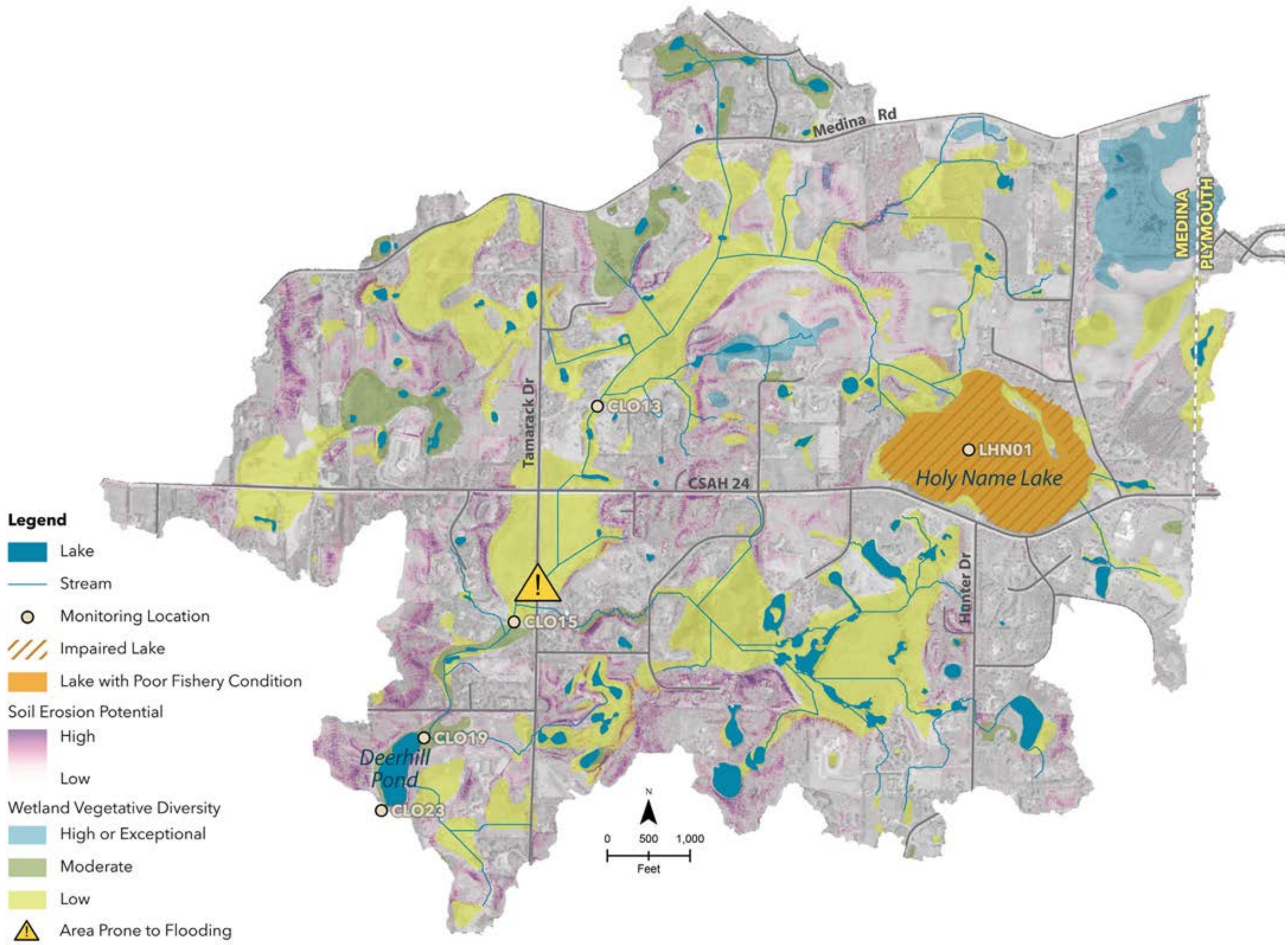
Project ID	Project Name	Location	Est. Load Reduction (lbs)	Est. Construction Cost	Lifecycle Cost/Benefit ($/lb/TP/30 year)	Timeline
Stream Channel & Ravine Stabilization						
WF01	Crosby Creek Ravines	Medina	31	$380,000	$719	Short-term
WF02	Swamp-School Corridor Improvements	Medina	7.2	$446,000	$2,065	Mid-term
WF03	Wolsfeld Woods Ravine	Medina	46	$290,196	$227	Mid-term
Wetland Restoration						
WF04	Crosby Wetland Restoration	Medina	12.7	$289,500	$1,154	Near-term
WF05	Willow Drive Wetland Restoration	Medina	18.5	$137,500	$336	Mid-term
Internal Sediment Phosphorus Control						
WF06	School Alum Treatment	In-Lake	92.7	$213,600	$77	Mid-term
WF07	Krieg Alum Treatment	In-Lake	TBD	$181,200	TBD	Mid-term
WF08	Wolsfeld Alum Treatment	In-Lake	60	$459,360	$255	Long-term
Biological Management						
WF09	Swamp Drawdown	In-Lake	TBD	$42,348	TBD	Mid-term
WF10	Wolsfeld Carp Management	In-Lake	TBD	$200,000	TBD	Long-term

HOLY NAME MANAGEMENT UNIT



The Holy Name Management Unit (MU) encompasses 2,008 acres and represents the northeast drainage area of the subwatershed. It is located primarily in the City of Medina and includes a very small portion of the City of Plymouth. This subwatershed contains one lake towards the east of the MU, Holy Name Lake. The MU is unique for its abundance of large and small wetlands. Land use consists primarily of undeveloped areas, single-family residential, and agricultural areas.

ISSUES



Water Quantity

Flooding. Flooding has been identified on Tamarack Road.

Water Quality

Excess Nutrients. Holy Name Lake is on the state list of impaired waters due to excess nutrients, but has been recently meeting standards.

Stream phosphorus concentrations at the headwaters of the Holy Name MU are over four times greater (450 µg/L) than the state water quality standard (100 µg/L), while the concentration near the outlet of the MU is 150 ug/L.

Ecological Integrity

80 percent of wetlands within the Holy Name MU have low vegetation diversity based on MCWD's functional assessment of wetlands.

Lakes. Holy Name Lake has poor vegetation species diversity and a fish population that is dominated by fish species that thrive in poor water quality conditions such as black bullhead and goldfish.

DRIVERS

Watershed

Stormwater Runoff. Watershed modeling in this MU identified agricultural areas as the primary contributor of phosphorus to streams, lakes, and wetlands. Stormwater runoff volume is relatively low here due to little impervious cover and many wetlands that provide storage and treatment for stormwater runoff.

The MCWD constructed a regional stormwater treatment pond (Deerhill Pond) at the outlet of this MU in the 1990's which continues to provide treatment by reducing total phosphorus by 6 percent prior to reaching Long Lake. The large number of existing wetlands and MCWD's Deerhill Pond appear to be effective, as phosphorus concentrations are reduced from 450 µg/L at the outlet of Holy Name to 150 µg/L at the outlet of the MU.

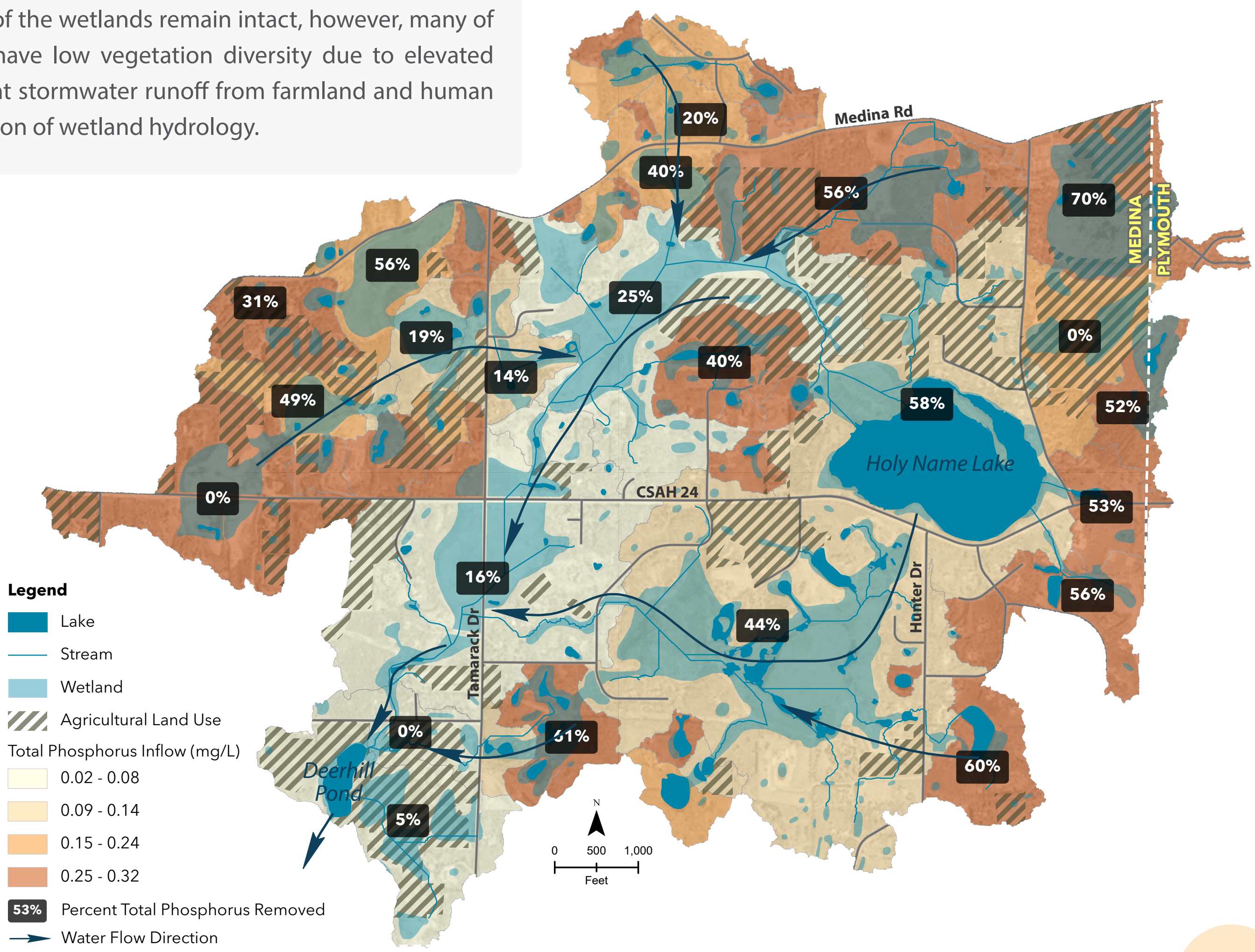
Altered Wetlands. The Holy Name MU is unique since many of the wetlands remain intact, however, many of them have low vegetation diversity due to elevated nutrient stormwater runoff from farmland and human alteration of wetland hydrology.

In-Lake

Internal Phosphorus Loading. Internal loading in Holy Name Lake is elevated, which is a result of historic watershed nutrient loading and represents approximately 40 percent of the total phosphorus load.

Biological. The role of fish in shallow lakes such as Holy Name is much greater than deeper lakes such as Wolsfeld or Long Lake since they can resuspend sediments throughout the entire lake. Therefore, the presence of black bullhead and goldfish could be a driver of poor water quality and low submerged aquatic vegetation species diversity.

Holy Name Lake also has a history of drastic shifts in water quality, which is common in shallow lakes that are being flipped between a clear water and turbid water state by a combination of nutrient and biological drivers.



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STRATEGIES & OPPORTUNITIES

Watershed

Stormwater Management. The District's regional treatment at Deerhill Pond could be evaluated for retrofit potential to increase treatment effectiveness to benefit downstream Long Lake (HN03).

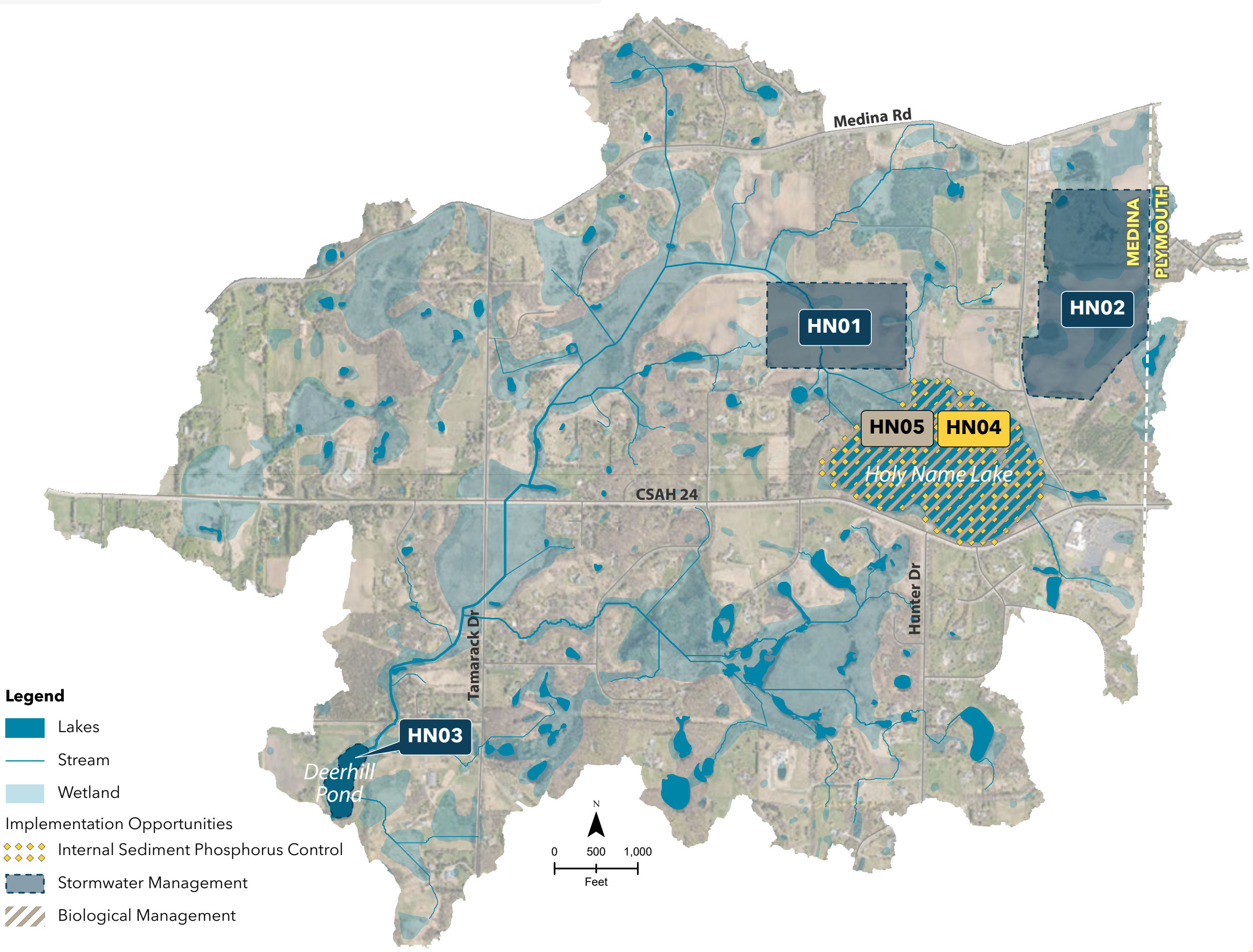
There are several properties in the MU that are in agricultural use. Potential best practices that could be explored with property owners include wetland restoration, alternative tile intakes, buffers, and manure management.

Some of the agricultural properties within this MU are starting to be converted to rural residential use. This conversion is expected to reduce nutrient loading based on current regulatory standards and may present opportunities for partnership to achieve greater benefit. Load reduction benefit for two sites that were undergoing development during this assessment have been quantified (MD06, MD08).

In-Lake

Internal Sediment Phosphorus Control. Alum treatment at Holy Name Lake is recommended to reduce internal loading (HN04).

Biological Management. Given the presence of black bullhead and goldfish in Holy Name Lake, rough fish management could be considered if other efforts to reduce external and internal nutrient loading are not sufficient to restore the lake to meeting water quality standards (HN05).



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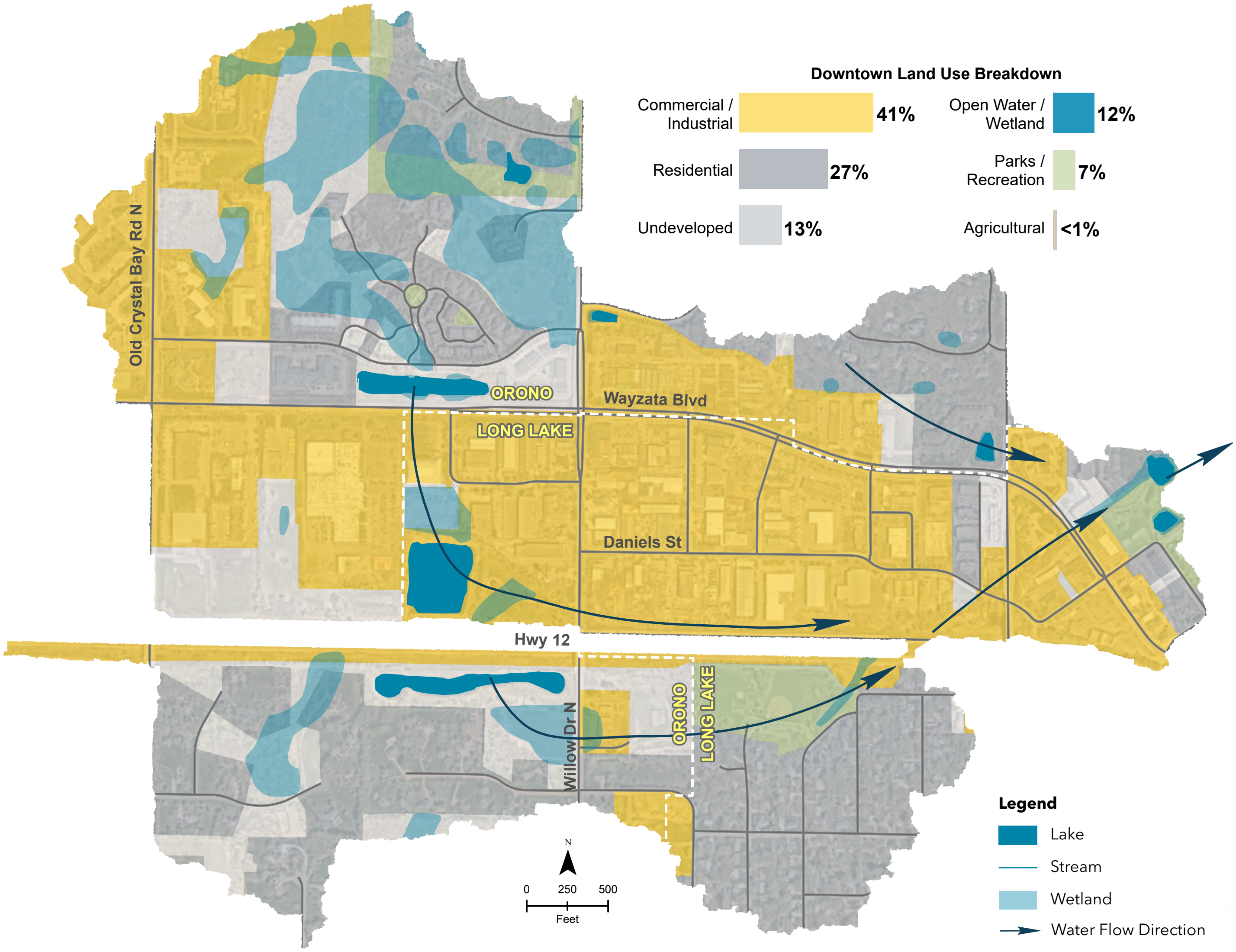
IMPLEMENTATION OPPORTUNITIES SUMMARY

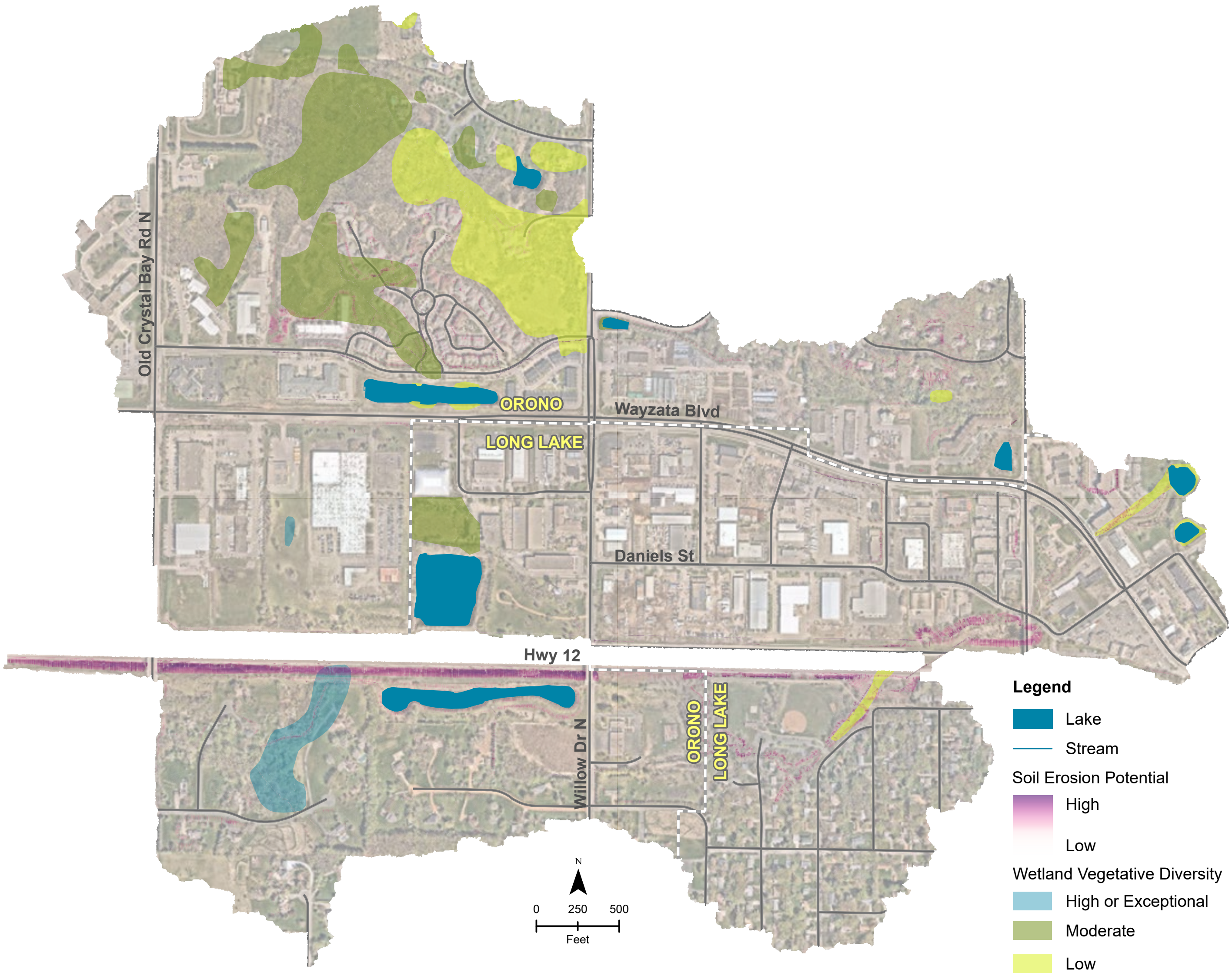
HOLY NAME MANAGEMENT UNIT

Project ID	Project Name	Location	Est. Load Reduction (lbs)	Est. Construction Cost	Lifecycle Cost/Benefit ($/lb/TP/30 year)	Timeline
Stormwater Management						
HN01	Holy Name Estates Development	Medina	11.4	N/A	N/A	Completed
HN02	Preserve of Medina	Medina	22.4	N/A	N/A	Near-term
HN03	Deerhill Pond Retrofit	Medina	11.8	$157,400	$725	Long-term
Internal Sediment Phosphorus Control						
HN04	Holy Name Alum Treatment	MCWD	69.6	$163,200	$78	Mid-term
Biotic Management						
HN05	Holy Name Rough Fish Management	In-Lake	TBD	TBD	TBD	Long-term

DOWNTOWN MANAGEMENT UNIT



The Downtown Management Unit (DMU) encompasses 518 acres and represents the western drainage area of Long Lake. It is located primarily in the City of Long Lake and the City of Orono. The headwaters of the DMU are located in the northwest corner of the MU, which consists of residential areas that are surrounded by large wetlands and undeveloped areas. Land use transitions into industrial and commercial as water moves southeast through the MU, which ultimately outlets at Nelson Lakeside Park. While the MU does not contain any lakes, MCWD's Functional Wetland Assessment (Wenck, 2003) identifies 19 wetlands.



Water Quantity

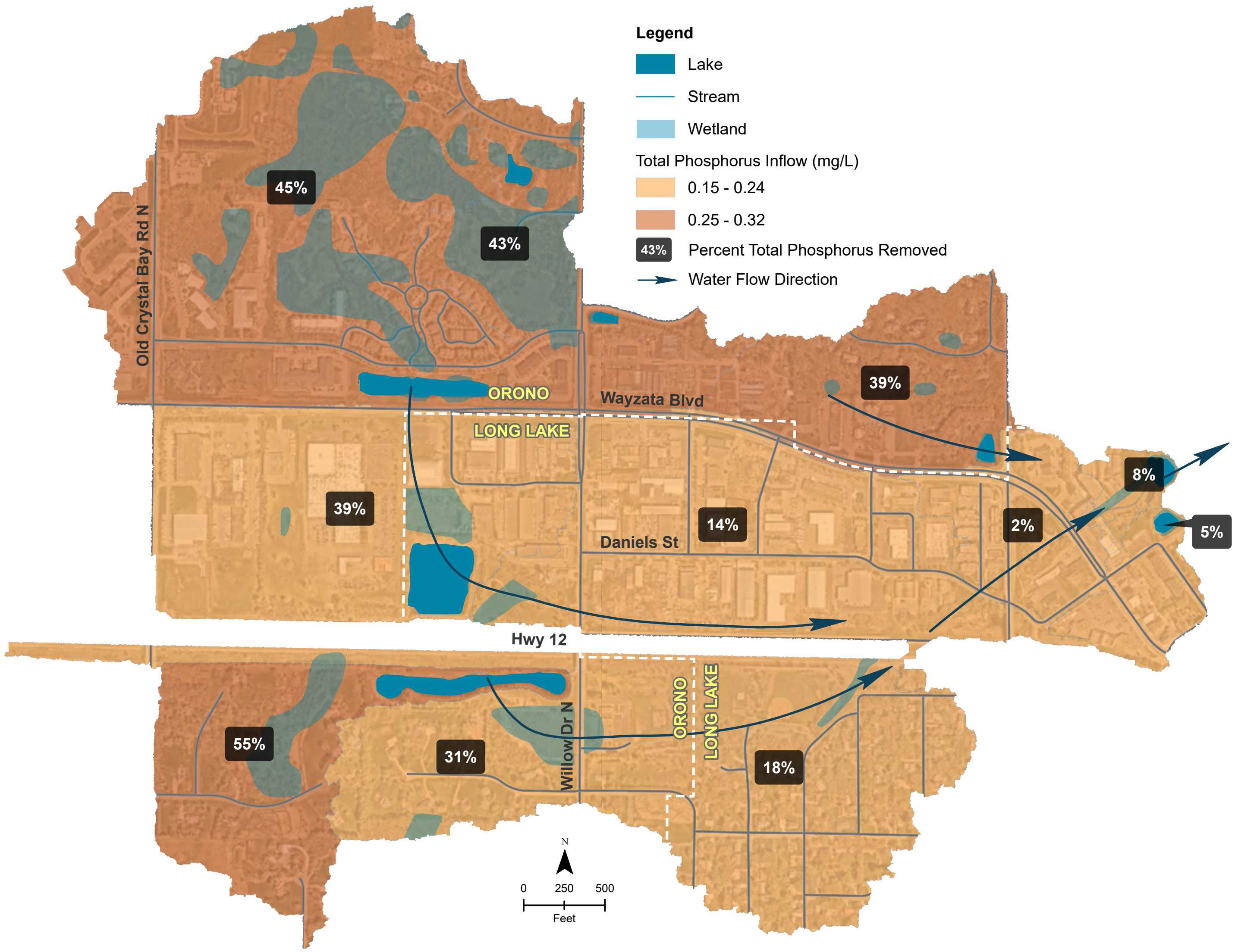
Runoff Volume. The Downtown MU has nearly four times the volume of runoff per unit area compared to the other MUs in this subwatershed assessment.

Water Quality

Excess Nutrients. Average phosphorus concentrations in stormwater runoff from the Downtown MU are 300 µg/L, which is three times greater than the State water quality standard for streams (100 µg/L).

Ecological Integrity

Wetlands. The northwest portion of the MU has several wetlands with low or moderate vegetation diversity. Other wetlands in the MU were likely replaced by development.

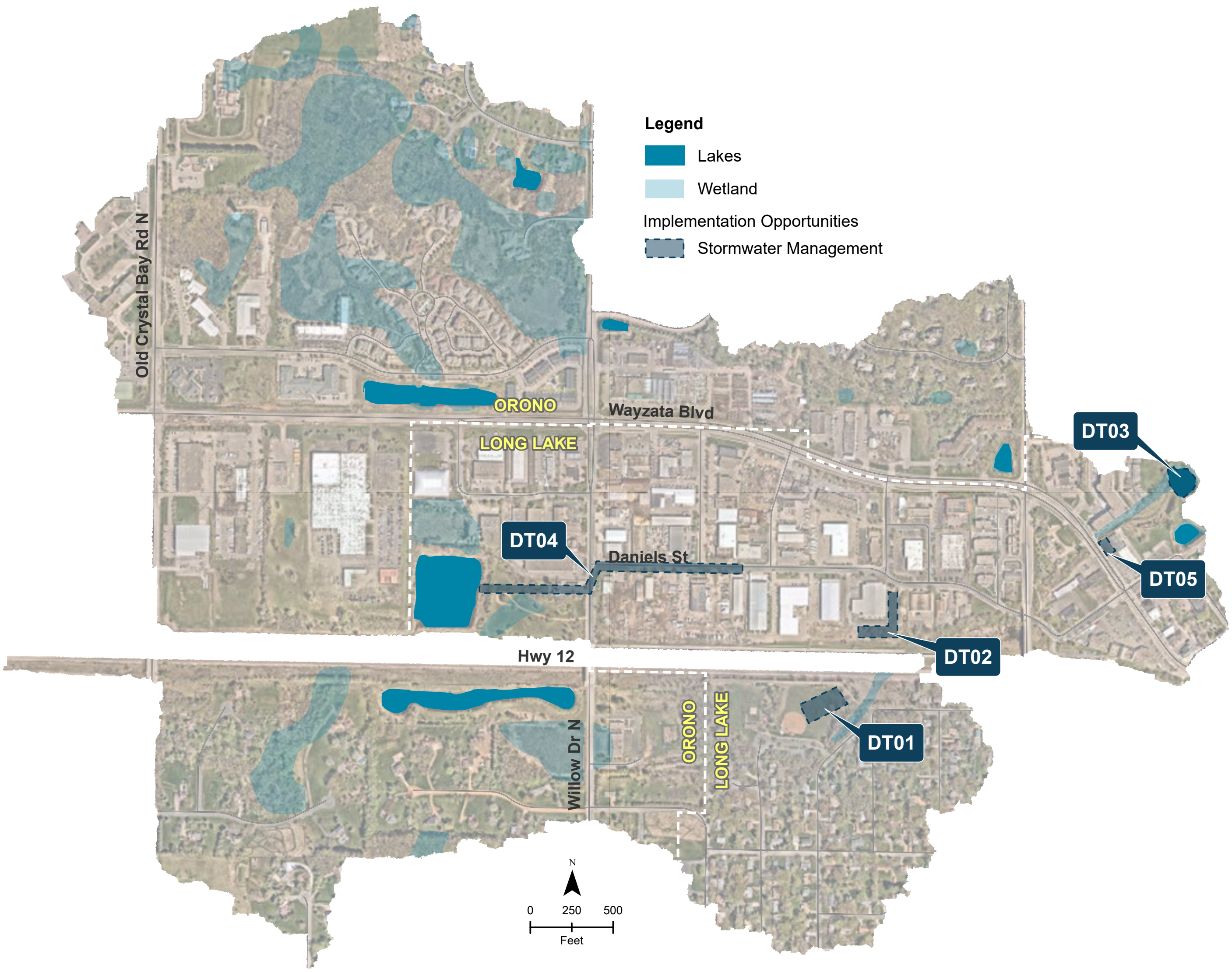


Watershed

Stormwater Runoff. The Downtown MU's elevated phosphorus concentrations and runoff volumes are caused by the high amount of impervious land use and the lack of stormwater treatment in the central portion of the MU.

The elevated runoff volume and phosphorus concentrations from this MU result in it having the largest phosphorus load to Long Lake even though it is much smaller than other MUs such as the Wolsfeld or Holy Name MUs.

The combination of highly impervious areas with very little stormwater treatment is the primary reason that the Downtown MU has the greatest pollutant load to Long Lake.



Watershed

Stormwater Management. While there is some existing treatment within the MU, particularly in Nelson Lakeside Park, there is not adequate treatment capacity for the volume of runoff. Additional stormwater management practices are recommended to reduce the volume and pollutant load leaving this MU.

Several stormwater management opportunities have been identified within the MU, including some that are on public property (DT01, 02, 03, 04) and others that could be explored in tandem with future redevelopment (DT05).

IMPLEMENTATION OPPORTUNITIES SUMMARY

DOWNTOWN MANAGEMENT UNIT

Project ID	Project Name	Location	Est. Load Reduction (lbs)	Est. Construction Cost	Lifecycle Cost/Benefit ($/lb/TP/30 year)	Timeline
Stormwater Management						
DT01	Holbrook Park	Long Lake	34.7	$1,292,867	$1,278	Short-term
DT02	Long Lake Public Works	Long Lake	27	$1,148,258	$1,463	Mid-term
DT03	Nelson Park North Pond Retrofit	Long Lake	10.8	$524,483	$1,729	Mid-term
DT04	Daniels Street Reconstruction	Long Lake	6.9	$621,502	$3,002	Long-term
DT05	fitHAUS Property	Long Lake	8.5	$369,065	$1,597	Development-dependent

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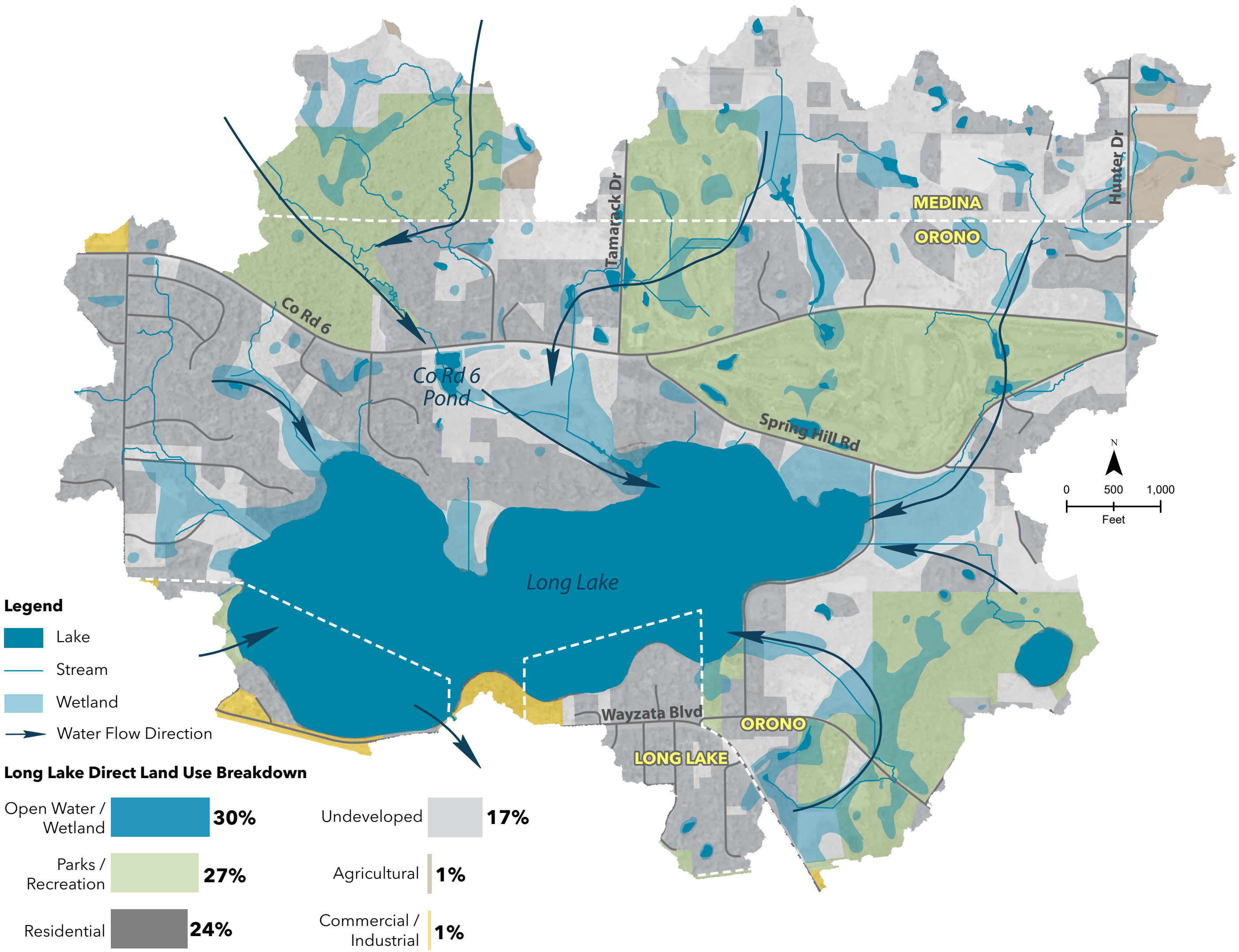
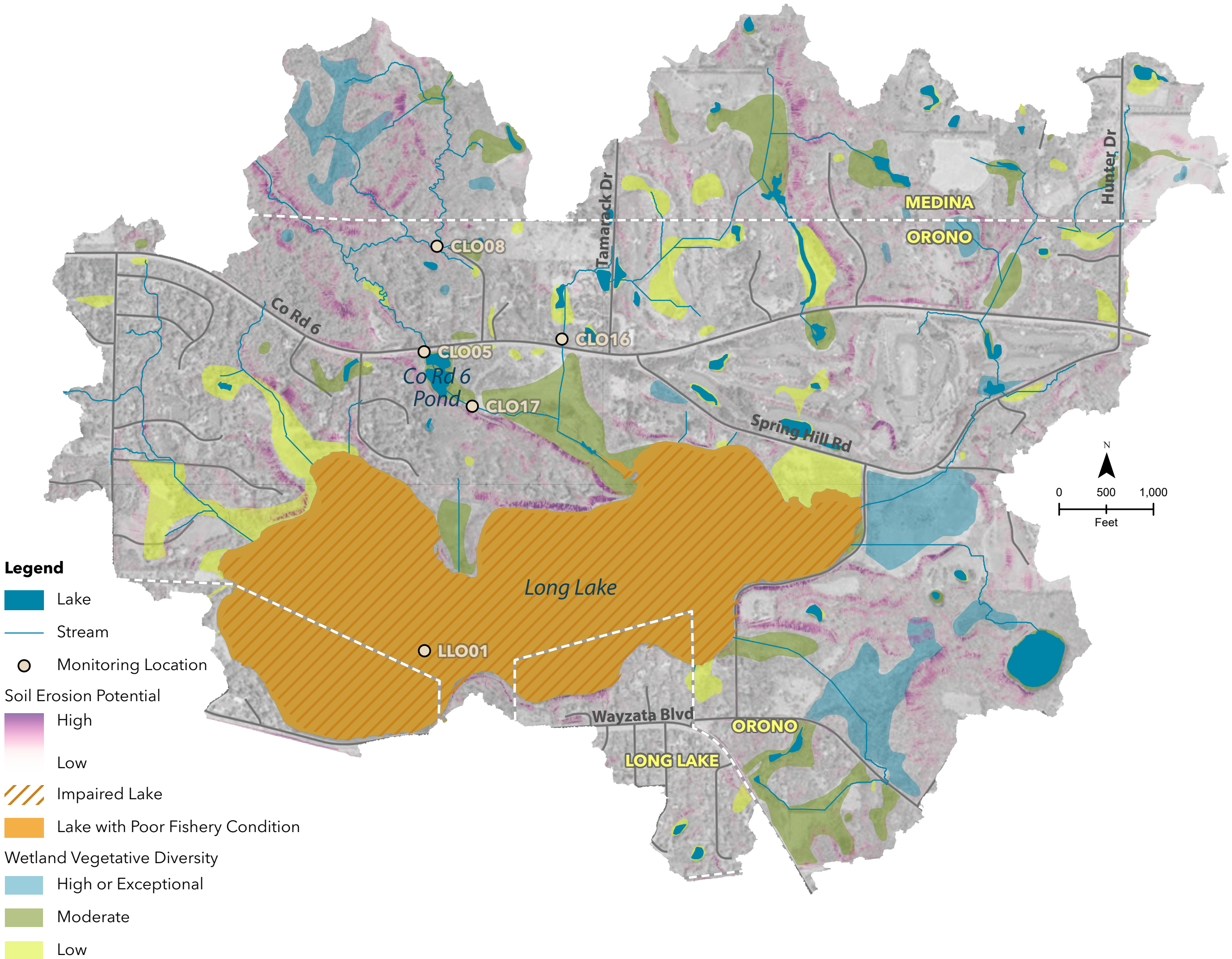
LONG LAKE DIRECT MANAGEMENT UNIT



The Long Lake Direct Management Unit (MU) encompasses 1,667 acres that surround Long Lake. Parts of the Cities of Medina, Orono, and Long Lake are within this MU. Residential uses and the Spring Hill Golf Club are the primary developed land uses. The remaining land uses in the Direct MU consists of undeveloped areas, preservation areas, and parks. Over a quarter of the land area is covered by water bodies – 284 acres of which is Long Lake, and a total of 243 acres of wetlands.



Water Quantity

Erosion. Several locations of stream erosion were identified through desktop assessment (see Technical Report for details).

Water Quality

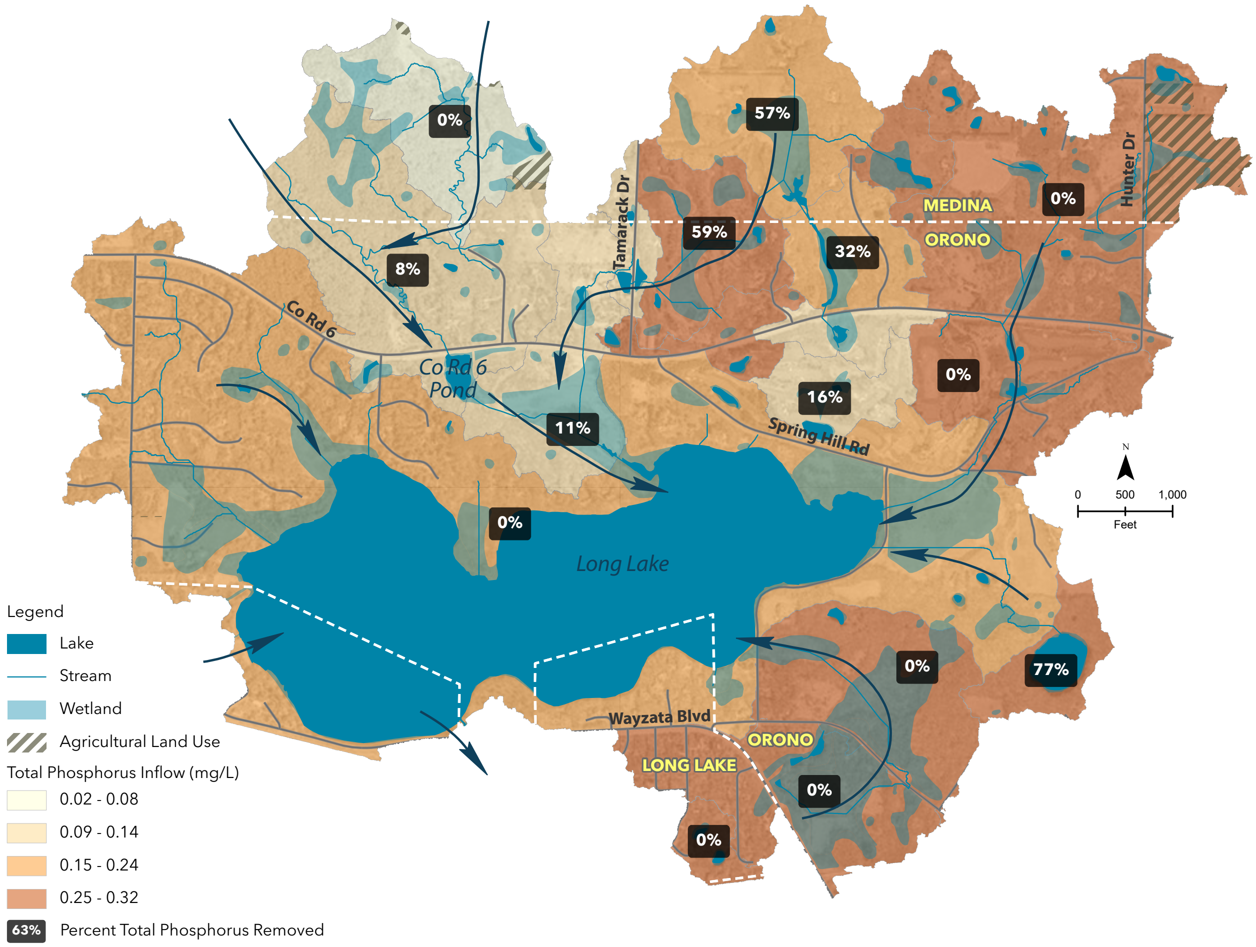
Excess Nutrients. Long Lake is impaired for excess phosphorus, which leads to poor water clarity and summer algal blooms.

Several small stream inlets that drain to Long Lake Creek Subwatershed have phosphorus concentrations that exceed the State of Minnesota phosphorus standards.

Ecological Integrity

Lakes. Long Lake has poor or impaired fisheries and aquatic submerged vegetation (SAV) populations based on low species diversity and/or dominance of vegetation/fish that thrive in poor water quality conditions.

Wetlands. 72 percent of wetlands have low or moderate vegetation diversity based on MCWD's functional assessment of wetlands.



Watershed

Stormwater Runoff. Watershed modeling and field monitoring in the Direct MU identified residential and golf course stormwater runoff as a contributor of phosphorus to Long Lake.

The MCWD constructed a regional stormwater treatment pond (Co Rd 6 Pond) at the confluence of the two upstream tributaries in the 1990's which continues to provide treatment by reducing total phosphorus by 38% prior to reaching Long Lake.

Altered Wetlands. Elevated nutrient stormwater runoff from and human alteration of wetland hydrology are the primary drivers of low species diversity of wetlands in this system.

Erosion. Geographic assessment of erosion identified natural geologic conditions including steep slopes and highly erodible soils as the primary drivers of erosion.

In-Lake

Internal Phosphorus Loading. Internal loading in Long Lake is elevated, which is a result of historic watershed nutrient loading and represents approximately 48% of the total phosphorus load.

Biological. Common carp have been observed in Long Lake, but are not believed to have a significant impact on water quality because of the lake's depth. Based on research from the University of Minnesota, carp present in lakes deeper than 30 feet have little to no impact on water quality.

STRATEGIES & OPPORTUNITIES

Watershed

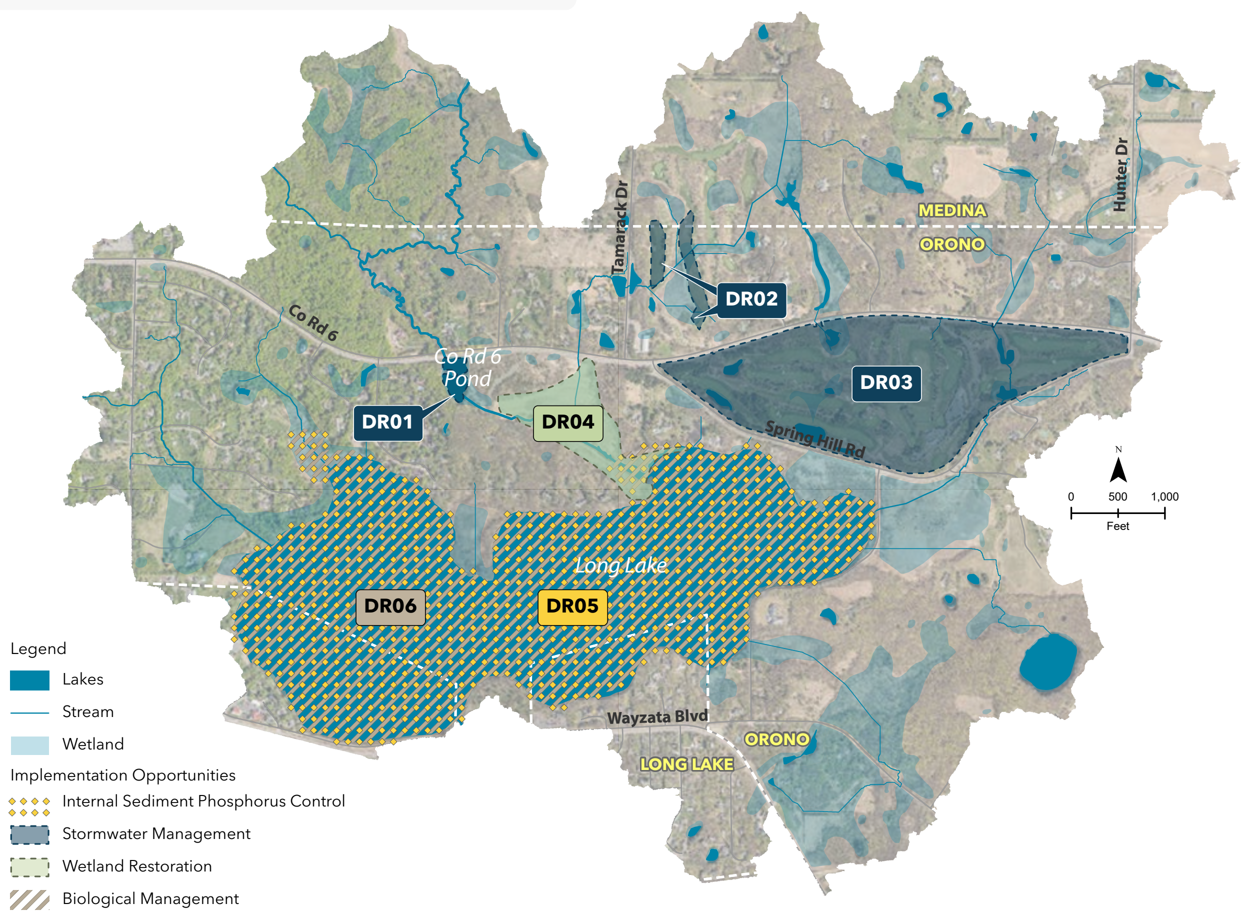
Stormwater Management. Retrofit of the existing, District-owned County Rd 6 regional treatment pond is recommended. Enhancing the pond with a filter bench could increase nutrient removal from the upper subwatershed before entering Long Lake (DR01).
Spring Hill Golf Club covers a large portion of the MU, and monitoring data from downstream of this area (Tamarack Rd) show elevated phosphorus concentrations. Evaluation of treatment opportunities, such as reuse or filtration of stormwater from existing ponds/wetlands, is recommended (DR02, 03).

Wetland Restoration. There is a large wetland at the confluence of the two tributary stream channels that collect drainage from the Wolsfeld and Holy Name MUs (DR04). Monitoring data shows that nutrient loading increases between the inlet and the outlet of this wetland, suggesting potential for water quality and ecological improvements.

In-Lake

Internal Sediment Phosphorus Control. Alum treatment in Long Lake is recommended (DR05). MCWD completed an alum treatment of Long Lake in the mid-1990s. Watershed loading should be reduced prior to investing in another alum treatment to increase longevity.

Biological Management. The presence of carp in this subwatershed does not appear to be driving water quality issues in the impaired lakes, therefore, carp management has not been prioritized as a near-term strategy. However, since carp appear to be actively recruiting in the subwatershed and migrating to/from Tanager, future management may be considered as part of a broader strategy for the Lake Minnetonka system (DR06). MCWD will continue to monitor the water quality and vegetation response to recent carp management efforts led by the LLWA.



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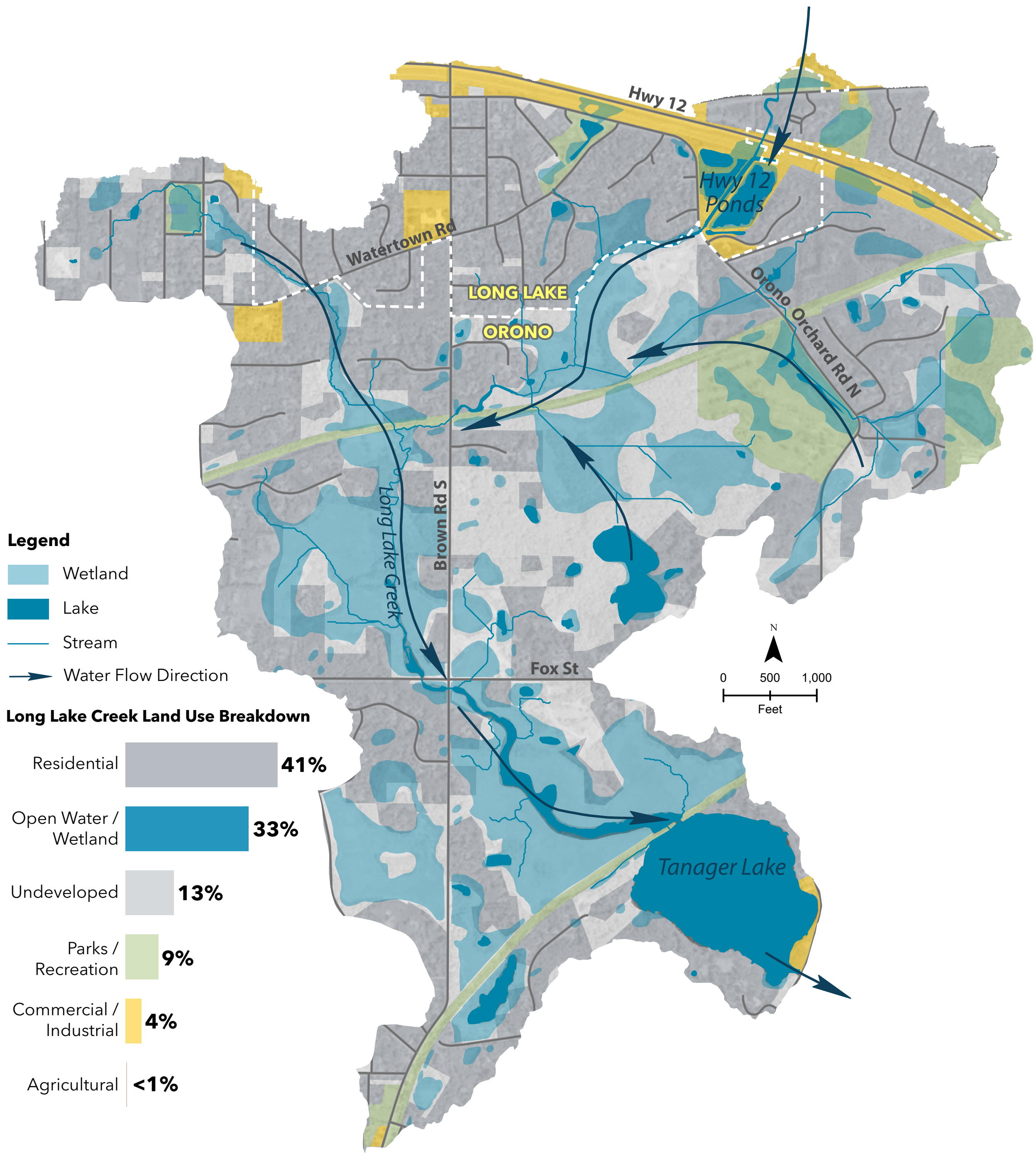
IMPLEMENTATION OPPORTUNITIES SUMMARY

LONG LAKE DIRECT MANAGEMENT UNIT

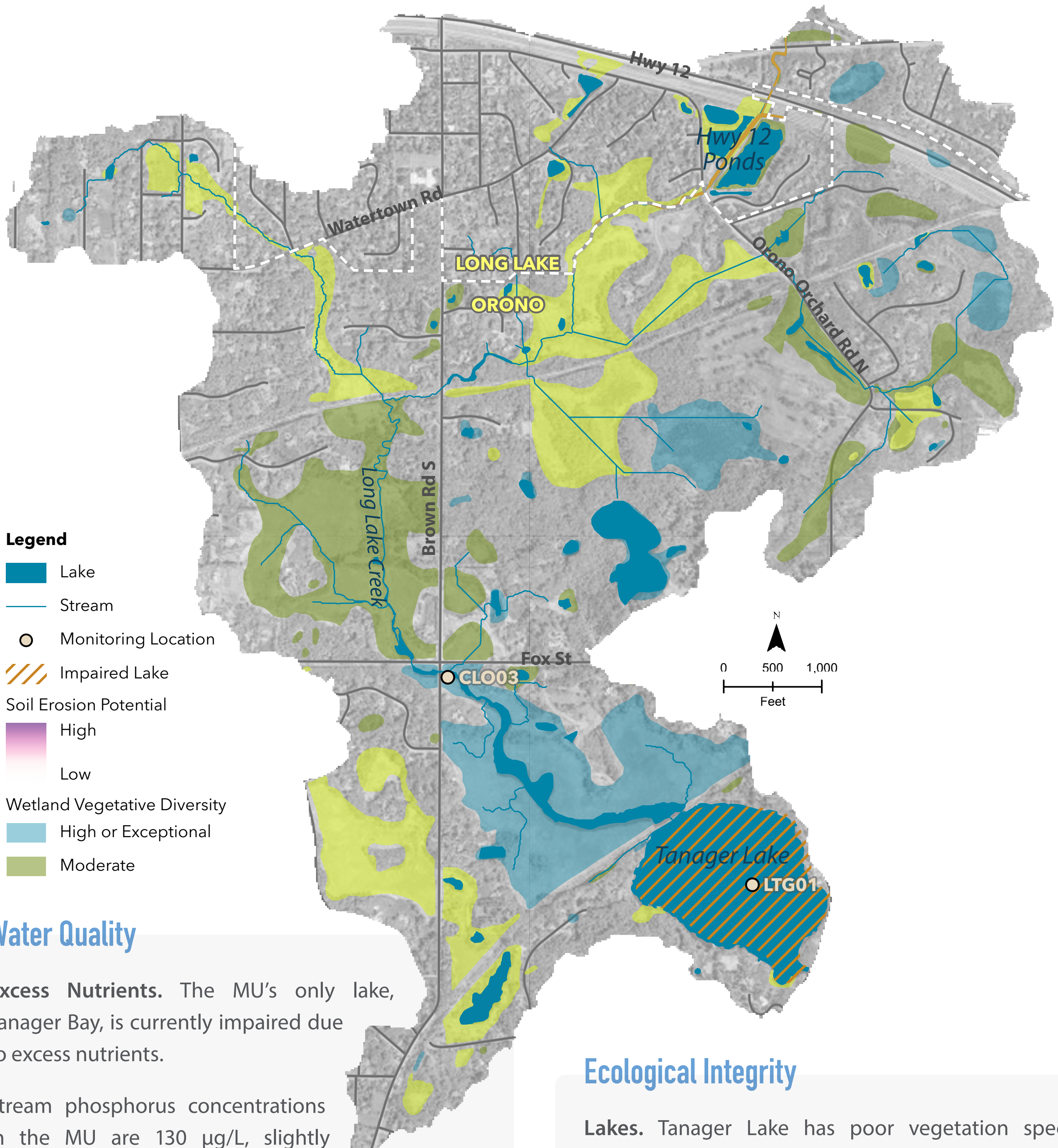
Project ID	Project Name	Location	Est. Load Reduction (lbs)	Est. Construction Cost	Lifecycle Cost/Benefit ($/lb/TP/30 year)	Timeline
Stormwater Management						
DR01	CR 6 Pond Retrofit	Orono	42	$570,151	$809	Short-term
DR02	Spring Hill Golf Club Reuse (north)	Orono	9.8	$157,125	$872	Short-term
DR03	Spring Hill Golf Club Reuse (south)	Orono	40.3	$697,768	$578	Short-term
Wetland Restoration						
DR04	County Rd 6 Wetland Restoration	Orono	TBD	TBD	TBD	Long-term
Internal Sediment Phosphorus Control						
DR05	Long Lake Alum Treatment	In-Lake	273	$538,560	$66	Long-term
Biotic Management						
DR06	Long Lake Carp Management	In-Lake	N/A	$449,138	N/A	Long-term

LONG LAKE CREEK MANAGEMENT UNIT



The Long Lake Creek Management Unit (MU) begins at the outlet of Long Lake and is the headwaters of Long Lake Creek, which drains 1,436 acres that ultimately flows into Tanager Bay. This MU includes portions of the City of Long Lake and City of Orono. The land use in the northern portion of the MU is dominated by residential areas and the Orono public golf course, which transitions to undeveloped areas and wetlands in the southern portion of the MU.

