Lake Cornelia and Lake Edina
Water Quality Improvement Project
Feasibility Study/Preliminary Engineering Report

DRAFT

Photo by Larry Olson

Prepared for
Nine Mile Creek Watershed District

June 2020

4300 MarketPointe Drive, Suite 200
Minneapolis, MN 55435
952.832.2600
www.barr.com

Contents

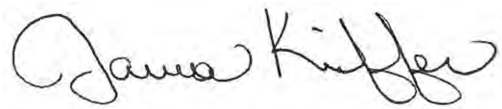
List of Tables

List of Figures

List of Appendices, Attachments, or Exhibits

Certifications

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
PE #: 43571

June 10, 2020
Date

Acronyms

µg/L	microgram per liter
AACE	Association for the Advancement of Cost Engineering
BMP	best management practice
cfs	cubic feet per second
DWSMA	Drinking Water Supply Management Area
FIN	Fishing in the Neighborhood
GIS	geographic information systems
HP	horsepower
HSG	hydrologic soil group
LiDAR	light detection and ranging
MIDS	Minimal Impact Design Standards
MnDNR	Minnesota Department of Natural Resources
NMCWD	Nine Mile Creek Watershed District
NRCS	Natural Resources Conservation Service
NWL	normal water level
RPBCWD	Riley Purgatory Bluff Creek Watershed District
SAFL	Saint Anthony Falls Laboratory
SRP	soluble reactive phosphorus
TDP	total dissolves phosphorus
TP	total phosphorus
UAA	Use Attainability Analysis
VHS	viral hemorrhagic septicemia
YOY	young of the year

1 Introduction and Project Background

1.1 Introduction

This report summarizes and assesses the feasibility of potential actions for improving the water quality of Lake Cornelia and Lake Edina, located downstream of Lake Cornelia. It is prepared in response to a water quality study the Nine Mile Creek Watershed District (NMCWD) completed for Lake Cornelia and Lake Edina in 2019 (Reference (1)).

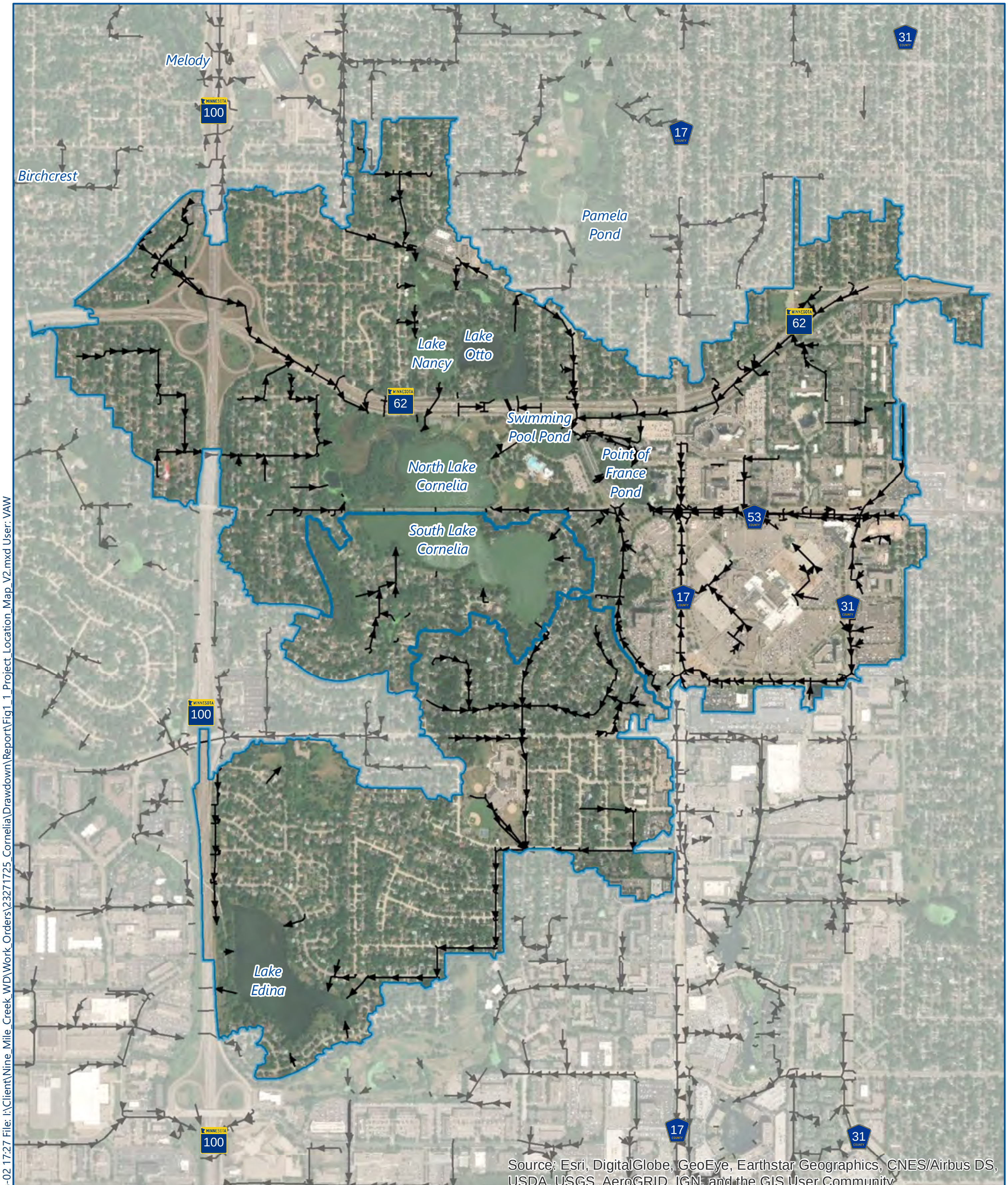
1.2 Project Background

The NMCWD was established by the Minnesota Water Resources Board in 1959 and consists of land that drains into Nine Mile Creek. The District encompasses approximately 50 square miles in southern Hennepin County and includes portions of the cities of Bloomington, Edina, Eden Prairie, Hopkins, Minnetonka, and Richfield (Figure 1-1). Nine Mile Creek has two branches; the north branch is fed by groundwater and stormwater and begins in Hopkins. The south branch originates in Minnetoga Lake and surrounding wetlands in Minnetonka. The north and south branches join north of Normandale Lake, just south of Interstate 494 in Bloomington. Lake Cornelia is located approximately 0.4 miles east of the north branch of Nine Mile Creek.

Stormwater management within the urbanized Nine Mile Creek watershed was guided initially by the District's Overall Plan dated March 1961. That plan was revised by the Watershed District in April 1973, as prescribed by the Minnesota Water Resources Board. The 1973 revised Overall Plan guided development in the District until it was further revised in May 1996, March 2007 and again in the 2017 Nine Mile Creek Watershed District Water Management Plan (amended 2018, 2019), in accordance with the Metropolitan Surface Water Management Act and Watershed Law: Minnesota Statutes Chapters 103B and 103D, respectively (Reference (2)).

The water quality in Lake Cornelia and Lake Edina is often poor, primarily due to excess phosphorus in the lakes which fuels algal growth and decreases water clarity. The 2019 water quality study found that phosphorus in Lake Cornelia comes from several sources, including stormwater runoff from the watershed (external source) and internal sources such as nutrient-rich sediments and decomposition of invasive curly-leaf pondweed. The study found that phosphorus in Lake Edina primarily comes from stormwater runoff within the watershed and flows from upstream Lake Cornelia.

The water quality study identified several recommendations to improve water quality in Lake Cornelia and downstream Lake Edina. This feasibility study report evaluates several water quality improvement approaches to address concerns associated with excess phosphorus in Lake Cornelia and Lake Edina as well as the prevalence of curly-leaf pondweed in Lake Cornelia. The report also evaluates options to revive a healthy native fish population in Lake Cornelia.



Major Watersheds

Storm Sewer

N

0 600 1,200 1,800

Feet

Project Location

Lake Cornelia and Lake Edina Water Quality Improvement Project

Edina, Minnesota

FIGURE 1-1

2 Lake Cornelia and Lake Edina Overview

The characteristics of Lake Cornelia, Lake Edina, and their watersheds are described in the following sections.

2.1 Lake Cornelia

2.1.1 Lake Cornelia Characteristics

Lake Cornelia is a shallow lake with a northern and southern basin, which are connected by a storm sewer pipe beneath West 66th Street. North Cornelia, spanning 19 acres, has a maximum depth of 7 feet, and a mean depth of approximately 3 feet. South Cornelia, with a water surface area of 33 acres, has a maximum depth of 8 feet, and a mean depth of approximately 4 feet. Runoff that flows through Lake Cornelia drains to Lake Edina, which ultimately discharges into the North Fork of Nine Mile Creek.

2.1.2 Watershed Characteristics

North Cornelia receives stormwater runoff from a relatively large watershed (863 acres) (Figure 2-1). Land use within the highly developed watershed includes a large commercial area (including the Southdale Shopping Center and Fairview Southdale Hospital), portions of Highway 62 and Highway 100, residential areas (high and low density), and Rosland Park. Most of the runoff from the highly impervious commercial area drains through a series of waterbodies (i.e., Point of France Pond and Swimming Pool Pond) prior to reaching North Cornelia. In addition to flows from North Cornelia, South Cornelia receives runoff from a relatively small, residential watershed (112 acres).

2.1.3 Lake Cornelia Water Quality

Water quality in Lake Cornelia is poor, with summer-average total phosphorus and chlorophyll *a* concentrations well above the state standard for shallow lakes (Figure 2-2). The poor water quality is primarily due to excess phosphorus in the lake, which fuels algal growth and decreases water clarity (Figure 2-3). The phosphorus in Lake Cornelia comes from several sources, including stormwater runoff from the watershed (external source) and internal sources such as nutrient-rich sediments and decomposition of curly-leaf pondweed. Fish activity, specifically the disruption caused by bottom-feeding species such as bullhead, carp and goldfish, may also be decreasing water clarity. Additional information around these sources of phosphorus in Lake Cornelia can be found in the 2019 water quality study (Reference (1)).

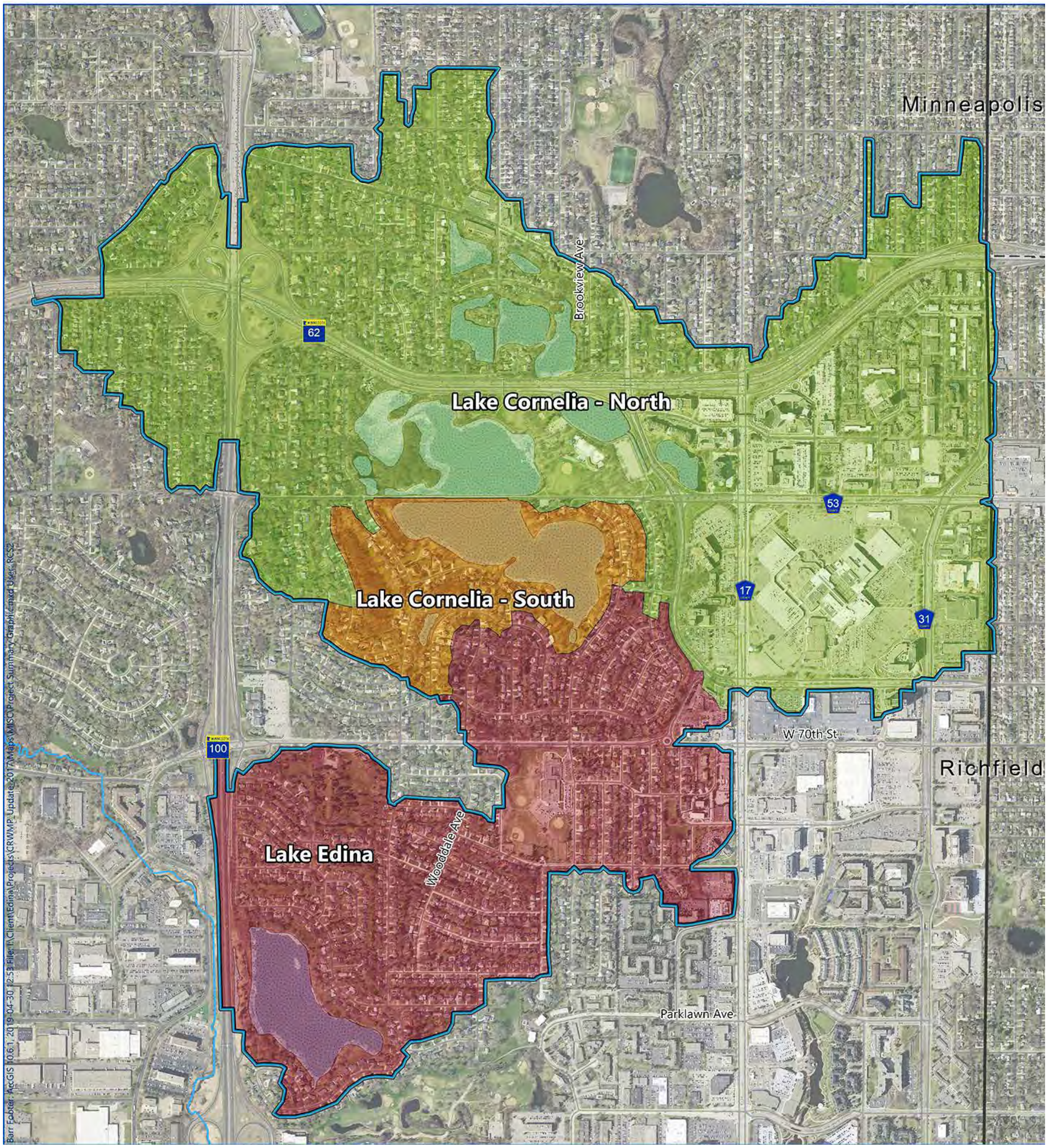


Figure 2-1 Lake Cornelia and Lake Edina Watersheds

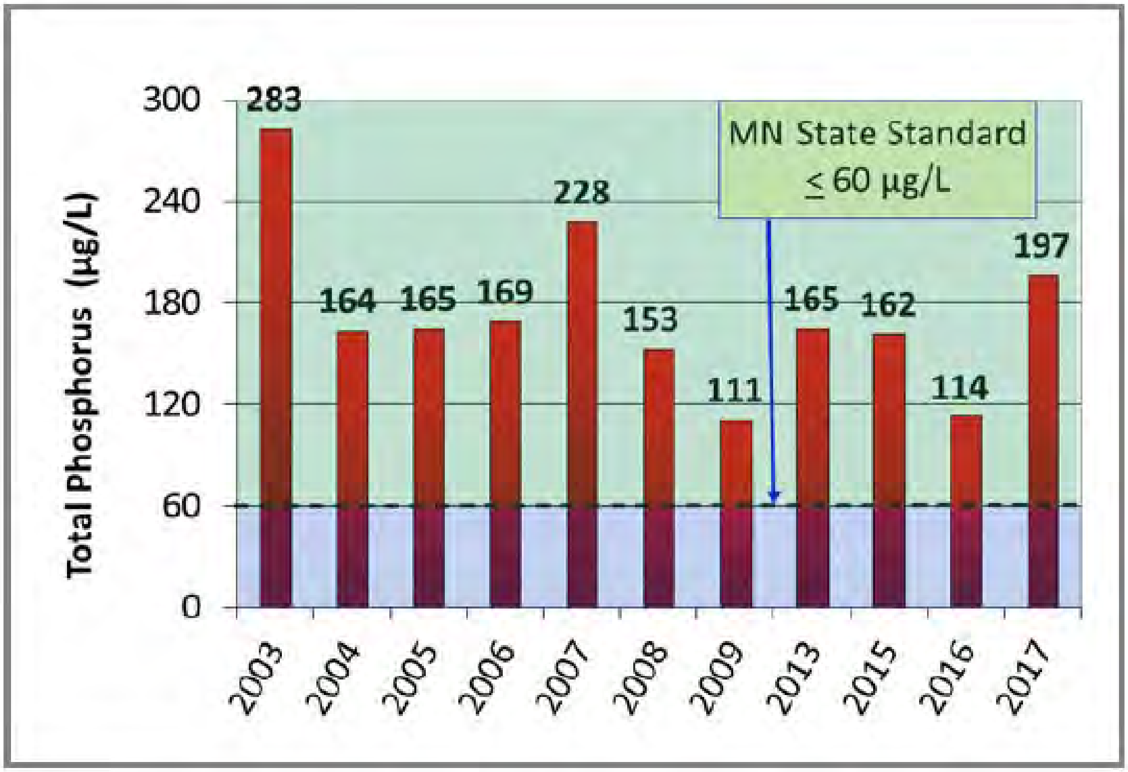


Figure 2-2 **Summer average phosphorus concentrations in Lake Cornelia (North Basin) have historically been well above the state standard for shallow lakes**

Figure 2-3 **Photos of Blue-green Algae in Lake Cornelia (North Basin) (2017)**

2.2 Lake Edina

2.2.1 Lake Edina and Watershed Characteristics

Lake Edina is a shallow, 25-acre lake with a maximum depth of 5 feet and a mean depth of approximately 3 feet. The Lake Edina watershed encompasses approximately 400 acres (Figure 2-1). Land use within the watershed is primarily low-density residential, with smaller portions of high-density residential, commercial, institutional (Cornelia Elementary School), and park.

2.2.2 Lake Edina Water Quality

Water quality in Lake Edina, located downstream of Lake Cornelia, is also poor, with summer-average total phosphorus and chlorophyll *a* concentration generally not meeting the state standard for shallow lakes (Figure 2-4).

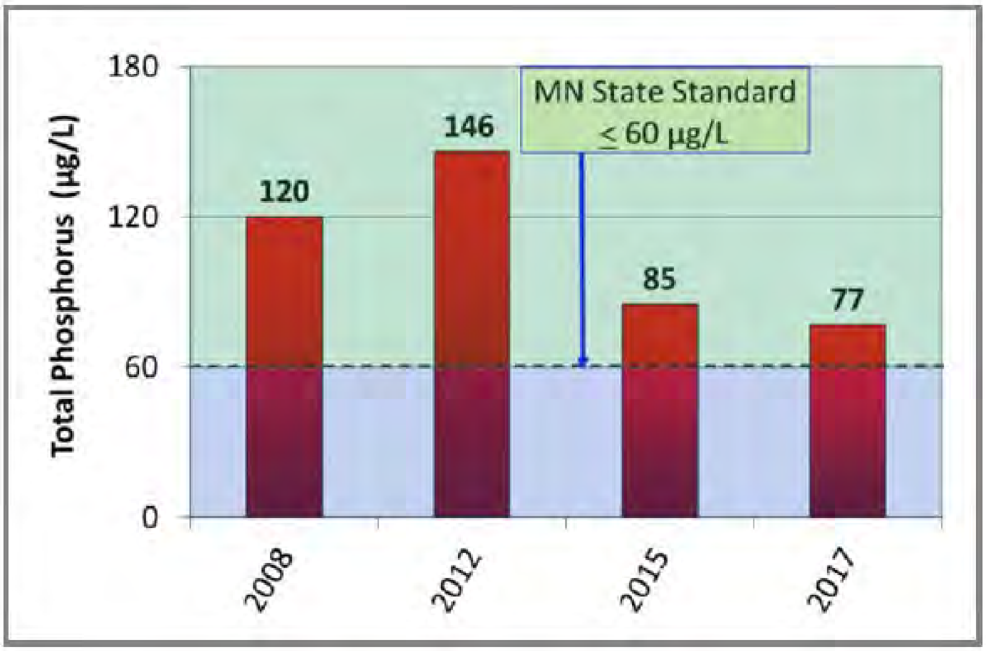


Figure 2-4 Summer average phosphorus concentrations in Lake Edina have historically been above the state standard for shallow lakes

The poor water quality is primarily due to excess phosphorus in the lake, which fuels algal production and decreases water clarity. Phosphorus in Lake Edina comes from several primary sources, including stormwater runoff from the watershed and flows from upstream Lake Cornelia. Curly-leaf pondweed has been observed at low levels in Lake Edina in recent years, but was not observed in spring of 2020.

