Lake Holiday, Wing Lake, and Lake Rose Water Quality Improvement Project

Feasibility Study/Preliminary Engineering

Prepared for
Nine Mile Creek Watershed District

December 2023

4300 Market Pointe Drive
Suite 200
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Contents

List of Tables

List of Figures

List of Appendices

Certification

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.

Janna Kieffer

12/13/2023

Janna Kieffer
PE #: 43571

Date

Abbreviations

AIS	Aquatic Invasive Species
AACE	Association for the Advancement of Cost Engineering
BMP	Best Management Practice
CAMP	Citizen Assisted Monitoring Program (MCES)
FQI	Floristic Quality Index
HDPE	High-Density Polyethylene
IBI	Index of Biological Integrity
MCES	Metropolitan Council of Environmental Services
MNDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer System
NGVD29	National Geodetic Vertical Datum of 1929
NMCWD	Nine Mile Creek Watershed District
NOAA	National Oceanic and Atmospheric Administration
N-P-K	Nitrogen-Phosphorus-Potassium
NWI	National Wetland Inventory
OHWL	Ordinary High Water Level
P8	Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
WHO	World Health Organization
UAA	Use Attainability Analysis
ZVI	Zero Valent Iron

1 Introduction and Project Background

In August 2022, the Nine Mile Creek Watershed District (NMCWD) completed the *Lake Holiday, Wing Lake, and Lake Rose Water Quality Study* to assess and prescribe management activities to improve water quality in these three lakes within the City of Minnetonka (Barr Engineering Co., 2022). Following the water quality study, NMCWD completed this feasibility and preliminary engineering study to further evaluate the feasibility of the recommended management activities.

1.1 Project Background

Lake Holiday, Wing Lake, and Lake Rose are in the northwestern portion of the Nine Mile Creek watershed and are three of the furthest upstream lakes in the watershed. The three lakes and their watersheds are located entirely within the City of Minnetonka. The total area tributary to Lake Holiday, Wing Lake, and Lake Rose is approximately 670 acres. The lake subwatersheds are shown in Figure 1-1. The Lake Holiday, Wing Lake, and Lake Rose watersheds are nearly fully-developed. The major land use classification is single-family residential, which constitutes over 82% of the tributary watershed. The watershed also includes open water, highway, institutional (churches, schools), open space parks, and, to a lesser extent, forest/grassland, developed parks, commercial, and multi-family residential land uses.

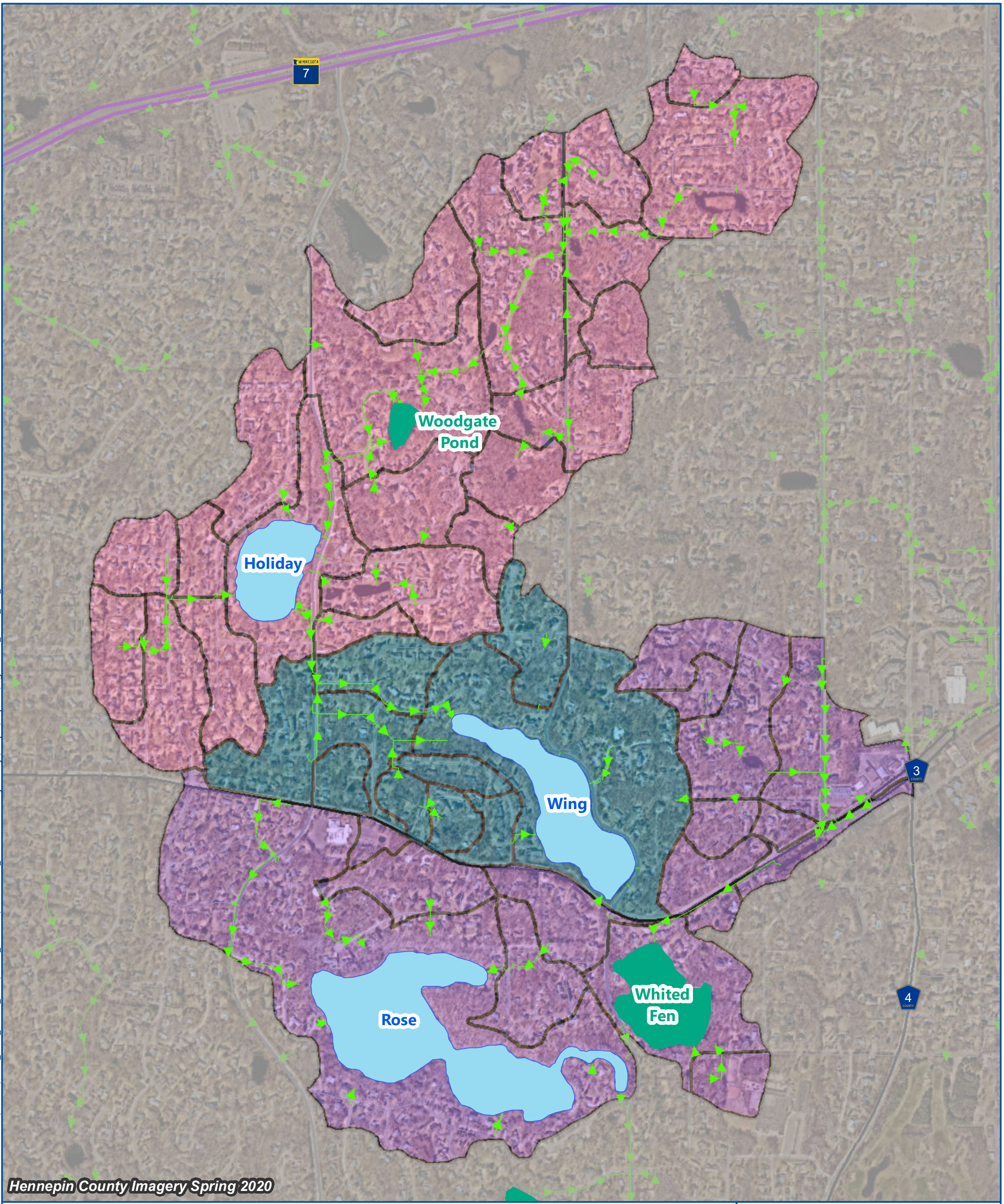
The Lake Holiday watershed, as shown by the pink areas in Figure 1-1, is approximately 286 acres. Runoff from the watershed enters Lake Holiday through overland flow and from several storm sewer outfalls at various points along the lakeshore. Lake Holiday also receives pumped discharge from Woodgate Pond. Outflow from Lake Holiday is pumped to Wing Lake. The Wing Lake watershed, represented by the yellow areas, is approximately 127 acres. Runoff from this watershed enters Wing Lake via overland flow and short sections of storm sewer at various locations along the lakeshore. Discharge from Wing Lake flows by gravity to Lake Rose. The Lake Rose watershed is approximately 257 acres and is shown by the orange areas. Most of the runoff to Lake Rose is conveyed through the storm sewer, while the areas immediately surrounding the lake contribute runoff via overland flow.

Recent monitoring data indicate that Lake Holiday and Wing Lake are not meeting Minnesota's water quality standards for shallow lakes, and while Lake Rose's water quality has generally been improving, Lake Rose does not consistently meet state standards for shallow lakes. The water quality in the lakes is moderate to poor, primarily due to excess nutrients (e.g., phosphorus and nitrogen) in the lakes, which fuels algal growth and decreases water clarity.

Wing Lake and Lake Rose are both included on the State of Minnesota's impaired waters list for excess nutrients. The Lower Minnesota River Watershed Total Maximum Daily Load (TMDL), completed by the MPCA in 2020, identifies a phosphorus load reduction to these lakes of 38% and 41%, respectively (Minnesota Pollution Control Agency, 2020). The required phosphorus load reductions identified in the TMDL are divided among watershed, upstream lake, and internal load, to be addressed through a combination of management practices targeting these sources.

The 2022 water quality study found (or confirmed) that phosphorus in Lake Holiday, Wing Lake, and Lake Rose comes from several sources, including stormwater runoff from the watershed (external source) and internal sources such as nutrient-rich sediments (Barr Engineering Co., 2022).

The 2022 water quality study identified several recommendations to improve water quality. This feasibility study report evaluates several water quality best management practices (BMPs) to reduce phosphorus loadings to the lakes. This feasibility study also evaluates the prevalence of curly-leaf pondweed in Lake Holiday and discusses recommended management approaches to improve the aquatic plant community.



- Public Water Inventory Waterbodies
- Public Water Inventory Wetlands
- Storm Sewer

Lake Subwatersheds

- Lake Holiday
- Wing Lake
- Lake Rose

LAKE HOLIDAY, WING LAKE, & LAKE ROSE SUBWATERSHEDS & STORMWATER CONVEYANCE

FIGURE 1-1

2 Lake Holiday, Wing Lake, and Rose Lake Overview

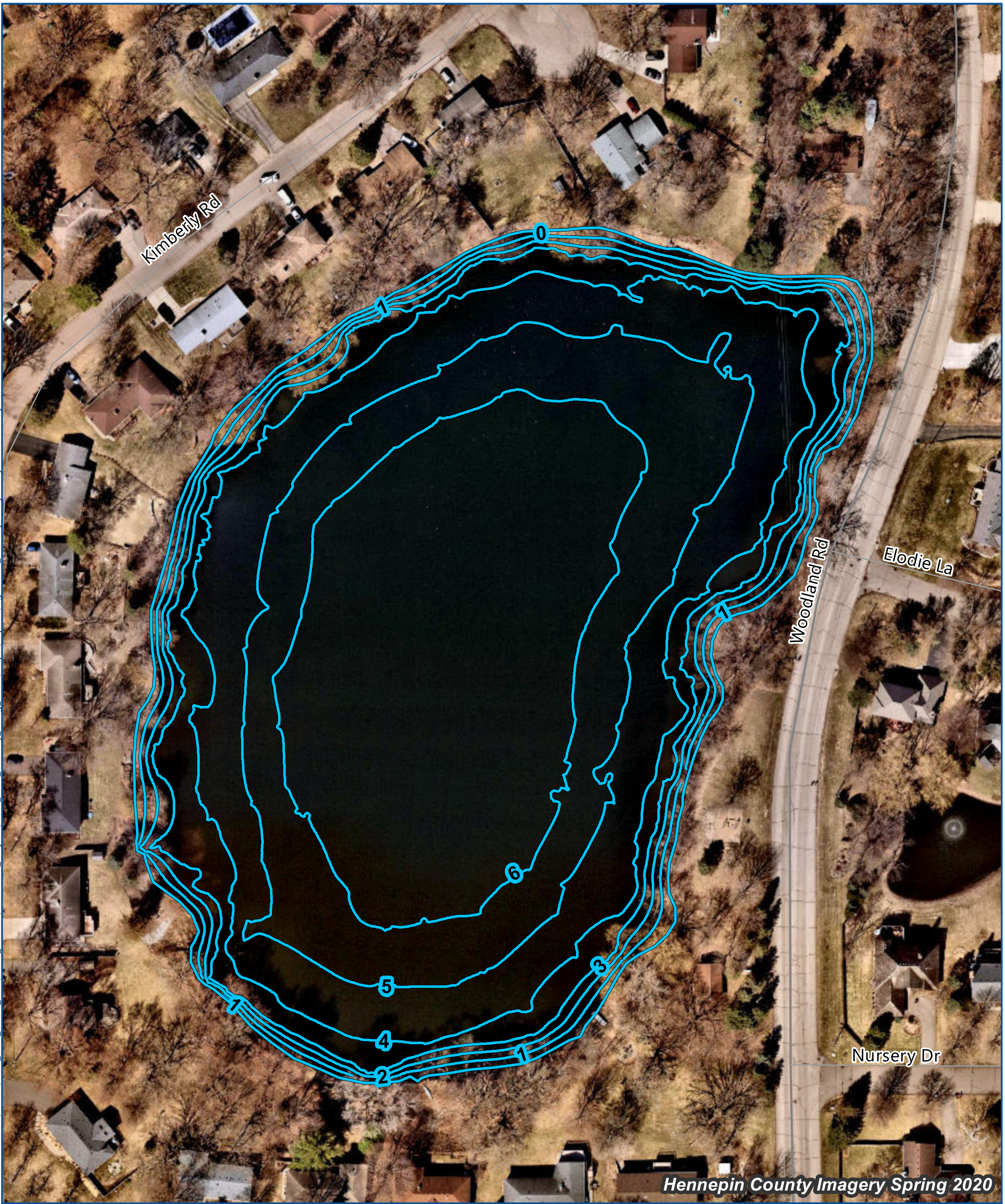
The following sections describe the characteristics of Lake Holiday, Wing Lake, and Lake Rose. All three lakes are in the southwestern portion of the City of Minnetonka, south of Highway 7 and west of Interstate 494. Additional background information can be reviewed in the *Lake Holiday, Wing Lake, and Lake Rose Water Quality Study* (Barr Engineering Co., 2022).

2.1 Lake Holiday

Lake Holiday has a water surface area of approximately 8.3 acres, a maximum depth of 5.5 feet, and a mean depth of 3.1 feet at a water surface elevation of 936.7 (NGVD29). At this elevation, the lake volume is approximately 28.7 acre-feet. Figure 2-1 shows the bathymetry of Lake Holiday. Lake Holiday is land-locked, with no gravity surface outlet. Water surface elevations are controlled by a three-stage pump. Each pump has a maximum discharge rate of 1,050 gallons per minute (gpm) (2.3 cfs). The total discharge rate while all three pumps are activated is 3,150 gpm (7.0 cfs). The first of three pumps turns on when the water elevation reaches 936.7 (NGVD29), with a second pump activated at a water elevation of 937.2 (NGVD29) and a third at 937.7 (NGVD29). Water pumped from Lake Holiday discharges via gravity towards Wing Lake.

Recent monitoring data indicate that Lake Holiday is not meeting Minnesota’s water quality standards for shallow lakes (Figure 2-2). The summer average (June 1-Sept 30) total phosphorus concentrations between 1993 and 2020 in Lake Holiday were above the shallow lake standard of 60 µg/L (ranging from 144–338 µg/L). The Lake Holiday summer average chlorophyll-*a* concentrations between 1993 and 2020 were also above the shallow lake standard of 20 µg/L (ranging from 44–195 µg/L). The summer average Secchi disk depths between 1993 and 2020 ranged from 0.2–0.6 meters and were less than the minimum 1.0-meter Secchi depth standard.

The plant community of Lake Holiday is degraded. In the most recent plant survey completed in June 2022, only 6 submerged and 3 floating plant species were observed. The Minnesota Department of Natural Resources (MNDNR) Lake Plant Eutrophication Index of Biotic Integrity indicates a minimum of 11 species is required for a healthy plant community. Of the species observed, the most abundant were the invasive species curly-leaf pondweed. Curly-leaf pondweed was observed at 90% of the monitored locations. Additional discussion on the plant survey and the impact of curly-leaf pondweed can be reviewed in Section 5.2.



City of Minnetonka Bathymetry (2009)
(Depth in feet)
*0' depth = 938.3 (NGVD-29)

LAKE HOLIDAY
BATHYMETRY

FIGURE 2-1

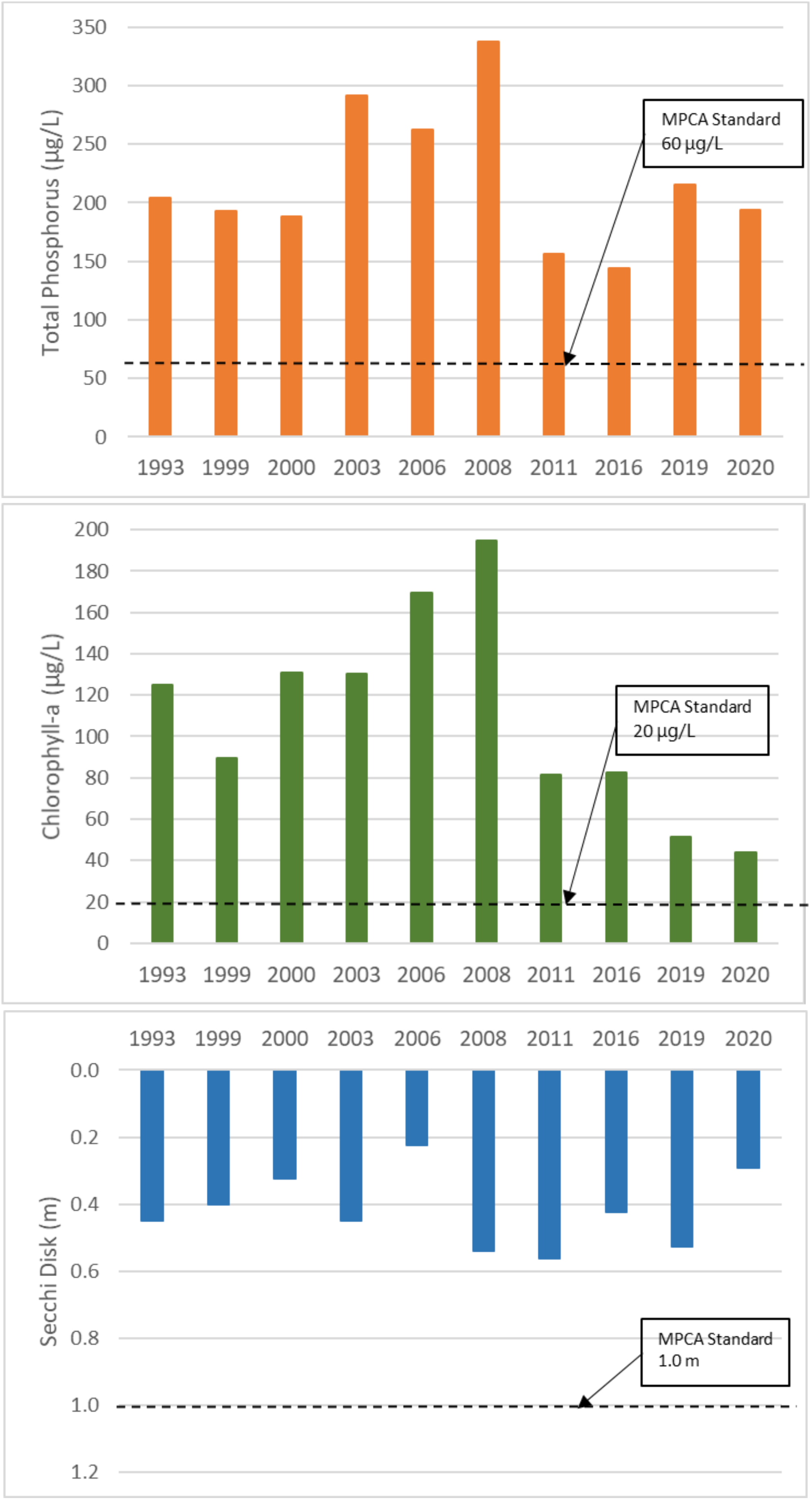


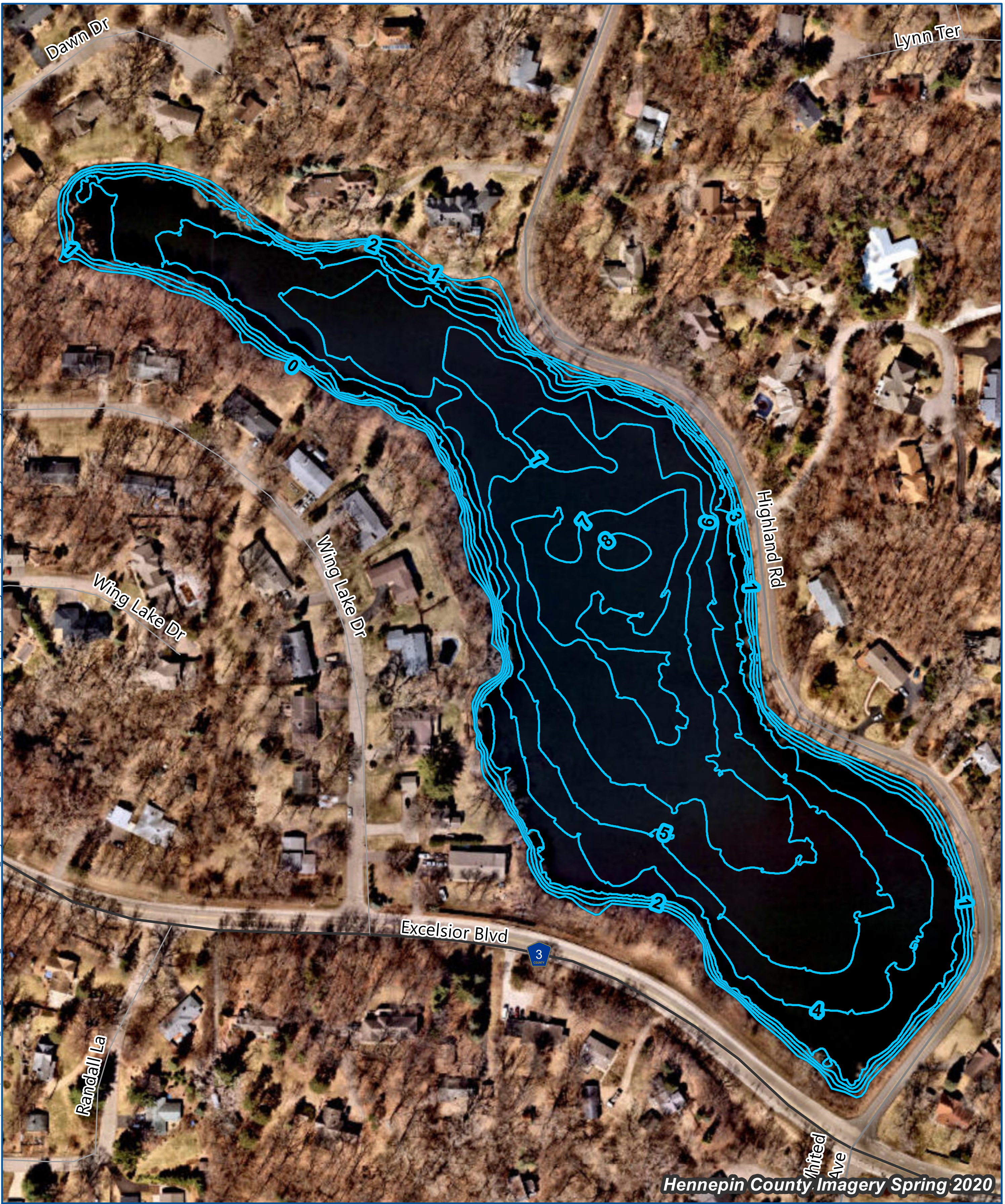
Figure 2-2 **Summer average total phosphorus and chlorophyll-*a* concentrations and Secchi disk depths in Lake Holiday between 1993 and 2020.**

2.2 Wing Lake

Wing Lake has a water surface area of approximately 13.6 acres, a maximum depth of approximately 7.3 feet, and a mean depth of 3.1 feet at a water surface elevation of 938.8 (NGVD29). At this elevation, the lake volume is approximately 48.7 acre-feet. Figure 2-3 shows the bathymetry of Wing Lake. The water level in the lake is controlled by weather conditions (snowmelt, rainfall, and evaporation), intermittently pumped inflow from Lake Holiday, groundwater flow, inflow from its direct subwatersheds, and the Wing Lake outlet. The Wing Lake outlet is a concrete structure with a small orifice at an elevation of approximately 938.8 (NGVD29) and a secondary control elevation of 939.8 (NGVD29). Water that discharges through the Wing Lake outlet flows to Lake Rose.

Recent monitoring data indicates that Wing Lake is not meeting Minnesota's water quality standards for shallow lakes (Figure 2-4). The summer average (June 1-Sept 30) total phosphorus concentrations between 1993 and 2020 in Wing Lake were above the shallow lake standard of 60 µg/L (ranging from 77–172 µg/L). The Wing Lake summer average chlorophyll-*a* concentrations between 1993 and 2020 were also above the shallow lake standard of 20 µg/L (ranging from 25–78 µg/L). The summer average Secchi disk depths between 1993 and 2020 ranged from 0.5–1.1 meters, with all but two summer average Secchi depths less than the minimum 1.0-meter standard.

The plant community of Wing Lake is also degraded. In the most recent plant survey completed in June and August 2020, only 7-8 plant species were observed. The MNDNR Lake Plant Eutrophication Index of Biotic Integrity indicates a minimum of 11 species is required for a healthy plant community (Figure 2-5).