ISSUES



Water Quality

Excess Nutrients. The MU's only lake, Tanager Bay, is currently impaired due to excess nutrients.

Stream phosphorus concentrations in the MU are 130 µg/L, slightly greater than the state water quality standard of 100 µg/L.

Water Quantity

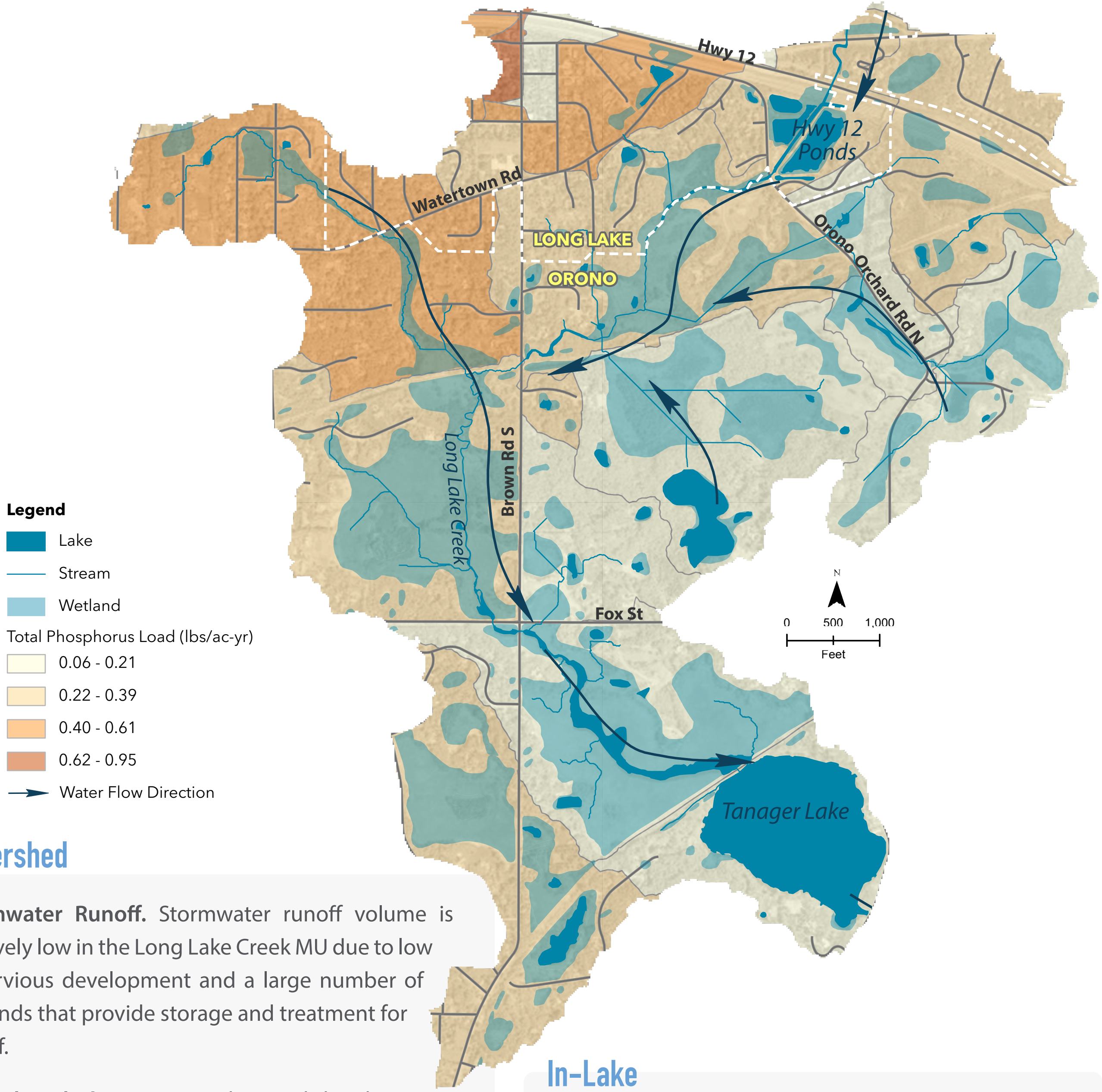
Erosion. Stream erosion and unstable banks have been identified at several locations along Long Lake Creek.

Ecological Integrity

Lakes. Tanager Lake has poor vegetation species diversity and a poor fish community because it is dominated by fish species, such as common carp, that thrive in poor water quality conditions.

Wetlands. 69 percent of wetlands within this MU have low or moderate vegetation diversity based on MCWD's functional assessment of wetlands.

DRIVERS



Watershed

Stormwater Runoff. Stormwater runoff volume is relatively low in the Long Lake Creek MU due to low impervious development and a large number of wetlands that provide storage and treatment for runoff.

Altered Hydrology. Long Lake Creek has been heavily altered since pre-settlement conditions from physical modifications to the channel locations, ditching, and increased runoff from impervious surfaces. Changes in hydrology and channel morphology have led to areas of streambank erosion.

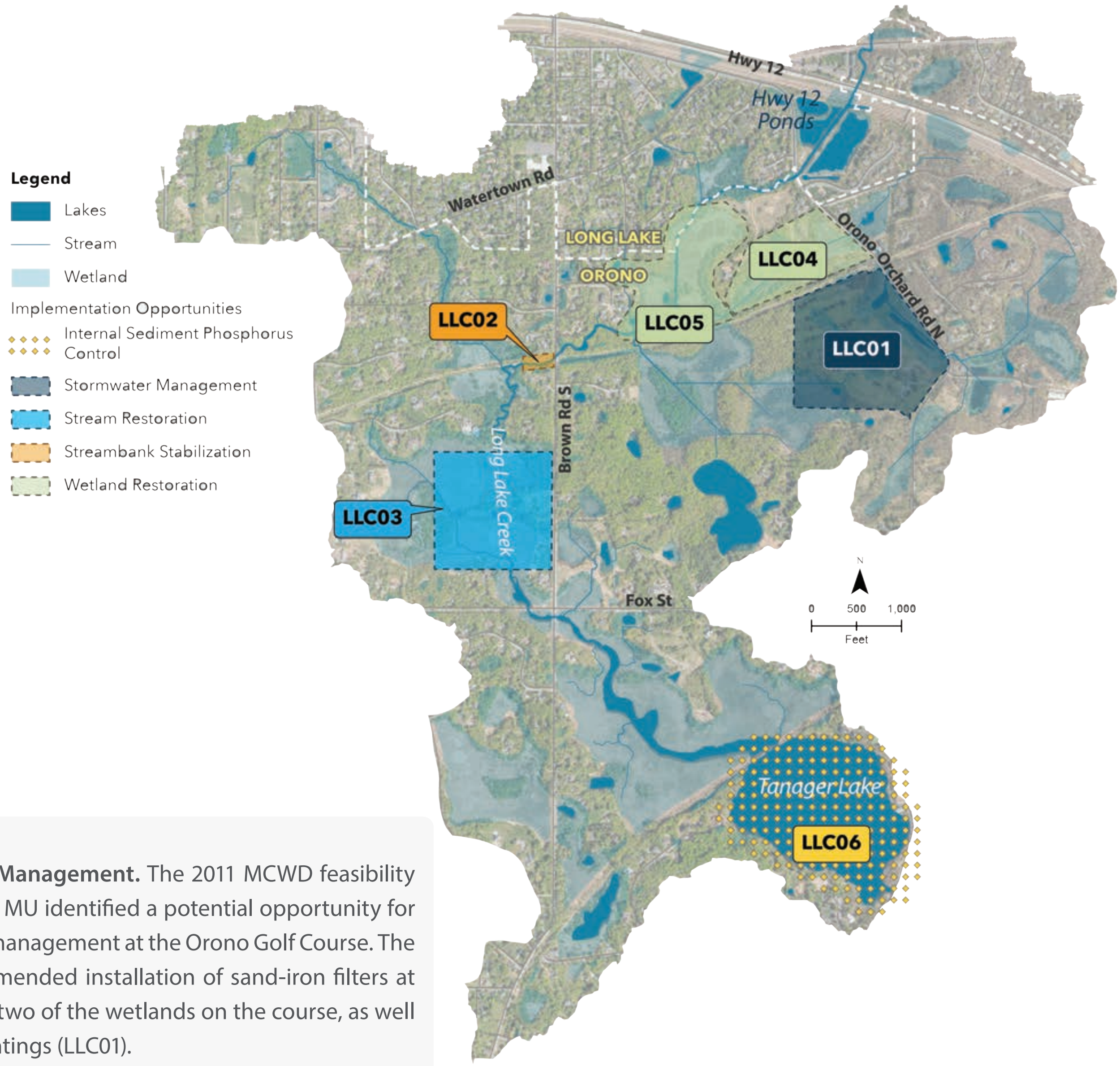
Altered Wetlands. This MU has a high percentage of wetland area, however, many of them have low vegetation diversity due to elevated nutrients in stormwater runoff from residential land use and human alteration of wetland hydrology.

In-Lake

Internal Phosphorus Loading. Internal loading in Tanager Lake is elevated as a result of historic watershed nutrient loading and represents approximately 20 percent of the total phosphorus load.

Biological. Common carp have been observed in Tanager Bay, but likely have a small impact on water quality since it is a deep lake. Recent University of Minnesota research shows that carp have insignificant impacts on water quality in lakes with depths greater than 15 feet.

STRATEGIES & OPPORTUNITIES



Watershed

Stormwater Management. The 2011 MCWD feasibility study for this MU identified a potential opportunity for stormwater management at the Orono Golf Course. The study recommended installation of sand-iron filters at the outlet of two of the wetlands on the course, as well as buffer plantings (LLC01).

Stream Restoration/Bank Stabilization. The 2011 study identified two priority opportunities for channel stabilization or restoration along Long Lake Creek (LLC02, 03). The proposed Reach 2 restoration involves re-meandering the stream channel back to its historic alignment.

Wetland Restoration. The 2011 study identified two priority opportunities for wetland restoration. Both of these wetlands have been ditched and partially drained, and the proposed projects involve restoring wetland hydrology and connection to the floodplain (LLC04, 05).

In-Lake

Internal Sediment Phosphorus Control. Alum treatment on Tanager Lake is recommended to address internal loading once sufficient progress is made on addressing loading from upstream lakes and other external nutrient sources (LLC06).

IMPLEMENTATION OPPORUNITIES SUMMARY

LONG LAKE CREEK MANAGEMENT UNIT

Project ID	Project Name	Location	Est. Load Reduction (lbs)	Est. Cost	Lifecycle Cost/Benefit ($/lb/TP/30 year)	Timeline
Stormwater Management						
LLC01	Orono Golf Course Wetland Improvements	Orono	11.2	$244,600	$949	Short-term
Streambank Stabilization/Restoration						
LLC02	Brown Road Outfall Stabilization	Orono	11.6	$58,800	$183	Mid-term
LLC03	Reach 2 Stream Restoration	Orono	30.1	$468,200	$573	Long-term
Wetland Restoration						
LLC04	Orchard Creek Wetland Restoration	Orono	4.9	$40,800	$359	Mid-term
LLC05	Long Lake Creek Wetland Restoration	Orono	36.8	$163,800	$182	Long-term
Internal Sediment Phosphorus Control						
LLC06	Tanager Lake Alum Treatment	In-Lake	164.7	$384,120	$78	Long-term

IMPLEMENTATION PLAN SUMMARY

IMPLEMENTATION STRATEGY

The purpose of the assessment was to provide a subwatershed-scale understanding of the issues and drivers throughout the system to identify the most cost-effective strategies and project opportunities for the partners to pursue. The project recommendations in this Roadmap are focused on projects that will make significant, measurable impact toward restoring the five impaired lakes in the subwatershed.

Based on the assessment findings, MCWD recommends a tiered implementation approach:

1. **Regional Treatment:** Prioritize implementation of regional treatment projects in the near-term
2. **Landscape Projects**: Implement additional projects on the landscape as opportunities and capacity allow to further reduce external loading
3. **Internal Load Management:** Address internal loading once sufficient progress is made to reduce external nutrient sources

REGIONAL TREATMENT

In the mid-1990s, the MCWD constructed three regional stormwater management ponds throughout the subwatershed: Deerhill Pond (treats drainage from the Holy Name MU), County Road 6 Pond (treats drainage from the Wolsfeld and Holy Name MUs), and the Nelson Lakeside Park Ponds (two ponds that treat drainage from the downtown area). The City of Long Lake installed additional treatment in the late 2000's via a low-flow bypass and filtration system within Nelson Lakeside Park.

While these practices are still functional and reducing nutrient loads to Long Lake, there is potential to retrofit the ponds for increased effectiveness. Given the high volume and nutrient load of runoff from the Downtown MU, it is also recommended that additional regional treatment be installed upstream of Nelson Lakeside Park to create a treatment train and increase overall effectiveness of the system.

Enhancement and addition of regional treatment is recommended as the first priority because these projects can treat a large drainage area while more dispersed, localized treatment is implemented over time. The opportunities identified are also under public ownership or easement, making it easier to move these projects forward quickly. Of the regional treatment options evaluated, the following two projects have been prioritized for near-term implementation because they provide the largest load reductions:

COUNTY ROAD 6 POND RETROFIT:

- **Description:** Retrofit of an MCWD-owned pond with a filter bench to increase effectiveness. Treats the largest drainage area of any project.
- **Metrics:** TP load reduction to Long Lake = 75 lbs/yr, construction cost = $525,000
- **Next steps:** MCWD is conducting a feasibility assessment for this project in winter 2022-23 and has budgeted for project design in 2023.

HOLBROOK PARK REGIONAL STORMWATER MANAGEMENT:

- **Description:** Regional stormwater management in a Long Lake-owned park. Treats a large portion of the Downtown MU, which produces the highest runoff volume and nutrient loading per unit area.
- **Metrics:** TP load reduction to Long Lake = 47 lbs/yr, construction cost = $1.3 million
- **Next steps:** The City of Long Lake and MCWD are working to determine roles and funding strategy with a goal of initiating feasibility work in 2023. The project is expected to receive $175,000 through BWSR's Watershed-Based Implementation Funding program.

LANDSCAPE PROJECTS

With plans for additional regional treatment underway, more localized projects can be implemented on the landscape over time. A total of 19 specific landscape project opportunities have been prioritized through the assessment and discussions with the partners, as outlined in the MU sections. These include stormwater management, streambank/ravine stabilization, and wetland restoration projects. A few of these are tied to development or infrastructure projects, so the timing will be opportunity-driven. The rest can be advanced based on city capacity to lead the projects and the partnership's ability to secure grant funding, as needed.

In addition to these known opportunities, the partnership should continue to seek new opportunities that align with the identified issues, drivers, and management strategies. This could include coordination between the partners on annual review of capital improvement plans and tracking of private development opportunities (e.g. sketch plan review). It could also include outreach and marketing to identify landowners who may be considering developing or selling their property or may have a resource issue they would like help addressing (e.g. erosion, flooding).

INTERNAL LOAD MANAGEMENT

All five of the impaired lakes, as well as Krieg Lake in the Wolsfeld MU, have elevated internal phosphorus loading and will likely require an alum treatment in order to meet water quality standards. Internal phosphorus loading from the sediments is due to the accumulation of nutrients from watershed runoff over time. Therefore, it is important to address the major sources of nutrient loading from the watershed before implementing in-lake treatment to ensure it is successful and has a lasting effect.

In addition, poor water quality often leads to poor aquatic vegetation, which leads to poor fish communities. To restore healthy biotic communities, the stressors must first be addressed. For this reason, the Roadmap generally recommends sequencing the work to first address watershed loading, then internal loading, then the biotic community.

As described in the MU sections, there are two lakes that are believed to be impacted by biological drivers – Holy Name Lake and Swamp Lake. Both are shallow systems with large populations of bottom-feeding fish (black bullheads and goldfish) that resuspend sediment. Water quality data for Holy Name indicate that the lake has been flipping between a turbid and clear water state over the years. These significant changes in water quality are an indicator of biological drivers. The lake is currently close to meeting water quality standards, so the recommendation is to implement projects to reduce external loading, then treat with alum, then monitor to see how the system responds to determine if biological management is needed.

Swamp Lake, a large wetland at the upstream end of the Wolsfeld MU, has very high TP concentrations and is a significant source of nutrients to downstream School Lake. Because Swamp and School Lakes have small and fairly undeveloped drainage areas, the opportunities for watershed load reduction are limited. For these reasons, MCWD is planning for additional assessment of Swamp Lake as a near-term priority.

ROLES

Each of the partners has an important role to play in executing this strategy. The following is a general characterization of roles for implementing the roadmap. Specific roles for the design, construction, maintenance, and funding of each project will be determined on a case-by-case basis and memorialized through cooperative agreements

Cities

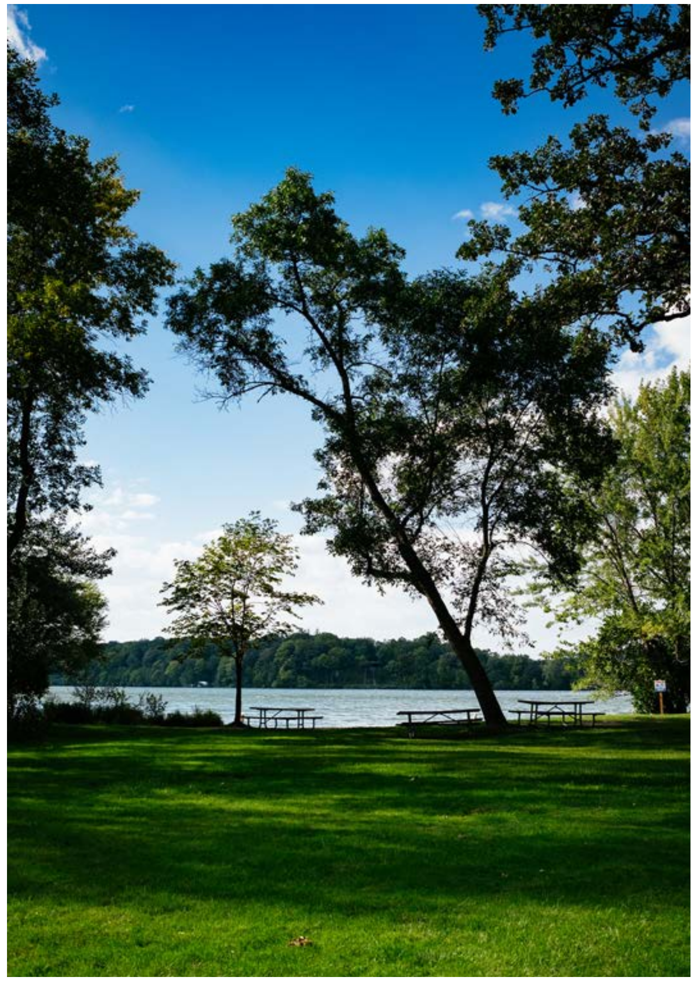
As the regulated parties with assigned load reductions through the state TMDL, cities have the primary responsibility to implement projects and best practices on the landscape. As such, the pace and scale of implementation will be largely driven by each city.

MCWD

The MCWD will provide technical and financial support to cities for implementation of projects on the landscape. The MCWD will also lead the implementation of projects to address internal loading and any retrofits to existing MCWD-owned ponds.

LLWA

The LLWA will support the implementation of capital projects by continuing to build awareness and support in the community (e.g. relaying information, helping to convene and connect with residents, advising the partners on engagement efforts). The LLWA can also build community capacity for local action such as the implementation of residential best practices (e.g. raingardens, shoreline plantings, adopt-a-drain).



FUNDING

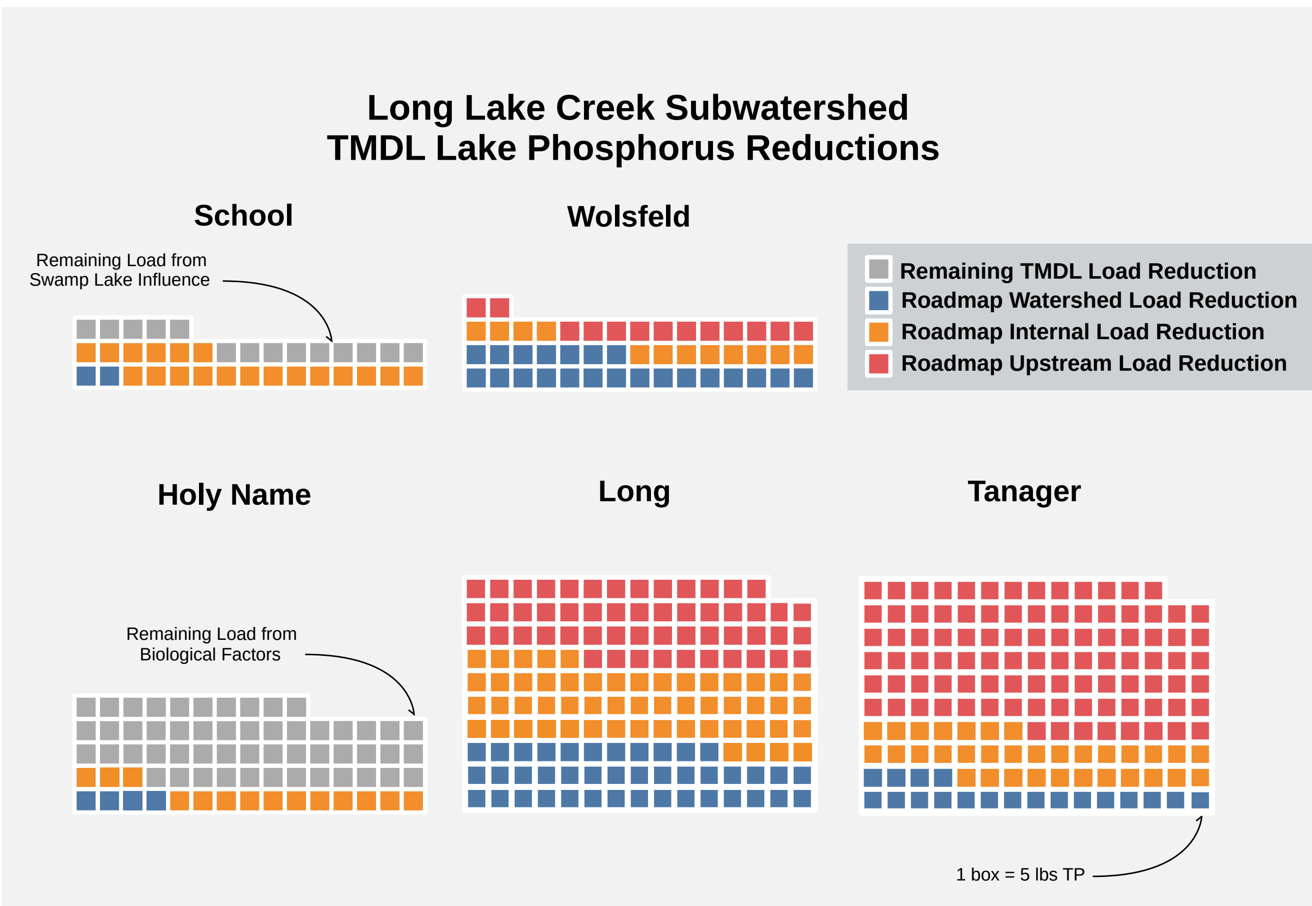
Based on discussions with the cities, it is assumed that implementation will be largely dependent on funding support from grants or other sources. The District will continue to coordinate with the partners and provide recommendations for the funding strategy with the goal of leveraging the maximum amount of external funding. This will involve evaluating the recommended projects (estimated benefits, costs, readiness to implement) against the potential grant sources (eligibility requirements, review criteria, available funds, timelines) to find the best matches.

Appendix C summarizes potential funding sources. Projects that are identified in this Roadmap will be strong candidates for a variety of state and regional grant programs as well as MCWD's new Land & Water Partnership program. This program is currently operating in a pilot phase and is scheduled for adoption in mid-2023. It is designed to provide funding and technical support for partner-led projects that align with MCWD goals and priorities by integrating them into the MCWD's Capital Improvement Plan. Most grants require a match, and it is recommended that the cities begin to dedicate funds or develop a strategy for contributing to grant matches.

PROGRESS TOWARD GOALS

Of the 59 projects evaluated, 34 are recommended for advancement based on their high cost-effectiveness and feasibility to implement. A full list of evaluated projects is included as Appendix B. The graph below shows the total load reductions required by the state to achieve water quality standards for each of the impaired lakes (total number of boxes) and the estimated progress that would be made by implementing the recommended projects (colored boxes). The different colors indicate the source of the reduction, including landscape projects (watershed load reduction), in-lake projects (internal load reduction), and improvements to upstream lakes (upstream load reduction).

If completed in total, these projects are estimated to achieve the TMDL reductions required by the state for Wolsfeld Lake, Long Lake, and Tanager Lake. The estimated percent progress toward the state requirements for School Lake and Holy Name Lake are 57 percent and 26 percent, respectively, with the remaining load attributed to biological drivers (as described in the previous section). Load reductions from biological management are difficult to estimate, so these have not been included in the graph.



The table below provides a breakdown of the state-required load reductions for each city, as well as internal load reductions, compared to the total estimated load reductions and construction costs for the 34 recommended projects. This provides a sense of the scale of implementation needed to restore the impaired lakes.

Location	Total Load Reduction Required by TMDL (lbs TP/yr)	Total Load Reduction from Recommended Projects (lbs TP/yr)	Number of Projects	Construction Cost
City of Long Lake	172	88	5	$3,956,175
City of Medina	237	161	8	$1,700,596
City of Orono	187	187	9	$2,227,525
In-Lake	625	660	12	$2,681,526
Total	1221	1096	34	$10,565,822

ONGOING PARTNERSHIP COORDINATION

This Roadmap provides a data-driven strategy and suite of projects that could be implemented to restore the five impaired lakes in this system. Undoubtedly, there will be projects in the Roadmap that will not be implemented, and there will be new opportunities that will arise. Therefore, it will be important for the partners to continue to coordinate and remain adaptive as they work together toward achieving their shared water quality goals. The MCWD plans to continue convening the partners, at least annually, to maintain a shared strategy and set of priorities for the partnership to advance.

One key area for ongoing coordination will be the identification of new project opportunities. The cities, through their land use authority and development review processes, are well positioned to track development activity that may present opportunities for stormwater management, wetland restoration, or streambank/ravine stabilization. As cities plan for their own infrastructure, parks, and facility improvements, these projects may also present opportunities to implement strategies from the Roadmap. The LLWA has a large membership of residents who are passionate about water resource protection who can also serve as a valuable network for identifying project opportunities. As opportunities are identified, MCWD can provide technical assistance to evaluate the potential costs and benefits.

At the annual meetings, the partners can revisit the implementation strategy, provide progress updates, identify any emerging opportunities, and develop shared priorities and a funding strategy for the coming year. As projects are implemented, MCWD will continue to monitor and track the progress, both in terms of estimated results from modeling and the measured response in the waterbodies. This will allow for ongoing adaptive management based on current data.

Restoration of these impaired lakes will require long-term commitment and investment by the partners. By prioritizing and focusing on the highest impact and most cost-effective project opportunities, the partners can build community support and momentum for ongoing efforts.

APPENDIX

2016 City Partnership Resolutions

Project Opportunity Tables and Maps

Grant Opportunities

Assessment Methodology, Data, and Findings

Appendix B

Long Lake Creek Subwatershed Assessment: Technical Report

Long Lake Creek Subwatershed Assessment: DRAFT Technical Report

MINNEHAHA CREEK
WATERSHED DISTRICT

TABLE OF CONTENTS

1 INTRODUCTION AND WATERSHED DESCRIPTION 1

1.1 PURPOSE 1
1.2 SCOPE 1
1.3 WATERSHED DESCRIPTION 1

2 METHODS 5

2.1 WATER QUALITY ISSUE AND DRIVER ANALYSIS 5
2.2 WETLAND ASSESSMENT 7
2.3 NUTRIENT SOURCE ASSESSMENT 8
2.4 FISHERIES ASSESSMENT 11
2.5 AQUATIC VEGETATION MONITORING 13

3 SUBWATERSHED ASSESSMENT 13

3.1 WOLSFELD MANAGEMENT UNIT 13
3.2 HOLY NAME MANAGEMENT UNIT 43
3.3 DOWNTOWN MANAGEMENT UNIT 62
3.4 DIRECT MANAGEMENT UNIT 69

4 REFERENCES 96

APPENDIX A STREAM AND LAKE WATER QUALITY DATA

APPENDIX B P8 CALIBRATION DOCUMENTATION

APPENDIX C SEDIMENT GEOCHEMICAL DATA

APPENDIX D DISSOLVED OXYGEN PROFILES

APPENDIX E SUBMERGED AQUATIC VEGETATION DATA

APPENDIX F SURFACE AND CHANNEL EROSION PHOTOS

APPENDIX G COMMON CARP STATISTICAL ANALYSIS

1 Introduction and Watershed Description

1.1 Purpose

The purpose of the diagnostic study is to develop a holistic-comprehensive analysis of the subwatershed that will help refine a strategic implementation approach that will examine Long Lake Creek Subwatershed to develop an approach to the watershed's issues in a systematic method.

Information from this report will be summarized within the Long Lake Creek Subwatershed Implementation Roadmap (Roadmap) to develop implementation strategies and integrate water projects with city, county and state land use planning and development objectives to accomplish mutual goals through economical and efficient use of public dollars.

1.2 Scope

The scope of the diagnostic assessment includes developing a refined understanding of phosphorus sources for impaired lakes in the Long Lake Creek Subwatershed to identify implementation actions to improve water quality and ecological health. The water and phosphorus budgets include the development of lake response models for the major lakes to refine our understanding of internal versus external loading and target reductions to meet water quality goals. The diagnostic study also investigates fish and plant communities in the lakes to develop an understanding of the health of the biological communities and how these conditions may affect water quality.

Dickey's Lake, Lydiard Lake, and Tanager Bay are not included in this diagnostic study. The rationale for why each lake was omitted from this study is outlined in Table 1-1.

Table 1-1. Description of why specific lakes and their drainage areas were excluded from the Long Lake Creek Diagnostic Study

Lake	Rational
Lydiard	Lydiard is a landlocked basin and is currently meeting water quality standards. Therefore, it wasn't included in the study because it doesn't impact downstream waterbodies.
Dickey's	Dickey's currently is meeting water quality standards, which means that watershed landuse have not impacted in-lake dynamics to the degree the lake is considered impaired. Therefore, improvements to this system would likely yield small benefits relative to the cost of the management activity.
Tanager	A diagnostic study for the drainage area between Long Lake and Tanager Bay was completed in 2011, which includes a comprehensive analysis of watershed projects and in-lake projects to improve conditions in Tanager Bay.

1.3 Watershed Description

Long Lake Creek Subwatershed is 11.9 square miles (7,619 acres) and located along the northern boundary of the MCWD and includes portions of the cities of Long Lake, Medina, Orono and Plymouth. The subwatershed is generally characterized by large areas of undisturbed land (37%) including large wetland and wooded areas, single family-residential in the central and eastern subwatershed (28%), lakes (9%), agriculture (10%), as well as park and open space (10%). The Luce Line Trail passes through this subwatershed, as well as the proposed Southwest Hennepin Regional Trail.

1.3.1 Drainage Pattern and Management Unit Development

The headwaters of the Long Lake Creek Subwatershed include Holy Name Lake in the Northeast, School Lake in the Northwest, and an urbanized subwatershed directly west of Long Lake (Figure 1-1). The northern headwaters drain through streams to converge just north of Long Lake. The western headwater area drains primarily through a series of stormwater infrastructure in the cities of Orono and Long Lake. Long Lake drains south into wetlands that discharge into Tanager Lake, which connects via a channel to Lake Minnetonka.

To facilitate the analyses and planning, the watershed was broken into management units based on the three major tributaries to Long Lake and the drainage area between Long Lake and Tanager Bay (Figure 1-2). Each tributary largely falls along municipal boundaries and each has unique land use characteristics. Therefore, the data analysis and source assessment sections of this document are by management unit instead of aggregated at the entire subwatershed scale.

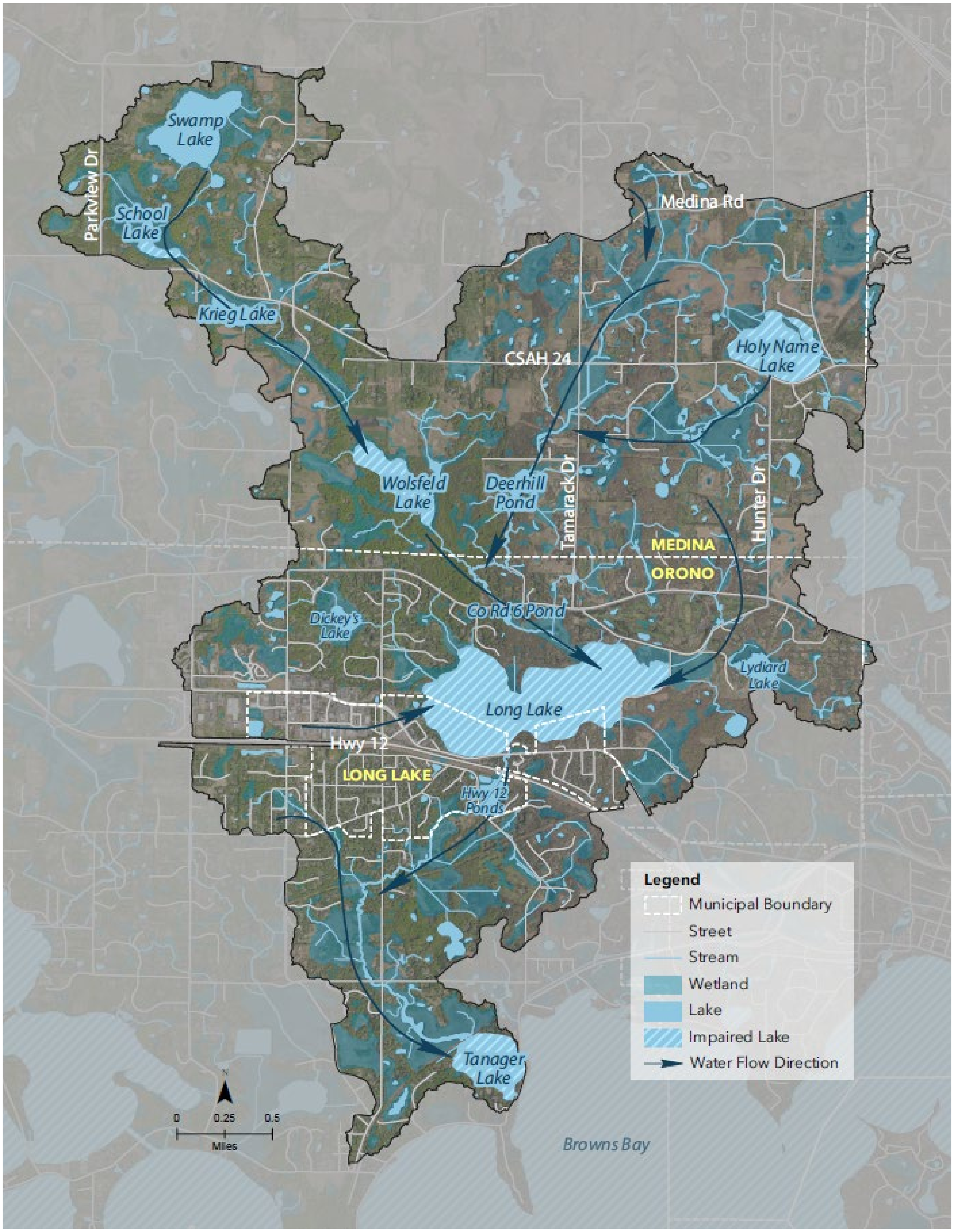


Figure 1-1 Watershed overview with flow patterns (arrows) and lake impairment status (cross-hatched lakes)

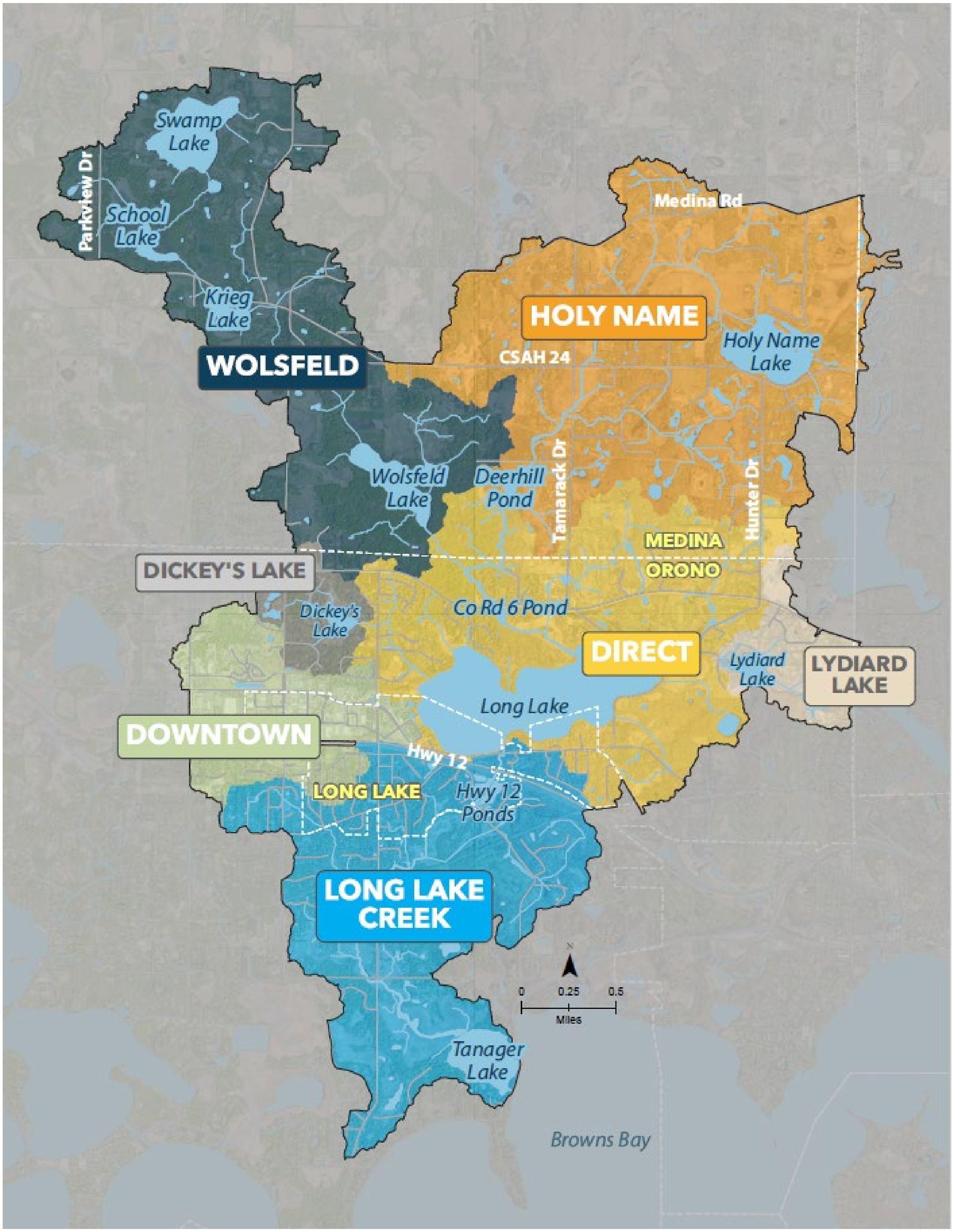


Figure 1-2 Management Units developed for the Long Lake Creek Subwatershed Assessment based on landuse type and municipal boundaries.

2 Methods

2.1 Water Quality Issue and Driver Analysis

2.1.1 Stream and In-lake Water Quality

Water quality in Minnesota lakes is often evaluated using three associated parameters: total phosphorus, chlorophyll-a, and Secchi depth. Total phosphorus is typically the limiting nutrient in Minnesota's lakes, meaning that algal growth will increase with increases in phosphorus. However, there are cases where phosphorus is widely abundant and the lake becomes limited by nitrogen or light availability. Chlorophyll-a is the primary pigment in aquatic algae and has been shown to have a direct correlation with algal biomass. Since chlorophyll-a is a simple measurement, it is often used to evaluate algal abundance rather than expensive cell counts. Secchi depth is a physical measurement of water clarity by lowering a black and white disk until it can no longer be seen from the surface. Higher Secchi depths indicate less light-refracting particulates in the water column and better water quality. Conversely, high total phosphorus and chlorophyll-a concentrations point to poorer water quality and thus lower water clarity. Measurements of these three parameters are interrelated and can be combined into an index that describes water quality.

Table 2-1 Available lake monitoring data in the Long Lake Creek Subwatershed. Water quality dataset details are located in Appendix A

Lake	**Site ID**	**Years Monitored**
Holy Name	LHN01	2006-2008; 2014-2016; 2018-2019
Swamp	LSW01	2020
School	LSH01	2017
Krieg	LKG01	--
Wolsfeld	LWO01	2014-2017
Long Lake	LLO01	2013-2022
Tanager	LTG01	2013-2022

Water quality in streams is evaluated for several purposes, however, the focus of this report will be on stream phosphorus concentrations because elevated watershed runoff and erosion are the primary drivers of poor water quality in lakes. There are many cases where prolonged periods of elevated phosphorus from landuse change lead to elevated internal phosphorus loading or poor ecological conditions that exacerbate poor clarity conditions. However, identify the watershed source must be identified before in-lake management begins since in-lake issues are typically a symptom of a larger watershed issue.

Table 2-2 Available stream monitoring data in the Long Lake Creek Subwatershed

Stream Site	Site ID	Years Monitored
School Lake Tributary (School Lk Outlet)	RCLO12	2020
School Lake Tributary (Krieg Lk Outlet)	RCLO11	2017
School Lake Tributary (Wolsfeld Lk Inlet)	RCLO10	2017
School Lake Tributary (Wolsfeld Lk Outlet)	CLO09	2017-2019
Holy Name Tributary (Tamarack & Harmony Ln)	CLO13	2019
Holy Name Tributary (Tamarack Dr)	CLO15	2017-2019
Deerhill Pond Inlet (Main Inlet)	CLO19	2018-2019
Deerhill Pond Outlet	CLO23	2019
Holy Name Tributary (Upstream of Confluence)	CLO08	2017-2019
Long Lake Creek (County Road 6 Pond Outlet)	CLO05	2014-2022
Long Lake Creek (County Road 6 Pond Outlet)	CLO17	2018-2022
Long Lake Creek (Fox and Brown St)	CLO03	2013-2022

2.1.2 Watershed Modeling

Watershed modeling was conducted for the Upper Long Lake Creek subwatershed to better understand phosphorus loading from watershed sources and support engineering design through scenario analysis. The first step in the modeling process is to delineate the minor catchments within the Long Lake Creek Subwatershed using the Agricultural Conservation Practice Framework (ACPF), which has several sub-tools that can be used for pre-processing digital elevation models (DEM). The resolution of the subwatershed minor catchments was based on the locations of wetlands, ponds, stream confluences, or other major watershed devices.

The P8 Model (Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds, IEP, Inc., 1990) was used in this study to simulate the hydrology and phosphorus loads introduced from the watershed of each basin and the transport of phosphorus throughout the system. P8 is a useful diagnostic tool for evaluating and designing watershed improvements and best management practices (BMPs). The model requires user input on watershed characteristics, basin attributes, local precipitation and temperature, and other parameters relating to water quality and basin removal performances.

The device volumes used in the P8 model were identified from surveys collected by MCWD or as-built drawings from engineered structures such as ponds. Wetland device surface areas were estimated using the National Wetland Inventory (NWI), MCWD's Functional Assessment of Wetlands (FAW), and Minnesota Department of Natural Resource (MnDNR) public water database. The volume of each wetland was calculated assuming a three-foot average depth, which was multiplied by the surface area of the wetland.

The P8 model uses the SCS method, which has inputs of curve number and impervious fraction, to simulate runoff. The input parameters were calculated in GIS using land use and soil type. The P8 model was calibrated to match stream flow from continuous monitoring stations with continuous flow records (Figure 1-1) model and monitored data. More details on the P8 model calibration can be found in Appendix B.

2.1.3 Erosion Assessment

Most water quality models, including P8, do not include upland or channel erosion processes and are typically based on empirically developed landuse runoff concentrations (MPCA, 2022; USEPA, 2009). District staff conducted an initial assessment in the Wolsfeld Management Unit using the Universal Soil Loss Equation (USLE), anecdotal information from local partners, and aerial photography to identify areas of potential erosion based on landcover, soil erodibility, and slope. The results from this analysis indicated that there are several areas that have the potential for land surface erosion.

Surface Erosion

Average upland sediment loss in the impaired reach watershed was modeled using the Universal Soil Loss Equation (USLE). This model provides an assessment of existing soil loss from upland sources and the potential to assess sediment loading through the application of Best Management Practices (BMPs). USLE predicts the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, land use and management practices. The general form of the USLE has been widely used in predicting field erosion and is calculated according to the following equation:

$$A = R \times K \times LS \times C \times P$$

Where A represents the potential long term average soil loss (tons/acre) and is a function of the rainfall erosivity index (R), soil erodibility factor (K), slope-length gradient factor (LS), crop/vegetation management factor (C) and the conservation/support practice factor (P). USLE only predicts soil loss from sheet or rill erosion on a single slope as it does not account for potential losses from gully, wind, tillage or streambank erosion.

MCWD, City of Medina, Stantec conducted field erosion investigations in upland areas that appear to have rill and gully erosion and areas near stream channels. The goal of the field visits was to 1) verify that erosion is actively occurring in areas with potential erosion and 2) to characterize the severity and sediment load from the eroding areas. Other areas further away from water bodies or areas with a high slope without gully or rill erosion identified using the USLE analysis were not investigated in the field since the likelihood of active erosion is low in these areas.

Channel Erosion

Channel erosion, unlike surface erosion, is typically driven by excess runoff or major changes in landuse that cause major hydrology changes within a watershed resulting in elevated channel velocities. A desktop geographic analysis of longitudinal stream channel elevation provided insight into stream channel sections with high slopes that may be actively eroding. Areas with potential erosion were investigated in the field using established methods for estimating the severity of erosion and associated phosphorus loading from historic erosion (NRCS, 2015).

2.2 Wetland Assessment

Wetlands play a key role in the ecological health of a watershed by providing:

- habitat fish, waterfowl and other wildlife by providing spawning areas, food, and cover
- remove pollutants such as sediment and nutrients from watershed runoff
- storage capacity to reduce the volume and rate of runoff to downstream lakes and streams

When a wetland is functioning properly it can support each of these functions, however, impacts to one wetland function can also inhibit a wetland's other ecosystem functions. For example, excess nutrient loading to a wetland changes the nutrient composition of the wetland soils and the ability of a wetland to properly assimilate and remove phosphorus and nitrogen (MCWD, 2019). The impact to nutrient cycling is not isolated since increasing soil nutrient concentrations can create favorable conditions for invasive vegetation species to outcompete native wetland plant species (EPA, 2002). Therefore, each ecosystem service must be assessed to determine the condition of the wetland to inform potential management interventions.

2.2.1 Vegetation Assessment

MCWD utilized two approaches for assessing vegetation in the Long Lake Creek Subwatershed. The first approach was utilizing MCWD's Functional Assessment of Wetlands (FAW) study, which "provided a comprehensive inventory and assessment of existing wetland functions within the MCWD" (Wenck 2003)". The FAW study used the MCWD's Minnehaha Creek Rapid Assessment Method (MCRAM), which is comprised of 72 metrics on wetland functions, which include vegetation diversity. The FAW dataset provides 1) a comprehensive snapshot of the overall health of wetland vegetation health within the Long Lake Subwatershed and 2) identifies areas where more refined data collection is needed to inform restoration efforts.

The second method used is the Rapid Floristic Quality Assessment for wetlands developed by the Minnesota Pollution Control Agency. The RFQA assessment framework was developed after the completion of MCRAM and represents a significantly more robust assessment method for wetland vegetation communities. The RFQA provides a more accurate representation of current vegetation conditions and differentiates between vegetation communities that provides better information to identify wetland restoration strategies.

2.2.2 Nutrient Cycling

Wetland phosphorus cycling is governed primarily by the amount of phosphorus delivered to the wetland and the amount of phosphorus that sediment or soil within a wetland can adsorb. Excessive nutrient loading from land use change can overwhelm a wetland's ability to assimilate phosphorus and nitrogen. The response by wetlands, however, is difficult to perceive since increased nutrient loading does not necessarily result in obvious visual changes within wetlands.

MCWD's approach for assessing wetland nutrient cycling health was to collect water quality samples at the inlet and outlet of wetlands to determine if a wetland's nutrient assimilative capacity has been exhausted.

2.3 Nutrient Source Assessment

MCWD's philosophy for managing water resources focuses on characterizing issues, identifying underlying drivers that are causing the issues, and outlining management strategies to achieve measurable change towards identified goals. Typically, the underlying driver of in-lake issues such as degraded ecology, poor water quality, or excess flooding is caused by the introduction of human induced landscape change such increased development or agricultural practices.

The primary goal of the in-lake assessment is to characterize the phosphorus budget of each impaired lake to quantify sources of phosphorus and determine how phosphorus reductions would impact lake clarity and algal blooms. The development of a phosphorus budget for impaired lakes is a critical step in the lake restoration process to ensure that the projects identified and implemented are targeting the correct locations and meet phosphorus reduction goals to meet water quality standards.

The secondary goal of in-lake assessment is to determine if in-lake phosphorus cycling and biological conditions have been negatively impacted by historic watershed loading and poor water quality. Over time, many of the in-lake issues caused by land use change become drivers. For example, watershed phosphorus sources slowly increase phosphorus sediment release (internal phosphorus loading), which creates a positive feedback loop that further degrades water quality. Another example includes tolerant fish species such as common carp or black bullhead. Common carp and black bullhead both thrive in poor water quality systems, which means that many degraded lakes can promote the introduction and establishment of carp. However, their introduction can further degrade lake ecosystems.

2.3.1 Lake Nutrient Budgets

The lake response modeling focuses on total phosphorus, chlorophyll-a and Secchi depth. For this assessment, the BATHTUB model was selected to link phosphorus loads with in-lake water quality. A publicly available model, BATHTUB was developed by William W. Walker for the U.S. Army Corps of Engineers (Walker 1999). BATHTUB has been used successfully in many lake studies in Minnesota and throughout the United States.

BATHTUB is a steady-state annual or seasonal model that predicts a lake's summer (June – September) mean surface water quality. BATHTUB's time-scales are appropriate because watershed phosphorus loads are determined on an annual or seasonal basis, and the summer season is critical for lake use and ecological health. BATHTUB has built-in statistical calculations that account for data variability and provide a means for estimating confidence in model predictions. The heart of BATHTUB is a mass balance phosphorus model that accounts for water and phosphorus inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and (if appropriate) groundwater; and outputs through the lake outlet, groundwater (if appropriate), water loss via evaporation, and phosphorus sedimentation and retention in lake sediments. BATHTUB allows choice among several different mass balance phosphorus models.

For deep lakes in Minnesota, the option of the Canfield-Bachmann lake formulation has proven to be appropriate in most cases. The Canfield-Bachmann equation is a simple empirical model that predicts phosphorus sedimentation and ultimately in-lake phosphorus concentrations based on phosphorus and water loads. For shallow Minnesota lakes, other options, such as a second order decay model, have often been more useful. BATHTUB's in-lake water quality predictions include two response variables, chlorophyll-a concentration and Secchi depth, in addition to total phosphorus concentration. Empirical relationships among in-lake total phosphorus, chlorophyll-a, and Secchi depth form the basis for predicting the two response variables. Among the key empirical model parameters is the ratio of the inverse of Secchi depth (the inverse being proportional to the light extinction coefficient) to the chlorophyll-a concentration.

A BATHTUB lake response model was constructed for key lakes in the Long Lake Creek subwatershed. The selection of the subroutines is based on past experience in modeling lakes in Minnesota and is focused on those that were developed based on data from natural lakes. The Canfield-Bachmann natural lake model was chosen for the phosphorus model. For more information on these model equations, see the BATHTUB model documentation (Walker 1999). Model coefficients are also available for calibration or adjustment based on known cycling characteristics.

2.3.1.1 Internal Loading

Internal phosphorus loading from lake sediments has been demonstrated to be an important aspect of the phosphorus budgets of lakes. However, measuring or estimating internal loads can be difficult, especially in shallow lakes that may mix many times throughout the year. To estimate internal loading in the lakes, sediment cores were collected from the deepest portion of the lake. Phosphorus release rates were then measured in the lab under both anoxic (without oxygen) conditions (Appendix C). Sediment chemistry was also collected to evaluate the potential sources of phosphorus from the sediment as well as to provide initial dosing calculations for chemical addition. These measured release rates are then combined with measured oxygen conditions in the lake to estimate the mass of phosphorus released into the water column. To quantify anoxia, an anoxic factor (AF; Nürnberg 2004), which estimates the period where anoxic conditions exist over the sediments, is calculated from the dissolved oxygen profile data (Appendix D). The anoxic factor is expressed in days and represents the number of days anoxia existed over an area equal to the lake surface area. The anoxic factor is then used along with a sediment release rate to estimate the total phosphorus load from the sediments.

2.3.1.2 Watershed Loading

Watershed loading developed in the 2014 Upper Lakes Total Daily Maximum Load (TMDL) (Wenck, 2014) will be used for the lake nutrient budgets in this assessment. Point source dischargers, which include Municipal Storm Sewer Systems, were assigned wasteload allocations for phosphorus by the Minnesota Pollution Control Agency in the Upper Lakes TMDL developed in 2014. Therefore, MCWD will be using the loading from that study to ensure that phosphorus estimates that have an impact on discharge permittees do not change.

One deviation from the 2014 TMDL study will be the evaluation of specific sources of nutrient loading. Specific sources of watershed loading will be included in the overall watershed loading estimate with the assumption that the original watershed TMDL load included any specific sources identified in this study since it was based on empirically measured watershed phosphorus samples collected in the Long Lake Creek Subwatershed.

An example of this approach is as follows. There is a specific area that has been identified as contributing 25 pounds of phosphorus per year to an impaired downstream lake that has an overall watershed load of 100 pounds. This study assumes that the 25 pounds of phosphorus loading was inherently included in the TMDL. Therefore, the specific watershed loading based on erosion is 25 pounds of phosphorus per year and watershed loading from other areas now represents 75 pounds of phosphorus per year to the impaired lake. The overall watershed load doesn’t change in magnitude, but the specificity of the source does change, which improves our ability to help partner communities better target load reductions to meet their MS4 wasteload allocation goals set by the MPCA.

2.4 Fisheries Assessment

2.4.1 Fish Community Sampling

The initial goal of the fishery assessment is to understand what fish species should exist in each lake based on MnDNR lake classes (Schupp, 1992), which are based on lake morphometry (depth and size) and eutrophication status. The fish community expected based on the MnDNR lake class is a useful metric to compare relative to determine if fish community is driven by physical factors such as morphometry and water quality or if other factors management factors may be impacting the fish community such as invasive species.

MnDNR survey game fish populations using standardized trap and gill net survey methods to assess gamefish populations within lakes. MnDNR standard trap and gill net surveys consist of setting trap and gill nets at predetermined locations based on lake size (Schlagenhaft 1993). The trap and gill nets are meant to tangle or entrap fish over a 12-24 hour period. Trap nets contain a lead net perpendicular to shore with a series of hoops and funnels at the end of the net that direct and entrap fish. The gill nets catch fish via gill entanglement and consist of multi-sized mesh panels. The gill nets are typically set in deeper (~8-12 feet), open water habitats. Fish captured from trap and gill net assessments are identified, total length measured and weighed. MCWD did not replicate these sampling efforts, but rather, reviewed MnDNR findings from these surveys where they existed across the subwatershed (i.e. Long Lake).

In lakes with no reportable MnDNR fisheries information or dated information (~>10 years) we implemented trap net or mini-fyke net (smaller style of trap net) to assess the fish community. We implemented this net type as commonly used in shallow lake ecosystems following a standardized sampling technique (Herwig et al. 2010). At least three nets were used to entrap fish over a 12-24 hour period.

2.4.2 Carp Assessment

The carp assessment consists of two distinct activities including 1) an assessment of carp population size in each lake and 2) characterize the potential source of carp in each lake to inform management recommendations.

The first step is assessing if common carp are present in each water body and determining the total population size if they are present. The population size, represented by carp biomass per hectare, can be compared to thresholds developed by the University of Minnesota (Bajer, 2009) to identify if carp are abundant enough to negatively impact native vegetation, food webs, and water quality in each lake.

If carp are present, it is also important to identify the source of carp in each aquatic system. Characterizing the source of carp includes three methods:

- Juvenile carp assessment: Characterize if carp offspring (young of year) exist within each lake
- Carp age assessment: Characterizing the age of common carp in each lake system provides evidence carp are actively reproducing in the Long Lake Creek Subwatershed and if conditions are favorable for carp recruitment
- Carp Movement: Identify if carp are able to immigrate into the system from Lake Minnetonka and move freely through the system

2.4.2.1 Population Density

Biologists and scientists from MCWD and WSB conducted a common carp population assessment on Long Lake, Wolsfeld Lake, and Tanager Lake on in 2019 and 2020 using standard research methods described in (Bajer and Sorensen 2012).

All common carp were netted, counted and measured for total length (weight was extrapolated from length using a regression model) prior to being released. This information, along with the amount of time spent electrofishing, were used in linear regression models developed by (Bajer and Sorensen 2012) to estimate the current population size and density within each lake.

2.4.2.2 Juvenile Carp Source Assessment

We do not directly assess egg production or survival. Rather, we skip a lifestage and look to sample for juvenile carp. Sampling juvenile carp assumes that eggs survived but the carp is still susceptible to either predation or death-inducing abiotic stressors in their nursery habitats (i.e. winterkill). The trap or mini-fyke netting technique used in fish community sampling is also the netting technique commonly used to detect the presence of juvenile carp in nursery habitats. Therefore, utilizing this gear had an additional benefit to directly sample for the presence of juvenile carp.

2.4.2.3 Age Dynamics

An aging assessment was conducted in Long Lake, Wolsfeld Lake, and Tanager to characterize the historical trends in common carp recruitment. In June 2019, otoliths were collected from Long Lake (n=27), Wolsfeld Lake (n=28), and Tanager Bay (n=35). Common carp were sampled via electrofishing, removed from the system, and frozen for subsequent analysis following established protocols for common carp outlined in Bajer and Sorensen (2010). More specifically, the asterisci otoliths (i.e. ear bones) were extracted, embedded in epoxy, and sectioned using a slow speed saw. Annual growth rings were counted using a compound microscope by two independent readers.

2.4.2.4 Adult Migration

Since the observation and tracking of a juvenile population can be infrequent and difficult we also implemented an adult movement assessment to better understand where adult carp where moving throughout the year and whether there was large migrations into habitats that may have been suitable for serving as a nursery. We will refer to this as carp tracking.

WSB and Carp solutions, with support of MCWD staff, tracked carp within the subwatershed utilizing two different types of tracking tags: Passive Integrated Transponders (PIT) tags, and Radio Frequency (RF) tags. RF tags were historically implemented into ~15 carp within Long Lake. The RF tags are uniquely coded for individual detection and utilize a telemetry searching based detection method to determine an x-, y- coordinate positioning of each RF tagged carp. This type of tag is relatively expensive and invasive to the fish requiring a surgical procedure therefore, less carp are typically tagged.

PIT tags are much smaller and less evasive tags to the carp, therefore, can be implanted cost-effectively into many fish. PIT tags are magnetic tags much like a microchip for a common household pet, therefore, will uniquely code the fish and last the length of its life. These tags require the fish pass over a magnetic switch, therefore, they are typically used in areas where fish are passing through an area (i.e. stream channel, culvert). We targeted implanting ~150 individual carp in Long, Tanager, and Wolsfeld lakes (only systems with adult carp) and positioned PIT readers in four unique locations over the course of ~365 days.