Water quality in Lake Edina is highly influenced by the water quality of Lake Cornelia. While this report primarily evaluates management strategies and recommendations for Lake Cornelia, associated watershed-level improvements are expected to yield some level of indirect water quality benefit to Lake Edina.

3 Summary of Evaluated Management Practices

The goals of this project are to evaluate the feasibility and cost effectiveness of the management strategies recommended by the 2019 Use Attainability Analysis (UAA) study to help improve Lake Cornelia and Lake Edina water quality, including:

- Stormwater treatment system in Rosland Park to remove additional phosphorus from stormwater flowing through Swimming Pool Pond prior to discharge into Lake Cornelia;
- Other watershed management best management practices (BMPs), including stormwater retrofit BMPs in the Lake Edina watershed and opportunities for treatment of upstream ponds
- Curly-leaf pondweed management in Lake Cornelia;
- Installation of a winter aeration system in Lake Cornelia to minimize winter kill of predator fish and reduce recruitment of bottom-feeding fish; and
- Other fishery management strategies, including potential stocking of predator fish and removal of goldfish and other bottom-feeding fish in Lake Cornelia and upstream hydraulically-connected waterbodies.

One of the recommendations of the 2019 water quality study, conducting an alum treatment of Lake Cornelia to minimize release of phosphorus from lake-bottom sediments, was completed by NMCWD in the spring of 2020. The objective of this preliminary engineering study is to evaluate the feasibility of the other recommended management activities for Lake Cornelia and Lake Edina. The following sections of the report summarize the findings of the feasibility evaluation and recommendations for lake and watershed management practices:

- Section 4 Stormwater Treatment in Rosland Park
- Section 5 Other Watershed BMPs
- Section 6 Curly-leaf Pondweed Management
- Section 7 Fishery Management
- Section 8 Conclusions and Recommendations

4 Stormwater Treatment in Rosland Park

The 2019 water quality study concluded that stormwater runoff is a major contributor of phosphorus to Lake Cornelia, representing 48% to 76% of contributions to North Cornelia in modeled years. The study recommended implementation of a stormwater BMP located in Rosland Park to remove phosphorus from water flowing from the Swimming Pool Pond to North Lake Cornelia. Swimming Pool Pond (DNR wetland 679W) receives runoff from approximately 410 acres, which represents approximately 47% of the total area tributary to North Lake Cornelia (Figure 4-1).

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

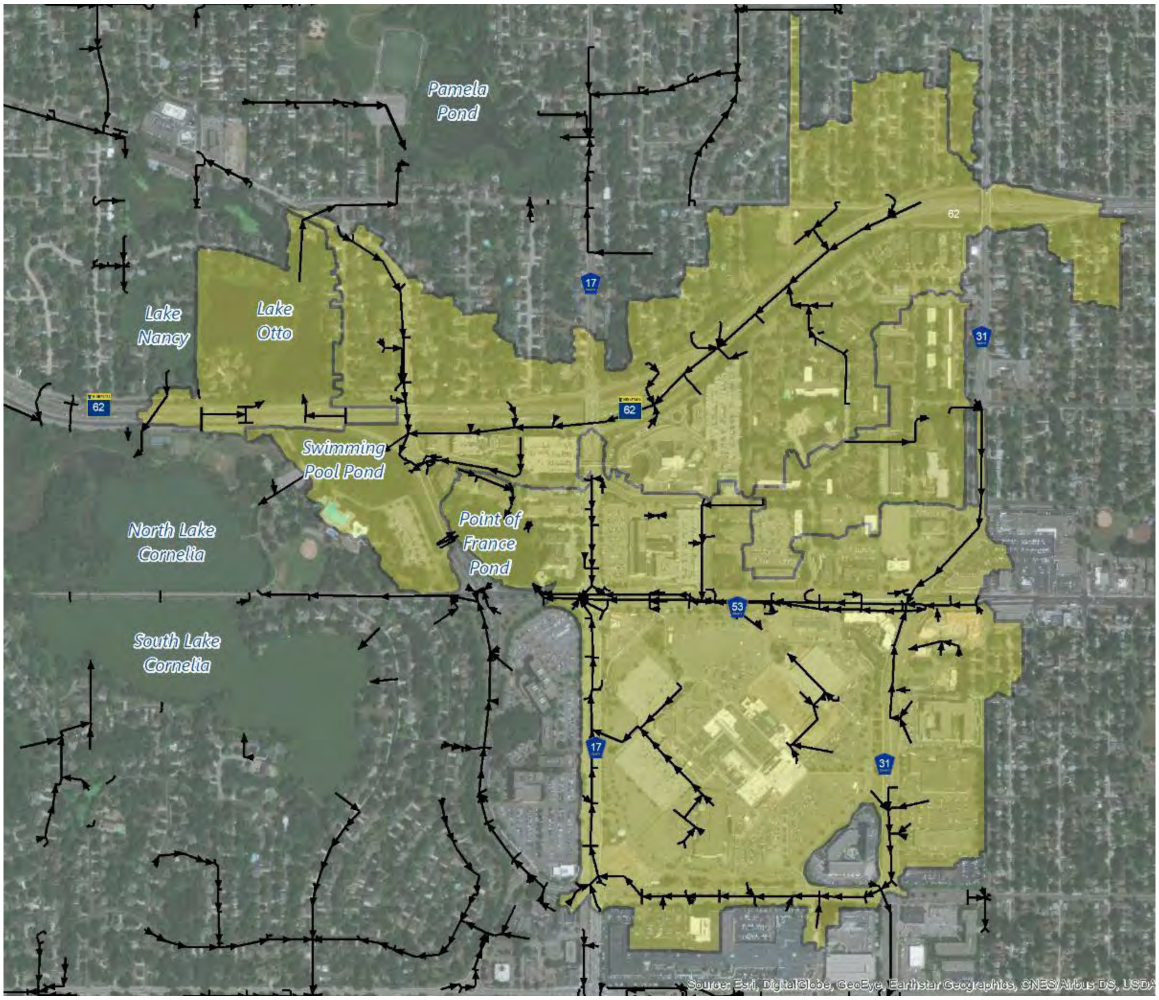


Figure 4-1 Runoff from approximately 410-acres, shown in yellow, flows through Swimming Pool Pond

4.1 Conceptual Design Options

Three high-level stormwater management concepts for a BMP at Rosland Park were developed and presented to NMCWD, City of Edina, and Edina Parks and Recreation Commission staff throughout a series of meetings in fall 2019. Throughout these meetings, the preliminary concepts were modified to match the visions and constraints of the various stakeholders involved.

Initially, two BMP design concepts were developed for consideration by NMCWD and City of Edina staff. Concept #1 was a subsurface filtration treatment vault located under the existing parking lot between Swimming Pool Pond and North Cornelia, similar to the BMP evaluated as part of the 2019 water quality study. Concept #2 was a “stream-like” series of small, shallow surface filtration basins within the nearby green space at the park, with water from Swimming Pool Pond being pumped to the upstream end of the chain of BMPs. Preliminary presentation of this concept incorporated solar energy generation to power the pump. Based on feedback obtained from NMCWD and City of Edina staff, Concept #2 was revised to include a pump-driven filtration treatment vault located at the edge of the North Parking lot, instead of the “stream-like” series of small filtration basins. In this revised option (Concept #3), water would be pumped from Swimming Pool Pond into an above-ground treatment vault, with the pump potentially powered (or offset) by solar energy generation. After passing through the filtration system, treated water would be discharged to Lake Cornelia. Concept #3 reflects the City’s desire to minimize the BMP footprint and associated impacts on current or future park use.

At a November 20, 2019, meeting with NMCWD and City of Edina Staff, Concept #3 was identified as the preferred stormwater feature concept. The above-ground filtration vault design would allow for more design flexibility and increased treatment capacity, would simplify operation and maintenance of the filtration system, would minimize parkland impacts, and would provide an opportunity to incorporate public art or education into the feature to make the system not only a functional means of reducing phosphorus to Lake Cornelia, but an attractive element of the park as well.

The stormwater treatment concepts, including the preferred Concept #3, were presented to the Edina Parks and Recreation Commission on December 10, 2019, and the NMCWD board of managers on December 18, 2019. At that meeting, the NMCWD board of managers approved moving forward with Concept #3. A copy of the December 18, 2019, presentation is included as Appendix A.

4.2 Feasibility Analysis/Preliminary Design

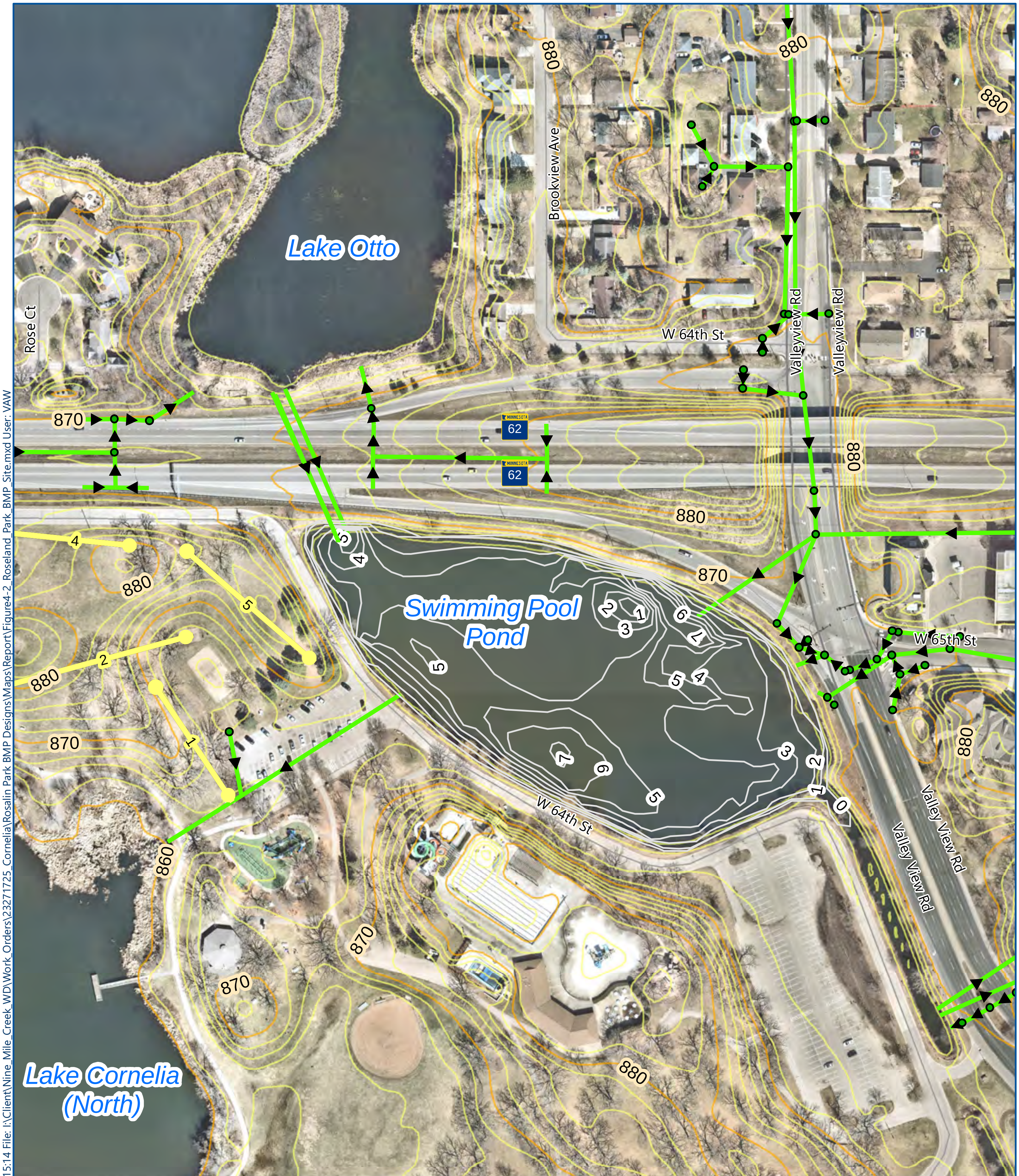
Following direction from NMCWD and the City of Edina, feasibility analysis and preliminary design for the proposed filtration vault (Concept #3) began in late-December 2019. Feasibility analysis included performing a site characterization and developing a hydraulics analysis using XPSWMM. The preliminary design phase included developing filtration media recommendations and further defining the filtration vault sizing, height, flow regime, and pumping regime. Each of these phases are discussed in detail in the subsequent sections.

4.2.1 Site Characterization

Site characterization for the proposed filtration vault in Rosland Park included a review of geographic information systems (GIS) data to understand the existing topography, soil conditions, park features, existing storm sewer upstream and downstream of Swimming Pool Pond, and Swimming Pool Pond bathymetry. Figure 4-2 shows several existing site features, including topography, storm sewer, and bathymetry for Swimming Pool Pond. The topographic information shown in the figure is based on Minnesota Department of Natural Resources (MnDNR) light detection and ranging (LiDAR) data developed in 2011. Storm sewer information (e.g., diameters, invert elevations, etc.) were obtained from the City of Edina. Bathymetry information for the water bodies surrounding Rosland Park, including Swimming Pool Pond, North Cornelia, and Point of France Pond, were also provided by the City of Edina. Bathymetric information for Lake Otto was collected by NMCWD as part of this study.

Existing soil information within Rosland Park is limited; soils in this area do not have a Natural Resources Conservation Service (NRCS) hydrologic soil group (HSG) classification designated. Given that much of the area around Lake Cornelia was part of a large wetland complex prior to develop in the 1960s 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 stability for construction.

Review of existing park infrastructure and vegetation was another important aspect of site characterization, as it was important to site the filtration treatment vault in a location that minimizes park impacts. Figure 4-2 shows the existing park features in the proposed project area, including detailed aerial imagery and locations of several existing disc golf course holes. Nearmap imagery was used for this analysis. The most recently available satellite imagery of the project area is from April 5, 2020, and has 3-inch resolution, which allowed for detailed review of the park features.



● Storm Manhole
Storm Sewer
Disc Golf Course
Pond Bathymetry (Depth)

2 Foot Contours, 2011
10-Foot Contour
2-Foot Contour

N

200 100 0 200 Feet

Rosland Park BMP
Site Characterization
Lake Cornelia and Lake Edina
Water Quality Improvement Project
Edina, Minnesota

FIGURE 4-2

4.2.1.1 Swimming Pool Pond Outlet Structure

Discharge from Swimming Pool Pond is controlled by an outlet structure located on the west side of the pond near the parking lot for the disc golf course and playground (see Figure 4-2). The outlet structure, constructed in the mid-1960s, controls the water level at elevation 862.9 feet. Original construction drawings of the Swimming Pool Pond outlet structure indicate flow capacity is restricted within the structure by a 10-inch steel pipe with a 3-¾" orifice opening. City of Edina staff conducted a field investigation to confirm the configuration of the Swimming Pool Pond outlet in April 2020 and found that the existing metal plate with a 3-¾" orifice appears to have been removed at some point in the past as the orifice plate restricting flows into the 10" steel pipe was not visible during the site visit. Therefore, discharge from Swimming Pool Pond appears to now be controlled by a 10" steel pipe rather than a 3-¾" orifice. The storm sewer pipe between the outlet structure and North Lake Cornelia is an 18-inch reinforced concrete pipe (RCP).

4.2.1.2 Lake Otto Outlet

Lake Otto (MnDNR wetland 678W) is located just north of Trunk Highway 62, is connected to Swimming Pool Pond via two 60-inch diameter corrugated metal pipes (CMP). Although detailed information on these pipes is not available, a site visit confirmed that the pipes are both fully submerged below the normal water elevation, therefore acting as equalizer pipes between Lake Otto and Swimming Pool Pond. The two 60-inch diameter storm pipes are believed to be owned by the Minnesota Department of Transportation (MnDOT).

4.2.1.3 Point of France Pond Outlet Structure

Point of France Pond (MnDNR wetland 680W) is located southeast of Swimming Pool Pond on the east side of Valley View Drive and north of West 69th Street. Water levels in this pond are controlled at 863.4 feet by two 60-inch wide weir structures that were installed in the mid-2000s as part of a pond dredging and improvement project conducted by the City of Edina. The weir structures tie into two existing 66-inch CMP. With the reconfiguration of the Point of France outlet structure, water levels in Point of France Pond are controlled independently of water levels in Swimming Pool Pond.

4.2.1.4 Water Quality in Swimming Pool Pond

In 2018, University of Minnesota researchers partnered with the City of Edina and NMCWD to conduct a pilot study in Swimming Pool and Point of France Ponds to assess the effectiveness of applying iron filings to pond sediments to reduce the release of phosphorus from the sediments. The first step of the pilot study was to assess the extent of sediment phosphorus release occurring to determine if the waterbodies were good candidates for the proposed iron filings. In March 2019, the University of Minnesota researchers published their findings indicating that minimal internal phosphorus release was occurring in Swimming Pool Pond and Point of France Pond (Reference (3)).

The 2019 University of Minnesota report, included as Appendix B, was reviewed and used to better understand existing water quality in Swimming Pool Pond. Water quality samples were taken at six locations throughout Swimming Pool Pond from May through September 2018 in the epilimnion (surface layer) and hypolimnion (bottom layer). Samples were analyzed for total phosphorus (TP), total dissolved phosphorus (TDP), and soluble reactive phosphorus (SRP). TP represents all phosphorus fractions measured in the sample, whether particulate or dissolved. TDP represents the fraction of phosphorus that filters through a 0.45 micron pore size filter (organic and inorganic). SRP represents the readily bioavailable inorganic form of phosphorus (PO_4^{3-}), sometimes also referred to as orthophosphate. This water quality data helped to characterize the phosphorus loading that will be treated in filtration vault.

Table 4-1 provides a summary of the water quality data obtained at the six sampling sites. The sampling data generally shows that the TP concentrations in Swimming Pool Pond can range widely throughout the year. Within the epilimnion, the maximum TP concentration measured of 181 µg/L (August 22, Site 3) was 134 µg/L greater than the lowest TP concentration measured (May 16, Site 6). The observed percent fraction of TP that was either TDP or SRP also ranged quite substantially between sampling events.