Hennepin County Imagery Spring 2020

9 MILE CREEK WATERSHED DISTRICT

City of Minnetonka Bathymetry (2009)
(Depth in feet)
*0' depth = 940.3 (NGVD-29)

N

0 100 200
Feet

WING LAKE BATHYMETRY

FIGURE 2-3

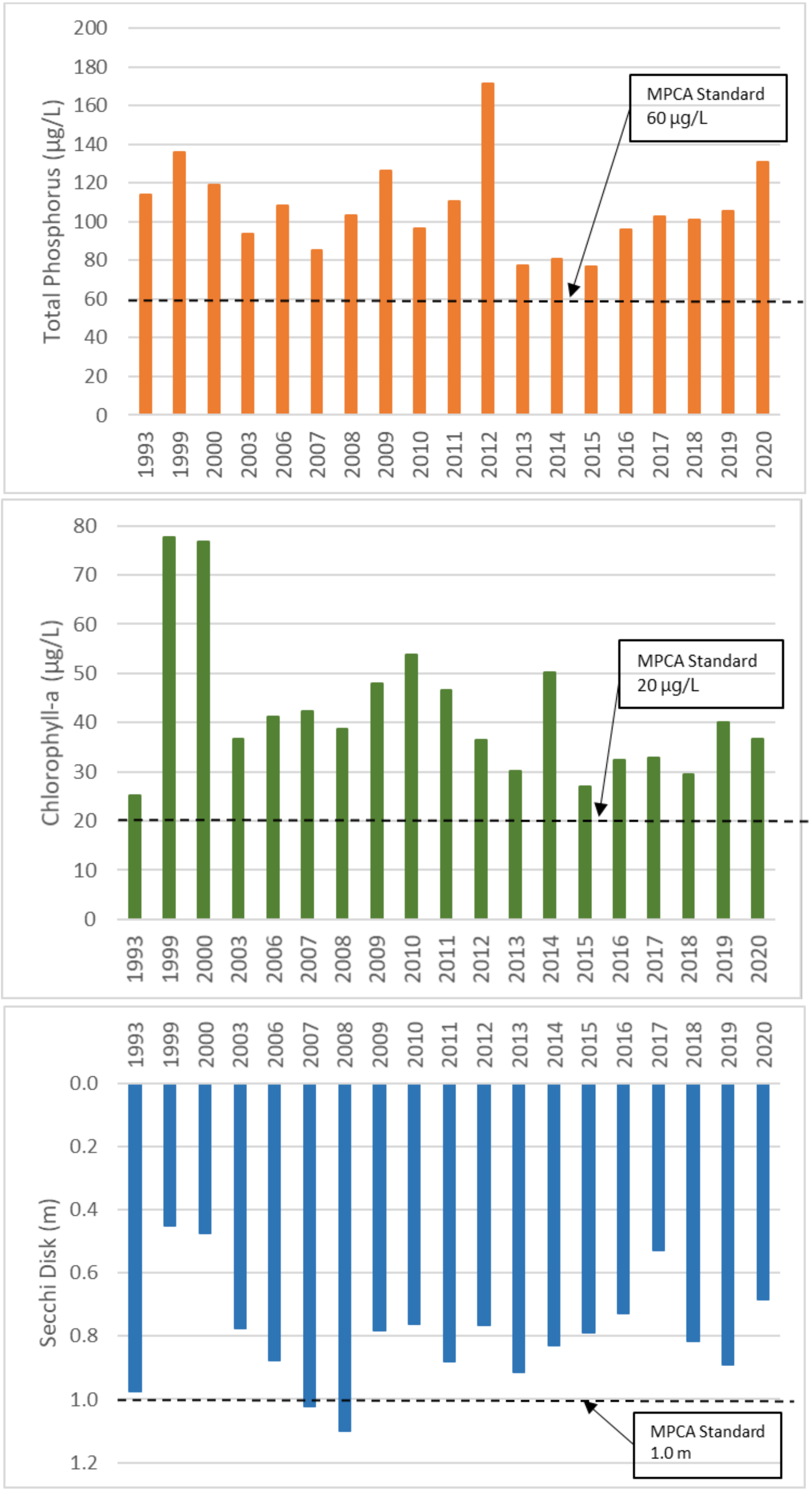


Figure 2-4 Summer average total phosphorus and chlorophyll-*a* concentrations and Secchi disk depths in Wing Lake between 1993 and 2020

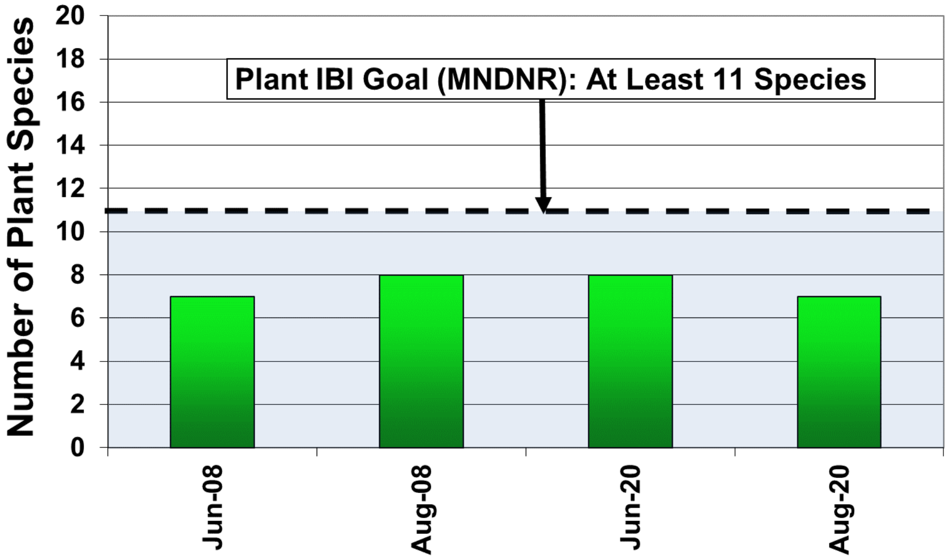


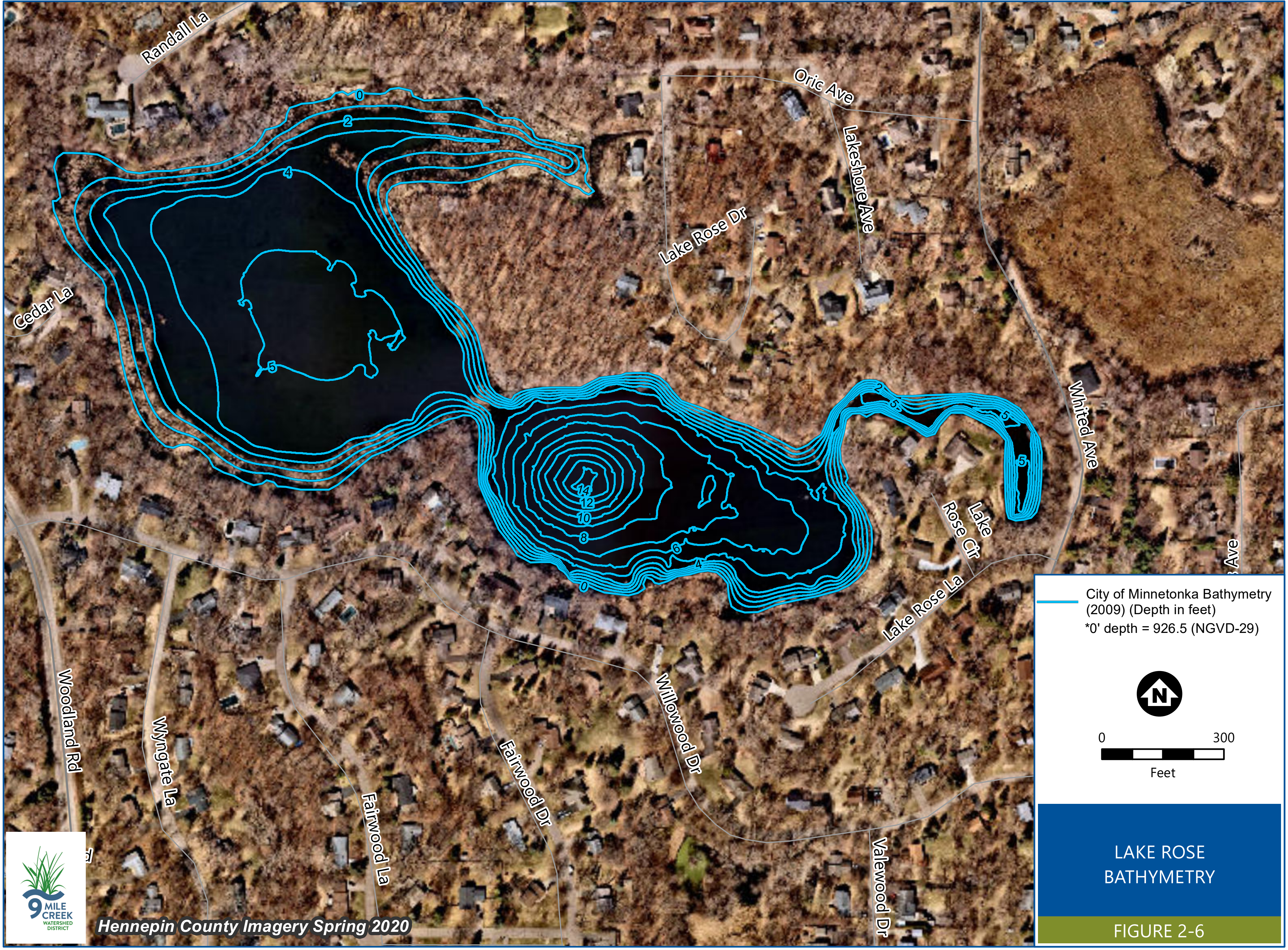
Figure 2-5 Wing Lake macrophyte species richness compared with plant IBI threshold for species richness

2.3 Lake Rose

Lake Rose has a water surface area of approximately 29.7 acres, a maximum depth of approximately 14.4 feet, and a mean depth of 4.6 feet at a water surface elevation of 926.6 (NGVD29), which is the elevation of the control outlet. At this elevation, the lake volume is approximately 121.7 acre-feet. Figure 2-6 shows the bathymetry of Lake Rose. The water level in the lake is controlled by weather conditions (snowmelt, rainfall, and evaporation), inflow from Wing Lake (if water surface elevations on Wing Lake are greater than 938.8 (NGVD29)), groundwater flow, inflow from its direct subwatersheds, and the Lake Rose outlet. Flow through the Lake Rose outlet is conveyed south and east via storm sewer and is ultimately discharged to Birch Island Lake in Eden Prairie.

Recent monitoring data indicates that the water quality in Lake Rose has been improving (Figure 2-7). The summer average (June 1-Sept 30) total phosphorus concentrations from 1993 through 2020 in Lake Rose were above the shallow lake standard of 60 µg/L (ranging from 68–150 µg/L), although observed phosphorus concentrations have generally been decreasing since 2007. The Lake Rose summer average chlorophyll-*a* concentrations from 1993 through 2019 were also above the shallow lake standard of 20 µg/L (ranging from 23–84 µg/L) but generally decreasing since 2007. The summer average chlorophyll-*a* concentration of 15 µg/L observed in 2020 met the shallow lake standard (<20 µg/L). Secchi disk transparency measurements have shown a general increase in transparency since 2000. Summer average Secchi disk transparency depths have increased from 0.5 meters in 2000 to slightly greater than 1.0 meters in 2020. From 2016–2020 the observed summer average Secchi disk transparency depths have met the State's shallow lake water quality standard of greater than 1.0 meter.

The plant community of Lake Rose has generally been improving in recent years. In the most recent plant surveys completed in June and August 2020, 10-12 plant species were observed. The MNDNR Lake Plant Eutrophication Index of Biotic Integrity indicates a minimum of 11 species is required for a healthy plant community (Figure 2-8).



City of Minnetonka Bathymetry (2009) (Depth in feet)

*0' depth = 926.5 (NGVD-29)

LAKE ROSE BATHYMETRY

FIGURE 2-6

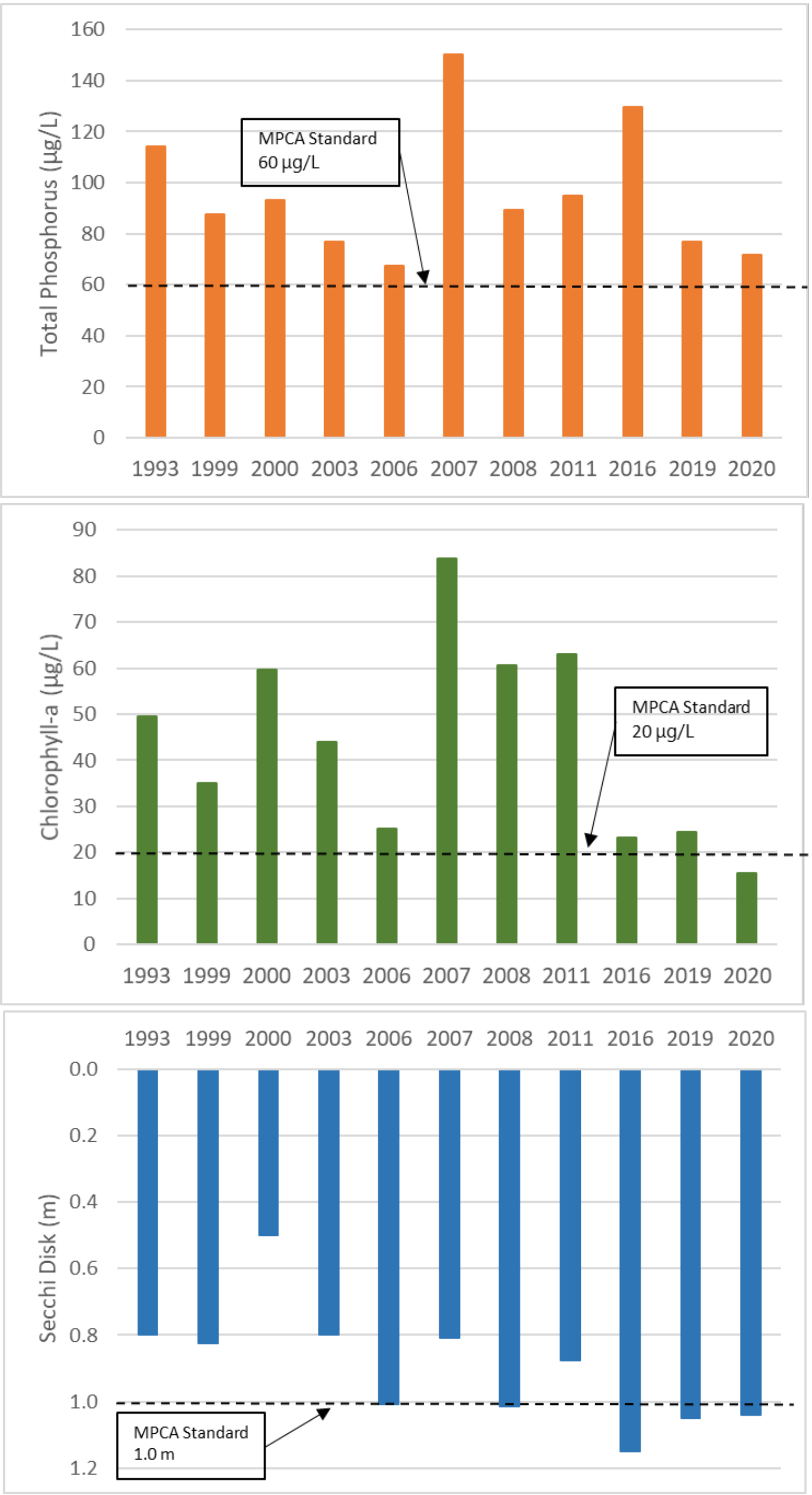


Figure 2-7 Summer average total phosphorus and chlorophyll-*a* concentrations and Secchi disk depths in Lake Rose between 1993 and 2020

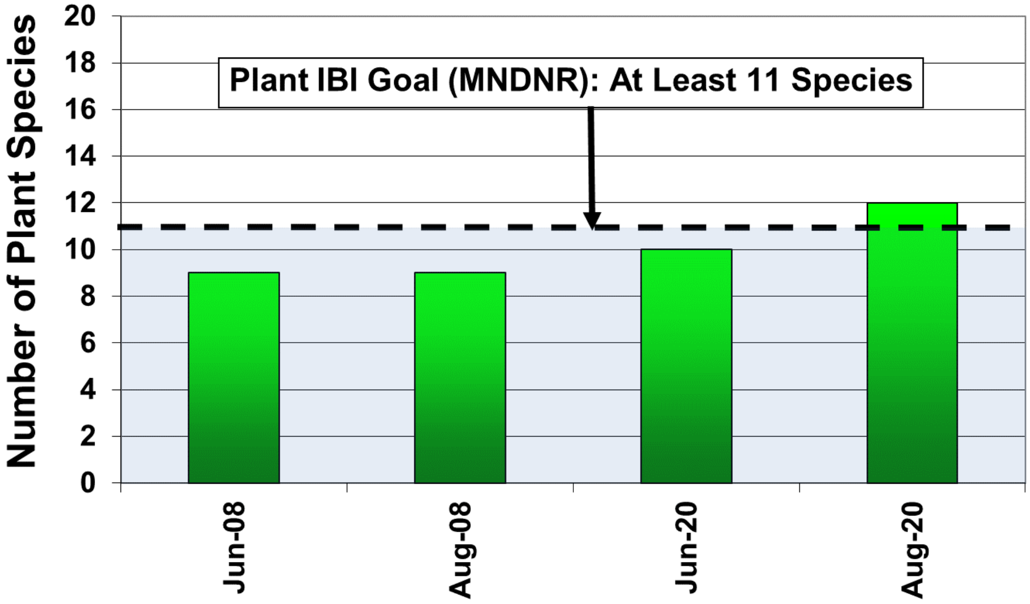


Figure 2-8 Lake Rose macrophyte species richness compared with plant IBI threshold for species richness

3 Summary of Evaluated Management Practices

The goals of this study are to evaluate the feasibility and cost-effectiveness of the management strategies recommended in the *Lake Holiday, Wing Lake, and Lake Rose Water Quality Study* (Barr Engineering Co., 2022).

The following sections of the report summarize the findings of the feasibility evaluation and recommendations for lake and watershed management practices:

- Section 4 – Holiday Lake Park Filtration System, to reduce in-lake phosphorus concentrations
- Section 5 – Lake Holiday In-Lake BMPs
    - Lake Holiday sediment treatment to reduce internal phosphorus loading from sediments
    - Lake Holiday aeration to reduce internal phosphorus loading from sediments
    - Lake Holiday curly-leaf pondweed management to improve aquatic plant community
- Section 6 – Wing Lake Sediment Treatment, to reduce internal phosphorus loading from sediments
- Section 7 – Lake Rose Sediment Treatment, to reduce internal phosphorus loading from sediments
- Section 8 – Enhanced Street Sweeping in Lake Holiday, Wing Lake, and Lake Rose subwatersheds to reduce external nutrient loads
- Section 10 – Conclusions and Recommendations

NMCWD staff have been working to implement the pilot phase of a soil sampling program within the Lake Holiday, Wing and Rose subwatersheds in 2023. Results from the initial pilot phase of that program are summarized in Section 9.

4 Holiday Lake Park Filtration System

Opportunities to install stormwater BMPs in the Lake Holiday watershed were evaluated as part of the 2022 *Lake Holiday, Wing Lake, & Lake Rose Water Quality Study* to reduce phosphorus concentrations in the lake (Barr Engineering Co., 2022). One of the stormwater BMPs investigated during this study included a pumped, recirculating filtration system within Holiday Lake Park, located adjacent to Lake Holiday. A treatment concept design was developed during the 2022 water quality study and investigated further as a part of this feasibility study.

This feasibility study included two phases of analysis: (1) evaluation of recirculating filtration BMP conceptual design(s) and selection of a preferred concept by the NMCWD and City of Minnetonka, and (2) feasibility analysis and preliminary engineering design of the selected conceptual BMP. Each of these phases is described in subsequent sections.

4.1 Site Characteristics

The proposed recirculating filtration BMP would be installed in Holiday Lake Park, located on the east side of Lake Holiday along Woodland Road (Figure 4-1). The park currently provides recreational opportunities through open green spaces, benches, a picnic shelter, and a swing set. The park also contains a storage building connected to the picnic shelter. A control panel, positioned on a concrete pad, is located on the south end of the park adjacent to this building. This control panel controls the subsurface, three-stage pump system that maintains the water levels on Lake Holiday since Lake Holiday has no gravity surface outlet.

The optimal location for a recirculating BMP would be within the northern portion of the park. Siting a filtration BMP in the northern portion of the park capitalizes on existing gently sloped, open green space with minimal shading. Constructing within existing open green space minimizes tree removal and reduces impacts on existing park features. Minimal shading also provides conditions suitable for faster drying of filtration media between treatment events. This is discussed in more detail in subsequent sections.

In the early phases of the feasibility study, the NMCWD and the City of Minnetonka provided the following comments regarding park safety and aesthetics. These components were incorporated for all subsequent design phases:

- Safety
    - Natural or constructed barriers should be considered to discourage access to the basin by park users.
    - Within recent years Lake Holiday has experienced cyanobacteria blooms in the summer and the fall. Pumping operations should consider minimizing cyanobacteria exposure to park users.
- Aesthetics
    - Preference for more vegetation around and within the basin (if possible)

- Incorporation of pollinator species
- A vegetative buffer zone between park users and basin features

In the early planning phases, the City also expressed some concern regarding the level of maintenance required for a filtration BMP. Operations and maintenance considerations are addressed in Section 4.3.2.4.

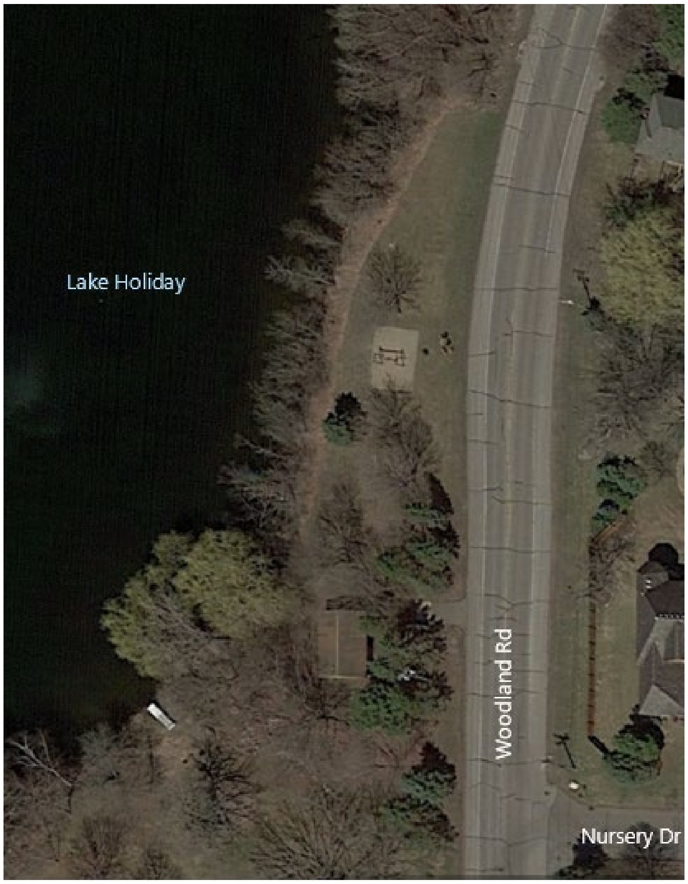


Figure 4-1 **Holiday Lake Park**

4.2 Holiday Lake Park Conceptual Design Options

The general operation of a recirculating filtration BMP in Holiday Lake Park would be as follows:

1) Water from Lake Holiday would be pumped into a filtration BMP system when Lake Holiday water levels are below the elevation at which the pump(s) to Wing Lake turn on.
2) Water would be pumped at pre-determined intervals to allow the filtration media to dry out between treatment stages and to target the highest aerated conditions in the lake.
3) Pumped water directed to the filtration BMP system would filter through treatment media, where particulates would be captured, and dissolved contaminants would adsorb.
4) Filtered water would then gravity flow back into Lake Holiday.

    a. Recirculating water from Lake Holiday ensures that water levels will not be affected by the filtration BMP.

5) Filtration media would be periodically maintained to sustain contaminant removal effectiveness. If backwashing is required, backwash water would be discharged into the nearby sanitary sewer.

Two high-level filtration BMP concepts within Holiday Lake Park were developed and presented to NMCWD and City of Minnetonka staff through a series of meetings in winter 2022/2023. Throughout the process, the preliminary concepts were modified to incorporate feedback from the various stakeholders involved. Two types of recirculating filtration basin were considered during the feasibility study: (1) a slow sand filter and (2) a rapid sand filter. With water being pumped directly from Lake Holiday, the potential for a filtration basin to become clogged with algae and/or other organic material was a somewhat unique yet significant design consideration. An overarching goal of investigating two different filter types was to try to balance the following interconnected yet often competing design criteria:

- Design complexity (simple is better)
- Maintenance complexity and frequency
- Long-term functionality
- Treatment effectiveness (e.g., TSS and TP removal effectiveness)
- Initial capital cost and annual maintenance costs

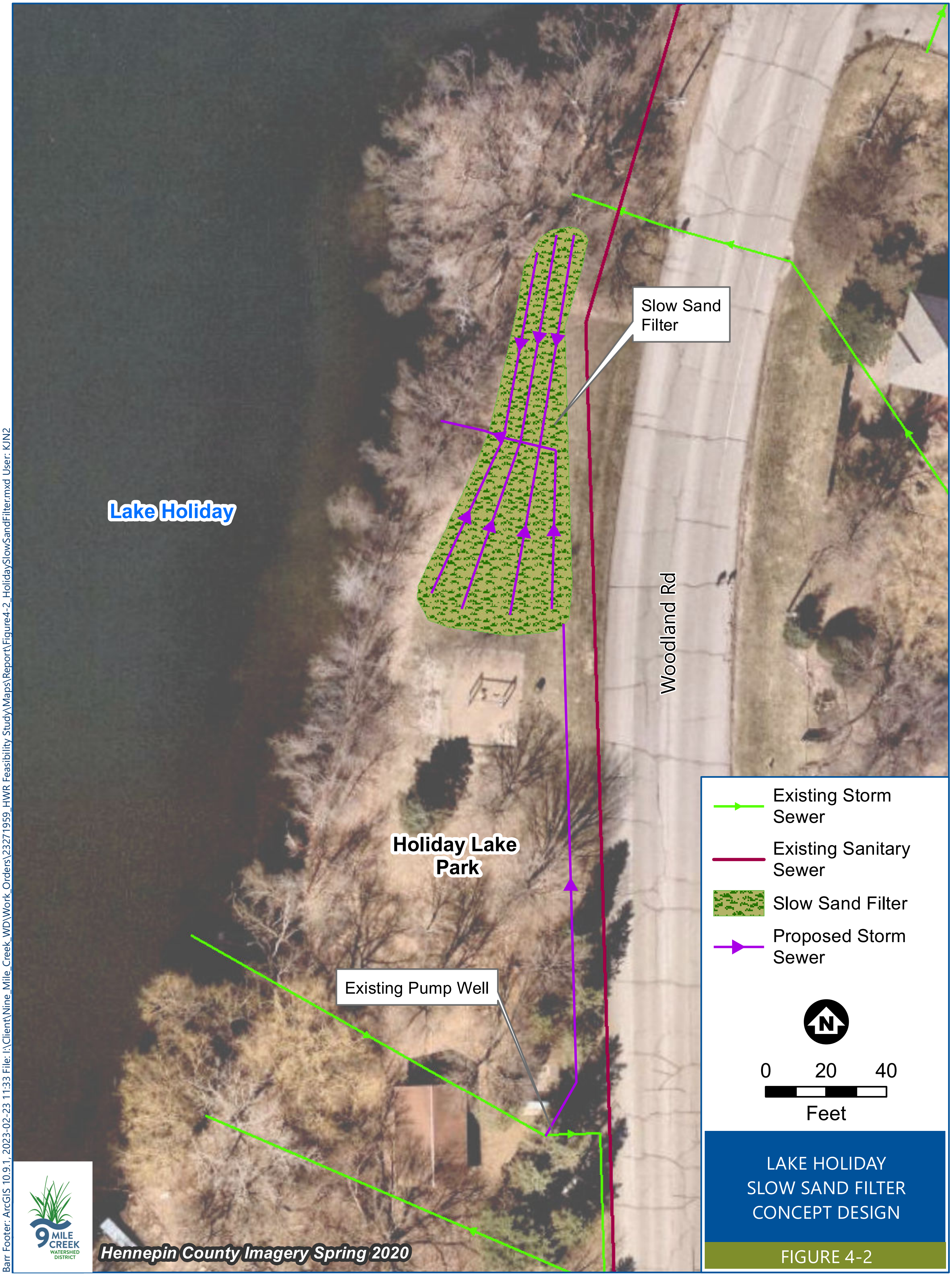
This section describes the different basin characteristics, concept designs, and estimated benefits (e.g., total phosphorus removal efficiency) of each filter type. The section also discusses which concept design was selected for feasibility/preliminary engineering design.