2.5 Aquatic Vegetation Monitoring

Aquatic plants are beneficial to lake ecosystems, providing spawning and cover for fish, habitat for macroinvertebrates, refuge for prey, and stabilization of sediments. However, in high abundance and density they limit recreation activities, such as boating and swimming, and may reduce aesthetic value. Excess nutrients in lakes can lead to non-native, invasive aquatic plants taking over a lake. Some exotics can lead to special problems in lakes. For example, under the right conditions, Eurasian watermilfoil can reduce plant biodiversity in a lake because it grows in great densities and out-competes all the other plants. Ultimately, this can lead to a shift in the fish community because these high densities favor panfish over larger game fish. Species such as curly-leaf pondweed can cause very specific problems by changing the dynamics of internal phosphorus loading. All in all, there is a delicate balance within the aquatic plant community in any lake ecosystem.

The relative health of the submerged aquatic vegetation (SAV) community can be assessed with the MnDNR's Floristic Quality Index (FQI). The FQI is an assessment tool used to determine the biological health of the SAV community and is a metric in MCWD's E-Grade toolkit (MCWD, 2018). FQI scores are compared to a threshold for context and classification of biological impairment status (MCWD, 2018). Lakes with greater FQI scores and species richness are typically comprised of diverse native communities with abundant plant growth across the entire littoral area. As health begins to deteriorate, we typically see a reduction in diversity, an increased presence of invasive species, increasing monodominance, and decreased depth of growth. To assess the presence, abundance, and health of the SAV community MCWD has been conducting point intercept surveys during periodically in August over the past decade. Late summer surveys provide the greatest assessment of SAV health, abundance, and spatial distribution.

3 Subwatershed Assessment

MCWD's approach to addressing water resource problems is characterizing the location and severity of issues, understanding the underlying drivers of the issues, and developing a strategy for improving each issue. To do this, each management unit will cover three general sections:

1) An overview of the watershed including landuse description and water resources
2) A characterization water quantity, water quality, and ecological integrity issues within each management
3) An assessment of the source or cause of the issues surrounding water quantity, water quality, and ecological integrity.

3.1 Wolsfeld Management Unit

3.1.1 Watershed Description

The Wolsfeld Management Unit (Wolsfeld MU) encompasses 1,670 acres and represents the northwest drainage area of the subwatershed. It is located primarily in the City of Medina and includes a small portion of the City of Orono. The headwaters of the Wolsfeld Management Unit begin in Swamp Lake and flow into School Lake, which is currently impaired for excess nutrients (Figure 3-1 and Table 2-1). The outlet of School Lake is located at its southeast corner and flows through Krieg Lake, which flows under Willow Road into a large wetland complex in the center of the management unit. The large wetland surrounded by agricultural area drains to Wolsfeld Lake, which represents the most downstream location of this management unit (Figure 3-1). Land use is primarily represented by undeveloped, agricultural, and low-density residential. The management unit includes two large natural and scientific preserve areas. The arrows on the map above represent the MU's drainage pathway.

Table 3-1. Wolsfeld Management Unit lake morphometry, impairment status, and DNR Lake Class

Lake	Surface Area (acre)	Maximum Depth (ft)	Lake Volume (ac-ft)	Percent Littoral Area (%)	Impairment Status	DNR Lake Class
Swamp	73.2	5	233	100	Not Impaired*	44
School	11.2	21	116.1	90	Impaired	36-37
Krieg	13.3	92	185	53	Not Impaired*	30
Wolsfeld	34	26	445	85	Impaired	36-37

*The MPCA deemed these lake as not having enough information to designate them as impaired. The surface water quality data that MCWD has collected has indicated that both of these lakes would be considered impaired based on state standards

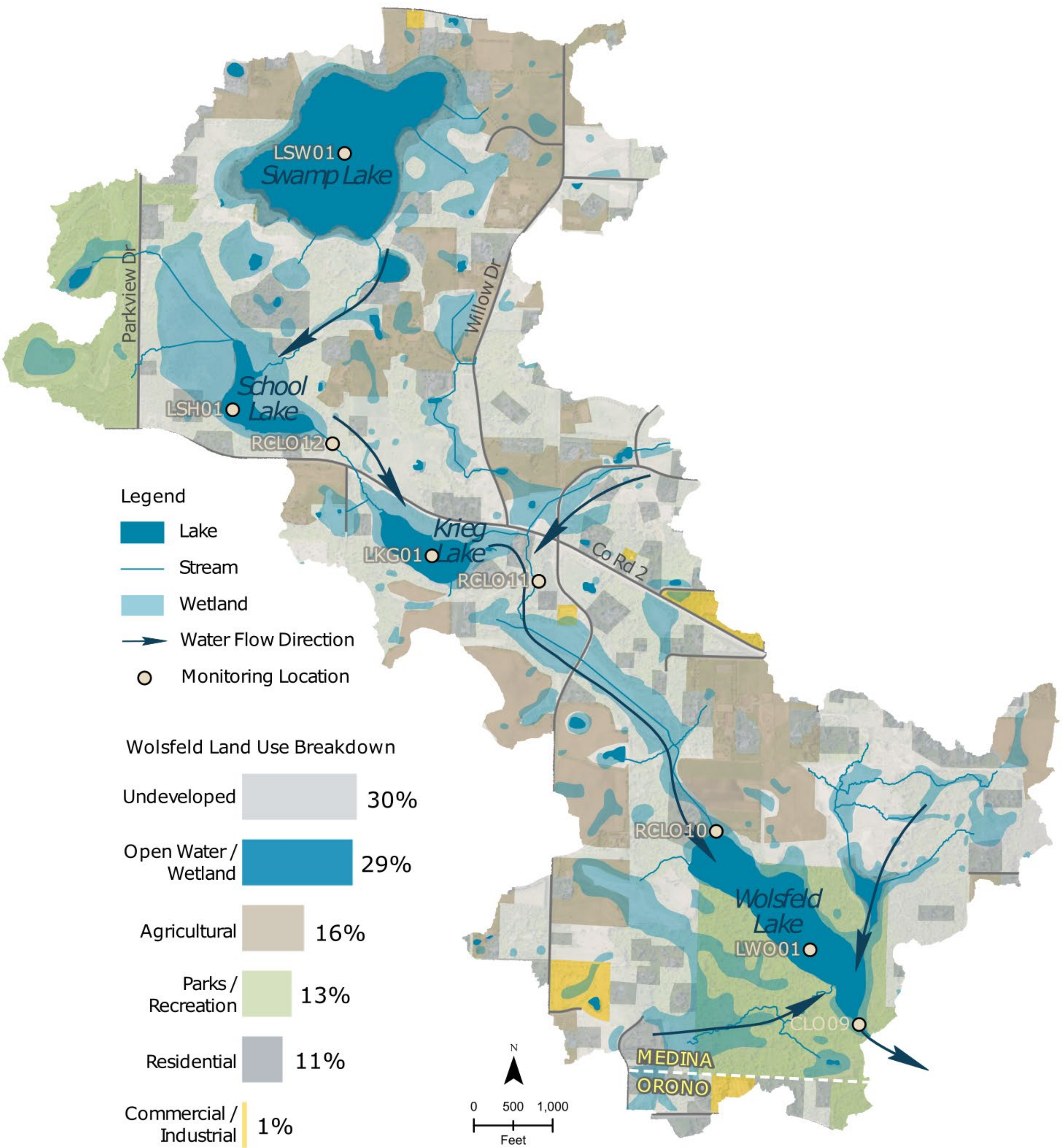


Figure 3-1. Wolsfeld Management Unit overview including flowpaths, major water bodies, and landuse (Source: MLCCS).

3.1.2 Water Quality Overview

Stream and lake total phosphorus concentrations over the past 10 years were evaluated to characterize the historic water quality conditions in the Wolsfeld MU. These data have been arranged from the uppermost stream monitoring location (Swamp Lake) to the outlet of the management unit located just downstream of Wolsfeld Lake (Figure 3-2). Total phosphorus concentrations in all lakes and streams exceed total phosphorus standards set by the State of Minnesota (0.04 mg/L for lakes; 0.1 mg/L for streams). Appendix A contains more detailed lake and stream water quality data that includes trends based on annual averages.

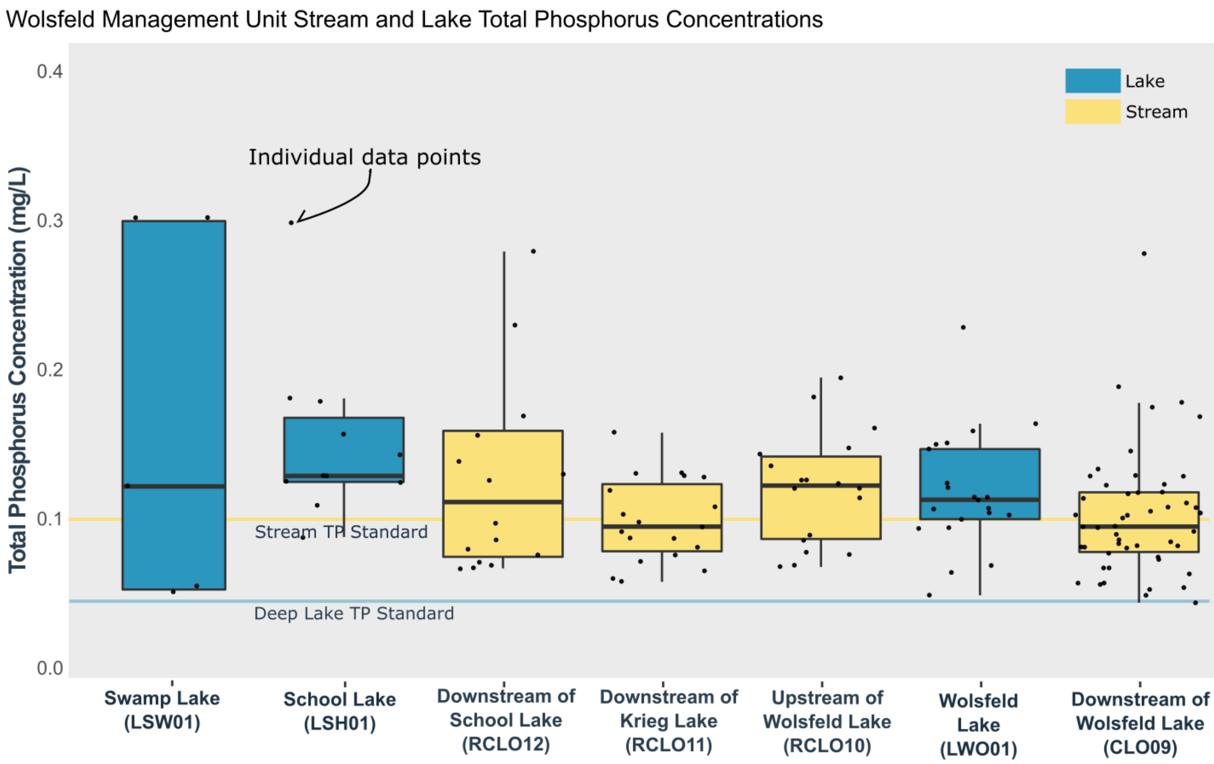


Figure 3-2. Lake (blue) and stream (yellow) total phosphorus concentrations in the Wolsfeld Management unit from upstream (left) to downstream (right). Swamp Lake is shallow enough that it qualifies as a wetland, which means lake standards are not used to identify if Swamp Lake is impaired for excess nutrients.

Overall, water quality generally improves from upstream to downstream in this management unit, however, all streams and lakes exceed total phosphorus standards within this management unit (Figure 3-2). The notable exception to this spatial trend of improving water quality conditions from upstream to downstream is the area that lies between the monitoring station just downstream of Krieg Lake and the monitoring station just upstream of Wolsfeld Lake. Median total phosphorus concentrations at the site downstream of Krieg Lake are 0.094 µg/L and 0.122 µg/L at the monitoring location upstream of Wolsfeld Lake, which represents a 37 pound increase in total phosphorus between the two monitoring sites. An increase at this location is surprising since the feature located between these sites is a wetland, which should remove particulate phosphorus. Further assessment of the potential driver of phosphorus concentrations will be discussed in subsequent sections describing water quality modeling, wetland nutrient cycling, and watershed erosion processes.

3.1.3 Watershed Nutrient and Runoff Characterization and Source Assessment

3.1.3.1 Watershed Runoff Modeling

Total phosphorus runoff concentrations derived from watershed modeling in the Wolsfeld MU span a large range based on model output (0.05-0.32 mg/L), which are similar to in-stream phosphorus concentrations measured by MCWD staff (Figure 3-2 and Figure 3-3). High runoff concentrations generally occur in upstream areas within the watershed that coincide with agricultural landuse (Figure 3-3). However, many of the areas with elevated total phosphorus runoff have downstream ponds and wetlands that provide sufficient treatment for total phosphorus removal (Figure 3-3), which is supported by stream and lake data (Figure 3-2.) that demonstrated a gradual improvement in total phosphorus concentrations from upstream to downstream locations.

The area located between Krieg Lake and Wolsfeld Lake was identified as an area of elevated phosphorus loading based on stream phosphorus monitoring. Watershed modeling suggests that watershed runoff containing elevated phosphorus should decrease by approximately 45 pounds by the wetlands within these minor catchments (Figure 3-3). It is important to note that the P8 model only takes into account watershed runoff and particulate phosphorus settling, which doesn't include phosphorus loading from stream channel erosion, surface erosion, or wetland phosphorus release. Subsequent sections analyzing phosphorus contributions from wetland nutrient cycling and erosion processes may shed light on the observation of phosphorus concentration increases between Krieg Lake and Wolsfeld Lake.

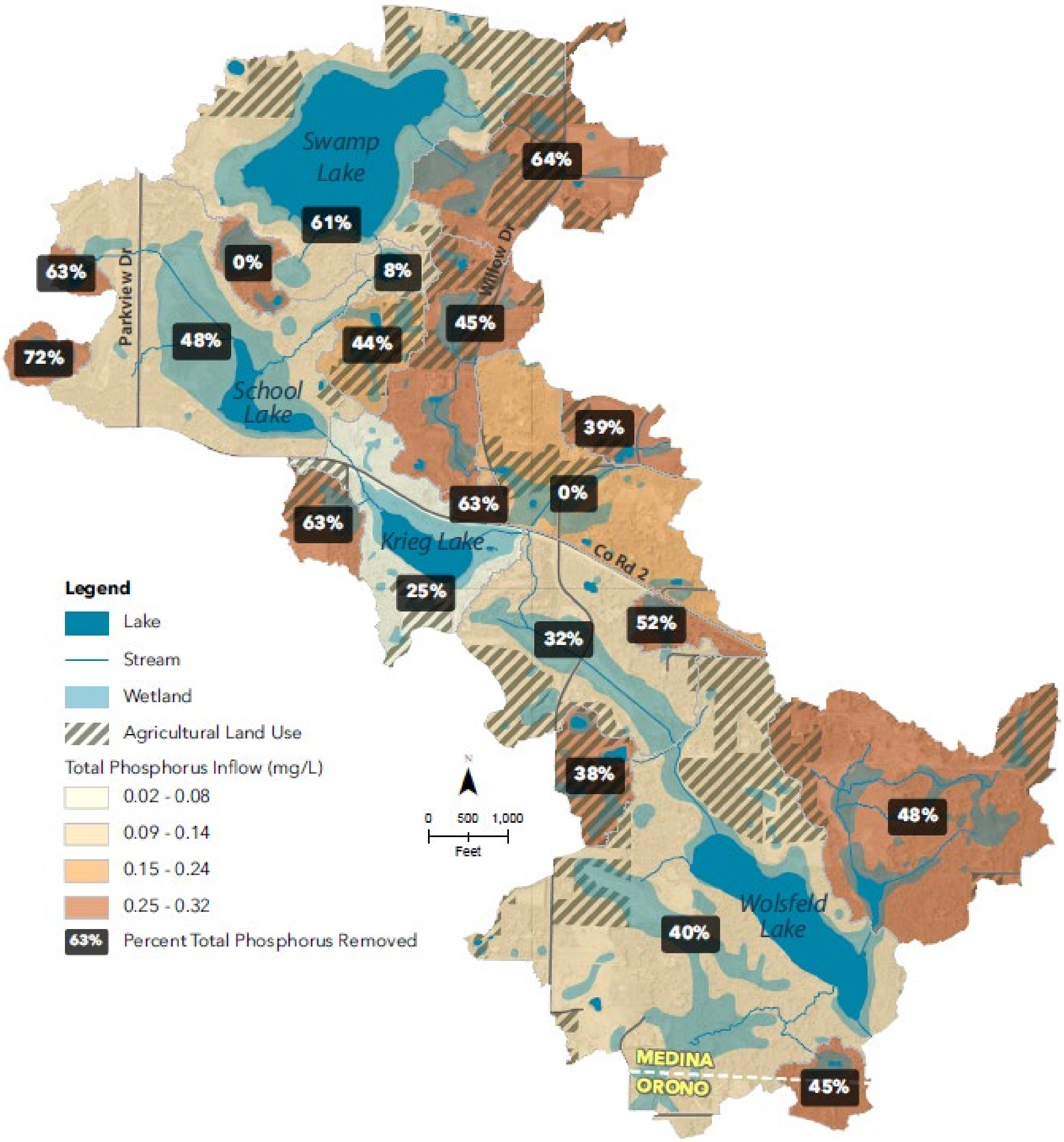


Figure 3-3 Phosphorus runoff concentration at the outlet of each catchment that includes treated runoff from upstream ponds or lakes and direct untreated runoff. The white numbers in black boxes represent the phosphorus reduction at the outlet of each catchment. All values within this map are based on P8 output.

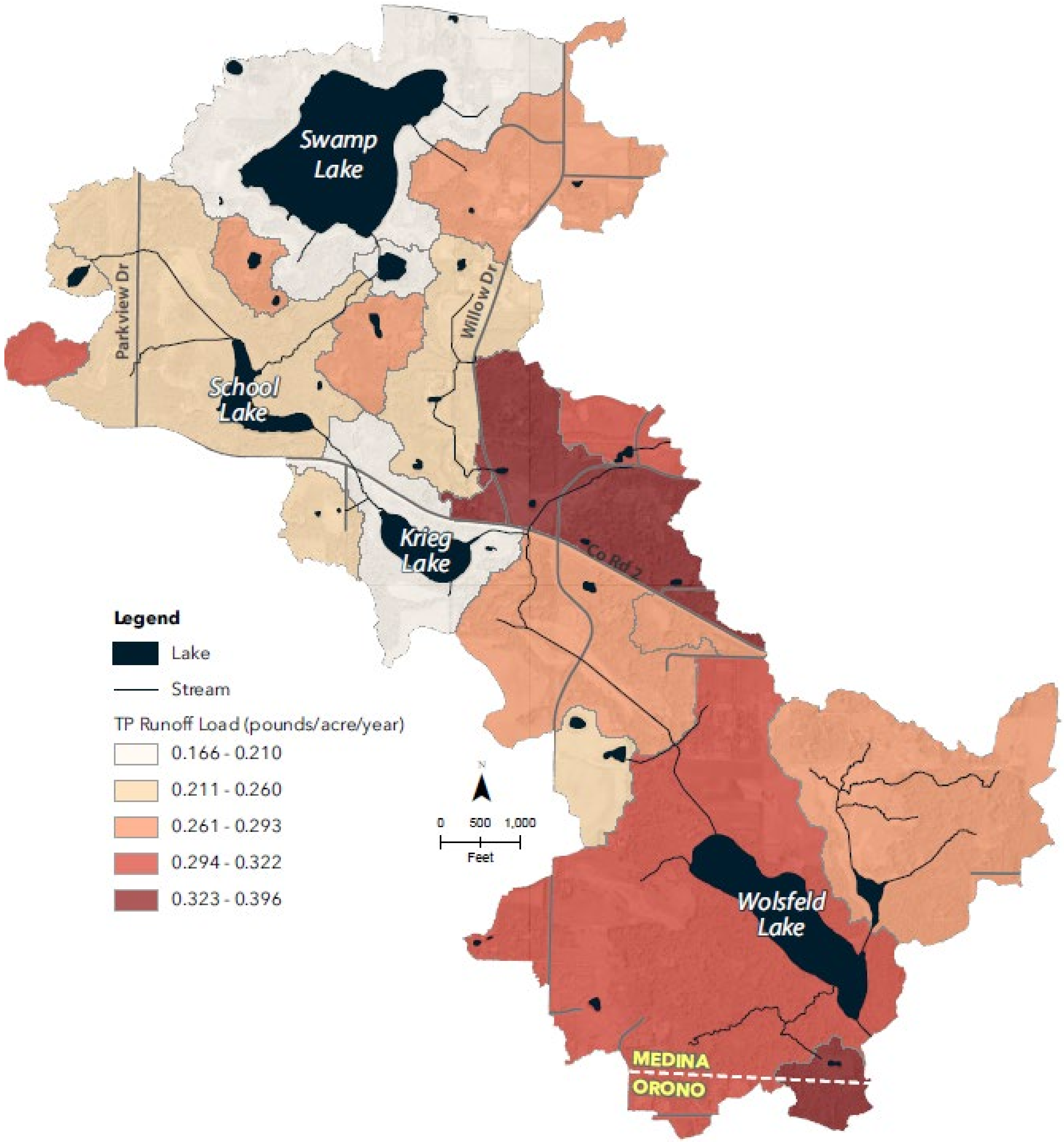


Figure 3-4. Unit area total phosphorus loading from each catchment based on P8 modeling output.

3.1.3.2 Erosion Assessment

Surface Erosion

Four locations emerged as having potential rill and gully erosion based on the USLE analysis, proximity to a stream or lake, and anecdotal information from local partners based on methods outlined in section 2.1.3. The four sites that were identified based on from the USLE analysis or anecdotal information are listed in Table 3-2 along with field-estimated annual erosion rates, reach lengths, and annual phosphorus loading.

Table 3-2 Locations of potential surface erosion that were field verified by MCWD, Stantec, or partner staff

Location	Description	Active Erosion	Estimated Annual P Loading (lbs P/y)	Erosion Conclusion
WMU-1	Gully SW of Willow Rd Wetland	Yes	13-22	Field assessment revealed that downcutting due to surface erosion has led to a small gully forming in this area. Erosion appears to be active and contributes nutrients to downstream water bodies. This area also appears to be contributing debris that may be clogging the channel and causing upstream flooding
WMU-2	Gully SE of Willow Rd Wetland	Yes	12-20	Field assessment revealed severe downcutting due to surface erosion. Erosion appears to be active and contributes nutrients to downstream water bodies. This erosion also appears to be contributing debris that is causing channel blockage and upstream flooding
WMU-3	Ravine SW of Wolsfeld Lake	Yes	34-57	Field assessment revealed severe downcutting due to surface erosion. Erosion is contributing sediment and nutrients directly to Wolsfeld Lake.
WMU-4	Ravine NW of Wolsfeld Lake	No[1]	7.2	Field assessment by WSB and MCWD staff revealed that this area is not experiencing active erosion.

[1]No further investigation was conducted on the WMU-4 location since the site investigation indicated that active erosion wasn't an issue.

Channel Erosion

The Wolsfeld MU has four distinct stream channels that are located between large wetlands or lakes (Figure 3-5). Of these, MCWD and Stantec staff conducted field investigations of two stream reaches including the reach between Swamp and School Lake and the stream reach just upstream of Wolsfeld Lake (Table 3-3).

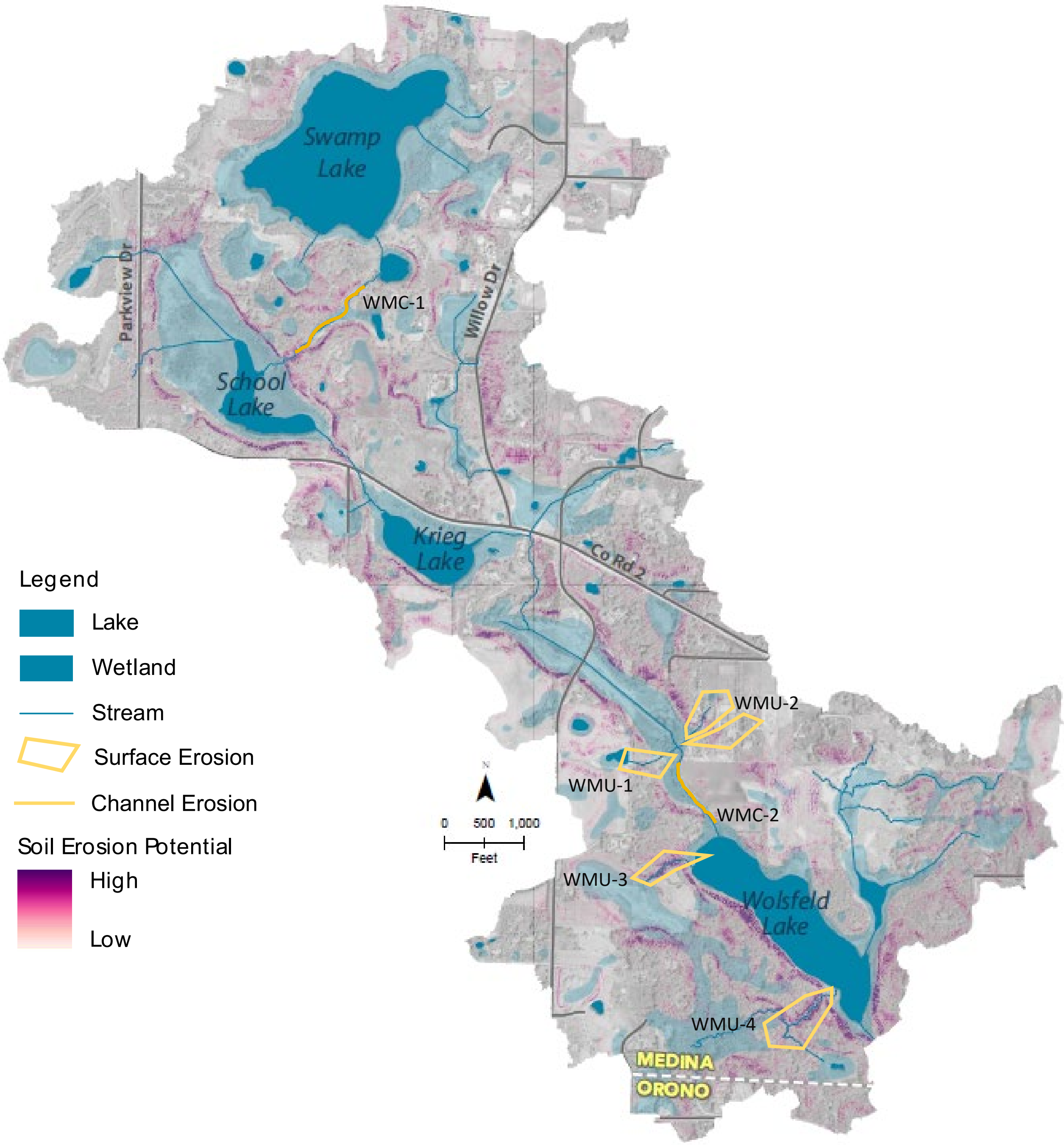


Figure 3-5 Areas of potential erosion based on the Universal Soil Loss Equation (USLE) estimates

Table 3-3 Locations of potential surface erosion that were field verified by MCWD or Stantec staff

Location	Description	Reach Slope	Erosion Conclusion
WMC-1	Stream Bank Erosion between Swamp and School Lake	1%	Field investigation by Stantec characterized a small amount of downcutting that is leading to approximately 7 lbs P/yr in loading to School Lake.
WMC-2	Channel Erosion just upstream of Wolsfeld Lake	3%	Field investigation confirmed downcutting is occurring in this reach, but further investigation is required to quantify the phosphorus load associated with erosion.

The channel between Swamp lake and School Lake did demonstrate bank erosion during field surveys of the channel by Stantec Engineering. The phosphorus load from bank erosion is approximately 7.2 lbs P/yr, which is delivered to School Lake. Another location with potential erosion is the stream channel located just upstream of Wolsfeld Lake. MCWD staff conducted a qualitative assessment of the channel and verified that the channel had some level of downcutting. Further field investigation is required to estimate the phosphorus load contribution to Wolsfeld Lake.

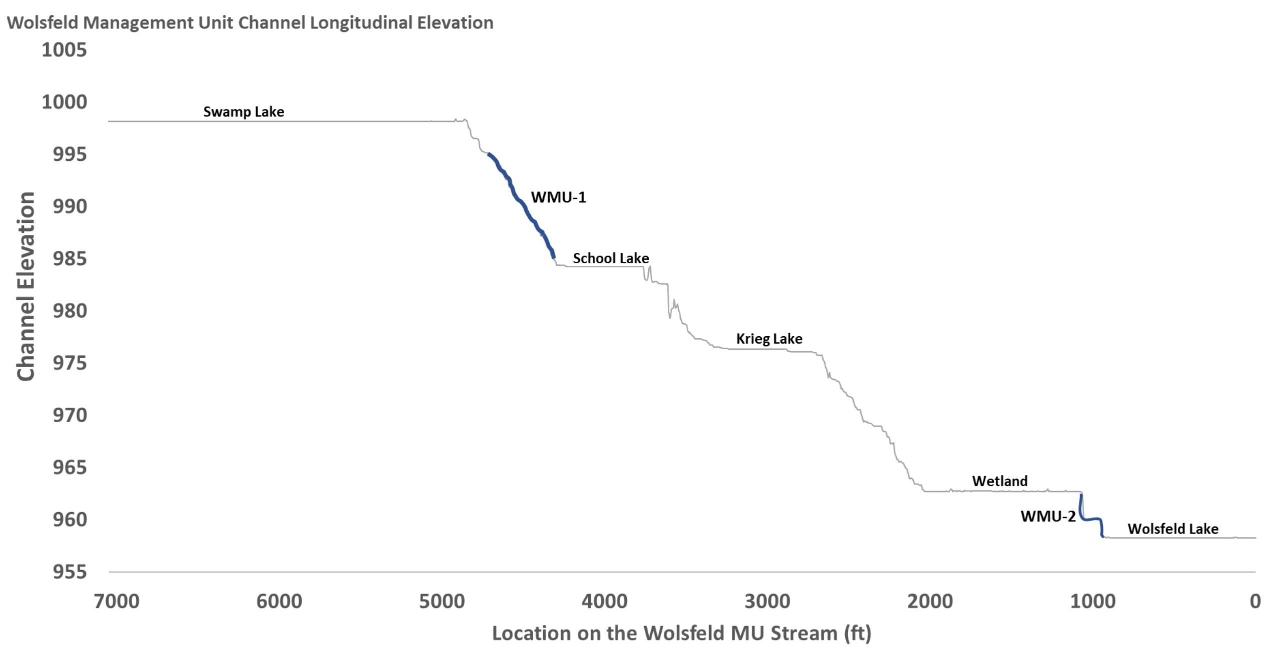


Figure 3-6 Long Lake Creek stream profile from the most upstream water body (Swamp Lake) to the outlet of the management unit (Wolsfeld Lake) with areas of high potential channel erosion highlighted in blue.

Erosion Drivers

The goal of upcoming sections is to identify which drivers have the greatest impact on erosion in the Wolsfeld MU since surface and channel erosion appears to be one of the main drivers of phosphorus loading to lakes within the Wolsfeld MU. Characterizing the primary factors leading to erosion is a critical step to inform potential projects to remediate past erosion issues and identify watershed protection activities to prevent erosion in the future. The drivers assessed in this report include:

1) Natural Drivers
    a. Soil erodibility
    b. Drainage area slope
2) Anthropogenic Drivers
    a. Landcover
    b. Landuse change:
    c. Excess runoff

Surface Erosion Drivers

The Wolsfeld MU did have several locations of surface erosion that have led to gully and ravine erosion in drainage areas to Wolsfeld Lake and in the direct drainage area of Wolsfeld Lake. This erosion appears to be the confluence of natural and anthropogenic factors influencing the surface erosion occurring within the Wolsfeld MU.

The two naturally occurring geological factors that have the greatest influence on surface erosion include the steepness of slopes and the erodibility of soils within the MU. The Wolsfeld MU is unique within the Long Lake Creek Subwatershed since it has steep slopes near most of its stream channels, lakes, and wetlands (Figure 3-5).

The other geologic factor, soil erodibility, is also a contributing factor to surface erosion within the Wolsfeld MU. Soils within the Wolsfeld MU are among the most erodible based on the USDA's erodibility factor (k-factor) (Figure 3-7). These soils have relatively high silt and sand content, which easily detach under low runoff events.

The assessment of the natural factors that may cause erosion clearly shows that the Wolsfeld MU has a high potential for erosion (Figure 3-5). However, the areas where surface erosion are contributing substiantial phosphorus loads are surprising because 1) many of these in areas that are well vegetated (Figure 3-8) and 2) stormwater runoff is near pre-development levels in the Wolsfeld MU (Figure 3-10). Furthermore, why is erosion is occurring in some areas that have the potential for erosion and not occurring in other areas with equally high potential? MCWD's ability to answer these questions is critically important to determine if naturally occurring erosion is inevitable or if management interventions are necessary to address mass wasting during ravine erosion.

MCWD staff compared historic photos relative to the USLE output to provide insights into factors causing erosion in the Wolsfeld MU. The initial assessment of the aerial photos suggests that landcover hasn't changed in the Wolsfeld MU between today (Figure 3-8) and the 1940s (Figure 3-9). Upon closer review, the extent of cultivated row crop areas was much greater in 1940 and extended much closer to streams and lakes (Figure 3-9). The historic photos revealed that the locations of ravine erosion identified through USLE analysis and field surveys was due to agricultural practices exposing bare soils in areas with high slopes in the early 1900s.

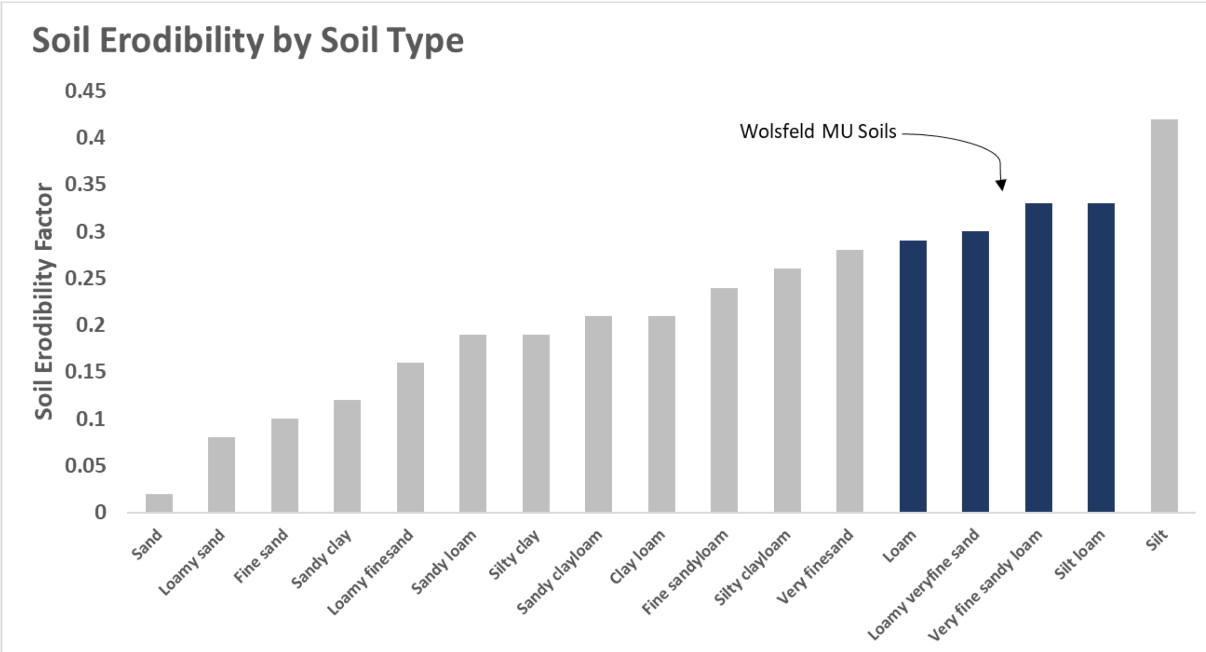


Figure 3-7 Erodibility of soils within the Wolsfeld Management Unit

Many of the areas where erosion began in the early 1900s have been revegetated, however, the highly erodible soils and steep slopes in the Wolsfeld MU have resulted in continued ravine and gully erosion. Areas that have been identified as having active erosion will likely need some level of slope stabilization or best management since have continued to erode despite revegetation between 1940 and today (Figure 3-8 and Figure 3-9; Table 3-2). Conversely, there are several areas where ravines are no longer active, which suggests that there are areas where revegetation has slowed or stopped ravine downcutting, which may not require future restoration actions (Table 3-2).

Channel Erosion Drivers

There appears to be some level of erosion at each of the four stream sections within the Wolsfeld MU with the reach just upstream of Wolsfeld Lake having the most severe downcutting. Channel erosion, unlike surface erosion, is primarily driven by increased runoff rates that causes greater stream velocities and shear stress resulting in downcutting. Therefore, the first dataset to investigate is the water yield (inches of runoff/year) from each minor subwatershed within the Wolsfeld MU to determine if excess runoff could be an issue in stream channels in Wolsfeld MU (Figure 3-10).

Watershed modeling results indicated that water yield from minor subwatersheds in the Wolsfeld MU were equal or less than predevelopment water yields in Minnesota for forested areas with C soils (5 in/yr; Figure 3-10). These results are consistent with relatively low amount of channel erosion occurring in three of the four stream reaches within the Wolsfeld MU.

The most dramatic channel erosion occurring within the final stream reach just upstream of Wolsfeld Lake based on field investigations and the longitudinal stream/lake elevation analysis. The drivers of this erosion are unclear, however, the presence of highly erodible soils in the MU combined with agricultural practices that were historically in close proximity to the stream channel appear to be the most likely factors.

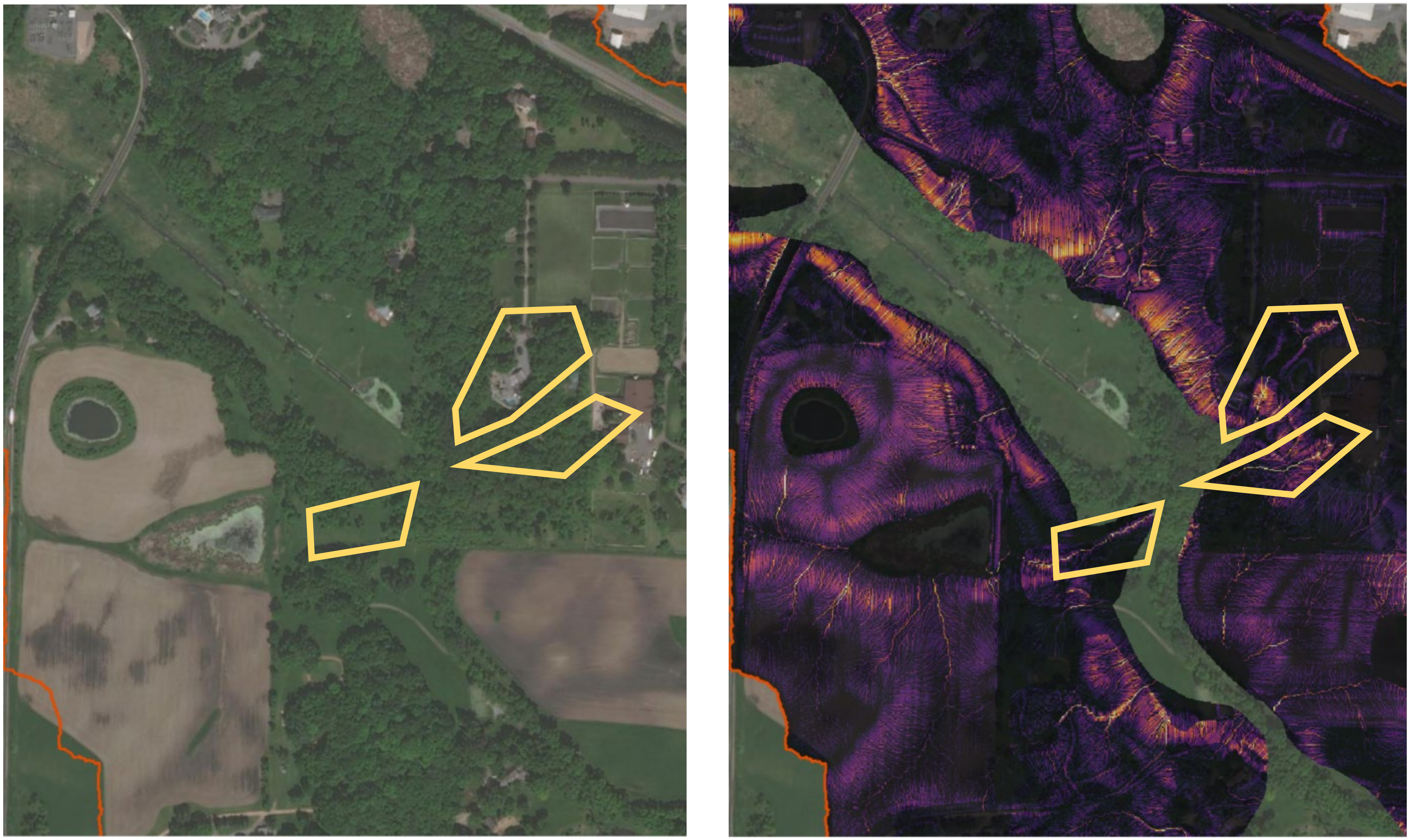


Figure 3-8 Current aerial photos of the areas downstream of Willow Rd. with erosion that has been field verified (left) and aerial photos with the USLE output overlay (right). Yellow polygons have been added to identify the areas of erosion.

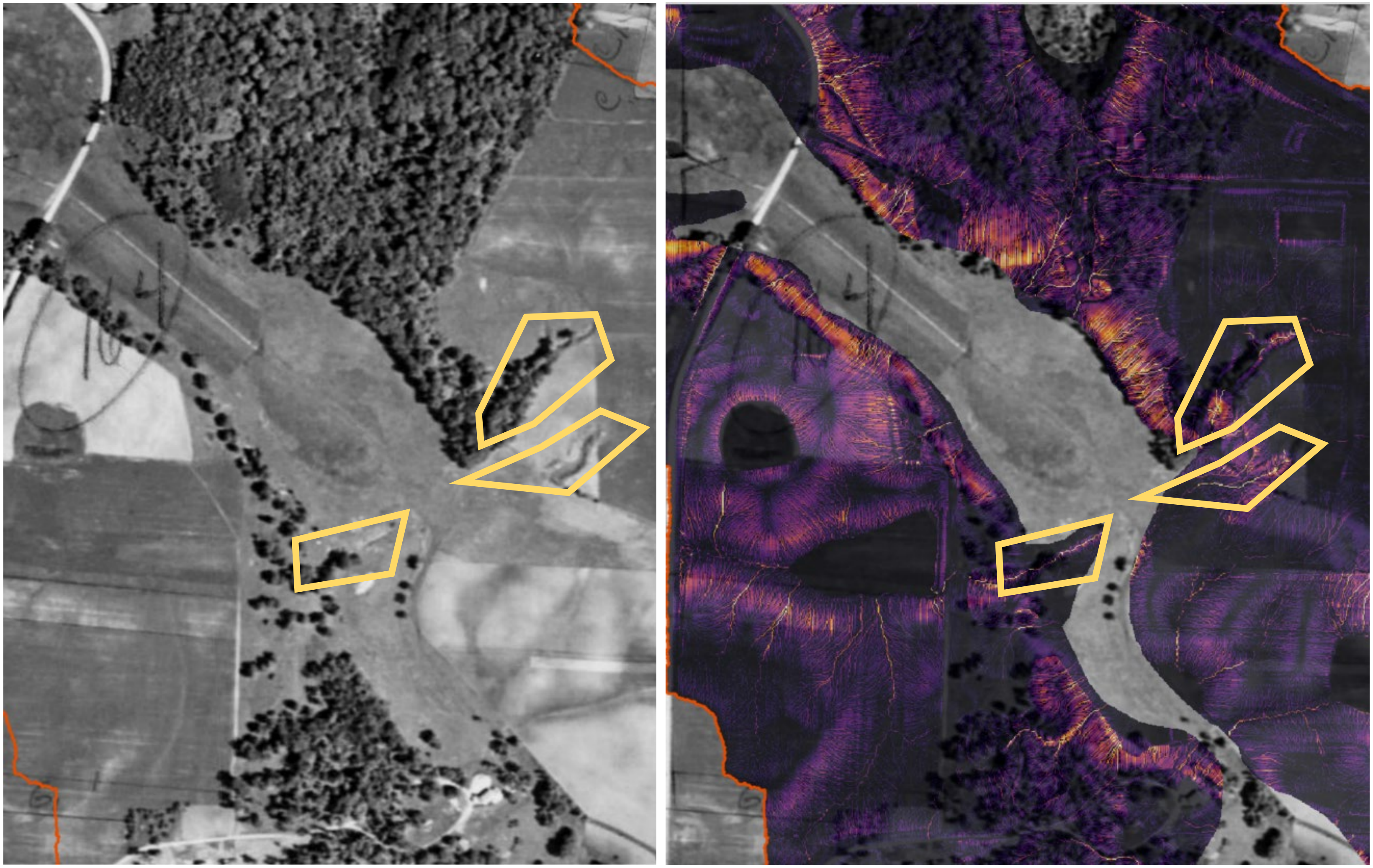


Figure 3-9 Historical photos from 1952 aerial photos of the areas downstream of Willow Rd. with erosion that has been field verified (left) and aerial photos with the USLE output overlay (right). Yellow polygons have been added to identify the areas of erosion where evidence of erosion can be seen from photos before forest has been re-established

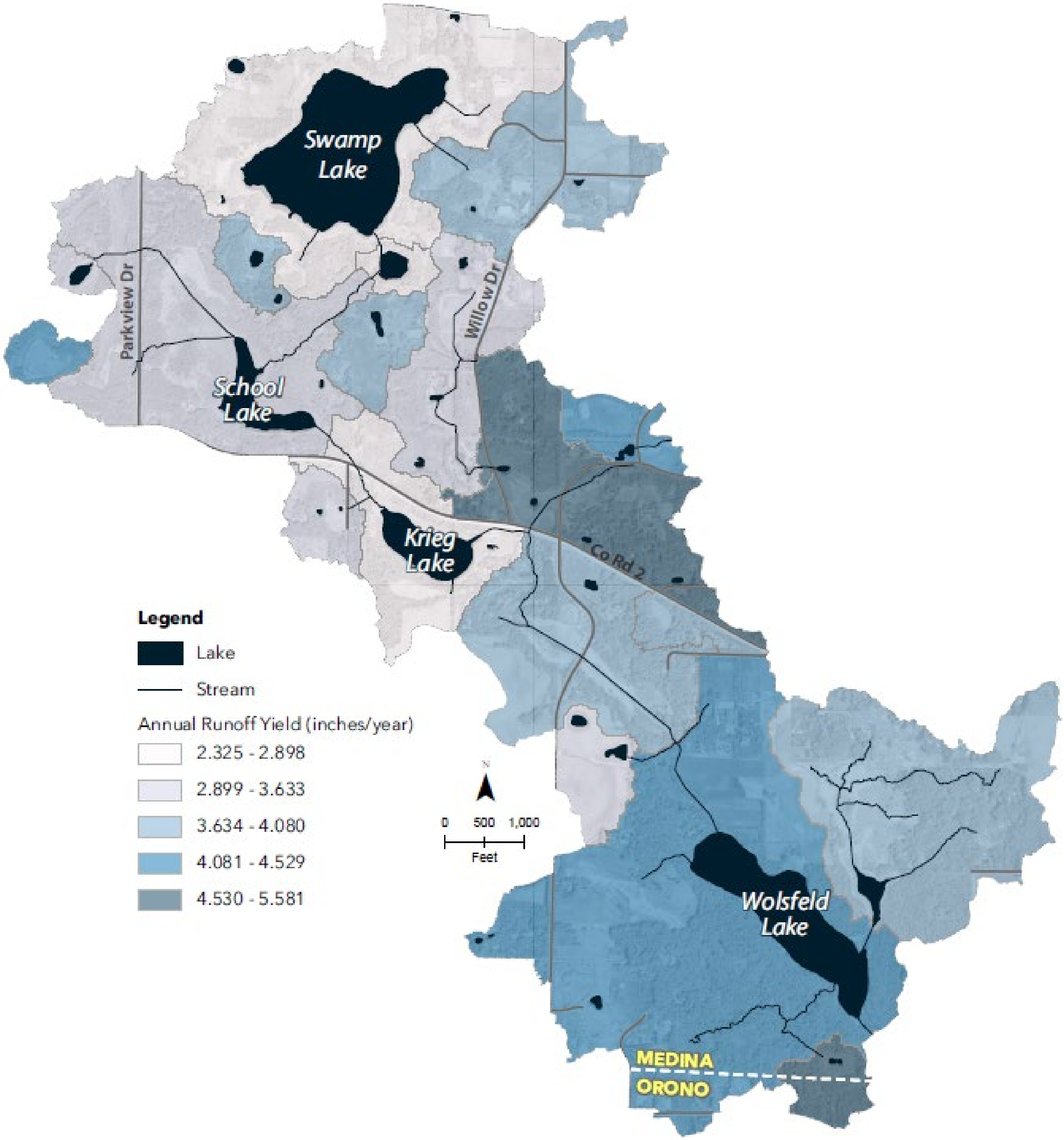


Figure 3-10 Annual water yield within the Wolsfeld Management Unit based on P8 model output

Overall, low runoff volumes within the Wolsfeld MU are very low due to very little impervious area and sufficient runoff storage from existing wetlands and lakes. However, erosion occurring within the stream reach just upstream of Wolsfeld Lake suggests that this MU is highly susceptible to channel erosion due to relatively steep slopes and highly erodible soils. Therefore, slight increases in impervious areas and subsequent runoff from future landuse development within the Wolsfeld MU may have disproportionately large impact on channel erosion causing further degradation of in-stream and lake water quality conditions.

3.1.3.3 Wetlands

Storage

Wetlands cover approximately 27% of the Wolsfeld MU based the FAW (Figure 3-11), which is close to the pre-settlement coverage in the state of Minnesota (~35%) (Anderson and Craig, 1984). This area is relatively undeveloped and likely has retained many of its wetlands that provide storage for stormwater runoff. The low annual water yield estimates (Figure 3-10) within the watershed suggest that wetland storage, in combination with low impervious areas, in the Wolsfeld MU are providing beneficial flood and nutrient reduction to lakes within the subwatershed and downstream water bodies such as Long Lake.

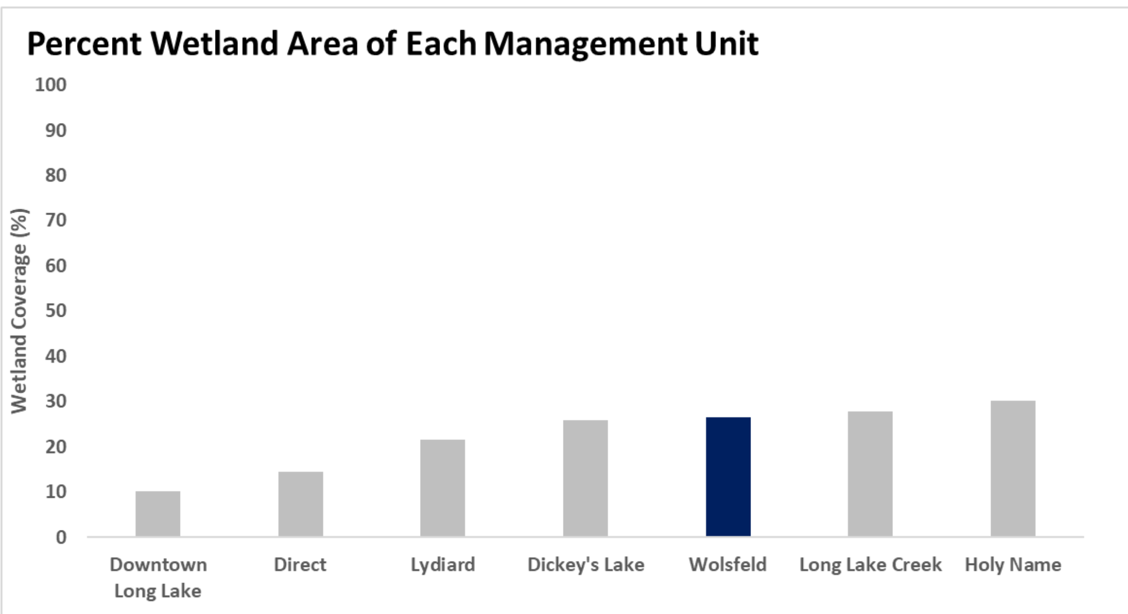


Figure 3-11 Percentage area of management unit covered by wetlands

Vegetation Diversity

Wetland vegetation diversity spans a large range within the Wolsfeld MU with most wetlands (74%) having low or moderate vegetation diversity based on the FAW (Figure 3-12). These data suggest that elevated watershed nutrient runoff and changes in hydrology have negatively impacted wetland vegetation, which is a well-established phenomenon that has been well documented in literature (EPA 2002). Species that are tolerant to environmental change such as cattail (*Typha latifolia L.)* and reed canary grass (*Phalaris arundinacea)* can outcompete other intolerant wetland plant species as human driven watershed runoff enriches soil nutrients and changes wetland water levels.

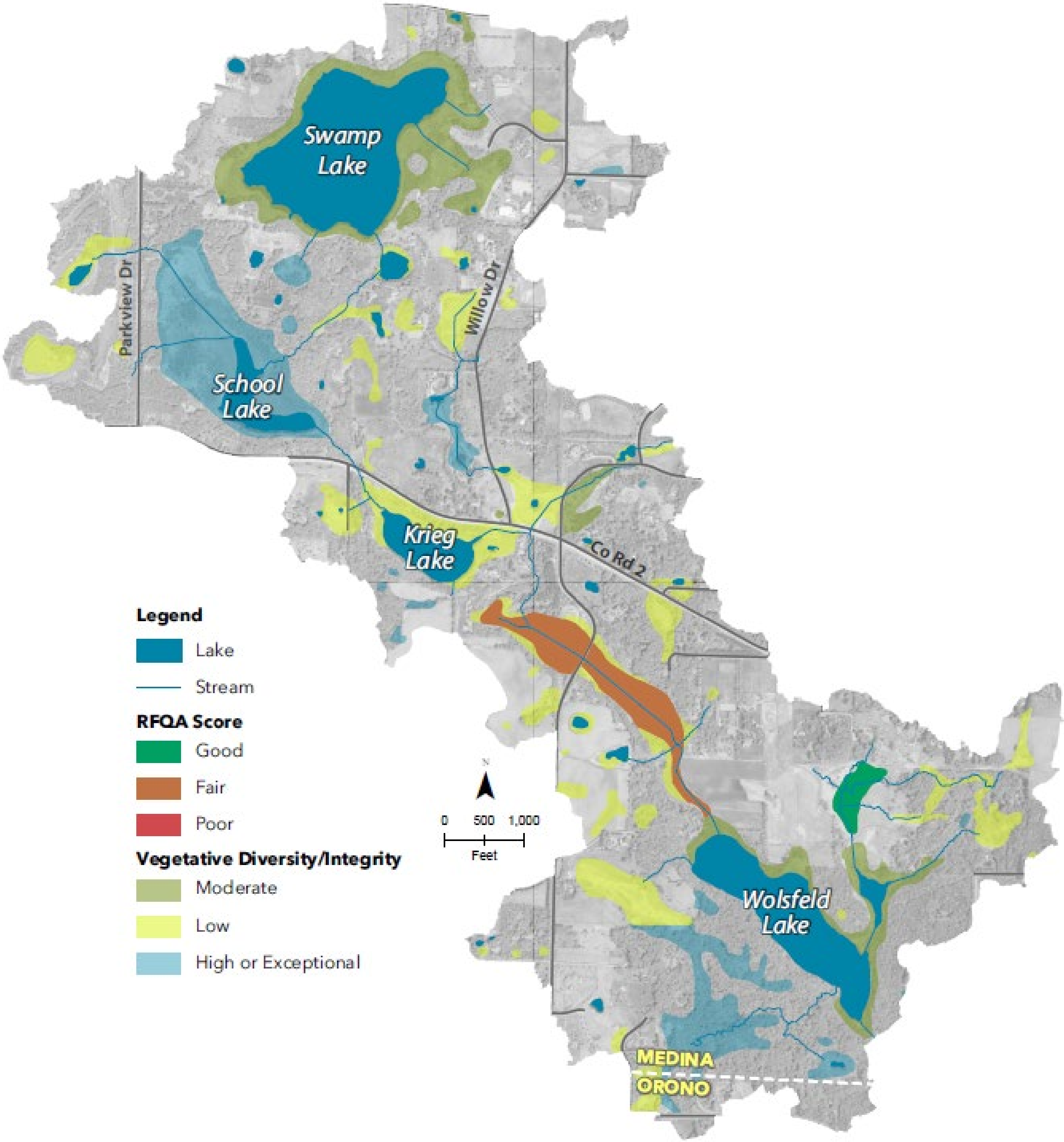


Figure 3-12 Wetland vegetation diversity based on the FAW throughout the entire MU and individual RFQA wetland assessments conducted in 2019.

Wetland Nutrient Cycling

Initial water quality monitoring at Willow Creek Rd. and just upstream of Wolsfeld Lake suggested that phosphorus loading increased by approximately 45 pounds per year. MCWD staff and Stantec staff investigated the wetland to identify its hydrologic and nutrient conditions. During this investigation it became clear that erosion was the most likely factor causing elevated phosphorus concentrations due to two primary reasons:

1) The annual phosphorus contributions from erosion were approximately 30-50 pounds per year, which represents the net increase observed in water quality monitoring data
2) The wetland appears to have a low level of water inundation and is ditched, which decrease its likelihood of contributing phosphorus through subsurface flow.

Further investigation could be conducted to rule out this wetland as a potential source of phosphorus due to historic nutrient loading from watershed runoff. However, the probability of the wetland being a source is low since the elevated nutrient loading in this area can be explained based on erosion processes.

3.1.4 In-Lake Assessment

3.1.4.1 Internal Phosphorus Loading from Sediment Release

MCWD staff collected sediment cores in each lake within the Wolsfeld MU to characterize the amount of phosphorus that is release under anoxic conditions. Internal loading estimates using the sediment release rates and dissolved oxygen profiles revealed that sediment phosphorus release is relatively high in School, Krieg, and Wolsfeld Lake compared to sediment release rates collected in other lakes throughout Minnesota (Figure 3-13). Swamp Lake sediment release rates were much lower than other lakes within the management unit, which suggests that the impact of internal phosphorus loading in Swamp Lake is relatively low (Figure 3-13).

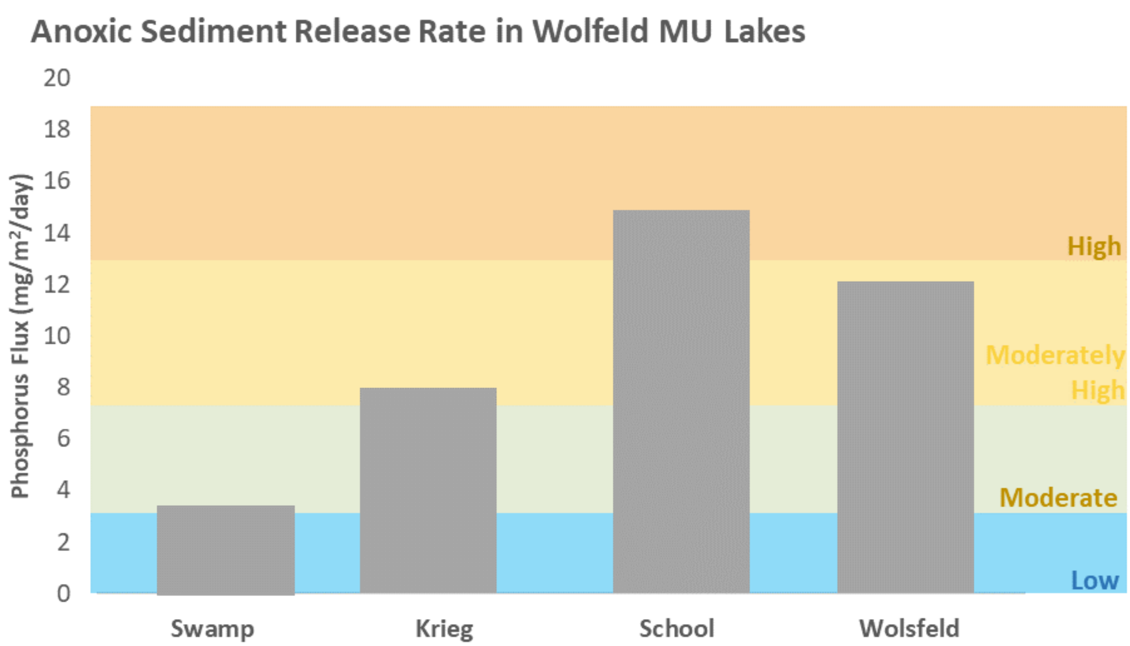


Figure 3-13 Sediment phosphorus release rate for each lake in the Wolsfeld Management Unit.