Table 4-1 Summary of Water Quality Data for Swimming Pool Pond from May through September 2018[1]

Sampling Location	Average TP (Range) (µg/L)	Average TDP (Range) (µg/L)	Average SRP (Range) (µg/L)	Average %TDP (Range)	Average %SRP (Range)
Epilimnion	95 (47–181)	33 (6–58)	13 (1–30)	37% (9%–80%)	15% (1%–36%)
Hypolimnion	100 (67–152)	32 (6–51)	15 (1–23)	33% (8%–52%)	18% (1%–28%)

[1]Data summarized from Appendix B of *Assessment of Internal Phosphorus Loading in Swimming Pool Pond and Point of France Pond, City of Edina* (Reference (3)).

Figure 4-3 summarizes measured phosphorus concentrations in the epilimnion from one of the sampling sites (Site 3). The green points represent the grab sample TP measurements that were taken. The orange and purple points show the percent of the sample that was measured as TDP and SRP, respectively. This data indicates that the TP concentrations generally increased in the late summer and early fall. As the TP concentrations increased, a decrease in the percent of the sample that was TDP and SRP was observed. This indicates that a higher percentage of the sample was particulate rather than dissolved phosphorus in the late summer and early fall. The increase in particulate fraction is likely due to an increase in algal growth at the end of the growing season. Conversely, at the start of the sampling period, the TP concentrations are lower and a higher percentage of the sample is dissolved phosphorus. This wide range of concentrations and fractions of phosphorus throughout the growing season observed in Swimming Pool Pond help inform design decisions for the proposed filtration vault.

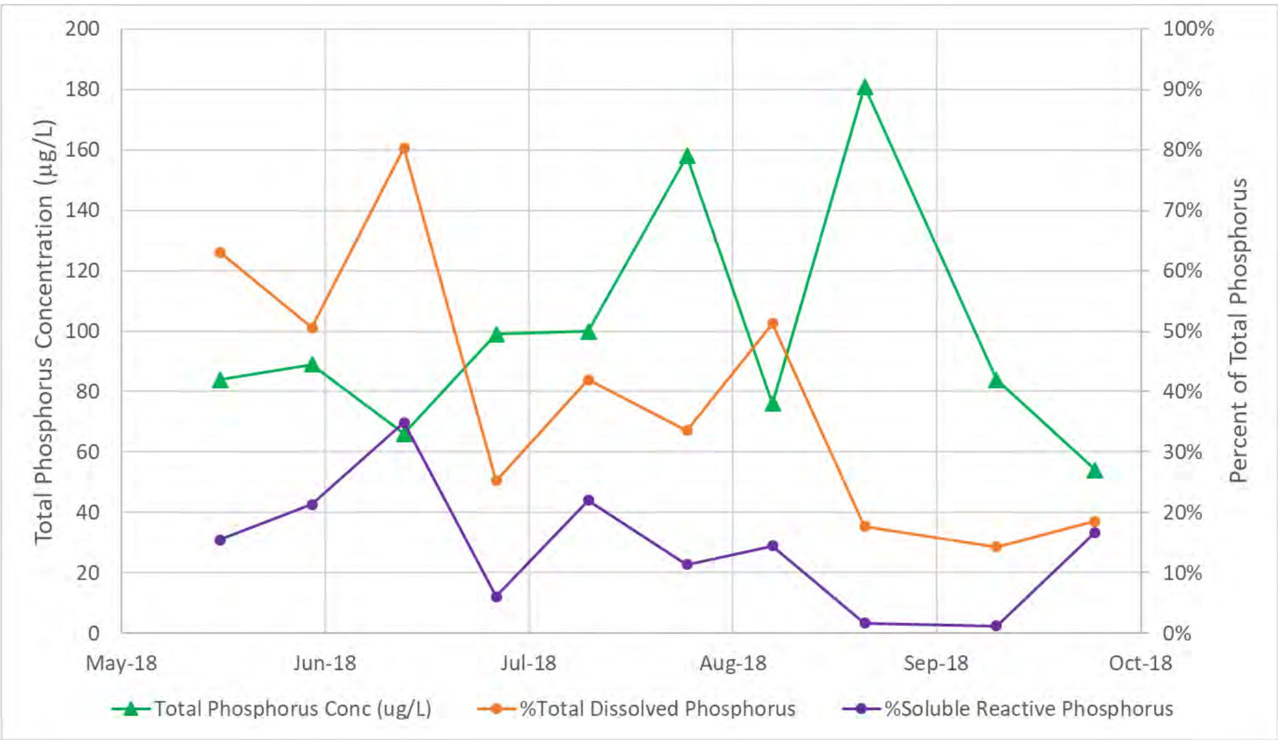


Figure 4-3 Swimming Pool Pond Sampling Site 3 (Epilimnion) TP Concentrations and Percent TDP and SRP over time

4.2.2 Design Considerations

A number of design factors were considered during preliminary design including:

- Size and aesthetics of filtration vault system
- Treatment pumping rate;
- Daily and annual treatment (pumping) duration;
- Pumped drawdown depths of Swimming Pool Pond and Lake Otto;
- Pollutant removal effectiveness (selection of treatment media); and
- Operations and maintenance

These design factors are discussed in detail in the following subsections.

4.2.2.1 Filtration Vault Size and Aesthetics

Figure 4-4 shows the location of the proposed filtration vault system in relation to Swimming Pool Pond and the nearby parking lot. Feedback during conceptual design indicated a preference to minimize the size and impacts to open space usage in the park; the filtration vault footprint has been optimized to meet these preferences. The preliminary filtration vault design assumes the footprint of the filtration vault is approximately 1,200 square feet (100 feet wide by 12 feet deep), similar to Concept #3 developed during the conceptual design phase.

Figure 4-4 Location of the Proposed Filtration Vault System in Rosland Park

Due to the prominent size of the filtration vault and it location within the park (adjacent to the parking lot), the aesthetics of the BMP are an important consideration. Several renderings were developed to show potential design variations that would create a visually-appealing park amenity (see Figure 4-5 through Figure 4-8). Details of the aesthetics will be determined as part of final design. Suggestions of incorporating park signage, public art, and/or educational signage or features into the final design have been discussed.

Figure 4-5 Rendering showing the approximate size and location of the concrete filtration vault with limestone facing on vault walls

Figure 4-6 Rendering showing the concrete filtration vault with partially-buried vault walls and a low limestone wall

Figure 4-7 Rendering showing the concrete filtration vault with tiered wall planted with shrubs and flowering plants

Figure 4-8 Rendering showing the concrete filtration vault with tiered wall planted with native grasses

4.2.2.2 Treatment Pumping Rate

Because the proposed filtration vault at Rosland Park is above ground and higher in elevation than water levels in Swimming Pool Pond, a gravity-driven system is not feasible and a pump will be necessary to convey water from the pond to the treatment vault. The pumping rate selected to treat water from Swimming Pool Pond is dependent on BMP size, cost, and filtration rate/capacity of the selected filtration media. A treatment flow rate of 1.0 cubic feet per second (cfs) was selected for preliminary design as it meets the initial criteria. A 4 to 5 horsepower (HP) pump is required to meet this flow rate. During detailed design, flowrates can be optimized to analyze the effectiveness of a variable pump, which allows flowrates to be adjusted for climatic conditions and optimized to match the media filtration rate throughout the media life.

4.2.2.3 Daily and Annual Treatment Duration

The daily and annual pumping duration impacts the volume of water passed through the proposed filtration vault and also impacts the pollutant removal effectiveness and the life of the filtration media. Treating a larger volume of water must be balanced with media treatment potential. Some filtration media have limitations pertaining to the duration of inundation. For example, if spent lime is exposed to longer inundation periods, the material can lose stability and its useful life is reduced. If iron-enhanced sand or iron fillings are exposed to longer inundation periods, phosphate that was previously captured by the media can be released when oxygen levels are too low. To improve media pollutant removal effectiveness, inundation periods of no longer than 12 hours per day for the filtration vault are recommended. Two daily pumping regimes are currently being considered: (1) 12 hours pump on, 12 hours pump off and (2) 2 hours pump on, 2 hours pump off throughout the course of 24 hours. Daily pumping duration can be optimized in the field after installation.

The proposed annual treatment duration is from April 15 through November 15. The annual treatment duration may need to be modified each year based on the onset of freezing temperatures.

4.2.2.4 Pumped Drawdown Depths of Swimming Pool Pond and Lake Otto

Operation of the proposed pump will be dependent on water levels in Swimming Pool Pond; the pump will operate when water levels are higher than or slightly below the control elevation. There are a number of factors to consider when selecting a draw down depth, including:

- Optimization of volume treated (the greater the depth pumped, the greater the treatment volume);
- Permitting requirements;
- Impacts to riparian land owners, including Lake Otto residential properties; and
- Impacts to riparian habitat areas

The depth of drawdown below the control elevation of Swimming Pool Pond (and Lake Otto) was given much consideration as part of this feasibility and preliminary design analysis, with a goal of balancing maximizing the volume of water pumped to the filtration system with minimizing impacts of pumping on riparian land owners riparian of Swimming Pool Pond and Lake Otto. A hydraulic modeling analysis was conducted to help determine how much water would be treated under various pumping scenarios and what impacts the pumping scenarios would have on water levels. Pumping scenarios included evaluation of pumped drawdown depths of 3 inches and 6 inches. A pumping scenario that isolates Lake Otto from Swimming Pool Pond by constructing a weir at the Lake Otto outlet was also considered; however, considerable construction constraints and associated costs make this option undesirable.

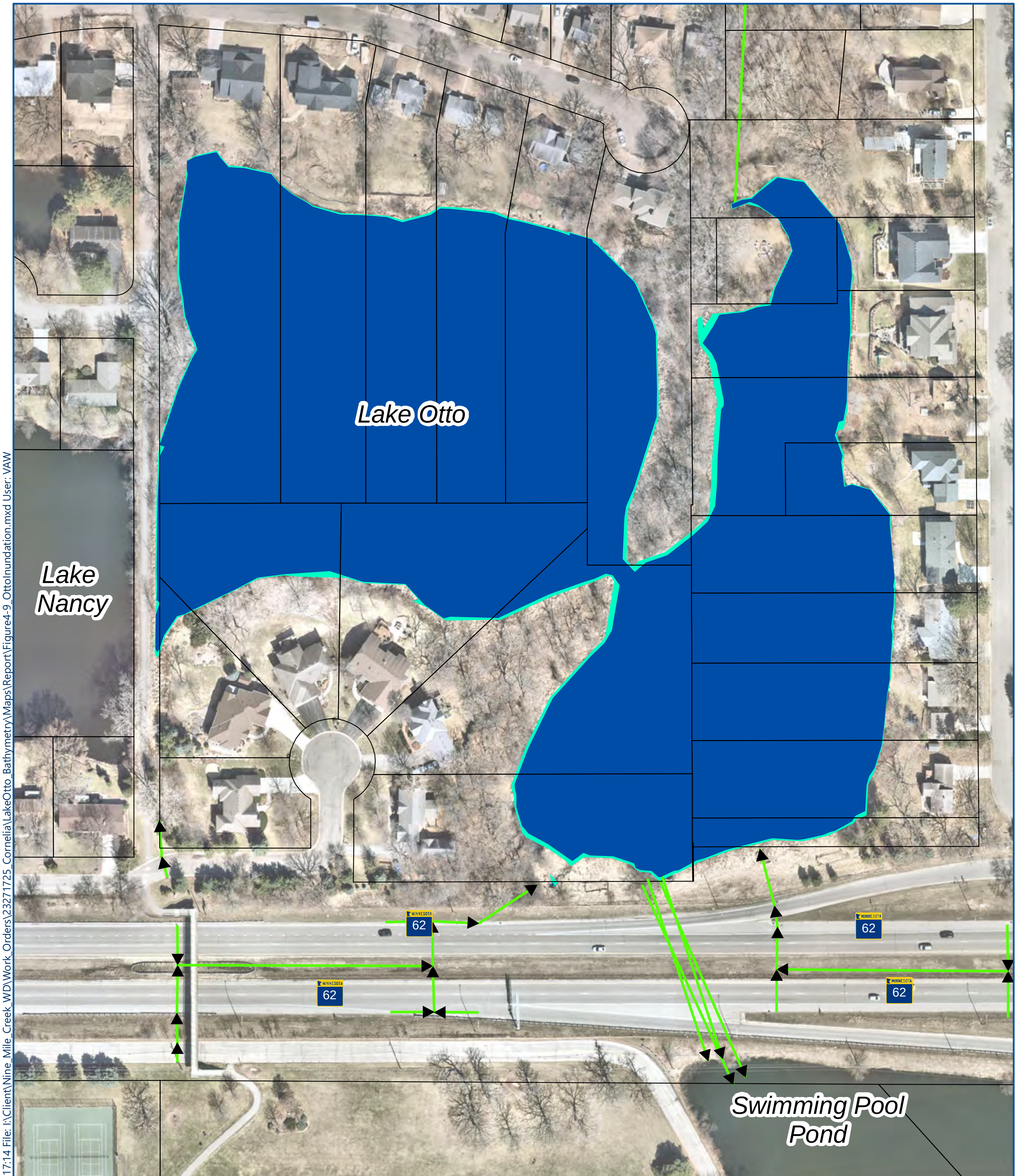
Based on results of the modeling analysis and communication with NMCWD and City of Edina staff, the recommended pump draw down depth is 3.6 inches (0.3 feet) below the control elevation of 862.9 feet. Under this scenario, the pump would turn off when water levels in Swimming Pool Pond reach 0.3 feet below the control elevation. Figure 4-9 compares the inundation extents of Lake Otto when water levels are at the control elevation and when they are 3.6 inches lower. Additional information on the hydraulic modeling analysis is included as Appendix C.

As summarized in Table 4-2, the amount of water pumped to the proposed filtration vault on an average annual basis under the 3.6 inch drawdown scenario is 108 acre-feet per year. This treatment volume represents approximately 52% of the flow between Swimming Pool Pond and North Cornelia, on average. The volume of water treated by the proposed BMP will vary year-to-year, depending on climatic conditions; model results based on 35-years of precipitation data indicate the annual volume of water treated will range from 60 to 130 acre-feet.

Table 4-2 Summary of Amount of Water Pumped/Treated by Proposed Filtration Vault

Scenario	Average Annual Pumped Volume (ac-ft)[1]	Range Annual Pumped Volume (ac-ft)[1]	% of Discharge from Swimming Pool Pond Treated
Pump turns off when 3.6 inches below normal water level	108	61–143	52%

[1] Treatment season is April 15 through November 15.



Lake Otto Inundation Extents Comparison
Lake Cornelia and Lake Edina Water Quality Improvement Project
Edina, Minnesota

FIGURE 4-9

Results from the 35-year hydraulic modeling analysis also were used to evaluate potential impacts on water levels in Swimming Pool Pond and Lake Otto under various pumping scenarios. Water level fluctuations in these waterbodies are typical, with water being higher than the control elevation following rain or snowmelt events and water being lower than the control elevation during dry periods due to evaporation and/or interaction with groundwater. However, some additional water level fluctuation will occur with the proposed pumping at Swimming Pool Pond. Table 4-3 compares the estimated frequency of lowered water levels under existing conditions and the recommended 3.6-inch pumping depth scenario for Swimming Pool Pond and Lake Otto.

Table 4-3 Summary of Water Level Fluctuation in Swimming Pool Pond and Lake Otto under Recommended Pumping Scenario

Scenario	Average days/treatment period[1] Swimming Pool Pond and Lake Otto greater than 3 inches below existing NWL	Average days/treatment period[1] Swimming Pool Pond and Lake Otto greater than six inches below existing NWL
Existing conditions	25 (12%)	5 (3%)
Pump turns off when 3.6 inches below normal water level	108 (50%)	13 (6%)

[1] Treatment season is April 15 through November 15.

4.2.2.5 Filtration Media Selection and Pollutant Removal Effectiveness

A three-chamber filtration vault is proposed to test three different filtration treatment media types, with a goal of assessing and ultimately using the media that most effectively removes phosphorus. Figure 4-10 shows a plan view of the proposed treatment vault, with each treatment media chamber approximately 35 feet long, 12 feet wide, and 3 feet deep. These dimensions are anticipated to allow for sufficient contact time of the treatment media for pollutant removal.

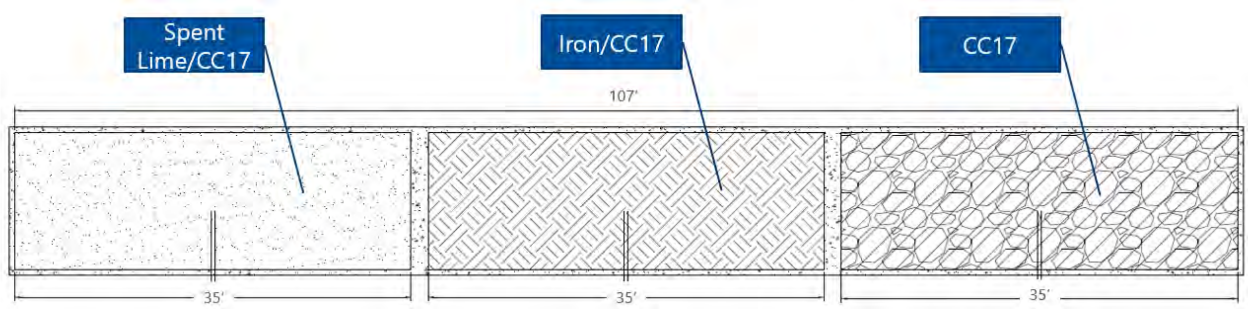


Figure 4-10 Plan View of Three-Chamber Filtration Vault

Figure 4-10 identifies three different filtration media that are recommended for use in the proposed filtration vault: CC17, a spent lime and CC17 combination (they are separate layers in the cell), and an iron and CC17 combination. Swimming Pool Pond receives stormwater from an approximately 410-acre watershed. As the runoff flows through Swimming Pool Pond, most of the large sized solids and attached phosphorus particles are removed through sedimentation; hence the solids and phosphorus particles that leave Swimming Pool Pond are small. It is important that the media used in the filtration vault be able to filter these small solids and phosphorus particles. All of the recommended media have this filtration capacity.

CC17 Filtration Media

CC17 is a crushed limestone ($CaCO_3$) material that has greater solubility than most limestone materials. The CC17 media acts primarily as a filter. This media can remove particulate phosphorus (the small and large particles) and a limited amount of dissolved phosphorus. This media will serve as a control to determine what phosphorus mass can be removed by simple filtration. However, the benefit of this media is that it has high hydraulic conductivity (e.g., it can filter a lot of water) and can filter a significant amount of water with a limited footprint.

Spent Lime + CC17 Filtration Media

Spent lime is a waste byproduct of drinking water treatment and consists of newly precipitated and consolidated calcium carbonate. Spent lime is similar to the other media in that it filters solids and particulate phosphorus, however, it also removes dissolved phosphorus (ortho-P or $PO_{4,,}$ also known as SRP) by raising the pH of the treated water thereby causing the precipitation of calcium phosphate ($CaPO_4$). The main benefit of spent lime is that it has very high hydraulic conductivity and can treat large volumes of water. Spent lime is also a waste material and this provides a beneficial reuse of this material. The CC17 media would be added to the bottom of the filter bed to capture small particulate phosphorus particles.