4.2.1 Slow Sand Filter

Slow sand filters are commonly used in drinking water treatment plant designs to remove contaminants as water slowly filters through the media. Particulates and contaminants are removed from the water through physical capture by the filtration media and through decomposition from microbial processes in a thin layer on the surface of the filter bed. This thin layer contains a large variety of microorganisms and enables slow sand filters to remove bacteria, E. coli, organic matter, and turbidity at effective rates.

Slow sand filters offer several advantages over other filter types, including (1) simple design, construction, and operation, (2) minimal annual maintenance (raking media 1–2 times per year), (3) no backwashing necessary, (4) no upstream pretreatment systems required, and (5) can be planted with rhizome-type plant species. However, some disadvantages restrict where slow sand filters can be effectively applied for treatment, including (1) requiring a treatment flowrate that is 50 to 100 times slower than rapid sand or high-rate filters, (2) requiring a large amount of land to treat a comparable volume of water as rapid and or high-rate filters, and (3) requiring a greater depth of media for filtration (>5 feet of sand).

A slow sand filter was conceptually designed to treat pumped water from Lake Holiday. The conceptual footprint for the slow sand filter was sized to utilize all the open green space within the northern portion of the park and to extend slightly north, which would require the removal of less than a dozen trees (Figure 4-2). The basin was sized to be as large as possible to maximize the volume of water filtered without impacting existing park infrastructure.



LAKE HOLIDAY
SLOW SAND FILTER
CONCEPT DESIGN

FIGURE 4-2

4.2.2 Rapid Sand Filter

Rapid sand filters are another commonly used practice in water treatment to remove contaminants as water rapidly filters through various media types in two distinct stages. The first stage consists of filtration through coarser media (e.g., anthracite, support gravel) that targets the removal of larger particulates. The second stage utilizes finer media (e.g., fine sand, iron-enhanced sand) to target the removal of smaller particulates and dissolved contaminants. Rapid sand filters can apply "rapid" treatment flowrates because the first-stage coarser media, and sometimes also the second-stage finer media, are backwashed to remove trapped particulates. During the backwashing process, the media is fluidized, and the particulates are released to discharge with the backwashed water. After the filter has been backwashed and the previously captured particulates removed, the filter can be placed back in operation to treat additional water.

Rapid sand filters offer several advantages over other filter types, including (1) high treatment flowrates, (2) smaller basin footprints to achieve desired pollutant removal benefits, and (3) requiring less depth of fine media for filtration (2–2.5 feet). However, some disadvantages limit where rapid sand filters can be effectively utilized for treatment, including (1) having greater design, construction, and operational complexities, (2) requiring more frequent maintenance, including backwashing of the treatment media, and (3) no vegetation can be planted within the basin media.

A rapid sand filter was conceptually designed to treat pumped water from Lake Holiday using a treatment flowrate between 0.5 and 0.7 cfs. This design treatment flow rate would require less than 1,000 square feet of total filter media area for the BMP footprint, which is less than 20% of the existing open green space area in the northern portion of the park.

Conceptually, the rapid filtration system would utilize a two-stage process where water would first be pumped from Lake Holiday into a pretreatment concrete vault containing coarse media to remove particulates. Filtered water would then discharge into a second filtration system containing fine media to remove smaller particulates and dissolved contaminants. A pretreatment concrete vault would be utilized for stage-one treatment so that the course media could be backwashed effectively. The second phase would consist of a natural basin constructed within the existing topography.

4.2.3 Concept Design Conclusions

At a January 24, 2023, meeting with NMCWD and City of Minnetonka staff, the rapid sand filter was selected as the preferred conceptual BMP alternative to be evaluated further. Since the available land for the slow sand filter was severely limited in comparison with design guidance for this type of filter system, the phosphorus removal from the slow sand filter was much lower than that of the rapid sand filter. Table 4-1 compares the estimated pounds of phosphorus removed from Lake Holiday during the growing season between the slow and rapid sand filters. Another advantage of the rapid sand filter is the smaller footprint requirement, which would minimize parkland impacts and provide additional opportunities to incorporate native plantings, educational features, or other natural design enhancements to the park.

While the rapid sand filter conceptual design provides more phosphorus removal with a smaller footprint, concerns expressed by the City of Minnetonka and/or NMCWD related to this concept included:

1. Operational and maintenance complexity (e.g., backwashing), maintenance complexity
2. Limited case studies and previous applications
3. High capital and on-going maintenance costs

These topics were further explored during feasibility/preliminary engineering design (see Section 4.3).

Table 4-1 Growing season estimated pounds of phosphorus removed from Lake Holiday

Lake	Pounds of Phosphorus Removed (Growing Season)	
	Slow Sand Filter Concept	Rapid Sand Filter Concept
Lake Holiday	0.3	13

4.3 Feasibility Analysis—Rapid Filtration BMP

Following direction from NMCWD and the City of Minnetonka, feasibility analysis for the proposed rapid filtration BMP (rapid sand filter) began in late-February 2023. Feasibility analysis included performing a site characterization and preliminary engineering/schematic design for the pump system, pre-treatment vault, and filtration basin. The preliminary engineering design phase specifically investigated the pump system orientation and sizing, pre-treatment vault sizing and layout, filtration basin sizing and layout, and landscaping, as well as further defined overall operation and maintenance needs.

4.3.1 Site Characterization

Site characterization for the proposed rapid sand filtration system in Lake Holiday Park included a review of geographic information systems (GIS) data to understand the existing topography, soil conditions, park features, lake bathymetry, and existing utilities (e.g., pump well, storm infrastructure, sanitary infrastructure). Figure 4-3 shows several existing site features, including topography, bathymetry, storm sewer, and sanitary sewer. The topographic information shown in the figure is based on MNDNR light detection and ranging (LiDAR) data developed in 2011. Lake Holiday bathymetry, as well as storm and sanitary sewer information (e.g., diameters, invert elevations, etc.), were obtained from the City of Minnetonka. Reviewing the existing storm and sanitary sewer alignments and elevations was important to determine how the proposed rapid sand filtration could connect to the existing systems for forward flow treatment and backwash discharge.

Existing soil information within Holiday Lake Park was reviewed on the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) web soil survey (USDA, 2023). The NRCS classified the soil within Holiday Lake Park as soil with hydrologic soil group (HSG) classification C. Given that much of the area around Lake Holiday was part of a large wetland complex prior to development in the early 1900s and beyond, the soils throughout much of the low-lying park areas are likely hydric. Soil boring analysis is recommended for the next design phase to better understand soil characteristics and stability for construction.

A review of existing park infrastructure and vegetation was another important aspect of site characterization, as it was important to site the filtration infrastructure in locations that minimize park impacts. Figure 4-3 shows the existing park features in the proposed project area, including detailed aerial imagery. Recently available Near Map satellite imagery of the project area was used for this analysis and is from May 6, 2022. The Near Map imagery has a 3-inch resolution, which allows for a detailed review of the park's features.

4.3.2 Preliminary Engineering/Schematic Design

Figure 4-4 shows the Holiday Lake Park rapid filtration BMP schematic design and conceptual planting plan. The forward treatment process of the rapid filtration BMP would generally work as follows:

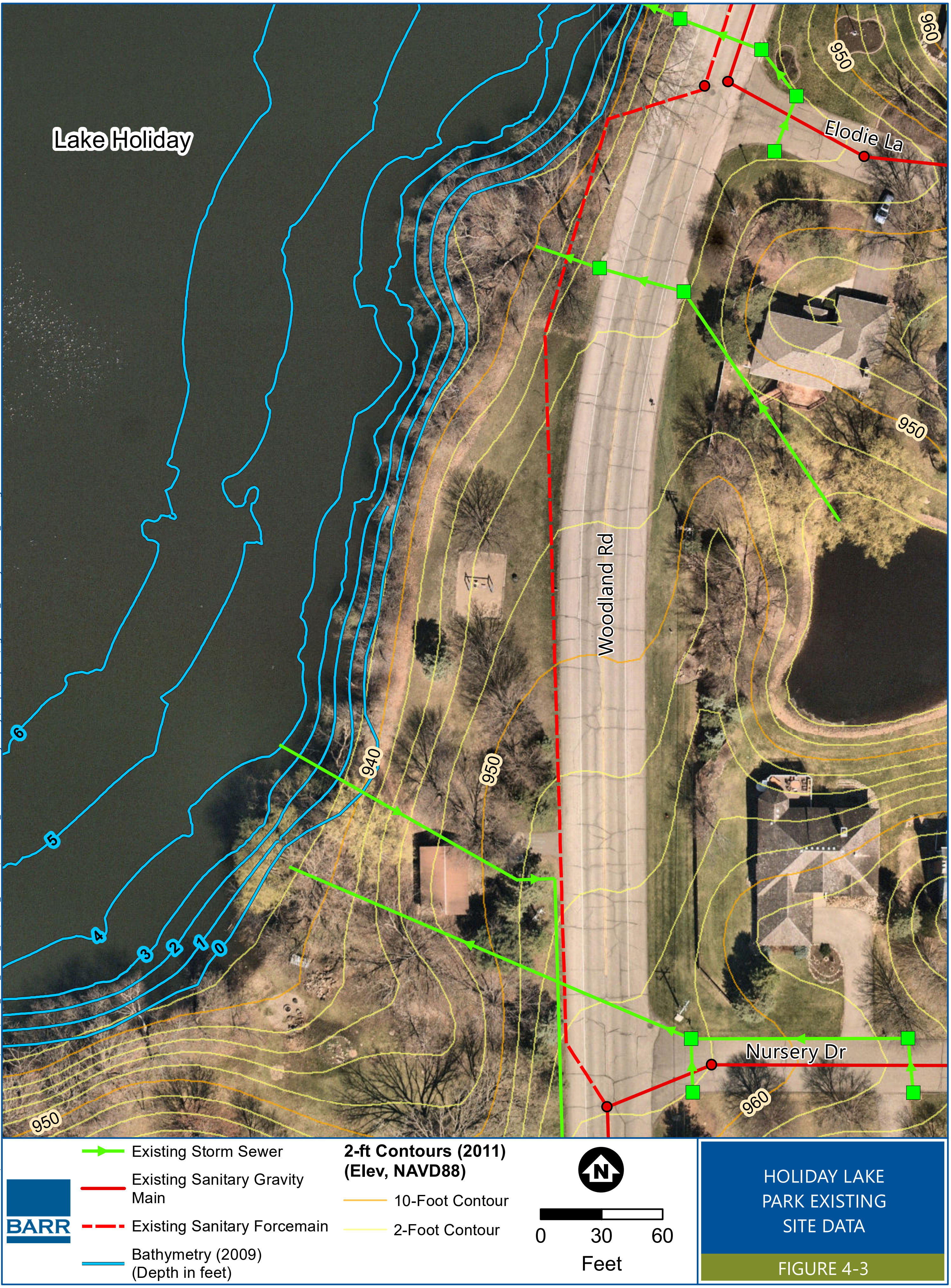
- Water would be pumped from Lake Holiday through a new inlet pipe located just north of the existing outlet pipe.
- Pumped water would flow pressurized at a treatment rate of 300 gallons per minute (gpm) through a flow meter manhole and discharge into an aeration manhole. Once in the aeration manhole, water would discharge vertically to then cascade downward by gravity, aerating the water in the process.
- Downstream of the aeration manhole, water would flow by gravity to a pretreatment concrete vault, with five cells through which water would filter downward through layers of anthracite and support gravel to remove particulates.
- Pretreated water would discharge through subsurface draintile to a filtration basin. Within the filtration basin, water would flow upward through the treatment media (e.g., iron-enhanced sand), removing smaller particulates and dissolved contaminants.
- Treated water would pool on top of the filtration basin before discharging through a beehive outlet grate. Water entering the outlet structure would be conveyed back to Lake Holiday.

The backwashing process of the rapid filtration BMP would generally work as follows:

- Ball valves would be opened and closed to target backwashing one pretreatment cell at a time.
- Pumped water, at a backwash rate of 500 gpm, would flow upwards through each pretreatment cell (one at a time) to fluidize the anthracite and release captured particulates. Anthracite would re-settle after backwashing.

Backwashed water would flow downstream to a second pump manhole (labeled as “Backwash pump” in Figure 4-4), specifically installed to pump backwashed water downstream to an existing sanitary manhole at the intersection of Woodland Road and Nursery Drive. Pumped water would flow at 500 gpm toward the existing sanitary manhole.

- Once entering the existing sanitary manhole, backwashed water would flow by gravity through the City of Minnetonka’s existing sanitary sewer system.



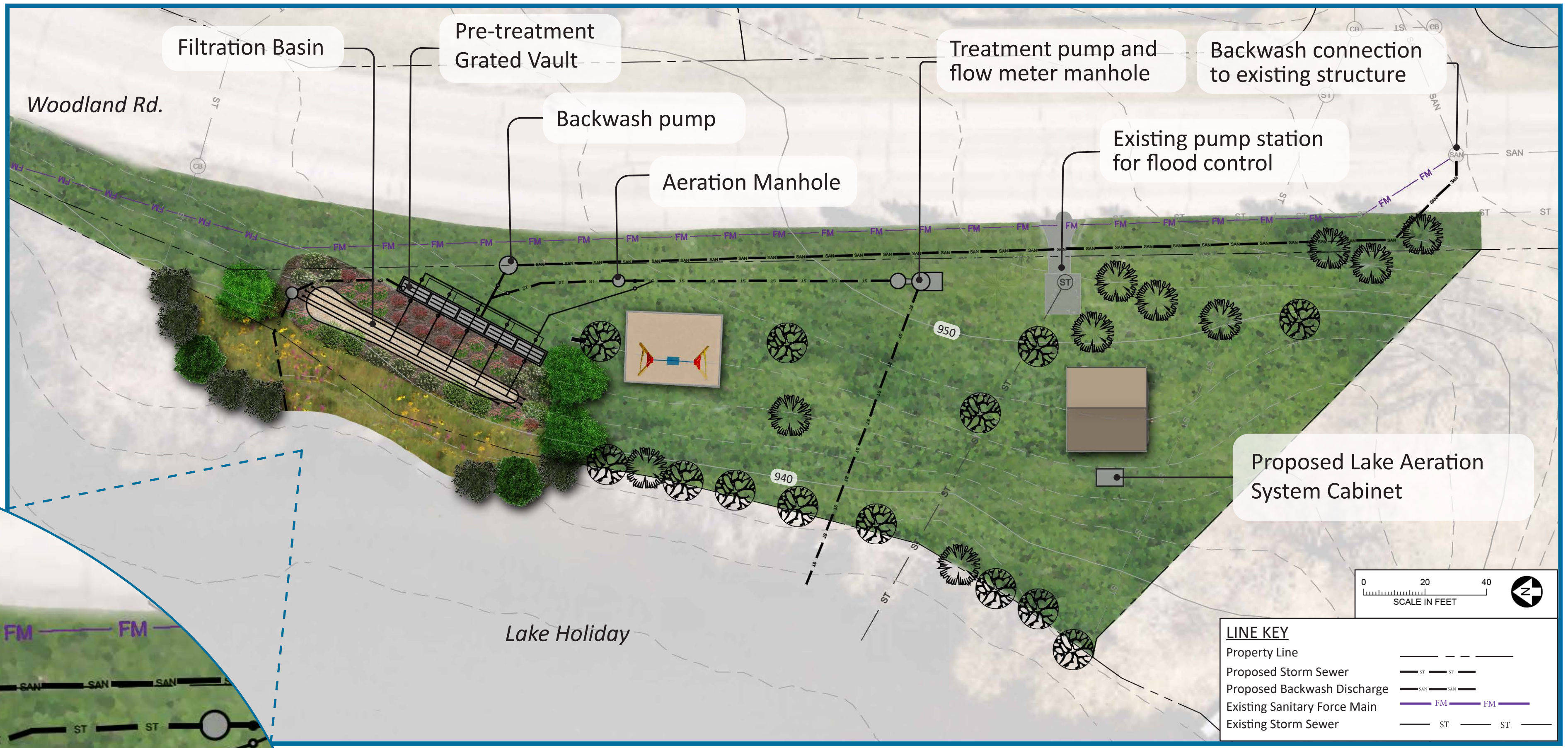
HOLIDAY LAKE PARK EXISTING SITE DATA

FIGURE 4-3

Rapid Filtration BMP - Schematic Design and Conceptual Planting Plan

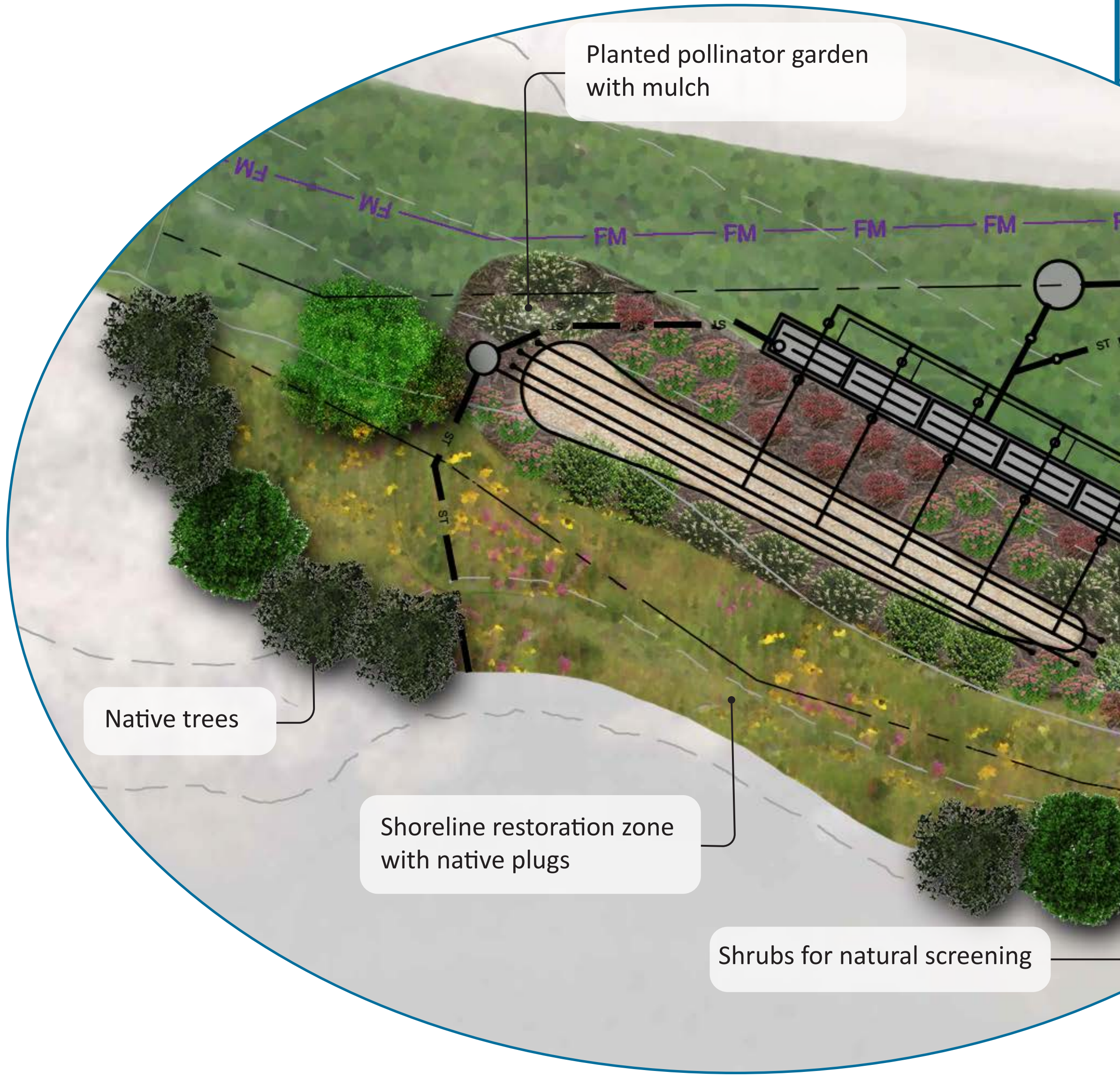
POLLINATOR PLANTING EXAMPLES

DESIGN - PLAN VIEW



LINE KEY

Property Line	— — —
Proposed Storm Sewer	— ST —
Proposed Backwash Discharge	— SAN —
Existing Sanitary Force Main	— FM —
Existing Storm Sewer	— ST —



SHORELINE RESTORATION EXAMPLES

Figure 4-4

The next sections provide further details on various design components of the rapid sand filtration system.

4.3.2.1 Pumping Operations

The schematic design of the rapid filtration BMP assumes that the pumping infrastructure will be separate from the existing pump system, which is used to control water surface elevations on Lake Holiday. As currently shown, a new, submerged intake pipe would be installed north of the existing outlet pipe that would direct water from Lake Holiday to the treatment pump station. The treatment pump station would contain two pumps, one for forward flow (300 gpm) and one for backwash water supply (500 gpm). A higher flowrate pump for the backwash water supply would reduce overall costs by reducing the number of pretreatment cells needed and associated reinforced concrete, piping, and valves. A higher flowrate pump for the backwash water supply would also improve maintenance efficiency and costs over the long-term, requiring less time to backwash fewer pretreatment cells during each maintenance visit. A meter manhole would be installed downstream of the pump station, with a flow meter to monitor the performance of the pumps. Adjacent to the pump station and the meter manhole would be a control panel for pump operation and monitoring.

A separate pump station will be required to discharge backwash water to existing sanitary infrastructure because the invert elevations of the existing sanitary sewer are approximately four feet higher than the filtration system backwash outlet. A 500 gpm post-backwash pump station would be located directly north of the pretreatment concrete vault. Water that enters this pump station after backwashing would flow pressurized to the sanitary manhole at the intersection of Woodland Road and Nursery Drive, after which water would flow by gravity in the existing sanitary pipes. Discharging backwash water into the existing sanitary sewer rather than back into Lake Holiday will be critical to achieving desired phosphorus removals and improving in-lake water quality concentrations. Any potential impacts on noise and related design considerations as associated with changes and additions to the existing pumping systems would be considered as part of the final project design.

4.3.2.2 Pretreatment Operation and Layout

With water being pumped to the filter directly from Lake Holiday, the potential for clogging due to algae and/or other organic material is a significant design consideration. The schematic design includes two primary pretreatment steps to help prevent and/or remedy clogging: 1) a fish/debris screen at the water intake and 2) an anthracite pretreatment vault directly upstream of the filter.

In the schematic design, a fish/debris screen is positioned upstream of the pumps, within the treatment pump station, to block larger debris and fish from being pumped from Lake Holiday to the filtration system. Further design of the screen will require careful consideration of the size of the screen openings, balancing the objective of blocking small fish and debris with minimizing the potential for clogging with organic material.

In the schematic design, an anthracite pretreatment vault is positioned upstream of the filtration basin to filter out debris, particulates, and organic matter (e.g., algae) and minimize clogging of the filtration basin. The surface area of the grated concrete vault is approximately 300 square feet with five separate cells, each containing anthracite and support gravel. Anthracite, also known as hard coal, is often used in water treatment for rapid filtration processes because the media is effective at capturing particulates and can be fluidized during backwash processes. The schematic design includes liftable, open grates on top of the vault for ease of maintenance and to facilitate media drying between operation cycles. An example pretreatment concrete vault with an open grate from the installation in Rosland Park in the City of Edina is shown in Figure 4-5.

Figure 4-5 Pretreatment concrete vault with an open grate in Rosland Park (Edina)

In addition to considering pretreatment options to prevent and/or remedy clogging of the filtration media, another important pretreatment step to evaluate is the aeration of the influent water. In the schematic design, an aeration manhole is positioned upstream of the anthracite pretreatment vault. The purpose of the aeration manhole is to increase the dissolved oxygen concentration of the water pumped from Lake Holiday. Dissolved oxygen concentrations are increased by discharging the pressurized water from the pump station vertically within the aeration manhole through a pipe positioned like a standpipe. Water that discharges vertically within the aeration manhole will cascade downward to the bottom of the structure. As the water falls, dissolved oxygen concentrations will increase. Higher dissolved oxygen concentrations are important to maintain the nutrient absorption capacity of the media within the filtration basin. Any media enhanced with iron is sensitive to anoxic (low oxygen) conditions. The longer iron-enhanced media is exposed to anoxic conditions, the higher the probability of orthophosphate being released back out of the filtration media and flushed back into Lake Holiday. Installing an aeration manhole will also offer operational flexibility by allowing the system to operate for longer durations and provide the option to operate during the nighttime when oxygen concentrations are the lowest (i.e., algae and plants not producing oxygen from photosynthesis).

4.3.2.3 Filtration Basin Sizing and Landscaping

The goal of the filtration basin is to remove smaller particles and dissolved contaminants, including dissolved phosphorus. The filtration basin, with a bottom area of approximately 600 square feet in the schematic design, will include filter media enhanced with iron (or other additives) to promote the removal of orthophosphate. To maintain optimal performance of the filtration media, vegetation within the media should be avoided.