The other factor to consider for internal loading is the amount of time and the total area that the sediment is exposed to anoxic conditions, which is referred to as the anoxic factor. Both School Lake and Wolsfeld Lake are dimictic, which means that they mix vertically twice per year (Appendix D). Both also have dissolved oxygen data to characterize the stratified period of low oxygen (Appendix D), which corresponds to increasing phosphorus concentrations in the hypolimnion during summer months (Figure 3-14). In 2017, the hypolimnetic phosphorus concentration decreases dramatically in October, which corresponds to the highest chlorophyll-a concentration (Figure 3-14). This demonstrates how the period of mixing phosphorus enriched hypolimnetic water with surface water results in elevated chlorophyll-a concentrations (Figure 3-14).

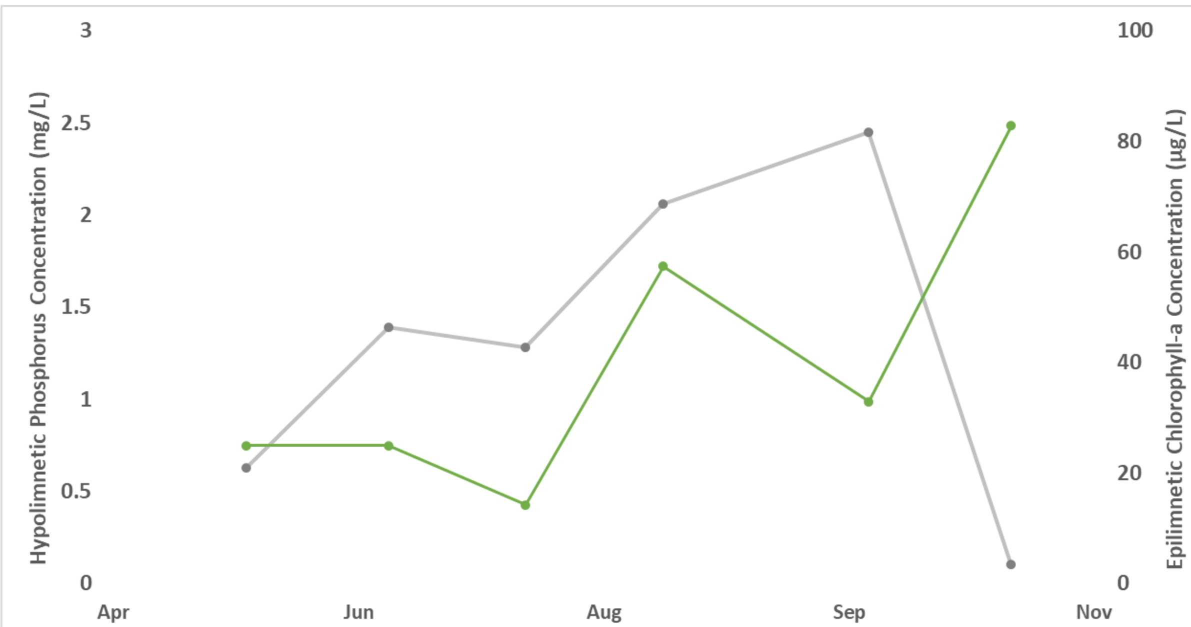


Figure 3-14 Average monthly hypolimnetic phosphorus concentration in 2017 (grey) and epilimnetic chlorophyll-a concentrations.

This results in low oxygen concentrations in the warmer months that results in elevated phosphorus concentrations in the hypolimnion that drive late season (August and September) algal blooms ()

3.1.4.2 Lake Submerged Aquatic Vegetation

Submerged aquatic vegetation (SAV) surveys were conducted in Swamp, School, Krieg, and Wolsfeld lakes in 2019 to characterize the vegetation community (Figure 3-15). The results from these surveys demonstrated that the macrophyte community in each lake is dominated by coontail, which is a native plant that is tolerant of poor water quality conditions (Appendix E). The Floristic Quality Index (FQI) analysis provides a quantitative framework for the point intercept data, which categorizes all of the lakes with degraded or poor vegetation communities with very low species diversity due to non-native and/or tolerant species (Figure 3-15).

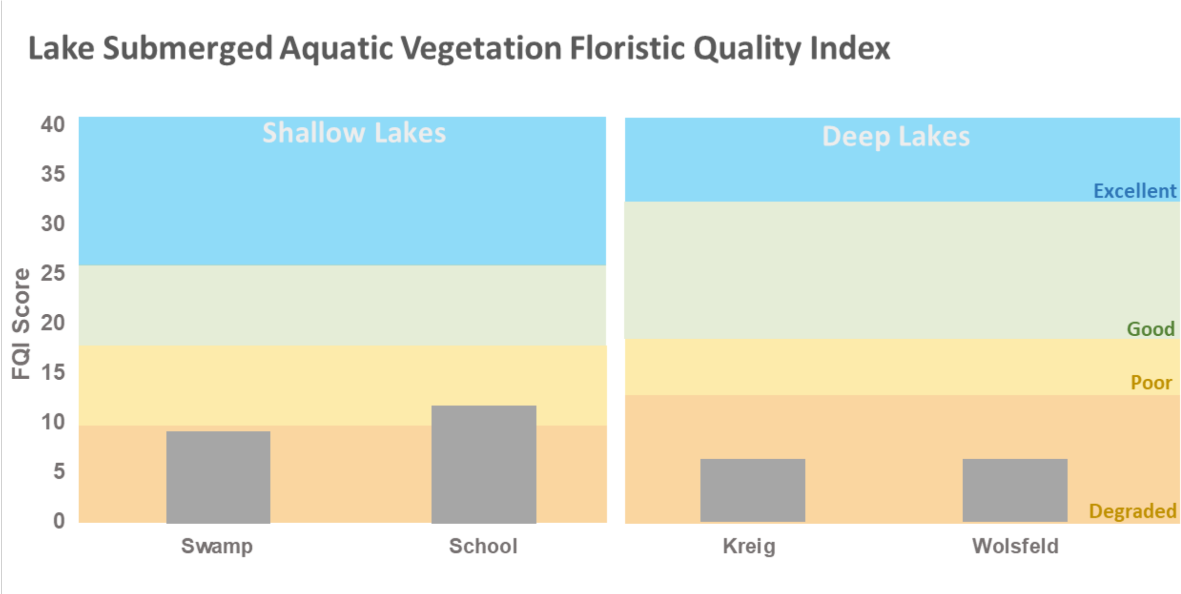


Figure 3-15 Vegetation results compared to Floristic Quality Index

3.1.4.3 Fisheries

Condition

The Minnesota Department of Natural Resources (MnDNR) has developed a classification system for Minnesota lakes that characterizes what fish should be present based on a lake's chemical and physical properties. The lake classifications for Swamp Lake, School Lake, Krieg Lake, and Wolsfeld Lake are located in Table 3-4 that lists the primary fish species that should exist in each lake based on its designated classification. Overall, the lake classification suggests for each lake in the Wolsfeld MU suggests that no species sensitive to poor water quality (intolerant species) are likely to be observed and tolerant species such as Black Bullhead are expected due to the poor water quality conditions of all lakes in the Wolsfeld MU (Table 3-4; Figure 3-2).

Table 3-4 MnDNR lake class based on lake morphomentry and water quality conditions.

Lake	DNR Lake Class	Primary Fish Species Expected	Secondary Fish Species Expected
Swamp	44	Black Bullhead*, Bluegill, Black Crappie	Pumpkinseed
School	36	Northern Pike, Black bullhead*, Bluegill	Pumpkinseed, Black Crappie, and Yellow Perch
Krieg	30	Northern Pike, Black bullhead*, Bluegill	Yellow bullhead, Pumpkinseed, Black Crappie
Wolsfeld	36	Northern Pike, Black bullhead*, Bluegill	Pumpkinseed, Black Crappie, and Yellow Perch

* Fish that are tolerant of degraded habitat conditions

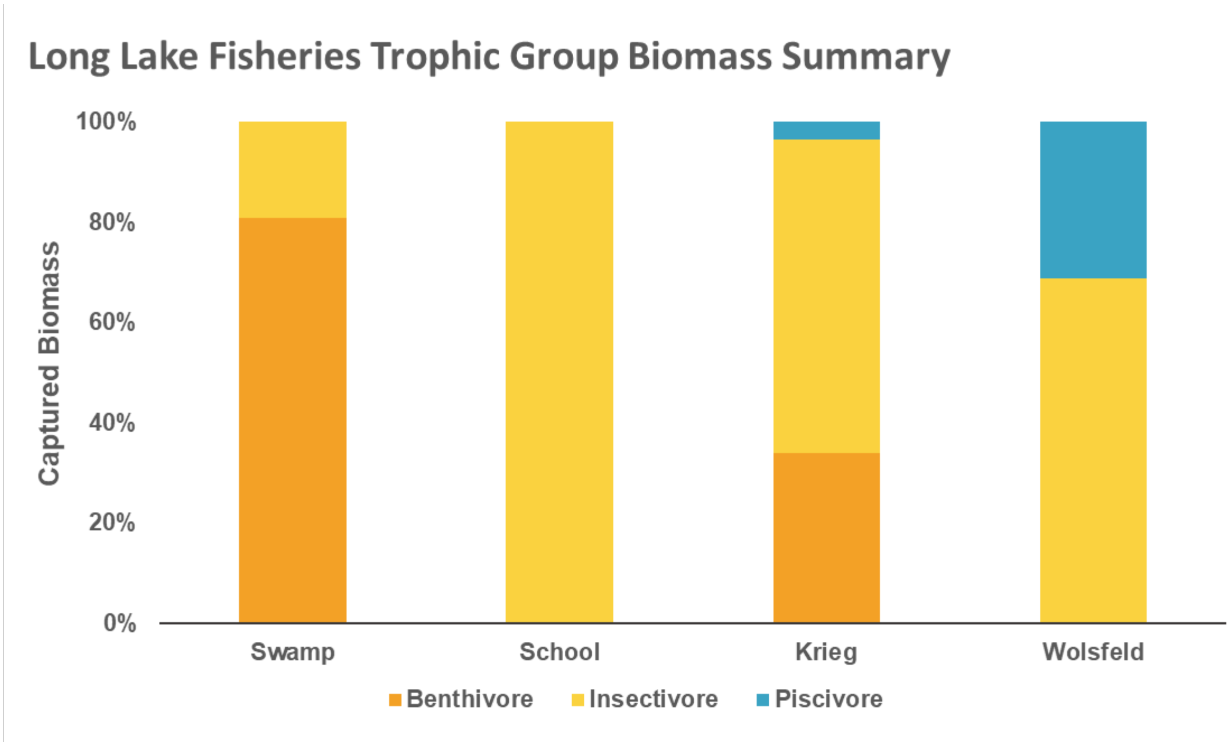


Figure 3-16 Fisheries biomass summary by trophic group for the Wolsfeld management unit.

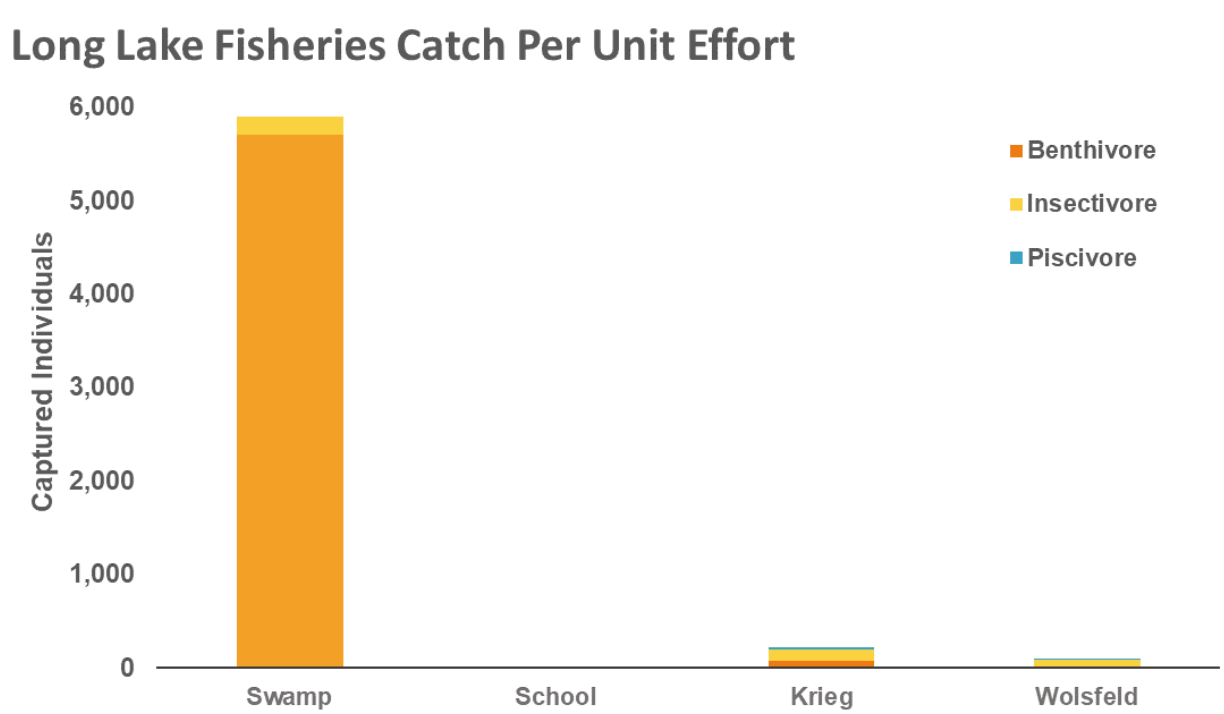


Figure 3-17 Fisheries CPUE individual summary by trophic group for the Wolsfeld MU

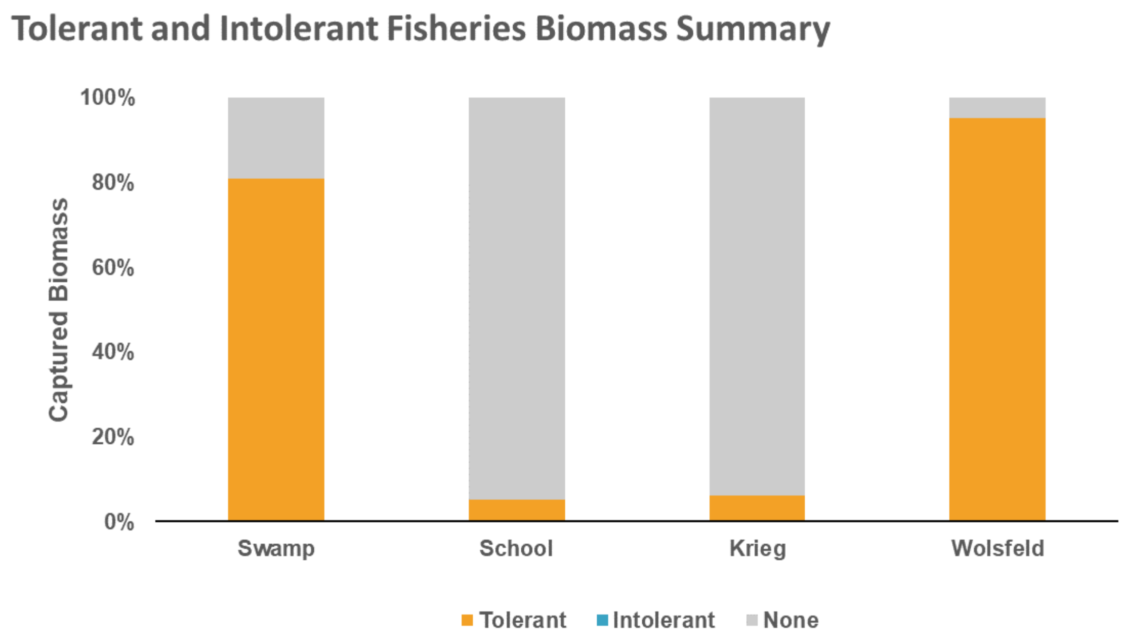


Figure 3-18 Fisheries biomass summary of tolerant and intolerant fish observed in the Wolsfeld MU

Lakes within the Wolsfeld MU have not been sampled using the fish index of biological integrity (IBI), which is a method used to characterize the health of the lake based on the fish species that are present. However, we can compare the relative abundance of fish species that are sensitive to poor water clarity and habitat conditions (intolerant fish) relative to fish species that thrive in poor water clarity and habitat conditions (tolerant fish). There were no sensitive species observed in any of the lakes within the Wolsfeld MU. Furthermore, Swamp and Wolsfeld appear to be dominated by tolerant species including black bullhead, fathead minnow, and common carp (Figure 3-18). These results are consistent with the species expected for each lake based on MnDNR lake classes, which suggests that poor water clarity due to excess watershed phosphorus loading is the primary driver of a degraded fish community.

Carp Biomass Assessment

Two methods were used to 1) identify if carp are present in each lake of the Wolsfeld MU and 2) characterize the total biomass of carp in lakes, where access was possible, if carp have been observed. MCWD's trap net assessments did not result in any observations of common carp within Swamp, School, and Krieg Lake. MCWD also reviewed historic MnDNR surveys on School and Wolsfeld lake (MnDNR 1979 and MnDNR 1960) and scientific literature to identify if other fish surveys on these lakes had observed carp. The only lake within this management unit where carp have been observed in the past 50 years was Wolsfeld Lake.

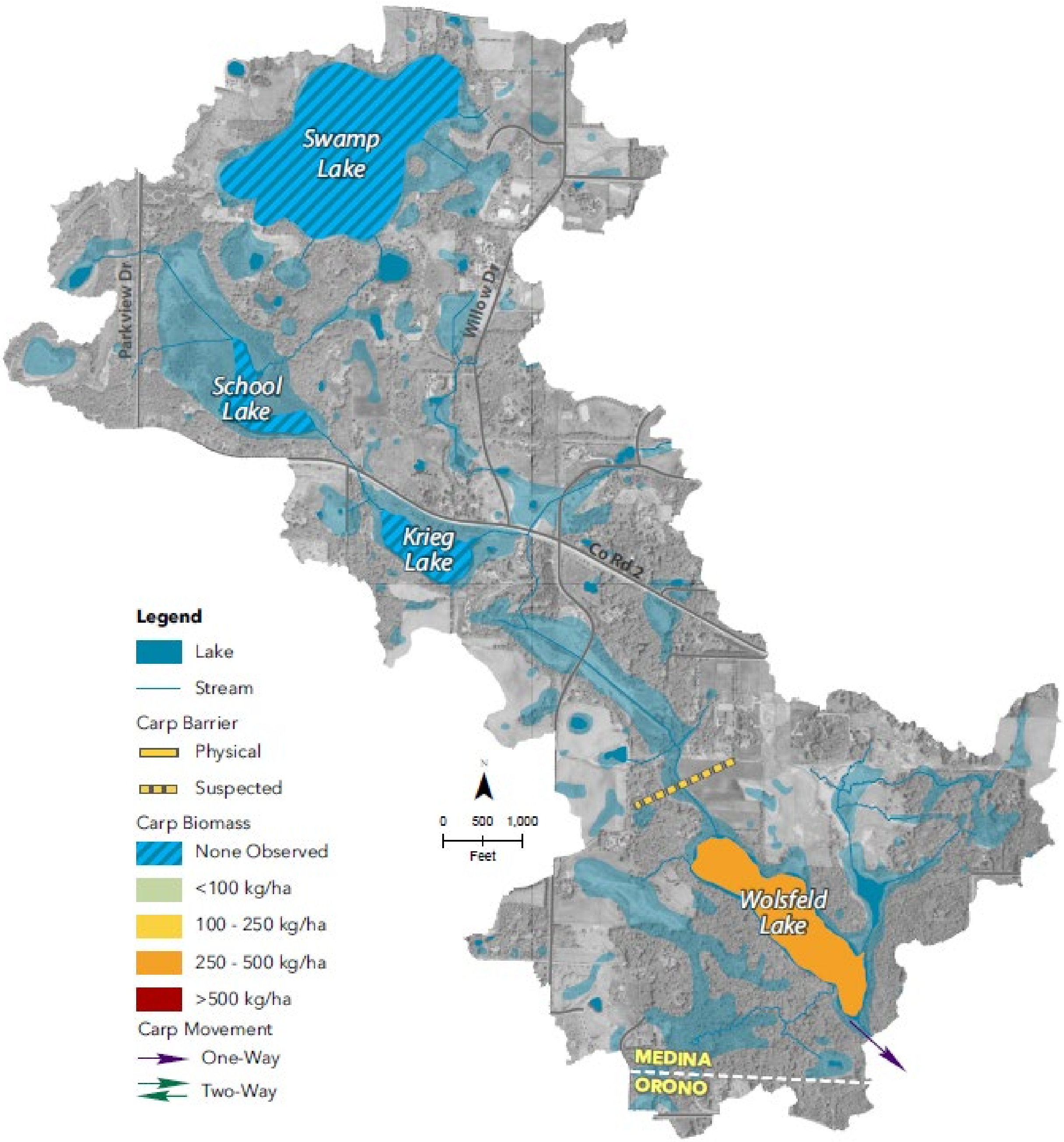


Figure 3-19 Carp movement and movement overview for the Wolsfeld Management Unit.

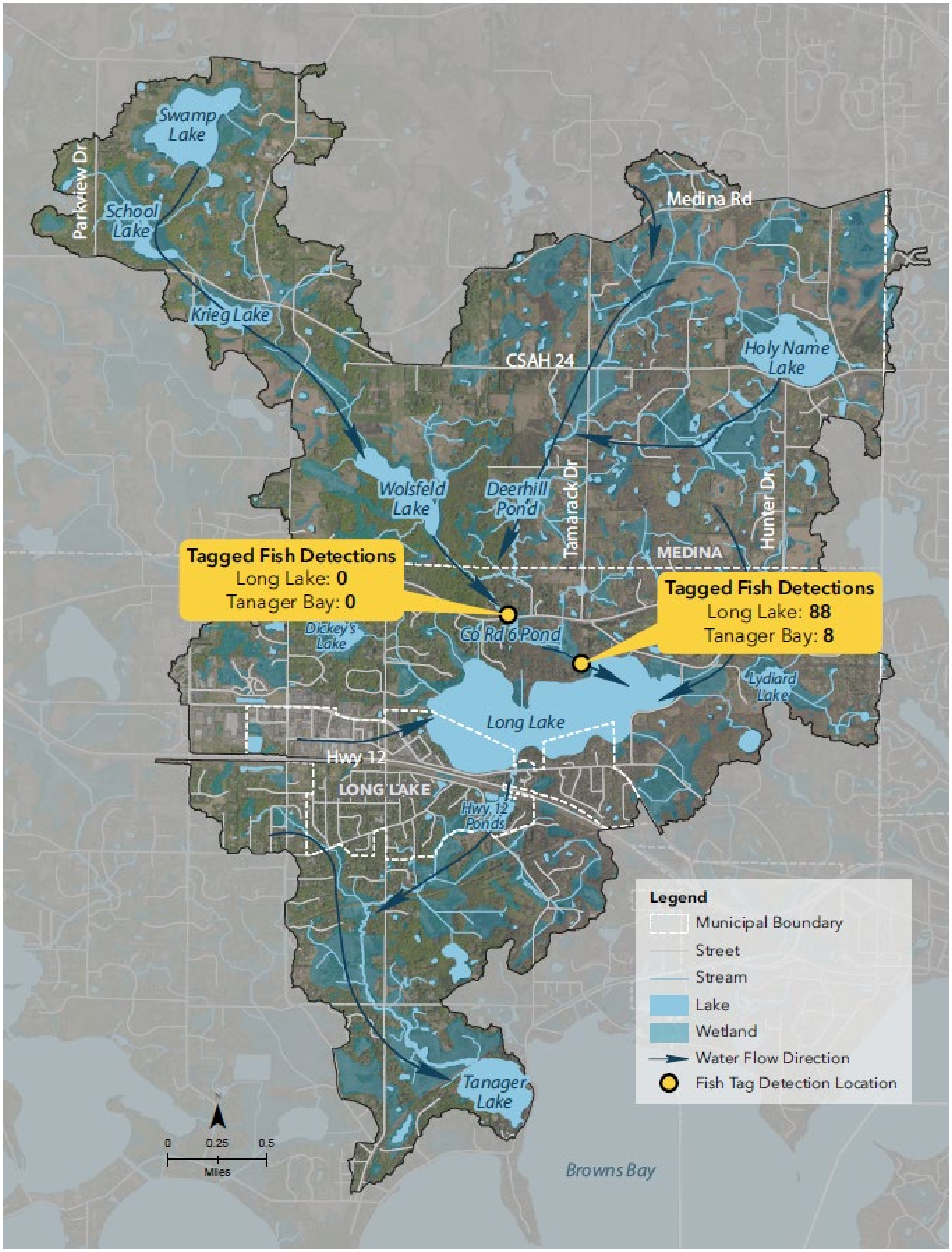


Figure 3-20 Carp movement monitoring locations located just downstream of the Wolsfeld MU to identify if carp can freely migrate to and from

WSB staff conducted two carp electrofishing biomass assessments on Wolsfeld Lake to quantify the total population in the lake. The biomass estimate from the 2019 and 2020 carp biomass surveys were 396 kg/ha and 451 kg/ha, respectively. These biomass results are well above the 100 kg/ha threshold in which carp may negatively impact ecological conditions due to benthic foraging (Bajer et al. 2009). With that being said, the benthic area in Wolsfeld Lake is relatively small (<20%), which limits the potential impact on lake sediments compared to shallow lakes where sediment resuspension would have a larger impact due to the large littoral areas (80% or higher). Further discussion about the impact of carp on Wolsfeld Lake will be discussed in the Biological Influence on Nutrient Cycling section.

The carp movement and age assessment provided valuable insight into the source of carp in the Wolsfeld MU. The pit tag assessment suggested that carp cannot migrate into Wolsfeld Lake from Long Lake, since no carp originally tagged in Long Lake or Tanager Lake were detected upstream of the County Road 6 pond even though there were a high number of detections of carp from Long and Tanager Bay detected downstream of the County Road 6 Outlet (Figure 3-21). Overall, it appears that carp can move into areas near the outlet of the County Road 6 Pond, but the CR6 Pond Outlet serves as a barrier for carp passage into the Wolsfeld MU.

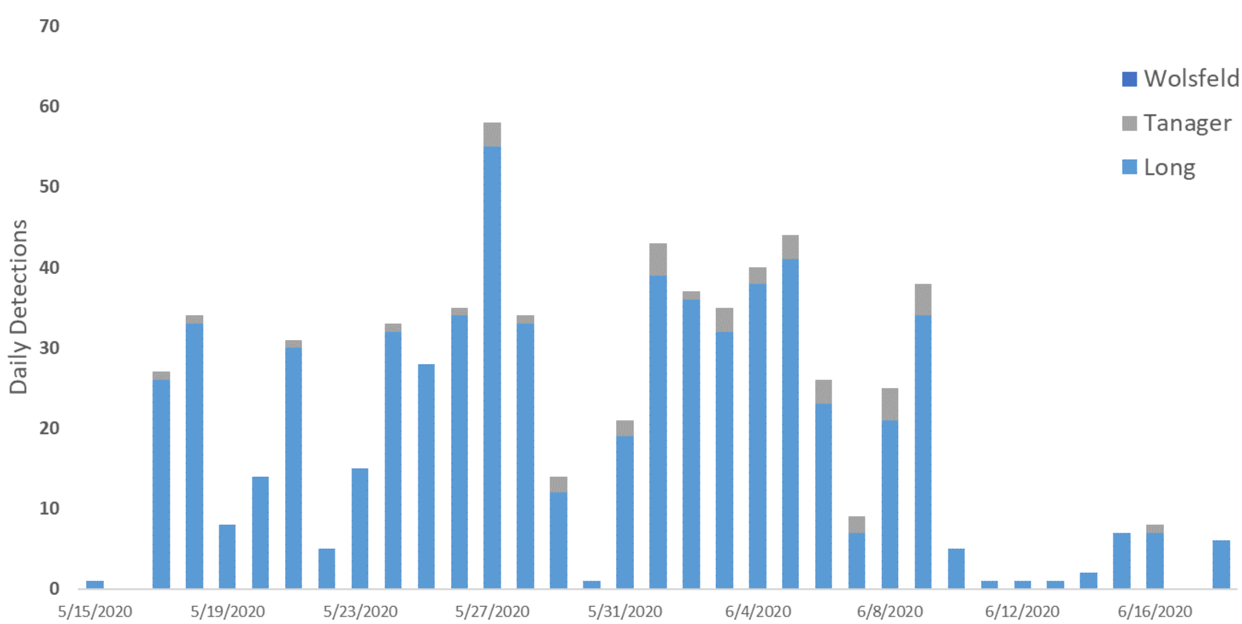


Figure 3-21 Daily detections of pit tagged carp at the County Road Six Pond outlet.

Another line of evidence to identify the source of carp within the Wolsfeld MU is carp age data (Figure 3-22 and Figure 3-23), which show that carp collected in Wolsfeld Lake are young (3-9 years) and that there is a notable absence of older individuals in Wolsfeld Lake (Figure 3-22). The population age of carp in Wolsfeld Lake, Long Lake, and Tanager Bay were compared using a Kruskal-Wallis test to determine if the there was a significant difference in median age among the three lakes (Appendix G). The results of analysis showed that there was a significant difference between median age of the three lakes. A pairwise Wilcoxon test was then used to identify which medians were different, which indicated that is a significant difference ($p < 0.05$) between Wolsfeld Lake and the other downstream lakes (Long and Tanager). Carp age data coupled with migration data provide strong evidence that the primary source of carp in Wolsfeld Lake is due to active recruitment in Wolsfeld Lake or a small wetland area directly connected to Wolsfeld Lake. Furthermore, these data also suggest that carp do not migrate into Wolsfeld Lake from Lake Minnetonka and Long Lake.

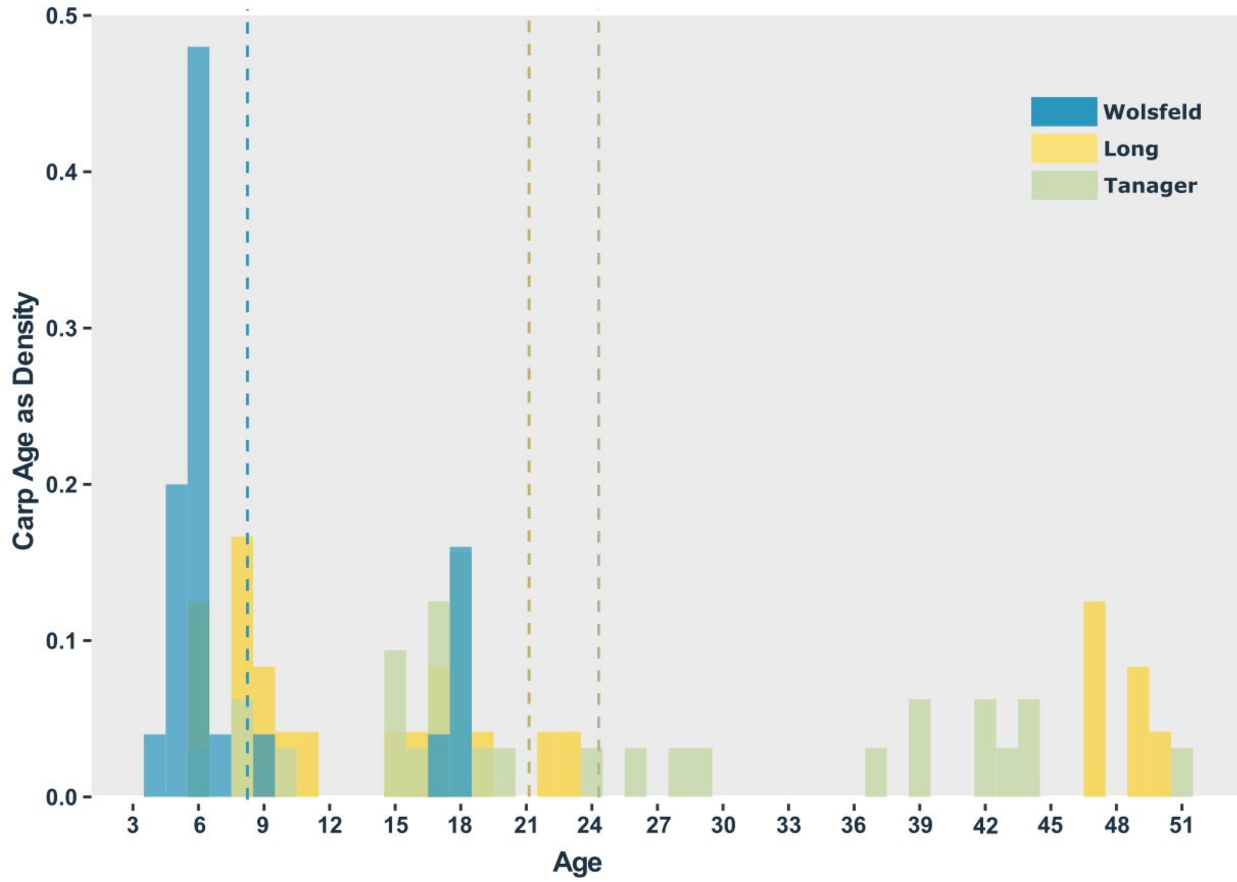


Figure 3-22 Age structure of common carp within the Wolsfeld MU

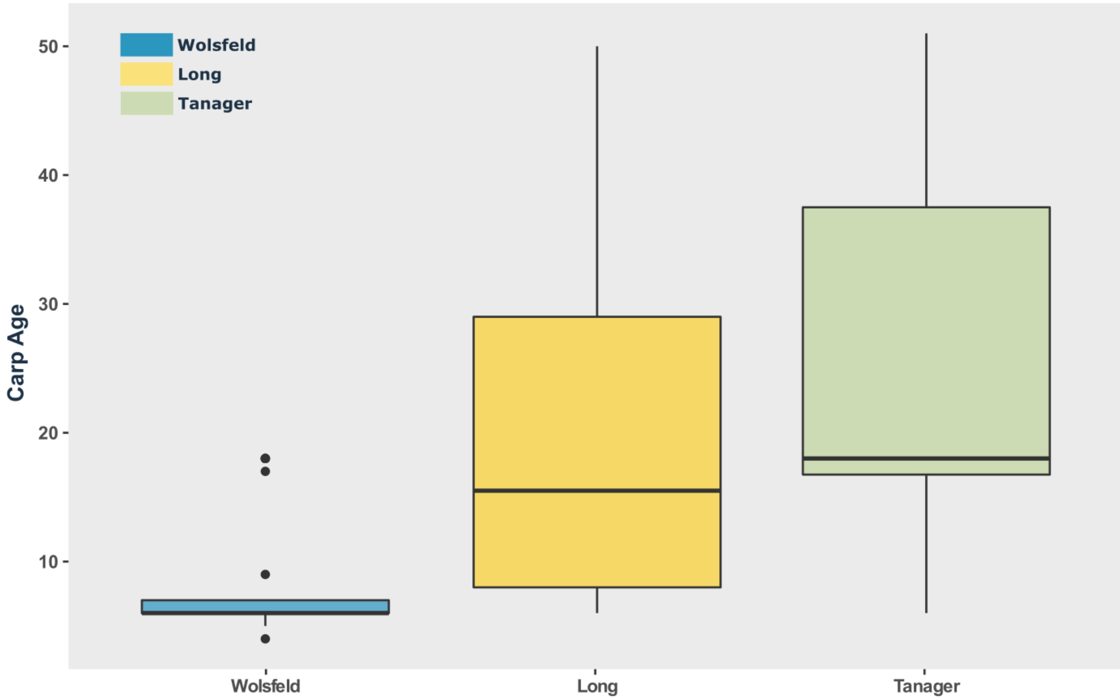


Figure 3-23 Boxplot of carp age of Wolsfeld, Long, and Tanager Lake

3.1.5 Lake Nutrient Budget

3.1.5.1 Watershed Loading

There are two primary types of watershed loading considered in this analysis including:

- **Watershed runoff:** Dissolved and particulate constituents associated with storm runoff events
- **Erosion:** The process in which mass wasting of soil from hillslopes or stream channels

Both of these processes deliver phosphorus to downstream lakes, which contribute to poor water quality conditions. Field estimates were developed for each type of erosion, which substituted a portion of the existing the empirically derived TMDL phosphorus budgets assumed that the empirically derived phosphorus budget developed in the TMDL implicitly included erosion processes.

School Lake

Watershed loading in the School Lake drainage area accounts for approximately half (100 lbs TP/yr) of the School Lake phosphorus budget (Figure 3-24). A small portion of the watershed loading is from channel erosion (7.2 lbs P/yr) based on field investigations, which suggests that the remaining phosphorus loading can be contributed to overland runoff processes.

There are not many opportunities for watershed projects in the School Lake drainage area for two reasons:

1) The area that drains to School Lake is relatively small and undeveloped.
2) Watershed runoff phosphorus concentrations are very low (90 ug/L; Figure 3-3) since the area is undeveloped and well vegetated.

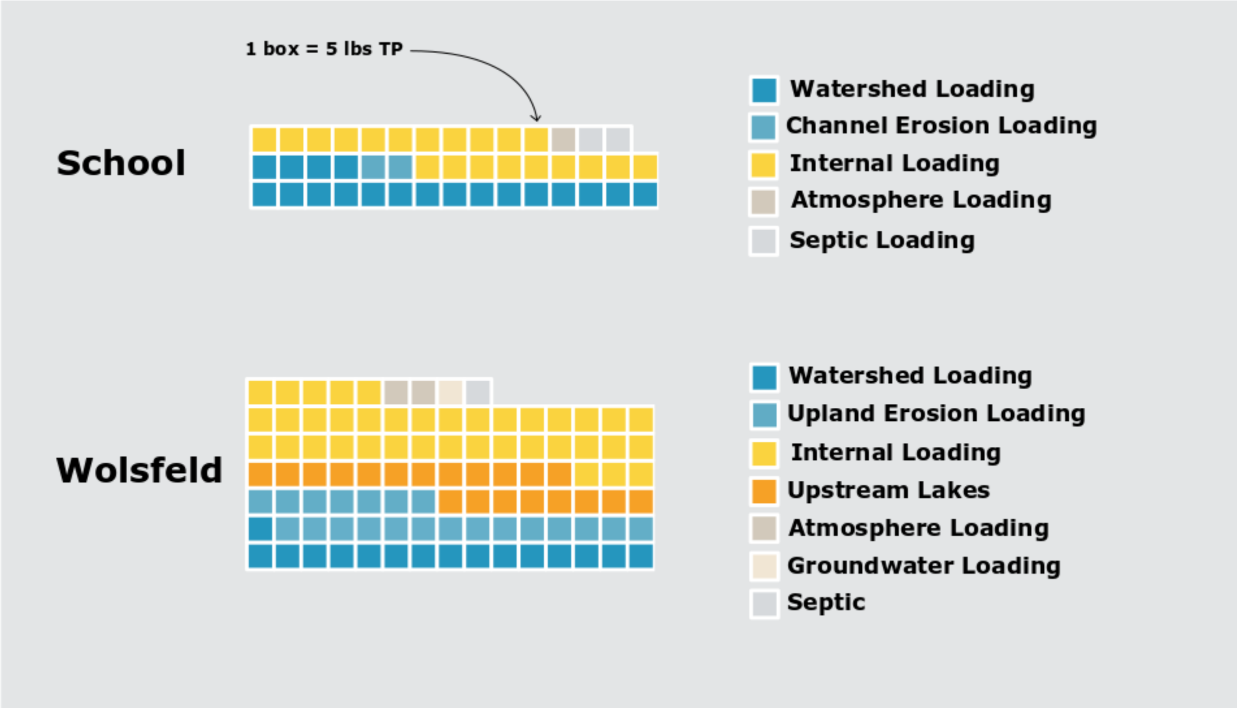


Figure 3-24 Phosphorus budgets for School Lake and Wolsfeld Lake

Wolsfeld Lake

Watershed loading in the Wolsfeld Lake drainage accounts for approximately 37% of the total phosphorus budget to Wolsfeld Lake (185 lbs P/yr; Figure 3-24). This drainage area has a variety of land cover, which include large lot residential, undeveloped, and agricultural. The greatest source of watershed loading in the Wolsfeld Lake drainage area appears to be upland erosion within the Wolsfeld Woods SNA and areas located between Krieg Lake and Wolsfeld Lake based on field derived phosphorus loading estimates using the BWSR erosion calculator (BWSR, 2019).

Another potential area of phosphorus loading includes in-channel erosion processes. A longitudinal cross section of the main channel and lakes within the Wolsfeld MU (Figure 3-6) suggests that channel erosion may be occurring in the stream section directly upstream of Wolsfeld Lake, which requires further field investigation to verify. However, this does not appear to the main source of phosphorus within the Wolsfeld Lake drainage area due to the relatively low gradient of the stream channel.

Lastly, watershed runoff concentrations are elevated in agricultural areas (Figure 3-3), however, the runoff volumes within this MU are quite low due to the very low amount of impervious surfaces (Figure 3-10). Therefore, watershed phosphorus loading (runoff concentration x runoff volume) is generally low in most areas within the Wolsfeld MU (Figure 3-4).

3.1.5.2 Internal Loading

Sediment phosphorus release rates were measured by collecting sediment cores in each impaired lake (School and Wolsfeld) to gain a more precise characterization of the impact of internal phosphorus loading on the overall nutrient budget (Figure 3-13).

School Lake

Sediment phosphorus release from sediments accounts for nearly half (47%) of the measurable total phosphorus load to School Lake (Figure 3-24) and is larger than the other two phosphorus loads (watershed and atmospheric) to School Lake combined. The elevated internal loading is driven by School Lake's elevated phosphorus release rate of 14.9 mg m^{-2} d^{-1}, which represents the highest release rate of any other lake in the Long Lake Creek Subwaterhed (8-15 mg m^{-2} d^{-1}; Figure 3-13).

Wolsfeld Lake

Sediment phosphorus release from sediments accounts for a majority (76%) of the measurable total phosphorus load to Wolsfeld Lake (Figure 3-24). The elevated internal loading is driven by Wolsfeld Lake's elevated phosphorus release rate of 12.1 mg m^{-2} d^{-1}, which represents the second highest release rate of any other lake in the Long Lake Creek Subwaterhed (8-15 mg m^{-2} d^{-1}; Figure 3-13).

3.1.5.3 Upstream Lakes

School Lake

The TMDL originally written for School Lake (Wenck, 2014) did not take into account upstream lake nutrient loading since the only upstream lake, Swamp Lake, is not impaired for excess phosphorus. Therefore, there is no assumption in the TMDL that upstream lake phosphorus reductions are necessary to meet water quality standards in School Lake.

However, MCWD's literature review and data collection efforts found that phosphorus concentrations in Swamp Lake are well above state standards (Figure 3-2). These findings provide two critical insights for School Lake including:

1) An explanation of why School Lake has elevated phosphorus concentrations when watershed landuse loading is relatively low
2) Evidence that restoration of Swamp Lake will be necessary for improving School Lake

Wolsfeld Lake

Krieg Lake is nearest upstream lake in the Wolsfeld lakeshed, however, it is not currently impaired for excess phosphorus, which is why the TMDL did not allocate load reductions for Krieg Lake. The next upstream lake, School Lake, was identified in the 2014 TMDL as the nearest upstream lake that is impaired for excess phosphorus (Wenck, 2014). The TMDL assumes that meeting phosphorus standards for School Lake would result in a 63 lbs TP/yr reduction for Wolsfeld Lake (Figure 3-24).

3.1.5.4 Watershed Storage and Phosphorus Removal Capacity

The Wolsfeld MU has many intact wetlands and small ponds that serve as treatment in most areas of the watershed (Figure 3-3). These wetlands provide phosphorus removal capacity to drainage areas that have prevented even poorer water quality conditions within the lakes of this management unit. Overall, this management unit does appear to have ample storage based on the modeled water yields (Figure 3-10), however, more treatment in areas with agricultural runoff would likely improve water quality conditions within School Lake, Krieg Lake, and Wolsfeld Lake.

3.1.5.5 Biological Influences on Nutrient Cycling

All lakes within the Wolsfeld MU have benthic feeding fish species (Figure 3-16 and Figure 3-19), however, the majority of lakes within the Wolsfeld MU are deep lakes. Therefore, the impact of sediment resuspension on these lakes is likely minor since benthic fish will forage in the littoral area of the lake, which is relatively small on deep lakes (<20% of lake area). The only lake that is shallow and has a high number of benthivores is Swamp Lake, which have an extremely high number of black bullhead based on trap net surveys conducted in 2019 and 2020 (Figure 3-17). Therefore, Swamp Lake appears to be the only lake where sediment resuspension by benthivores may be having a measurable impact on phosphorus cycling.

Another line of evidence to characterize the impact of biology on phosphorus cycling is comparing modeled lake phosphorus concentrations relative to measured phosphorus concentrations. For example, lake models were able to accurately predict phosphorus concentrations in School and Wolsfeld based on watershed loading and sediment phosphorus release inputs, which suggest that physical process are governing phosphorus cycling. Conversely, lake modeling was unable to replicate phosphorus concentrations in Swamp Lake based on the nutrient loading inputs which suggests that other process such as wind driven resuspension or sediment resuspension by black bullhead are coming into play.

3.2 Holy Name Management Unit

3.2.1 Watershed Description

The Holy Name Management Unit (Holy Name MU) encompasses 1,670 acres and represents the northeast drainage area of the subwatershed. It is located primarily in the City of Medina and includes a small portion of the City of Plymouth. The headwaters of the Holy Name Management unit begin in Holy Name Lake, which is currently impaired for excess nutrients (Figure 3-25 and Table 3-5). The outlet of Holy Name Lake flows northwest through a series of large wetlands and ultimately exits the MU through a stormwater pond owned by MCWD (Figure 3-25). The Holy Name MU is unique for its abundance of large and small wetlands (Figure 3-25). Land use consist primarily of undeveloped areas, single-family residential, and agricultural areas.

Table 3-5. Holy Name Management Unit lake morphometry, impairment status, and DNR Lake Class

Lake	Surface Area (acre)	Maximum Depth (ft)	Lake Volume (ac-ft)	Percent Littoral Area (%)	Impairment Status	DNR Lake Class
Holy Name	70.0	8	340	100	Impaired	44

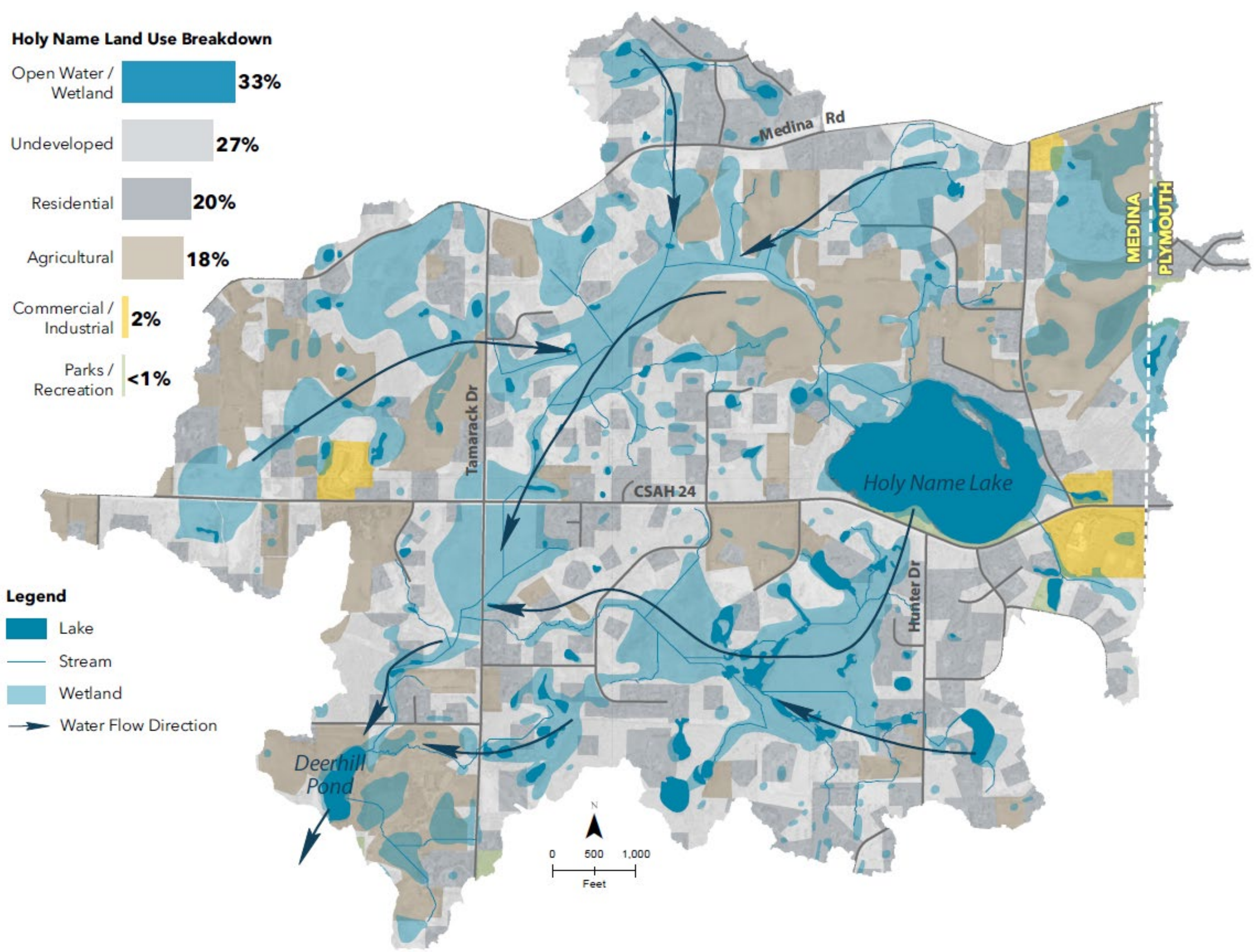


Figure 3-25. Holy Name Management Unit overview including flowpaths, major water bodies, and landuse (Source: MLCCS).

3.2.2 Water Quality Overview

Stream and lake total phosphorus concentrations from 2019 were evaluated to characterize the water quality conditions in the Holy Name Management Unit to assess how total phosphorus concentrations change throughout the subwatershed (Figure 3-26). Other data were available, however, it is useful to look at a single year if data is available at all monitoring sites since it provides a snapshot of how total phosphorus concentrations change under one climatological and hydrological regime. These data have been arranged from the uppermost stream monitoring location (Holy Name Lake) to the outlet of the management unit located just downstream of Deerhill Pond (Figure 3-26). Total phosphorus concentrations in all lakes and streams exceed total phosphorus standards set by the State of Minnesota (0.06 mg/L for shallow lakes; 0.1 mg/L for streams). Appendix A contains more detailed lake and stream water quality data that includes trends based on annual averages.

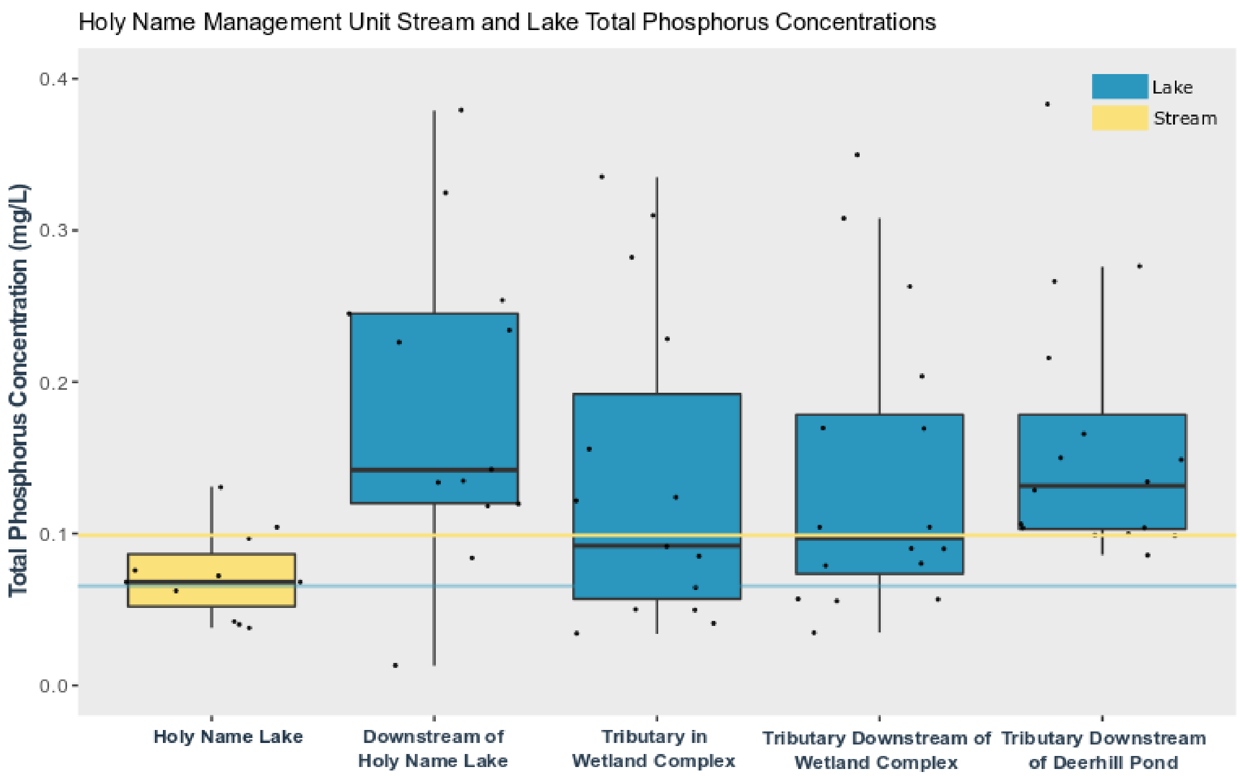


Figure 3-26. Lake (blue) and stream (yellow) total phosphorus concentrations in the Holy Name Management Unit from upstream (left) to downstream (right). Holy Name Lake is shallow enough that it qualifies as a wetland, which means lake standards are not used to identify if Holy Name Lake is impaired for excess nutrients.

Water quality conditions within Holy Name Lake, the uppermost sampling location, indicate that phosphorus concentrations are near state standards for shallow lakes. However, water quality conditions in the late 2000s were much worse (Figure 3-27) than conditions between 2014 and 2018, which suggest that Holy Name Lake is flipping between a turbid and clear shallow lake state. Further discussion of potential drivers of the drivers of shallow lake water quality will be discussed in the in-lake assessment for Holy Name Lake.

Total phosphorus concentrations downstream of Holy Name Lake increase, but begin to decrease in-between and downstream of the large wetland complex. Overall, stream total phosphorus concentrations are near or meeting total phosphorus standards for streams, which suggests that the large number of wetlands is providing treatment for elevated runoff from agricultural and residential landuse (Figure 3-26). Median concentrations of total phosphorus increase slightly between the outlet of the final wetland and downstream of Deerhill Pond (Figure 3-26). However, the increases are relatively small and may be due to runoff downstream of Deerhill pond since pond-specific monitoring has shown that the pond is still effectively removing phosphorus (Figure 3-26).

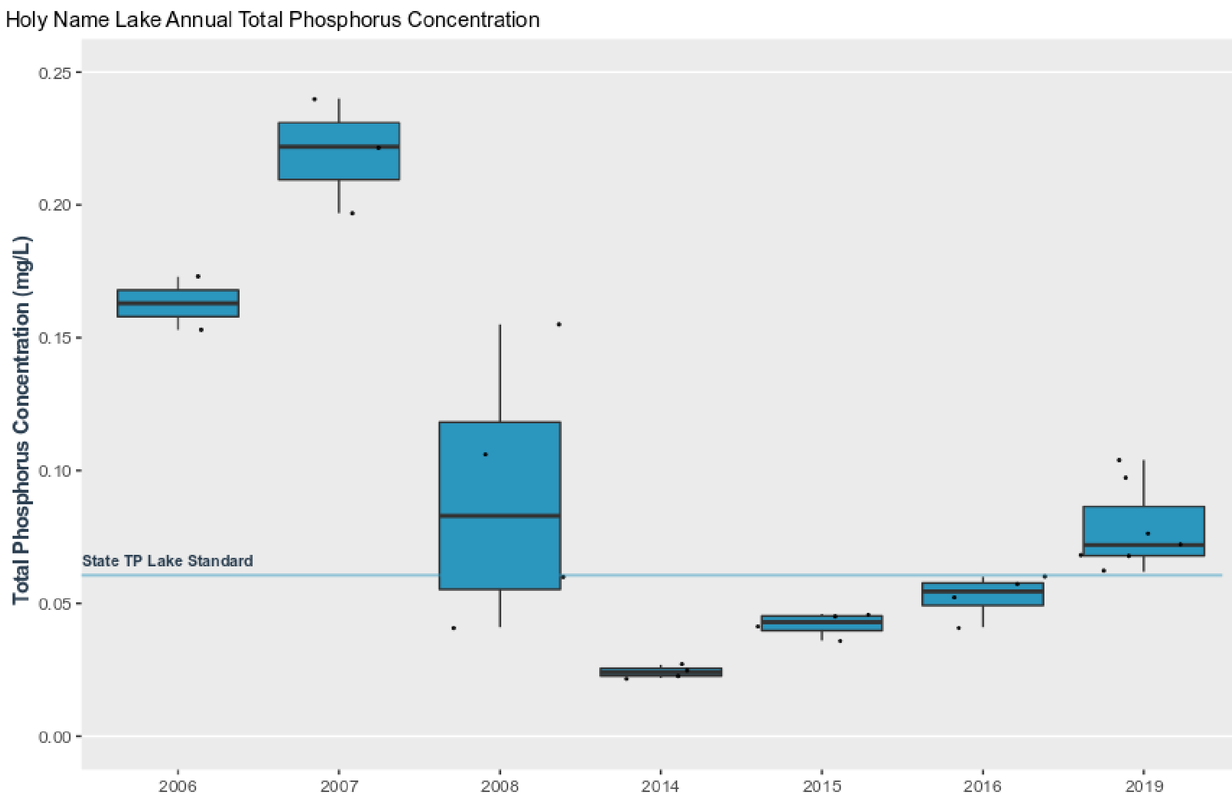


Figure 3-27. Annual total phosphorus concentrations for Holy Name Lake (blue boxplots) and individual sampling points (black dots).

3.2.3 Watershed Nutrient and Runoff Characterization and Source Assessment

3.2.3.1 Watershed Runoff Modeling

Total phosphorus runoff concentrations in the Holy Name MU span a large range based on model output (Figure 3-27; 0.02-0.32 mg/L), which is similar to in-stream phosphorus concentrations measured by MCWD staff (Figure 3-26). High runoff concentrations generally occur in upstream areas within the watershed that coincide with agricultural landuse (Figure 3-26). However, many of the areas with elevated total phosphorus runoff have downstream ponds and wetlands that provide sufficient treatment for total phosphorus removal (Figure 3-28), which is supported by stream and lake data (Figure 3-26) that demonstrated a gradual improvement in total phosphorus concentrations from upstream to downstream locations.

Overall, these data suggest that the large number of wetlands in the Holy Name Subwatershed still have capacity to remove phosphorus despite elevated runoff from agricultural landuse over the past century. However, continued loading to the wetlands may overwhelm their capacity to remove phosphorus, which would result in wetlands beginning to export phosphorus instead of removing it. Therefore, restoration opportunities should be targeted to reduce agricultural runoff to ensure that wetlands continue to act as phosphorus sinks instead of phosphorus sources.

One area of agricultural runoff that should be prioritized is the northeast and eastern drainage area of Holy Name Lake. These areas contribute a relatively large phosphorus load to Holy Name Lake, which may be important to reduce or eliminate the frequency in which Holy Name Lake transitions from turbid to clear state.