Iron-enhanced CC17 Filtration Media

Because sand has a low hydraulic conductivity relative to the other filtration media considered, it is not recommended for use in the filtration vault (the footprint of a sand filter at this site would need to be approximately 10 times larger to achieve similar treatment benefits). Instead of iron-enhanced sand filtration, we are proposing to test an iron-enhanced-CC17 filtration media. This filter media should have significantly higher treatment capacity than iron-enhanced sand and be able to remove dissolved phosphorus. Iron actively binds organics, solids, and dissolved phosphorus which is often referred to as ortho-P (the resultant iron and phosphate compound is $FePO_4$).

Table 4-4 summarizes the phosphorus removal estimates for each of the evaluated filtration media. The table also summarizes filtration rates, necessary contact time, and required filtration vault sizing based on these parameters for each of the evaluated filter media. The removal efficiency values are based upon small and large scale test systems designed and evaluated by Barr on other projects. The filtration rates were either examined in the field or estimated from literature values.

Prior to design and construction, it is recommended that testing of the proposed filtration media be considered, including evaluating the hydraulic conductivity of the CC17 and iron-enhanced CC17 media and conducting bench scale testing of the media for phosphorus removal effectiveness.

Table 4-4 Summary of Evaluated Filtration Media

Filtration Media	Total Phosphorus Removal Estimate (range)	Approximately Filtration Rate (feet/hour)	Estimated Required Contact Time (minutes)	Required Vault Size at 1.0 cfs Flow (feet^2)[1]
CC17 aggregate	45%	12 – 24	10 -20	<1,200
Spent lime	65% (8%–92%)	>24	10 – 20	<1,200
Iron-enhanced sand	80% (70%–92%)	0.33	<1	10,800
Iron-enhanced CC17 aggregate	80% (70%–92%)	6 – 12	<1	<1,200

[1] During the conceptual design phase, stakeholders determined that a vault size less than 1,200 ft^2 was preferred

4.2.2.6 Operations and Maintenance

Ease of operating and maintaining the filtration vault is paramount in ensuring long-term function of the BMP. The following filtration vault design features are proposed to assist with operations and maintenance:

- A lockable surface grate that can be lifted by hand to allow for easier maintenance. The entire grate can be removed to allow full access to filter media so it can be maintained and replaced by hand or with equipment.
- Valves on the filter discharge pipes to regulate flow through the filters to maximize treatment effectiveness.
- Visible filter discharge pipes so that flow rates from each of the treatment cells can easily be inspected. Little or no flow from the discharge points indicate the filters are plugged and need maintenance.
- Filter discharge pipes that are easy to access to allow for the easy collection of filtered water samples for testing.
- A variable-drive pump so that the treatment flow rate can be adjusted for climatic conditions or media filtration rate changes over the life of the media.

The anticipated maintenance requirements for the proposed filtration vault include:

- Removing accumulated debris from surface of the filter approximately two times per year, which will likely include manually removing/replacing the grate, raking the surface of the filter media, and removing debris with a vac truck.
- Replacing filter media every 2 or 3 years, which will likely include manually removing/replacing the grate, removing filter media with a vac truck, and disposing of the material (may require landfill disposal).
- Periodic pump station maintenance.

- Periodic maintenance of skimmer at pump intake.

4.2.3 Water Quality Benefits

The total phosphorus removal estimates for the three recommended treatment media (CC17, CC17/Spent Lime, Iron-enhanced CC17) and the modeled average annual treatment volume were used to estimate the average annual pounds of total phosphorus removed by the treatment vault. As described in Table 4-4, the estimated total phosphorus removal efficiency for CC17, CC17/Spent Lime, and Iron-enhanced CC17 are 45%, 65%, and 80%, respectively. Assuming that each media chamber is supplied with equal volumes of water from Swimming Pool Pond, the combined total phosphorus removal efficiency for the entire treatment vault is anticipated to be approximately 63%.

The TP loading to the treatment vault was estimated based on three years (2015, 2016, and 2017) of phosphorus loading results from the p8 water quality model developed for the 2019 UAA water quality study (Reference (1)). Based on the modeling results, the average total phosphorus concentration discharging from Swimming Pool Pond for the months of April through November was approximately 116 µg/L. This modeled concentration is slightly higher than the average TP concentration measured in Swimming Pool Pond in 2018 by the University of Minnesota (Reference (3)). Average TP concentrations measured from May through September were 95 and 100 µg/L in the epilimnion and hypolimnion, respectively. Comparing the monitoring dates to rainfall data from the Minneapolis Airport, only two of the samples were collected on days where precipitation was recorded at the airport, in which rainfall depths were less than 0.1 inches on both days. Therefore, it appears that larger spikes in total phosphorus concentrations from major runoff events are not captured in the University of Minnesota monitoring data (measurements of internal loading were the main focus of the study). The p8 model data represents an average of dry and wet weather conditions; therefore, an average TP concentration of 116 µg/L was used as the loading estimate to the treatment vault.

Table 4-5 summarizes the average annual volume of water pumped and associated total phosphorus removal estimate for the recommended pumping drawdown scenario. The average annual removal of 22 pounds of phosphorus from the filtration vault is anticipated. In the 2019 UAA for Lake Cornelia and Lake Edina, the average TP removal estimate for the Spent Lime/CC17 Vault from April through September was approximately 20 pounds, which resulted in an approximate decrease in the summer average TP concentration of North Cornelia by approximately 5 µg/L. Due to the similarity in estimated pounds of phosphorus removed for the feasibility-level designed three-chamber treatment vault, a similar reduction in TP concentration in North Cornelia can be expected with this design.

Table 4-5 Rosland Park Treatment Vault Total Phosphorus Removal Summary

Scenario	Average Annual Pumped Volume (Range) [ac-ft][1]	Average Total Phosphorus Load to Vault (Range) [pounds]	Total Phosphorus Removal Efficiency Estimate	Average Annual Total Phosphorus Removal (Range) [pounds]
Pump turns off when 3.6 inches below normal water level	108 (61–143)	34 (19–45)	63%	22 (12–28)

[1] Treatment season is April 15 through November 15.

4.2.4 Permitting

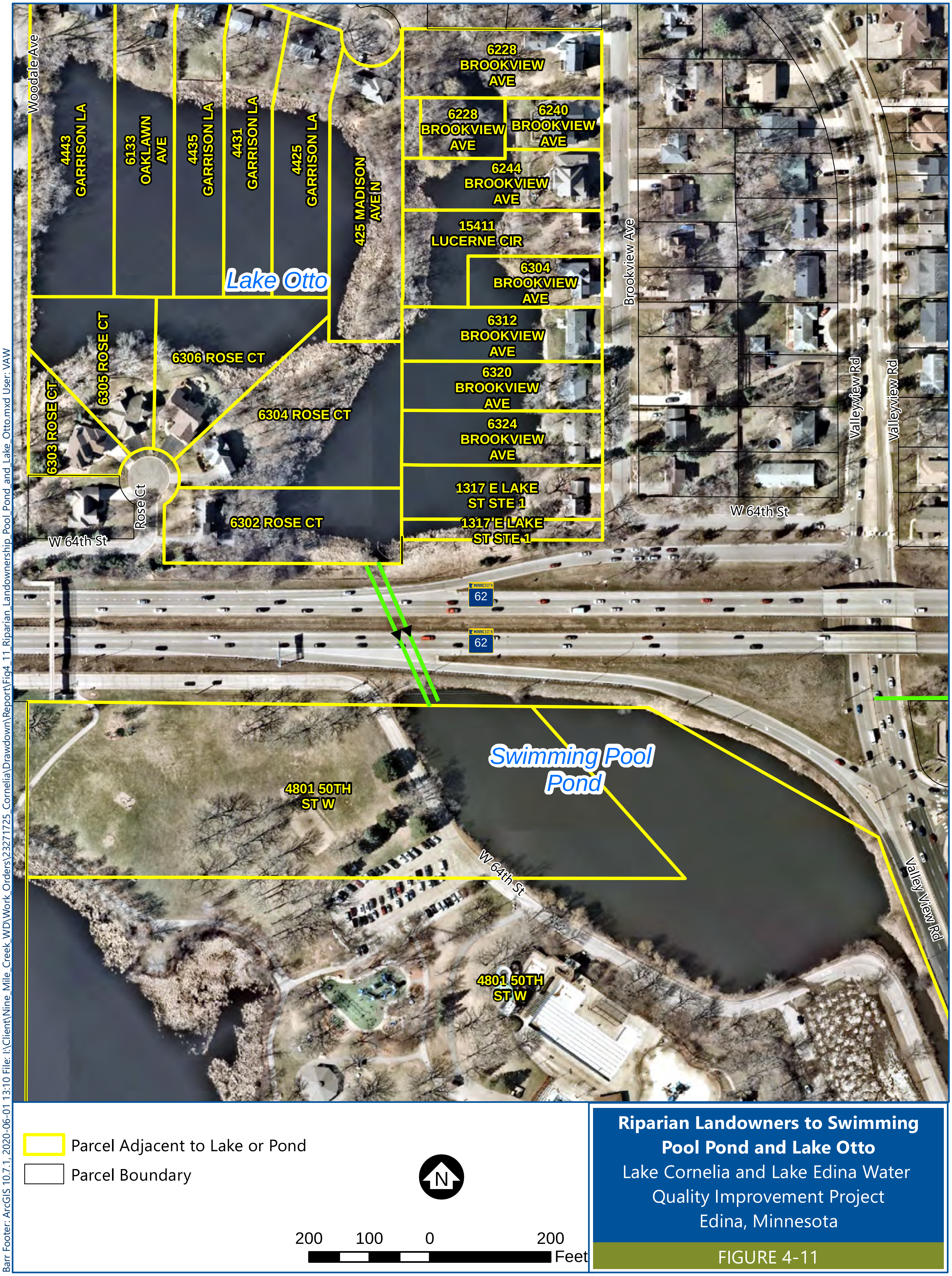
Based on preliminary discussions with staff from the MnDNR, the proposed pumping from Swimming Pool Pond will require a water appropriations permit. A Work in Public Waters permit could also be required, depending on the extent of proposed pumping draw down depth. Preliminary discussions with MnDNR staff indicated a Work in Public Waters permit would not be necessary if the pumping draw down depth is less than one half foot. Notification of impacted riparian landowners and an accounting of support will be required as part of the permitting process. Figure 4-11 shows the landowners riparian to Swimming Pool Pond and Lake Otto. Both of these permits have a permitting timeframe of 90–150 days and will include a 30-day public comment period.

It is not anticipated that a permit will be necessary from MPCA for the proposed filtration vault. However, discussion with MPCA staff regarding the proposed BMP and proposed filtration media is recommended prior to or early in the design process to confirm.

NMCWD will need to obtain the necessary rights to construct the proposed filtration vault on property owned by the City of Edina. It is anticipated that NMCWD and City of Edina will enter into a cooperative agreement upon ordering of the project. A permit for construction of the proposed filtration vault will also be required from NMCWD.

4.2.5 Opinion of Probable Cost

A feasibility-level design cost estimate was developed for the Rosland Park filtration vault and is shown Table 4-6. The opinion of probable cost provided generally corresponds to standards established by the Association for the Advancement of Cost Engineering (AACE). A class 3 feasibility-level opinion of cost was used based on the level of project definition (between 10% and 40%), wide-scale use of parametric models to calculate estimated costs (i.e., making extensive use of order-of-magnitude costs from similar projects), and uncertainty with an acceptable range of between -15% and +20% of the estimated project cost. A more detailed opinion of probable cost for the proposed filtration vault in Rosland Park is included in Appendix D.



Riparian Landowners to Swimming Pool Pond and Lake Otto

Lake Cornelia and Lake Edina Water Quality Improvement Project

Edina, Minnesota

FIGURE 4-11

Table 4-6 Rosland Park Treatment Vault Feasibility-Level Cost Estimates

Item Description	Estimated Cost
Mobilization/Demobilization (10%)	$40,000
Safety, Erosion Control, and Site Prep	$20,000
Pump Station - Complete	$110,000
Intake and Discharge Pipes, Manholes, and Appurtenances	$55,000
Stormwater Filter Vault and Filter Material - Complete	$200,000
Paving and Vegetation Restoration	$15,000
Contingency (30%)	$132,000
Construction Subtotal	**$572,000**
Engineering and Design (30%)	$172,000
Estimated Total Cost for Construction	**$744,000**
Low Range (-15%)	$632,000
High Range (+20%)	$892,000
+Public Art/Education	$50,000–$100,000

4.2.6 Cost-Benefit Analysis

The estimated annualized cost per pound TP removed is summarized in Table 4-7. This cost assumes an estimated annual operations and maintenance cost of approximately $11,000 for annual power costs, filter media adjustments approximately every 3 years, annual vac truck usage to removed debris and sediments, pump maintenance, and periodic skimmer maintenance.

Table 4-7 Rosland Park Treatment Vault Feasibility-Level Cost Estimates

BMP	Feasibility-Level Cost Estimate[1]	Feasibility-Level Cost Range (-15% - +20%)	Estimated Life of Project	Estimated Annualized Cost per Pound TP Removed
Rosland Park Treatment Vault	$744,000	$632,000–$892,000	30 years	$2,200

[1] Feasibility-level cost estimate does not include annual costs for operations and maintenance. Cost does include engineering and design estimate

[2] Feasibility-level estimated annualized cost per pound total phosphorus removed assumes an annual maintenance cost of approximately $11,000 and an inflation rate of 3%.

5 Other Watershed Best Management Practices (BMPs)

The 2019 UAA study for Lake Cornelia and Lake Edina confirmed that stormwater runoff is a major contributor of phosphorus to Lake Cornelia and Lake Edina. In North Cornelia, external phosphorus loading from the watershed ranged from 48% to 76% of annual phosphorus sources in modeled years (Reference (1)). For South Cornelia, the main contribution of phosphorus comes from North Cornelia; direct watershed phosphorus loading does contribute phosphorus, but to a much smaller extent than the other sources due to the relatively small size of the direct watershed (13% of the size of the direct watershed to North Cornelia). The two main sources of phosphorus loading to Lake Edina are the upstream lakes (North and South Cornelia) and the direct watershed runoff.

Reducing external phosphorus loading is an important part of any lake management strategy. For lakes like Lake Cornelia that have been exposed to significant external nutrient loadings for extended periods of time, appreciable sediment and nutrients have accumulated in the lake bottom sediments. As contributions from the watershed continue, phosphorus will continue to build-up over time in the lake sediments, increasing the internal loading potential and worsening water quality conditions in the lake.

The first Use Attainability Analysis for Lake Cornelia was developed by NMCWD in 2006, and revised in 2010 to reflect additional water quality monitoring data and evaluation of additional watershed Best Management Practices (BMPs). Similar to the conclusions of the 2019 UAA update, previous analyses indicated that while implementation of watershed BMPs can improve water quality in Lake Cornelia, there are no “silver bullets”. Significant improvements in lake water quality will require a combination of watershed and in-lake management practices.

As part of the 2019 UAA study, several watershed best management practices (BMPs) were evaluated to assess their effectiveness in reducing phosphorus loading to Lake Cornelia and Lake Edina. Numerous potential BMPs were considered, including review of the watershed BMPs evaluated as part of the previously-completed UAA. Criteria used in the evaluation included cost effectiveness, land availability, maximizing benefit to the Lake Cornelia and Lake Edina chain of lakes, dissolved phosphorus removal, and building on effectiveness of existing stormwater treatment systems. Ultimately, the stormwater treatment BMP in Rosland Park was recommended because it meets many of the target criteria, including the greatest predicted improvements per unit cost and availability of public land.

To expand on the evaluation conducted as part of the 2019 UAA, this study also included a high-level evaluation of other potential BMP opportunities to reduce watershed phosphorus loading to Lake Cornelia and Lake Edina. The sections below summarize the high-level evaluation of stormwater BMP retrofit opportunities in the Lake Edina watershed and discussion regarding opportunities for treatment in ponds upstream of Lake Cornelia.

5.1 Stormwater BMP Retrofit Opportunities in Lake Edina Watershed

Watershed runoff comprises a significant portion of the external phosphorus loading to Lake Edina, ranging from 35% to 45% of annual phosphorus sources in modeled years (Reference (1)). A high-level watershed analysis was conducted as part of this study to identify potential opportunities to implement stormwater BMPs in the Lake Edina watershed, with a focus on partnership projects on publicly-owned lands. Two properties were identified for potential to incorporate infiltration-based BMPs: Cornelia Elementary School, owned by Edina Public Schools, and the open green space area between Lynmar Lane and Bristol Boulevard owned by the City of Edina (from this point forward referred to as Lynmar basin). These two areas were selected due to the availability of open green space adjacent to impervious surfaces (e.g., streets, parking lots, buildings, sidewalks, playground), soils conducive to infiltration capacity, a high level of visibility for educational opportunities, and low to moderate Drinking Water Supply Management Area (DWSMA) vulnerability.