The schematic design includes restoring the area surrounding the filtration basin with native vegetation. The sloped areas immediately surrounding the filtration basin can be mulched and planted with perennials that are pollinator-friendly to introduce color, provide an ecological benefit, and offer aesthetic features for park users. Taller and thicker shrubs can be installed between the filtration features and the existing playground to act as a natural barrier and discourage entrance into the basin. To incorporate the filtration features and proposed piping into the existing park topography, tree removal will be necessary along the shoreline and select locations throughout the park. The shoreline can be restored with native plugs and seeding, and trees can be installed to offset the tree removals needed during construction. The exact placement of the trees or shrubs can be determined in the next phase of design. Providing maintenance access near the northeast corner of the site is recommended.

4.3.2.4 Operation and Maintenance Considerations

Table 4-2 identifies the expected general inspection and maintenance procedures for the rapid filtration system and the recommended maintenance frequency for each task. Anticipated maintenance activities and frequency are based on Barr's experience with a similar treatment system at Rosland Park in Edina and information shared by operators of other filtration BMPs within the metro area. As noted within the table, certain filter system components, such as the fish/debris intake screen, are expected to need inspection (and anticipated maintenance) more frequently than others. It is anticipated that some project components, such as recalibrating the flowmeter and replacing the filtration media will require maintenance on a less frequent basis. The maintenance activity column denotes the type of maintenance action that is anticipated when the associated inspection indicates that maintenance of that component is needed.

Table 4-2 Inspection and maintenance activities for a rapid filtration system

Inspection Activity	Recommended Inspection Frequency	Maintenance Activity
1. Visual inspection of fish/debris screen for clogging	Daily to weekly inspection depending on lake turbidity conditions. Necessary frequency may vary seasonally.	Clean the fish screen of debris

Inspection Activity	Recommended Inspection Frequency	Maintenance Activity
2. Pretreatment filter clogging—Visually inspect by observing water level in pretreatment cells or observing amount of flow through the overflow discharge	Daily to weekly visual inspection depending on lake turbidity conditions. Necessary frequency may vary seasonally.	Backwash as needed
3. Visual inspection for trash and debris in filtration vault and basin, structures, inlet pipes, and surrounding area	Weekly or following large or intense storm events	Conduct site cleanup and/or trash removal as needed
4. Visual inspection of pump station, including functionality of floats and presence of floating debris	At least once every two weeks (conduct during backwash process)	Conduct maintenance as needed
5. Visual inspection of meter manhole, including meter functionality and excessive joint leakage	At least once every two weeks (conduct during backwash process)	Conduct maintenance as needed.
6. Recalibration of magnetic flowmeter	Recalibrate every 3–5 years.	Conduct maintenance as needed.
7. Visual inspection of aeration manhole	At least once every two weeks (conduct during backwash process)	Conduct maintenance as needed.
8. Inspection of structural components of all troughs	At least once every two weeks (conduct during backwash process)	Conduct maintenance as needed.
9. Inspection of media condition and/or clogging in filtration basin	At least once every two weeks (conduct during backwash process)	Notify maintenance staff if there is reduced filtration capacity of the filter media following backwashing; Jet draintile when clogged conditions exist. Till media if surface compacted.
10. Inspect landscaping conditions (e.g., presence of weeds, health of plants and shrubs, depth of mulch).	At least once a month	Conduct maintenance as needed.
11. In-depth inspection of pump stations and electrical control panel	Annually inspect pump stations and controls for degradation or damage (i.e., cables, ventilation, impellers, insulation, lifting device, water level floats)	Conduct maintenance as needed.
12. Replacement of filtration basin media	Estimated every 2–3 years	Remove filtration basin media and install new media.

4.3.3 Cost-Benefit Analysis

Water quality modeling was completed for the rapid filtration BMP during the *Lake Holiday, Wing Lake, and Lake Rose Water Quality Study* to estimate phosphorus removal (Barr Engineering Co., 2022). Further design in this study did not change the expected treatment capacity of the BMP and did not warrant changes to the original water quality modeling completed in 2022. Assuming a treatment flow rate of 300 gpm for 12 hours/day, the estimated annual removal is 13 pounds of total phosphorus from waters in Lake Holiday.

A planning-level estimate of probable costs was developed for the rapid filtration BMP. Table 4-3 summarizes the estimated construction, engineering/design, and operations and maintenance costs for the project based on 2023 values. The opinion of cost is intended to aid in evaluating and comparing alternatives and should not be assumed as an absolute value. The Association for the Advancement of Cost Engineering (AACE) Class 4 opinion of cost was used based on the partial project definition, use of parametric models to calculate estimated costs (i.e., making use of order-of-magnitude costs from similar projects), and uncertainty, with an acceptable range of between -20% and +30% of the estimated project cost. A detailed opinion of probable cost for the Lake Holiday rapid filtration BMP is included in Appendix A.

Table 4-3 Planning-level cost estimates for rapid filtration BMP

Project	Construction Cost Estimate	Engineering/ Design Cost Estimate	Total Capital Cost Estimate (-20% – +30%)	Annual Operations and Maintenance Cost Estimate	Every ~3 years Operations and Maintenance Cost Estimate
Rapid Filtration BMP	$935,000	$320,000	$1.25 million ($1.0–$1.6 million)	$22,000	$55,000

Assuming the costs presented in Table 4-3, a 30-year project lifespan, and an annual total phosphorus removal of 13 pounds, the annualized cost-benefit for the project is approximately $8,000 per pound of TP removed.

4.3.4 Permitting

A sanitary sewer extension permit from the Minnesota Pollution Control Agency (MPCA) could potentially be required for this project due to the additional flow volume and increased pollutants entering the existing collection system. The MPCA recommends submitting an environmental review pre-screening form and scheduling a pre-application meeting to discuss project details. Additional information about the sanitary sewer extension permit is available on the MPCA Wastewater permit forms webpage.

MCES fees for municipal wastewater treatment in 2023 were $3,210.79 per million gallons of water (Rates/Charges - Metropolitan Council (metrocouncil.org)). Assuming the pretreatment vault requires weekly backwashing at 10 minutes per cell, this results in an estimated additional 775,000 gallons of influent into the City of Minnetonka's existing sanitary system on an annual basis – resulting in an estimated $2,500 in additional MCES wastewater treatment fees per year. These fees are included in the annual O&M cost estimate shown in Table 4-3. Fees for treatment of the rapid filtration BMP backwash water would likely vary from year-to-year given fluctuations in MCES rates and variability in the actual frequency of backwash needed.

5 Lake Holiday In-Lake Treatments

5.1 Sediment Treatment and Aeration

The 2022 water quality study identified that a significant portion of the phosphorus in Lake Holiday originates from internal loading, which is a term used for phosphorus release from lake sediments. Phosphorus in lake bottom sediments is often bound to a range of different elements such as iron and manganese, aluminum, or calcium. It is the iron- and manganese-bound phosphorus (herein just identified as iron-bound phosphorus) fraction that releases from sediment during low oxygen conditions. Phosphorus can also be found incorporated into organic matter (organically bound phosphorus). Organically bound phosphorus also releases phosphorus from lake sediment but typically at a slower rate than iron-bound phosphorus; the rate of release is controlled by lake water temperature.

Analysis of sediment cores collected from Lake Holiday as part of the 2022 water quality study indicated that organically bound phosphorus is the primary source of internal loading in Lake Holiday. The prevalence of organically bound phosphorus presents a management challenge because traditional aluminum sediment treatments (e.g., alum treatments) target the iron-bound phosphorus and cannot directly bind phosphorus that is incorporated into organic matter. Over time organic phosphorus will decay and can be converted into a form that can bind with aluminum. However, aluminum ages and loses its binding capacity over time. Given the predominance of organically-bound phosphorus in Lake Holiday sediments, a combined aluminum and iron treatment of lake bottom sediments is recommended. This non-traditional approach of combining aluminum and iron as one treatment is somewhat experimental. Iron will capture (i.e., bind) phosphorus released from decaying organic matter. Iron should be available to bind and immobilize phosphorus if oxygen levels remain high in the lake. However, if oxygen concentrations in the lake are low, the bond between the iron and phosphorus can be broken, and the phosphorus re-released into the water column. To keep the phosphorus bound to the iron, aeration of Lake Holiday is also recommended (see Section 5.1.4).

Iron dosing is based on the concentration of organic phosphorus in the top four centimeters of lake bottom sediment. Previous data that Barr has collected suggests that a 40-to-1 ratio of iron to organic phosphorus on a mass basis will capture phosphorus released from organic matter. Iron will be added as liquid ferric chloride, which is an acid. To buffer the ferric chloride, aluminum, in the form of sodium aluminate (a base), will be added to maintain pH within the range of 6.5 to 8. Aluminum will also bind with available phosphorus in the water column and lake sediments during treatment and for a few years after treatment completion.

5.1.1 Laboratory Study with Aluminum and Iron Application

A series of jar tests were conducted to determine how much sodium aluminate should be added with the ferric chloride to maintain a pH between 6.5 and 8 and minimize the residual aluminum and iron in the water column, using a range of sodium aluminate doses and a fixed ferric chloride dose. Table 5-1 shows jar testing results with Lake Holiday water for pH, and Table 5-2 shows residual iron, aluminum, and turbidity results. Figure 5-1 shows an image of iron and aluminum floc in the jar tests. This type of floc is expected to settle to the bottom of Lake Holiday. It should be noted that the floc is expected to mix very rapidly into the sediment and will not be visible a few months after treatment.

At a mass ratio of 0.71 aluminum to iron, residual iron and aluminum will be low (0.34 mg/L for iron and 0.36 mg/L for aluminum) in the lake water column treatment, and lake pH is expected to range from 6.5 to 7. Dosing for aluminum was based on achieving an aluminum-to-iron ratio of 0.71 while applying iron at 77 g per square meter of lake surface area.

Table 5-1 Effect of aluminum (as sodium aluminate) and iron (as ferric chloride) dosing ratios on pH for jar tests conducted with Lake Holiday water

	Al/Fe Mass-Based Dosing Ratio									
	0.36		0.71		1.43		2.86		5.71	
	-----pH-----									
Lake	**Initial**	**24 Hours**	**Initial**	**24 Hours**	**Initial**	**24 Hours**	**Initial**	**24 Hours**	**Initial**	**24 Hours**
Holiday	5.9	6.5	6.5	7.0	8.8	8.8	9.7	9.8	10.5	11.0

Table 5-2 Residual iron, aluminum, and turbidity after 24 hours settling in jar tests with Lake Holiday water

	Al/Fe Mass-Based Dosing Ratio														
	0.36			0.71			1.43			2.86			5.71		
	----------------Residual Iron, Aluminum, and Turbidity in Jars-----------------														
Lake	**Fe**	**Al**	**Turb**	**Fe**	**Al**	**Turb**	**Fe**	**Al**	**Turb**	**Fe**	**Al**	**Turb**	**Fe**	**Al**	**Turb**
Holiday	0.85	0.44	0.8	0.34	0.36	0.8	0.36	6.0	0.8	0.26	58	0.8	0.42	130	0.8

(1) Units for aluminum and iron were mg/L, and for turbidity NTU.

Figure 5-1 **Picture of aluminum and iron floc in jar tests with Lake Holiday water treated with ferric chloride and sodium aluminate**.
(Note that the recommended dosing is the second jar from the left. The far-right jar is untreated Lake Holiday water.)

5.1.2 Iron and Aluminum Application Plan

The iron and aluminum application specifications in Table 5-3 are based on an aluminum-to-iron ratio of 0.71 while applying iron at 77 g per square meter of lake surface area (pH range 6.5 to 8.0). The total gallons of liquid ferric chloride and liquid sodium aluminate identified in Table 5-3 assume that liquid ferric chloride is 40 percent by weight (e.g., w/w) and liquid sodium aluminate is approximately 32 percent Na2Al2O4 by weight (e.g., w/w).

Iron and aluminum applications can be conducted either in the spring, summer, or fall, but for Lake Holiday, a fall (September through October) 2024 treatment is recommended after curly-leaf pondweed has died off (curly-leaf pondweed could disturb the even settling of aluminum and iron floc on the lake bottom). Also, the lake water level should not be too low, preventing treatment of the desired surface area. A potential location for contractor access to the site is shown in Figure 5-2.

Since the application of iron and aeration is new to the NMCWD, more comprehensive monitoring and assessment are recommended. The recommended monitoring program following the aluminum and iron application is summarized in Table 5-4. Follow-up sediment coring is recommended at 2 years, 5 years, and 10 years after treatment to assess the formation of iron-phosphate (Fe-P) and aluminum phosphate (Al-P). The results of follow-up water quality monitoring and sediment coring will be used to determine if another iron-aluminum treatment will be needed to bind remaining or accumulated phosphorus post-treatment. A comprehensive review of monitoring results is recommended at years 5 and 10 to evaluate the potential need for retreatment.

Table 5-3 Ferric chloride and sodium aluminate dosing and application plan for Lake Holiday.

Dosing and Application Plan	
Phosphorus Fraction within Lake Sediments (g m^{-2} cm^{-1})	
Organic Phosphorus	0.47
Iron-Bound Phosphorus	0.07
Iron and Aluminum Dosing	
Targeted pH	6.5–8.0
Iron Mass to Immobilize Organic P (g Fe m^{-2} 1 cm sediment depth)	15.3
Estimated Active Layer (cm) for Iron	4
Total Iron Dose (g Fe m^{-2})-25% Safety Factor Applied	77
Aluminum ($NaAl(OH)_4$) Mass for Buffering (g Al m^{-2} 1 cm sediment depth) and P Binding	10.9
Estimated Active Layer (cm) for Aluminum	4
Total Al Dose (g Al m^{-2})-25% Safety Factor Applied	54
Ferric Chloride and Sodium Aluminate Treatment Volumes	
Lake Area (ac)	8.8
Treatment Area (ac)	7.0
Total Mass Iron Applied (kg)	2,168
Total Mass Aluminum Applied (kg)	1,539
Iron Composition (kg Fe/gallon)	0.70
Sodium Aluminate Composition (kg Al/gallon)	0.59
Total Ferric Chloride (40% FeCl by weight) (gallons)	3,090
Final Sodium Aluminate Dose (gallons)	2,596

Table 5-4 Sediment treatment monitoring plan for Lake Holiday.

Activity By Year	Activity Details
Pre-treatment: Porewater sampling	Collect sediment porewater monthly, from May through August, to quantify internal load before treatment.
Year 1: Apply ferric chloride and sodium aluminate	Application in the fall of 2024
Year 2: Sediment coring and porewater sampling	Collect 5 sediment cores and analyze for phosphorus fractions, iron, and aluminum. Collect sediment porewater monthly, from May through August, to quantify internal load after treatment.
Year 2: Lake water monitoring	Parameters (1-meter composite): TP, TDP, SRP, TAl, TFe, Secchi Disk, Chl a
Year 4: Sediment coring	Collect 5 sediment cores and analyze for phosphorus fractions, iron, and aluminum
Year 4: Lake water monitoring	Parameters (1-meter composite): TP, TDP, SRP, TAl, TFe, Secchi Disk, Chl a
Year 5: Assess the need for additional treatment and monitoring	
Year 10: Sediment coring	Collect 5 sediment cores and analyze for phosphorus fractions, iron, and aluminum
Year 5–10: Lake water monitoring	Determine monitoring schedule based on Year 5 Data Assessment
Year 10: Assess the need for additional treatment	

LAKE HOLIDAY
POTENTIAL TREATMENT
AREA ACCESS

FIGURE 5-2

Barr Footer: ArcGIS 10.8.1, 2023-04-18 14:26 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\23271959_HWR Feasibility Study\Maps\Report\Figure 1 - Lake Holiday Access.mxd User: EMA

5.1.3 Sediment Treatment Permitting / Regulatory Considerations

There is no formal permitting program for the iron and aluminum treatments (Minnesota Pollution Control Agency, n.d.) being recommended, but a request must be submitted to the MPCA. Barr has historically made this request in a letter that includes a narrative describing the basis of the treatment (e.g., the need for the treatment to reduce internal loading of phosphorus into a waterbody), treatment doses, plans for monitoring and oversight during treatment, and when the application is planned.

5.1.4 Aeration Design

Installation of a forced-air aeration system is recommended for Lake Holiday to prevent low oxygen conditions (e.g., around 0–2 mg/L) that would impair the effectiveness of the iron treatment (see Figure 5-3) for dissolved oxygen concentrations recorded mid-depth in Lake Holiday). When oxygen drops below 2 mg/L in the lake water column, conditions in the lake bottom sediments are anaerobic (i.e., without oxygen), and iron is in the plus 2 form (Fe^{+2}). In this form, iron cannot bind to phosphorus. When oxygen is present, Fe^{+2} converts to Fe^{+3} (ferric iron), and phosphorus can bind to it. The purpose of adding iron to the Lake Holiday sediments is to bind iron. If there is insufficient oxygen available within the lake, this intended purpose is thwarted. Hence, the addition of an aeration system is included as part of the Lake Holiday treatment plan.

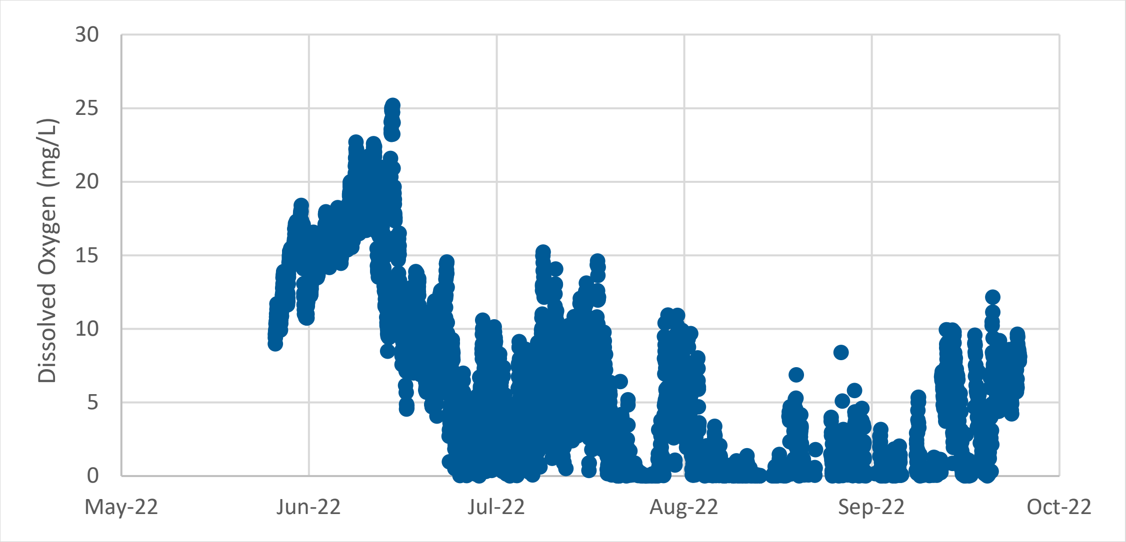


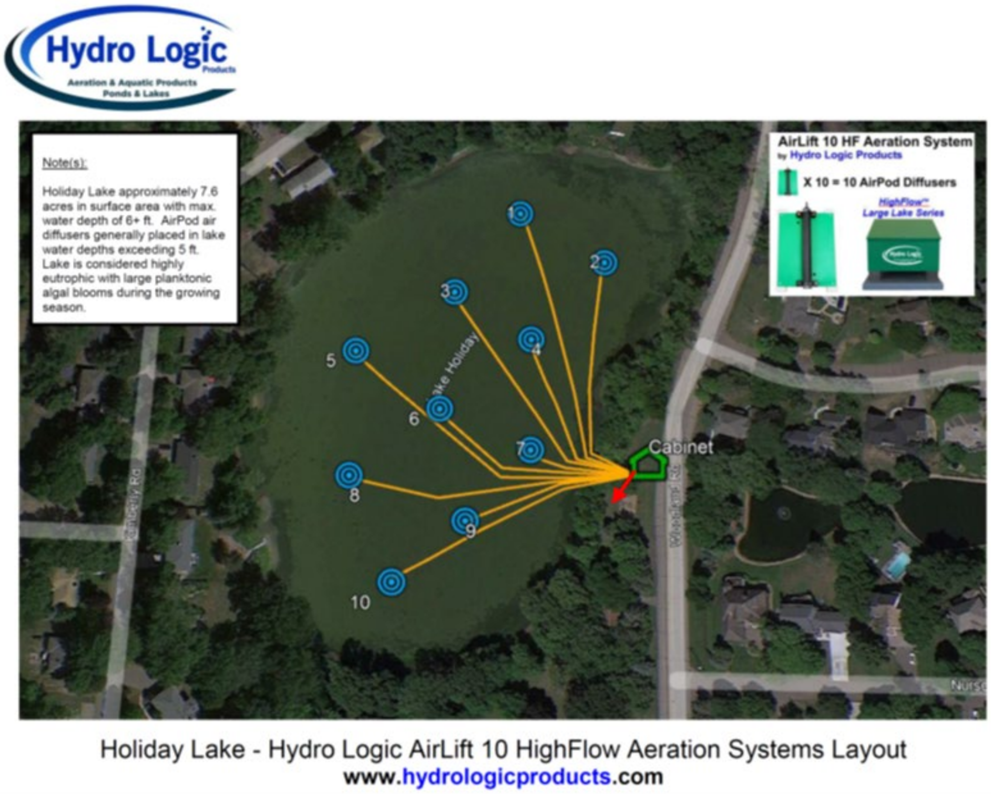
Figure 5-3 **Observed concentration of dissolved oxygen within Lake Holiday in 2022 (observations were recorded mid-depth)**

A consultancy and aeration equipment manufacturer/supplier (Hydro Logic, 2022) was contacted to assist in the preliminary design of an aeration system for Lake Holiday. The proposed layout of the aeration system is shown in Figure 5-4. Placement of a cabinet and compressor pump lakeside behind the pumphouse building is recommended (see red arrow in Figure 5-4). The aeration cabinet is designed to protect the compressors from weather and to help mitigate any noise impacts from the compressors during operation. The manufacturer specifications include an estimated sound from the compressors of 65 decibels at 2 meters from the cabinet which is equivalent to the sound of normal conversation.

Details of the aeration system are as follows:

- Hydro Logic Products AirLift 10 HighFlow aeration system (220V/single phase)
- Lockable powder-coated steel enclosure for the air pumps
- Two 1 HP dual-piston air compressors with 15 CFM capacity
- Two high-volume cooling fans
- 10 AirPod air diffusers
- Hydro Logic Products DownUnder weighted air supply tubing-5/8 inch, 4,000 feet total length

Additional specifications provided by Hydro Logic are in Appendix C.



Note(s):

Holiday Lake approximately 7.6 acres in surface area with max. water depth of 6+ ft. AirPod air diffusers generally placed in lake water depths exceeding 5 ft. Lake is considered highly eutrophic with large planktonic algal blooms during the growing season.

Figure 5-4 **Proposed layout of the aeration system at Lake Holiday**
(The red arrow shows the proposed location of the cabinet and compressor behind the existing building.)

The proposed system provides approximately 2 cubic feet of air per minute per acre of lake surface area. Advantages of the recommended system include: (1) a plate that holds the diffuser head separates the bottom sediment from the air bubbles, preventing entrainment of lake bottom sediment into the diffusers, (2) the diffuser is a cylinder and can be expanded with more forced air to unclog the diffuser membrane, (3) the diffuser head and plate are made of very durable High-Density Polyethylene (HDPE).

While there are other available aeration systems that function similarly, the stated advantages of the Hydro Logic system could reduce maintenance needs and result in greater longevity.

Associated requirements for on-park infrastructure to accommodate the aeration system include the following:

- A 5-foot-wide by 5-foot-long by 6-inch-deep concrete pad with PVC elbow installed in the pad to direct aeration hoses underground
- Six inches of class 5 aggregate base for the concrete pad
- Electrical install from the existing building (220V, single phase power)
- Approximately 350 linear feet (two runs) of 1-inch SDR 11 HDPE pipe extending from the concrete pad to splitter boxes
- Two splitter boxes (19 inches long by 14 inches wide by 12 inches high rectangular irrigation valve box) and valves to split airflow to the 10 diffuser heads

Based on dissolved oxygen measurements from Lake Holiday in 2022, Barr recommends that the system operate 24 hours a day from mid-May through mid-October. Winter operation is not currently planned, but the system could be run in the winter if desired. We also recommend that one pump delivers air to diffuser numbers 1, 2, 3, 4, and 7, and the other pump delivers air to diffusers 5, 6, 8, 9, and 10 (see Figure 5-5). The compressors can be configured to turn on or off independently, allowing aeration to be selectively delivered to one area of the lake or the other (e.g., diffusers 1, 2, 3, 4, and 7 on the north side of the lake). By using a splitter box with valves, air can be selectively delivered to a small area of the lake to keep it ice-free (open to the air) during the winter if there is interest in minimizing fish kill to promote a more balanced fishery (see Section 5.1.6, below).

Figure 5-5 Example of a splitter box located downstream of the compressor and at the water's edge

5.1.5 Aeration Permitting

Permitting of aeration systems is under the purview of the MNDNR. Completion of an online application (MPARs) is required. Additional information on the lake aeration permit program is available on the MNDNR Lake Aeration Program webpage.

5.1.6 Aeration System—Fisheries Considerations

During the May 9, 2023, project meeting with the City of Minnetonka, city staff requested more information on any potential benefits of operating the recommended aeration system year-round on the Lake Holiday fisheries community. Barr reviewed available data on fisheries within the lake to consider any potential benefits, in addition to how Lake Holiday fisheries may be impacting lake water quality. According to a fish survey conducted by Blue Water Science in September 2022 using standard trap nets, there are only four fish species in Lake Holiday: black bullheads, bluegill sunfish, fathead minnows, and stickleback minnows. Only one bluegill was caught, compared to 247 black bullheads and 895 fathead minnows. Black bullheads could be contributing to Lake Holiday turbidity; however, one study (conducted in a wetland) concluded that the effect of black bullheads on turbidity is likely not significant (Braig & Johnson, 2003). Although there is little research on the subject, it appears that bullhead removal can improve the overall fishery (Sikora, Vandehey, Sasas, Matzke, & Preul, 2021). Fathead minnows reportedly have a wide range of food sources, including phytoplankton, zooplankton, aquatic plants, and detritus; hence, elimination of fathead minnows may not directly improve water quality (i.e., it seems unlikely they are affecting the zooplankton population which in turn eats phytoplankton). There may not be a direct link between improving the diversity of the fish population in Lake Holiday and water quality, but winter aeration may still have a few benefits:

- Internal loading under the ice will be reduced as the sediment will be oxygenated.
- Spring phosphorus concentrations will be lower.
- Winter fish kill will be reduced or eliminated. If desired, sunfish and gamefish could be stocked to establish a gamefish population.