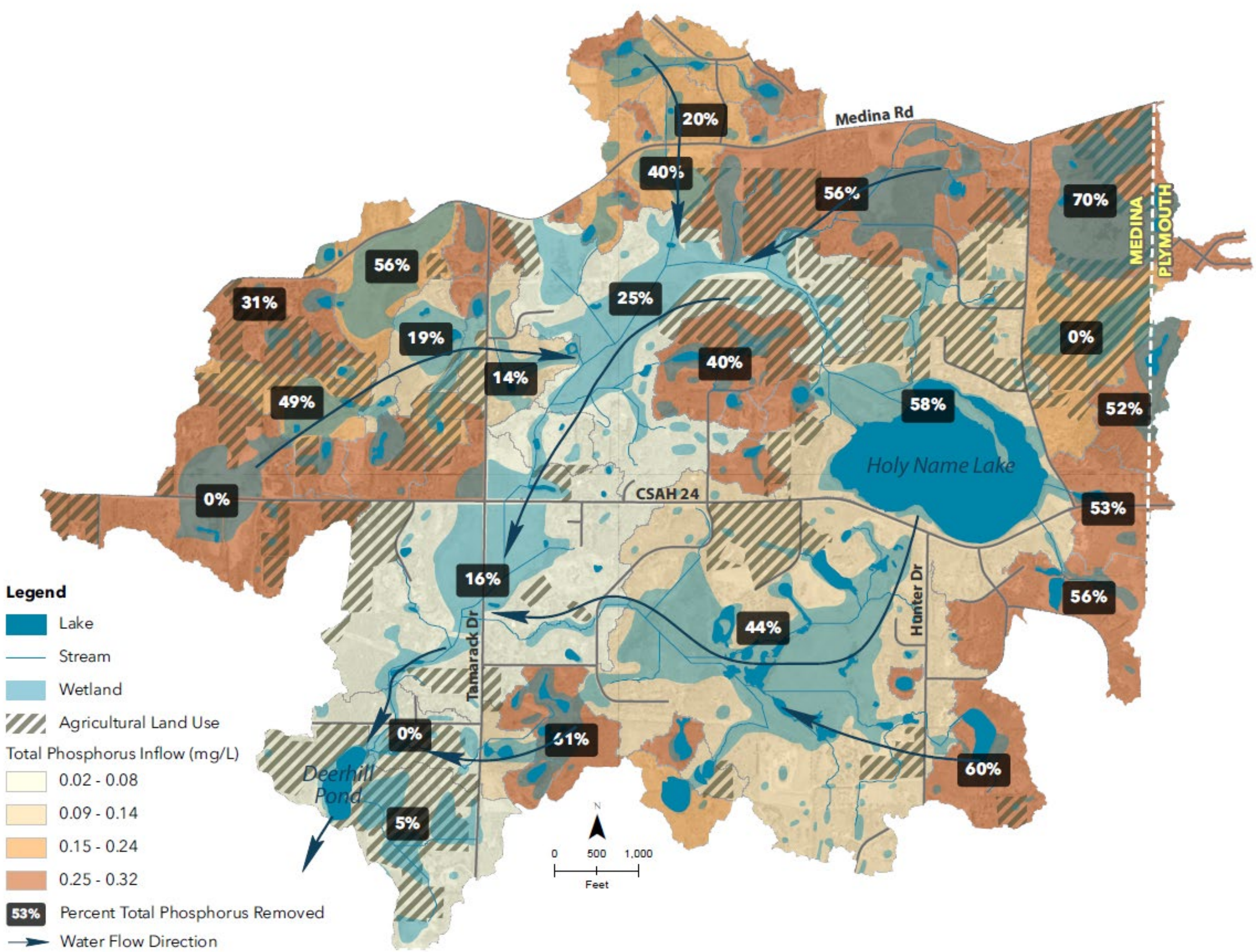


Figure 3-28 Phosphorus runoff concentration at the outlet of each catchment that includes treated runoff from upstream ponds or lakes and direct untreated runoff. The white numbers in black boxes

represent the phosphorus reduction at the outlet of each catchment. All values within this map are based on P8 output.

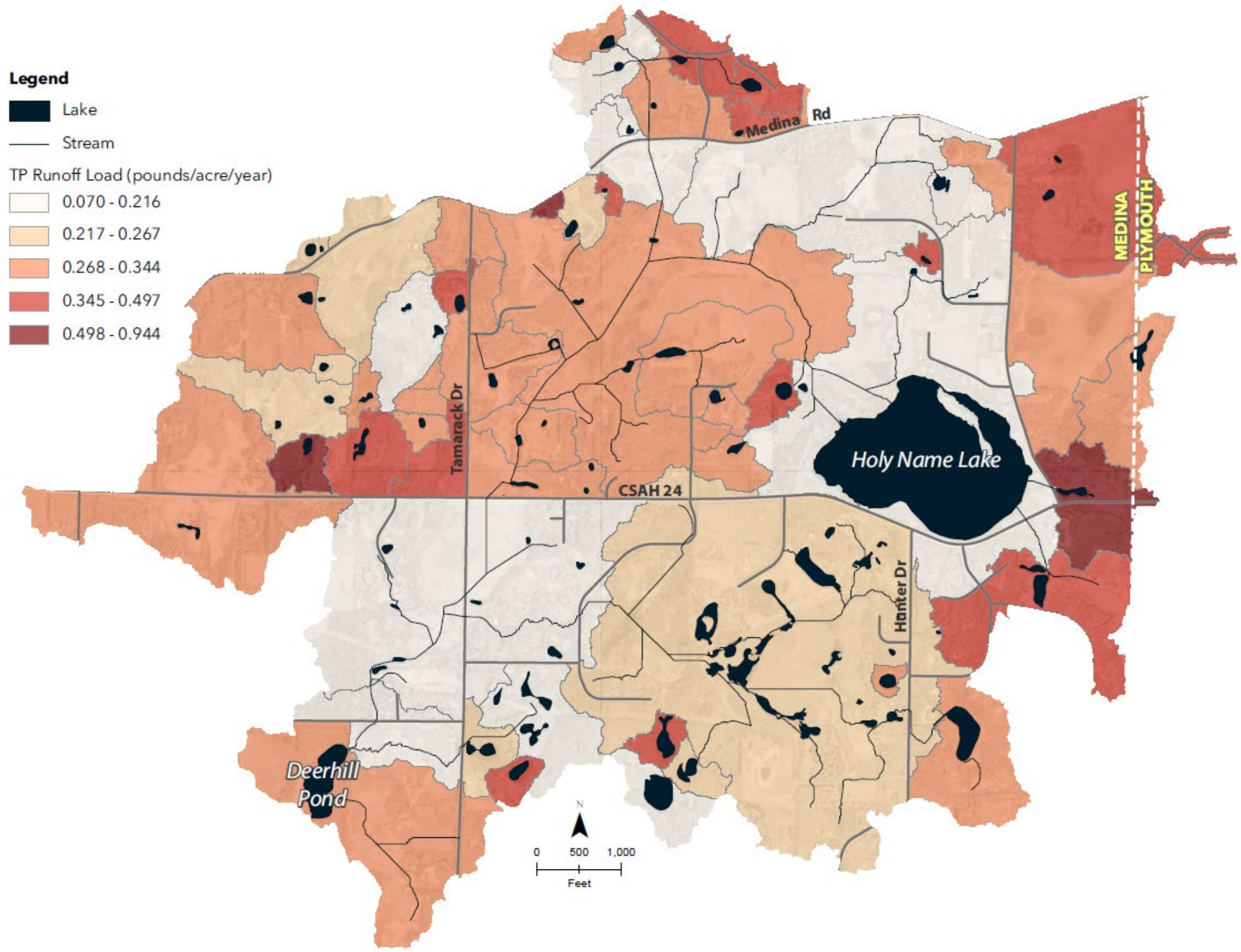


Figure 3-29. Unit area total phosphorus loading from each catchment based on P8 modeling output.

3.2.3.2 Erosion Assessment

Surface Erosion

There were several locations within the Holy Name MU that displayed elevated surface erosion (Figure 3-30). Many of these sites were not in close proximity to the main channels within the Holy Name MU (Figure 3-30), which means transport of sediment to the stream channel, and ultimately to lakes, is less likely. Furthermore, there were no reports from local partners or residents of severe surface erosion issues within the Holy Name MU.

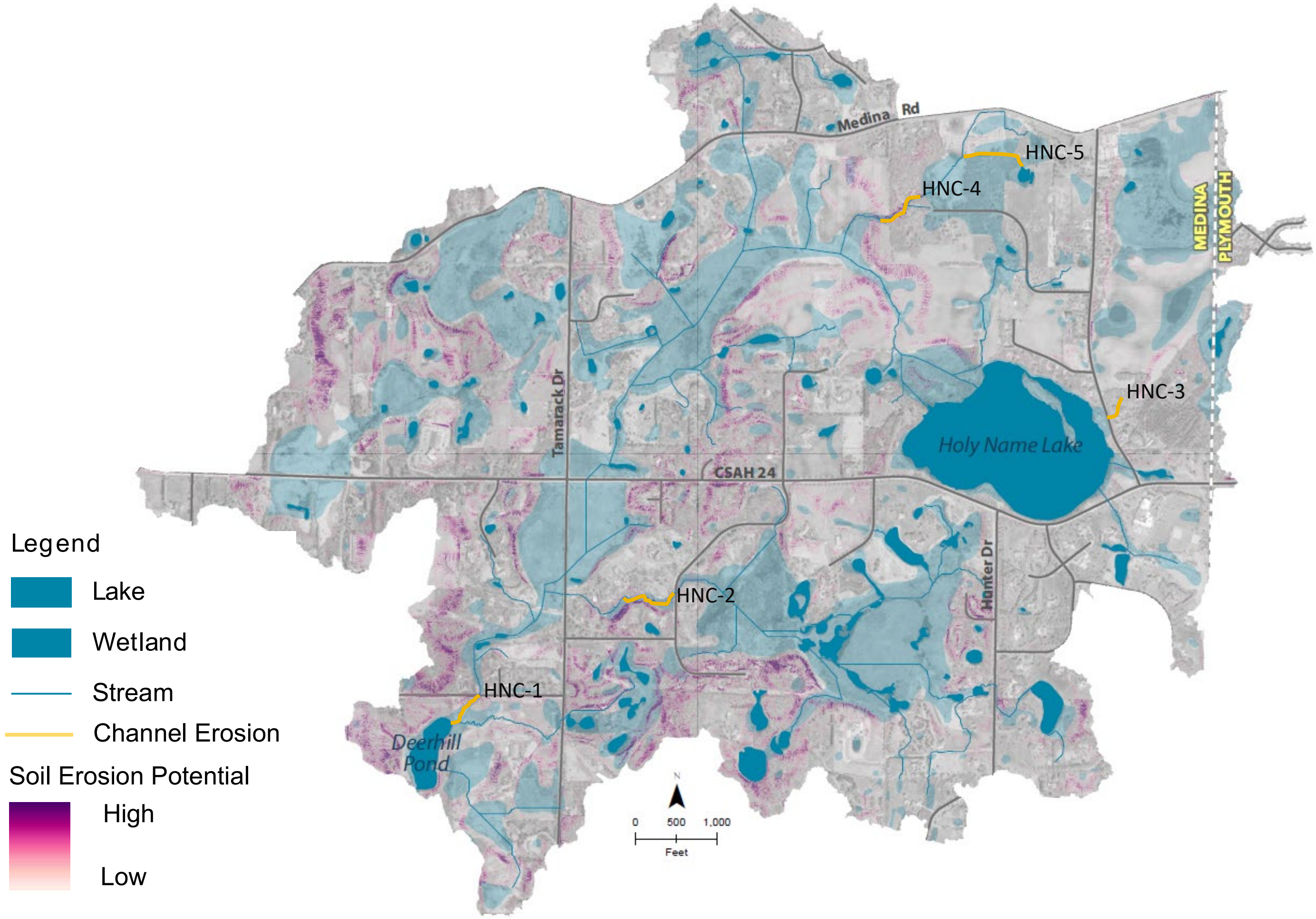


Figure 3-30 Areas of potential erosion based on the Universal Soil Loss Equation (USLE) estimates

Channel Erosion

The Holy Name MU has three stream channels including a northern reach that flows from the northeast portion of the watershed to the southwest and a reach that flows through Holy Name Lake from the northeast and flows southwest. These reaches converge downstream of a series of large wetlands located at the center of the subwatershed, which discharges to Deerhill Pond.

There were five locations that potentially have active channel erosion based on the longitudinal stream profile derived from LiDAR data from the State of Minnesota (Figure 3-31). Detailed explanation of the potential channel erosion locations is outlined in Table 3-6 based on the longitudinal stream profiles (Figure 3-31), the MCWD 2013 Stream Assessment (Interfluve, 2013), field investigations (Appendix F) and review of available site photos (Appendix F).

Table 3-6 Locations of potential stream channel erosion and surface erosion

Location	Description	Reach Slope	Erosion Conclusion
HNC-1	Potential stream downcutting immediately upstream of Deerhill Pond and south of Deerhill Road	7%	Hillslope analysis suggested some level of downcutting, however, the pond immediately downstream of the reach has had very little sediment deposition and has no evidence of a sediment delta forming. Therefore, this location doesn't appear to have active channel erosion.
HNC-2	Downstream of Holy Name Lake near Tamarack Dr.	4%	Further investigation of this location via aerial photos and review of stream assessment suggests this reach is not actively experiencing channel erosion
HNC-3	Inlet to Holy Name Lake near Holy Name Dr.	12%	The reach with dramatic slope lies between Holy Name Dr. and Holy Name Lake. Review of hillslope images does not show any clear evidence of erosion. MCWD recommends a field assessment to make a final determination of erosion at this location, however, the current LiDAR topography suggests that this location is experiencing active channel erosion.
HNC-4	Wetland reach downstream of headwater reach.	14%	Hillslope imagery and longitudinal profile (Figure 3-30) show channel erosion issues. This reach had been identified in the 2013 MCWD Stream Assessment as having active downcutting and a recommended project was identified to address the erosion issue.
HNC-5	Wetland Reach headwaters near intersection of Hunter Dr. and Medina Rd	3%	This reach was initially identified using the Longitudinal Profile (Figure 3-30), however, the slope of HNC-5 is relatively low. MCWD's 2013 stream assessment also evaluated this reach and found very little channel erosion, which confirmed that erosion is not a major issue in this location.

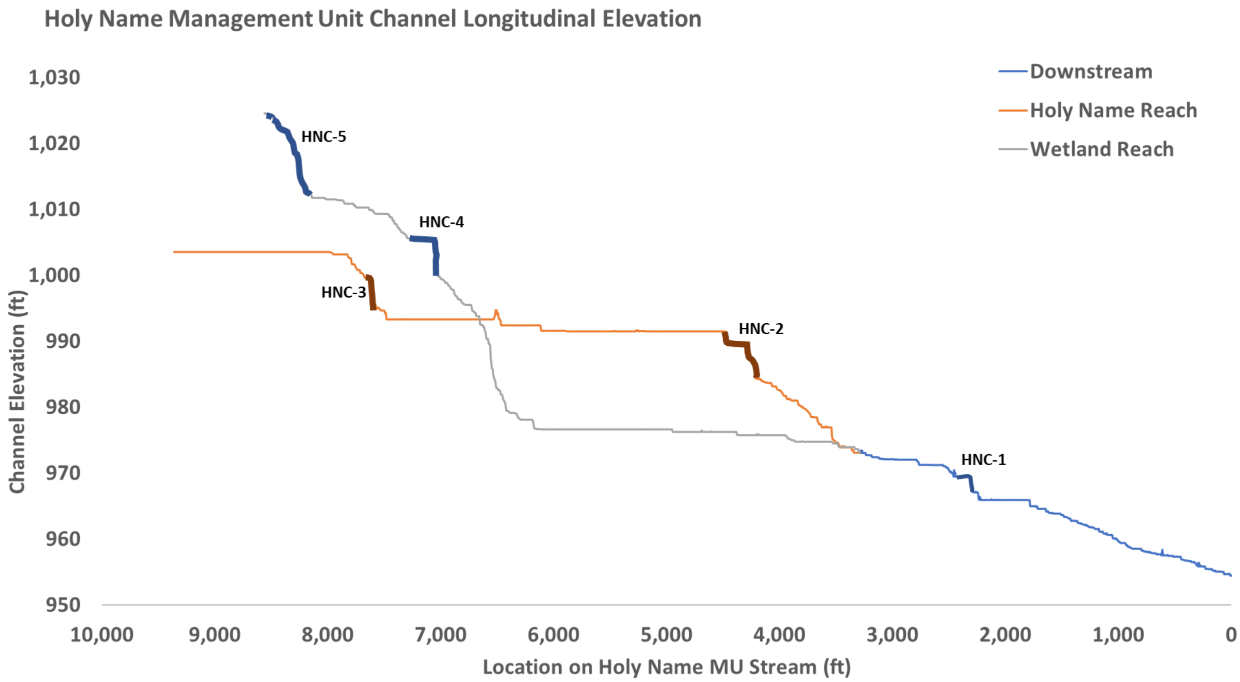


Figure 3-31 Holy Name MU stream profiles of the major tributaries that begin the northeast area of the MU and drain through Holy Nam Lake (orange) and through the large wetland complex (gray) that converge just upstream of Deerhill Pond (blue).

Erosion Drivers

The goal of upcoming sections is to identify which drivers have the greatest impact on erosion in the Holy Name MU since Surface and channel erosion appears to be one of the main drivers of phosphorus loading to lakes within the Holy Name MU. Characterizing the primary factors leading to erosion is a critical step to inform potential projects to remediate past erosion issues and identify watershed protection activities to prevent erosion in the future. The drivers assessed in this report include:

3) Natural Drivers
    a. Soil erodibility
    b. Drainage area slope
4) Anthropogenic Drivers
    a. Landcover
    b. Landuse change:
    c. Excess runoff

Surface Erosion Drivers

The Holy Name MU did have several locations of potential erosion, however, desktop review of aerial photos and slope indicates that the surface erosion has not led to severe gully or ravine erosion. The majority of surface erosion identified using the USLE model is in agricultural areas draining to wetlands, which suggests that active agricultural practices that result in periods of exposed soil in the spring and fall could potentially be driving surface erosion. Another factor, soil erodibility, is a contributing factor to surface erosion within the Holy Name MU. Soils within the Holy Name MU are among the most erodible based on the USDA's erodibility factor (k-factor) (Figure 3-7). These soils have relatively high silt and sand content, which easily detach under low runoff events.

Aerial photo review of several agricultural areas with the potential for high erosion high potential where gullies have formed have been taken out of active production (Figure 3-31), which suggests that sediment transport is likely limited. In addition, water quality data and watershed modeling demonstrate (Figure 3-26; Figure 3-28) that wetlands in this management unit are preventing transport of sediment to downstream waterbodies. However, reducing nutrient loading from surface erosion directly to wetlands is an important long-term strategy to ensure that they continue to act as a sink for phosphorus.

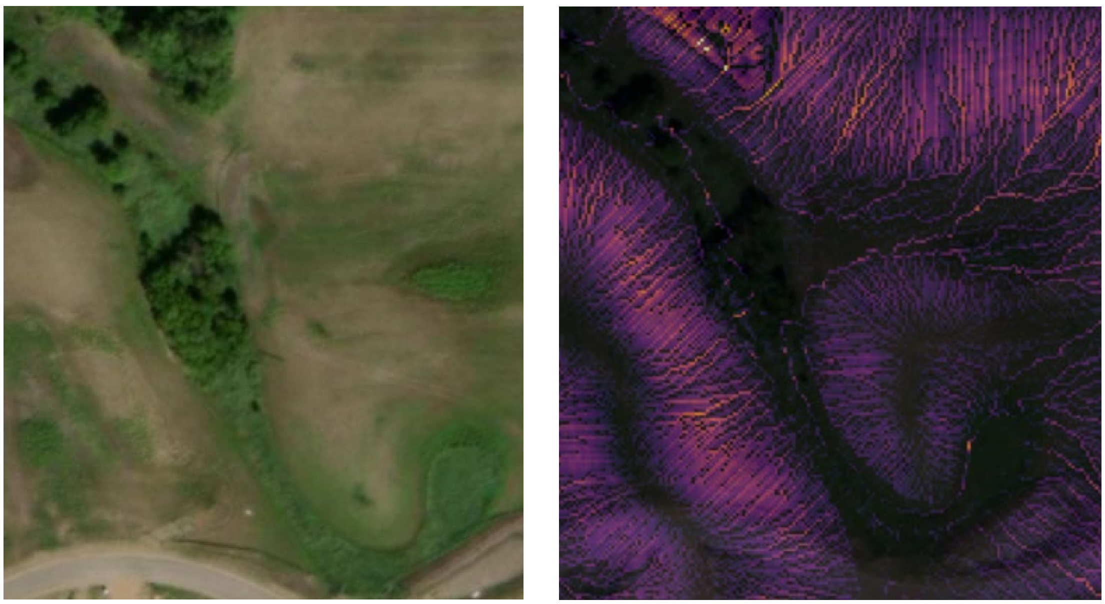


Figure 3-32. Example of agricultural field where areas of erosion have been taken out of active production.

Channel Erosion Drivers

There appears to be isolated channel erosion at two of the five stream reaches within the Holy Name MU. Channel erosion, unlike surface erosion, is primarily driven by increased runoff rates and volumes. Therefore, the first dataset to investigate is the water yield (inches of runoff/year) from each minor subwatershed within the Holy Name MU (Figure 3-33).

Watershed modeling results indicated that water yield from minor subwatersheds in the Holy Name MU were equal or less than predevelopment water yields in Minnesota for forested areas with C soils (5 in/yr; Figure 3-33). These results are consistent with relatively low amount of channel erosion occurring in three of the four stream reaches within the Wolsfeld MU.

The most dramatic channel erosion occurring within the final stream reach just upstream of Wolsfeld Lake based on field investigations and the longitudinal stream/lake elevation analysis. The drivers of this erosion are unclear, however, the presence of highly erodible soils in the MU combined with agricultural practices that were historically in close proximity to the stream channel appear to be the most likely factors.

Channel Erosion Drivers

Channel erosion appears to be relatively limited due to several factors in the Holy Name MU. Channel erosion, unlike surface erosion, is primarily driven by increased runoff rates and volumes. Therefore, the first dataset to investigate is the water yield (inches of runoff/year) from each minor subwatershed within the Holy Name MU (Figure 3-32).

Watershed modeling results indicated that water yield from nearly all of the minor subwatersheds in the Holy Name MU were equal or less than predevelopment water yields in Minnesota for forested areas with C soils (5 in/yr; Figure 3-32). The Holy Name MU also has a many intact wetlands that provide storage capacity that also serve to reduce runoff within the Holy Name MU. These results are consistent with relatively limited of channel erosion occurring in many of the stream reaches within the Holy Name MU.

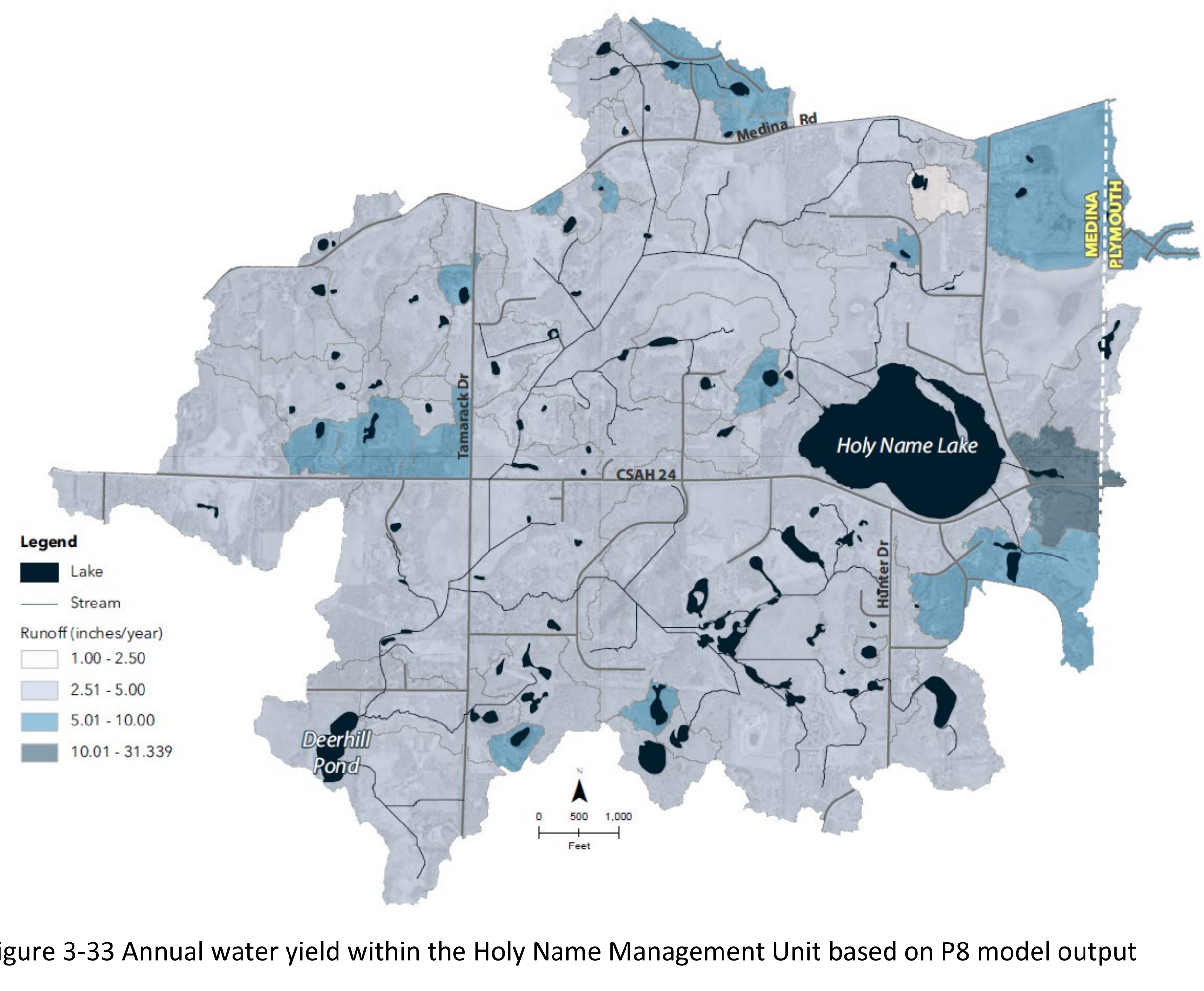


Figure 3-33 Annual water yield within the Holy Name Management Unit based on P8 model output

3.2.3.3 Wetlands

Storage

Wetlands cover approximately 30% of the Holy Name based the FAW (Figure 3-34; Figure 1-1), which is close to the pre-settlement coverage in the state of Minnesota (~35%) (Anderson and Craig, 1984) and represents the highest percent coverage of any management unit in the Long Lake Creek Subwatershed. This area is relatively undeveloped and likely has retained many of its wetlands that provide storage for stormwater runoff. The low annual water yield estimates (Figure 3-33) within the watershed suggest that wetland storage, in combination with low impervious areas, in the Holy Name MU are providing beneficial flood and nutrient reduction to lakes within the subwatershed and downstream water bodies such as Long Lake.

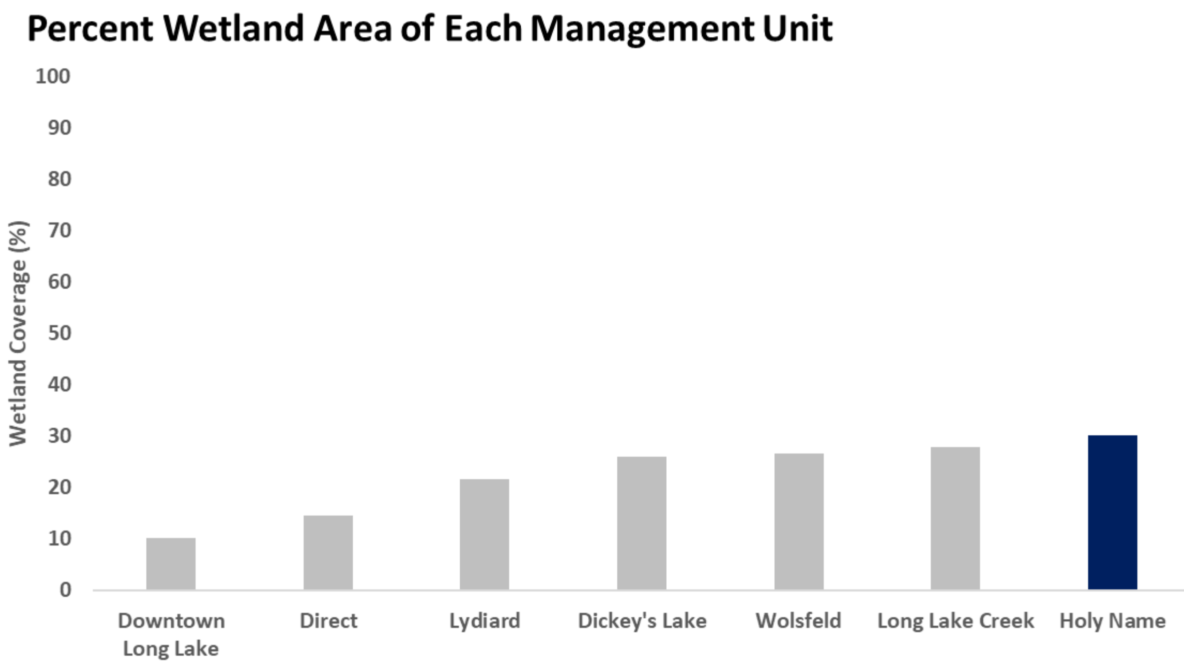


Figure 3-34 Percentage area of management unit covered by wetlands

Vegetation Diversity

Wetland vegetation diversity spans a large range within the Holy Name MU with the majority of wetlands having low (78%) or moderate (12%) vegetation diversity based on the FAW (Figure 3-35; Figure 3-36). These data suggest that elevated watershed nutrient runoff and changes in hydrology have negatively impacted wetland vegetation, which is a well-established phenomenon that has been well documented in literature (EPA 2002). Species that are tolerant to environmental change such as cattail (*Typha latifolia L.)* and reed canary grass (*Phalaris arundinacea)* are able to outcompete other intolerant wetland plant species as human driven watershed runoff enriches soil nutrients and changes wetland water levels. Overall, the Holy Name MU may have the greatest coverage of wetlands, but the majority of them are in poor condition due to elevated watershed nutrient loading and the introduction of invasive species.

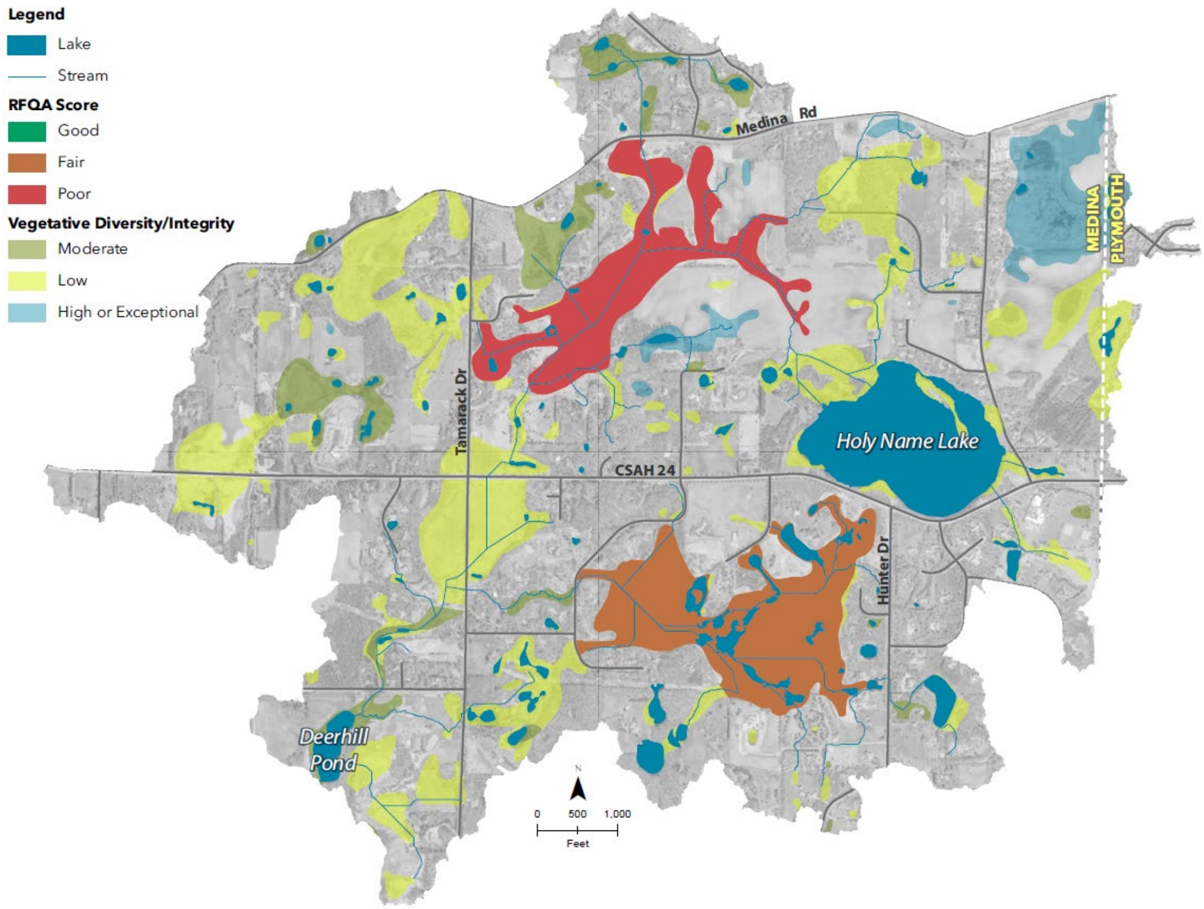


Figure 3-35 Wetland vegetation diversity based on the FAW throughout the entire MU and individual RFQA wetland assessments conducted in 2019.

Wetland Nutrient Cycling

Stream water quality monitoring within the Holy Name MU indicates that wetlands continue to act as a sink for phosphorus since concentrations at the outlet of each wetland are less than or equal to the inlet phosphorus concentrations (Figure 3-26). These data suggest that historic phosphorus loading has not exhausted the wetlands capacity to remove phosphorus. However, the poor vegetation diversity (Figure 3-35; Figure 3-36) suggests that the historic nutrient loading to the wetlands has changed how the wetlands assimilate nutrients. Therefore, reducing the amount of phosphorus loading to each wetland should be a management priority to 1) improve ecological conditions that will support native plant growth and 2) ensure that wetlands within Holy Name MU continue to act as a sink for phosphorus moving forward.

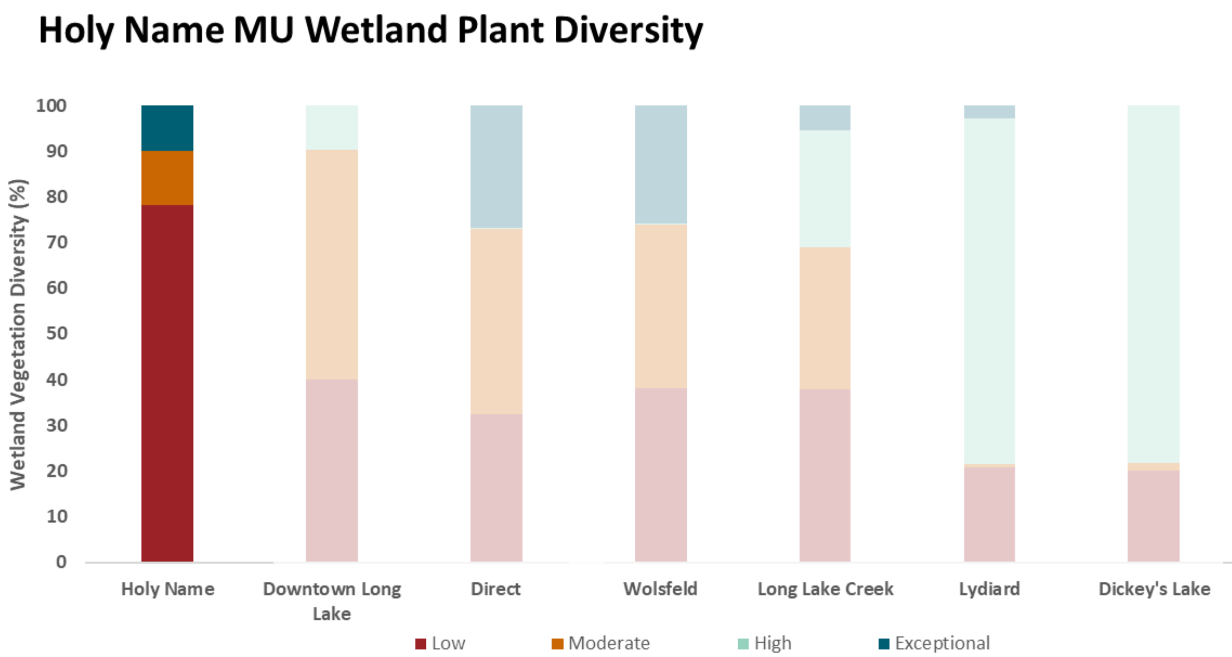


Figure 3-36 Wetland vegetation diversity of the Holy Name MU (highlighted) relative to other management units (faded) based on the FAW.

3.2.4 In-Lake Assessment

3.2.4.1 Internal Phosphorus Loading from Sediment Release

MCWD staff collected sediment cores from Holy Name Lake to characterize the amount of phosphorus that is release under anoxic conditions. Internal loading estimates using the sediment release rates and dissolved oxygen profiles revealed that sediment phosphorus release is relatively low for Holy Name Lake compared to sediment release rates collected in other lakes throughout Minnesota (Figure 3-37).

The other factor to consider for internal loading is the amount of time and the total area that the sediment is exposed to anoxic conditions, which is referred to as the anoxic factor. However, measuring or estimating anoxia in shallow lakes, such as Holy Name Lake, can be difficult since they may mix many times throughout the year. An anoxic factor for shallow lakes can be estimated using an empirical model based on a lakes geomorphology and average total phosphorus concentrations (Nürnberg 2004). The estimated anoxic factor and sediment phosphorus release rates can be used to estimate the internal load for Holy Name Lake.

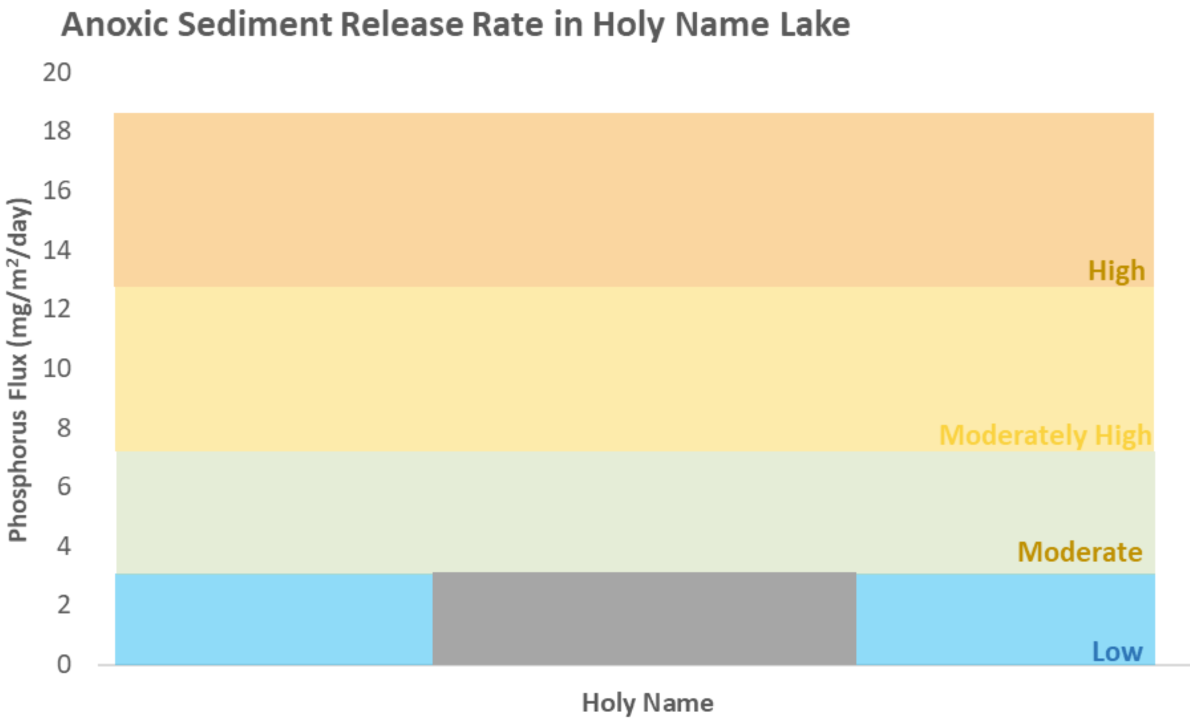


Figure 3-37 Sediment phosphorus release rate for each lake in the Holy Name MU.

3.2.4.2 Lake Submerged Aquatic Vegetation

Submerged aquatic vegetation (SAV) surveys were conducted in Holy Name Lake in 2019 to characterize (Figure 3-38). MCWD's E-grade health assessment E- provides a quantitative framework for the lake SAV data, which categorizes all of the lakes with excellent, good, poor, or degraded based on the FQI score. The results from these surveys demonstrated that the macrophyte community in each lake is dominated by curlyleaf pondweed, Eurasian watermilfoil, and coontail, which considered species tolerant of poor water quality conditions (Appendix E). However, there were four native species that were observed in Holy Name Lake, which indicate that conditions in support a slightly more diverse SAV community that includes native species such as flat-stem pondweed, Canadian waterweed, and water stargrass (Figure 3-38).

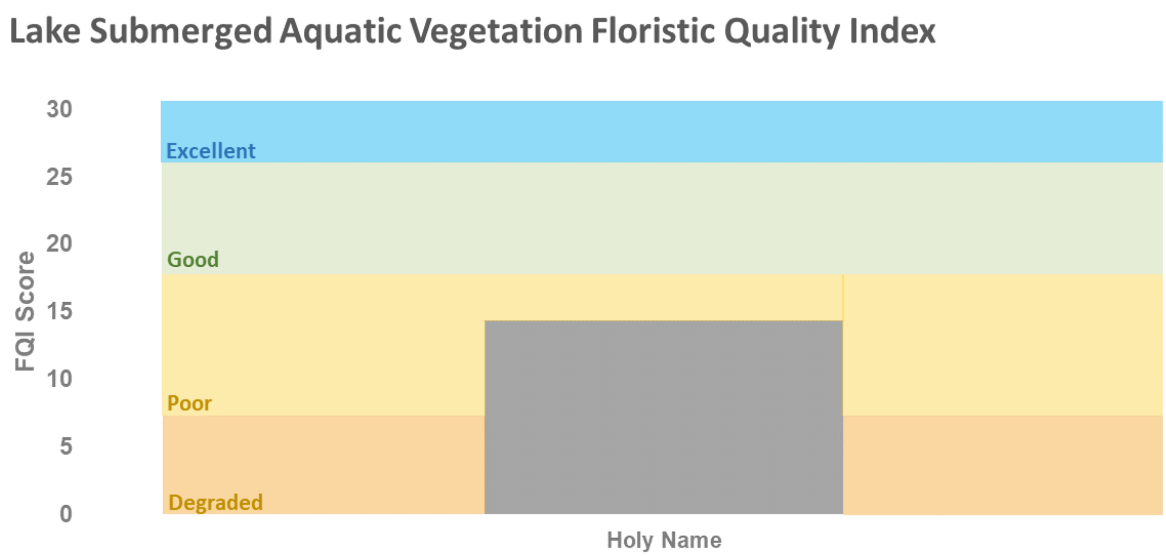


Figure 3-38 Vegetation results compared to Floristic Quality Index

3.2.4.3 Fisheries

Condition

The Minnesota Department of Natural Resources (MDNR) has developed a classification system for Minnesota lakes that considers each lake's chemical and physical properties to characterize what fish should be in the each lake. The lake classification for Holy Name Lake is in Table 3-7.

The Minnesota Department of Natural Resources (MnDNR) has developed a classification system for Minnesota lakes that characterizes what fish should be present based on a lake's chemical and physical properties. The lake classification for Holy Name Lake is in Table 3-7 that lists the primary fish species that should exist in each lake based on its designated classification. Overall, the lake classification in Holy Name Lake suggests that no species sensitive to poor water quality (intolerant species) should be observed and tolerant species such as Black Bullhead should be present due to the poor water quality conditions of Holy Name Lake (Table 3-4; Figure 3-2).

Table 3-7 MnDNR lake class based on lake morphomentry and water quality conditions.

Lake	DNR Lake Class	Primary Fish Species Expected	Secondary Fish Species Expected
Holy Name	44	Black Bullhead*, Bluegill, Black Crappie	Pumpkinseed

*Fish that are tolerant of degraded habitat conditions

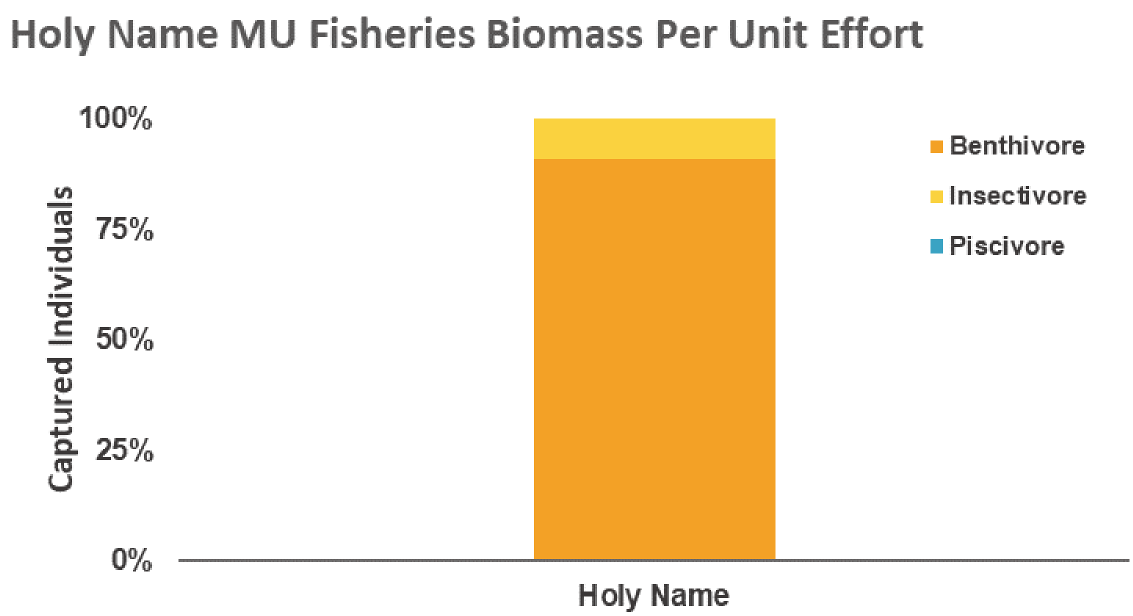


Figure 3-39 Fisheries biomass summary by trophic group for the Holy Name MU.

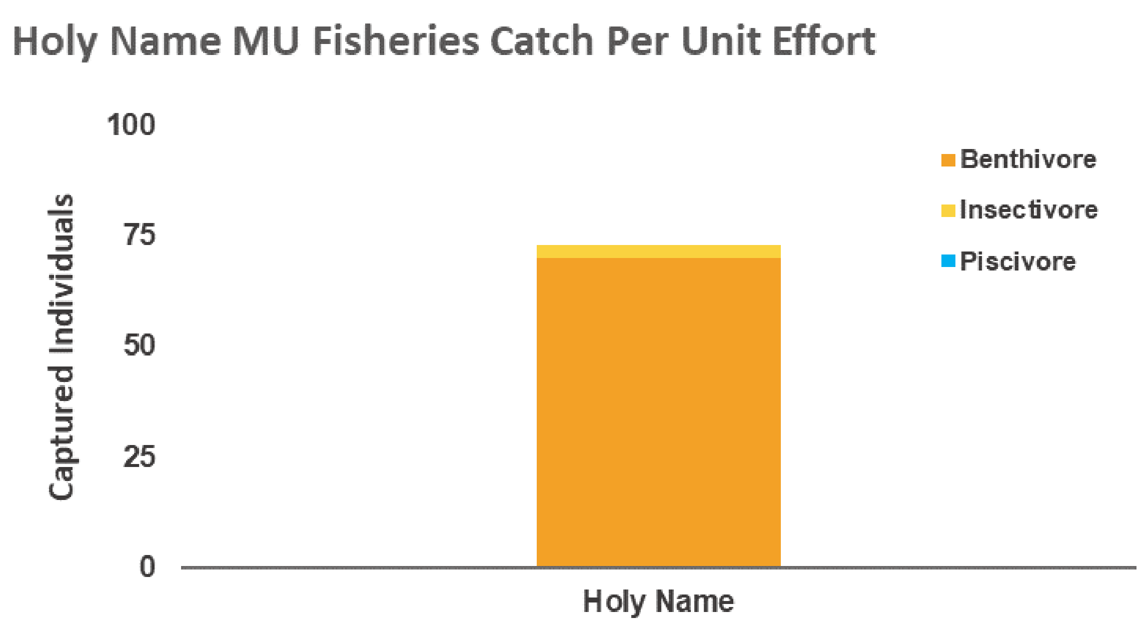


Figure 3-40 Fisheries CPUE individual summary by trophic group for the Holy Name MU

We compared the relative abundance of fish species that are sensitive to poor water clarity and habitat conditions (intolerant fish) relative to fish species that thrive in poor water clarity and habitat conditions (tolerant fish). There were no sensitive species observed in any of the lakes within Holy Name Lake, which suggests that native fish will not thrive in this lake due to poor ecological conditions such as low oxygen, poor vegetation, and low water clarity. The MnDNR has reported that Holy Name Lake has a history of frequent winter kills, which may be one factor supporting intolerant fish species and may explain Holy Name Lake's tendency to move between good water quality periods (clear states) and poor water quality conditions (turbid states).

Furthermore, Holy Name Lake's fish community appears to be dominated by Black Bullhead and Goldfish, which are tolerant of poor conditions and are benthivores (Figure 3-37; Figure 3-38). Not only do these species thrive in poor water quality conditions, they capable of further contributing to poor ecological conditions they are benthivores. Benthivores are a type of fish that feed in sediment, which can uproot plants and contribute to low water clarity.

These results suggest that anthropogenic impacts such as elevated historical agricultural runoff and surface erosion conditions have led frequent winterkills, low plant diversity, and poor water quality that has inhibited diverse fish communities and allowed intolerant fish species to thrive. Unfortunately, the intolerant benthivore fish species, Goldfish and Black Bullhead, appear to be further compounding the problem since they have the capacity to resuspend sediments and uproot plants.

Carp Assessment

WSB conducted two electrofishing biomass surveys in 2019 during which no carp were observed. Neither were carp present during any of the MnDNR's surveys between 1979 and 1994.

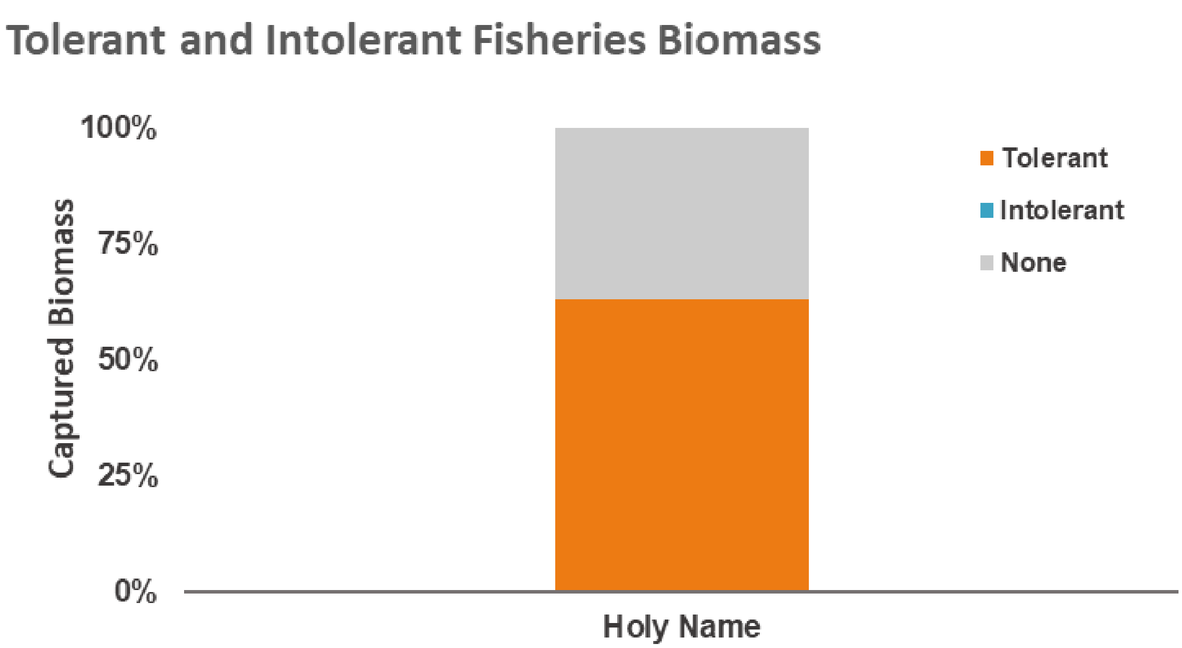


Figure 3-41 Fisheries biomass summary of tolerant and intolerant fish observed in the Holy Name MU

3.2.5 Lake Nutrient Budget

3.2.5.1 Watershed Loading

Watershed loading in the Holy Name MU drainage accounts for approximately 41% of the total phosphorus budget to Holy Name Lake (71.6 lbs P/yr; Figure 3-42). Both erosion and overland runoff were investigated to characterize the relative contribution of phosphorus to downstream waterbodies.

The greatest source of watershed loading in the Holy Name MU drainage area appears to be runoff from agricultural areas based on P8 watershed modeling and surface erosion estimates (Figure 3-28; Figure 3-30). The P8 modeling estimated that phosphorus loading represents approximately 75 lbs P/yr, which is similar to the entire watershed phosphors load estimated in the 2014 Upper Lakes TMDL. Surface erosion was also identified as a potential driver of watershed phosphorus loading in agricultural areas, however, ravine and gully erosion in this management unit appears to be relatively minimal based on desktop analysis and field investigation. Overall, it appears that BMPs associated with reducing nutrient runoff should be the focus instead of erosion mitigation techniques for agricultural fields.

The other potential watershed source of phosphorus to Holy Name Lake is channel erosion. MCWD's review of channel slope, surface erosion, and the 2013 Stream Assessment (Interfluve, 2013) suggest that channel erosion and surface erosion have a limited impact on phosphorus loading (Figure 3-29; Figure 3-30; Figure 3-31).

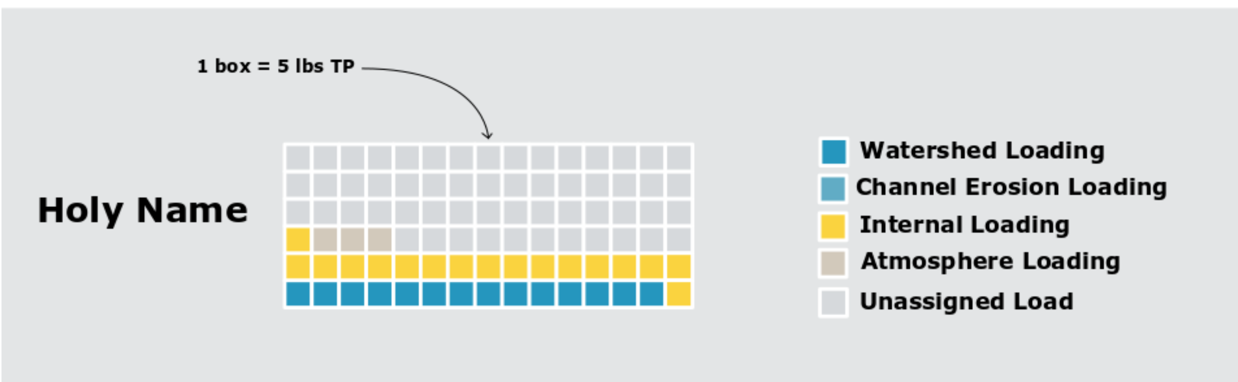


Figure 3-42 Phosphorus budgets for Holy Name Lake

3.2.5.2 Watershed Storage and Phosphorus Removal Capacity

The Holy Name MU has many intact wetlands and small ponds that serve as treatment in most areas of the watershed (Figure 3-28). These wetlands provide phosphorus removal capacity to drainage areas that have prevented even poorer water quality conditions within the lakes of this management unit. Overall, this management unit does appear to have ample storage based on the modeled water yields (Figure 3-33), however, more treatment in areas with agricultural runoff would likely improve water quality conditions within the Holy Name Lake direct drainage area.

3.2.5.3 Internal Loading

Sediment phosphorus release rates were measured by collecting sediment cores on Holy Name Lake to gain a more precise characterization of the impact of internal phosphorus loading. Sediment phosphorus release from sediments accounts for nearly half of the total phosphorus load to Holy Name Lake (Figure

3-42). It is somewhat counterintuitive that internal phosphorus loading represents such a large portion of the phosphorus budget since Holy Name Lake's (3 mg m^{-2} d^{-1}; Figure 3-37) sediment phosphorus release rates are relatively low compared to other lakes in the Long Lake Creek Subwatershed (8-15 mg m^{-2} d^{-1}; Figure 3-37).

The primary explanation for internal loading being the primary source of phosphorus is due to the relatively small area that drains to Holy Name Lake making the small internal load (87 lbs P/yr) relatively large compared to the relatively small watershed load (70 lbs P/yr). However, even a small watershed load can clearly have impacts on a water body since the internal load and poor water quality conditions are a direct reflection of the historical watershed loading that has occurred within Holy Name Lake.

3.2.5.4 Biological Influences on Nutrient Cycling

There are several indicators that are useful to determine if biological factors may be influencing water quality conditions for shallow lakes. Those factors include presence of rough fish, erratic water quality conditions, and difficulty balancing the nutrient budget, which are described in greater detail below:

1) **Rough Fish:** The dominant fish species in Holy Name Lake include Black Bullhead and Goldfish, which are both benthivores, which means they are capable of resuspending sediments and uprooting plants.
2) **Erratic Water Quality:** Water clarity in Holy Name Lake has been somewhat erratic over the past 10 years (Figure 3-27), which suggests that Holy Name Lake is flipping between a turbid state and clear state. This suggests that Holy Name Lake's ecosystem is somewhat unstable due to its nutrient loading and fish population.
3) **Phosphorus Budget:** The 2014 Upper Lakes TMDL (Wenck, 2014) used stream data to empirically derive watershed loading, which estimated that Holy Name's watershed load was 70 lbs P/year, which was very similar to MCWD's modeling estimates of 75 lbs P /year. However, the TMDL used literature release rates to "calibrate" the model to match in-lake phosphorus concentrations. The internal loading estimated in the TMDL was 362 lbs/yr compared to the measured internal load of 87 lbs/yr measured in this study. The need to over-estimate internal phosphorus loading to match elevated phosphorus concentrations is very common in lakes where biotic factors are reducing the lakes ability to settle phosphorus.

Overall, there are several lines of evidence that suggest that benthivores in Holy Name Lake are negatively influencing water quality and plant conditions. It may be useful to address watershed and internal loading to see if improving water clarity will move Holy Name Lake into a stable clear state. However, biological manipulation may be necessary if water quality and biotic conditions don't improve after phosphorus reductions occur.

3.2.5.5 Upstream Lakes

There are no upstream lakes that drain to Holy Name Lake.

3.3 Downtown Management Unit

3.3.1 Watershed Description

The Downtown Management Unit (DMU) encompasses 518 acres and represents the western drainage area of Long Lake. It is located primarily in the City of Long Lake and the City of Orono. The headwaters of the DMU are located in the northwest corner of the MU, which consists of residential areas that are surrounded by large wetlands and undeveloped areas. Land use transitions into industrial and commercial as water moves southeast through the MU, which ultimately outlets at Nelson Lakeside Park. While the MU does not contain any lakes, MCWD's Functional Wetland Assessment (Wenck, 2003) identifies 19 wetlands.

The DMU section of the report is structured differently than other sections because it does not have any lakes or stream reaches established by the State of Minnesota. The focus of this management unit section will be on characterizing the volume and pollutant load from runoff and wetland characteristics since it the DMU acts primarily as a drainage area with a few wetland receiving water bodies.