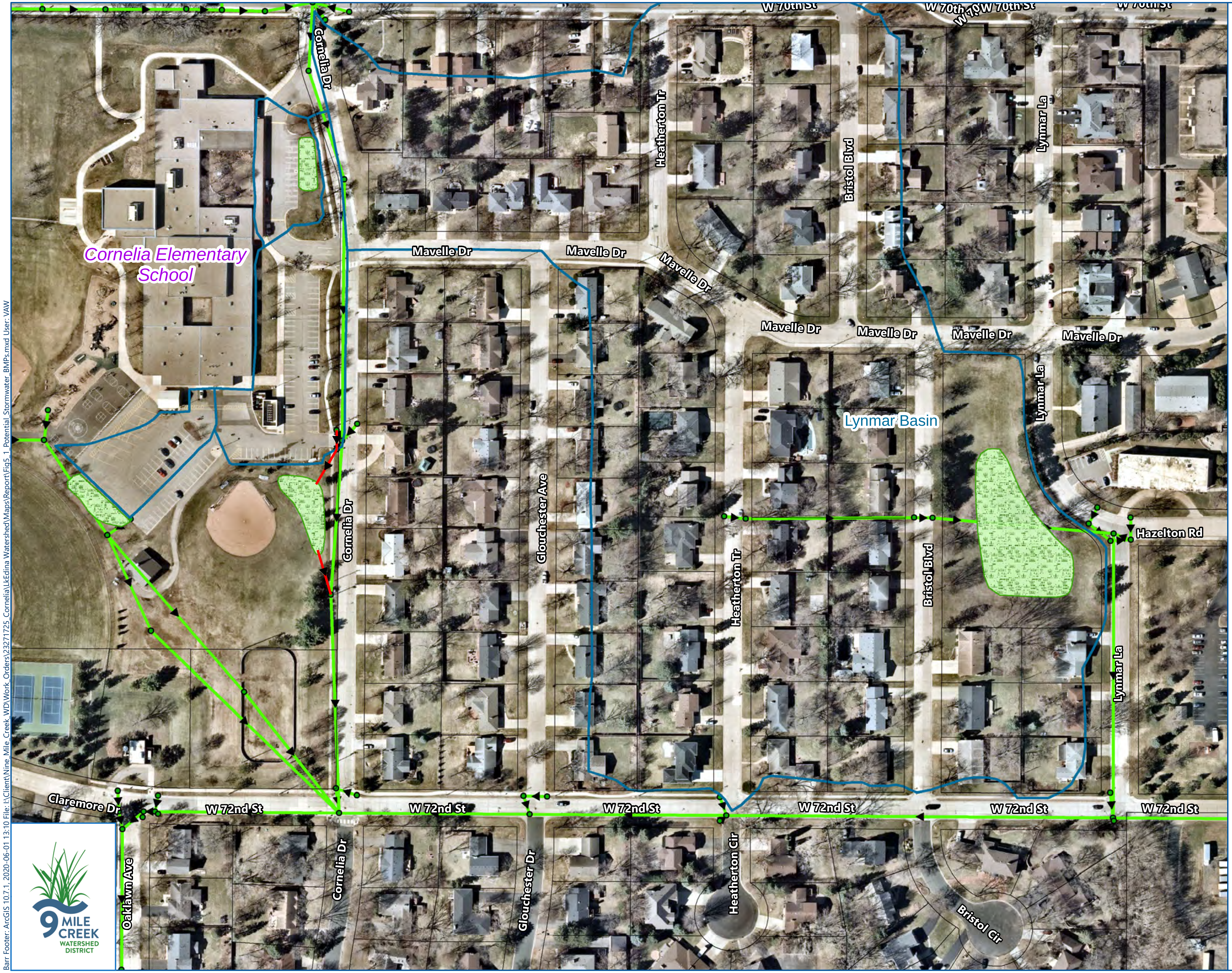
Figure 5-1 shows the locations of potential stormwater infiltration BMPs at Cornelia Elementary School and the Lynmar Basin. Three BMPs are located at Cornelia Elementary School and one larger infiltration-BMP is located within the Lynmar Basin. The rain gardens proposed at Cornelia Elementary School would collect and infiltrate stormwater runoff primarily from the school parking lots. The stormwater infiltration feature within the Lynmar Basin would collect runoff from an 18-acre residential watershed. This basin currently receives stormwater, but serves more as a dry pond, providing flood detention but minimal water quality benefits, based on currently available information. Table 5-1 summarizes the tributary watershed information for each conceptual watershed-level BMP and also discusses preliminary BMP sizing. More detailed sizing of the stormwater BMPs would be optimized in future design phases to coordinate the desires of NMCWD and the landowners.

If the NMCWD is interested in pursuing implementation of stormwater BMPs on these sites, the next step would be to contact the property owners to discuss partnership opportunities. The City of Edina has indicated potential interest in preliminary discussions. Edina Public Schools has not been contacted yet. It is recommended that the NMCWD consider preparing some sketches/renderings of the conceptual design for stormwater rain gardens prior to meeting with Edina Public Schools and City of Edina.

Table 5-1 Lake Edina Watershed Infiltration-BMPs Watershed and Sizing Summary

Location	BMP Name	Total Watershed Area (acres)	Impervious Area (acres)	Impervious %	Approx. BMP Area (feet^2)	BMP Depth (inches)	Concept Treatment Volume (ac-ft)	Concept Treatment Depth (inches)
Cornelia Elementary School	CES_North	0.5	0.3	63%	1,200	18	0.03	1.1
	CES_West	0.5[1]	0.5	100%	1,900	18	0.05	1.1
	CES_South	1.6	1.2	73%	3,700	18	0.10	1.1
Lynmar Basin	Lynmar Basin	18.1	11.0	61%	24,400	24	1.0	1.1

[1] Playground and parking lot redevelopment has occurred since Twin Cities LiDAR was collected (2011). There exists uncertainty in the total tributary area to CES_West. The total tributary area is possibly larger and needs additional investigation for BMP sizing.



Existing Storm Manhole
Existing Storm Sewer
Proposed Storm Sewer
Proposed Infiltration BMP
Tributary Drainage Areas
Parcel Boundary

N

0 150 300
Feet

Potential Stormwater BMPs
Lake Edina Watershed
Lake Cornelia and Lake Edina
Water Quality Improvement Project
Edina, Minnesota

FIGURE 5-1

5.1.1 Opinion of Probable Cost

Concept-level opinions of probable cost were developed for the two potential BMP projects within the Lake Edina watershed (Cornelia Elementary School and Lynmar Basin). The opinions of probable cost summarized in Table 5-2 generally correspond to standards established by the AACE. Class 5 opinions of cost were used based on the limited project definition, wide-scale use of parametric models to calculate estimated costs (i.e., making extensive use of order-of-magnitude costs from similar projects), and uncertainty with an acceptable range of between -30% and +50% of the estimated project cost.

5.1.2 Cost-Benefit Analysis

The water quality benefits of the concept-level infiltration basins located at Cornelia Elementary School and Lynmar Basin were estimated using the MPCA Minimal Impact Design Standards (MIDS) calculator. The estimated annual total phosphorus removals are approximately 3.6 and 20.5 pounds from the Cornelia Elementary School basins and the Lynmar Basin, respectively. The estimated annualized cost per pound of total phosphorus removed is also summarized in Table 5-2.

Table 5-2 Lake Edina Watershed Infiltration-BMP Concept-Level Cost Estimates

Location	Concept-Level Cost Estimate[1]	Concept Level Cost Range (-30% - +50%)	Estimated Life of Project	Estimated Annualized Cost per Pound TP Removed[2]
Cornelia Elementary School (3 Infiltration BMPS)	$332,000	$233,000–$498,000	30 years	$5,500
Lynmar Basin (1 Infiltration BMP)	$512,000	$359,000–$768,000	30 years	$1,500

[1] Concept-level cost estimates do not include annual costs for operations and maintenance. Costs do include engineering and design estimates.

[2] Concept-level estimated annualized cost per pound total phosphorus removed assumes an annual maintenance cost of approximately 10% of estimated construction costs per site and an inflation rate of 3%.

5.2 Opportunities for Treatment of Ponds Upstream of Lake Cornelia

Following completion of the 2019 UAA, there were follow-up questions posed by the NMCWD board of managers regarding opportunities to reduce phosphorus to Lake Cornelia by treating upstream ponds. Internal phosphorus loading in stormwater ponds or natural waterbodies that receive stormwater discharge (from this point forward referred to as ponds) has been increasingly identified as an issue in Minnesota. There are generally two causes of internal phosphorus loading in ponds: (1) high phosphorus in pond bottom sediment resulting from years of sediment accumulation and the occurrence of low oxygen during the summer months, and (2) an abundant population of fish such as carp, bullheads, and goldfish which disturb bottom sediments and cause phosphorus to release into the water column. In many cases ponds are afflicted by both problems—they have high phosphorus in bottom sediments as well as an abundant population of bottom-foraging fish.

Given the root cause of internal phosphorus loading in ponds, there are generally three viable approaches to reducing internal phosphorus loading:

- Remove and eliminate the bottom feeding fish such as carp;
- Bind the phosphorus in the pond bottom sediment by adding aluminum (alum), iron (e.g., iron filings, per the studies conducted by the University of Minnesota), or calcium (e.g., spent lime [calcium carbonate], which is currently being studied); and
- Aerate to improve oxygen concentrations.

Removing fish such as carp has been shown to be successful in the Ramsey Washington Metro Watershed District (Casey Lake and Markham Pond), with carp removal leading to significantly reduced phosphorus concentrations within the water column at the pond outlet. Lower turbidity and increased aquatic plant abundance occur in conjunction with carp removal. It should be noted that any activity (such as carp removal) that increases pond clarity also leads to the increased abundance of aquatic plants. This is often associated with the abundant growth of filamentous algae which for some residents is worse aesthetically than a turbid pond.

The use of alum (aluminum is the main component) is a well-established method for reducing internal phosphorus loading, and this approach is being implemented at Lake Cornelia. Alum treatment of stormwater ponds has become more common in recent years, as the amount of information regarding the potential for phosphorus release from ponds has increased. The longevity of this approach is generally not known and will likely be dependent upon the watershed size tributary to the ponds and sediment loads. If an alum treatment is conducted, follow-up analysis (e.g., sediment coring) will be needed every 2 to 4 years to determine if it is still effective. If a treatment is considered, it will be necessary to do a pH-buffered treatment consisting of a mixture of alum and sodium aluminate.

The use of iron is a potentially viable approach to reduce internal phosphorus loading in ponds, but this approach is considered experimental at this point. The short- and long-term benefits of treatment using iron to prevent release of phosphorus from lake- or pond-bottom sediments are still unknown. A study was conducted by the University of Minnesota Saint Anthony Falls Laboratory (SAFL) to evaluate the benefit of treating Swimming Pool Pond and Point of France Pond with iron to reduce internal P loading. The study concluded that “Present conditions in the Swimming Pool Pond and Point of France Pond suggest that the ponds are providing treatment of phosphorus. Thus, chemical treatment of sediment to reduce internal phosphorus loading is currently not recommended.” (Reference (3)).

The use of spent lime is also a potentially viable approach to reduce internal phosphorus loading in ponds, but is also considered experimental at this point. Spent lime is a waste material; repurposing of that material to treat phosphorus is an attractive attribute. However, there are potential challenges in identifying an approach to apply spent lime as it is a solid material that is largely insoluble in water. As such, spent lime needs to be ground and spread in some manner. The short- and long-term benefits of treatment using spent lime to prevent release of phosphorus from lake- or pond-bottom sediments are still unknown. Barr Engineering staff and its research partners are currently conducting a study funded by the Minnesota Stormwater Research Council to evaluate the effectiveness of using spent lime to reduce internal P loading in ponds.

Aeration may also help by increasing oxygen in the water column and reduce the rate of phosphorus release from bottom sediments. The effectiveness of aeration in reducing phosphorus release from bottom sediments is highly variable, depending on numerous factors including equipment, water body size, depth, and configuration, and watershed characteristics. The appropriate aeration approach, such as a fountain or forced air bubbler, would need to be evaluated on a pond-by-pond basis. One potential drawback of aeration is that it may reduce settling of particulate phosphorus delivered to ponds during storm events. Periodic maintenance is typically required to keep the aerators operational and on-shore storage of equipment (aerators and pumps) is often required.

Before considering further management action, it must be determined if a pond is exporting phosphorus as a consequence of internal phosphorus loading. Phosphorus monitoring at the ponds' inlet and outlet (or within the water column) is needed to establish the magnitude of internal phosphorus loading and phosphorus export from the pond. Full-year monitoring in the spring, summer, and fall would be necessary to quantify the magnitude of phosphorus export. Once it is established that a pond or series of ponds are releasing phosphorus, appropriate mitigation approaches can be identified and applied if the magnitude of phosphorus export justifies the action.

It is expected that carp and goldfish management efforts at Lake Cornelia will also benefit upstream ponds if there is a connection (e.g., active fish passage) between Lake Cornelia and these ponds. If there is a connection, it will be important to reduce or eliminate carp and goldfish populations in those ponds as well as in Lake Cornelia. Before additional upstream pond management activities are conducted, it is recommended that enough time is given to assess the benefits of carp and/or goldfish control efforts under consideration for Lake Cornelia. The carp and goldfish Passive Integrated Transponder (PIT) tagging and tracking study being undertaken by NMCWD (see Section 7), will allow the NMCWD to better understand the connectedness of Lake Cornelia and upstream ponds as it pertains to fish movement.

6 Curly-leaf Pondweed Management

The presence of curly-leaf pondweed and its mid-summer die-off negatively impacts the water quality of Lake Cornelia. Monitoring results presented in the 2019 water quality study indicate that curly-leaf pondweed contributes to up to 17% of the annual phosphorus loading to North Cornelia and up to 23% of the annual phosphorus loading to South Cornelia. Accordingly, management of curly-leaf pondweed is an important component of a long-term management plan for Lake Cornelia.

Curly-leaf pondweed has been observed in Lake Edina in recent years at low levels. The 2019 water quality study concluded that internal phosphorus loading from curly-leaf pondweed die-off/decay is minimal in Lake Edina.

Effective control of aquatic invasive species can require long-term management. A long-term curly-leaf pondweed management goal of reducing presence of the invasive plant until neither curly-leaf pondweed nor turions are observed in the lake would be most protective of Lake Cornelia and downstream lake ecosystems. However, this long-term management goal would require intensive treatment that may not be sustainable for the duration needed to be successful. As such, a more immediate goal of Lake Cornelia 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 growth of the native plant community and mid-summer die off of curly-leaf pondweed does not cause reduced water quality.

This feasibility study evaluates two alternatives for curly-leaf pondweed management: annual herbicide treatment (current approach) and a lake drawdown.

6.1 Annual Herbicide Treatments

The City of Edina has been conducting annual herbicide treatments in Lake Cornelia since 2017 to reduce the impact of curly-leaf pondweed die-back on water quality in Lake Cornelia and downstream Lake Edina and to help promote a healthy native aquatic plant population. Results of the spring 2020 pre-treatment plant survey indicate that annual treatments are having some level of effectiveness in reducing the population of curly-leaf pondweed in Lake Cornelia (Reference (4)). Since 2017, pre-treatment monitoring indicates a decrease in curly-leaf pondweed presence at sampling sites (Figure 6-1). Density of sampled curly-leaf pondweed has decreased as well. While annual herbicide treatments can reduce the extent and density of curly-leaf pondweed, this approach may necessitate long-term annual herbicide treatments to be effective.

The City of Edina anticipated conducting an herbicide treatment of Lake Edina in 2020 to manage curly-leaf pondweed. However, a pre-treatment survey in spring of 2020 found little or no curly-leaf pondweed in the lake.

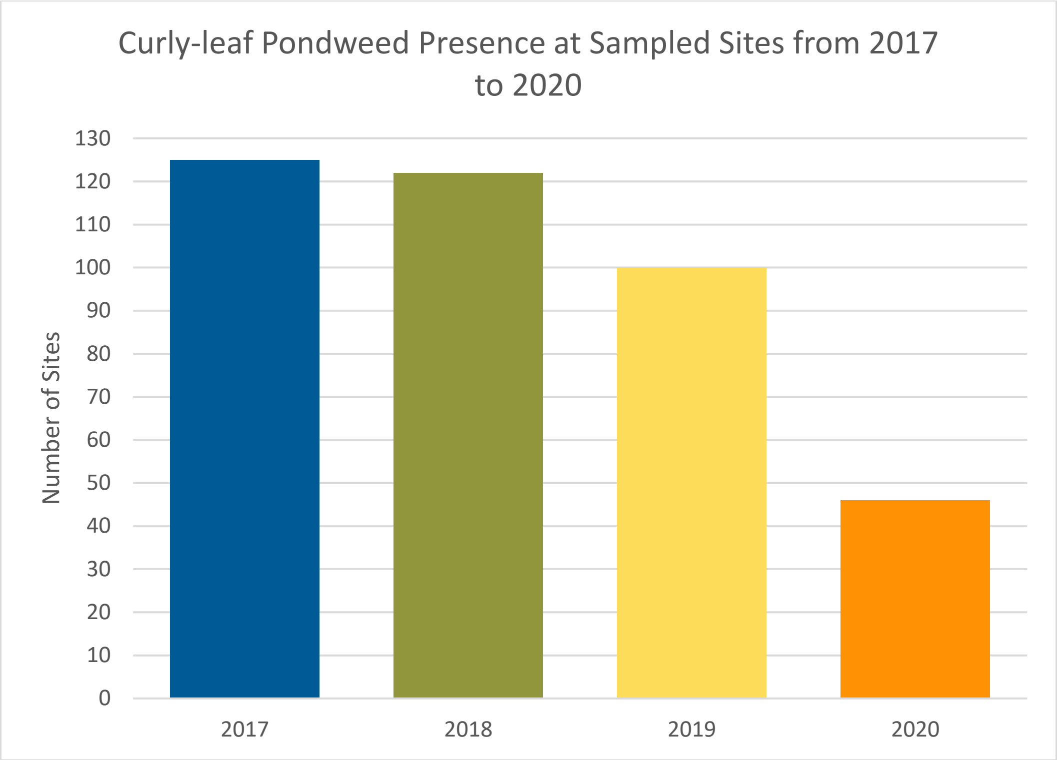


Figure 6-1 Curly-leaf Pondweed Presence at Sampled Sites from 2017 to 2020

6.1.1 Permitting

Herbicide treatment would require an Invasive Aquatic Plant Management Permit from the MnDNR. The permit requires completion of a pre-treatment vegetation survey and may require follow-up monitoring depending on the terms of the permit.

6.1.2 Opinion of Probable Cost

The planning-level opinion of probable cost for herbicide treatment of the curly-leaf pondweed in Lake Cornelia is approximately $28,000 per year of treatment, with a range of $26,000 to $34,000 (-10% to +20%). This estimate includes preparation of contract documents, permitting, and herbicide application. The cost estimate also includes potential costs related to monitoring that may be deemed appropriate or required by the MnDNR as part of permitting, including temperature measurements, herbicide residue monitoring, and aquatic plant monitoring. Note that the cost estimate included in the UAA study for herbicide treatment of Lake Cornelia was lower than the cost described in this report because it did not include costs incurred by city staff related to contracting and permitting, or monitoring costs. A detailed opinion of probable cost for the curly-leaf pondweed herbicide treatment is included in Appendix D.

6.2 Lake Drawdown

Another potential method to control curly-leaf pondweed is to draw down Lake Cornelia to allow the lake bed to freeze over the winter. Curly-leaf pondweed primarily propagates through 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 kill the turions, thus disrupting curly-leaf pondweed's reproductive cycle.

A high-level evaluation of conducting a drawdown to control curly-leaf pondweed in Lake Cornelia was included as part of this feasibility study due to the success of this approach in other lakes, including several in the NMCWD, and the desire to avoid recurring management activities. The sections below discuss drawdown background and methods, and a high-level feasibility assessment of a draw down in Lake Cornelia, including permitting, opinion of probable cost, and other considerations.

6.2.1 Background on Drawdown as Management Method

Several other waterbodies in the region have used drawdown as a means to achieve water quality objectives. A successful shallow lake restoration was conducted in Big Muskego Lake in southeast Wisconsin using a combination of several in-lake treatments, including an 18-month drawdown period. This drawdown resulted in the consolidation of sediments in addition to allowing for the removal of rough fish populations and reestablishment of native aquatic plant species. Sediment consolidation was desired for the reduction of future sediment resuspension, although the extent of consolidation was limited by rain and flood events during the drawdown period.

The NMCWD completed a drawdown on Southwest and Northwest Anderson Lakes in Eden Prairie in fall 2008. The drawdown was conducted using electrical pumps to dewater a significant portion of each lake in an effort to significantly reduce and potentially eliminate curly-leaf pondweed from the two lakes. The goal of the project was to expose as much of the lake sediment as possible to freezing conditions during the 2008-2009 winter season and chemically treat any remaining open water areas. Freezing the lake sediment was expected to effectively kill the young curly-leaf pondweed plants and the curly-leaf pondweed turions. Monitoring conducted in 2015 found several floating fragments of curly-leaf pondweed in Southwest Anderson Lake, but rooted curly-leaf pondweed plants were not. In Northwest Anderson Lake, curly-leaf pondweed was present but rare in the east end of the lake and was not found in the west portion of the lake. Overall, the drawdown effort has remained successful in controlling curly-leaf pondweed.