- If the fishery was improved, there might be a local recreational opportunity with the construction of a dock extending from Holiday Lake Park.

5.1.7 Cost-Benefit Analysis

As part of the *Lake Holiday, Wing Lake, and Lake Rose Water Quality Study* (Barr Engineering Co., 2022), water quality modeling was done to assess the effects of treating lake bottom sediment. Further design in this study did not warrant changes to the original water quality modeling completed in 2022. Water quality modeling indicates that a 70 percent reduction in internal loading will reduce phosphorus loading to Lake Holiday by approximately 10 pounds during the growing season.

Planning-level opinions of probable cost were developed for an iron (ferric chloride) and aluminum (sodium aluminate) application to lake bottom sediments and an aeration system. Table 5-4 summarizes the estimated construction, engineering/design, and operations and maintenance costs based on 2023 values. The opinions of cost are intended to aid in evaluating and comparing alternatives and are not an absolute value. The AACE Class 4 opinion of cost was used based on the partial project definition, use of parametric models to calculate estimated costs (i.e., making use of order-of-magnitude costs from similar projects), and uncertainty, with an acceptable range of between -20% and +30% of the estimated project cost. A detailed opinion of probable cost for the application of iron and aluminum and aeration system construction is in Appendix B.

Table 5-4 Planning-level cost estimates for ferric chloride and sodium aluminate treatment and aeration system installation in Holiday Lake

Project	Construction Cost Estimate	Engineering/ Design Cost Estimate	Total Capital Cost Estimate (-20% - +30%)	Annual Operations & Maintenance Cost Estimate	Annual Monitoring Cost
Lake Treatment	$72,000	$14,000	$86,000 ($69,000–$112,000)	$0	$2,600
Aeration Installation	$49,000	$18,000	$67,000 ($54,000 - $88,000)	$5,400	---

The annualized cost-benefit for Lake Holiday sediment treatment and aeration system is $2,100 per pound of phosphorus removed, assuming the costs presented in Table 5-4, a 15-year project lifespan, and 10 pounds of annual total phosphorus removal.

5.2 Curly Leaf Pondweed Management

5.2.1 Introduction

Curly-leaf pondweed is an invasive (i.e., non-native) aquatic plant commonly found in many Twin Cities metropolitan area lakes. Curly-leaf pondweed can dominate the aquatic plant community in shallow lakes by growing early in winter under the ice allowing the invasive species to crowd out native species. Additionally, the life cycle of curly-leaf pondweed negatively impacts lake water quality and ecosystem health. Because curly-leaf pondweed typically starts to die-back in late-June or early-July, large areas of a shallow lake are left with unvegetated areas for the later part of the growing season. Less submerged plants on a shallow lake bottom between July and October can result in higher turbidity within the lake due to sediment resuspension and an increased abundance of phytoplankton from reduced plant competition for nutrients. Furthermore, a healthy aquatic plant community throughout the entire growing season is important for providing (1) food for zooplankton, fish, and birds, (2) refuge for zooplankton against fish predation, and (3) spawning habitat for fish.

As a part of the *Lake Holiday, Wing Lake, & Lake Rose Water Quality Study*, Barr recommended the management of curly-leaf pondweed for Lake Holiday due to the high abundance and density throughout the lake (Barr Engineering Co., 2022). For Wing Lake and Lake Rose, a 2020 macrophyte survey indicated that the curly-leaf pondweed density and abundance were low, and the native macrophyte abundance was high. Due to the low density and extent of curly-leaf pondweed in Wing Lake and Lake Rose, the study recommended continued tracking of the invasive species growth but to hold off on treatment. Periodic surveys can help assess if conditions are changing and if management becomes necessary to protect native species.

Effective control of aquatic invasive species can require long-term management. A long-term curly-leaf pondweed management goal of reducing the presence of the invasive plant until neither curly-leaf pondweed nor turions are observed in the lake would be most protective of Lake Holiday and downstream lake ecosystems. However, this long-term management goal would require intensive treatment that may not be sustainable. As such, a more immediate goal of Lake Holiday curly-leaf pondweed management is to reduce the extent and density of the invasive plant throughout the lake such that it doesn’t significantly hinder the health of the native plant community. This is the goal that was used to inform the development of a curly-leaf pondweed treatment plan for the purposes of this study.

5.2.2 Point-Intercept Plant Survey

A Point-Intercept (PI) plant survey was completed by Endangered Resource Services LLC on behalf of NMCWD in June 2022 to assess the density and extent of curly-leaf pondweed and native plant species within Lake Holiday. Figure 5-6 summarizes the abundance of curly-leaf pondweed found at the 104 investigation sites throughout the lake. Abundance is represented by a “rake fullness” value of 1–3, where 1 represents few plants found on the rake head, 2 represents the rake head being half full, and 3 indicates that the rake was overflowing. If a species was observed within 6 feet of the boat but was not collected or uprooted with the rake, the species was given a “visual” designation. During the June 2022 PI survey, curly-leaf pondweed had a frequency of occurrence of approximately 90%, with an average rake fullness of 2.4, indicating very high density and extent of the invasive species within the lake.

The density and extent of native plant species within Lake Holiday were also recorded during the PI survey. Figure 5-7 summarizes the number of native species (native species richness) found at each sample point in June 2022. The highest abundance of native species was found just off the shoreline of the lake in the shallow nearshore region. A maximum of 6 different native species was found in only two of the sample locations. Over 50% of the sample locations observed 0 or 1 native plant species.

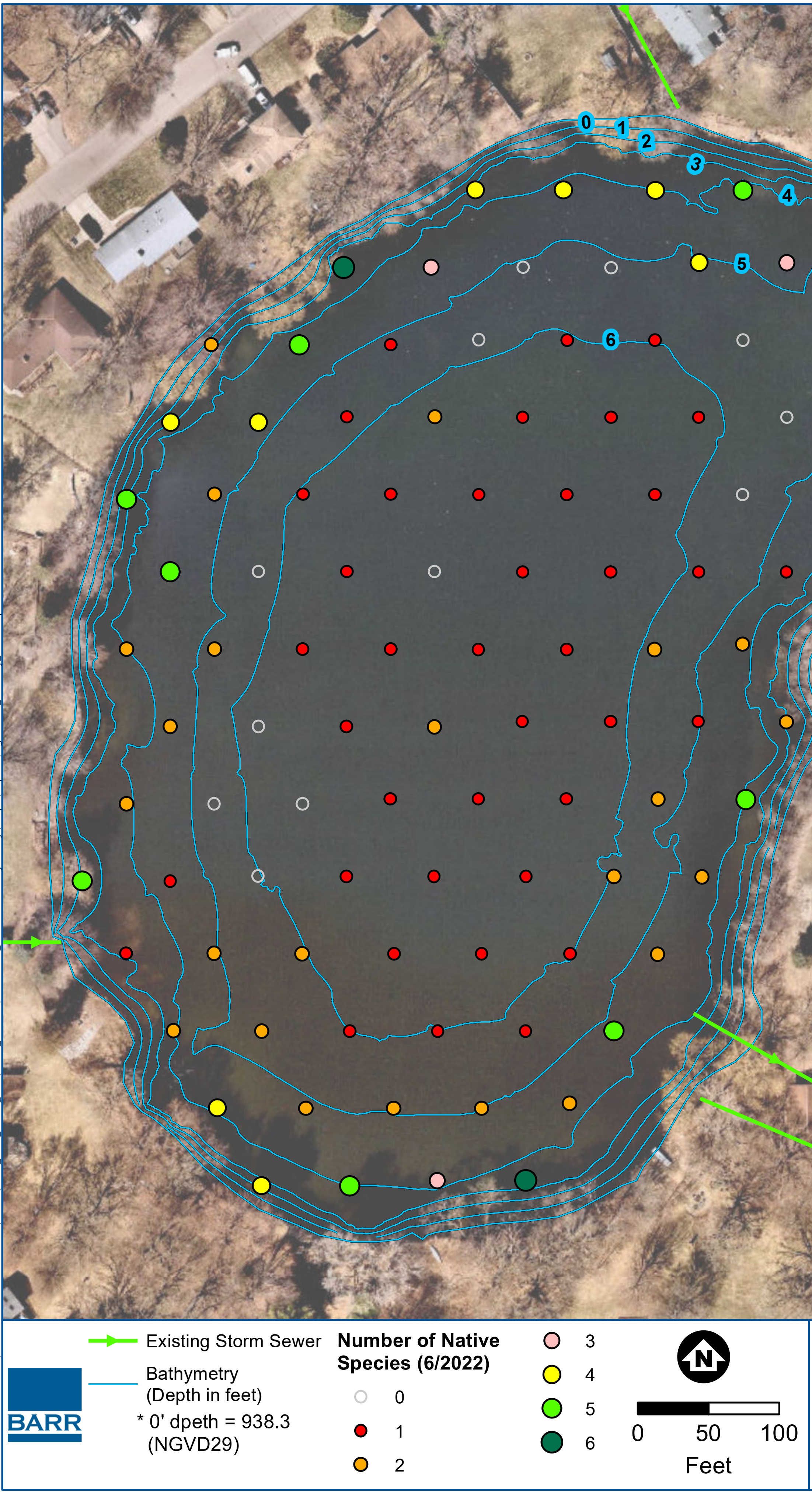
A summary of each plant species found during the June 2022 PI survey and the percent occurrence is summarized in Table 5-5.

Table 5-5 Lake Holiday submerged, emergent, and floating plant species—June 2022 point-intercept survey

Plant Taxa	Common Name	% Occurrence June 2022
All Taxa (Combined)		100
Submerged Taxa		
Potamogeton crispus	Curly-leaf pondweed	90
Potamogeton pusillus	Small pondweed	69
Elodea canadensis	Common waterweed	52
-	Filamentous algae	8
Stuckenia pectinata	Sago pondweed	5
Potamogeton zosteriformis	Flat-stem pondweed	Visual Only
Floating/Emergent Taxa		
Lemna minor	Small duckweed	26
Spirodela polyrhiza	Large duckweed	25
Wolffia columbiana	Common watermeal	20
Phalaris arundinacea	Reed Canary Grass	Visual Only

LAKE HOLIDAY
CURLY-LEAF PONDWEED (CLP)
JUNE 2022
POINT-INTERCEPT SURVEY

FIGURE 5-6



LAKE HOLIDAY
NATIVE SPECIES RICHNESS
JUNE 2022
POINT-INTERCEPT SURVEY

FIGURE 5-7

5.2.3 Management—Herbicide Treatments

Herbicide treatments are an effective method to control the extent and density of curly-leaf pondweed. In general, herbicides targeted for curly-leaf pondweed control are applied early in the season when curly-leaf pondweed is starting to emerge, and native species have minimally started to grow. This approach limits the exposure of native species to the herbicide. There are multiple herbicides available for curly-leaf pondweed control, and selection depends on several factors, including the surveyed extent and density of curly-leaf pondweed, lake bathymetry, lake size, and native plant species.

As a part of this feasibility study, Barr met with representatives from the MNDNR and a local invasive plant management contractor to discuss options for curly-leaf pondweed control. Based on these discussions and the extent and density of curly-leaf pondweed in Lake Holiday, the following herbicide management strategy is recommended:

Treat 50% of Lake Holiday with 6.1 µg/L of the herbicide Galleon. The first application would be just after ice-off conditions. The anticipated application zone is shown in

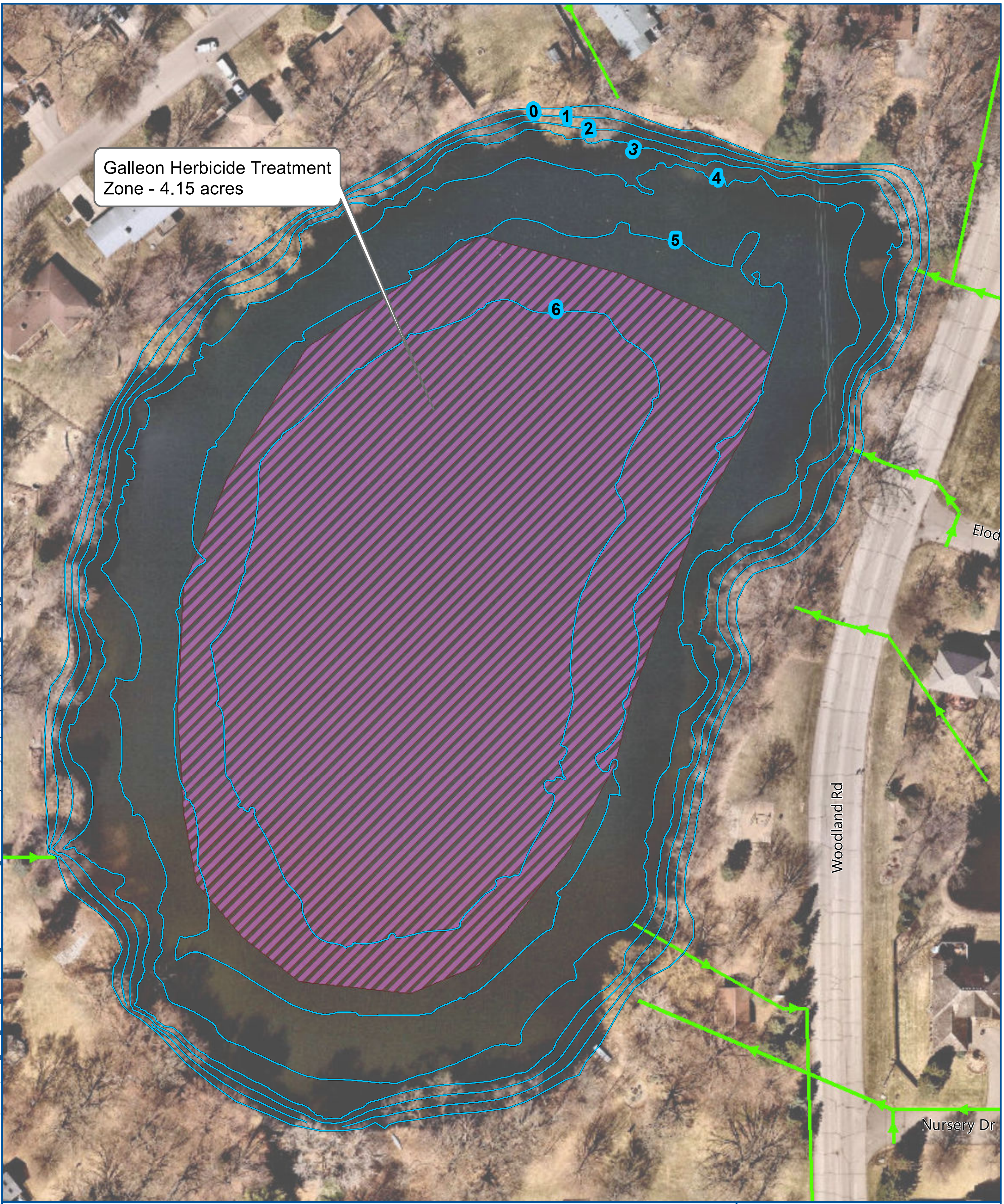
Figure 5-8.

- A spring 2024 or 2025 herbicide treatment is recommended, depending on permitting (see Section 5.2.4).
- After 14 days of exposure, measure in-lake concentrations of Galleon to determine if a second application is needed to increase concentrations above the toxicity threshold (“bump” application).
- Use this herbicide treatment approach for the first three years and modify it as necessary based on annual plant surveys.
- Following three years of treatment, assess native plant re-establishment success and discuss adjustments needed for management and restoration.

Galleon is a newer systemic herbicide that is typically used for larger-scale aquatic plant management. The low concentration needed for invasive species control, as well as its toxic specificity (i.e., reduced impacts on native plant species), make this herbicide a good option for management. Local invasive plant management contractors have stated that Galleon has been used on recent projects to control hydrilla, Eurasian watermilfoil, and curly-leaf pondweed. Lake Holiday native plant species that may have temporary impacts due to Galleon toxicity include sago pondweed, small duckweed, and common watermeal. The application zone shown in

Figure 5-8 avoids locations with these native species.

Historically, the contact herbicide Endothall has been used for larger-scale plant management efforts. In 2022 and 2023, the cost of Endothall significantly increased, making the herbicide a less cost-effective option for whole-lake treatments, especially since a higher concentration is needed for effective management. The MNDNR notes a typical target concentration for Endothall between 0.75–5.0 mg/L (depending on lake conditions) (MnDNR, 2020).



→ Existing Storm Sewer

— Bathymetry (Depth in feet)
* 0' dpeth = 938.3 (NGVD29)

▨ Galleon Treatment Zone

N

0 50 100
Feet

BARR

LAKE HOLIDAY
GALLEON HERBICIDE
TREATMENT ZONE

FIGURE 5-8

5.2.4 Permitting

Using the Galleon herbicide management strategy described above would not require a variance from the MNDNR nor the development of a Lake Vegetation Management Plan (LVMP). For lakes less than 20 acres, the MNDNR allows treatment of up to 50% of the littoral area without a variance.

The Galleon herbicide management strategy would require an Invasive Aquatic Plant Management Permit from the MNDNR. The permit requires the completion of a pretreatment vegetation survey and may require follow-up monitoring depending on the terms of the permit. To apply Galleon closely following ice-off conditions, the MNDNR will need to approve a pretreatment vegetation survey from the year prior or earlier if approved by MNDNR.

5.2.5 Cost Estimate

The planning-level opinion of probable cost for three years of curly-leaf pondweed herbicide treatments in Lake Holiday is approximately \$48,000 - \$63,000 (-10% to +20%). This estimate includes the preparation of contract documents, permitting, and herbicide application. The cost estimate also includes potential costs related to monitoring that may be required by the MNDNR as a permit condition, including aquatic plant monitoring. A detailed opinion of probable cost of the curly-leaf pondweed herbicide treatment is included in Appendix A.

5.2.6 Lake Drawdown Considerations

5.2.6.1 Lake Drawdown to Manage Curly-Leaf Pondweed

Another potential method to control curly-leaf pondweed is to draw down a lake to allow the lakebed to freeze over the winter. Curly-leaf pondweed primarily propagates through the production of dormant vegetative propagules called turions. Turions are produced in late spring, remain dormant in sediment through the summer, and germinate under cooler water conditions in the fall. A winter freeze can reduce the viability of turions, thus disrupting curly-leaf pondweed’s reproductive cycle.

While winter drawdowns have generally been effective in controlling curly-leaf pondweed growth in other NMCWD lakes (e.g., Normandale Lake, Northwest and Southwest Anderson Lakes), factors hindering the feasibility of this approach for Lake Holiday include:

- For winter drawdown practices, the MNDNR requires that the initial drawdown of the lake is completed by early to mid-October to encourage turtles to find new overwintering waterbodies. With a tributary watershed of 286 acres (watershed to lake area ratio of 35:1), maintaining drawn-down conditions during fall or winter precipitation may be difficult and costly.
- A drawdown initiated in late summer may result in negative impacts on downstream water quality in Wing Lake. Based on September monitoring data collected within the last decade by the NMCWD and the City of Minnetonka, the total phosphorus concentrations in Lake Holiday have been 26%–69% higher than Wing Lake (the downstream receiving water). Additionally, in the most recent monitoring years, Lake Holiday has experienced notable cyanobacteria blooms in late summer and early fall.

- There are limited nearby waterbodies with depths sufficient to support turtle overwintering.
- While Lake Holiday's water surface elevation is currently managed by pumps, at a minimum, a pipe extension would need to be installed to the center of the lake for a full lake drawdown (assuming the existing pumps can manage the head requirements). If the existing pumps cannot be used for a full lake drawdown, auxiliary pumps would need to be considered, which may be costly to set up and maintain.
- Written approval from over 75% of the shoreline property owners would be required.

Given the preliminary concerns regarding the feasibility of a Lake Holiday drawdown, management of curly-leaf pondweed with herbicide treatments is the recommended approach at this time.

5.2.7 Re-establishment of Native Plant Growth

The re-establishment of the native plant community in Lake Holiday will be an important part of achieving and maintaining improved water quality and healthy aquatic habitat. Implementation of in-lake management practices such as a sediment alum treatment or curly-leaf pondweed control typically results in the natural resurgence of submerged native plants by increasing water clarity and reducing aquatic invasive species' competition. However, if the implementation of the recommended in-lake management practices does not result in an increase in the extent and/or the number of native plant species, the NMCWD should consider other options to promote native plant species growth.

One option is to perform a partial or full lake drawdown for a few months in the fall to allow for sediment compaction and to stimulate dormant native seeds in the sediment bed. The MNDNR has had notable success with using fall drawdown to encourage native plant growth. However, as discussed above, several factors may limit the use of this technique in Lake Holiday. Another option to consider includes transplanting native plants from nearby reference lakes.

6 Wing Lake In-Lake Treatments

6.1 Aluminum and Iron Treatments

Similar to the other lakes within this study, internal loading from lake bottom sediments is a significant portion of the phosphorus in Wing Lake. Phosphorus released from the Wing Lake bottom sediments primarily comes from organic matter contained within the bottom sediments. This presents a similar challenge to what was described for Lake Holiday in that aluminum (e.g., alum treatments) cannot directly bind phosphorus that is incorporated into the organic matter. The recommended treatment of lake bottom sediments within Wing Lake includes both aluminum and iron. Iron will serve to capture phosphorus (e.g., bind it) once it is released from decaying organic matter. The use of iron in Wing Lake is somewhat different from Lake Holiday in that iron will be used to capture phosphorus and temporarily form iron-phosphate. It is anticipated that approximately 5 to 10 years after treatment, an aluminum treatment will be needed to convert iron-phosphate to aluminum-phosphate and more permanently immobilize phosphorus in the bottom sediment.

Iron dosing is based on the concentration of organic matter in the top four centimeters of lake bottom sediment. Previous studies of sediment phosphorus and iron suggest that a 40-to-1 ratio of iron to organic phosphorus on a mass basis will be able to capture phosphorus released from organic matter. Iron will be added as liquid ferric chloride, which is an acid, and hence aluminum, in the form of sodium aluminate, which is a base, is added to maintain pH in the range of 6.5 to 8. Aluminum will also serve to bind available phosphorus in the water column and in sediment during treatment and for a few years after treatment. Note that because aeration will not be applied in Wing Lake, it is possible that some iron will be lost from the system (e.g., iron depletion in the lake bottom sediments) as a consequence of periodic low oxygen in the lake water column, dissolution of iron into the water column, and flushing downstream. Follow-up monitoring (sediment coring) is recommended to understand to what degree iron is being lost from sediments and if additional iron treatments will be needed.

6.1.1 Laboratory Study with Aluminum and Iron

Similar to the Lake Holiday laboratory investigation, a series of jar tests were conducted with a range of aluminum doses and a fixed ferric chloride dose to determine how much sodium aluminate should be added with ferric chloride to maintain pH between 6.5 and 8 as well as minimize residual aluminum and iron in the water column. Table 6-1 shows jar testing results with water from Wing Lake for pH, and Table 6-2 shows results for residual iron, aluminum, and turbidity. Figure 6-1 shows an image of iron and aluminum floc in jar tests. This type of floc is expected to settle to the bottom of Wing Lake. It should be noted that the floc will mix in with the sediment and not be visible a few months after treatment.

The main purpose of the multiple jar tests was to understand how different ratios of aluminum and iron affect pH and residual iron and aluminum following treatment. The jar tests indicate that for a mass ratio of aluminum to iron ranging from 0.46 to 0.91, the pH will be within the target range of 6.5 to 8. An aluminum-to-iron dosing ratio of 0.71, the preferred ratio from the Lake Holiday jar tests, was also chosen for Wing Lake because (1) pH will be in an acceptable, near-neutral range, (2) residual aluminum and iron concentrations will be minimized, (3) an appropriate amount of aluminum will be added to the sediments to prevent internal phosphorus loading, and (4) consistent dosing ratios (e.g., gallons of sodium aluminate to gallons of ferric chloride) for Holiday and Wing Lake will reduce the potential for contractor error.

Table 6-1 Effect of aluminum (as sodium aluminate) and iron (as ferric chloride) dosing ratios on pH for jar tests conducted with water from Wing Lake

Lake	Al/Fe Mass-Based Dosing Ratio									
	0.46		0.91		1.83		3.66		7.31	
	-----pH-----									
	Initial	24 Hours	Initial	24 Hours	Initial	24 Hours	Initial	24 Hours	Initial	24 Hours
Wing	6.8	7.7	7.1	7.9	9.0	9.0	9.5	9.5	10.2	10.2

Table 6-2 Residual iron, aluminum, and turbidity after 24 hours of settling in jar tests with water from Wing Lake

Lake	Al/Fe Mass-Based Dosing Ratio														
	0.46			0.91			1.83			3.66			7.31		
	----------------Residual Iron, Aluminum, and Turbidity in Jars-----------------														
	Fe	Al	Turb	Fe	Al	Turb	Fe	Al	Turb	Fe	Al	Turb	Fe	Al	Turb
Wing	1.5	0.48	1.1	0.8	1.1	1.1	0.9	11	2.3	2.8	40	6.8	0.2	67	4.7

*Units for iron (Fe) and aluminum (Al) is mg/L, and for turbidity (Turb) is NTU.

Figure 6-1 **Picture of aluminum and iron floc in jar tests with water from Wing Lake treated with ferric chloride and sodium aluminate.**
(Note that the recommended dosing will be between the second and third jar from the left. The far-left jar is untreated water from Wing Lake.)

6.1.2 Iron and Aluminum Application Plan

The recommended treatments and doses for the Wing Lake sediment treatments are identified in Table 6-3. It can be seen in Table 6-3 that the recommended total iron dose of 47 grams of iron per square meter of lake surface area for Wing Lake is lower than that for Lake Holiday. This is the result of there being a lower measured concentration of organic phosphorus within the bottom sediments of Wing Lake. Using an aluminum-to-iron dosing ratio of 0.71, the aerial dosing rate for aluminum is 33 grams of aluminum per square meter of lake surface. The total gallons of liquid ferric chloride and liquid sodium aluminate identified in Table 6-3 assume that liquid ferric chloride is 40 percent by weight (e.g., w/w) and liquid sodium aluminate is approximately 32 percent $Na_2Al_2O_4$ by weight (e.g., w/w). The recommended follow-up monitoring to track the effectiveness of the aluminum and iron treatment in Wing Lake is described in Table 6-4.