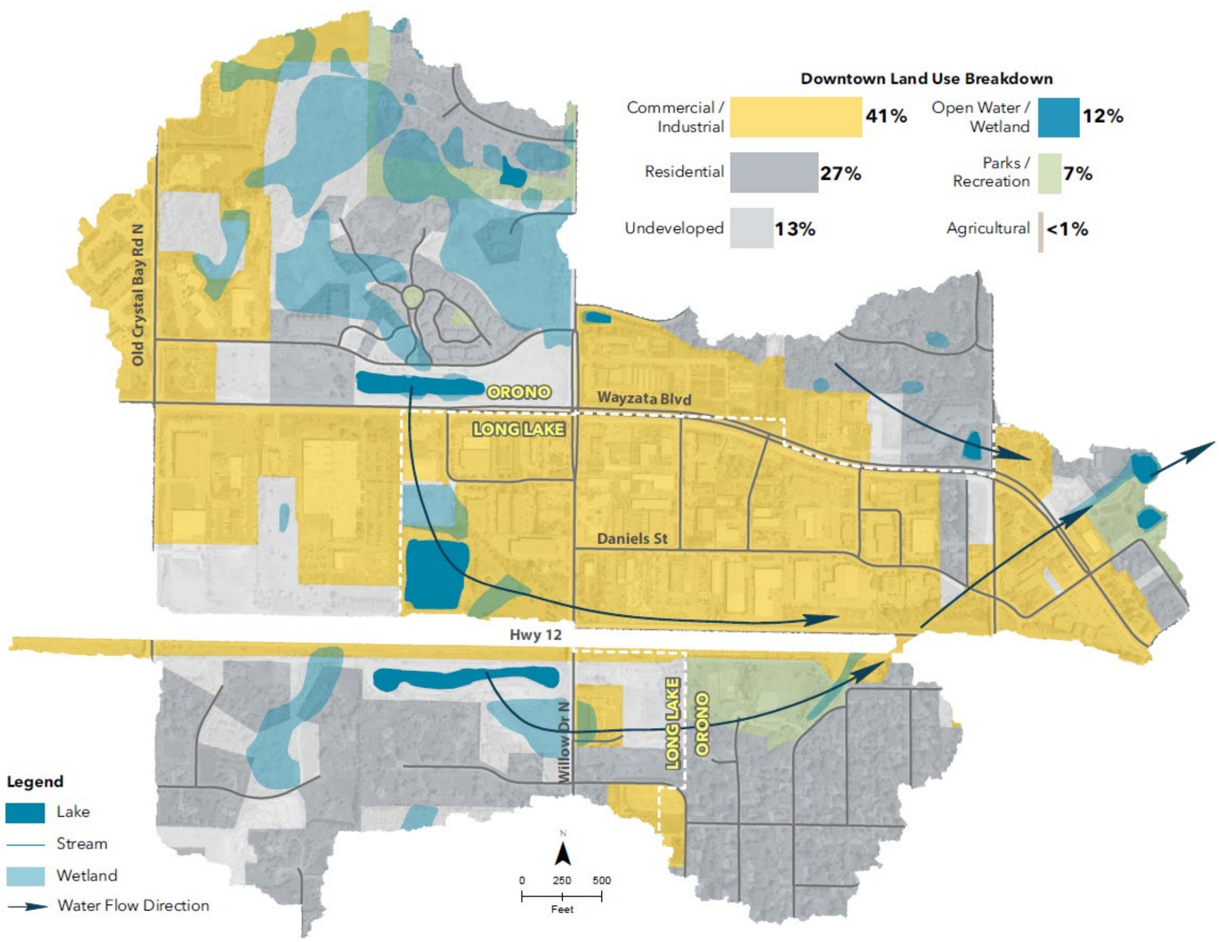


Figure 3-43. Downtown Long Lake Management Unit overview including flowpaths, major water bodies, and landuse (Source: MLCCS).

3.3.2 Water Quality Overview

The majority of the DMU's stream channels have been converted to stormwater pipes, which means that traditional stream monitoring in this management unit is much more difficult. MCWD's approach was to characterize the outlet of the entire management unit at the inlet of the Nelson Lakeside Park ponds to characterize the runoff from the entire management unit drainage area.

Stormwater and baseflow samples were collected during the 2020 growing season to characterize annual runoff conditions and calibrate the MCWD P8 watershed model. These data demonstrated that nearly all samples collected at this location had total phosphorus concentrations (Figure 3-44) that were well above the State of Minnesota TP stream standard (0.1 mg/L for streams). The median TP concentration at the inlet of the Nelson Lakeside Park Ponds is 0.210 mg/L, which is nearly double the total phosphorus standard (Figure 3-44).

The limited availability of water quality data in this subwatershed makes it difficult to identify if there specific areas that are driving elevated total phosphorus runoff. However, the total phosphorus concentrations measured at the management unit outlet clearly show that sources of elevated runoff containing elevated total phosphorus exist within the DMU (Figure 3-44). Further analysis using P8 watershed modeling will be used to identify areas contributing elevated total phosphorus runoff and areas where stormwater treatment is insufficient.

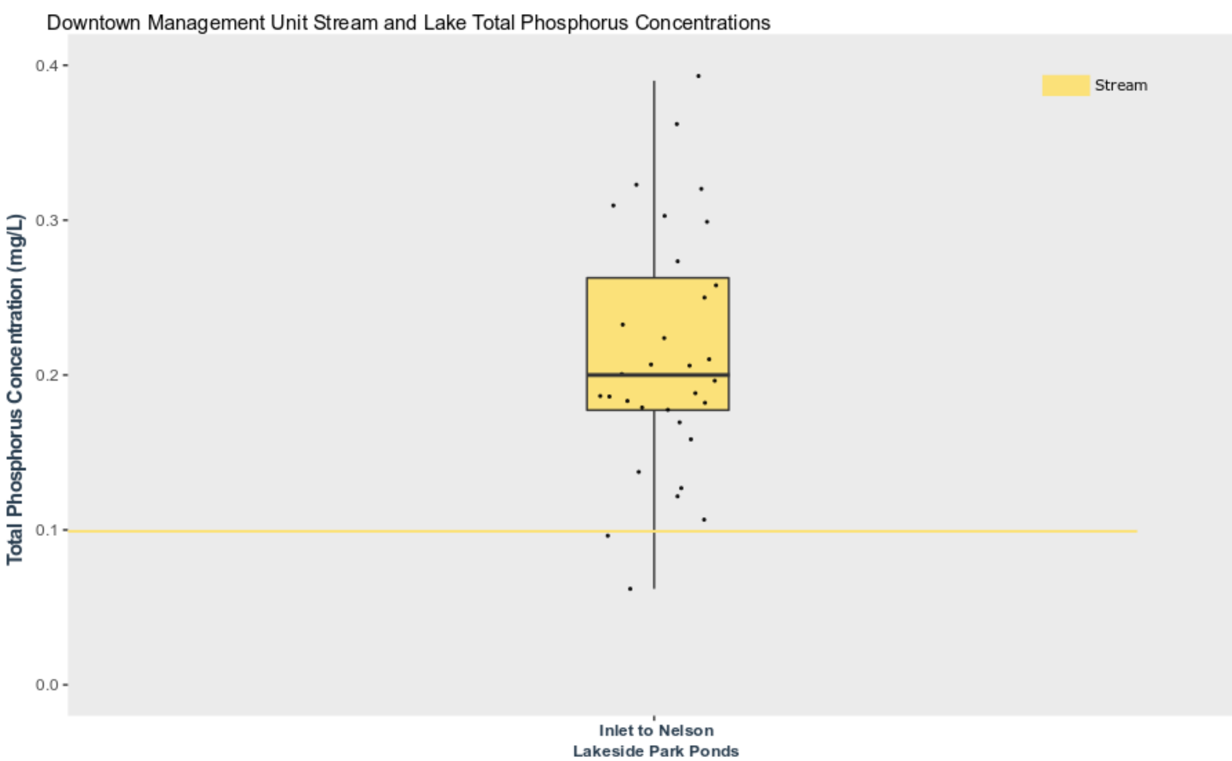


Figure 3-44. Stream total phosphorus concentrations in the Downtown Management at the inlet to the Nelson Lakeside Park Pond just upstream of Long Lake.

3.3.3 Watershed Nutrient and Runoff Characterization and Source Assessment

3.3.3.1 Watershed Runoff Modeling

P8 watershed modeling in the Downtown Management Unit demonstrated that total phosphorus concentrations within this drainage area fell within a higher range (0.15-0.32 mg/L) compared to other management unit's total phosphorus runoff concentrations (Figure 3-43). The highest runoff total phosphorus concentrations are located in the upstream minor subwatersheds (Figure 3-43), however, phosphorus concentrations only decrease slightly as they move downstream (Figure 3-43). These findings are very different than other management units in the Long Lake Creek Subwatershed that have poor water quality conditions in headwater minor subwatersheds, but generally improve as water flows downstream.

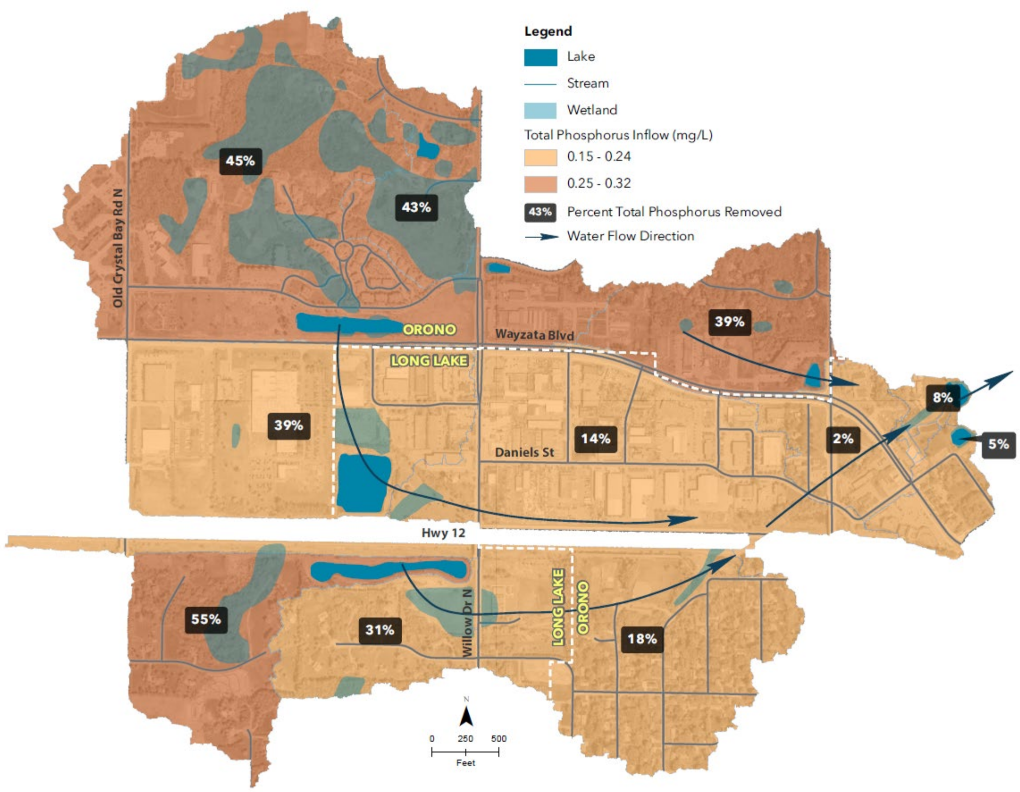


Figure 3-45 Phosphorus runoff concentration at the outlet of each catchment that includes treated runoff from upstream ponds or lakes and direct untreated runoff. The white numbers in black boxes represent the phosphorus reduction at the outlet of each catchment. All values within this map are based on P8 output.

As a reminder, elevated phosphorus concentrations in water can result from two main factors: high phosphorus runoff due to land use practices and the insufficient treatment capacity of stormwater runoff. One of the first observations when reviewing Figure 3-45 is that the phosphorus removal efficiency (white number in black squares) is very high in the headwater minor subwatersheds and very low in the downstream minor subwatersheds. There are two primary reasons for this observation:

1) Large existing wetlands provide a very large treatment removal capacity in the headwater minor subwatersheds that also have relatively small stormwater runoff volumes. Conversely, there is

very few or no stormwater treatment basins or wetlands located in downstream minor subwatersheds that receive a much larger runoff volume. This suggests that the few ponds are undersized compared to the runoff volume they receive.

2) Landuse in the downstream catchments have a high fraction of impervious area that results in large stormwater runoff volumes and elevated total phosphorus concentrations.

The combination of urbanization and low stormwater treatment capacity in the DMU results in the greatest phosphorus concentrations at the outlet of this subwatershed relative to other management units draining to Long Lake. The primary strategy for improving water quality and reducing runoff volumes in the DMU should be adding stormwater treatment capacity.

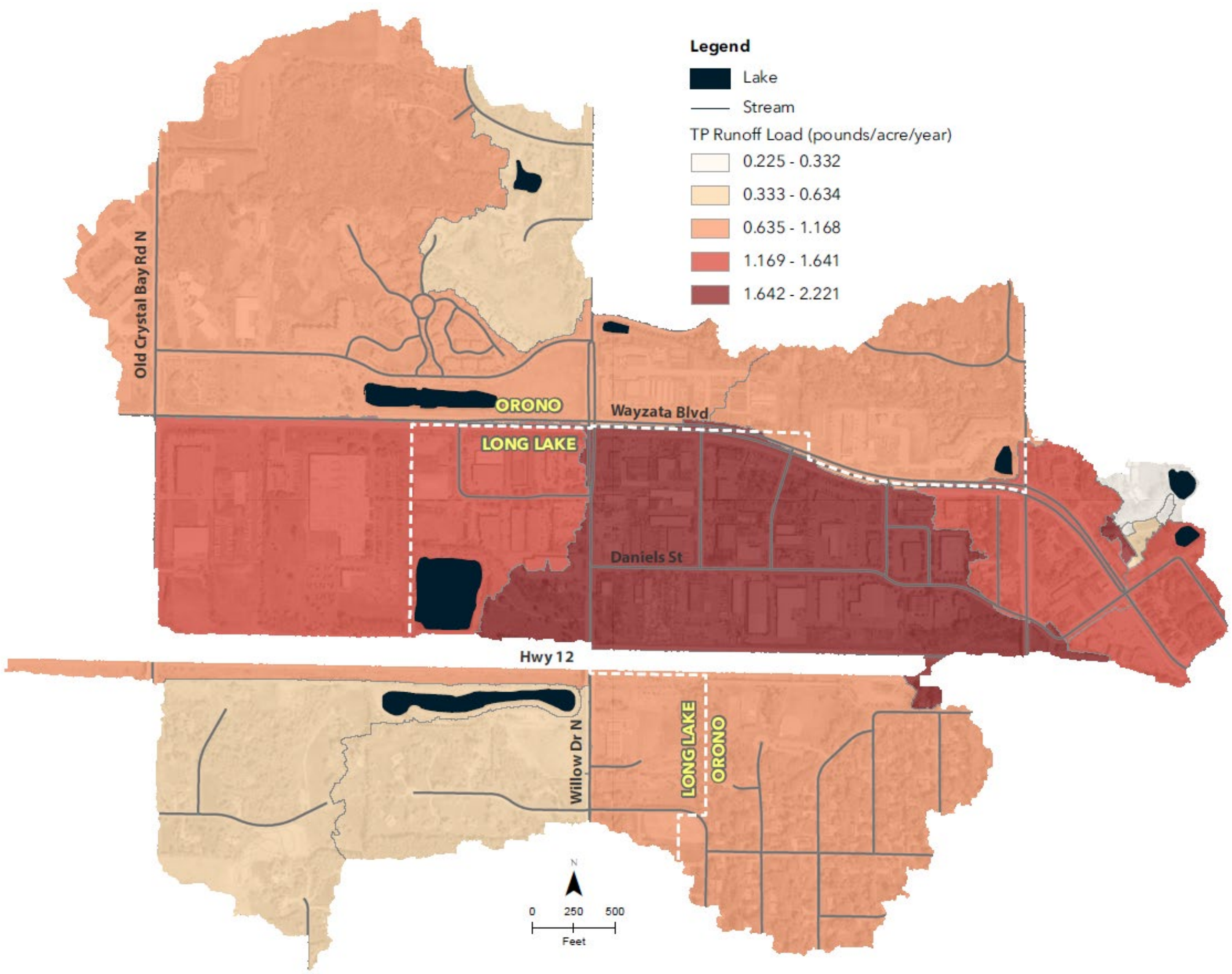


Figure 3-46. Unit area total phosphorus loading from each catchment based on P8 modeling output.

3.3.3.2 Erosion Assessment

Surface Erosion

There are a few areas that were identified as having high erosion potential in the DMU including areas next to railroad tracks in the south west portion of the DMU and area surrounding a stormwater pond in the eastern portion of the watershed just south of Daniels St (Figure 3-45). Both of these areas do have steep slopes, however, they are well vegetated and are not a major source of sediment transport of phosphorous to downstream waterbodies. Overall, surface erosion appears to be a limited issue within the DMU since urban and residential development prevents erosion from occurring.

Figure 3-47 Areas of potential erosion based on the Universal Soil Loss Equation (USLE) estimates.

Channel Erosion

Natural stream channels in the DMU have been converted to underground storm pipes, which means that channel erosion cannot occur within this management unit.

3.3.3.3 Wetlands

Storage

Wetlands cover approximately 10% of the DMU based the FAW (Figure 3-48), which is the lowest percent coverage of any management unit within the Long Lake Creek Subwatershed (Figure 3-48). The elevated annual water yield estimates (Figure 3-47) within the watershed suggest that wetland storage, in combination with low impervious areas, in the Downtown MU are not providing beneficial flood and nutrient reduction to lakes within the subwatershed and downstream water bodies such as Long Lake.

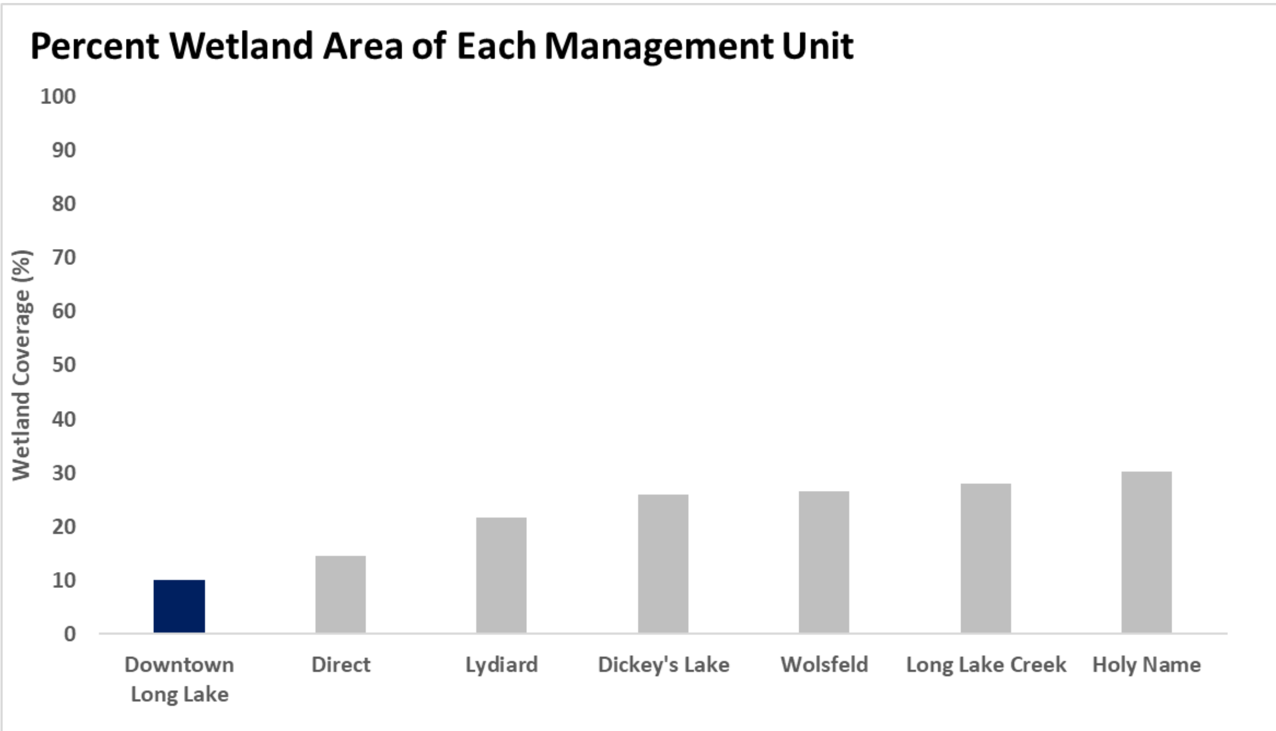


Figure 3-48 Percentage area of management unit covered by wetlands.

Vegetation Diversity

Wetland vegetation diversity in the DMU are generally in poor condition with the majority of wetlands (90%) having low or moderate vegetation diversity based on the FAW (Figure 3-50). These data suggest that the few remaining wetlands in this management unit have been negatively impacted from elevated watershed nutrient runoff and changes in hydrology.

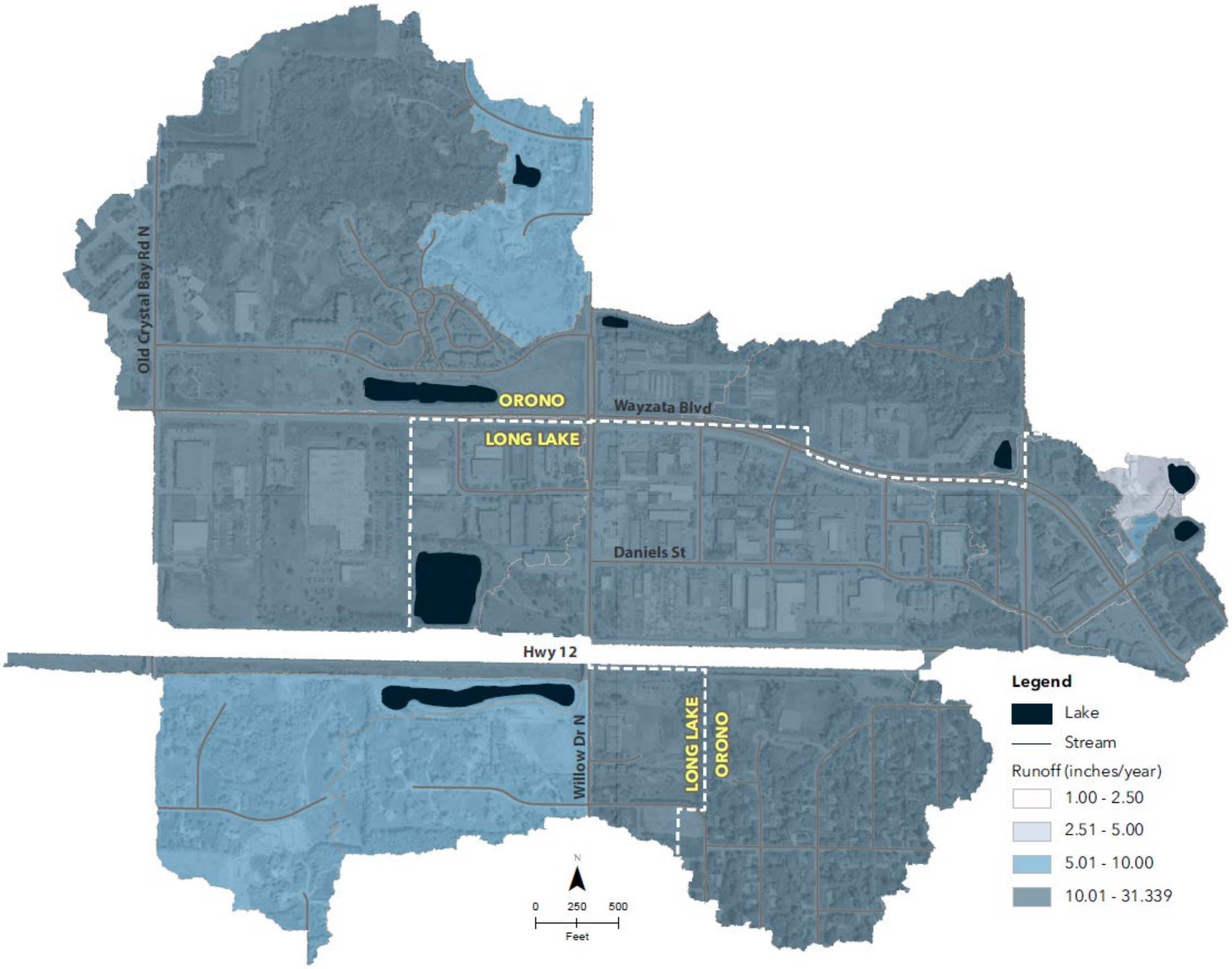


Figure 3-49 Annual water yield within the Downtown Management Unit based on P8 model output.

3.3.3.4 Watershed Storage and Phosphorus Removal Capacity

The Downtown MU is the only subwatershed in the Long Lake Creek Subwatershed that has less than 15% and has very few ponds for stormwater treatment. It is useful to understand why the Downtown MU has so few wetlands or stormwater treatment practices that result in stormwater runoff that is four to five times greater in volume than other management units. The development history of the DMU provides a unique lens into the intersection of development, regulation, and landuse change since this management unit has three areas that developed under different sets of regulations and development approaches. These areas include 1) the easternmost portion of the watershed that had a mix of residential and industrial landuse prior to 1940, 2) the central portion of the management unit that developed between 1960 and 1990, and 3) the northwest portion of the subwatershed that developed in the late 1990 and 2000s.

It is useful to understand when each area experienced development pressure since the areas that developed prior to 1990, such as the central and eastern portion of the management unit, appear to have retained no wetland areas and have very few stormwater treatment facilities. Conversely, the northwestern portion of the management unit has large wetlands that serve to reduce volume and pollutant runoff.

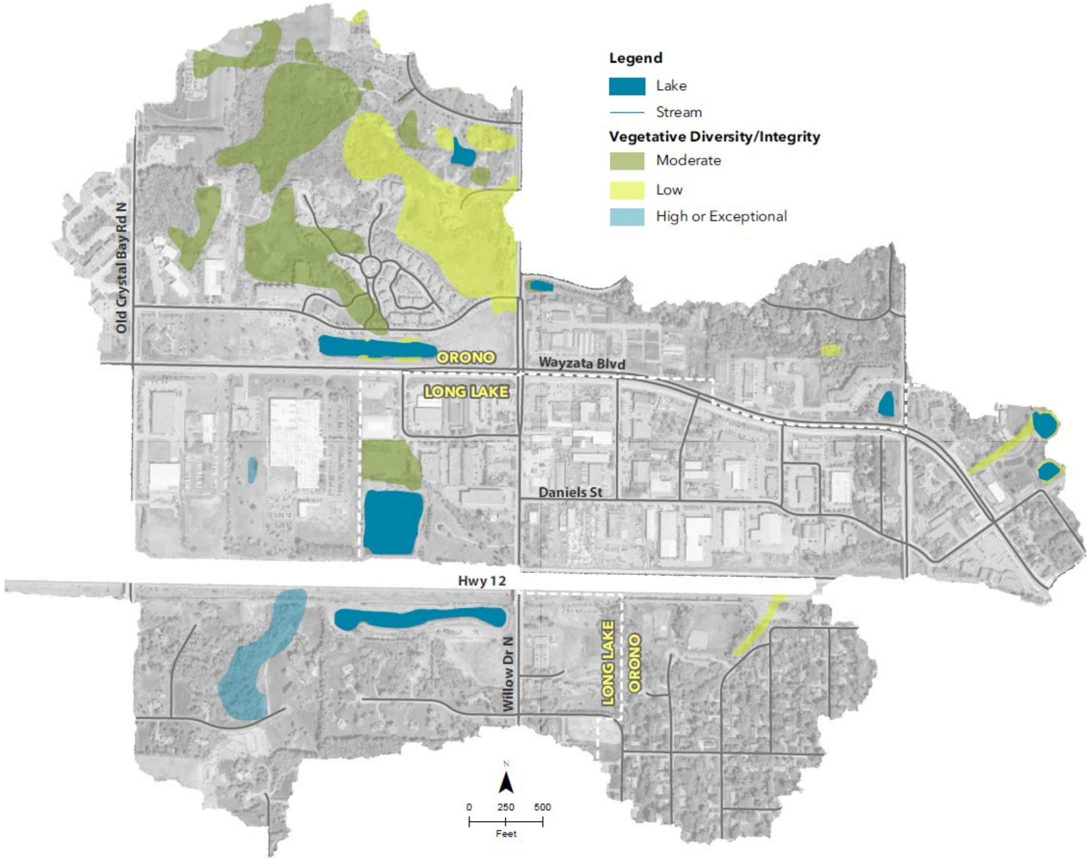


Figure 3-50 Wetland vegetation diversity based on the FAW throughout the Downtown MU and individual RFQA wetland assessments conducted in 2019.

Improving storage in the Downtown MU will be difficult since landuse change will be relatively slow and provide minimal opportunity for wetland restoration. However, identifying public properties for restoration or BMPs in the central portion of the watershed will likely provide the greatest return on investment since this area has the greatest highest runoff volumes and total phosphorus concentrations, which is combined with the lowest amount of stormwater storage (Figure 3-45; Figure 3-46; Figure 3-49).

3.4 Direct Management Unit

3.4.1 Watershed Description

The Long Lake Direct Management Unit (Direct) encompasses 1,667 acres that surround Long Lake. Parts of the Cities of Medina, Orono, and Long Lake are within this MU (Figure 3-51. Residential areas and the Spring Hill Golf Club are the primary developed land use within this management unit. The remaining land uses in the Direct MU consists of undeveloped areas, preservation areas, and parks. Over a quarter of the land area is covered by water bodies – 284 acres of which is Long Lake, and a total of 243 acres of wetlands.

Table 3-8. Direct Management Unit lake morphometry, impairment status, and DNR Lake Class

Lake	Surface Area (acre)	Maximum Depth (ft)	Lake Volume (ac-ft)	Percent Littoral Area (%)	Impairment Status	DNR Lake Class
Long Lake	286.5	35	3,982	54	Impaired	24

The Direct MU represents a small drainage area surrounding Long Lake that receives drainage from other larger management units including the Wolsfeld MU, Holy Name MU, Downtown MU, and Dickey's MU. Therefore, the focus of this section is assessing the impact phosphorus inputs from each management unit relative to in-lake process such as sediment phosphorus release and impacts from fish.

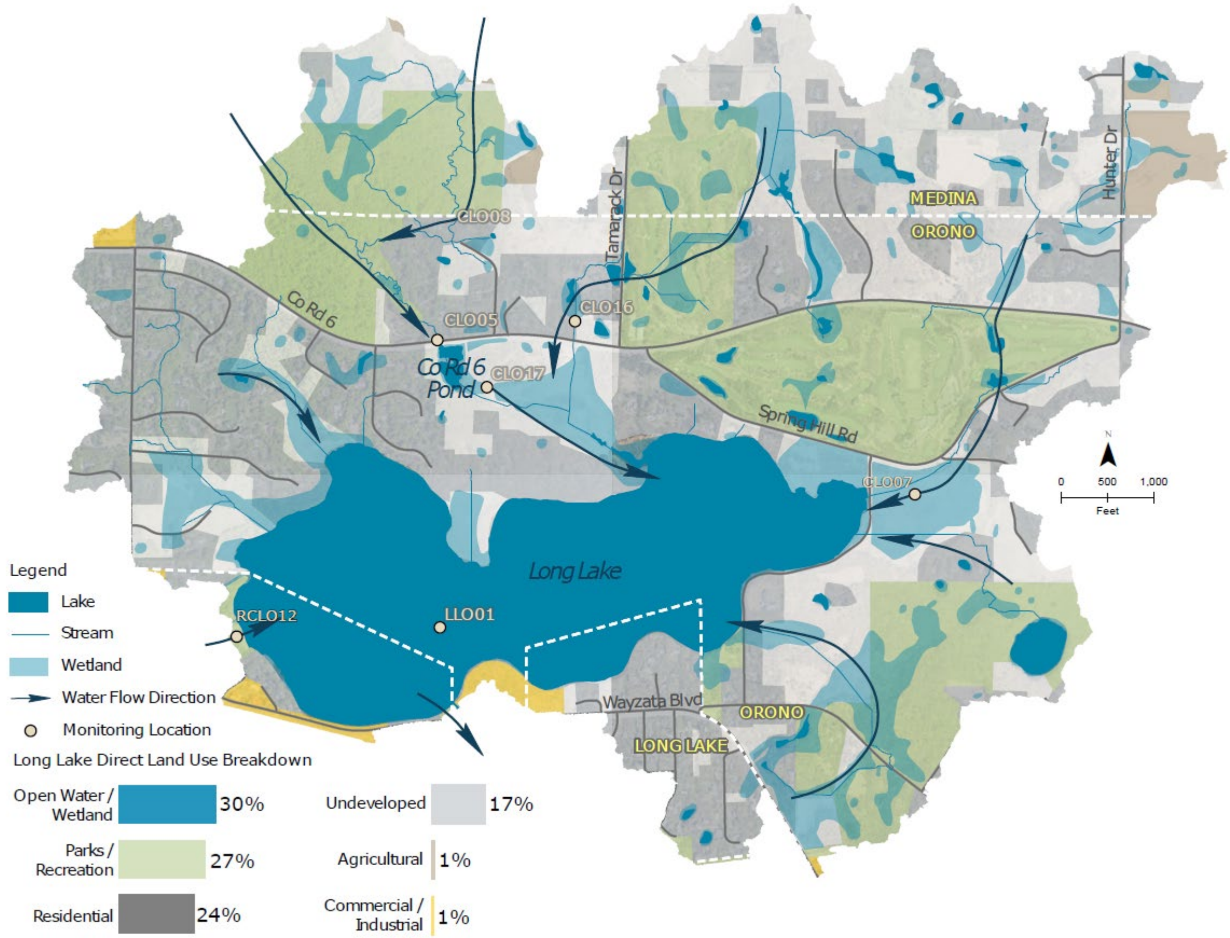


Figure 3-51. Direct Management Unit overview including flowpaths, major water bodies, and landuse (Source: MLCCS).

3.4.2 Water Quality Overview

The Direct MU drainage area is relatively small and consists of relatively few channelized streams, which is why the focus of this section will focus on the water quality of streams draining into Long Lake from other management units. Phosphorus concentrations at all tributaries to Long Lake were above the total phosphorus stream standard (0.100 mg/L TP) based on historical monitoring data (Figure 3-52). However, the difference between the median phosphorus concentration of each site is large, which provides evidence of which management units should receive priority for watershed load reduction projects.

The two tributaries with the highest median phosphorus concentrations include the Downtown MU outlet (RCLO12) and a small tributary outlet south of County Road 6 (RCLO16) that drains portions of Spring Hill Golf Course and a few residential properties (Figure 3-52). The source of high phosphorus concentrations from the Downtown MU are from high levels of impervious runoff without sufficient stormwater treatment prior to reaching Long Lake, which is discussed in Section 3.3.3.1. The small tributary draining the central region of the Direct MU (RCLO16) has the highest phosphorus concentrations, which will be discussed in greater detail in the source assessment. However, this small tributary has concentrations that are over an order of magnitude greater than the stream TP standard and median concentrations of 0.500 mg/L, suggesting that phosphorus reductions are needed.

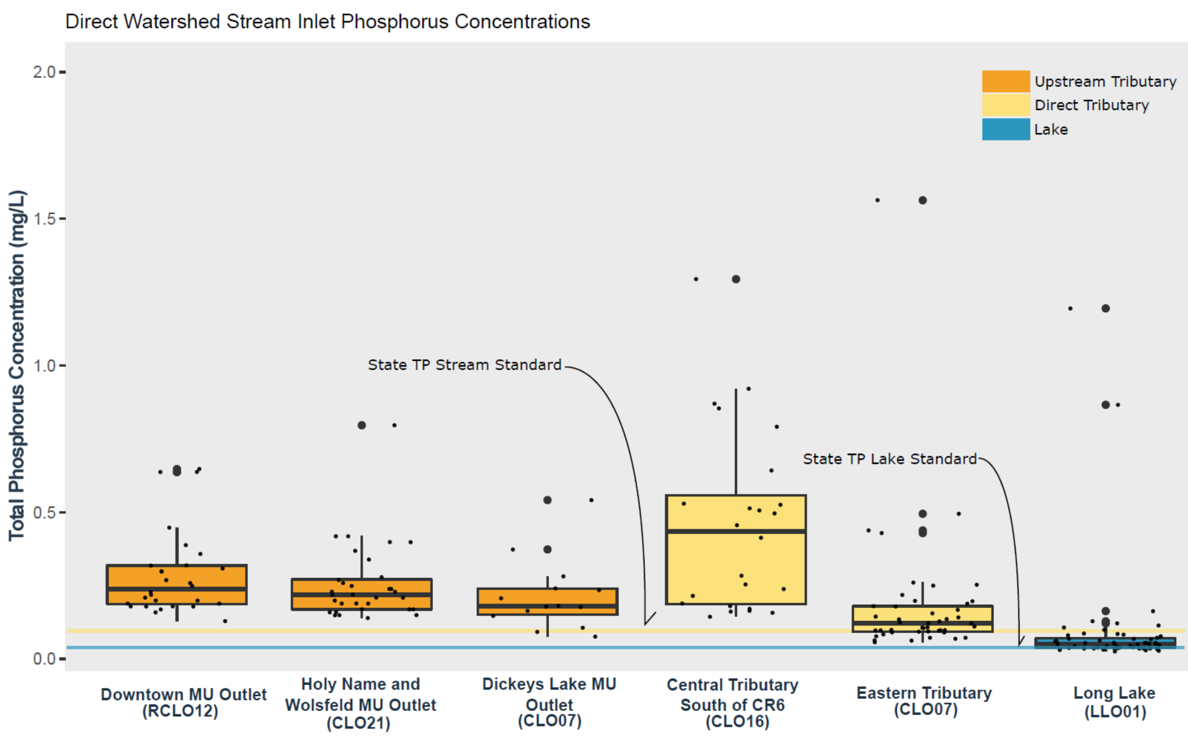


Figure 3-52. Total phosphorus concentrations in Long Lake (blue) and tributaries draining to Long Lake from upstream tributaries (orange) and runoff from the direct subwatershed (yellow).

The two tributaries with the lowest phosphorus concentrations include the Dickey's Lake MU (CLO07) and the eastern portion of the Direct MU (CLO07) (Figure 3-52). The eastern portion of the Direct DMU has the lowest median TP concentrations at 0.122 mg/L and the outlet of the Dickey's Lake MU has slightly higher TP concentrations at 0.181 mg/L. Overall, both of these drainage areas have relatively low runoff TP concentrations due to the large areas of undeveloped areas or large lot residential.

The confluence of Wolsfeld MU outlet and the Holy Name MU outlet is located just upstream of the County Road 6 Pond (CLO07), which is owned and maintained by MCWD (Figure 3-51). Both of these management units have areas with high phosphorus runoff, however, the large amount of stormwater treatment and storage from the abundant lakes and wetlands results in total phosphorus concentrations that are relatively low (Figure 3-51). Furthermore, the MCWD's County Road 6 Pond serves as phosphorus removal prior to reaching Long Lake. However, additional phosphorus reductions from MCWD's County Road 6 Pond may be possible to further improve water quality discharge that reaches Long Lake.

3.4.3 Watershed Nutrient and Runoff Characterization and Source Assessment

3.4.3.1 Watershed Runoff Modeling

Modeled total phosphorus runoff concentrations in the Direct MU generally fall within the 0.15 to 0.32 mg/L range (Figure 3-53), which is similar to the concentrations measured in the eastern direct tributary (Figure 3-52) but an underestimate compared to concentrations measured in the central tributary just south of County Road 6 (Figure 3-52). Elevated runoff concentrations in the eastern portion of the subwatershed can be attributed to relatively low density of wetlands and stormwater BMPs combined with relatively steeps slopes near the lake and high phosphorus runoff from surrounding golf courses (Figure 3-53).

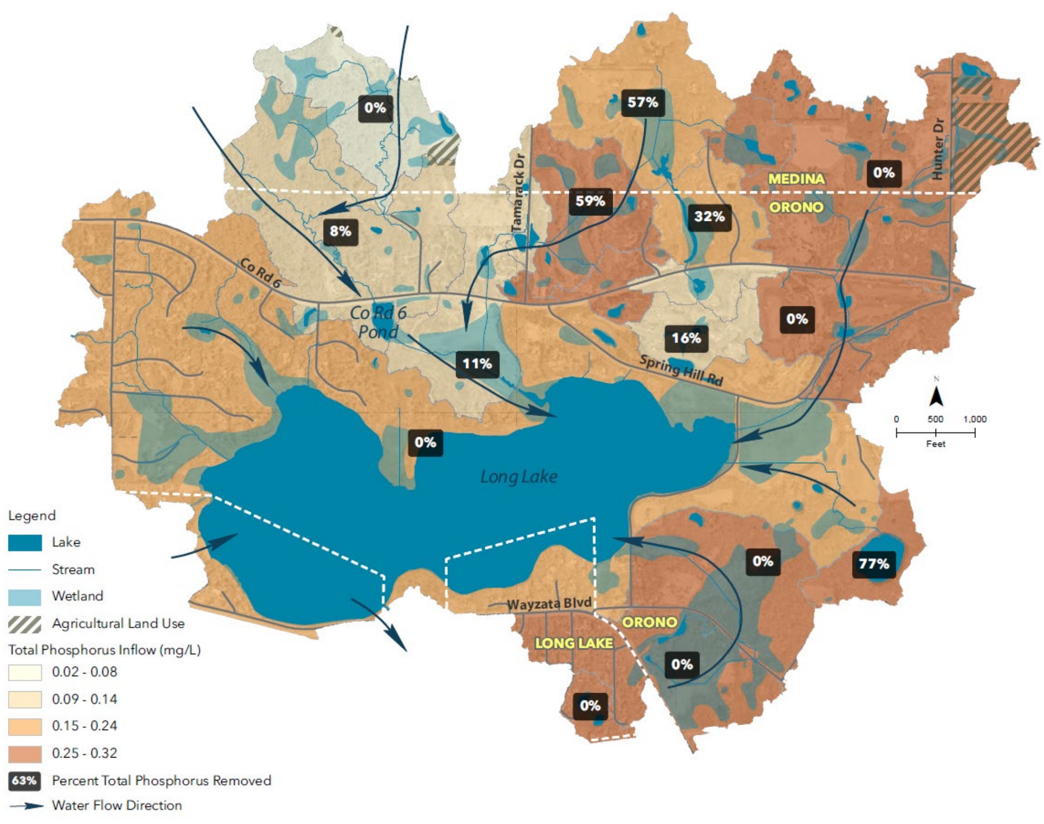


Figure 3-53 Phosphorus runoff concentration at the outlet of each catchment that includes treated runoff from upstream ponds or lakes and direct untreated runoff. The white numbers in black boxes represent the phosphorus reduction at the outlet of each catchment. All values within this map are based on P8 output.

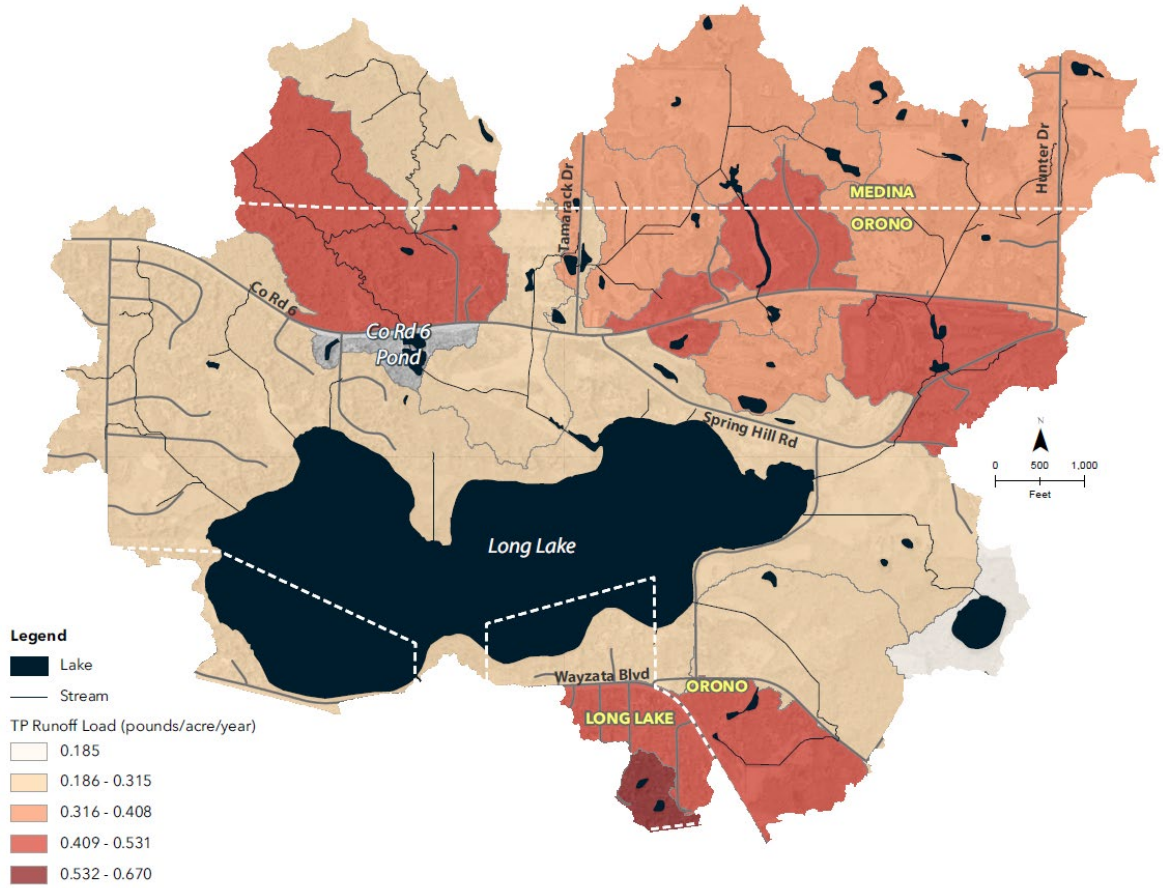


Figure 3-54. Unit area total phosphorus loading from each catchment based on P8 modeling output.

Overall, these data suggest that additional stormwater treatment of runoff from golf courses in the north-east portion of the Direct MU would reduce elevated runoff from reaching Long Lake. Other areas such as the southeast portion of the Direct MU have somewhat elevated TP runoff, however, these areas are largely undeveloped and likely have low potential for phosphorus reduction based on the phosphorus load from these areas (Figure 3-52). Therefore, restoration opportunities should be targeted reducing elevated runoff in the north-central and north-east portions of the Direct MU.

The north central portion of the Direct MU should be prioritized for further feasibility assessment and data collection based on the unusually high total phosphorus concentrations (Figure 3-52). The median total phosphorus concentration in this location is 0.498 mg/L, which is nearly double the modeled phosphorus concentrations (Figure 3-52). Elevated stormwater runoff alone does not explain the measured phosphorus concentrations since P8 uses empirically derived phosphorus runoff concentrations based on landuse from the literature (Walker, 1990). One potential hypothesis is that historic loading to this series of wetlands has overwhelmed their capacity to remove phosphorus and they are now exporting elevated phosphorus. More intensive monitoring in this area would help elucidate the source of elevated phosphorus and potential solutions based on the subsequent findings.

3.4.3.2 Erosion Assessment

Surface Erosion

The Direct MU has a few concentrated areas that were identified as having potential surface erosion including areas upstream of the County Road 6 Pond near Wolsfeld Lake, in areas surrounding Spring Hill Golf Course, and shoreline locations on Long Lake (Figure 3-55). These sites are generally well vegetated based on desktop review and don't appear to be major sources of sediment and phosphorus to Long Lake relative to other sources such as elevated stormwater runoff and wetland phosphorus export.

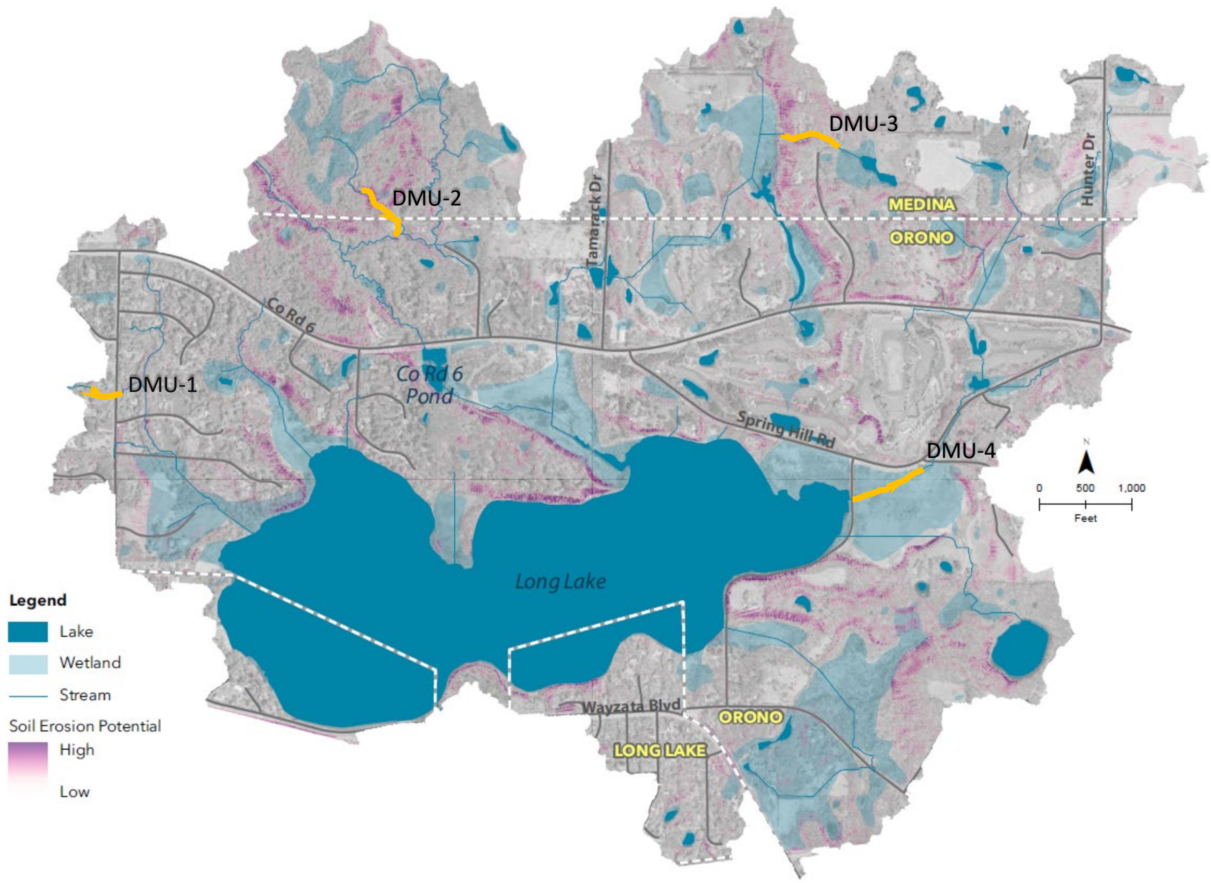


Figure 3-55 Areas of potential erosion based on the Universal Soil Loss Equation (USLE) estimates

Channel Erosion

The Direct MU has a large number of small tributaries draining to Long Lake, which were surveyed in 2013 as part of MCWD's Stream Assessment (Interfluve, 2013). This report focused on the surveyed locations that had evidence of channel erosion based on field surveying photos and notes taken by the Interfluve geomorphologists (Figure 3-55; Table 3-9).

Table 3-9 Locations of channel erosion based on the MCWD 2013 Stream Assessment (Interfluve, 2013), field investigations (Appendix F) and review of available site photos (Appendix F).

Location	Description	Active Erosion	Potential Project Identified in 2013 Stream Assessment
DMU-1	Channel Erosion downstream of Dickeys Lake	Yes	Yes
DMU-2	Tributary channel erosion in small tributary upstream of County Road 6 Pond	Yes	No
DMU-3	Small tributary just north of County Road 6 on Willowbrook Dr.	Yes	Yes
DMU-4	Tributary channel erosion east of Long Lake near Spring Hill Road	Yes	Yes

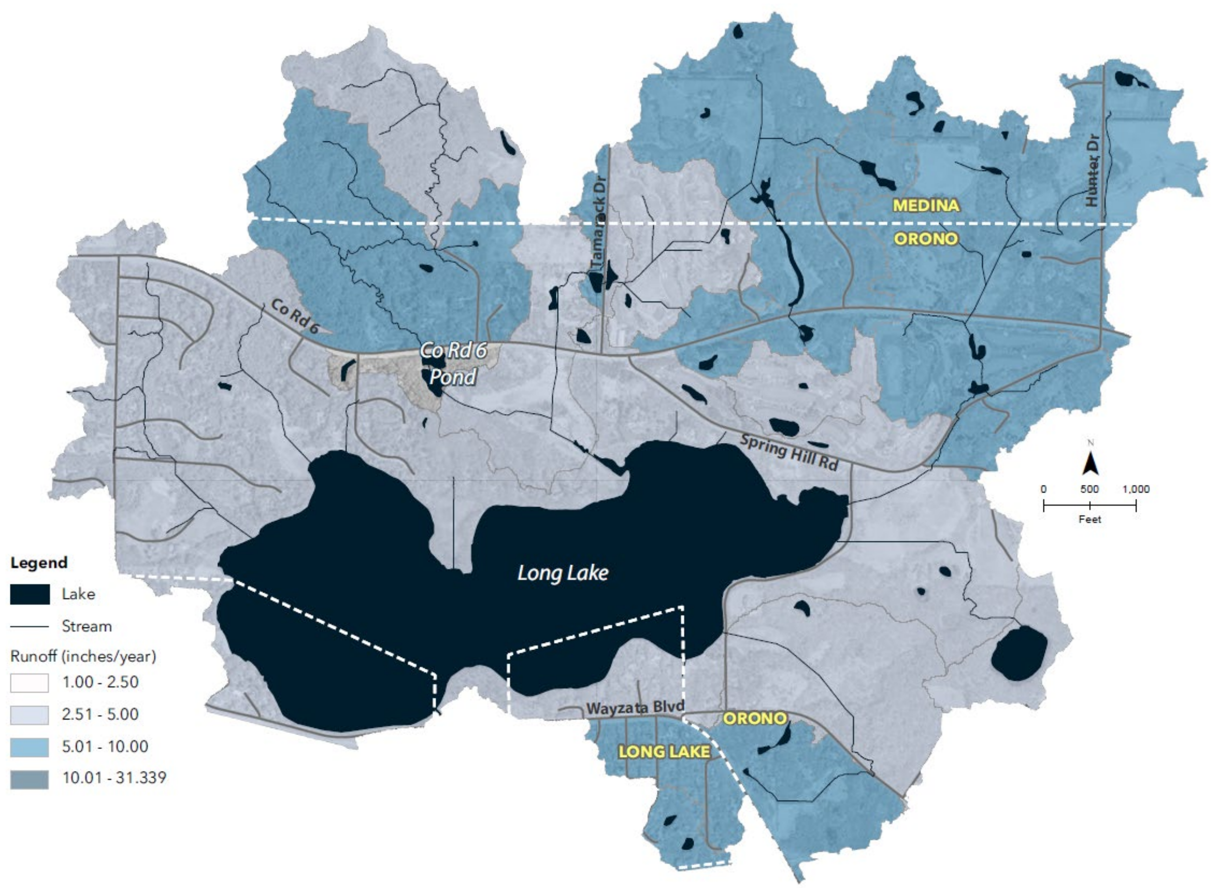


Figure 3-56 Annual water yield within the Direct Management Unit based on P8 model output

3.4.3.3 Wetlands

Storage

Wetlands cover approximately 14% of the Direct MU based the FAW (Figure 3-57; Figure 1-1), which is well below presettlement conditions (~35%) (Anderson and Craig, 1984) and the second lowest percent coverage in the Long Lake Creek Subwatershed (Figure 3-57; Figure 1-1). The Direct MU is less developed than the other management unit with similar percent coverage of wetlands (Downtown MU), however, there are large golf courses and residential areas that may have decreased the wetland coverage. There are several areas that have water yields that are greater than presettlement conditions in several areas (Figure 3-56). The elevated annual water yield estimates (Figure 3-56) within the management unit suggest that wetland storage, in combination with moderate levels of development, in the Direct MU suggest that more wetland coverage would improve flood storage and reduce nutrient runoff to Long Lake.

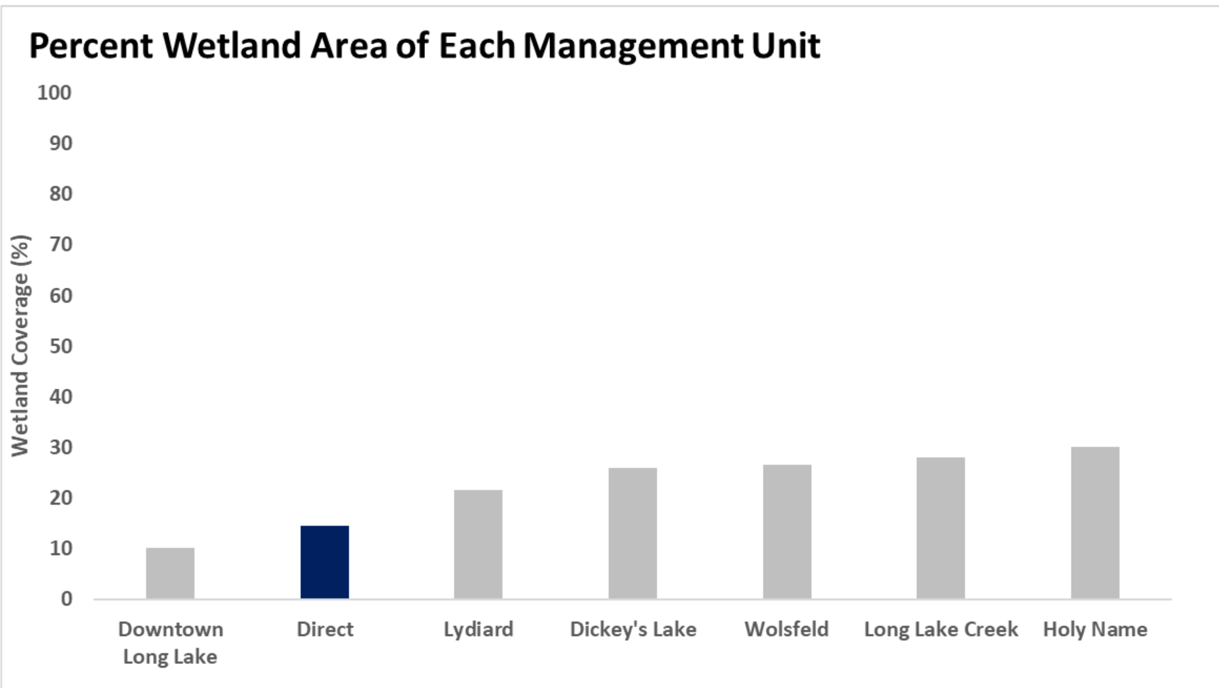


Figure 3-57 Percentage area of management unit covered by wetlands

Vegetation Diversity

Wetland vegetation diversity is relatively poor within the Direct MU with the majority of wetlands having low (32.5%) or moderate (40.6%) vegetation diversity based on the FAW (Figure 3-58; Figure 3-59). These data suggest that elevated watershed nutrient runoff and changes in hydrology have negatively impacted wetland vegetation, which is a well-established phenomenon that has been well documented in literature (EPA 2002). Species that are tolerant to environmental change such as cattail (*Typha latifolia L.)* and reed canary grass (*Phalaris arundinacea)* are able to outcompete other intolerant wetland plant species as human driven watershed runoff enriches soil nutrients and changes wetland water levels.

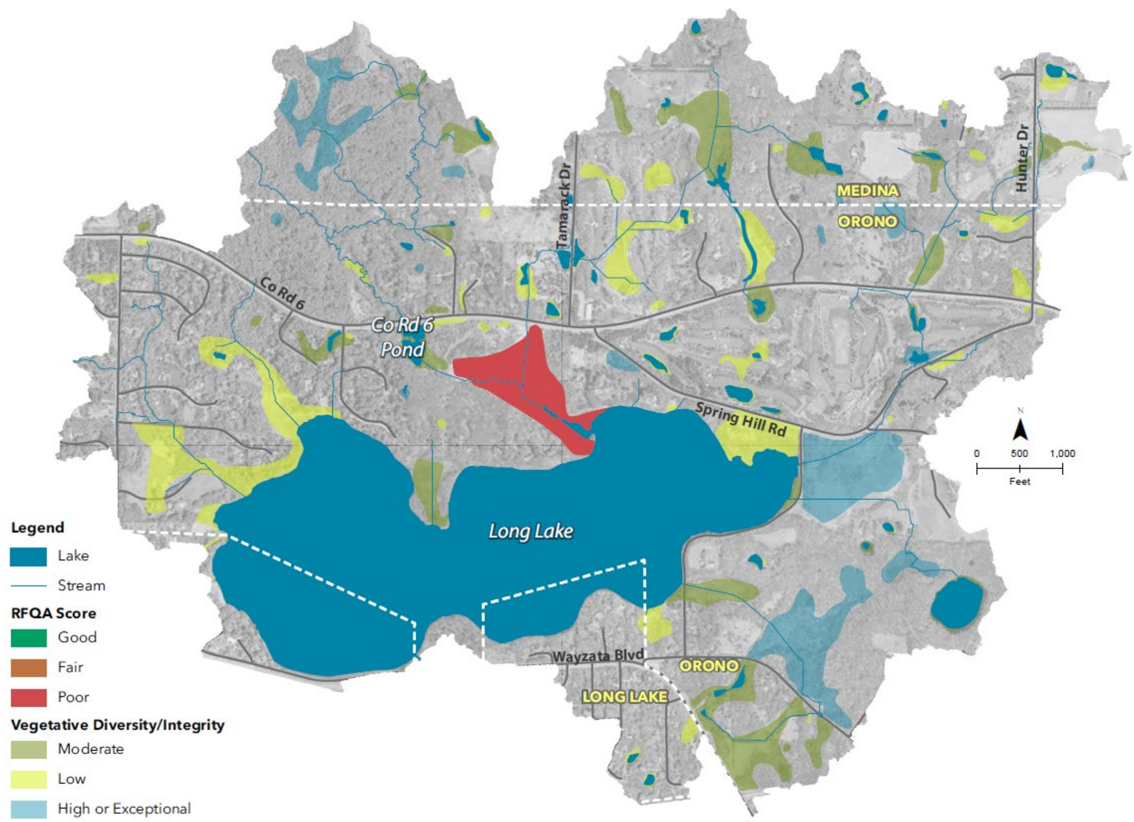


Figure 3-58 Wetland vegetation diversity based on the FAW throughout the Direct MU and individual RFQA wetland assessments conducted in 2019.