Three Rivers Park District performed a successful lake level drawdown on Cleary Lake in Scott County, Minnesota to control curly-leaf pondweed (personal communications with John Barton). The initial Cleary Lake drawdown was not a complete drawdown because of a restriction in the outlet channel which limited the volume of water that would flow out of the lake by gravity. As a result, the initial drawdown was only effective at controlling curly-leaf pondweed over the portions of the lakebed exposed to freezing conditions. Therefore, the Park District did a complete drawdown the following year by modifying the outlet channel and installing temporary pumps to completely dewater the lake. The Park District has indicated the drawdown was extremely effective at controlling curly-leaf pondweed.

The NMCWD also conducted a drawdown of Normandale Lake in Bloomington in fall 2018. The initial drawdown was conducted using diesel pumps to dewater a significant portion of the lake in order to install a new bypass pipe which would drain the lake by gravity. The pipe was installed in November 2018 and was successful in keeping the majority of the lake drawn down over the 2018–2019 winter season.

Freezing the lake bottom sediments killed many of the curly-leaf pondweed turions; sediment samples taken in the fall of 2019 found that the number of turions had decreased dramatically. Aquatic plant surveys conducted in June 2019 and May 2020 indicate reduced frequency and density of curly-leaf pondweed throughout Normandale Lake.

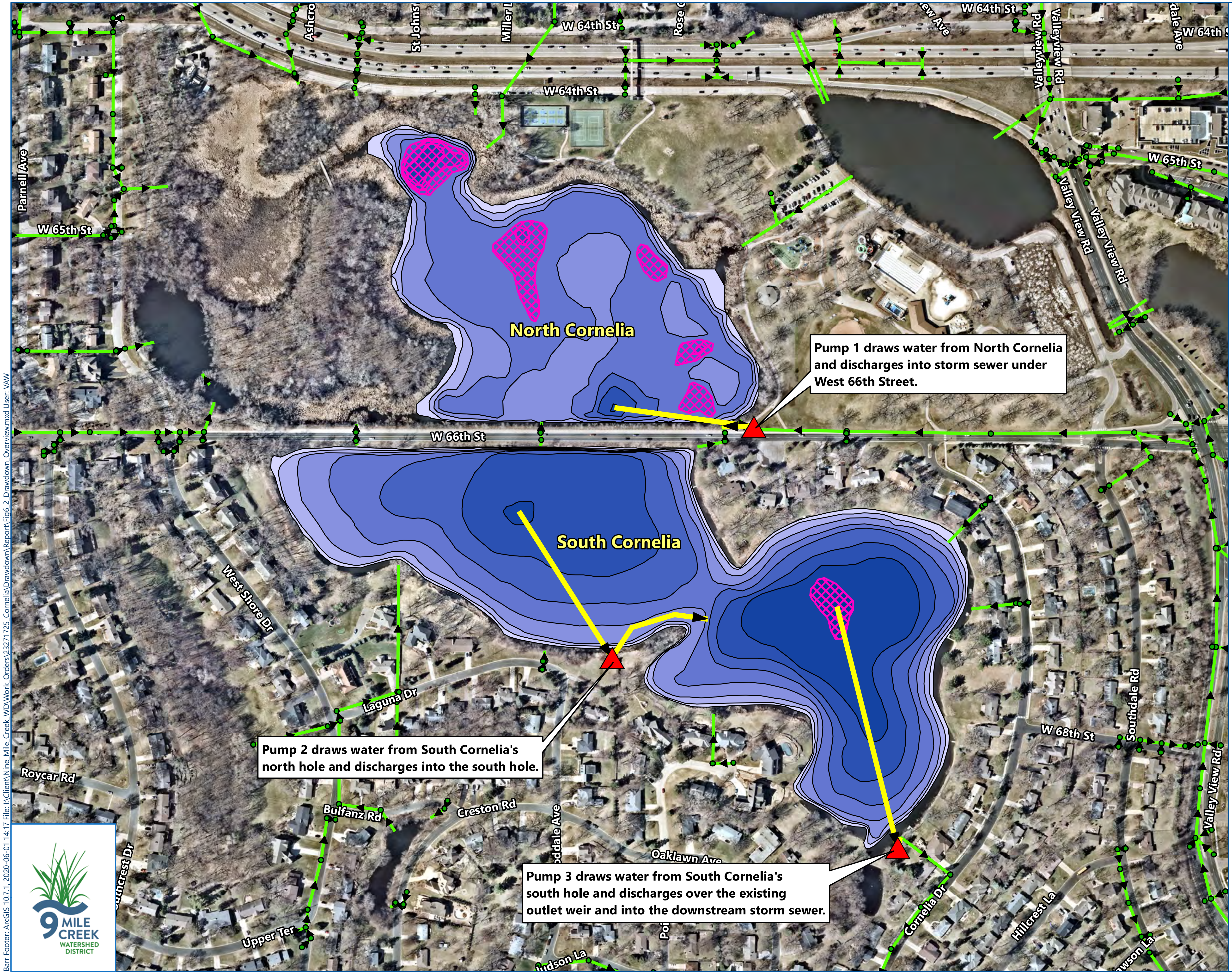
6.2.2 Drawdown Method

Outlet modification, siphoning and temporary pumping are drawdown methods that have been used in similar projects. Modifying the outlet to draw down the lake by gravity is not feasible since a large portion of the lake is below the elevation of the outlet weir and downstream storm sewer. Siphoning could be used to draw the lake down below the outlet elevations but difficulties in maintaining and re-priming the siphon once the lake is drawn down and then receives inflow in response to precipitation events, especially during winter months, make this option impractical. Installing temporary pumping is the only feasible option for dewatering Lake Cornelia. Temporary pumps have the potential to quickly draw the lake down in the late summer and can be easily turned on and off as needed to keep the lake drawn down over the fall and winter months. Based on similar projects, it is assumed that diesel pumps with mufflers would be used to reduce noise in this residential area.

Figure 6-2 shows the approximate lake bathymetry of Lake Cornelia. As shown, there are several deeper holes throughout both the North and South basins. Three temporary pumping stations would be needed to draw down most of North Cornelia and the two deep holes in South Cornelia as shown in Figure 6-2. Pump 1 would be located on the southeast side of North Cornelia in the park area and would pump water from North Cornelia to the north hole in South Cornelia through the 15-inch diameter storm sewer under West 66th Street. Pump 2 would be located on city of Edina property on the south side of South Cornelia and would pump water from South Cornelia's north hole to its south hole. Pump 3 would be located on private property or stormwater easement, if available, on the southeast side of South Cornelia near the lake outlet and would pump water from South Cornelia's south hole over the existing outlet weir and into the downstream storm sewer. For this level of study, it is assumed that the pumping capacity at all three locations would be the same.

A lake level drawdown goal of approximately 851 feet was used for this high-level drawdown feasibility analysis. Figure 6-2 also shows the extent of open water within the lake at a drawdown elevation of 851 feet. For this analysis, it was assumed that the deeper hole on the far north side of the North basin and other smaller low areas would not be pumped, so would remain as open water to an elevation of approximately 854 feet.

The pumps would need to run continuously from mid-August to mid-September to draw down lake levels to the target elevation of 851 feet. After the lake is drawn down, the pumps would need to be run periodically to drain inflows due to precipitation events or potential groundwater inflows. For this study it is assumed that the pumps would need to run approximately 50 percent of the time from mid-September through February; this could vary widely depending on precipitation and climate conditions.



Potential Pump Locations

Potential Pump Pipelines

Existing Storm Manhole

Existing Storm Sewer

Approximate Extent of Open Water During Drawdown[1]

Approximate Lake Bathymetry[2]

858-859 Feet

857-858 Feet

855-856 Feet

854-855 Feet

853-854 Feet

852-853 Feet

851-852 Feet

<851 Feet

**Note:*

[1] Proposed drawdown elevation is approximately 851 feet. For pumped areas, open water extent will be at Elevation 851. For unpumped low areas, open water extent will be at approximately Elevation 854.

[2] Elevations calculated from measured bathymetry depths assuming lake was near control elevation of 859.1 feet.

N

0 300 600

Feet

Lake Drawdown Overview

Lake Cornelia and Lake Edina Water Quality Improvement Project

Edina, Minnesota

FIGURE 6-2

6.2.3 Lake Drawdown Analysis

A predictive spreadsheet water balance model was created to evaluate several drawdown options in terms of how quickly Lake Cornelia could be drawn down in the fall, how likely the lake will remain drawn down over winter, and how quickly lake levels can rebound in the spring. Daily inflows to the lake were estimated based on P8 model results. Daily outflows from the lake were calculated using a rating curve that accounts for the existing outlet structure. Sixty-nine years of precipitation data (1949–2018) were input into the model to predict the water surface elevations in the lake over a wide range of actual climatic conditions. The model was also set up to predict the lake responses to the various drawdown options by allowing the user to vary the size of pumps as well as the dates that the pumps are turned on.

6.2.3.1 Drawdown Timing

The amount of time for Lake Cornelia to draw down to its target elevation of 851 feet is dependent on the starting elevation of the lake, pumping capacity, and amount precipitation received during the draw down period. Table 6-1 summarizes the time to draw down the lake with three different pump capacities (given in gallons per minute or gpm) assuming the lake starting elevation is at its control elevation of 859.1 feet and there are no watershed inflows during the drawdown period. While the assumption of no watershed inflows during the drawdown period is unlikely, the information summarized in the table provides a general comparison of timing with the various pumping capacity scenarios.

Table 6-1 Time to Draw Down Lake to Elevation 851 Assuming no Inflows

	2,000 gpm Pumps	3,000 gpm Pumps	4,000 gpm Pumps
Days to Drawdown to Elevation 851[1]	27	18	14

[1] Assumes lake starting elevation is at control elevation of 859.1 feet and no inflows during the drawdown period

For the Normandale Lake drawdown project, MnDNR indicated a preference for the lake to be drawn down by September 15 to minimize impacts to the area's turtle community as it prepares for winter hibernation. The predictive spreadsheet water balance model was used to evaluate the three pumping capacities, assessing the likelihood of meeting the DNR's September 15 drawdown guideline if the drawdown begins on August 15. Starting the drawdown earlier than August 15 had minimal impact on meeting the September 15 drawdown guideline or the overall effectiveness of a fall drawdown since summer precipitation events tend to fill the lake back up.

Figure 6-3 shows the likelihood (% of years modeled) of drawing the lake down to an elevation of 851 feet on a given date for each of the pump capacities, based on the predictive water balance model. The modeling shows that the 2,000 gpm pumps will succeed in drawing down the lake to the elevation of 851 feet by September 15 in less than 10 percent of the modeled years. On the other hand, increasing the pump capacity to at least 3,000 gpm improves the likelihood of drawing the lake down by September 15 to 77 percent. Increasing the pump capacity from 3,000 gpm to 4,000 gpm has less impact on the likelihood of drawing down the lake by September 15 (77% versus 90%). Under all three pump capacities, lake levels occasionally bounce back up during the fall and winter in response to rainfall events. However, increasing the pump capacity to at least 3,000 gpm decreases the amount of time it takes for the lake to draw back down.

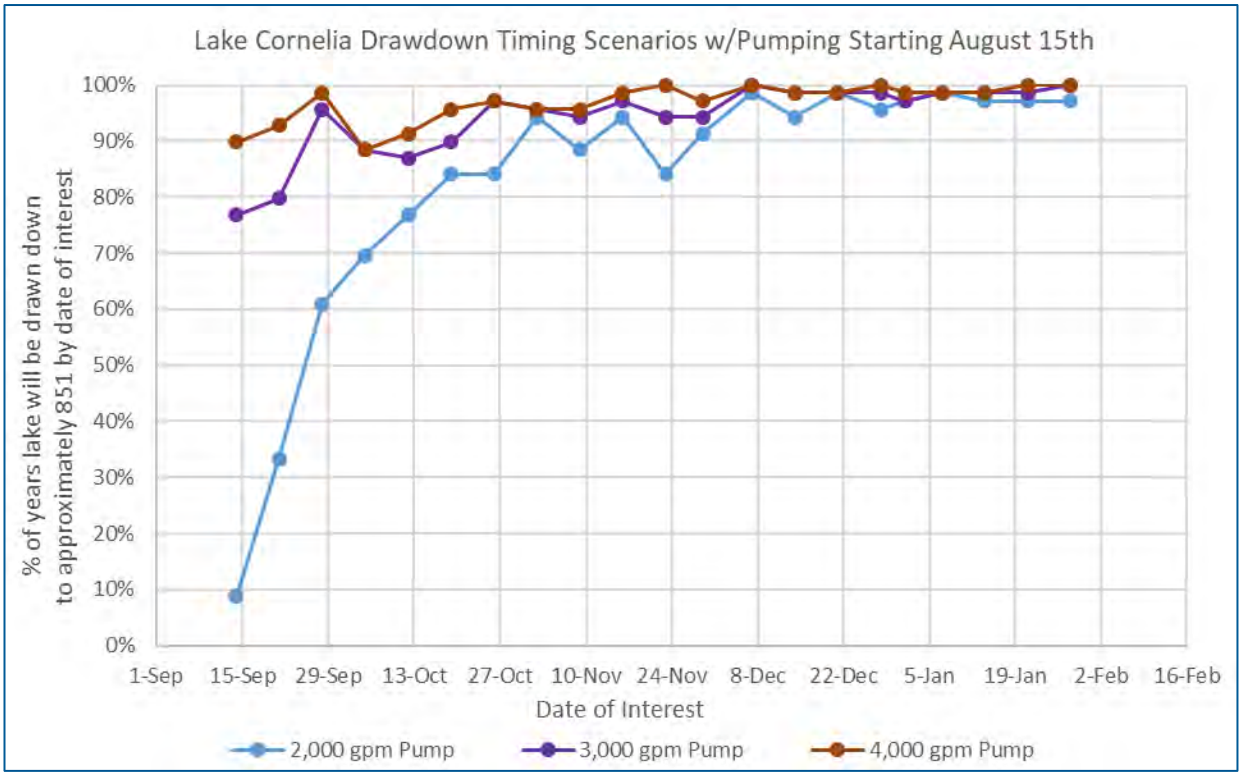


Figure 6-3 Drawdown Effectiveness of Various Pump Capacities, based on August 15 Start Date

6.2.3.2 Maintaining Winter Drawdown Conditions

A lake drawdown would allow much of the lake bed to freeze over the winter. Maintaining the drawdown over the winter months is important to maximize the extent to which and amount of time the sediments are frozen. Rainfall or snowmelt events do occasionally happen during the winter months and the resulting increased inflows from the Lake Cornelia watershed can cause the lake level to quickly bounce up. The predictive water balance model was used to evaluate the likelihood of maintaining low lake levels during the months of December through February for each of the evaluated drawdown options, based on a 69-year time period representing a wide range of climate conditions. Figure 6-4 shows the percentage of years that the drawdown target elevation of 851 feet was exceeded at least once during a given month due to a rainfall or snowmelt event. Model results indicate that, while all three pump sizes will perform fairly well at keeping the lake levels below the target elevation of 851, increasing the pump size to at least 3,000 gpm will keep the likelihood of exceeding the target elevation in any given month to less than 26 percent. Increasing the pumping capacity from 3,000 gpm to 4,000 gpm has less impact on the likelihood of exceeding the target elevation.