An area for potential contractor access to the sediment treatment application area for Wing Lake is shown in Figure 6-2. It can be seen that there are several locations for access along Highland Road, and the best site will need to be identified in consultation with the City of Minnetonka. It should be noted that a staging location will also be necessary during treatment application to place tanks that feed the treatment barge. Identification of a location for treatment staging will be determined in consultation with the City of Minnetonka.

Table 6-3 **Ferric chloride and sodium aluminate dosing plan for Wing Lake**

Dosing Plan	
Phosphorus Fraction within Lake Sediments (g m^{-2} cm^{-1})	
Organic Phosphorus: Average Top 6 cm	0.29
Iron-Bound Phosphorus: Average Top 6 cm	0.03
Iron and Aluminum Dosing	
Targeted pH	7.0–8.0
Iron Mass to Immobilize Organic P (g Fe m^{-2} 1 cm sediment depth)	9.4
Estimated Active Layer (cm) for Iron	4
Total Iron Dose (g Fe m-2)-25% Safety Factor Applied	47
Aluminum ($NaAl(OH)_4$) Mass for Buffering (g Al m^{-2} 1 cm sediment depth) and P Binding	6.7
Estimated Active Layer (cm) for Aluminum	4
Total Al Dose (g Al m-2)-25% Safety Factor Applied	33
Ferric Chloride and Sodium Aluminate Treatment Volumes	
Lake Area (ac)	13.6
Treatment Area (ac)-2 foot contour	13.3
Total Mass Iron Applied (kg)	2,531
Total Mass Aluminum Applied (kg)	1797
Iron Composition (kg Fe/gallon)	0.70
Sodium Aluminate Composition (kg Al/gallon)	0.59
Total Ferric Chloride (40% FeCl by weight) (gallons)	3,607
Final Sodium Aluminate Dose (gallons)	3,031

Table 6-4 Sediment treatment monitoring plan for Wing Lake.

Activity By Year	Activity Details
Pre-treatment: Porewater sampling	Collect sediment porewater monthly, from May through August, to quantify internal load before treatment.
Year 1: Apply ferric chloride and sodium aluminate	Application in the spring of 2024
Year 2: Sediment coring and porewater sampling.	Collect 5 sediment cores and analyze for phosphorus fractions, iron, and aluminum. Collect sediment porewater monthly, from May through August, to quantify internal load after treatment.
Year 2: Lake water monitoring	Parameters (1-meter composite): TP, TDP, SRP, TAl, TFe, Secchi Disk, Chl a.
Year 4: Sediment coring	Collect 5 sediment cores and analyze for phosphorus fractions, iron, and aluminum
Year 4: Lake water monitoring	Parameters (1-meter composite): TP, TDP, SRP, TAl, TFe, Secchi Disk, Chl a.
Year 5: Assess the need for additional treatment	
Years 5-10: Lake water monitoring	Determine monitoring schedule based on Year 5 data assessment
Year 10: Sediment coring	Collect 5 sediment cores and analyze for phosphorus fractions, iron, and aluminum
Year 10: Assess the need for additional treatment	

WING LAKE
POTENTIAL TREATMENT
AREA ACCESS

FIGURE 6-2

Barr Footer: ArcGIS 10.8.1, 2023-04-18 15:01 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\23271959_HWR Feasibility Study\Maps\Report\Figure 1 - Wing Lake Access.mxd User: EMA

6.1.3 Permitting/Regulatory Considerations

See section 5.1.3 for permitting requirements.

6.1.4 Cost-Benefit Analysis

Water quality modeling was completed to evaluate the effects of treating lake bottom sediments and reducing internal loading as part of the *Lake Holiday, Wing Lake, and Lake Rose Water Quality Study* (Barr Engineering Co., 2022). Further design in this study did not warrant changes to the original water quality modeling completed in 2022. Water quality modeling indicates that a 50 percent reduction in internal loading will reduce phosphorus loading to Wing Lake by approximately 10 pounds during the growing season.

A planning-level opinion of probable cost was developed for an iron (ferric chloride) and aluminum (sodium aluminate) application to lake bottom sediments of Wing Lake. Table 6-4 summarizes the estimated construction, engineering/design, and operations and maintenance costs for the project based on 2023 values. The opinion of cost is intended to aid in evaluating and comparing alternatives and should not be assumed as an absolute value. The AACE Class 4 opinion of cost was used based on the partial project definition, use of parametric models to calculate estimated costs (i.e., making use of order-of-magnitude costs from similar projects), and uncertainty, with an acceptable range of between -20% and +30% of the estimated project cost. A detailed opinion of probable cost for the application of iron and aluminum is included in Appendix B.

Table 6-4 Planning-level cost estimate for ferric chloride and sodium aluminate treatment of Wing Lake

Project	Construction Cost Estimate	Engineering/ Design Cost Estimate	Total Capital Cost Estimate (-20% - +30%)	Annual Operations & Maintenance Cost Estimate	Annual Monitoring Cost
Lake Treatment	$84,000	$14,000	$98,000 ($79,000–$128,000)	$0	$2,600

The annualized cost-benefit for the project is $1,400 per pound of phosphorus removed, assuming the costs presented in Table 6-4, a 10-year project lifespan, an annual total phosphorus removal of 10 pounds, and follow-up sediment monitoring.

7 Lake Rose In-Lake Treatments

7.1 Aluminum Treatment

7.1.1 Aluminum Application Plan

The 2022 water quality study identified that internal loading is a significant source of phosphorus to Lake Rose. The recommended treatment of Lake Rose bottom sediments to reduce internal loading is an aluminum application versus an aluminum and iron treatment, as the phosphorus chemistry of Lake Rose bottom sediments is amenable to aluminum binding (e.g., iron-bound phosphorus is the predominant phosphorus fraction). Using this approach, iron-phosphate in the lake bottom sediments will be converted to aluminum phosphate with the application of alum and sodium aluminate. Since it is standard practice to apply alum and sodium aluminate with a 2:1 ratio (gallon/gallon) and Barr has had past success with this approach, a laboratory study was not necessary to prepare for this treatment. The treatment plan for Lake Rose is summarized in Table 7-1. Note that recommended monitoring is not as intensive as for Lakes Holiday and Wing, as iron is not being used in this treatment, and the expected outcome of an aluminum-only treatment is well understood.

Figure 7-1 shows a potential location where the contractor has public access for sediment treatments at Lake Rose. There is a public corridor that extends near the intersection of Randall Lane and Hathaway Lane to Rose Lake. The lake is shallow at this location; hence, the lake level at the time of treatment will likely determine whether this is a workable access location. Other potential access locations are not public and will require the consent of lake residents.

Table 7-1 Alum and sodium aluminate dosing plan for Lake Rose

Dosing Plan	
Phosphorus Fraction within Lake Sediments (g m^{-2} cm^{-1})	
Organic Phosphorus: Average Top 6 cm	0.18
Iron-Bound Phosphorus: Average Top 6 cm	0.28
Aluminum Dosing	
Targeted pH	6.5 - 8.0
Aluminum Mass (g Al m^{-2} 1 cm sediment depth) for P Binding	14
Estimated Active Layer (cm) for Aluminum	6
Total Al Dose (g Al m^{-2})	87
Alum and Sodium Aluminate Treatment Volumes	
Lake Area (ac)	29.7
Treatment Area (ac)-2 foot contour	20.2
Total Mass Aluminum Applied (kg)	7,079
Alum Composition (kg Al/gallon)	0.22
Sodium Aluminate Composition (kg Al/gallon)	0.59
Total Alum Applied (gallons)	13,701
Sodium Aluminate Applied (gallons)	6,850

Table 7-2 Sediment treatment monitoring plan for Lake Rose.

Activity By Year	Activity Details
Year 1: Apply alum and sodium aluminate	Application in the spring of 2024
Year 2: Lake water monitoring	Parameters (1-meter composite): TP, TDP, SRP, TAl, TFe, Secchi Disk, Chl a.
Year 3-10: Lake water monitoring	Conduct periodic monitoring
Year 10: Sediment coring	Collect 5 sediment cores and analyze for phosphorus fractions and aluminum.
Year 10: Assess the need for additional treatment	

LAKE ROSE
POTENTIAL TREATMENT
AREA ACCESS

FIGURE 7-1

Barr Footer: ArcGIS 10.8.1, 2023-04-18 14:39 File: I:\Client\Nine_Mile_Creek_WD\Work_Orders\23271959_HWR Feasibility Study\Maps\Report\Figure 1 - Lake Rose Access.mxd User: EMA

7.1.2 Permitting/Regulatory Considerations

See permitting requirements identified in Section 5.1.3

7.1.3 Cost-Benefit Analysis

Water quality modeling was completed to evaluate the effects of treating lake bottom sediments and reducing internal loading as part of the *Lake Holiday, Wing Lake, and Lake Rose Water Quality Study* (Barr Engineering Co., 2022). Further design in this study did not warrant changes to the original water quality modeling completed in 2022. Water quality modeling indicates that a 50 percent reduction in internal loading will reduce phosphorus loads to Lake Rose by approximately 36 pounds during the growing season.

A planning-level opinion of probable cost was developed for an alum and sodium aluminate application to lake bottom sediments. Table 7-2 summarizes the estimated construction, engineering/design, and operations and maintenance costs for the project based on 2023 values. The opinion of cost is intended to aid in evaluating and comparing alternatives and should not be assumed as an absolute value. The AACE Class 4 opinion of cost was used based on the partial project definition, use of parametric models to calculate estimated costs (i.e., making use of order-of-magnitude costs from similar projects), and uncertainty, with an acceptable range of between -20% and +30% of the estimated project cost. A detailed opinion of probable cost for the application is included in Appendix B.

Table 7-2 Preliminary engineering-level cost estimates Alum and sodium aluminate treatment of Lake Rose

Project	Construction Cost Estimate	Engineering/ Design Cost Estimate	Total Capital Cost Estimate (-20% - +30%)	Annual Operations & Maintenance Cost Estimate	Annual Monitoring Cost
Lake Treatment	$133,000	$15,000	$148,000 ($119,000–$193,000)	$0	$1,500

The annualized cost-benefit for the project is $500 per pound of phosphorus removed, assuming the costs presented in Table 7-2, a 10-year project lifespan, and an annual total phosphorus removal of 36 pounds.

8 Enhanced Street Sweeping

Enhanced or "targeted" street sweeping was identified as a management action to consider in the *Lake Holiday, Wing Lake, and Lake Rose Water Quality Study* (Barr, 2022) to help reduce external nutrient loading to the lakes. Because the Lakes Holiday, Wing, and Rose watersheds are nearly fully developed, land availability for installing structural stormwater treatment BMPs is limited. Enhanced street sweeping was identified as an alternate "source control" approach to reducing sediment and nutrients to these waterbodies. During the 2022 study, planning-level cost estimates were developed for the implementation of an enhanced street-sweeping program, but the pollutant removal from an enhanced street-sweeping program was not evaluated.

Wing Lake and Lake Rose are both included on the State of Minnesota's impaired waters list for excess nutrients. The Lower Minnesota River Watershed Total Maximum Daily Load (TMDL), completed by the MPCA in 2020, identifies a phosphorus load reduction to these lakes of 38% and 41%, respectively. As discussed at a July 6, 2023 project meeting, the City of Minnetonka has identified enhanced street sweeping as a potential practice for meeting their portion of the Lake Rose wasteload allocation (WLA) to comply with the Municipal Separate Storm Sewer System (MS4) program general permit. The TMDL (Minnesota Pollution Control Agency, 2020) identifies that 7 pounds of TP reduction per growing season is required for the Minnetonka WLA to Lake Rose.

The following subsection describes the modeling analysis used to estimate the water quality impact of existing and enhanced street sweeping operations in the Lakes Holiday, Wing, and Rose watersheds.

8.1 Existing Street Sweeping Evaluation

As noted in the 2022 water quality study, street sweeping can be an effective, non-structural BMP for reducing sediment and nutrient pollutant loading from impervious surfaces. The City of Minnetonka currently performs one city-wide street sweeping operation per year in the spring, immediately following snowmelt. To (a) evaluate the effectiveness of current street sweeping operations and (b) estimate the potential impact of "enhanced" street sweeping operations, the Barr-developed GIS-Based Water Quality Model (GISWQM; Barr, 2018) was used to calculate pollutant loading and estimate street sweeping pollutant recovery. Development of the GISWQM for the Lakes Holiday, Wing, and Rose watersheds and evaluation of existing conditions is discussed in the following subsections.

8.1.1 Model Development

As the name suggests, the GISWQM is a "GIS-based" water quality model that exists as a series of calculation modules in ESRI GIS mapping software programs, including ArcGIS and ArcGIS Pro. The model utilizes a P8-based methodology for annualized pollutant loading and utilizes Minimal Impact Design Standards (MIDS) calculator methodology to evaluate the performance of water quality BMPs.

Within the GISWQM, a street sweeping module is used to estimate street sweeping recovery from seasonal street sweeping operations prior to routing pollutants downstream. The calculator utilizes a series of regression equations (Kalinosky, Baker, & Hobbie, 2014) (Sutherland & Jelen, 1997) for calculating street sweeping pollutant recovery as a function of:

- Seasonal street sweeping frequency (i.e., the number of sweeping operations in the spring, summer, and fall),
- Curb-length swept (i.e., the total curb length of all road areas included in street sweeping operations), and
- Canopy cover (i.e., the percentage of tree canopy overhanging street areas).

Road area and curb length were digitized for each study area subwatershed utilizing the best available imagery and road centerline data. Canopy cover was estimated utilizing 2022 NearMap imagery (September 1, 2022; 12-inch resolution) and GIS processing techniques to calculate the percentage of tree canopy overhang over road surfaces within each subwatershed. Subwatershed and major watershed divides were developed using the subwatershed delineation from the 2022 water quality study. These were further subdivided by a 250- by 250-foot grid to provide a higher degree of model resolution. Figure 8-1 shows the average percent canopy cover overhang calculated within subwatersheds tributary to Lakes Holiday, Wing, and Rose.

In addition to estimating pollutant loading and street sweeping pollutant recovery, the GISWQM also estimates the impact of downstream treatment to differentiate between raw pollutant “recovery” and effective pollutant “reduction,” as described below:

- Raw pollutant “recovery” is the pollutant recovered from the street surface via street sweeping operations.
- Effective pollutant “reduction” is the pollution that is prevented from reaching a downstream waterbody (i.e., Lakes Holiday, Wing, or Rose), considering other treatment that occurs in downstream waterbodies that are accounted for within the model.

The following provides an example of the calculation of pollutant “recovery” versus pollutant “reduction” for a hypothetical subwatershed in the Lake Holiday drainage area:

- Runoff from Subwatershed A passes through two ponds prior to discharging to Lake Holiday: Pond A and Pond B. Pond A removes 60% of influent TP, and Pond B removes 40% of influent TP.
- The GISWQM estimates the annual street sweeping recovery within Subwatershed A to be 4 pounds of TP per year. I.e., pollutant “recovery” = 4 lbs TP/year.
- To account for downstream treatment, the effective pollutant “reduction” from Subwatershed A is calculated as follows:
    - “Recovery” = 4 lbs TP/year
    - “Reduction” = (4 lbs TP/year recovery) x (1 – 0.6) x (1 – 0.4) = 0.96 lbs TP/year.

As illustrated by this example, street sweeping pollutant “reduction” is always less than or equal to raw pollutant “recovery” and accounts for the effectiveness of other pollutant removal that occurs as runoff flows through downstream waterbodies prior to reaching the receiving waterbody. To calculate the cumulative impact of all BMPs within the Lakes Holiday, Wing, and Rose watersheds, the cumulative pollutant reduction from each subwatershed was evaluated utilizing the P8 water quality models for each area. Figure 8-2 shows the estimated cumulative TP reduction for each subwatershed in the Lakes Holiday, Wing, and Rose watersheds due to existing BMPs, wetlands, or ponds. In “untreated” areas, shown in Figure 8-2, street sweeping pollutant “recovery” is assumed to be equivalent to “reduction,” as there is limited or no downstream treatment prior to discharge to the lake in these areas.

The data sources described above were used to develop a GISWQM spanning the Lakes Holiday, Wing, and Rose watersheds. Annual pollutant loading, street sweeping recovery, and street sweeping reduction were evaluated for existing sweeping operations. The results of this analysis are summarized in the following section.

8.1.2 Existing Street Sweeping Performance

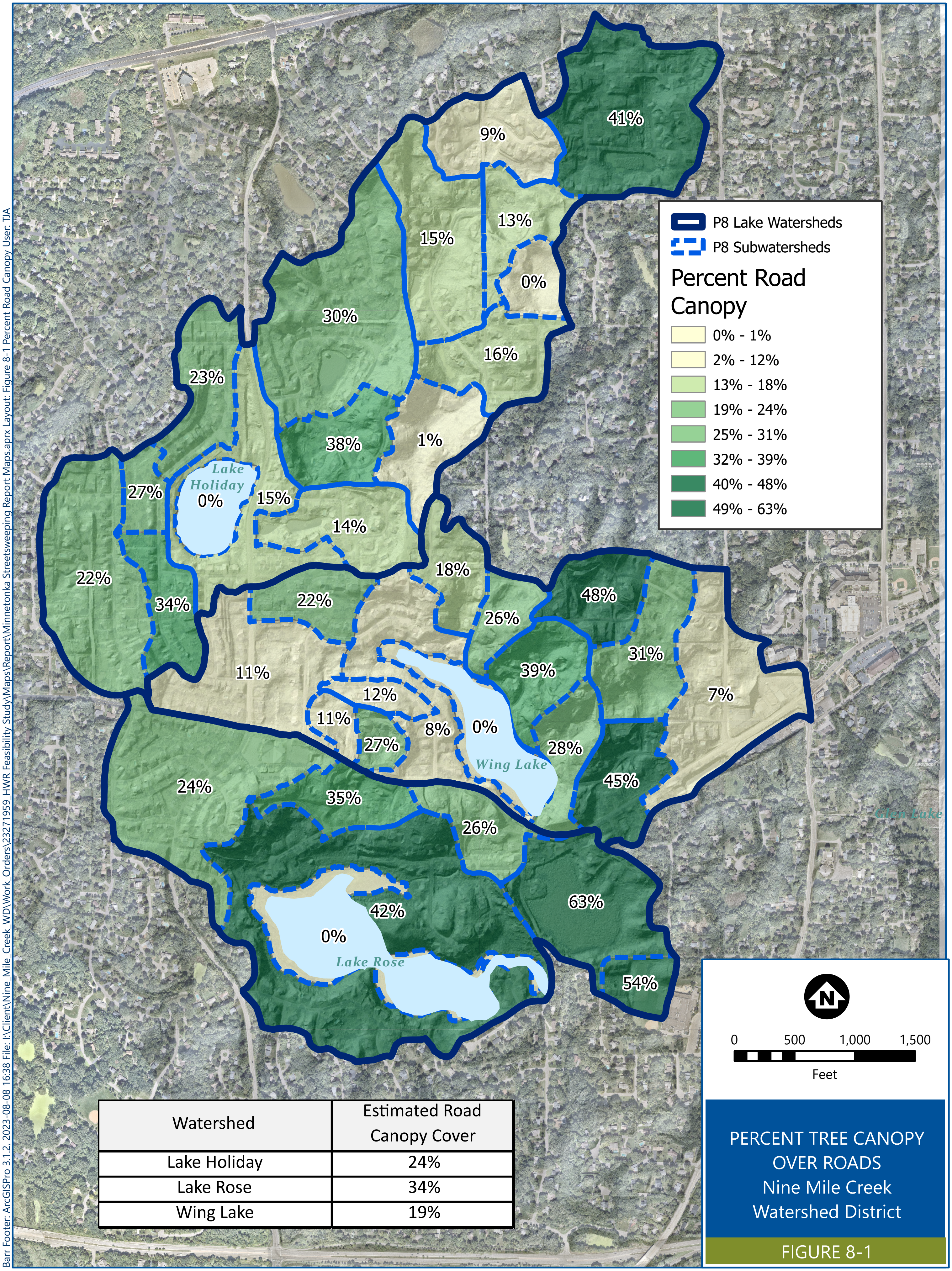
As discussed in Section 8.1, the City of Minnetonka currently performs one city-wide street sweeping operation per year in the spring, immediately following snowmelt. Existing street sweeping operations (i.e., one spring sweeping) were evaluated using the GISWQM. Table 8-1 provides estimated street sweeping “recovery” and “reduction” for this sweeping, as calculated by the GISWQM.

Table 8-1 Estimated annual phosphorus removal from street sweeping under existing conditions

		GISWQM: Street Sweeping Performance Summary			
Watershed	Annual Phosphorus Loading (lbs/yr)	Annual Phosphorus Recovery [1] (lbs/yr)	% Annual Phosphorus Recovery (%)	Effective Phosphorus Reduction [1] (lbs/yr)	% Effective Phosphorus Reduction (%)
Lake Holiday	91	3.9	4.3%	2.4	2.6%
Wing Lake	74	2.7	3.6%	1.6	2.1%
Lake Rose	56	2.6	4.6%	2.3	4.1%
TOTAL:	221	9	4.2%	6	2.8%

[1] Total phosphorus street sweeping “recovery” and “reduction” as defined in Section 8.1.1.

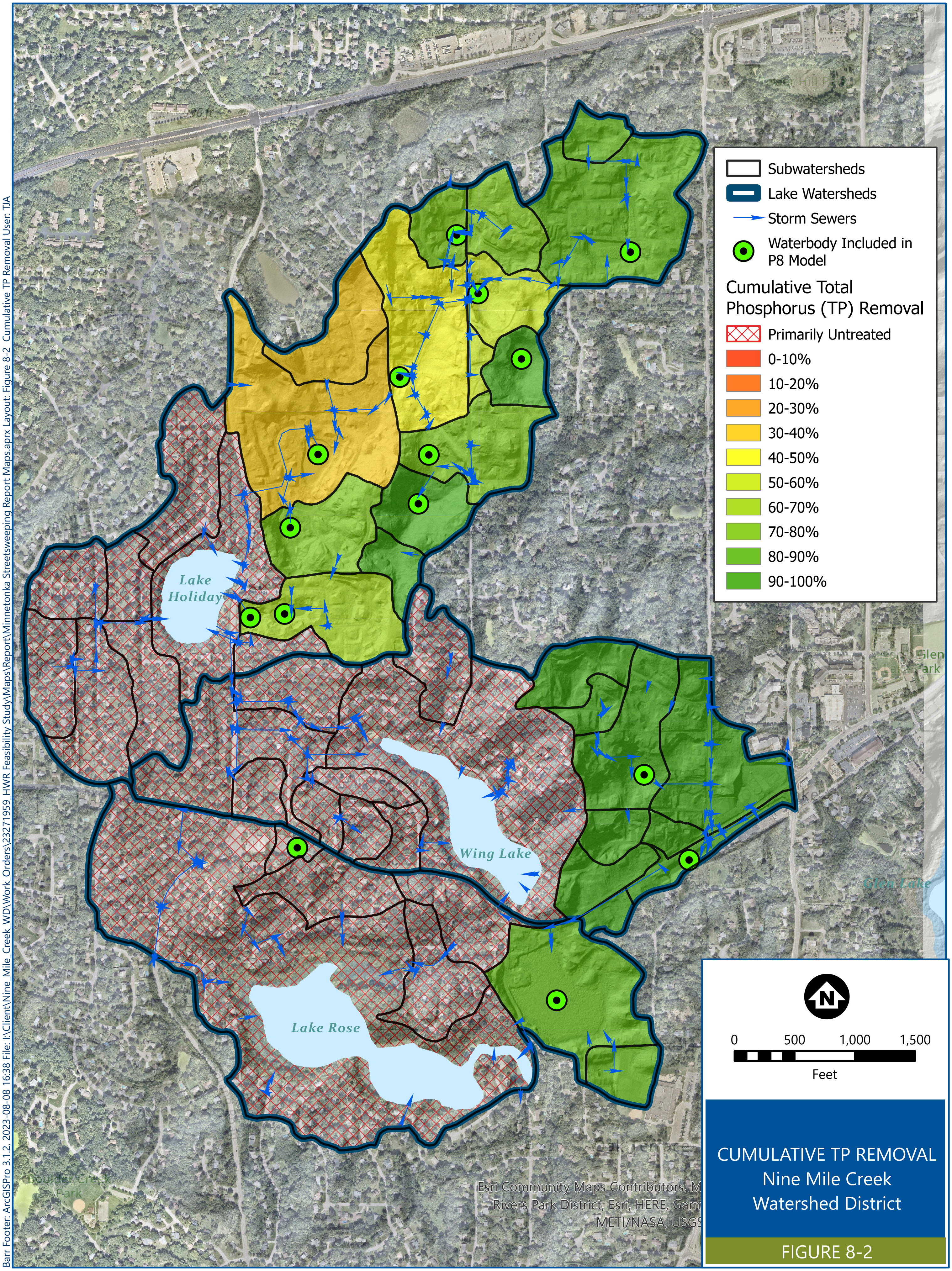
As shown in Table 8-1, under current operations, street sweeping results in approximately 3 to 5% raw TP recovery in each watershed, which equates to 2 to 4% effective TP reduction in each area. As noted in Section 8.1.1, reduction and recovery estimates shown above are estimated as a function of curb length swept, street sweeping frequency, and canopy cover (Kalinosky, Baker, & Hobbie, 2014), as well as total phosphorus removals predicted by P8 models for downstream waterbodies. To confirm these estimates, numbers shown in Table 8-1 should be verified using other methods of estimating street sweeping performance, including weight-based estimates as described in Section 8.2.3.



Watershed	Estimated Road Canopy Cover
Lake Holiday	24%
Lake Rose	34%
Wing Lake	19%

PERCENT TREE CANOPY OVER ROADS
Nine Mile Creek
Watershed District

FIGURE 8-1



CUMULATIVE TP REMOVAL
Nine Mile Creek
Watershed District

FIGURE 8-2

8.2 Enhanced Street Sweeping Evaluation

The GISWQM model was used to evaluate "enhanced" street sweeping alternatives beyond the current practice of one city-wide sweeping in the spring following snowmelt. The following subsections outline (a) the seasonal effectiveness of street sweeping operations, (b) a high-level cost-benefit analysis for additional street sweeping operations, and (c) considerations related to the implementation and tracking of enhanced street sweeping efforts.