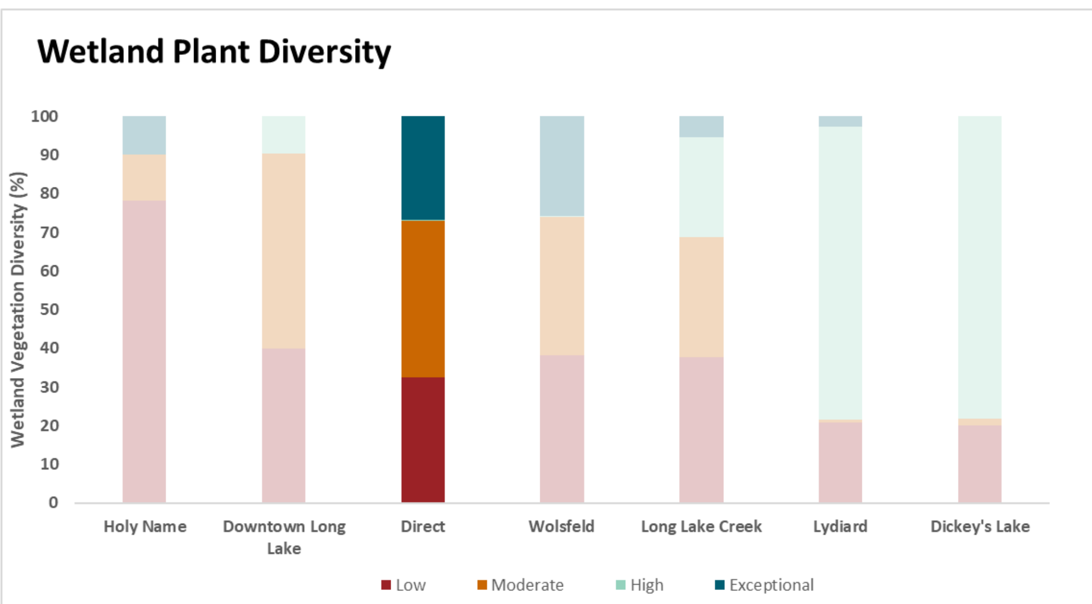


Figure 3-59 Wetland vegetation diversity of the Direct MU (highlighted) relative to other management units (faded) based on the FAW.

Wetland Nutrient Cycling

Stream water quality monitoring within the Direct MU was focused on the outlet of other management units since many of the tributaries that drain areas within the Direct MU are very small with highly intermittent flow, which makes monitoring the inlet and outlet of most wetlands impractical. However, the total phosphorus results draining the central portion of the Direct MU just south of County Road 6 had unusually high phosphorus concentrations. These data suggest that historic phosphorus loading has exhausted the wetland's capacity to remove phosphorus, which has resulted in the wetland exporting very high phosphorus concentrations (Figure 3-52). Further analysis of the impact of wetland phosphorus impact to Long Lake is discussed further in the Nutrient Budget discussion for Long Lake (Section 3.4.5.2).

3.4.4 In-Lake Assessment

3.4.4.1 Internal Phosphorus Loading from Sediment Release

MCWD staff collected sediment cores from Long Lake to characterize the amount of phosphorus that is release under anoxic conditions. Internal loading estimates using the sediment release rates revealed that sediment phosphorus release is relatively high for Long Lake compared to sediment release rates collected in other lakes throughout Minnesota (Figure 3-60). The moderately high phosphorus anoxic release rates means that there is potential for Long Lake sediments to release phosphorus during anoxic periods in Long Lake (Figure 3-60).

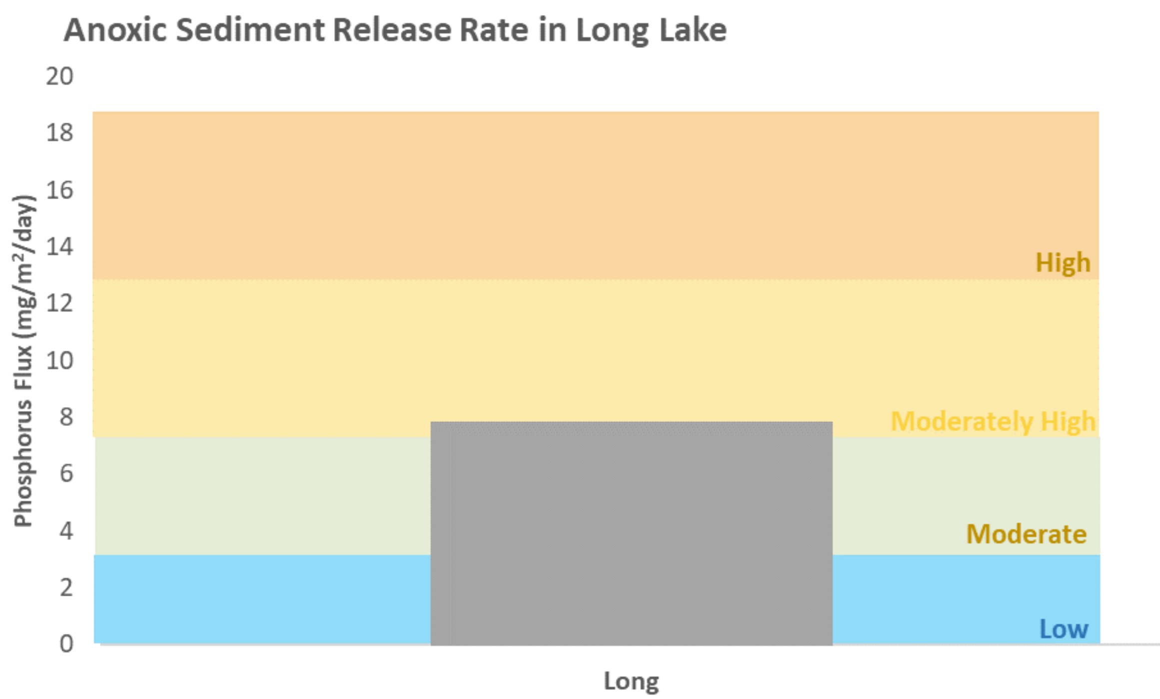


Figure 3-60 Sediment phosphorus release rate from Long Lake sediment.

The other factor to consider for internal loading is the amount of time and the total area that the sediment is exposed to anoxic conditions, which is referred to as the anoxic factor. Long Lake has dissolved oxygen data to characterize the amount of anoxia that occurs each year (Figure 3-61). These data showed that both lakes have long periods of anoxia in the deeper portions of the lake (hypolimnion), which result in internal phosphorus loading (Figure 3-61).

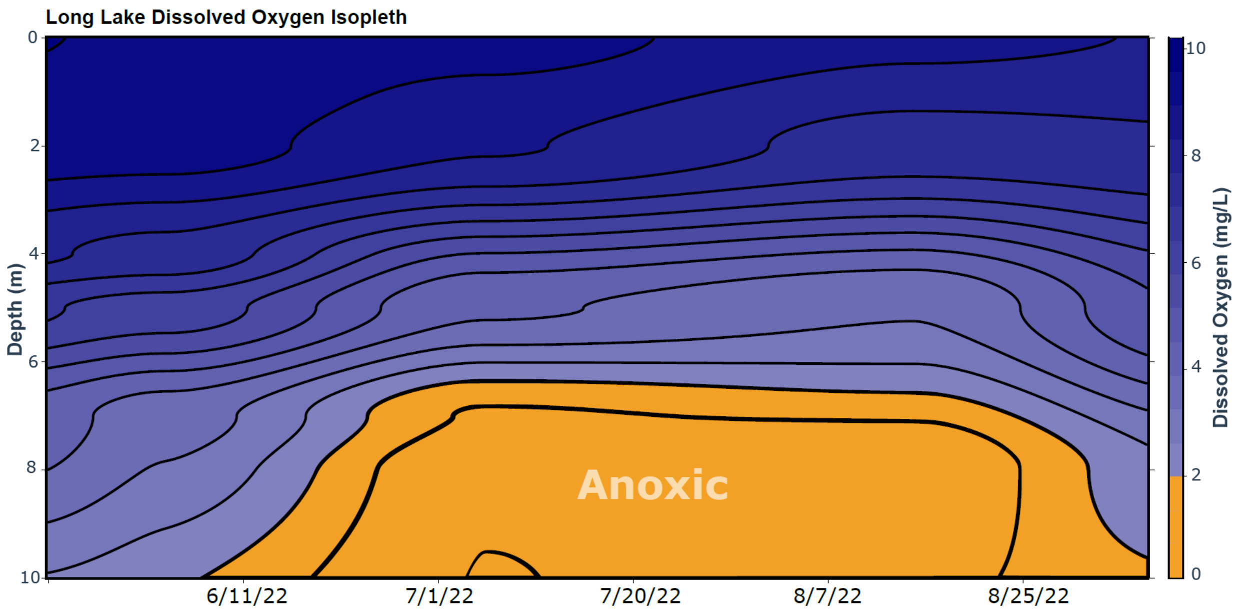


Figure 3-61 Long Lake dissolved oxygen data that demonstrates the period of anoxia that occurs each year.

Monitoring of hypolimnetic phosphorus concentrations in Long Lake demonstrate that phosphorus in the hypolimnion of Long Lake steadily increase between April and September due to anoxic phosphorus release from sediments (Figure 3-62). Hypolimnetic phosphorus concentrations rapidly decrease after September due to the destratification of the Long Lake. Overall, the sediment release rates, anoxic conditions, and hypolimnetic phosphorus data provide strong evidence that internal loading is an important factor in phosphorus cycling in Long Lake. These data will be compiled in upcoming sections to quantify the internal load of Long Lake.

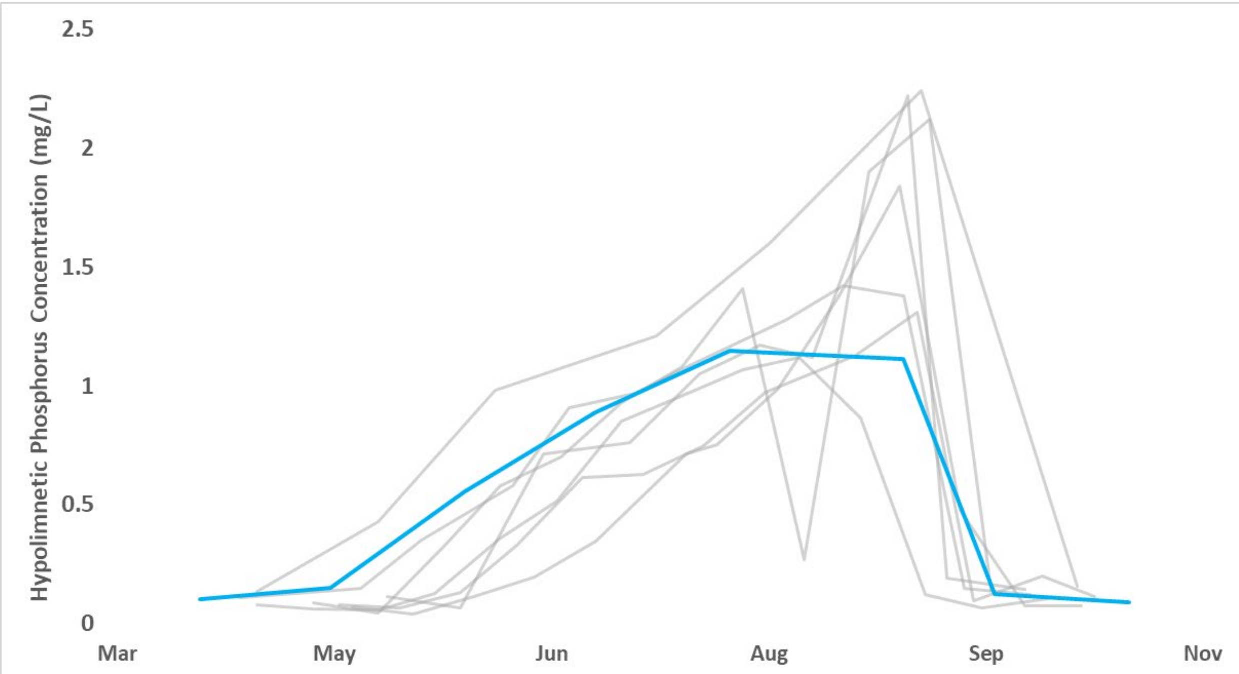


Figure 3-62 Average monthly hypolimnetic phosphorus concentration timeseries between 2007 and 2019 (blue) and average monthly hypolimnetic phosphorus concentrations for individual years (light grey).

3.4.4.2 Lake Submerged Aquatic Vegetation

Submerged aquatic vegetation (SAV) surveys were conducted in Long Lake in 2019 to characterize (Figure 3-63). MCWD's E-grade health assessment provides a quantitative framework for the lake SAV data, which categorizes all of the lakes with excellent, good, poor, or degraded based on the FQI score. The results from these surveys demonstrated that the macrophyte community in each lake is dominated by Eurasian watermilfoil and coontail, which are considered species tolerant of poor water quality conditions (Appendix E). The late summer survey indicated that the only species growing deeper than five feet was coontail, which provides evidence that poor water clarity is limiting growth of all plant species besides coontail.

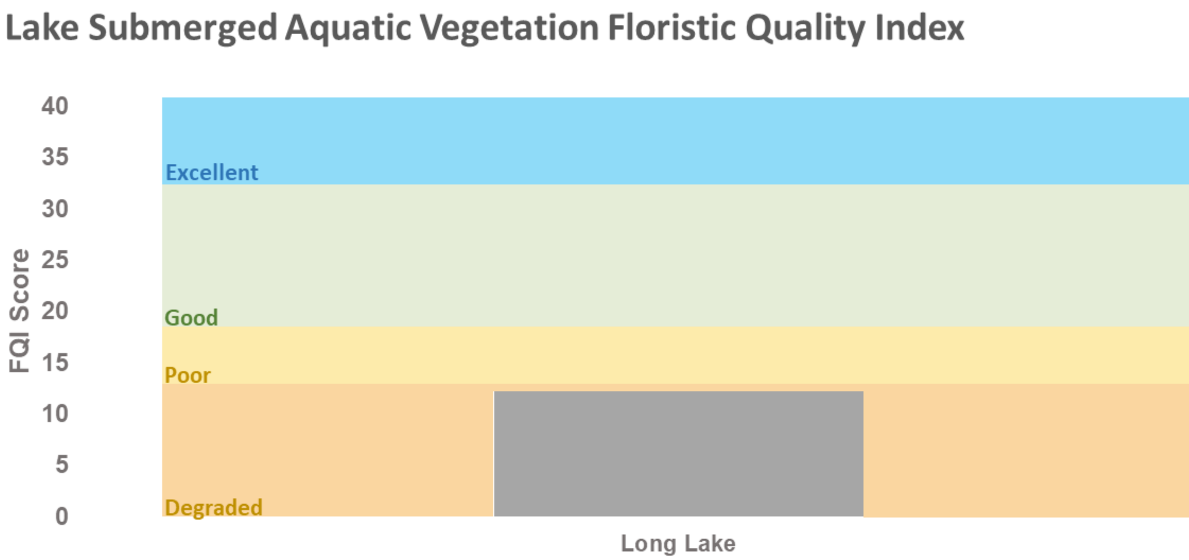


Figure 3-63 Vegetation results from Long Lake compared to Floristic Quality Index thresholds developed in MCWD's E-Grade scoring system.

3.4.4.3 Fisheries

Condition

The Minnesota Department of Natural Resources (MDNR) has developed a classification system for Minnesota lakes that considers each lake's chemical and physical properties to characterize what fish should be in the each lake. The anticipated fish species based on Long Lake's classification are located in Table 3-10, which lists the primary fish species that should exist in each lake based on its designated classification. Overall, the lake classification in Long Lake suggests that no species sensitive to poor water quality (intolerant species) should be observed and tolerant species such as common carp may be present due to the poor water quality conditions of Long Lake (Table 3-10; Figure 3-64).

Table 3-10 MnDNR lake class based on lake morphomentry and water quality conditions.

Lake	DNR Lake Class	Primary Fish Species Expected	Secondary Fish Species Expected
Long	24	Northern Pike, Bluegill, Common Carp*	Bowfin, Black bullhead*, Yellow Bullhead, Pumpkinseed, Largemouth Bass, Black Crappie, Yellow Perch, White Sucker

* Fish that are tolerant of degraded habitat conditions

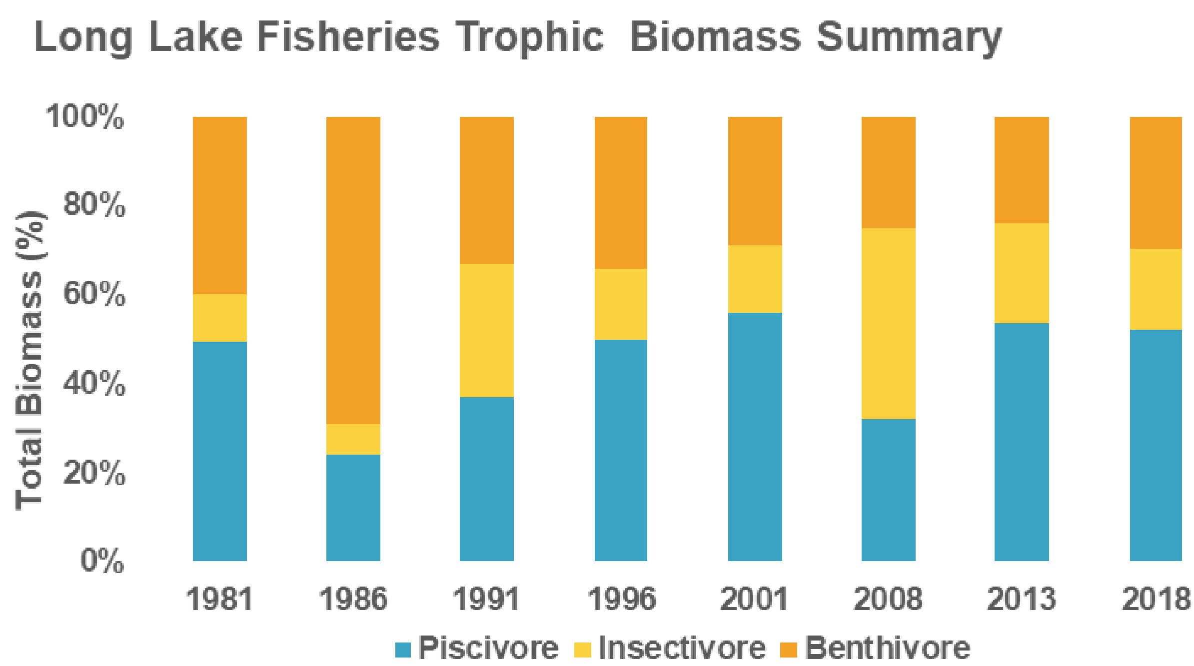


Figure 3-64 Fisheries biomass summary by trophic group for Long Lake.

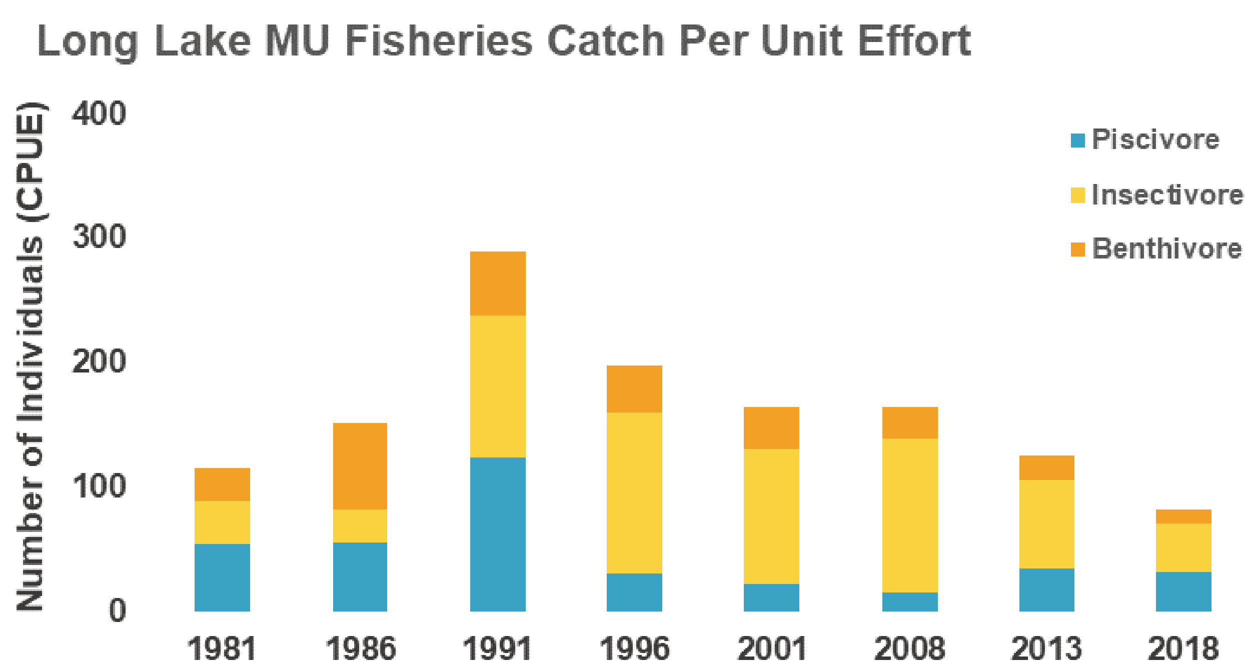


Figure 3-65 Fisheries CPUE individual summary by trophic group for Long Lake.

Long Lake has been sampled using the fish-IBI, which was used to characterize the health of the lake based on the fish species that are observed. The overall diversity of Long Lake was lower than in similar lakes and received an IBI score of 13 indicating that it has a degraded fish community due to the absence of intolerant species, low number of vegetation-dwelling species (two), and relatively high percent biomass of tolerant species in the trap net surveys. However, we can compare the relative abundance of fish species that thrive in poor water clarity and habitat conditions (tolerant fish) over time (Figure 3-66).

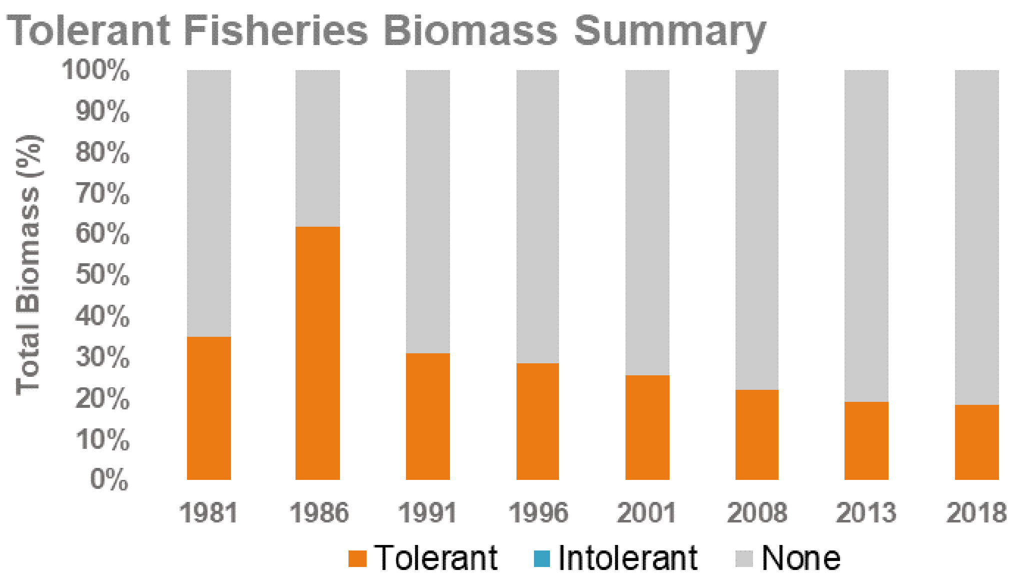


Figure 3-66 Fisheries biomass summary of tolerant and intolerant fish observed in the Direct MU.

Carp Source Assessment

MCWD also conducted a source assessment of common carp within each management unit to understand if carp are actively recruiting and characterize how carp can move through the management unit and subwatershed to inform potential carp management activities.

The carp movement and age assessment provided valuable insight into the source of carp in the Direct MU. The pit tag assessment suggested carp are capable of moving between Long Lake and Tanager Lake since there are carp from Tanager Bay detected at the inlet of the Hwy 12 pond inlet and carp from Long Lake at the Hwy 12 Pond outlet (Figure 3-69 and Figure 3-70). In addition, PIT tag antennas placed at the County Road 6 pond upstream of Long Lake detected tagged carp from Tanager Bay (Figure 3-21), which further supports that carp can move freely between Tanager Bay and Long Lake.

Another line of evidence to identify the source of carp within the Wolsfeld MU is carp age data (Figure 3-22), which show that there is not a significant difference between the age of carp captured in Long Lake and carp captured in Tanager Bay (Figure 3-22). Carp age data coupled with migration data provide strong evidence that carp from Tanager Bay are able to migrate into Long Lake, which means Tanager Bay acts as a source of carp to Long Lake. Overall, biomass removal may not limit carp in Long Lake since Tanager Bay, and the larger Lake Minnetonka Bay area, will serve as a source of carp to Long Lake.

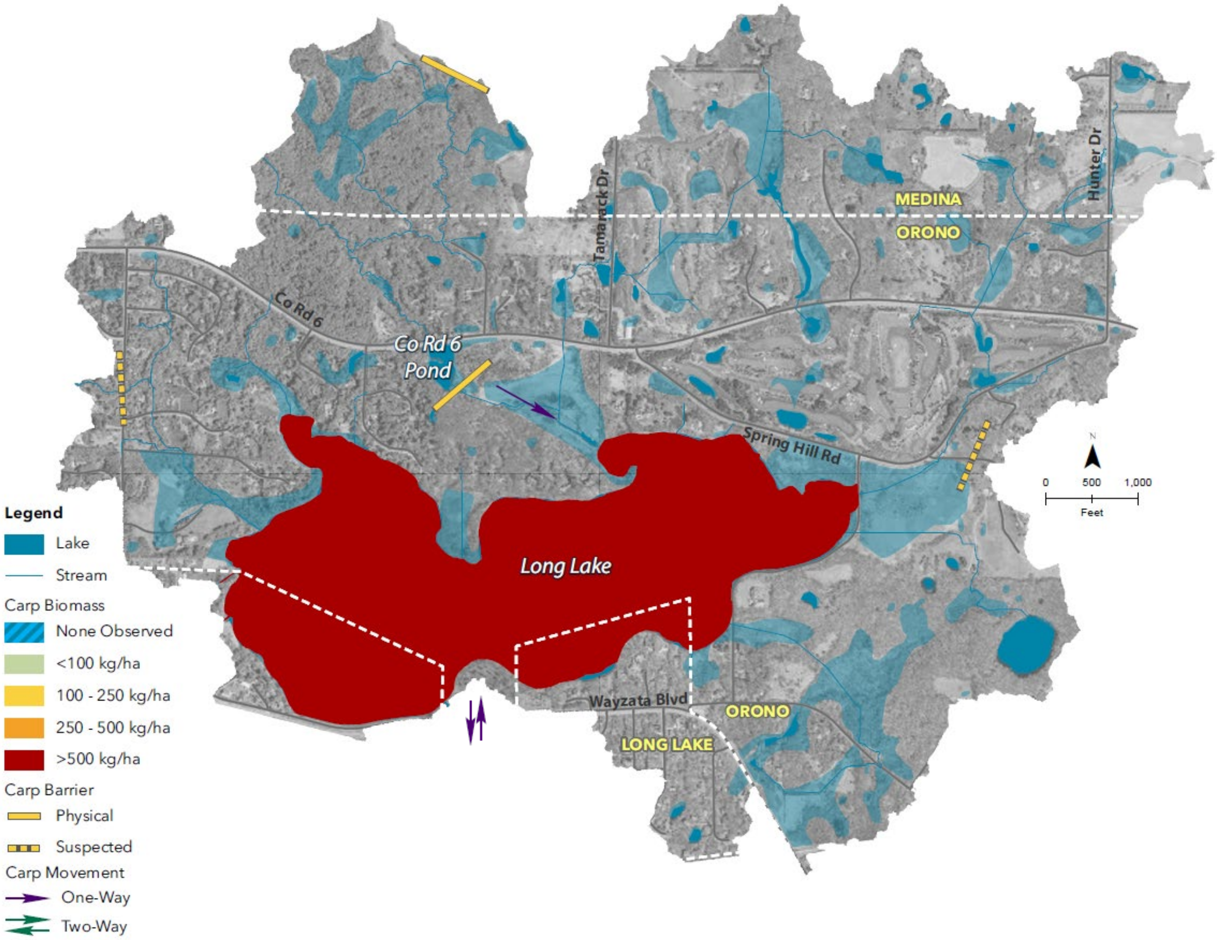


Figure 3-67 Carp movement and movement overview for the Direct Management Unit.

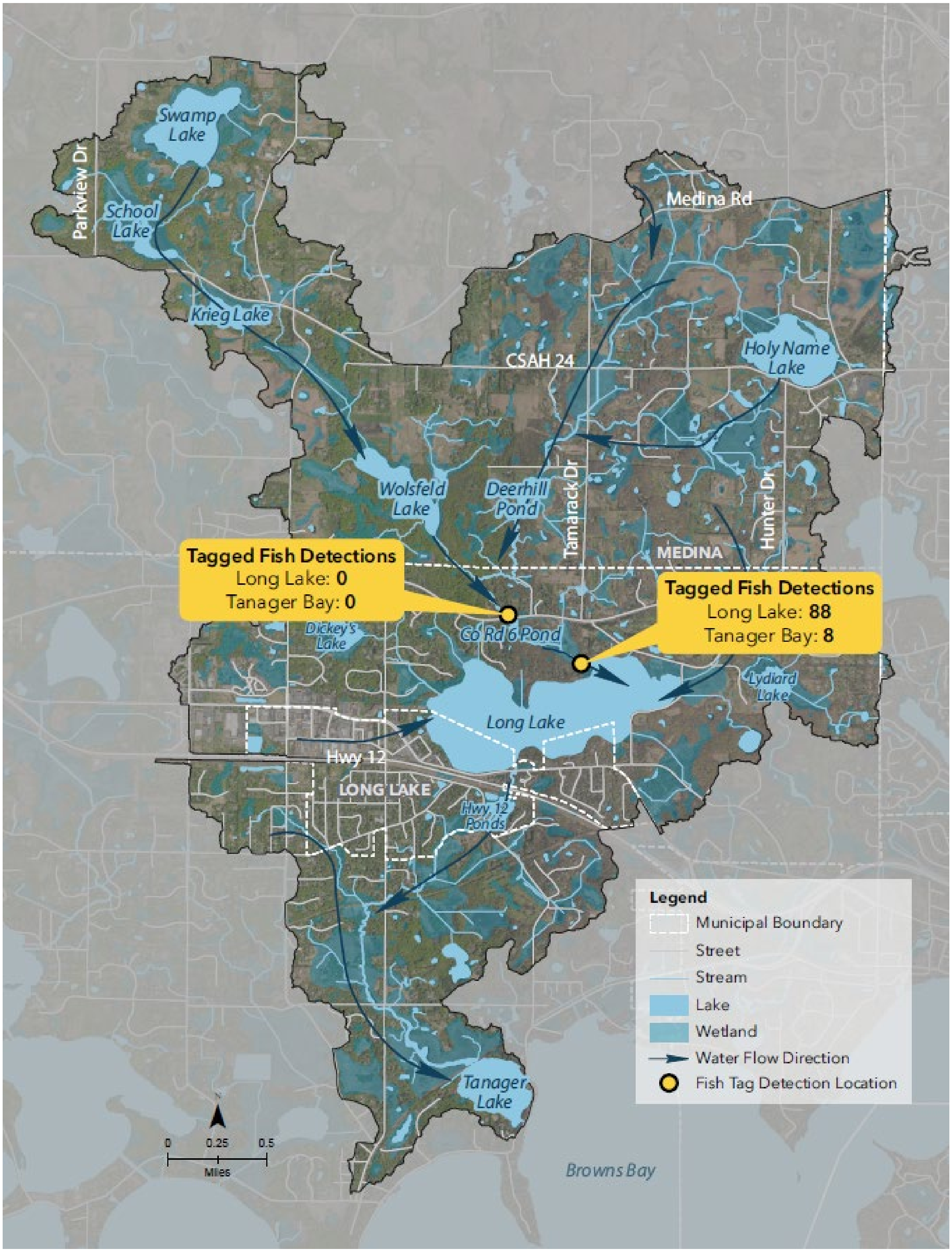


Figure 3-68 Carp movement monitoring locations located just downstream of the Direct MU to identify if carp can freely migrate into Long Lake from Tanager Lake.

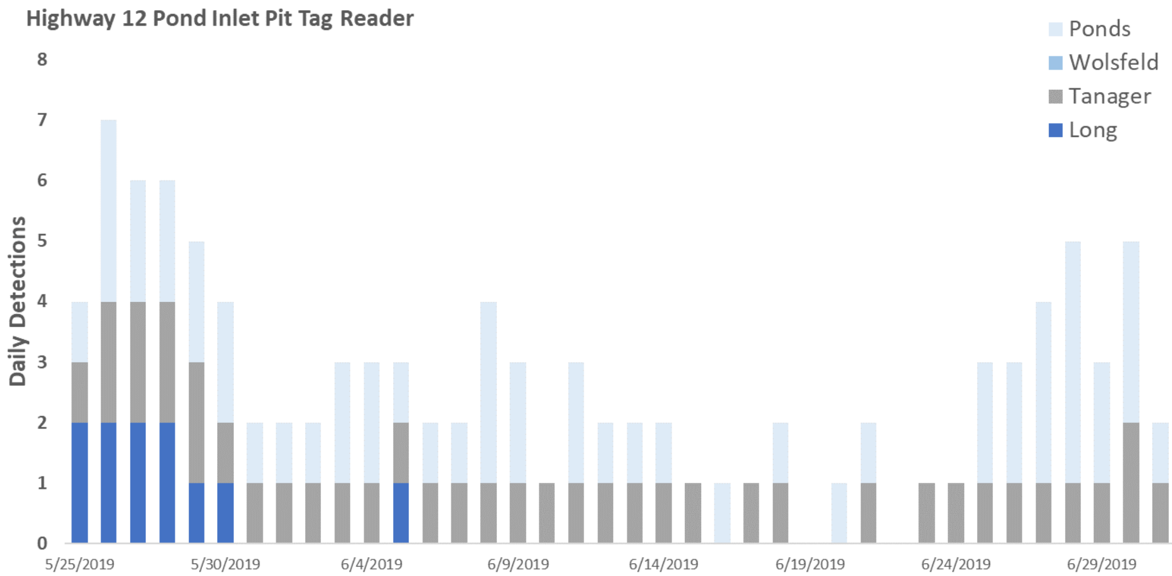


Figure 3-69 Daily detections of pit tagged carp at the Highway 12 Pond inlet pit tag reader.

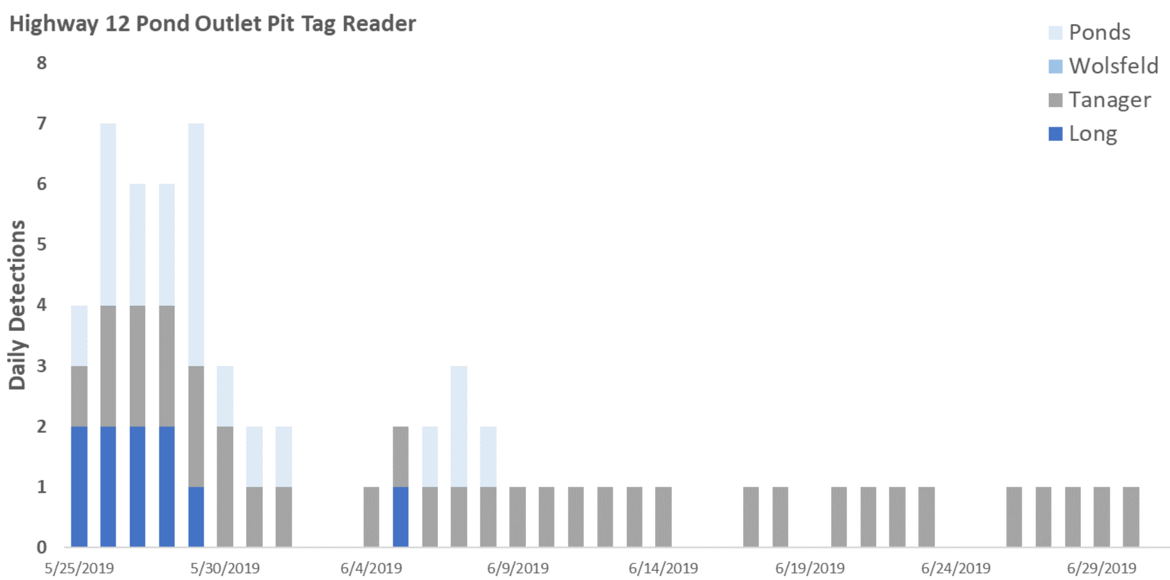


Figure 3-70 Daily detections of pit tagged carp at the Highway 12 Pond outlet pit tag reader.

3.4.5 Lake Nutrient Budget

3.4.5.1 Watershed Loading

Long Lake is the receiving water body of several other upstream management units in addition to the Direct MU drainage area (Figure 1-2). Therefore, the discussion of Long Lake's phosphorus budget must extend beyond the Direct MU and include phosphorus loading from all other management units (Figure

3-71) to provide a holistic characterization of Long Lake's phosphorus budget. Therefore, the watershed load analysis for Long Lake will include:

1) A detailed phosphorus loading source assessment for the Direct MU to identify potential areas of focus for load reduction within the Direct MU
2) An assessment of the magnitude of each management unit's phosphorus load to Long Lake to help identify which management units have the greatest phosphorus load reduction opportunities.

Direct MU

Watershed loading from the Direct MU accounts for approximately 13% of the total phosphorus budget to Long Lake (296 lbs P/yr; Figure 3-71). This drainage has a variety of land cover, however, parks, golf courses, residential areas, and undeveloped areas comprise 98% of the drainage area. Overall, the Direct MU represents the second largest phosphorus load to Long Lake, which will be discussed relative to the other management units that comprise drainage areas to Long Lake in the next section.

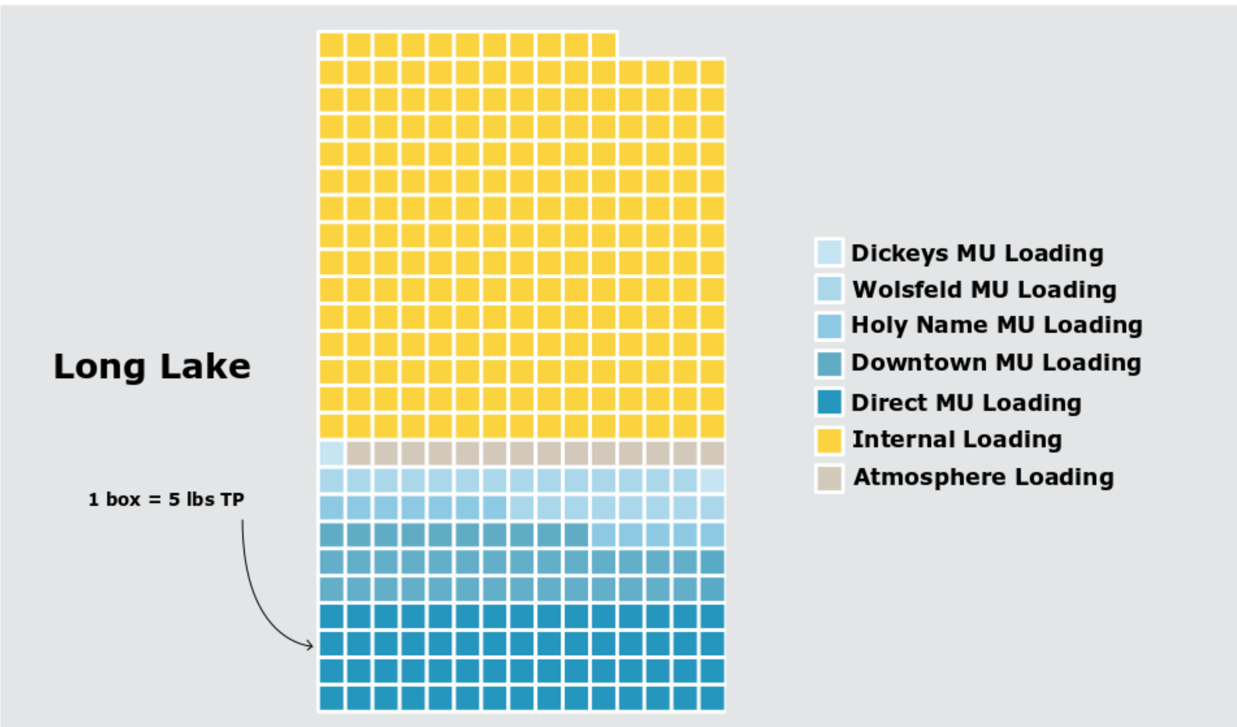


Figure 3-71 Phosphorus budget for Long Lake

The largest source of watershed phosphorus in the Long Lake Direct MU is from a relatively small minor subwatershed located that converges with the outlet of the MCWD owned stormwater pond just south of County Road Six (Figure 3-52). Stream monitoring data from a monitoring site just south of County Road Six Pond (Figure 3-52) had phosphorus concentrations that were nearly an order of magnitude greater than any other stream site (Figure 3-52). Further investigation of the source of this phosphorus is necessary since phosphorus concentrations greater than 1.0 mg/L are much higher than typically observed in stormwater runoff (MPCA, 2023). Interestingly, the flow from this site is quite low (0.45 cfs in 2018), which represents a very small percent of the total flow from the Direct MU (1.5%). However, the phosphorus load from this small drainage area represents 29% of the Direct MU phosphorus load (Figure 3-72) despite only representing 12% of the Direct MU due to the extremely high phosphorus concentrations.

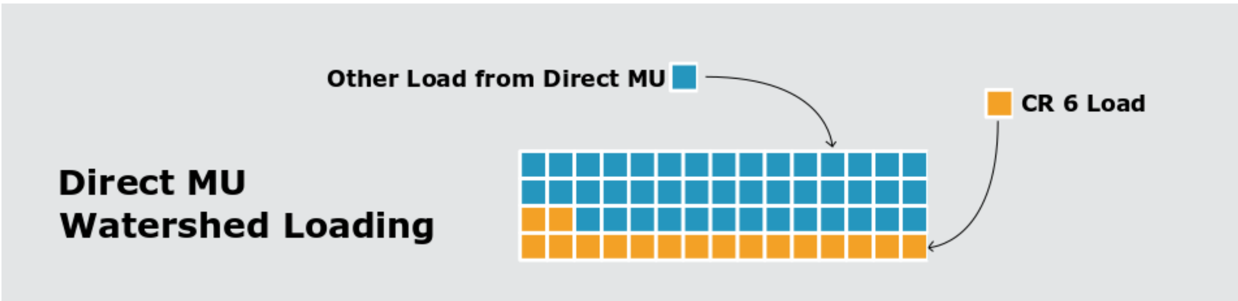


Figure 3-72 Watershed phosphorus loading depicting the load from the small tributary relative to the remainder of the Direct MU load

The other sources of phosphorus loading from the Direct MU include overland runoff, channel erosion, and surface erosion. Overall, landuse runoff is relatively low in this management unit since the majority of landuse is undeveloped or large lot residential, which has low runoff volumes and phosphorus concentrations. The golf courses in the Direct MU are likely sources of elevated phosphorus concentrations, however, the areas primarily drained by the golf course do not have unusually high phosphorus concentrations (Figure 3-52).

Channel and surface erosion also play a small role in watershed loading based on the USLE analysis and field investigations conducted in MCWD's Stream Assessment. However, the majority of erosion does not appear to be severe or the primary driver of phosphorus loading in this management unit.

Long Lake Drainage Area Phosphorus Loading

Assessing Long Lake's nutrient budget requires an analysis of each upstream management unit loading to better understand where to focus efforts for watershed phosphorus load reduction to meet water quality standards for Long Lake. We will provide a brief overview of each management unit in context of its phosphorus contribution to Long Lake and potential for phosphorus load reductions.

Direct Management Unit: The largest contributor of phosphorus to Long Lake is the Direct MU due to two factors including 1) it is the second largest management unit and 2) it has relatively low stormwater treatment and wetland storage. With that being said, a large portion of the Direct MU is undeveloped, which suggests that there may be fewer opportunities for stormwater BMPs to reduce phosphorus loading. One area that has an unusually high phosphorus load includes a small drainage area in the central portion of the Direct MU with phosphorus concentrations and order of magnitude higher than any other location within the Long Lake drainage area (Figure 3-52).

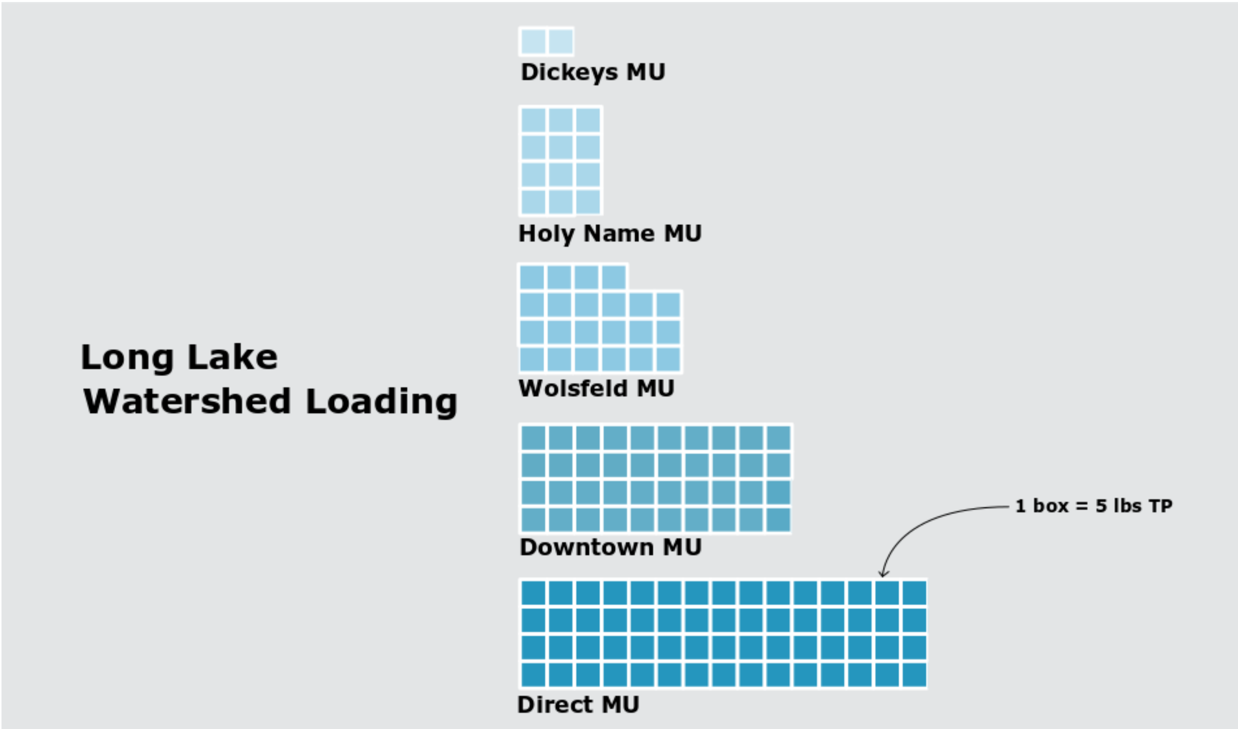


Figure 3-73 Phosphorus loading from each management unit to Long Lake

Downtown Management Unit: The Downtown MU represents one of the smallest drainage areas to Long Lake, however, it has a disproportionately large phosphorus load contribution (Figure 3-74). Dividing the phosphorus load by the management unit land area gives an area weighted phosphorus load (Figure 3-74), which shows that the Downtown MU has the highest per unit area phosphorus loading rate of any management unit in the Long Lake Creek Subwatershed Assessment. The primary reason for the elevated phosphorus loading in the Downtown MU is due to the high percentage of impervious area combined with very few stormwater treatment devices or wetlands to remove phosphorus and suspended sediments (Figure 3-43). In addition, the area weighted runoff from the Downtown MU is nearly double any other management unit, which further reinforces the lack of storage from stormwater BMPs or wetlands (Figure 3-75).

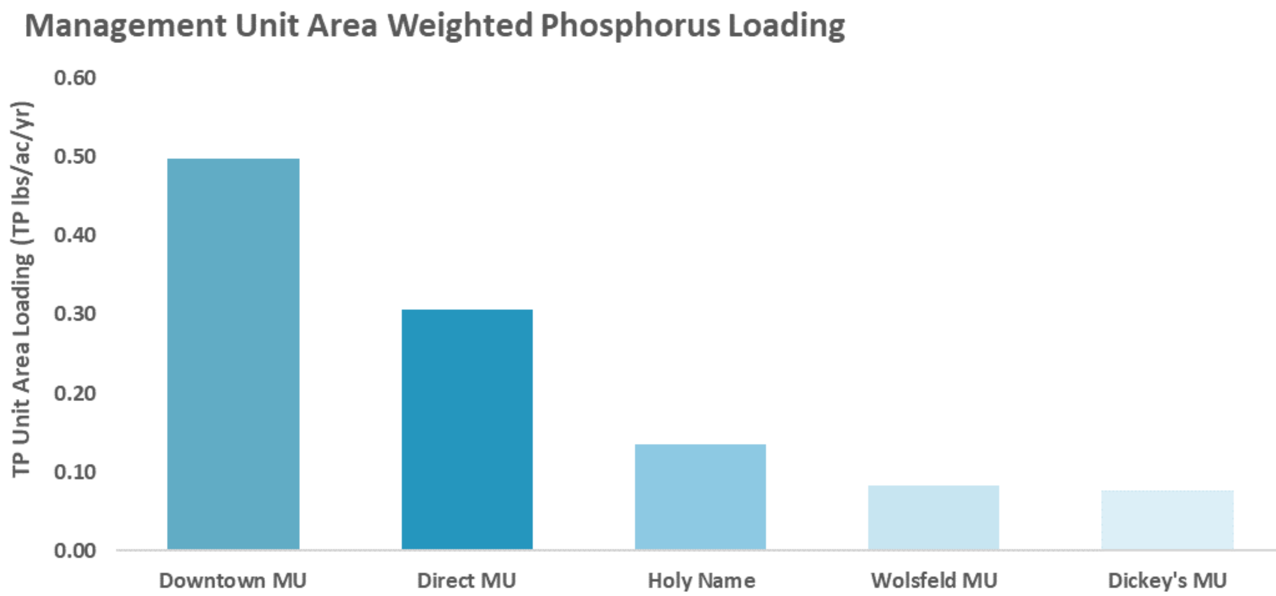


Figure 3-74 Phosphorus unit area loading for each management unit draining to Long Lake

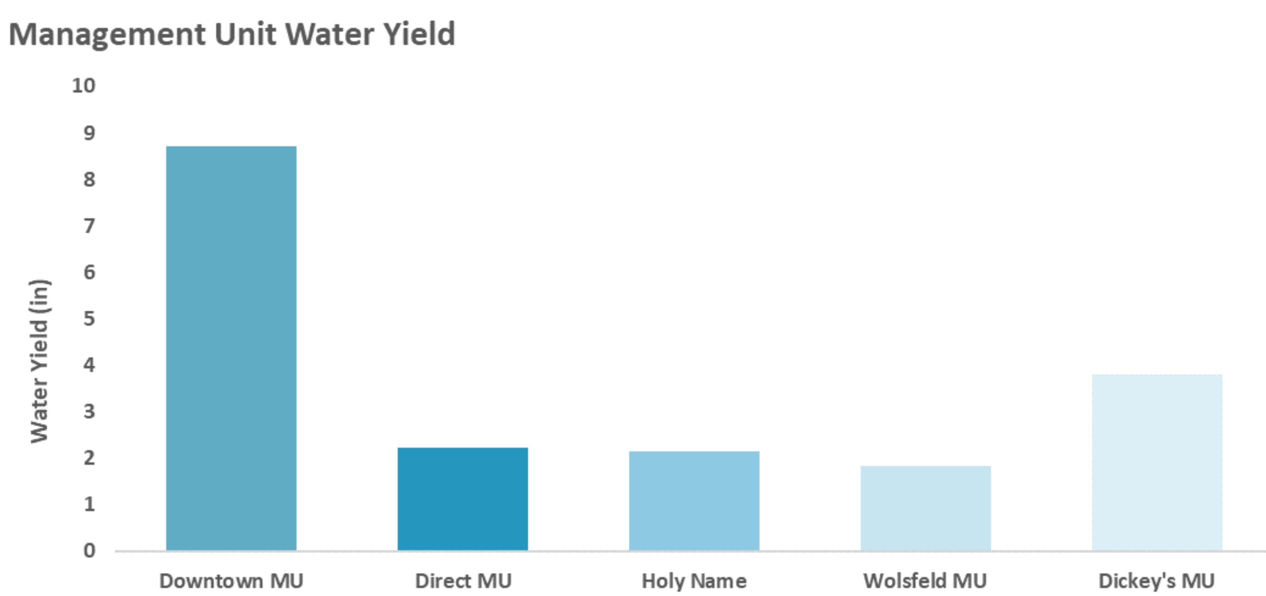


Figure 3-75 Phosphorus unit area runoff for each management unit draining to Long Lake

Wolsfeld MU: The Wolsfeld MU represents the third largest phosphorus load to Long Lake and contains two impaired water bodies (School Lake and Wolsfeld Lake). This management unit has relatively low contribution to the Long Lake since the abundant number of lakes and wetlands remove a large portion of the watershed phosphorus loading (Figure 3-1). Improving watershed runoff and internal phosphorus loading to lakes in this management unit will not only improve water quality conditions in Wolsfeld MU lakes, but also provide load reductions to Long Lake.

Holy Name MU: The Holy Name MU represents the largest drainage area to Long Lake, but has the second lowest phosphorus load relative to other drainage areas. This management unit contains the highest proportion of wetlands compared to any other watershed, which results in the second lowest unit area runoff and phosphorus loading compared to other management units (Figure 3-74; Figure 3-75).

Dickey's MU: The Dickey's MU is the smallest drainage area and represents the smallest phosphorus load to Long Lake (Figure 3-74). This management unit is comprised primarily of residential areas with moderate runoff (Figure 3-75) and has a large lake (Dickey's Lake) with relatively low phosphorus concentrations that improves water quality conditions prior to Long Lake.

3.4.5.2 Watershed Storage and Phosphorus Removal Capacity

The Direct MU has less storage and phosphorus removal capacity relative to other management units in the Long Lake Subwatershed due to low wetland coverage (Figure 3-57) and very few stormwater management practices in management unit. It is difficult to know if development has been the primary driver of wetland and storage loss in this management unit, however, it seems unlikely since a large portion of the area is undeveloped. Increasing the amount of storage may reduce the amount of stormwater phosphorus loading, however, the direct management unit is made of many small tributaries that would likely have a low impact on load reduction relative to loading from larger upstream management units.

One area that does have high phosphorus loading is the drainage area that outlets just south of County Road Six, which was discussed in the previous section. Interestingly, the drainage area for this monitoring point has several wetlands and ponds that should provide sufficient removal capacity; however, this area has the highest phosphorus concentrations of any monitoring location in the Long Lake Subwatershed. One potential explanation may be that historic phosphorus loading to wetlands in this drainage area has surpassed their ability to assimilate and remove phosphorus, which has resulted in the wetlands acting as phosphorus sources instead of sinks.

A primary mechanism of phosphorus release in wetlands is the desorption of mineral-bound phosphorus. Phosphate adsorbs to minerals such as Fe, Al, Ca, or Mg, which are found in wetland sediment and in suspended particles that enter wetlands and eventually settle in wetland sediment. Phosphorus bound to these oxidized metals can be mobilized if geochemical parameters such as dissolved oxygen or pH are significantly altered within the wetland. For example, mineral-bound phosphate is released from wetland sediments if sediment porewater is anoxic (devoid of oxygen). A cursory assessment of the relationship between oxygen and phosphorus at this site suggests that there may be a relationship between low oxygen conditions and high phosphorus concentrations (Figure 3-76). Further investigation into what wetland is exporting phosphorus would help identify the potential phosphorus reduction strategy.

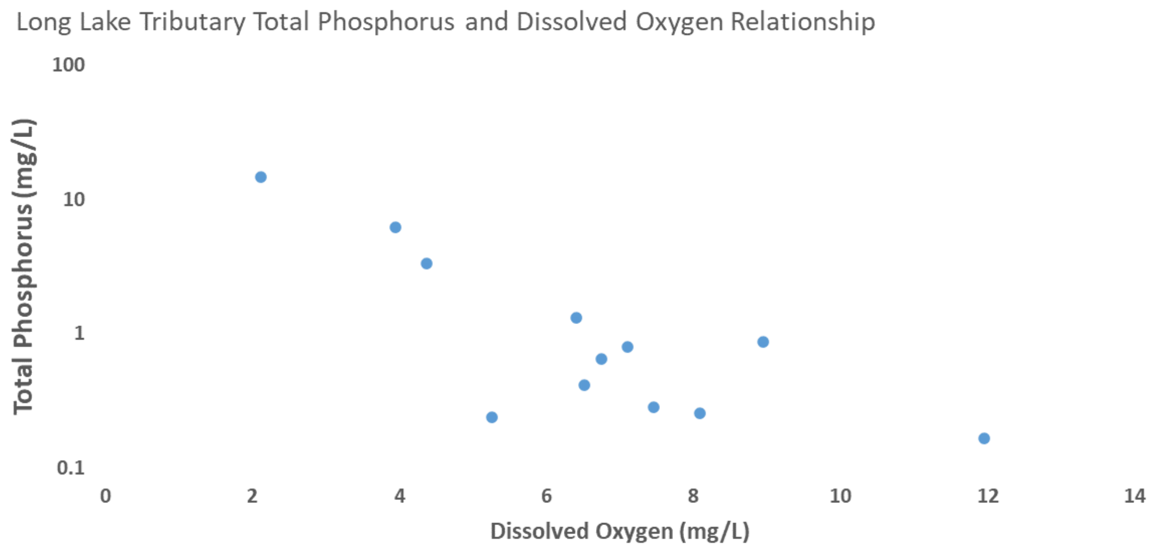


Figure 3-76 Relationship between dissolved oxygen and total phosphorus at the monitoring station located just south of County Road 6 that has been identified as having extremely high TP concentrations

3.4.5.3 Internal Loading

Sediment phosphorus release from sediments accounts for nearly half of the total phosphorus load to Long Lake (Figure 3-71). Elevated phosphorus release rates measured in Long Lake drive elevated phosphorus concentrations in the hypolimnion (Figure 3-62) that result in elevated surface phosphorus concentrations in the late summer and fall (Appendix A). Addressing internal loading will be a critically important management activity for Long Lake, however, watershed load reductions outlined by Long Lake's TMDL required reductions will ensure that the alum treatment will provide long lasting phosphorus reductions.

3.4.5.4 Biological Influences on Nutrient Cycling

Long Lake, like many other lakes in the Long Lake Subwatershed, contain benthiverous fish (common carp) that do have the potential to impact water quality and vegetation conditions. However, academic literature on carp's impacts to nutrient cycling suggests that carp have limited impacts on lakes that thermally stratify (Bajer et al., 2015). Long Lake is considered a deep lake and stratifies each year, however, there are large shallow areas that could be susceptible to carp foraging and spawning activities that negatively impact aquatic vegetation and lake nutrient cycling. There are several indicators that are useful to determine if biological factors may be influencing water quality conditions for shallow lakes. Those factors include presence of rough fish, erratic water quality conditions, seasonal water quality conditions, and difficulty balancing the nutrient budget, which are described in greater detail below:

Common Carp Population: Electrofishing surveys on Long Lake indicate that carp biomass are above the literature threshold (100 kg/ha), which means that carp biomass could have a measurable impact to aquatic vegetation throughout the entire lake and are at a level where they may be resuspending sediments and uprooting plants.