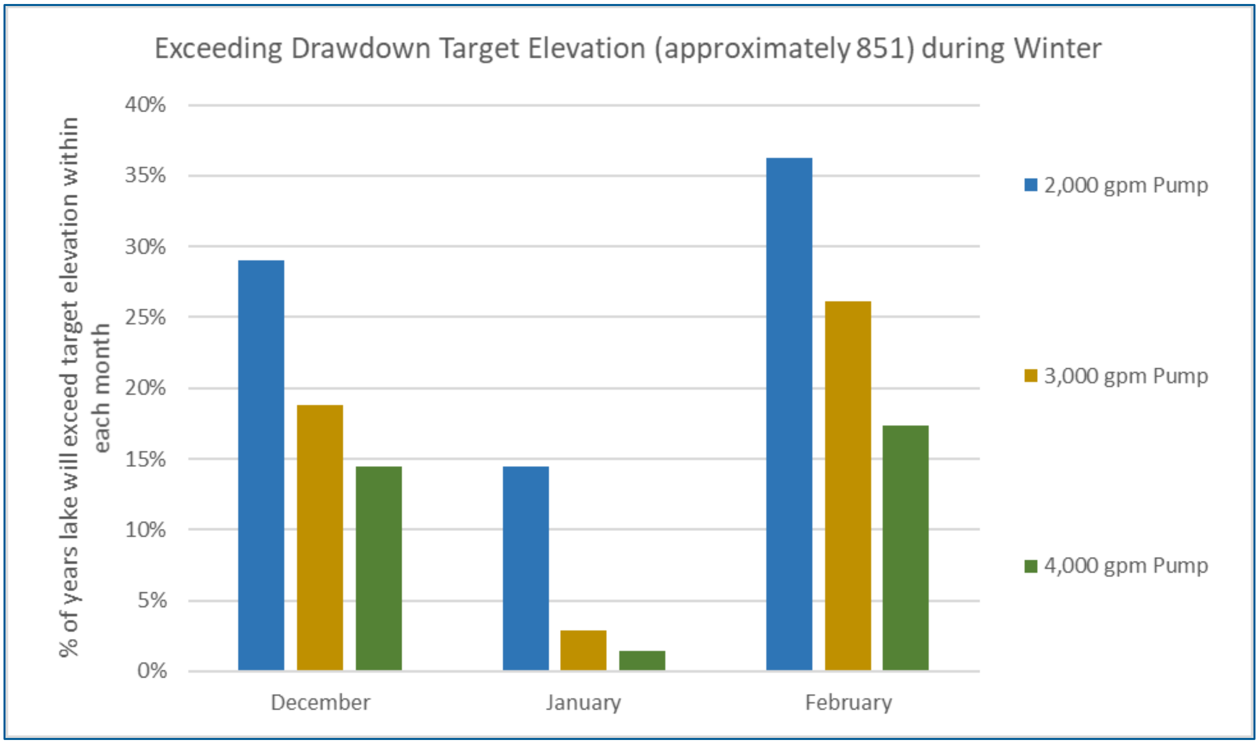


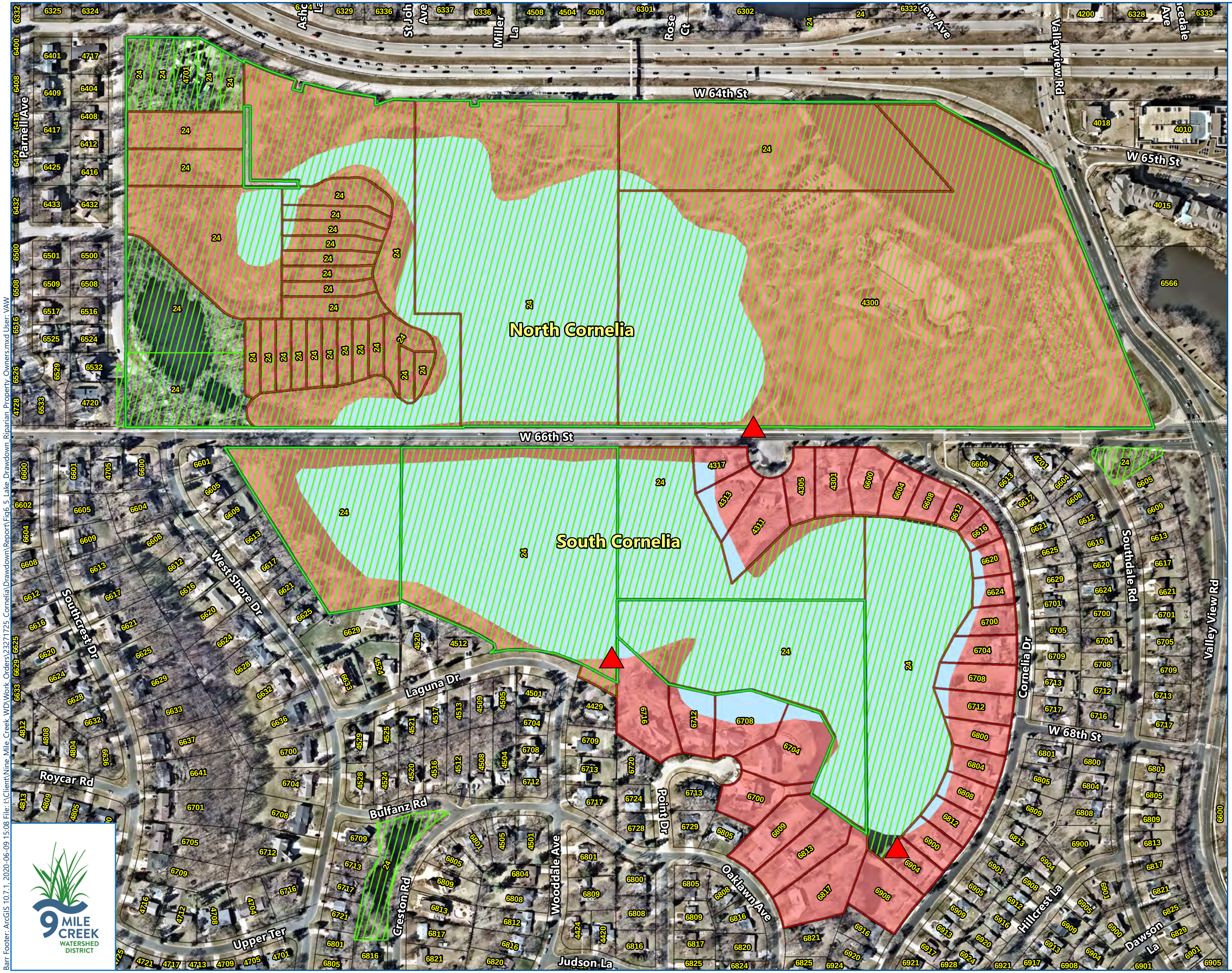
Figure 6-4 Effectiveness of Maintaining Drawdown Conditions during Winter Months

6.2.4 Permitting

Conducting a lake drawdown would require approval from the MnDNR through a Work in Public Waters Permit. Under Minnesota Statute Section 103G.408, 75 percent of the riparian landowners must authorize a drawdown. The City of Edina owns all of the property adjacent to North Lake Cornelia and approximately half of the shoreline property around South Lake Cornelia. South Lake Cornelia has 31 private, riparian landowners; 24 landowners (75%) would need to authorize the drawdown for it to proceed Figure 6-5 identifies the riparian property owners around Lake Cornelia.

The pumping stations needed to pump water from North Lake Cornelia and from the west half of South Lake Cornelia can be located on City of Edina property. NMCWD would need to obtain the necessary rights to use property owned by the City of Edina in a cooperative agreement between the two entities for the project. NMCWD would also need to obtain the necessary rights to use private property near the South Lake Cornelia outlet. A pump would need to be located on private property near this outlet to pump the water out of the east half of South Lake Cornelia and over the outlet weir.

Permits/approvals for the drawdown may also be required from the City of Edina, U.S. Army Corps of Engineers, the MPCA and NMCWD, depending on dewatering method.



Lake Drawdown
Riparian Property Owners
Lake Cornelia and Lake Edina Water Quality Improvement Project
Edina, Minnesota

FIGURE 6-5

6.2.5 Opinion of Probable Cost

A planning-level opinion of probable cost has been developed for the 3,000 gpm pump capacity option (Table 6-2). Costs were not developed for the 2,000 gpm pump scenario because the pump capacity is too low based on the model results discussed in the preceding sections. Likewise, costs were not developed for the 4,000 gpm pump scenario since there is very little benefit to using the larger pump capacity. The planning-level opinion of probable cost for conducting a winter drawdown in Lake Cornelia using 3,000 gpm pumps is approximately $1,829,000, with a range of $1,281,000 to $2,744,000 (-30 percent to +50 percent). The opinion of probable cost is based on engineering judgement, experience with similar projects, and review of actual bid values from recent, similar projects. A detailed opinion of probable cost for a drawdown of Lake Cornelia is included in Appendix D.

The opinion of cost was developed assuming the pumps would need to run continuously from mid-August to mid-September and then run approximately 50 percent of the time from mid-September through February. The opinion of costs include an expected accuracy range (-30 percent to 50 percent), based on the current extent of project definition, wide-scale use of parametric models to calculate estimated costs (i.e., making extensive use of order-of-magnitude costs from similar projects or proposals), and project uncertainty.

6.2.6 Other Drawdown Considerations

Temporary pumping would likely require construction of temporary enclosures to store the pumps, minimizing the potential for vandalism or accidents. Pumping during winter months introduces the potential for complications related to flash freezing, frazil ice, etc. The pumps would need to be checked daily in times of extreme cold to ensure they are functioning properly. The pumps would operate on diesel fuel and would need to be refueled daily when running. The pumps will also need noise baffling for noise reduction due to their proximity to residential areas.

Table 6-2 Summary of Estimated Costs for Lake Drawdown, Assuming 3,000 gpm Pump Capacity

Items	Estimated Cost
Mobilization/Demobilization	$5,000
Pump set-up, rental, and removal (3,000 gpm pump)	$507,300
Daily servicing (including refueling and maintenance) during initial 30-day drawdown period[1]	$137,400
Periodic servicing (including refueling and maintenance) to maintain drawdown[1]	$388,800
Site restoration	$7,500
HDPEP inlet and outlet pipes for all three pipes (2,400 Feet Total)	$36,000
Construction subtotal:	**$1,082,000**
Construction contingency (30%)	$325,000
Estimated construction cost	**$1,407,000**
Planning, engineering, and design (30%)	$422,000
Total	**$1,829,000**
Low range (-30%)	$1,281,000
High range (+50%)	$2,744,000

[1] Cost estimate assumes one month of continuous pumping (August 15 through September 15) followed by 6.5 months of intermittent pumping (September 15 through March 1) to keep the lake drawn down. The cost estimate assumes pumping 50% of the time during the intermittent period but this could vary widely depending on precipitation and climate conditions.

7 Fishery Management

7.1 Overview of Lake Cornelia Fishery

The NMCWD commissioned a fisheries assessment in 2018 to gain a more complete understanding of the fishery of Lake Cornelia and connected water bodies, including quantifying the common carp (*Cyprinus carpio*) population. The fish survey included Lake Cornelia (North and South), and upstream waterbodies Lake Nancy, Swimming Pool Pond, and Point of France Pond; the 2018 survey did not include Lake Otto. Figure 7-1 shows North and South Cornelia and the upstream waterbodies and the storm sewer that connect the various waterbodies.

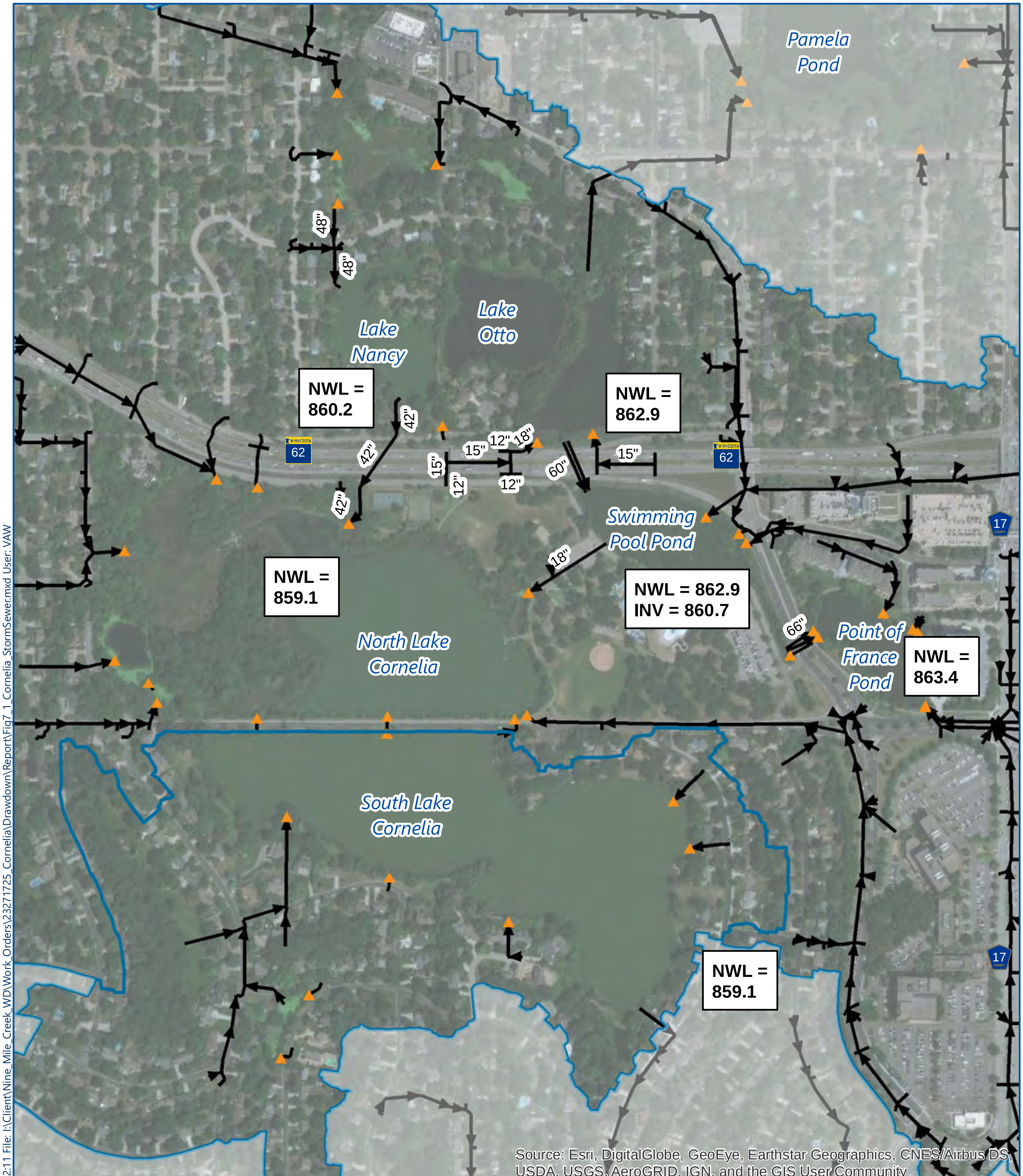
Overall, the fish sampled in the Lake Cornelia system were small in size and species richness was limited, likely a result of the 2017–2018 winterkill and past winterkills that have occurred (Reference (5)). Common carp populations were relatively low in Lake Cornelia. Conversely, goldfish (*Carassius auratus*) were found in large numbers in Lake Cornelia. Goldfish were the most abundant fish species captured through electrofishing and were determined to have an established breeding population. While most of the goldfish captured were young of the year (YOY) or one year old, fully-grown fish up to 14.4 inches in length were also captured. While carp were found in lesser numbers in Lake Cornelia, they were more abundant in Point of France Pond and are being included in consideration of management options.

Similar to carp, goldfish have the potential to negatively impact water quality by increasing in-lake turbidity due to benthic feeding habits (Reference (6), Reference (7)). The bottom-feeding fish can also increase in-lake nutrient levels and contribute to blue-green algae blooms from nutrient cycling through the fish gut (Reference (8), Reference (9)). Goldfish have also been documented to reduce growth of aquatic plants (Reference (6)). With the high numbers of goldfish in the Lake Cornelia system and their potential to reduce water quality, management options to reduce the goldfish population are being considered by NMCWD and its partners.

The sections below provide additional information regarding goldfish and potential management approaches to help reduce the goldfish and carp populations and maintain a healthy fishery in Lake Cornelia.

7.2 Goldfish Literature Review

While a relatively large amount of research has been conducted on common carp and their impact on water quality in Minnesota, limited research is available regarding goldfish and goldfish/carp hybrids. A literature review was conducted as part of this feasibility study to better understand the characteristics of goldfish and goldfish/carp hybrids and their role and movements within lake systems. Results of the literature search are summarized below.



Major Watersheds

Storm Sewer Outlet

Storm Sewer

N

0 600

Feet

Lake Cornelia Storm Sewer System

Lake Cornelia and Lake Edina Water Quality Improvement Project

Edina, Minnesota

FIGURE 7-1

7.2.1 Influence of Goldfish

Goldfish have a high tolerance to hypoxic conditions and can also survive prolonged periods of low temperatures (Reference (10), Reference (11), Reference (12), Reference (13), Reference (14)). Goldfish are omnivorous and can use a variety of food or prey items, including vegetation, during various life stages and/or seasonal periods (Reference (12), Reference (15), Reference (16)). As identified in the 2019 UAA study (Reference (1)), Lake Cornelia is a highly disturbed system with frequent winterkill, which creates conditions suitable for success of goldfish populations (Reference (12), Reference (17)) and reduced success of native fishes (Reference (18)). Rapid growth of young goldfish allow them to quickly grow past the size available to typical predators (Reference (19)). Frequent winterkill in Lake Cornelia contributes to a lack of native fish, including predator fish such as northern pike that could select for small goldfish as a soft-rayed food source (Reference (20)).

7.2.2 Hybridization

Goldfish hybridization with common carp has been documented and is likely occurring in Lake Cornelia as potential spawning areas may overlap (Reference (21), Reference (22), Reference (23), Reference (24), Reference (12)).

7.2.3 Goldfish Control Methods

Several potential methods for controlling the goldfish population in Lake Cornelia are discussed below. Integration of management methods has been shown to be successful and is the recommended approach for Lake Cornelia (Reference (25), Reference (26), Reference (27), Reference (28), Reference (29)). Integrated efforts to control nuisance populations of fish can consider a combination of a number of techniques, including removal, drawdown, stocking, reduced access to spawning areas, habitat improvement, and winterkill mitigation.

7.2.3.1 Removal

Physical removal of goldfish has been successful in some circumstances (Reference (8)) using a combination of monofilament gill nets and electrofishing. Goldfish also may be susceptible to capture in appropriately mesh size baited nets due their highly developed olfactory and tactile systems used for foraging similar to common carp (Reference (30), Reference (31), Reference (32), Reference (29), Reference (15), Reference (33), Reference (34)). Maxwell (Reference (5)) documented successful capture of goldfish using both electrofishing and trap (fyke) nets.

7.2.3.2 Biologic (Predation)

No successful documentation of biologic control of goldfish or goldfish/carp hybrids was found as part of the literature review. Indirect evidence of the impact of native fish populations on goldfish is via Laird and Page (Reference (35)), where in Illinois goldfish were noted as unable to compete with native fish and could only survive in severely disturbed areas.

Stocking a certain species of fish such as bluegill, northern pike, or largemouth bass to control another species of fish is documented as one of the least successful type of fish control programs when used as the only element of a control effort (Reference (36)). Bajer et al (Reference (37)) documented that bluegill predation on common carp eggs can achieve control of the species; however similar documentation of the effect of bluegill predation on goldfish eggs was not found at part of the literature review. Conditions and requirements for successful bluegill populations is well documented and can be compared to conditions in Lake Cornelia (Reference (38), Reference (39), Reference (40), Reference (41)). However, conditions in Lake Cornelia are not currently well suited to establishment of a successful bluegill population.

7.2.3.3 Drawdown

Lake level drawdown can have an impact on success of goldfish spawning success. Yamamoto et al (Reference (14)) noted that as little as a 12-inch drawdown following spring goldfish spawning reduced spawning success of goldfish and other cyprinds.

7.2.3.4 Reduced Access to Spawning Areas

Common carp actively seek winterkill waters as preferred spawning areas; no documentation was found to suggest that goldfish target similar spawning areas (Reference (42)). However, goldfish do spawn on vegetation during May-June, and warming water temperatures trigger spawning (Reference (23), Reference (24)). Large areas of Lake Cornelia with high densities of vegetation may contribute to success of goldfish larva (Reference (14)). Fish barriers can be an effective method to reduce access to spawning areas.

7.2.3.5 Chemical control

Chemical toxicants for removal of undesirable fish populations is documented as one of the more successful fish control techniques (Reference (36), Reference (43)). Use of chemical toxicants, however, can generate conflicting views by lake users, residents, or the community at large making the use of chemical control mechanisms dependent on public acceptance. The use of chemical toxicants as part of an integrated pest management program for control of nuisance fish species that includes habitat manipulation, stocking etc. has been shown to be successful (Reference (27)).

7.2.3.6 Winterkill Mitigation

Review of the 2018 fishery data indicate that the Lake Cornelia fishery tends to be heavily influenced by frequent winterkill events, evidenced by a low number of bluegill and other predator fish. The frequency of winterkills and the availability of connected shallow waterbodies that winterkill which likely act as nurseries, are most likely preventing bluegills and other sunfish from effectively controlling goldfish within the system. Management activities such as winter aeration can help to prevent winterkill and promote survival of predator fish.

7.3 Recommended Goldfish and Carp Management Approach

Based on the literature review of goldfish in lake systems and currently-available information regarding the fishery in Lake Cornelia, an integrated approach to goldfish and carp management using a combination of management actions is anticipated to be the most successful option. The following management approach is recommended:

1) **Conduct removal of goldfish and carp in combination with mitigation of recurrent winterkill through the use of winter aeration**
   As identified in the literature review, there are several potential methods for goldfish removal, including biological control, lake drawdown, physical removal and chemical control. A combination of physical removal and biological control (predation) is the preferred approach at this time (versus lake drawdown and/or chemical treatment), as removal efforts can be selective/targeted to goldfish to reduce impacts to other fish and wildlife. However, additional information is needed to assess the potential effectiveness of removal efforts, including monitoring of the goldfish and carp populations in the Lake Cornelia system to understand their movements (assess feasibility of targeted removals) and assess the efficacy of baited box nets for removal of goldfish (see Section 7.4).

2) **Stock native fish following removal of large numbers of goldfish and winterkill mitigation.**
   Stocking of native fish such as bluegill, largemouth bass and/or pike is likely to reduce success of goldfish following initial removal of a large biomass of the existing goldfish population and mitigation of winterkill to allow for native fish populations to survive for more than just a few seasons. Stocking of native fish will be affected by availability of disease free fish stocks in the region (Reference (44)).