8.2.1 Seasonal Street Sweeping Evaluation

Table 8-2 through Table 8-5 provide a summary of seasonal street sweeping effectiveness as evaluated using street sweeping regression equations (Kalinosky, Baker, & Hobbie, 2014) within the GISWQM. The results for one spring sweeping estimate the performance of the City's existing street sweeping operation, while the results of subsequent sweepings per season show the potential pollutant recovery and reduction of enhanced street sweeping operations. While results reported in Tables 8-2 through 8-5 are cumulative for a given season, results between seasons (e.g., spring, summer, and fall) are not cumulative. For this reason, results for a given annual street sweeping scenario (e.g., two spring sweepings, one summer sweeping, three fall sweepings) can be calculated by summing the recovery/reduction values from the tables below (e.g., for Lake Holiday, the estimated recovery for the scenario described would be 6.2 lbs/spring + 2.8 lbs/summer + 13 lbs/fall) = 22 lbs TP recovery/year). Results of this analysis show that estimated phosphorus removals from street sweeping are highest in the fall, followed by the spring and then summer months. The amount of overall phosphorus removed increases with the number of sweepings; however, the marginal benefit achieved decreases with each additional sweeping (Figure 8-3).

Table 8-2 Estimated annual phosphorus removal from seasonal street sweeping: Lake Holiday

Season	Sweepings per Season (#)	Annual Phosphorus Loading, Recovery, and Reduction				
		Annual Loading (lbs/yr)	Cumulative Recovery (lbs/yr) [1]	Cumulative Recovery (%)	Effective Reduction (lbs/yr) [1]	Effective Reduction (%)
Spring	1	90.9	3.9	4.3%	2.4	2.6%
	2		6.2	6.8%	3.7	4.1%
	3		7.3	8.0%	4.4	4.8%
	4		7.7	8.4%	4.6	5.1%
Summer	1		2.8	3.1%	1.7	1.8%
	2		4.4	4.8%	2.6	2.9%
	3		5.2	5.7%	3.1	3.4%
	4		5.4	6.0%	3.3	3.6%
Fall	1		7.0	7.7%	4.2	4.6%
	2		11.0	12.1%	6.6	7.3%
	3		13.0	14.3%	7.8	8.6%
	4		13.6	15.0%	8.2	9.0%

[1] Total phosphorus street sweeping "recovery" and "reduction" as defined in Section 8.1.1.

Table 8-3 Estimated annual phosphorus removal from seasonal street sweeping: Wing Lake

Season	Sweepings per Season (#)	Annual Phosphorus Loading, Recovery, and Reduction				
		Annual Loading (lbs/yr)	Cumulative Recovery (lbs/yr) [1]	Cumulative Recovery (%)	Effective Reduction (lbs/yr) [1]	Effective Reduction (%)
Spring	1	74.2	2.7	4%	1.6	2%
	2		4.2	6%	2.5	3%
	3		5.0	7%	2.9	4%
	4		5.2	7%	3.1	4%
Summer	1		1.9	3%	1.1	2%
	2		3.0	4%	1.8	2%
	3		3.5	5%	2.1	3%
	4		3.7	5%	2.2	3%
Fall	1		4.8	6%	2.8	4%
	2		7.5	10%	4.4	6%
	3		8.9	12%	5.2	7%
	4		9.3	13%	5.5	7%

[1] Total phosphorus street sweeping "recovery" and "reduction" as defined in Section 8.1.1.

Table 8-4 Estimated annual phosphorus removal from seasonal street sweeping: Lake Rose

Season	Sweepings per Season (#)	Annual Phosphorus Loading, Recovery, and Reduction				
		Annual Loading (lbs/yr)	Cumulative Recovery (lbs/yr) [1]	Cumulative Recovery (%)	Effective Reduction (lbs/yr) [1]	Effective Reduction (%)
Spring	1	56.2	2.6	4.6%	2.3	4.1%
	2		4.1	7.3%	3.6	6.5%
	3		4.8	8.6%	4.3	7.7%
	4		5.1	9.1%	4.5	8.0%
Summer	1		1.8	3.3%	1.6	2.9%
	2		2.9	5.2%	2.6	4.6%
	3		3.4	6.1%	3.0	5.4%
	4		3.6	6.4%	3.2	5.7%
Fall	1		4.6	8.2%	4.1	7.3%
	2		7.3	13.0%	6.5	11.5%
	3		8.6	15.3%	7.6	13.6%
	4		9.0	16.1%	8.0	14.3%

[1] Total phosphorus street sweeping "recovery" and "reduction" as defined in Section 8.1.1.

Table 8-5 **Estimated annual phosphorus removal from seasonal street sweeping: Lakes Holiday, Wing, and Rose combined**

Season	Sweepings per Season (#)	Annual Phosphorus Loading, Recovery, and Reduction				
		Annual Loading (lbs/yr)	Cumulative Recovery (lbs/yr)	Cumulative Recovery (%)	Effective Reduction (lbs/yr)	Effective Reduction (%)
Spring	1	221.2	9.2	4.2%	6.3	2.8%
	2		14.5	6.5%	9.9	4.5%
	3		17.1	7.7%	11.6	5.3%
	4		18.0	8.1%	12.2	5.5%
Summer	1		6.5	2.9%	4.4	2.0%
	2		10.3	4.6%	7.0	3.2%
	3		12.1	5.5%	8.2	3.7%
	4		12.7	5.8%	8.7	3.9%
Fall	1		16.4	7.4%	11.1	5.0%
	2		25.8	11.6%	17.5	7.9%
	3		30.4	13.7%	20.7	9.3%
	4		31.9	14.4%	21.7	9.8%

[1] Total phosphorus street sweeping "recovery" and "reduction" as defined in Section 8.1.1.

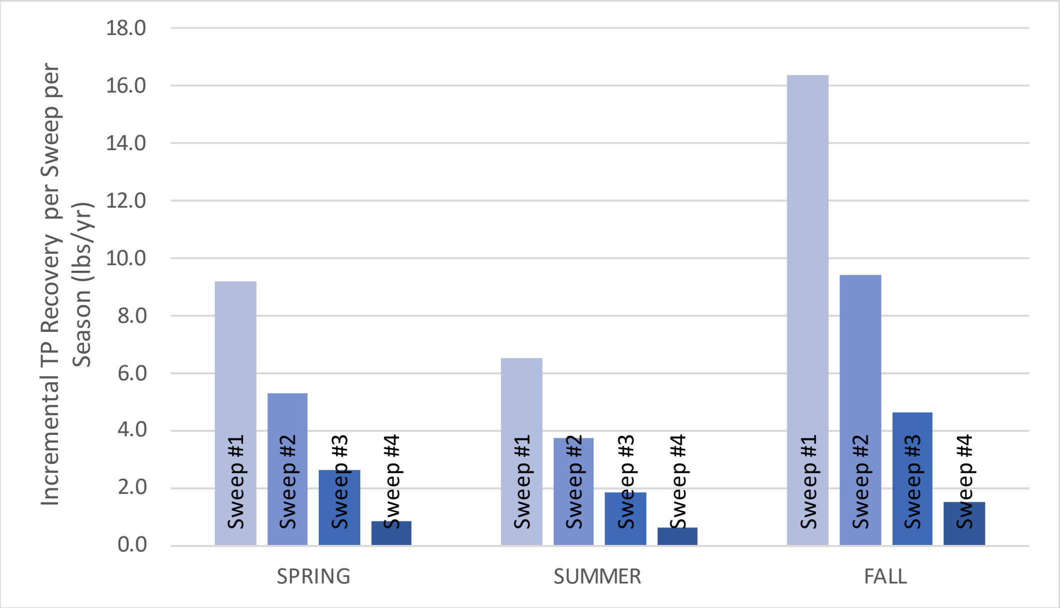


Figure 8-3 **Incremental seasonal street sweeping recovery per season**

8.2.2 Cost-Benefit Analysis

For the purposes of generating a cost-benefit analysis for “enhanced” street sweeping operations within the Lakes Holiday, Wing, and Rose watersheds, it is assumed that additional sweeping efforts will be completed utilizing contracted street sweeping. This assumption was based on information developed as part of the City of Minnetonka’s *2017-2019 Enhanced Street Sweeping Pilot Program Study* (Barr Engineering Co., 2020), which utilized an estimated contracted sweeping cost of $248 per curb-mile swept. A recently compiled survey of street sweeping cost estimates from cities within the Ramsey-Washington Metro Watershed District indicates an average sweeping cost of approximately $150/curb-mile swept, which includes a combination of in-house and contracted sweeping approaches (Barr Engineering Co., 2023 [study in progress]). Table 8-6 provides a summary of curb miles swept and the estimated total contracted cost to perform up to four sweeping operations within the Lakes Holiday, Wing, and Rose watersheds, assuming a cost of $248 per curb-mile swept.

Table 8-6 Seasonal street sweeping cost estimate for contracted sweeping

Number of Seasonal Sweeps (#)	Curb-Miles Swept (miles)	Total Annual Cost ($)
1	27.5	$6,824
2	55.0	$13,649
3	82.6	$20,473
4	110.1	$27,297

Table 8-7 provides a cost estimate and cost-benefit summary for seasonal street sweeping operations conducted in the Lakes Holiday, Wing, and Rose watersheds corresponding to the alternative discussed in Section 8.2.

Table 8-7 Cost-benefit of total phosphorus (TP) removal for seasonal street sweeping alternatives

				Cost-Benefit: Contracted Sweeping	
Season	Sweepings per Season (#)	TP Recovery (lbs/yr)	TP Reduction (lbs/yr)	TP Recovery Efficiency ($/lb/yr)	TP Reduction Efficiency ($/lb/yr)
Spring	1	9.2	6.3	$742	$1,091
	2	14.5	9.9	$942	$1,385
	3	17.1	11.6	$1,196	$1,759
	4	18.0	12.2	$1,519	$2,234
Summer	1	6.5	4.4	$1,047	$1,540
	2	10.3	7.0	$1,330	$1,956
	3	12.1	8.2	$1,689	$2,484
	4	12.7	8.7	$2,145	$3,155
Fall	1	16.4	11.1	$417	$614
	2	25.8	17.5	$530	$779
	3	30.4	20.7	$673	$990
	4	31.9	21.7	$855	$1,257

Based on the results highlighted in Table 8-7, street sweeping conducted in the fall is the most cost-effective for the removal of TP, followed by spring and then summer sweepings. Cost-benefit values for TP recovery range from approximately $400 to $2,000, while cost-benefit values for TP reduction (i.e., TP prevented from reaching Lakes Holiday, Wing, and Rose) vary from $600 to $3,000.

8.2.3 Implementation Considerations

Results of the enhanced street sweeping analyses indicate that the phosphorus removal achieved from street sweeping varies by season and by the number of sweepings. The greatest phosphorus removal occurs from fall sweepings, followed by spring and then summer. The number of sweepings per season increases the overall phosphorus removal achieved; however, the marginal benefit decreases with each additional sweeping. The conclusions of the analysis suggest that an enhanced street sweeping program should prioritize at least one fall sweeping since the City of Minnetonka already conducts street sweeping once in the spring. One or two sweeping events in the summer could also be considered. Summer season sweepings could be timed following the release of summer flowering material and seeds (e.g., maple seeds) to maximize effectiveness, and fall sweeping should be timed with leaf drop to the extent practicable.

The City of Minnetonka has identified enhanced street sweeping as a potential practice to meet the waste load allocation (WLA) for Lake Rose in the Lower Minnesota River Watershed TMDL, which reflects a 7-pound reduction of TP loading per growing season from the Lake Rose watershed (Minnesota Pollution

Control Agency, 2020). The phosphorus removal estimates summarized in Section 8.2.1 can be used to inform a targeted street-sweeping program to meet the WLA requirements.

The analysis presented in this study demonstrates that street sweeping, and in particular fall street sweeping, is cost-efficient in terms of dollars spent per pound of phosphorus removed compared to common, structural BMPs. While cost-effectiveness for stormwater management practices can vary widely depending on a variety of factors, the estimated annualized costs per pound of phosphorus removal from seasonal street sweeping alternatives shown in Table 8-7 are below the costs for many common structural stormwater management practices, which can range up to $14,000 or more per pound of total phosphorus per year (RWMWD, 2018). However, it is important to note that structural BMPs generally provide more consistent pollutant removal throughout spring through fall, so it is difficult to directly compare the cost-effectiveness with street sweeping.

As discussed, the effectiveness of street sweeping in reducing phosphorus loading to downstream lakes will vary depending on other treatment (sedimentation) that occurs in other downstream ponds or wetlands prior to reaching the lake. Enhanced sweeping should prioritize additional sweeping efforts in the “untreated” portions of the watershed first (i.e., areas that are not treated by water quality BMPs or other waterbodies prior to discharge to the lakes) if the capacity for enhanced sweeping is limited.

The following list provides additional recommendations regarding estimating and tracking the effectiveness of an enhanced street sweeping program:

- Consider the collection of swept material weight during sweeping operations. This can be used to track the effectiveness of operations and can be utilized to produce estimates of pollutant reduction. If it is not feasible to collect weights for every hopper load, consider developing an estimate of material weight for a typical load and using that to perform estimates (e.g., determine the average weight of a full hopper and use this value to estimate collected material weights per load).
- If weights are collected, consider evaluating associated pollutant reduction as estimated using the MPCA’s Street Sweeping Phosphorus Calculator. This calculator estimates the total phosphorus recovery associated with the wet or dry weight of swept material collected.
- Consider performing a validation effort between the MPCA’s weight-based calculator, the GISWQM calculator, and observed results from the 2020 enhanced street sweeping study to determine if a relationship/correction could be developed to improve calculator estimates.

9 Soil Testing Program

Lawn fertilizer, which contains nitrogen and other nutrients, is a source of pollution to urban lakes. The *Lake Holiday, Wing Lake, and Lake Rose Water Quality Study* identified soil testing as one strategy to reduce nutrient inputs into these lakes. The NMCWD initiated a soil testing pilot program in 2023 aimed to improve knowledge of lawn nutrient needs among homeowners and reduce over-fertilization of residential lawns in the subwatersheds of Holiday, Wing, and Rose lakes.

Postcards were mailed to single-family residential home addresses in these subwatersheds with information on how to participate in the free soil testing program. Those that signed up through a registration link received a soil testing kit in the mail that contained a hand trowel, soil sample bag, and instructions for taking a soil sample. Participants dropped their soil samples off at the NMCWD office in Eden Prairie, then NMCWD staff brought the samples to the University of Minnesota soil testing lab for analysis. Once the samples were analyzed, the participants received their results, along with a short video created by NMCWD staff on how to interpret the information.

By late-August 2023, forty-six households had signed up to participate in the pilot program, with 38 households turning in a soil sample and receiving an analysis report. The number of households that signed up to participate in the program between the three subwatersheds was as follows: 17 households in the Lake Holiday subwatershed, 15 households in the Wing Lake subwatershed, and 14 households in the Lake Rose subwatershed. Staff intend to follow-up with participants to track what changes to fertilization practices, if any, occurred following soil sampling.

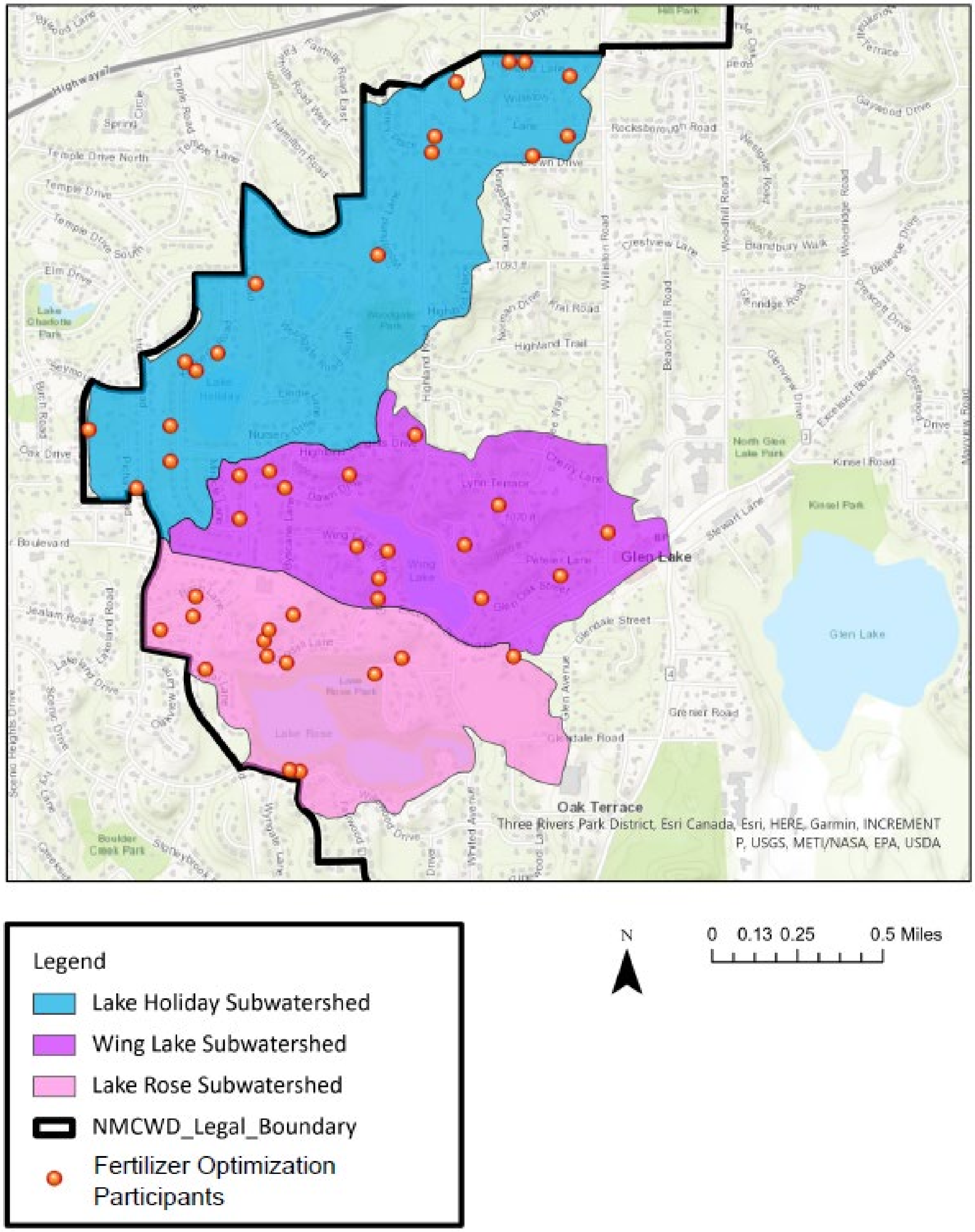


Figure 9-1 Households Participating in Pilot-Year of the NMCWD's Soil Testing Program (source: NMCWD)

10 Conclusion and Recommendations

In 2022, the NMCWD completed a water quality study of Lakes Holiday, Wing, and Rose in Minnetonka to assess and prescribe management activities to improve water quality within these lakes. The study recommended further consideration of several potential watershed and in-lake management activities. This report summarizes a feasibility analysis and evaluation of the following management activities, which were included within those recommendations:

- Installation of a recirculating enhanced filtration basin within Holiday Lake Park.
- A combined aluminum (sodium aluminate) and iron (ferric chloride) treatment in Lake Holiday, in conjunction with the installation of a lake aeration system.
- A curly-leaf pondweed management option within Lake Holiday.
- A combined aluminum (sodium aluminate) and iron (ferric chloride) treatment in Wing Lake.
- An aluminum (alum + sodium aluminate) treatment in Lake Rose.
- Enhanced street sweeping within the watersheds draining to Lakes Holiday, Wing, and Rose.

As a result of this study, the following recommendations were developed:

- City and NMCWD staff agreed that the preferred design alternative for an enhanced filtration BMP within Holiday Lake Park would be a rapid sand filtration system. This was due primarily to this design alternative's reduced footprint, estimated pollutant removal efficiencies, and the ability to incorporate native plantings and/or other natural design enhancements with the system.
    - The planning-level estimated cost of a rapid sand filtration BMP at Holiday Lake Park is shown in Table 9-1. The estimated cost-benefit is $8,000 per pound of TP reduction.
    - Due to the substantial cost and some remaining uncertainty with the operational and maintenance complexities of the rapid filtration BMP at Holiday Lake Park, it is recommended that the City and NMCWD first focus on implementation of the recommended in-lake management activities and enhanced street sweeping within these watersheds to observe the level of water quality improvement that can be achieved through these practices, before further pursuit of the filtration BMP. A re-consideration of the potential benefits of adding the filtration system should be included as part of the assessment of in-lake treatment effectiveness and consideration of need for additional treatments at Lake Holiday at the 5- and 10-year milestones post-application.
- A combined aluminum (sodium aluminate) and iron (ferric chloride) treatment is recommended for Lake Holiday in conjunction with the installation of a lake aeration system. The estimated treatment area within the lake is 7.0 acres.
    - It is recommended that the Lake Holiday ferric chloride and sodium aluminate treatment be performed in the fall of 2024, assuming lake water levels are high enough to allow treatment of the desired surface area. Treatment should be performed after curly-leaf

    pondweed has died off (curly-leaf pondweed could disturb the even settling of aluminum and iron floc on the lake bottom).

    - The installation of a forced-air aeration system is recommended as part of the Lake Holiday treatment plan. It is recommended that the cabinet and compressor pumps for this system be placed beside the pumphouse building within Holiday Lake Park.
    - The planning-level estimated costs of the ferric chloride and sodium aluminate treatment and aeration system in Lake Holiday are shown in Table 9-1. The estimated cost-benefit of the combined activities is approximately $2,100 per pound of TP reduction.
    - Since the application of iron and aluminum is new to the NMCWD, more comprehensive monitoring and assessment of the Lake Holiday in-lake treatment is recommended. The recommended monitoring program includes follow-up sediment coring at 2 years, 5 years, and 10 years after treatment; lake water monitoring at years 2, 4, and 5-10 (the frequency of lake water monitoring within years 5-10 would be determined as part of a year 5 comprehensive review of results); and a comprehensive review of monitoring results at years 5 and 10 to evaluate the potential need for retreatment.
- Management of curly-leaf pondweed in Lake Holiday is recommended.
    - Based on the extent and density of curly-leaf pondweed in the lake, applying the herbicide Galleon in the spring for three consecutive years is recommended. The herbicide treatment approach can be adjusted, as necessary, based on annual macrophyte surveys.
    - A spring 2024 or 2025 herbicide treatment is recommended, depending on permitting.
    - Following three years of treatment, the success of native plant re-establishment should be reviewed. If native plant re-establishment is not successful, other management and restoration options could be considered (e.g., partial or full lake drawdown, transplanting native plants from reference lakes).
- A combined aluminum (sodium aluminate) and iron (ferric chloride) treatment is also recommended for Wing Lake. The estimated treatment area within the lake is 13.3 acres.
    - It is recommended that the Wing Lake ferric chloride and sodium aluminate treatment be performed in the spring of 2024, assuming lake water levels are high enough to allow treatment of the desired surface area. A spring treatment is recommended to minimize impacts from aquatic plant growth (e.g., water lilies and other aquatic vegetation).
    - The planning-level estimated cost of the ferric chloride and sodium aluminate treatment in Wing Lake is summarized in Table 9-1. The estimated cost-benefit of the iron and aluminum treatment is approximately $1,300 per pound of TP reduction.
    - Since the application of iron and aluminum is new to the NMCWD, more comprehensive monitoring and assessment of the Wing Lake in-lake treatment is recommended. The recommended monitoring program includes follow-up sediment coring at 2 years, 5

    years, and 10 years after treatment; lake water monitoring at years 2, 4, and 5-10 (the frequency of lake water monitoring within years 5-10 would be determined as part of a year 5 comprehensive review of results); and a comprehensive review of monitoring results at years 5 and 10 to evaluate the potential need for retreatment.

- An aluminum (alum and sodium aluminate) treatment is recommended for Lake Rose.
    - It is recommended that the Lake Rose alum and sodium aluminate treatment be performed in the spring of 2024, assuming lake water levels are high enough to allow treatment of the desired surface area. A spring treatment is recommended to minimize impacts from aquatic plant growth (e.g., water lilies and other aquatic vegetation).
    - The recommended post-treatment monitoring for Lake Rose is not as intensive as for Lakes Holiday and Wing, as iron is not being used in this treatment, and the expected outcome of an aluminum-only treatment is well understood. Recommended monitoring includes lake water monitoring in year 2 and periodic monitoring in years 3-10. Follow-up sediment coring is recommended 10 years after treatment, at which point an analysis should also be completed to evaluate the potential need for retreatment.
    - The planning-level estimated cost of the recommended alum and sodium aluminate treatment in Lake Rose is included in Table 9-1. The estimated cost-benefit of the aluminum treatment is approximately $500 per pound of TP reduction.
- Results of the enhanced street sweeping analyses indicate that the phosphorus removal achieved from street sweeping varies by season and by the number of sweepings. Conclusions from the analysis suggest that an enhanced street sweeping program within the Lakes Holiday, Wing, and Rose subwatersheds should prioritize at least one fall sweeping, since the City of Minnetonka already conducts street sweeping once in the spring. One or two sweeping events in the summer could also be considered. Summer season sweepings could be timed following the release of summer flowering material and seeds (e.g., maple seeds) to maximize effectiveness, and fall sweeping should be timed with leaf drop to the extent practicable.
    - It is recommended that the City of Minnetonka and NMCWD continue discussions on the additional amount and prioritization of areas for enhanced street sweeping within the Lakes Holiday, Wing, and Rose subwatersheds that may be best, taking into account water quality improvement goals for each of these waterbodies in addition to considerations for operational constraints. As of the preparation of this report, the City of Minnetonka is planning to add one additional fall sweeping within the subwatersheds draining to Lakes Holiday, Wing, and Rose as a pilot test.