Seasonal Water Clarity: Spring water clarity has been identified as a water quality metric that may be negatively impacted by common carp in stratified lakes (Bajer et al., 2014). We plotted water clarity measurements between 2012 and 2022 based on their day of the year (Figure 3-77), which indicated that there are many spring conditions where water clarity is quite good (secchi measurement > 3 m; Figure 3-77), however, there are also years where spring water clarity is quite low (secchi measurement < 1.5 m; Figure 3-77).

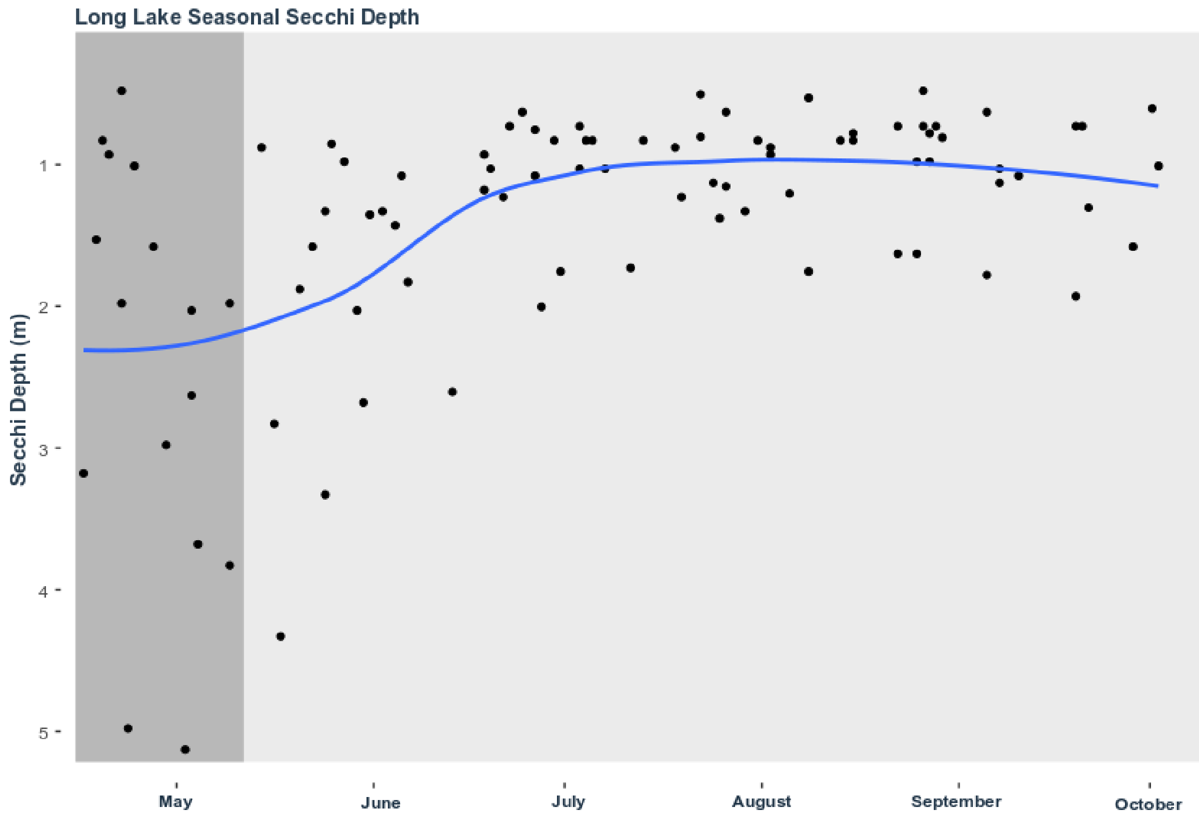


Figure 3-77 Long Lake secchi depth measurements between 2013 and 2022 organized by day of year (1-365) to depict seasonal changes in water quality concentrations.

There are two potential mechanisms for poor water quality in spring months, which include 1) impacts from carp spawning in spring months or 2) impacts to clarity from unusually high runoff years causing elevated suspended sediment loading. We tested this hypothesis by sorting each spring into a category of high precipitation (>7.5 inches of precipitation in April and May) and low precipitation (<7.5 inches of precipitation in April and May) (Figure 3-78). These results demonstrated that the median clarity during low precipitation spring periods was substantially greater (3.5 m) compared to median water clarity during the spring periods with high runoff (1.7 m). It helps explain why there are some years with very good spring water clarity (dry years) and other years with poor water clarity (wet years) in the spring. If we had observed consistently poor water clarity in the spring, that would indicate that carp were causing the impact. This observation supports the hypothesis that elevated suspended sediment delivered during high precipitation spring years is the driver of poor clarity in spring months, which further suggests that common carp's impact to water clarity in Long Lake may be negligible.

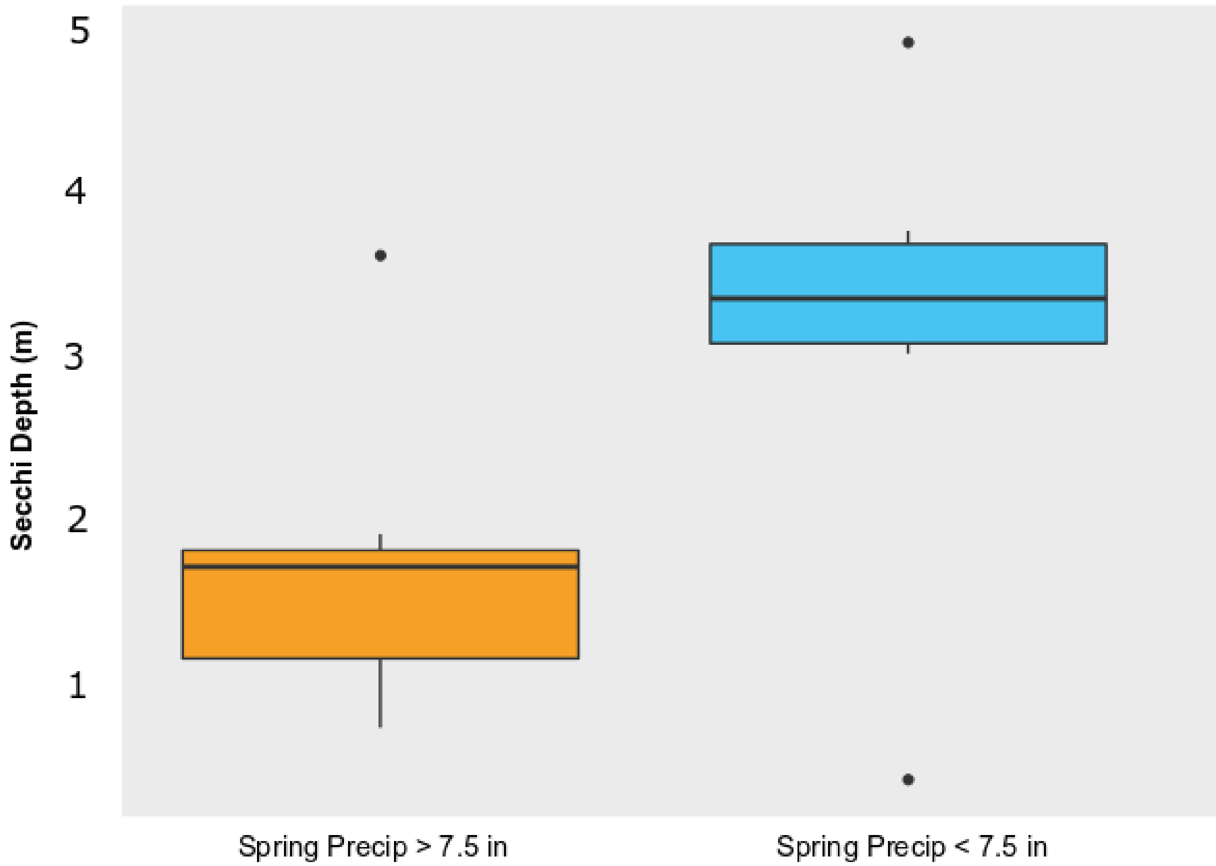


Figure 3-78 Comparison of secchi depth in April and May during high precip conditions (>7.5 in) and low precipitation conditions (<7.5 in)

Lake Nutrient Budget: One of the hallmarks of a lake where biotic factors, such as carp, are impacting are impacting water quality conditions is difficulty calibrating a lake model using robust nutrient input data. Many lake models assume that the three general factors for lake phosphorus budgets are 1) the amount of phosphorus inputs to a lake, 2) the amount of phosphorus that settles to the bottom of the lake, and 3) the residence time of the lake.

The 2014 Upper Lakes TMDL (Wenck, 2014) and MCWD's lake response models were able to predict phosphorus concentrations in the lake based on the phosphorus inputs and flow, which suggest that watershed loading, internal loading, and phosphorus settling are governing the nutrient budget relative to other factors such as common carp or an unaccounted characterized phosphorus source.

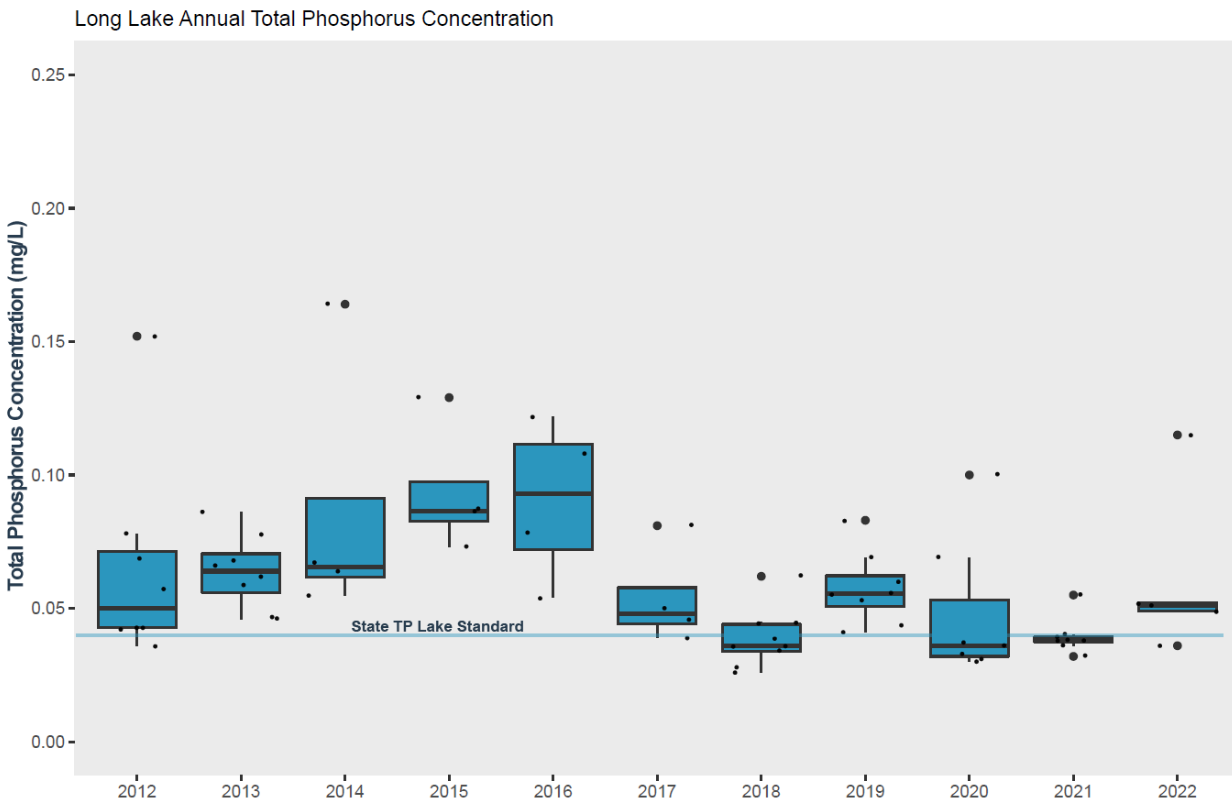


Figure 3-79 Annual total phosphorus concentrations for Long Lake (blue boxplots) and individual sampling points (black dots).

3.4.5.5 Upstream Lakes

There are three lakes that are directly upstream of Long Lake including Holy Name Lake, Wolsfeld Lake, and Dickey's Lake. Of those lakes, Wolsfeld and Holy Name represent 276 lbs/yr and 79 lbs/yr, which represent 17% of Long Lake's total nutrient budget. Meeting water quality standards in Wolsfeld Lake and Holy Name Lake would result in a 266 lbs/yr reduction to Long Lake, which represents 37% of the total reductions required to meet water quality goals for Long Lake.

4 References

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Appendix C

Stantec 01-24-23 Memo: Long Lake Subwatershed Assessment

Stantec

Memo

To:	Brian Beck, Research & Monitoring Program Manager, MCWD Becky Christopher, Policy Planning Manager, MCWD	From:	Todd Shoemaker, PE, CFM, Stantec Eric Osterdyk, CFM, Stantec
File:		Date:	January 24, 2023

Reference: Long Lake Subwatershed Assessment

The purpose of this assessment was to identify watershed and in-lake Best Management Practices (BMPs) to improve water quality for the four impaired lakes in the Upper Long Lake Creek Subwatershed. Wenck, now part of Stantec (Stantec), worked collaboratively with District Staff and its local partners to provide water resources engineering to assess the nutrient and ecological conditions of the subwatershed and then identify and prioritize water quality improvements.

Stantec initially developed BMP cost estimates and phosphorus load reductions for over 25 potential projects. The District met with the City and other local stakeholders to distil the list of projects down to eight to review in greater depth. See below for a summary of project narrative, assumptions, findings/results, and recommendations/next steps.

Nelson Lakeside Park

Project Narrative: Stantec investigated a total of nine scenarios (1A-1I) to optimize water quality treatment on the Nelson Lakeside Park. The existing Nelson Lakeside Park has five stormwater BMPs (three filtration basins and two stormwater ponds) that have a total footprint of approximately 61,500 ft^2 (Figure 1). The existing BMPs provide relatively low pollutant removal efficiency based on the District's P8 model.

The first two scenarios (1A & 1B) replace the existing onsite BMPs with alternative onsite treatment. These scenarios assume that there are no existing BMPs installed onsite. Stantec reviewed these scenarios with the mindset of, "What would we design if we could start fresh?" Scenario 1A replaces onsite treatment with a single stormwater pond, which will provide treatment through sedimentation. Scenario 1B replaces onsite treatment with a stormwater pond and a filtration basin, which will provide treatment through a combination of sedimentation and filtration.

The subsequent seven scenarios (1C – 1I) utilize different combinations of three BMPs (LL03, LL04-C, LL05) in downtown Long Lake (Figure 2). These projects are upstream of the existing Nelson Lakeside Park BMPs, which are to remain in place for these scenarios. LL03 is a subsurface infiltration system in the outfield of a ballfield in Holbrook Park. LL04-C is the reconstruction of Daniels Street storm sewer, which will re-route 27 acres of untreated runoff from Subwatershed LLC6 to the existing pond west of the cemetery. LL05 is a subsurface infiltration system on the Public Works property off Daniels Street.

Assumptions:
<u>Scenario 1A</u>

- All upstream runoff directed to existing creek is collected by the proposed combined stormwater pond.
- Proposed pond footprint equals total of existing BMP footprints.
- Stormwater pond has 10-foot permanent pool depth and 3:1 slope.

Reference: **Long Lake Subwatershed Assessment**

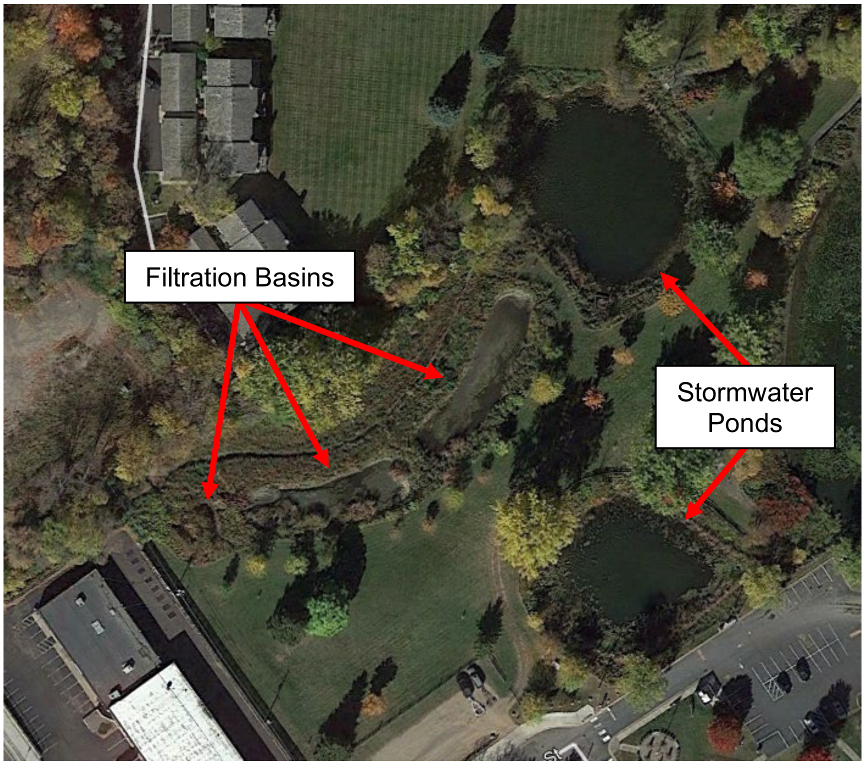

Figure 1. Nelson Lakeside Park existing BMPs.

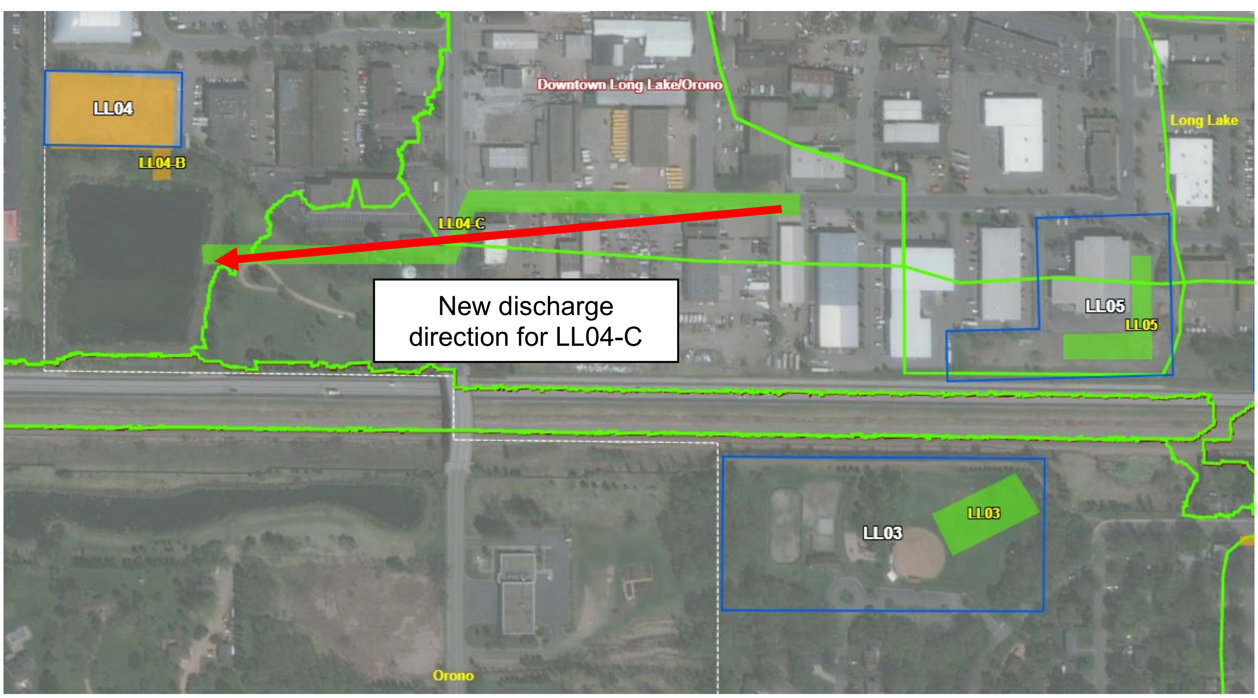

Figure 2. LL03, LL04-C, LL05 proposed BMP locations.

Scenario 1B

- All upstream runoff directed to existing creek is collected by the proposed stormwater pond and filtration basin.
- Proposed footprint of stormwater pond and filtration basin matches total existing BMP footprint.
- Stormwater pond has 10-foot permanent pool depth and 3:1 slope.
- Filtration basin filtration rate is one inch/hour and has a water quality depth of four feet to correspond with 48-hour drawdown.
- P0% and P10% removal efficiencies are 0% and 25%, respectively.

LL03

- System Footprint is 31,377 ft^2.
- Infiltration Rate is 0.8 inches/hour.
- Water quality depth of the system is 3.2 feet to correspond with 48-hour drawdown.
- Drainage area is 147 acres, which includes outflow from device LLC-12 and watershed LLC-11.
- Outlet is device LLC-11.

LL04-C

- City reconstruction of Daniels Street (not included in cost) from Brimhall to LLC7.
- Diverts 27 acres from LLC-6 to LLC-7.

LL05

- System Footprint is 27,035 ft^2.
- Infiltration Rate is 0.8 inches/hour.
- Water quality depth of the system is 3.2 feet to correspond with 48-hour drawdown.
- Drainage area is 24.84 acres from watershed LLC-6.
- Outlet is device LLC-6.

Findings/Results:
Stantec used the P8 model provided by MCWD to determine existing conditions TP removals. TP reduction noted in Table 1 are the TP reductions in addition to the existing conditions removals. Construction and lifecycle costs have not been updated from the initial opinion of probable cost completed in 2020.

Table 1. Scenarios 1A-1I results.

Option	Description	TP Reduction (lbs/yr)	Construction Cost	Lifecycle Cost	Normalized Lifecycle Cost ($/lb)
1A	Stormwater Pond	5.9	$ 1,217,580	$1,291,780	$ 7,348
1B	Pond and Filtration Basin	10.1	$ 1,365,360	$1,464,580	$ 4,815
1C	LL03	34.7	$ 1,292,867	$1,329,967	$ 1,279
1D	LL04-C	6.950	$ 621,502	$ 621,502	$ 2,981
1E	LL05	27.0	$ 1,148,258	$1,185,358	$ 1,462
1F	LL03 & LL04-C	40.7	$ 1,914,369	$1,951,469	$ 1,599
1G	LL03 & LL05	60.5	$ 2,441,125	$2,515,325	$ 1,386
1H	LL04-C & LL05	33.2	$ 1,769,760	$1,806,860	$ 1,814
1I	LL03, LL04-C, & LL05	65.6	$ 3,062,627	$3,136,827	$ 1,593

Recommendations/Next Steps:

Scenarios 1A & 1B

- Final pond sizing and outlet structure analysis.
- Closer review of existing infrastructure and proposed pond location.
- Investigate maintenance access to fishing pier.

Scenarios 1C-1I

- Complete soil borings to determine infiltration rate.
- Investigate tie in elevations for existing storm sewer.

Willow Lake Road Flooding

Project Narrative: Initial scope was for Stantec to investigate the potential for water quality, hydrology, and biological improvements of wetland D-118-23-22-038 and wetland D-118-23-22-017. However, after a site visit, MCWD staff attribute most of the nutrient loading to the significant erosion in two ravines just downstream of the Willow Road wetland (Figure 3). Therefore, the project focus has shifted from wetland restoration to ravine stabilization.

Assumptions:

Northeast ravine

- Length = 400 feet (Google Earth)
- Eroded length = 400 feet (assumed)
- Degree of erosion = severe (per photos from MCWD)

Southwest ravine

- Length = 600 feet (Google Earth)
- Eroded length = 600 feet (assumed)
- Degree of erosion = severe (assumed)

Findings/Results:

Northeast ravine

- Annual erosion (per WI NRCS method)
    - Soil mass = 68 ton/year
    - TP reduction per year = 14 lb/year
- Approximate construction cost = $225 per linear foot
- Approximate construction cost = $90,000
- Initial capital investment (includes permitting, legal, design, & contingency) = $152,000
- Total lifecycle cost = $189,100
- Normalized lifecycle cost = $450 per lb

Southwest ravine

- Annual erosion (per WI NRCS method)
    - Soil mass = 86 ton/year
    - TP reduction per year = 17 lb/year
- Approximate construction cost = $225 per linear foot
- Approximate construction cost = $135,000
- Initial capital investment (includes permitting, legal, design, & contingency) = $228,000
- Total lifecycle cost = $265,100

Reference: **Long Lake Subwatershed Assessment**

- Normalized lifecycle cost = $520 per lb

Recommendations/Next Steps:

- Educate property owners on concern and downstream impact.
- Determine willingness of property owner participation in solution.
- Develop stabilization plan if there is property owner cooperation.

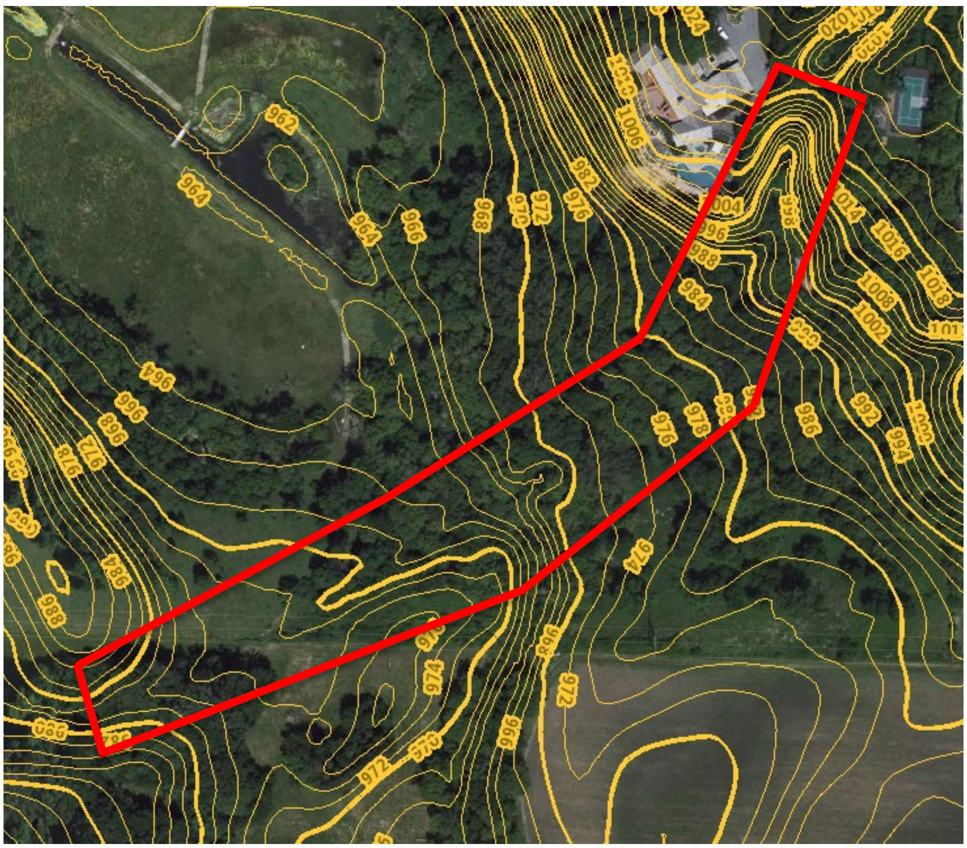

Figure 3. Ravine erosion downstream of the Willow Road Wetland.

OR04 Water Reuse

Project Narrative: Stantec developed a high-level load reduction and cost estimate for a water reuse system that would reuse water from a nearby wetland for irrigation on the Spring Hill Golf Course (Figure 4). A Department of Natural Resources (DNR) water appropriation permit is required when withdrawing more than 10,000 gallons of water per day or 1 million gallons per year. Therefore, Stantec looked at two different scenarios: 3A) Stay below the DNR Water Appropriation permit threshold; and 3B) Maximize treatment by irrigating all the greens south of 6th Ave N (HWY 6). Stantec used the Minimum Impact Standards (MIDS) calculator to model expected pollutant reductions from water reuse.

Reference: **Long Lake Subwatershed Assessment**

Assumptions:

- Source water is the wetland on north side of Long Lake.
- Cost of DNR Water Appropriation permit is not included in cost estimate.
- Irrigation system is already in place on the golf course.
- 1 inch of irrigation/week.
- Irrigation area is Hydrologic Soil Group (HSG) Type C (dominate HSG from NRCS Web Soil Survey).
- Irrigated vegetation type is "Turf".
- System goes offline during off season.
- Water is not retained on-site for non-irrigation uses.
- 30-year lifecycle.
- 3A specific assumptions
  - Irrigation Area = 2.58 acres (exact area to be determined)
  - Irrigation Period is June to August
- 3B specific assumptions
  - Irrigation Area = 50 acres (exact area to be determined)
  - Irrigation Period is May to September

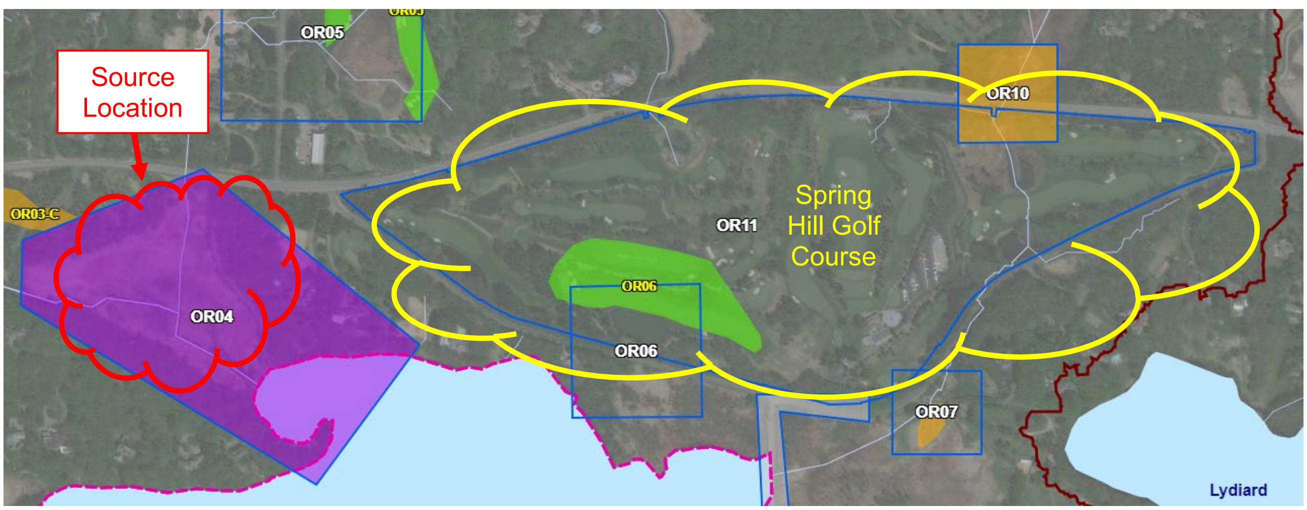

Figure 4. OR04 water reuse source and application area.

Findings/Results:

Table 2. OR04 water reuse estimated cost and phosphorus reduction.

Option	TP Reduction (lbs/yr)	Construction Cost	Total Lifecycle Cost	Lifecycle Cost/lb TP
3A	1.9	$ 463,200	$ 562,567	$ 9,896
3B	40.3	$ 524,200	$ 697,768	$ 578

Recommendations/Next Steps:

- Coordinate with Spring Hill Golf Course.
- Refine irrigation area based on course operations, playability, and irrigation system. Options 3A and 3B show range of what is possible on site.
- Apply for DNR Water Appropriation permit.

Long Lake Carp Barrier

Project Narrative: Stantec developed cost estimates for a carp barrier at the outlet of Long Lake (Figure 5). Although carp move both north and south through this location, the District wanted to prioritize capturing fish coming from Long Lake and moving south to Tanager Lake. Once carp congregate at the barrier, District staff can use the access road to quickly deploy a block and trap carp for subsequent removal.

Stantec provided a cost estimate for a traditional “brick and mortar” barrier (4A) as well as a low voltage electrical barrier (4B). The “brick and mortar” barrier has a lower up-front cost, but higher maintenance costs where the low voltage electrical barrier has a higher up-front cost with lower maintenance costs.

Figure 5. Long Lake carp barrier site.

Low Voltage Electrical Barrier Assumptions:

- Annual power cost of $2,000.
- Rice Creek Watershed District budgets $15,000 every seven years for replacement of electrodes.
- Barrier is not removed during the winter.

Findings/Results:

Table 3. Long Lake carp barrier costs.

Option	Barrier Type	Initial Capital Investment	Total Lifecycle Cost
4A	Brick & Mortar	$ 49,138	$ 235,939
4B	Low Voltage Electrical	$ 240,000	$ 351,301

Recommendations:

- Determine watershed preference of Brick & Mortar or Low Voltage Electrical approach.
- Finalize barrier location.

MD06, MD07, and MD08 Land Use Conversion

Project Narrative: Three parcels of agricultural land (MD06, MD07, and MD08) are planned for development (Figure 6). Stantec quantified the water quality benefit of these properties developing from agricultural land to rural residential according to the MCWD rules. MD06 and MD07 were evaluated as one parcel since both will develop concurrently.

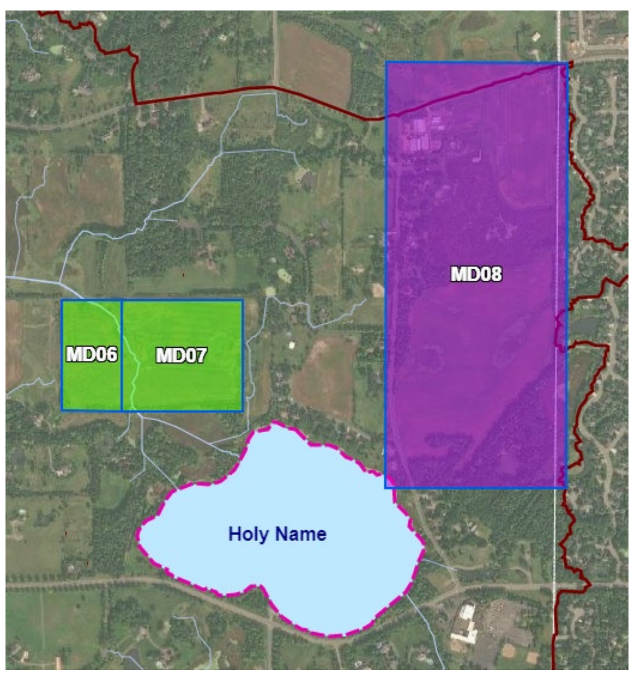

Figure 6. Land use conversion parcel locations.

Assumptions:

- MD06 and MD07 parcels evaluated together since both will develop concurrently.
- Land cover will change from agricultural to residential (30% Impervious)
- Future development will meet MCWD rules.
- Volume control rule of infiltrating the first one inch of rainfall from the site's impervious results in approximately 50% TP removal.
- Existing HSG is C and proposed HSG is D to account for compaction due to construction.
- Annual phosphorus load export rates for agriculture (HSG C) is 0.87 lb/ac/yr (MPCA Simple Estimator).
- Annual phosphorus load export rates for residential (30% impervious, HSG D) is 0.63 lb/ac/yr (MPCA Simple Estimator).

Findings/Results:

Table 4. Land use conversion phosphorus load reduction.

Option	Parcel	Parcel Area (ac)	Existing TP Load (lbs/yr)	Proposed TP Load without BMPs (lbs/yr)	Proposed TP Load with BMPs (lbs/yr)	TP Reduction (lbs/yr)
5A	MD06/MD07	20.6	17.9	13.0	6.5	11.4
	MD08	40.4	35.2	25.6	12.8	22.4
	Total	**61.0**	**53.1**	**38.6**	**19.3**	**33.7**

Recommendations/Next Steps:

- Review development plans once submitted by applicant.
- Ensure developments meet MCWD rules.
- Create water quality model for each development to verify TP removal.

Alum Treatment Cost Estimate

Project Narrative: MCWD prepared preliminary cost estimates to apply alum to several lakes in the Long Lake Creek Subwatershed. Stantec reviewed and updated the calculations based on industry best practices and recent related applications. Stantec added several items to the cost estimates based on guidance from MCWD.

Assumptions:

- All costs are for buffered treatments.
- Unit cost for alum is $2.38 and $6.79 for the buffer.
- Mobilization: $15,000 for lakes with public access and $35,000 for lakes with limited access, based on mobilization quoted for past MCWD projects.
- 10% engineering design cost with a minimum of $20,000.
- $15,000 for sediment monitoring after application.
- 20% contingency.

Findings/Results:

Table 5. Alum cost estimates.

Option	Lake Name	Total Dose (g/m^2)	$Al_2(SO_4)_3$ (gal)	$NaAlO_2$ (gal)	Material Cost	Sediment Monitoring	Mobilization	Engineering Cost	Total Cost
6A	Holy Name	45	14,943	7,471	$ 86,000	$ 15,000	$ 15,000	$ 20,000	$ 163,200
	School	346	18,671	9,336	$108,000	$ 15,000	$ 35,000	$ 20,000	$ 213,600
	Long	124	61,980	30,990	$358,000	$ 15,000	$ 35,000	$ 40,800	$ 538,560
	Wolsfeld	386	55,026	27,513	$318,000	$ 15,000	$ 15,000	$ 34,800	$ 459,360
	Swamp	77	37,705	18,853	$218,000	$ 15,000	$ 35,000	$ 26,800	$ 353,760
	Krieg	228	14,103	7,051	$ 81,000	$ 15,000	$ 35,000	$ 20,000	$ 181,200
	Tanager	297	45,173	22,586	$261,000	$ 15,000	$ 15,000	$ 29,100	$ 384,120

Swamp Lake Drawdown Cost Estimate

Project Narrative: Stantec developed a cost estimate for a drawdown on Swamp Lake (Figure 7). Stantec used our understanding of local hydrology and hydraulics of the area to determine the cost and engineering approach.

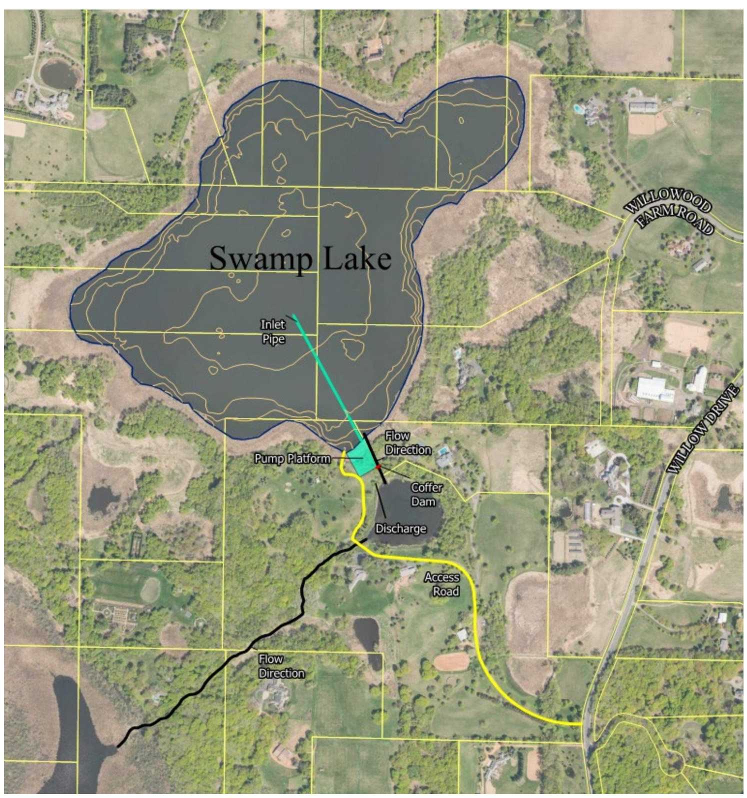

Figure 7. Swamp Lake drawdown map.

- A pump structure/platform will be hauled to the southeast end of Swamp Lake via the existing farm/access road.
- Intake piping will be used to pump water from the lowest depth of Swamp Lake to the adjacent pond to the southeast.
- A coffer dam will be placed upstream on the downstream end of the open channel to downstream pond.
- Riprap or alternative energy dissipation used at discharge point.
- Downstream silt curtain will be put in place to control erosion.
- Drawdown pumping would begin in late September and run periodically for approximately three months (until freeze conditions).
- Start the pump, maintain, and re-fuel the pump as needed in the morning, then shut down the pump at the end of the workday.
- Communicate daily with local property owners who currently gauge the lake levels.
- The pump will be outfitted with an insulated enclosure of plywood and insulation to limit noise and the effects of cold weather.
- Additional pumping will commence after rain events, or when the depth of the lake reaches 0.25'.

Assumptions:

- Drawdown volume (279 ac-ft) was determined from MCWD bathymetry data (223.3 ac-ft) and added 25% to account for groundwater seep from saturated side-slopes.
- No baseflow.
- 2,000 gpm diesel pump is estimated to achieve a conservative 2 cfs of pumping after losses though the intake/discharge piping (50% efficiency).
- Pump, intake hose, and discharge pipe have eight-inch diameter.
- Pump will operate for ten hours per day.
- Cost estimate includes an additional month of operation in base of large precipitation event/ to make sure lake is drawn down until freezing conditions in late November.

Findings/Results:

Table 6. Project 7A – Swamp Lake drawdown cost estimate.

NO	ITEM	UNITS	QUANTITY	UNIT PRICE	TOTAL
1	MOBILIZATION/DEMOBILIZATION (3%)	LS	1	$ 600	$ 600
2	SITE ACCESS	LS	1	$ 750	$ 750
3	SANDBAGGING AT INLET NEAR GOLF COURSE CULVERT	LS	1	$ 350	$ 350
4	8" DIESEL PUMP EQUIPMENT RENTAL	MONTHS	3	$ 3,000	$ 9,000
5	8" LAYFLAT INTAKE HOSE FOR 3 MONTHS	LF	950	$ 15	$ 14,250
6	8" PE DISCHARGE PIPE FOR 3 MONTHS	LF	125	$ 15	$ 1,875
7	PUMPING STRUCTURE FOR NOISE/TEMPERATURE CONTROL	LS	1	$ 1,000	$ 1,000
8	PUMP MAINTENANCE (OIL/FILTER CHANGE)	MONTHS	3	$ 150	$ 450
9	PUMP FUEL FOR 3 MONTHS (2 GAL/HR, 10 HRS/DAY, 15 DAY/MONTH)	GAL/MO	600	$ 3	$ 1,800
10	SITE RESTORATION	LS	1	$ 500	$ 500
11	EROSION CONTROL	LS	1	$ 1,500	$ 1,500
12	PERMIT FEE	LS	1	$ 500	$ 500
				Subtotal	$ 32,575
				Contingency (30%)	$ 9,773
				Total	**$ 42,348**

Recommendations/Next Steps:

- Start planning process with area DNR hydrologist a minimum of one year prior to desired drawdown.
- Obtain permission from property owner to access private drive.
- Prepare feasibility study ($35,000) that includes memo and engineering plans for DNR review and approval.
- Plan for three meetings with DNR to review feasibility and discuss project.
- Public meeting/outreach to garner support/consent (signatures) from at least 75% of property owners.
- Prepare and submit water appropriations permit.

2011 Long Lake Creek Feasibility Study

Project Narrative: The Long Lake Creek Feasibility Study was conducted in 2011 and identified numerous projects to reduce phosphorus in accordance with the 2007 MCWD Comprehensive Plan. Over the past 10 years, several of these projects have been completed. Stantec reviewed five of the uncompleted projects from the feasibility study and updated costs based on inflation (Figure 8). Stantec also added lifecycle maintenance costs to normalize cost based on total phosphorus removed over the life of the project.

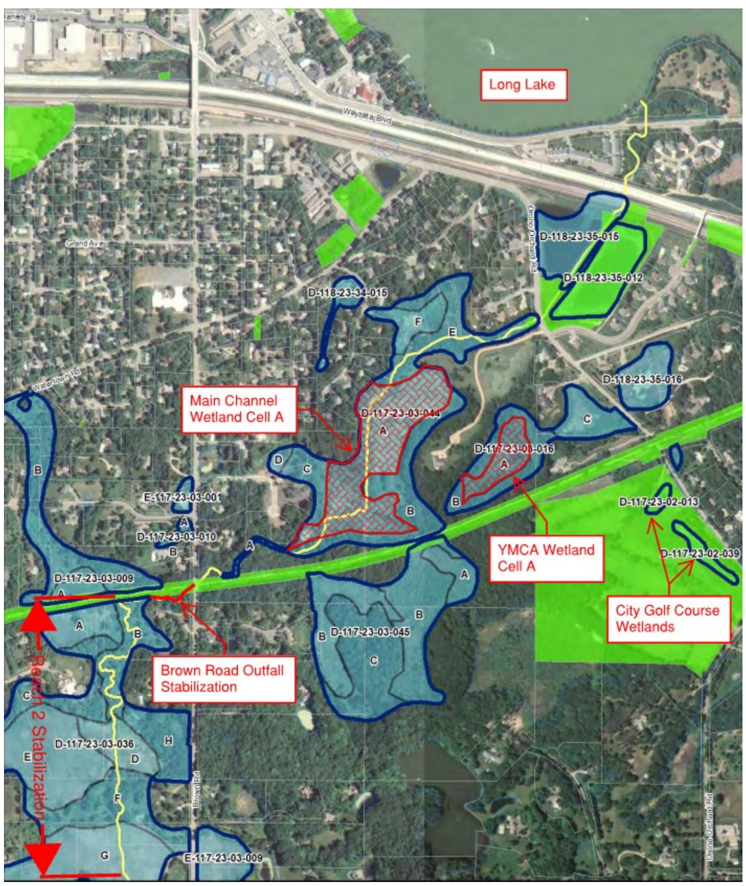

Figure 8. Long Lake Feasibility Study project locations.

Reference: Long Lake Subwatershed Assessment

The five projects Stantec reviewed were the Brown Road Outfall Stabilization (8A), Reach 2 Stream Restoration (8B), City Golf Course Wetland Restoration (8C), YMCA Wetland Restoration (8D), and the Main Channel Wetland Restoration (8E). See below for project summaries.

Brown Road Outfall Stabilization (8A) – Repair downstream culvert scour with combination of brush layering with rock toe protection, rock vanes, longitudinal fill stone toe protection, locked logs, and the introduction of ground cover to stabilize banks.

Reach 2 Stream Restoration (8B) – Stream restoration and remeander around Smith Dump site. Reconnect the stream to the former channel and constructing a new channel with a similar geometry. Restoration will decrease stream slope, diffuse flow, add sinuosity, and reconnect the stream to the former floodplain by adding stream length.

City Golf Course Wetland Restoration (8C) – Enhancement of wetlands D-117-23-02-013 and D-117-23-02-039. Establish native vegetation and buffer, enhance outlet with iron-enhanced sand filter.

YMCA Wetland Restoration (8D) – Restoration of wetland D-117-23-03-016. Remove reed canary grass, install ditch plug to improve wetland hydrology.

Main Channel Wetland Restoration (8E) – Restoration of wetland D-117-23-03-044A. Remove reed canary grass, increase outlet elevation with grade control structure.

Assumptions:

- 2011 cost estimates not re-evaluated, just adjusted for inflation.
- Average annual inflation since 2011 is 1.75%.
- 3–5-year maintenance for wetland restorations referenced in the report is included in the provided 2011 cost estimates.
- 2011 pollutant removals not re-evaluated.

Findings/Results:

Table 7. Long Lake Creek Feasibility Study updated costs.

Option	Project Name	2011 Cost Estimate	2021 Cost Estimate	Lifecycle Cost	TP Reduction (lb/yr)	Normalized Lifecycle Cost ($/lb)
8A	Brown Road Outfall Stabilization	$ 49,731	$ 58,800	$ 63,573	11.6	$ 183
8B	Reach 2 Stream Restoration	$396,100	$468,200	$517,087	30.1	$ 573
8C	City Golf Course Wetland Restorations	$206,900	$244,600	$318,800	11.2	$ 949
8D	YMCA Wetland Restoration	$ 34,500	$ 40,800	$ 52,733	4.9	$ 359
8E	Main Channel Wetland Restoration	$138,500	$163,800	$200,900	36.8	$ 182

Recommendations/Next Steps:

- For projects that may still be applicable, verify pollutant removal and cost estimates. Detailed modeling information and line-item cost estimates were not included in the 2011 report, so these could not be verified as part of this study.
- Limited information given in the report to review on engineering approach.
- YMCA Wetland Restoration cost appears low. Stantec is skeptical that ditch plug and vegetation management can be constructed for less than $50,000.

Appendix D

MCWD Professional Service Agreement Template

AGREEMENT BETWEEN
MINNEHAHA CREEK WATERSHED DISTRICT and
[CONSULTANT]

[Project Title]

This agreement is entered into by the Minnehaha Creek Watershed District, a public body with powers set forth at Minnesota Statutes chapters 103B and 103D (MCWD), and [CONSULTANT], a Minnesota corporation (CONSULTANT). In consideration of the terms and conditions set forth herein and the mutual exchange of consideration, the sufficiency of which hereby is acknowledged, MCWD and CONSULTANT agree as follows:

1. <u>Scope of Work</u>

CONSULTANT will perform the work described in the [DATE] Scope of Services attached as Exhibit A (the Services). Exhibit A is incorporated into this agreement and its terms and schedules are binding on CONSULTANT as a term hereof. MCWD, at its discretion, in writing may at any time suspend work or amend the Services to delete any task or portion thereof. Authorized work by CONSULTANT on a task deleted or modified by MCWD will be compensated in accordance with paragraphs 5 and 6. Time is of the essence in the performance of the Services.

2. <u>Independent Contractor</u>

CONSULTANT is an independent contractor under this agreement. CONSULTANT will select the means, method and manner of performing the Services. Nothing herein contained is intended or is to be construed to constitute CONSULTANT as the agent, representative or employee of MCWD in any manner. Personnel performing the Services on behalf of CONSULTANT will not be considered employees of MCWD and will not be entitled to any compensation, rights or benefits of any kind from MCWD.

3. <u>Subcontract and Assignment</u>

CONSULTANT will not assign, subcontract or transfer any obligation or interest in this agreement or any of the Services without the written consent of MCWD and pursuant to any conditions included in that consent. MCWD consent to any subcontracting does not relieve CONSULTANT of its responsibility to perform the Services or any part thereof, nor in any respect its duty of care, insurance obligations, or duty to hold harmless, defend and indemnify under this agreement.

4. <u>Duty of Care; Indemnification</u>

CONSULTANT will perform the Services with due care and in accordance with national standards of professional care. CONSULTANT will hold harmless and indemnify MCWD, its board members, employees and agents, from any and all actions, costs (including reasonable attorney fees), damages and liabilities of any nature arising from CONSULTANT's or a subconsultant's lack of professional due care, and will defend, hold harmless, and indemnify MCWD, its board members, employees and agents from any and all actions, costs, damages and liabilities of any nature arising from CONSULTANT's or a subconsultant's negligent or otherwise wrongful act or omission, or breach of a specific contractual duty owed by CONSULTANT to MCWD, other than the duty of professional due care. For any claim subject to this paragraph by an employee of CONSULTANT or a subconsultant, the indemnification obligation is not limited by a limitation on the amount or type of damages, compensation or benefits payable by or for CONSULTANT or the subconsultant under workers' compensation acts, disability acts or other employee benefit acts.

5. Compensation

MCWD will compensate CONSULTANT for the Services on [an hourly OR a lump-sum] basis and reimburse for direct costs in accordance with Exhibit A. Invoices will be submitted monthly for work performed during the preceding month. Payment for undisputed work will be due within 30 days of receipt of invoice. Direct costs not specified in Exhibit A will not be reimbursed except with prior written approval of the MCWD administrator. Subconsultant fees and direct costs, as incurred by CONSULTANT, will be reimbursed by MCWD at the rate specified in MCWD's written approval of the subcontract

[The total payment for each task will not exceed the amount specified for that task in Exhibit A.] The total payment for the Services will not exceed [$________]. Total payment in each respect means all sums to be paid whatsoever, including but not limited to fees and reimbursement of direct costs and subcontract costs, whether specified in this agreement or subsequently authorized by the administrator.

CONSULTANT will maintain all records pertaining to fees or costs incurred in connection with the Services for six years from the date of completion of the Services. CONSULTANT agrees that any authorized MCWD representative or the state auditor may have access to and the right to examine, audit and copy any such records during normal business hours.

6. Termination; Continuation of Obligations

This agreement is effective when fully executed by the parties and will remain in force until [DATE] unless earlier terminated as set forth herein.

MCWD may terminate this agreement at its convenience, by a written termination notice stating specifically what prior authorized or additional tasks or services it requires CONSULTANT to complete. CONSULTANT will receive full compensation for all authorized work performed, except that CONSULTANT will not be compensated for any part performance of a specified task or service if termination is due to CONSULTANT's breach of this agreement.

Insurance obligations; duty of care; obligations to defend, indemnify and hold harmless; duty to cooperate in assignment of intellectual property; and document-retention requirements will survive the completion of the Services and the term of this agreement.

7. No Waiver

The failure of either party to insist on the strict performance by the other party of any provision or obligation under this agreement, or to exercise any option, remedy or right herein, will not waive or relinquish such party's rights in the future to insist on strict performance of any provision, condition or obligation, all of which will remain in full force and affect. The waiver of either party on one or more occasion of any provision or obligation of this agreement will not be construed as a waiver of any subsequent breach of the same provision or obligation, and the consent or approval by either party to or of any act by the other requiring consent or approval will not render unnecessary such party's consent or approval to any subsequent similar act by the other.

Notwithstanding any other term of this agreement, MCWD waives no immunity in tort. This agreement creates no right in and waives no immunity, defense or liability limit with respect to any third party.

8. Insurance

At all times during the term of this Agreement, CONSULTANT will have and keep in force the following insurance coverages:

A. General: $1.5 million, each occurrence and aggregate, covering CONSULTANT's ongoing operations on an occurrence basis.

B. Professional liability: $1.5 million each claim and aggregate. Any deductible will be CONSULTANT's sole responsibility and may not exceed $50,000. Coverage may be on a claims-made basis, in which case CONSULTANT must maintain the policy for, or obtain extended reporting period coverage extending, at least three (3) years from completion of the Services.

C. Automobile liability: $1.5 million combined single limit each occurrence coverage for bodily injury and property damage covering all vehicles on an occurrence basis.

D. Workers' compensation: in accordance with legal requirements applicable to CONSULTANT.

General and automobile liability limits above $1 million may be met by means of a follow form excess or umbrella policy. CONSULTANT will not commence work until it has filed with MCWD a certificate of insurance clearly evidencing the required coverages and naming MCWD as an additional insured for general liability, and any associated excess or umbrella policy, along with a copy of the additional insured endorsement establishing coverage for CONSULTANT's ongoing operations as primary coverage on a noncontributory basis. The certificate will name MCWD as a holder and will state that MCWD will receive written notice before cancellation, nonrenewal or a change in the limit of any described policy under the same terms as CONSULTANT.

9. Compliance With Laws

CONSULTANT will comply with the laws and requirements of all federal, state, local and other governmental units in connection with performing the Services and will procure all licenses, permits and other rights necessary to perform the Services.

In performing the Services, CONSULTANT will ensure that no person is excluded from full employment rights or participation in or the benefits of any program, service or activity on the ground of race, color, creed, religion, age, sex, disability, marital status, sexual orientation, public assistance status or national origin; and no person who is protected by applicable federal or state laws, rules or regulations against discrimination otherwise will be subjected to discrimination.

10. Data and Information

All data and information obtained or generated by CONSULTANT in performing the Services, including documents in hard and electronic copy, software, and all other forms in which the data and information are contained, documented or memorialized (together, here and in sections 11 and 12, the "Materials"), are the property of MCWD. CONSULTANT hereby assigns and transfers to MCWD all right, title and interest in: (a) its copyright, if any, in the Materials; any registrations and copyright applications relating to the Materials; and any copyright renewals and extensions; (b) all works based on, derived from or incorporating the Materials; and (c) all income, royalties, damages, claims and payments now or hereafter due or payable with respect thereto, and all causes of action in law or equity for past, present or future infringement based on the copyrights. CONSULTANT agrees to execute all papers and to perform such other proper acts as MCWD may deem necessary to secure for MCWD or its assignee the rights herein assigned.

MCWD may immediately inspect, copy or take possession of any Materials on written request to CONSULTANT. On termination of the agreement, CONSULTANT may maintain a copy of some or all of the Materials except for any Materials designated by MCWD as confidential or non-public under applicable law, a copy of which may be maintained by CONSULTANT only pursuant to written agreement with MCWD specifying terms.

11. Data Practices; Confidentiality

If CONSULTANT receives a request for data pursuant to the Data Practices Act, Minnesota Statutes chapter 13 (DPA), that may encompass data (as that term is defined in the DPA) CONSULTANT possesses or has created as a result of this agreement, it will inform MCWD immediately and transmit a copy of the request. If the request is addressed to MCWD, CONSULTANT will not provide any information or documents, but will direct the inquiry to MCWD. If the request is addressed to CONSULTANT, CONSULTANT will be responsible to determine whether it is legally required to respond to the request and otherwise what its legal obligations are, but will notify and consult with MCWD and its legal counsel before replying. Nothing in the preceding sentence supersedes CONSULTANT's obligations under this agreement with respect to protection of MCWD data, property rights in data or confidentiality. Nothing in this section constitutes a determination that CONSULTANT is performing a governmental function within the meaning of Minnesota Statutes section 13.05, subdivision 11, or otherwise expands the applicability of the DPA beyond its scope under governing law.

CONSULTANT agrees that it will not disclose and will hold in confidence any and all proprietary Materials owned or possessed by MCWD and so denominated by MCWD. CONSULTANT will not use any such Materials for any purpose other than performance of the Services without MCWD written consent. This restriction does not apply to Materials already possessed by CONSULTANT or that CONSULTANT received on a non-confidential basis from MCWD or another party. Consistent with the terms of this section 11 regarding use and protection of confidential and proprietary information, CONSULTANT retains a nonexclusive license to use the Materials and may publish or use the Materials in its professional activities. Any CONSULTANT duty of care under this agreement does not extend to any party other than MCWD or to any use of the Materials by MCWD other than for the purpose(s) for which CONSULTANT is compensated under this agreement.

12. MCWD Property

All property furnished to or for the use of CONSULTANT or a subcontractor by MCWD and not fully used in the performance of the Services, including but not limited to equipment, supplies, and Materials, will remain the property of MCWD and returned to MCWD at the conclusion of the performance of the Services, or sooner if requested by MCWD. CONSULTANT further agrees that any proprietary Materials are the exclusive property of MCWD and will assert no right, title or interest in the Materials. CONSULTANT will not disseminate, transfer or dispose of any proprietary Materials to any other person or entity unless specifically authorized in writing by MCWD.

Any property including but not limited to Materials supplied to CONSULTANT by MCWD or deriving from MCWD is supplied to and accepted by CONSULTANT as without representation or warranty including but not limited to a warranty of fitness, merchantability, accuracy or completeness. However, CONSULTANT's duty of professional care under paragraph 4, above, does not extend to Materials provided to CONSULTANT by MCWD or any portion of the Services that is inaccurate or incomplete as the result of CONSULTANT's reasonable reliance on those Materials.

13. Notices

Any written communication required under this agreement to be provided in writing will be directed to the other party as follows:

To MCWD:

Administrator
Minnehaha Creek Watershed District
15320 Minnetonka Boulevard
Minnetonka, MN 55345

To CONSULTANT:

[Authorized Representative
Organization
Address]

Either of the above individuals may in writing designate another individual to receive communications under this agreement.

14. Choice of Law; Venue

This agreement will be construed under and governed by the laws of the State of Minnesota. Venue for any action will lie in Hennepin County.

15. Whole Agreement

The entire agreement between the two parties is contained herein and this agreement supersedes all oral agreements and negotiations relating to the subject matter hereof. Any modification of this agreement is valid only when reduced to writing as an amendment to the agreement and signed by the parties hereto. MCWD may amend this agreement only by action of the Board of Managers acting as a body.

IN WITNESS WHEREOF, intending to be legally bound, the parties hereto execute and deliver this agreement.

CONSULTANT

By___________________________ Date: _________________________
Its__________________________

Approved as to Form and Execution

____
MCWD Attorney

MINNEHAHA CREEK WATERSHED DISTRICT

By__________________________ Date: _________________________
Its_________________________

Exhibit A
Scope of Services