Table 10-1 Summary of planning-level costs for recommended capital improvement projects

Management Activity	Planning-Level Capital Cost Estimate (-20% - +30%)	Planning-Level Annual Operations & Maintenance Cost Estimate	Estimated Avg Annual TP Removal (lbs/year)
Lake Holiday Aluminum + Iron Treatment	$86,000 ($69,000–$112,000) [1]	$0	10
Lake Holiday Aeration	$67,000 ($54,000 - $88,000) [1]	$5,400	
Lake Holiday Curly-leaf Management	$51,000 ($48,000 - $63,000) [2,3]		
Wing Lake Aluminum + Iron Treatment	$98,000 ($79,000–$128,000) [1]	$0	10
Lake Rose Aluminum Treatment	$148,000 ($119,000–$193,000) [1]	$0	36
Enhanced Street Sweeping – one additional sweeping in the fall	N/A	$6,824[4]	11

[1] Cost reflects an accuracy range between -20% and +30% of the estimated project cost.

[2] Cost reflects an accuracy range between -10% and +20% of the estimated project cost.

[3] Assumes three consecutive years of herbicide treatment.

[4] Assumes one additional sweeping per year at a contracted rate of $248 per curb-mile swept.

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Appendix A

Engineer’s Opinion of Estimated Costs

Holiday, Wing, & Rose Lakes Water Quality Improvement Project

ENGINEERS OPINION OF COST

LAKE HOLIDAY RAPID FILTRATION BMP - SCHEMATIC DESIGN				
ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	COST
Mobilization/Demobilization	LS	1	$ 70,000.00	$ 70,000.00
Traffic and Pedestrian Safety Control Measures	LS	1	$ 5,000.00	$ 5,000.00
Construction Layout and Staking	LS	1	$ 8,000.00	$ 8,000.00
Erosion Control	LS	1	$ 4,000.00	$ 4,000.00
Clear and Grub Trees and Shrubs	LS	1	$ 10,000.00	$ 10,000.00
Filtration Vault and Basin Excavation	CY	230	$ 15.00	$ 3,450.00
Offsite Disposal of Excavated Material	CY	160	$ 25.00	$ 4,000.00
Filter Media	CY	56	$ 750.00	$ 42,000.00
Support Gravel	CY	30	$ 900.00	$ 27,000.00
Anthracite	CY	19	$ 1,650.00	$ 31,350.00
6-inch Perforated Dual Wall HDPE Draintile Pipe and Fittings, no sock (P)	LF	410	$ 30.00	$ 12,300.00
6-inch Solid PVC Storm Sewer Pipe and Fittings (P)	LF	90	$ 70.00	$ 6,300.00
4-inch Solid PVC Storm Sewer Pipe and Fittings (P)	LF	520	$ 70.00	$ 36,400.00
12-inch Solid PVC Storm Sewer Pipe and Fittings (P)	LF	120	$ 120.00	$ 14,400.00
12-inch CPE Storm Sewer Pipe and Fittings (P)	LF	80	$ 75.00	$ 6,000.00
15-inch Reinforced Concrete Storm Sewer Pipe (P)	LF	110	$ 120.00	$ 13,200.00
15-inch Nyloplast Storm Sewer Structure, Complete	EA	1	$ 3,000.00	$ 3,000.00
12-inch HDPE Flared End Section	EA	1	$ 800.00	$ 800.00
15-inch RCP Flared End Section	EA	1	$ 2,500.00	$ 2,500.00
6-inch Draintile Cleanout and Cover Unit	EA	7	$ 800.00	$ 5,600.00
PVC Ball Valve, Valve Box, and Pipe Stubs	EA	12	$ 1,700.00	$ 20,400.00
12-inch Dia. Cast Iron Gate Valve and Valve box	EA	2	$ 4,000.00	$ 8,000.00
Beehive Overflow Structure and Grate, Complete	LS	1	$ 5,000.00	$ 5,000.00
60-inch Dia. Precast Storm Sewer MH (Aeration)	LS	1	$ 12,000.00	$ 12,000.00
72-inch Dia. BMP Pump Station, Complete	LS	1	$ 110,000.00	$ 110,000.00
72-inch Dia. Discharge Pump Station, Complete	LS	1	$ 60,000.00	$ 60,000.00
60"-Dia. Meter Vault, Complete	LS	1	$ 25,000.00	$ 25,000.00
Connection to Existing Structure	LS	1	$ 500.00	$ 500.00
Random Riprap, Class II with Filter Fabric (P)	LS	2	$ 1,200.00	$ 2,400.00
Reinforced Concrete - Horizontal	CY	13	$ 810.00	$ 10,530.00
Reinforced Concrete - Vertical	CY	24	$ 1,700.00	$ 40,015.06
Structural Steel Framing	LB	800	$ 7.00	$ 5,600.00
Fiber Reinforced Plastic (FRP) Grating	SF	282	$ 37.00	$ 10,452.13
Stainless Steel Plate Troughs with Weir Plates	LB	670	$ 160.00	$ 107,200.00
Remove and Replace Bitminous and Class 5	SY	100	$ 90.00	$ 9,000.00
Remove and Replace Curb and Gutter	LF	20	$ 55.00	$ 1,100.00
Electrical, Complete	LS	1	$ 75,000.00	$ 75,000.00
Twice Shredded Hardwood Mulch (P)	CY	20	$ 95.00	$ 1,900.00
Perennials - 1 gallon pot (P)	EA	325	$ 35.00	$ 11,375.00
Shrub (#2 Gallon Container) (P)	EA	25	$ 50.00	$ 1,250.00
Low Maintenance Turf Seed Mix and Straw Protection	SY	1,600	$ 5.00	$ 8,000.00
Tree, 2.5" B&B with Protection	EA	11	$ 550.00	$ 6,050.00
Landscape Edging	LF	180	$ 21.00	$ 3,780.00

Native Shoreline Plug Planting	EA	650	$ 10.00	$ 6,500.00
Native Shoreline Seed Mix	AC	0.03	$ 6,000.00	$ 180.00
Erosion Control Blanket (netless, shoreline)	SF	390	$ 3.00	$ 1,170.00
Construction Subtotal =				$ 848,000.00
Contingency (10%)				$ 85,000.00
Construction Total =				***$ 933,000.00***
Engineering/Design/Construction Administration				***$ 320,000.00***
Total				***$ 1,253,000.00***
-20%				$ 1,003,000.00
30%				$ 1,629,000.00

Assumptions

- Assumes no dewatering is needed during construction
- Construction access can be accommodated by existing roadway
- Filtration basin bottom 600 square feet
- Pre-treatment vault 200 square feet
- 2.5' depth of filter media
- Filter basin overflow depth = 1'
- Assuming Class 3 opinion of cost with accuracy range of -20% to +30% standards established by the Association for the Advancement of Cost Engineering (AACE).
- Estimated total cost is reported to the nearest thousand dollars

Holiday, Wing, & Rose Lakes Water Quality Improvement Project

ENGINEERS OPINION OF COST

HOLIDAY LAKE FORCED AIR AERATION				
ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	COST
Aerator Equipment	LS	1	$ 13,500	$ 13,500
Aerator Installation (Electrical/Concrete Pad/Materials)	LS	1	$ 30,000	$ 30,000
			Construction Subtotal	$ 44,000
			Construction Total With Contingency (10%)	$ 48,400
Project Planning/Design/Engineering Assistance	HRS	120	$ 150	$ 18,000
			Total	***$ 67,000***
			-20%	$ 54,000
			30%	$ 88,000

Assumptions

- Engineering assistance with bid administration and contract documents

- Aerator installation includes:

*Mobilization of equipment to and from the site

*Prep area for new 5’ wide by 5’ long by 6” deep concrete pad

*Install 6” of class 5 aggregate base for concrete pad

*Electrical install from existing buidling

*Bore under asphalt patch and Install sleeve

*Install ~350 LF (two runs) of 1” SDR 11 HDPE pipe from new concrete pad to manifold

- Aerator equipment includes:

*Hydro Logic Products AirLift 10 HighFlow aeration system (220V/single phase).

*Lockable powder coated steel enclosure

*2, 1 HP dual piston air compressors wit 15 CFM capacity

*2 high volume cooling fans

*10 AirPod air diffusers

*Hydro Logic Products DownUnder weighted air supply tubing-5/8 inch, 4,000 ft total length.

- Assuming Class 4 opinion of cost with accuracy range of -20% to +30% standards established by the Association for the Advancement of Cost Engineering (AACE).
- Estimated total cost is reported to the nearest thousand dollars.

Holiday, Wing, & Rose Lakes Water Quality Improvement Project

ENGINEERS OPINION OF COST

HOLIDAY LAKE SEDIMENT TREATMENT

ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	COST
Sodium Aluminate Sediment Treatment	Gallons	2,596	$ 9	$ 23,000
Iron (Ferric Chloride) Sediment Treatment	Gallons	3,090	$ 14	$ 42,000
Construction Subtotal				$ 65,000
Construction Total With Contingency (10%)				$ 71,500
Project Planning/Design/Engineering Assistance	HRS	60	$ 150	$ 9,000
Engineer Data Review/Field Observation	HRS	40	$ 130	$ 5,200
Total				***$ 86,000***
-20%				$ 69,000
30%				$ 112,000

Assumptions

- Mobilization/Demobilization included in the per gallon treatment cost
- Engineering assistance with bid administration and contract documents
- Two engineering staff members to observe sediment treatments and perform pH monitoring.
- Assuming Class 4 opinion of cost with accuracy range of -20% to +30% standards established by the Association for the Advancement of Cost Engineering (AACE).
- Estimated total cost is reported to the nearest thousand dollars.

Holiday, Wing, & Rose Lakes Water Quality Improvement Project

ENGINEERS OPINION OF COST

WING LAKE SEDIMENT TREATMENT

ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	COST
Sodium Aluminate Sediment Treatment	Gallons	3,031	$ 9	$ 27,000
Iron (Ferric Chloride) Sediment Treatment	Gallons	3,607	$ 14	$ 49,000
Construction Subtotal				$ 76,000
Construction Total With Contingency (10%)				$ 83,600
Project Planning/Design/Engineering Assistance	HRS	60	$ 150	$ 9,000
Engineer Data Review/Field Observation	HRS	40	$ 130	$ 5,200
Total				***$ 98,000***
-20%				$ 79,000
30%				$ 128,000

<u>Assumptions</u>

- Mobilization/Demobilization included in the per gallon treatment cost
- No aerator installation
- Engineering assistance with bid administration and contract documents
- Two engineering staff members to observe sediment treatments and perform pH monitoring.
- Assuming Class 4 opinion of cost with accuracy range of -20% to +30% standards established by the Association for the Advancement of Cost Engineering (AACE).
- Estimated total cost is reported to the nearest thousand dollars.

Holiday, Wing, & Rose Lakes Water Quality Improvement Project

ENGINEERS OPINION OF COST

ROSE LAKE SEDIMENT TREATMENT				
ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	COST
Sodium Aluminate Sediment Treatment	Gallons	6,850	$ 9	$ 60,000
Alum Sediment Treatment	Gallons	13,701	$ 4	$ 61,000
			Construction Subtotal	$ 121,000
			Construction Total With Contingency (10%)	$ 133,100
Project Planning/Design/Engineering Assistance	HRS	60	$ 150	$ 9,000
Engineer Data Review/Field Observation	HRS	40	$ 130	$ 5,200
			Total	***$ 148,000***
			-20%	$ 119,000
			30%	$ 193,000

Assumptions

- Mobilization/Demobilization included in the per gallon treatment cost
- No aerator installation
- Engineering assistance with bid administration and contract documents
- Two engineering staff members to observe sediment treatments and perform pH monitoring.
- Assuming Class 4 opinion of cost with accuracy range of -20% to +30% standards established by the Association for the Advancement of Cost Engineering (AACE).
- Estimated total cost is reported to the nearest thousand dollars.

Holiday, Wing, & Rose Lakes Water Quality Improvement Project

ENGINEERS OPINION OF COST

CURLY-LEAF PONDWEED MANAGEMENT - Galleon				
ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	COST
Herbicide Contractor Mobilization/Demobilization	LS	2	$ 600.00	$ 1,200.00
Herbicide Contractor Application of Liquid Galleon	Quarts	0.9	$ 550.00	$ 495.00
Macrophyte Survey and Analysis Subcontor Costs	LS	2	$ 2,000.00	$ 4,000.00
Project Planning (permitting, contracting)	HRS	48	$ 180.00	$ 8,640.00
Subtotal (per year) =				$ 15,000.00
Contingency (10%)				$ 1,500.00
Total (per year)				**$ 17,000.00**
-10%				$ 16,000.00
+20%				$ 21,000.00
3-year Treatment Estimate				**$48,000 - $63,000**

Assumptions

- Macrophyte survey and analysis subcontracting includes surveys pre- and post-herbicide application.
- 50% of lake treated galleon dose concentration of 6.1 µg/L.
- Assuming Class 4 opinion of cost with accuracy range of -10% to +20% standards established by the Association for the Advancement of Cost Engineering (AACE).
- Estimated total cost is reported to the nearest thousand dollars.

Appendix B

Aeration System Specifications

Hydro Logic Products

Pond & Lake Aeration plus Aquatic Products

AirLift 10 HF Aeration System
by **Hydro Logic Products**

X 10 = 10 AirPod Diffusers

HighFlow™
Large Lake Series

AirLift 10 HighFlow™

SPECIFICATIONS

Large Lake AirLift™ Aeration Benefits:

- **Increase Dissolved Oxygen Concentrations**
- **Eliminate Stress to Fish & Aquatic Organisms**
- **Increase Water Clarity (Transparency)**
- **Reduce Algal Blooms (Algae)**
- **Reduce High Metal Concentrations**
- **Reduce Nutrient Releases by Anoxic Sediments**
- **Reduce Buildup of Poisonous Gases**
- **Reduce Release of Noxious Odors**
- **Reduce the Accumulation of Sediments**
- **May Reduce Nuisance Levels of Aquatic Plants**
- **No Electricity in the Water**
- **Warranties on all System Components**

Hydro Logic Products® AirLift 10 HighFlow™ large lake aeration systems are designed and built to cost effectively mix and aerate lakes. Our systems use billions of micron sized bubbles to improve pond and lake water quality. Our **AirLift 10 HighFlow™** aeration system can aerate ponds and lakes up to 22^+ acres in size depending on air diffuser placement, nutrient concentrations, biological oxygen demand (BOD), water depth and other physical characteristics of the waterbody.

Our **AirLift 10 HighFlow™** aeration system is powered by two (2) 1 H.P. energy efficient, dual piston air compressors equipped with our proprietary **SureStart™** technology. Our dual piston air compressors, which can deliver air under high pressures (water depths over 50 feet), operate very quietly (55 decibels at 2 meters or 6 feet). In comparison, the noise levels of our air compressors are about 15 decibels less than equivalent rotary vane air compressors.

Our **AirLift 10 HighFlow™** aeration system contains ten **(10) AirPod™** air diffusers. Each AirPod™ contains a self-cleaning 20-inch tube, EPDM flexible membrane air diffuser equipped with a **triple check valve** system. Our air diffusers are constructed to withstand total airflow from the compressor without damaging the EPDM membranes (unlike EPDM disc air diffusers). The base of the AirPod™ provides a large surface area between the EPDM membrane and the sediments, thereby preventing sediment disturbance during system operation. The AirPods are extremely easy to install. Simply fill the two ballast tubes with pea gravel or sand prior to their placement in the pond or lake.

Compressed air from our dual piston compressors are delivered to the AirPods using our **DownUnder™** self-weighted tubing. DownUnder™ air supply tubing is constructed of a flexible PVC composite and is kink proof and puncture resistant. Our easy to install tubing comes in several different lengths and diameters to meet your installation needs.

COMPRESSORS **(Drawing on Page 4)**

- **Two (2) one (1) HP dual piston air compressors with integral thermal motor overload protection**
- **Produce high airflow volumes (15 cfm combined) & operate under high pressures (45 psi max.)**
- **Oil-less air compressors that are virtually maintenance free**
- **SureStart™ technology allows air compressors to restart under pressure after power outages**
- **High air pressure allows diffusers to be cleaned in ponds or lakes (unlike rotary vane compressors)**
- **U.L. listed 240 volt (8.2 amps combined) under full load**
- **5-micron air filters maximize air compressor life expectancy**
- **Easy field repairs - plumbing connections with push-on style fittings & flexible 100 psi tubing**
- **Noise reduction - mounted on cylindrical vibration pads & connected to flexible tubing**
- **Extremely quiet operation (55 decibels @ 2 meters or 6 feet @ 20 psi)**
- **Two-year warranty (best in the industry)**

All of our dual piston air compressors are outfitted with our proprietary **SureStart™** technology. This allows automatic restart of our air compressors under full pressure during any power outage (blackouts or brownouts) without damaging the air compressor motors. Each air compressor is oil-less, thermally protected and requires no lubrication. All air compressors include rotors/stators manufactured with the most advanced magnetic materials, sealed heavy-duty precision bearings and starting capacitors. The only required routine maintenance of our air compressors is periodically changing the 5-micron air filters. Our air compressors typically can operate approximately 3 years or more before any decline in performance is observed. This is 2 to 3 times better performance over standard piston, diaphragm and rotary vane compressors. Thereafter, our air compressors can be easily serviced by replacing the piston seals. Airflow versus pressure performance curves for our dual piston compressor varies less than for diaphragm and rotary vane compressors. This simply means that our dual piston compressors provide more air while using less energy. Lastly, our dual piston air compressors can operate under high pressures, thereby allowing the air diffuser membranes to be easily cleaned without pulling the AirPods from the pond or lake.

CABINET **(Drawing on Page 4)**

- **Commercial grade, 14-gauge steel cabinet that is rustproof & vandal resistant**
- **Powder coated, forest green finish to blend into its surroundings**
- **Easy access design with lock & key for added security**
- **6½ foot 3 prong plug for easy connection to standard 2-pole 3 wire 15A/20A electrical outlet**
- **Electrical circuits are Class "A" GFCI protected with a trip 4-6mA trip rating**
- **Ball bearing fan-cooled to maximize life of air compressors**
- **SuperCool™ dual cooling fans (470 cfm) included to further improve air compressor longevity**
- **Manifold equipped with sealed valves to precisely control the airflow to AirPod diffusers**
- **Heavy duty (24”L x 24”W x 2”H) HDPE mounting pad included**
- **Overall dimensions (24”L x 24”W x 24.6”H)**
- **Five-year warranty (best in industry)**

The commercial-grade cabinet is constructed of 14-gauge steel with forest green electro-statically bonded powder coating. The cabinet is manufactured with a stamped ventilation intake grill and low resistance exhaust plenum (duct work). The cabinet comes equipped with sealed ball bearing cooling fan to maximize air compressor life and Class "A" GFCI Protection on all circuits. All cabinet components are easily disassembled using standard household tools. The cabinet includes a 5-year warranty against rust and corrosion and a 2-year warranty on all components mounted inside of the cabinet.

AirPod™ Air DIFFUSERS **(Drawing on Page 4)**

- **Ten (10) AirPods each equipped with single flexible, fine pore EPDM rubber membrane tube diffuser**
- **More durable than air stone, porous media & EPDM disc diffusers**
- **Produces extremely fine air bubbles (500 – 1,000 micron or 0.020 - 0.040 inch)**
- **Triple check valves prevent water & sediment from entering the air supply lines**
- **One EPDM tube diffuser is 20% larger than two 9-inch EPDM disc diffusers**
- **Self-cleaning & very low maintenance**
- **Large HDPE base (20"L x 15"W) to prevent sediment disturbance**
- **All AirPod components are corrosion resistant using PVC, fiberglass & HDPE materials**
- **Five-year warranty (best in the industry)**

Each **AirPod**™ air diffuser contains a self-cleaning 20-inch, EPDM flexible membrane tube diffuser equipped with a **triple check valve system**. The triple check valves prevent water and sediment from flowing back into the air supply lines during system shut down. The EPDM tube air diffuser is mounted to heavy-duty PVC strut with ratcheting tie downs to provide easy assembly/disassembly. The above components are secured to a large HDPE base. Two hollow ballast tubes are anchored beneath the base. The ballasts tubes are designed so that pea gravel or sand can be easily added to these tubes during installation.

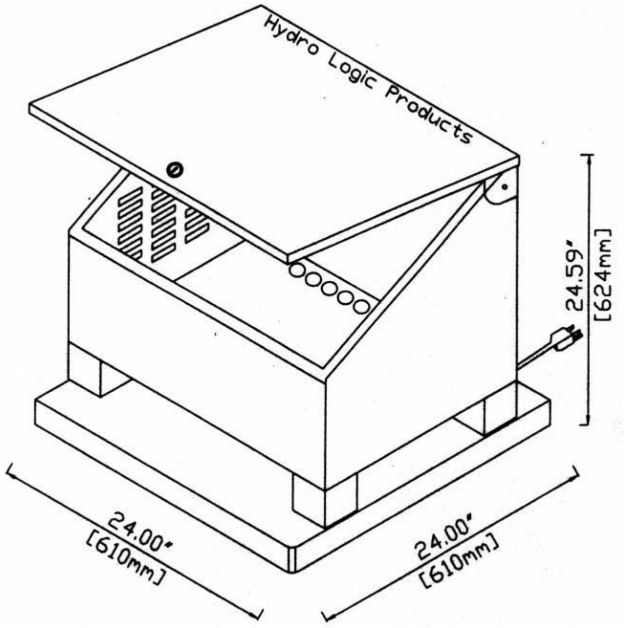
DownUnder™ SELF-WEIGHTED AIR SUPPLY TUBING **(Drawing on Page 4)**

- **Over-sized 0.58 inch I.D. for low-pressure drop applications***
- **Heavy-duty wall thickness for durability**
- **Self-weighted for easy installation**
- **Kink proof & puncture resistant**
- **Available in 100 ft. (boxed) & both 200 & 500 ft. (rolls) lengths**
- **10-year warranty (best in the industry)**

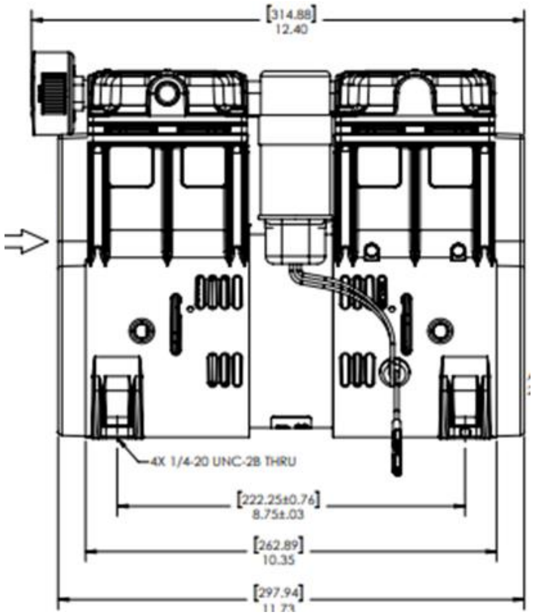
***** DownUnder™ air supply tubing is also available in 0.375 in. I.D. for smaller pond and lake applications

DownUnder™ air supply tubing is constructed of a flexible PVC composite and is self-weighted in order to firmly remain along the pond or lake bottom after the installation. Sections of DownUnder™ tubing are connected together using standard PVC solvent weld cement and ½ inch insert fittings. DownUnder™ air supply tubing has low friction walls for maximizing airflow rates and minimizing air pressure drops. Our DownUnder™ tubing is designed to reduce the overall system pressure requirements and to extend the life of the air compressors. The wall thickness provides long-term durability and protection against kinking and punctures. The air supply tubing remains flexible in cold temperatures allowing for easy year round installations.

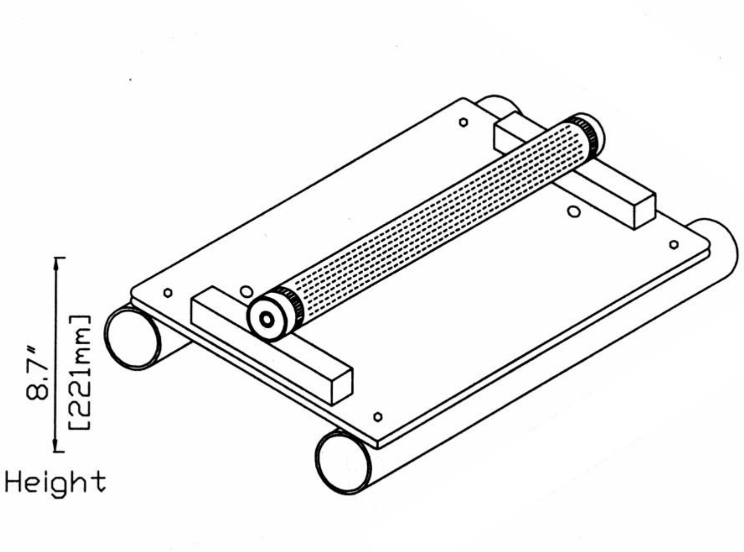
Drawings



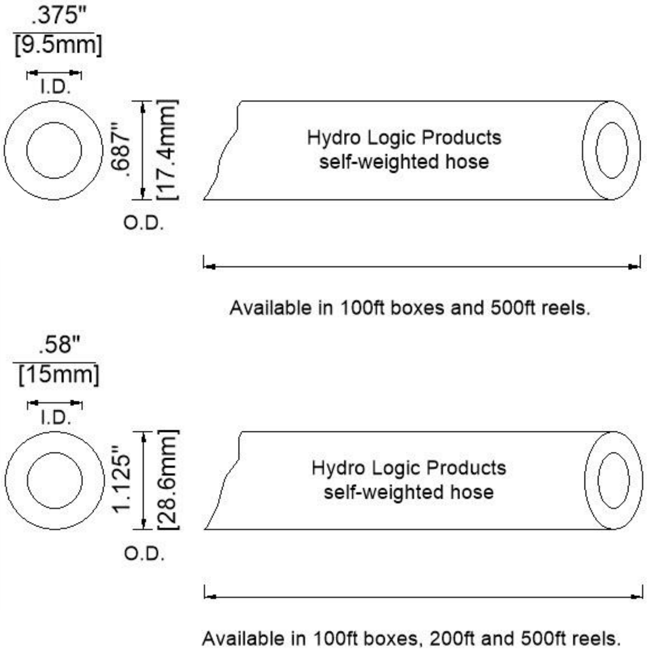
Air Compressor
Cabinet



Dual Piston Air Compressor
Side View



AirPod
Air Diffuser



DownUnder Self-Weighted
Air Supply Tubing

Important Notice: Install all electrical equipment in accordance with Article 680 of the National Electrical Code and all local codes. Hydro Logic Products reserves the right to improve and change our aeration system designs and/or specifications without notice or obligation.