7.4 Winter Aeration to Prevent Fish Kill

A comprehensive evaluation was conducted by Barr's subconsultant, Gantzer Water, to evaluate the feasibility of installing a winter aeration system that could be used in either North or South Cornelia, or both basins, to prevent periodic winter fish kill, promote the establishment of a self-sustaining native fish population, and reduce the carp and goldfish population in Lake Cornelia. The detailed report, developed by Gantzer Water, is provided in Appendix E.

Four different types of aeration systems were considered and evaluated according to the following criteria:

- Effectiveness
- Minimal potential aesthetic effects (on the lake and on shore)
- The system should not affect the normal winter ice thickness
- Ease of maintenance

7.4.1 Aeration Methods Considered

This section describes the types of aeration systems considered.

7.4.1.1 Full Lift Aeration

A full lift aeration system injects air into a tube at the bottom of the lake to draw water to the lake surface where the water is aerated. This system is often described as a "tube within a tube" system where open water is present at the top of the tube. A raft is also necessary to hold equipment and anchor the tube in place. See Figures 7 and 13 in the Gantzer report (Appendix E).

7.4.1.2 Full Lift Oxygenation

A full lift oxygenation system uses 95% pure oxygen that is injected at the bottom of the lake inside a tube. The tube draws water to the lake surface where it then cascades down the sides of the outer tube. This system is largely the same as the full lift aeration system except the oxygen injected into the water provides the aeration rather than contact of lake water with the atmosphere. See Figure 13 in the Gantzer report (Appendix E).

7.4.1.3 Oxygen Enhanced Full Lift Aeration

An oxygen-enhanced full lift aeration system uses air that is injected at the bottom of the lake inside a tube that draws water to the lake surface. This is also a “tube within a tube” system; however, as water cascades down the sides of the outer tube, 95% pure oxygen is injected to add additional oxygen to the lake water. There is open water at the top of the tube, and a raft would be necessary to hold equipment and anchor the tube in place. See Figures 9 and 13 in the Gantzer report (Appendix E).

7.4.1.4 Side Stream Saturation

A side stream saturation aeration system is very different from the others evaluated in that water is withdrawn from the lake, aerated with 95% pure oxygen, and discharged back into the lake. With this design there is no raft and there typically would not be any open water or thin ice. This design was considered because it is efficient, would have minimal aesthetic disturbance, and shouldn’t affect usage of the lake by residents (i.e., winter ice thickness is not anticipated to be impacted).

7.4.2 Recommended Aeration Method

The side stream saturation system was identified as the preferred approach as it will be most capable of meeting the criteria identified for this project, which include efficiency, minimal aesthetic disturbance (the piping and other aeration equipment should not be visible to lake users), and this system is not anticipated to affect usage of the lake by residents (i.e., winter ice thickness should not be measurably impacted). Figure 7-2 shows the essential components of the side stream saturation system.

To aerate both North and South Cornelia, two separate aeration systems will be required. Installation of an aeration system in South Cornelia only is recommended at this time for several reasons:

- Installation of the system in South Cornelia allows the system to be tested and refined prior to installation of a system in North Cornelia. There is no impediment to installing an aeration system in North Cornelia several years after installation in South Cornelia.
- There is potential for North Cornelia to freeze to the bottom due to its shallow nature, thereby rendering the aeration system less effective; and
- If North Lake Cornelia freezes to the bottom and kills all the native fish, it is possible that the North Cornelia fish population may be repopulated by the fish in South Cornelia. The possibility

of fish passage between South and North Cornelia will be better understood after completion of the carp and goldfish tracking study (see Section 7.6).

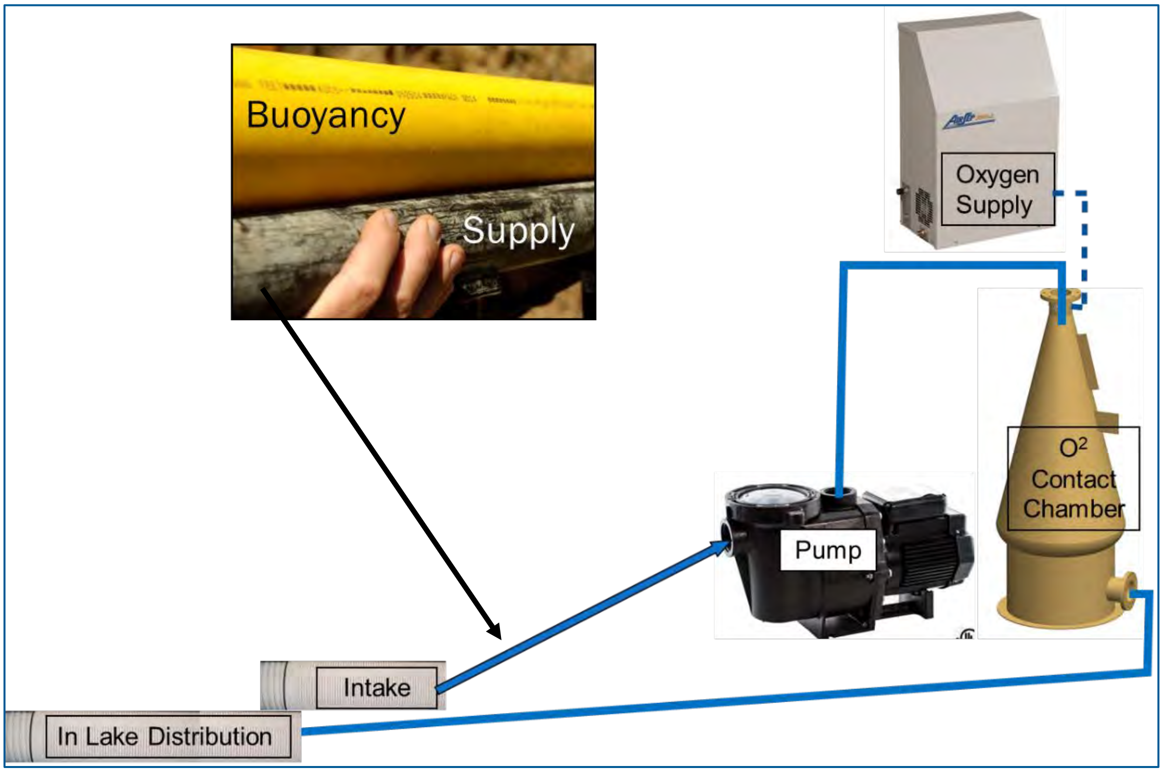
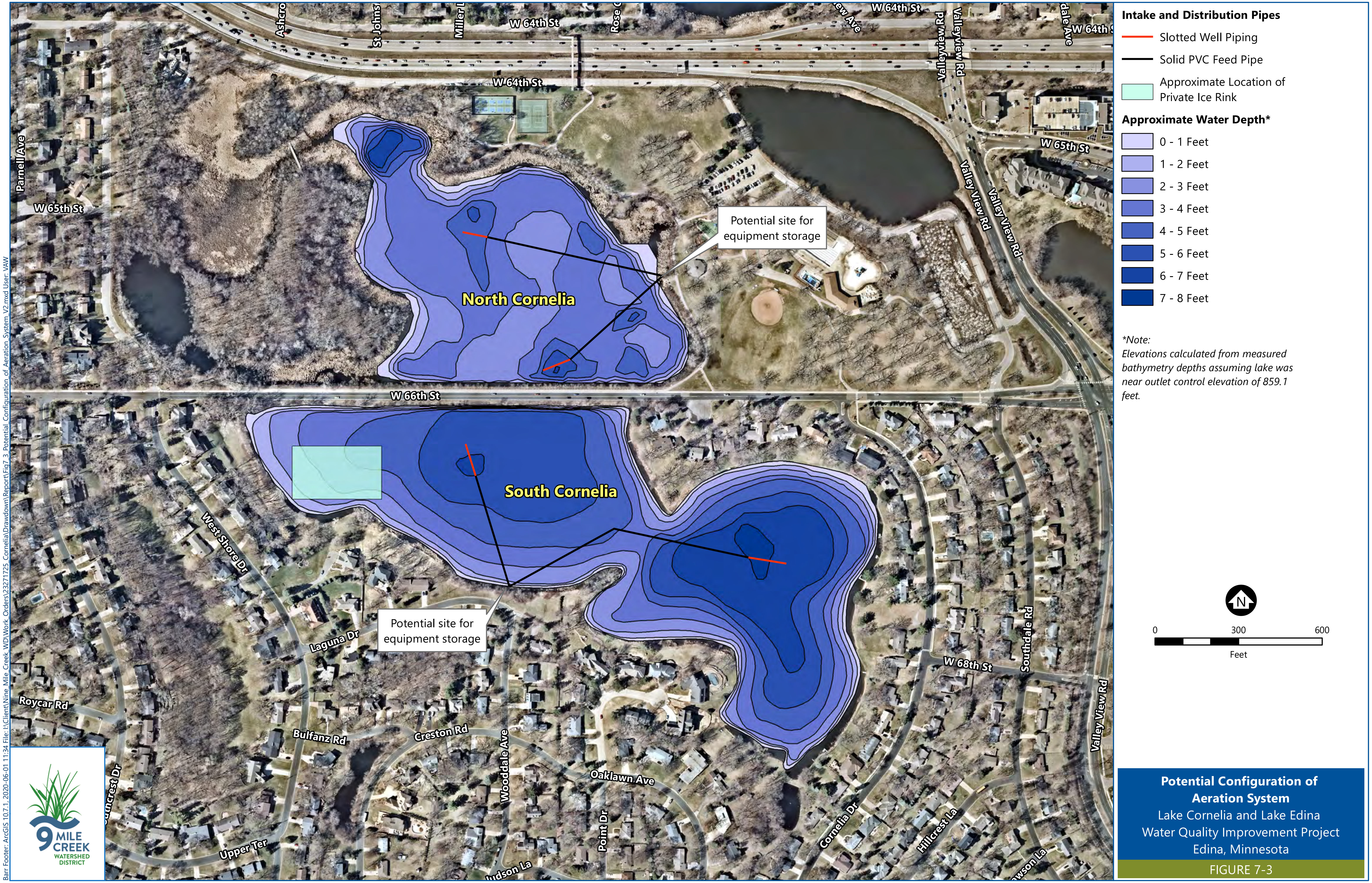


Figure 7-2 Main Components of the Side-stream Aeration System for Lake Cornelia

Figure 7-3 shows the potential configuration of a side stream aeration system in South Cornelia. The system includes an intake located in one bay of South Cornelia and an outlet in the other bay. The intake is located to minimize short circuiting and to pull water in a circular pattern in the west part of South Cornelia. Between the inlet and outlet, a pump and the oxygen injection system components would be housed in an approximately 8-foot by 8-foot building. The outlet consists of PVC pipe with slots designed to slowly feed water into the bottom of the lake at very low velocities. The intake and outlet pipes will be positioned approximately 4 inches above the lake bottom. This system will operate from January until about mid-March and will be able to deliver 17 kilograms/day of oxygen. Additional design details are provided in Appendix E.

7.4.3 Permitting

A MnDNR Aeration Permit would be required for installation of the aeration system. The permitting process is straightforward and requires minimal information such as the purpose of aeration (prevention of winter fish kill is one option), the permittee, period of operation, and a description of the system.



Potential Configuration of Aeration System
Lake Cornelia and Lake Edina
Water Quality Improvement Project
Edina, Minnesota

FIGURE 7-3

7.4.4 Opinion of Probable Cost

A planning-level opinion of probable cost has been developed for designing and installing a side stream aeration system in South Cornelia.

Costs were not developed for an aeration system in North Cornelia at this time due to the recommended staged approach. However, it is anticipated that design and installation of a side stream aeration system in North Cornelia would be similar to that of South Cornelia. The planning-level opinion of probable cost for designing and installing a side stream aeration system in South Cornelia is $202,000, with a range of $172,000 to $243,000 (-15 percent to +20 percent) (Table 7-1). The opinion of probable cost is based on engineering judgement, and experience with similar projects. The opinion of cost includes costs for specialty design services and technical support from Gantzer Water during project installation and system start-up including follow-up site visits, as needed. A detailed opinion of probable cost is included in Appendix D.

Table 7-1 Summary of Estimated Costs for Winter Aeration

Items	Estimated Cost
Mobilization/Demobilization	$9,700
Safety, erosion control, and site prep	$15,900
Aeration system	$76,400
Site restoration	$4,300
Construction subtotal:	$106,300
Construction contingency (30%)	$31,900
Estimated construction cost	**$138,200**
Gantzer Water design and commissioning support[1]	$22,000
Planning, engineering, and design (30%)	$41,500
Total	**$201,700**
Low range (-15%)	$171,500
High range (+20%)	$242,000

[1] Gantzer Water design and commissioning support includes engineering and design support, startup testing, operations and maintenance manual and training, and 2 years of startup support.

7.5 Stocking

Stocking of native fish such as bluegill, largemouth bass and/or pike is recommended to reduce success of goldfish following initial removal of a large biomass of the existing goldfish population and mitigation of winterkill (aeration) to allow for native fish populations to survive for more than just a few seasons.

North and South Cornelia have been sporadically stocked by the MnDNR West Metro Area Fisheries and via the MnDNR Fishing in the Neighborhood (FIN) programs since 1961 (Reference (45)). Stockings in the last 10 years have been comprised primarily of bluegill with some black crappie, along with hybrid and pumpkinseed sunfish. All fish stocked in the last 10 years are shown as adults (2+ year of age) on Lakefinder. The last noted stocking was in 2016 with 300 adult bluegills stocked. Lake Cornelia is managed as a highly disturbed winterkill lake under the FIN program. Ongoing stocking is influenced by availability of fish due to the area-wide presence of viral hemorrhagic septicemia (VHS) an infectious viral disease. VHS has precluded MnDNR from accessing fish for trap and transfer of adults from previously used sources (Reference (46)).

Stocking rates of adult bluegill by MnDNR have been variable based on the availability of fish; however, during several of the years from 2010 through 2016, adult bluegills were stocked at the rate of approximately 6 adults/surface acre (total stocking of approximately 300 fish). This rate is below rates recorded by Dauwalter and Jackson (Reference (47)) where the rate of stocking 3- to 5-inch bluegills in adjacent states such as South Dakota was approximately 100/surface acre (in combination with largemouth bass in a planned stocking management option). Spring stocking of sexually mature fish requires fewer fish; as few as 2 pair of sexually mature fish per ½ acre of surface water can provide an adequate initial stocking (Reference (48)). Using this guideline for stocking of sexually mature fish, Lake Cornelia would require approximately 420 sexually mature adults equally split between male and female for an initial stocking. Under some conditions as few as 10 pair of gravid brood stock bluegills per one hundred surface acres are suggested to be capable of establishing a population (Reference (49)).

Due to regularly occurring winterkill and/or frequent winter occurrences of very low oxygen levels in Lake Cornelia, carry-over of any bluegills stocked the previous year is highly variable. This factor combined with likely removal of some stocked bluegill via sport fishing results in low numbers of bluegills likely present each spring. Sampling in 2018 with fyke nets showed low numbers of bluegill in South Cornelia (1/net) with higher numbers in North Cornelia (10/net). The Minnesota statewide normal range for bluegill catch per unit effort in trap nets is 3.7- 42.9/net.

Future successful stocking of bluegill or other potential fishes to prey on various life stages of goldfish will be influenced by the availability of fish (Reference (44)) from VHS disease-free sources and prior mitigation of regularly recurring winterkill.

Future stocking schedules, species and rates should be determined in conjunction with MnDNR fisheries West Metro management and could include approaches such as:

a) Stocking 3–5” size disease free bluegills at a rate of 100/surface acre. This should be conducted in combination with largemouth bass in a planned management option.

b) Alternatively, initially stock up to 420 sexually mature bluegill adults from disease free sources equally split between male and female

c) Stock at rates similar to the past history of MnDNR management from disease free sources that include bluegill, largemouth bass and northern pike

7.5.1 Permitting

Since Lake Cornelia is a public water, all future potential stocking must be coordinated with MnDNR.

7.5.2 Costs

The approximate cost range for private hatchery, certified disease-free adult bluegills is $1–$3/fish plus transportation. Other species such as northern pike or largemouth bass have a higher cost/fish.

7.6 Additional Monitoring

A combination of physical removal and biological control (predation) is the recommended approach to manage goldfish at this time, as removal efforts can be selective/targeted to goldfish to reduce impacts to other fish and wildlife. As mentioned in Section 7.3, additional information is needed to assess the potential effectiveness of removal efforts, including monitoring of the goldfish population in the Lake Cornelia system to understand their movements (assess feasibility of targeted removals) and assessment of the efficacy of baited box nets for removal of goldfish.

Barr staff worked with staff from NMCWD and WSB to develop a monitoring program to gather additional information on goldfish and carp in the Lake Cornelia system. The monitoring program will help confirm goldfish and carp populations and will include analysis of age structure of a goldfish sample to better understand the environmental conditions that drive goldfish movements to connected water bodies. The monitoring program will also track movement of goldfish and carp, which is important in better understanding their mobility, spawning patterns and likelihood to travel/spread within a system. Finally, a possible goldfish removal method (baited box net trapping) will be tested to determine effectiveness with goldfish (this method has shown to be successful with carp. The goldfish and carp monitoring program will begin in summer 2020. A copy of the scope of work is included as Appendix F.

8 Lake Management Conclusions and Recommendations

In 2019, the NMCWD completed a water quality study for Lake Cornelia and downstream Lake Edina; the study recommended further consideration of several watershed and in-lake management activities to improve water quality in both lakes. This report summarizes a feasibility analysis and/or evaluation of options for several potential management activities, including the following:

- Feasibility analysis and preliminary design of a stormwater treatment filtration system in Rosland Park;
- Review of other potential watershed BMPs, including conceptual design of retrofit stormwater BMPs in the Lake Edina watershed and consideration of treatment opportunities in ponds upstream of Lake Cornelia;
- Evaluation of curly-leaf pondweed management options, including herbicide treatment and lake drawdown; and
- Evaluation of fishery management options to control goldfish and carp populations, including winter aeration to prevent winterkill of predator species, fish removal, and fish stocking

8.1 Stormwater Treatment in Rosland Park

The 2019 water quality study concluded that stormwater runoff is a major contributor of phosphorus to Lake Cornelia and recommended implementation of a stormwater best management practice (BMP) located in Rosland Park to remove phosphorus from water flowing from the Swimming Pool Pond to North Lake Cornelia. As part of this feasibility study, Barr staff worked closely with NMCWD and City of Edina staff from the Engineering, Public Works, and Parks and Recreation departments to identify a conceptual BMP design and location within Rosland Park. The proposed stormwater BMP is an above-ground filtration vault that will treat a significant portion of the water that flows from Swimming Pool Pond to Lake Cornelia. The above-ground filtration vault design allows for more design flexibility, increased treatment capacity, simplified operation and maintenance, and fewer concerns about functionality as compared with an underground system. The proposed location minimizes parkland impacts and provides an opportunity to incorporate plantings, park signage, public art or education into the feature design to make the system not only a functional means of reducing phosphorus to Lake Cornelia, but an attractive element of the park as well.

Under the proposed pumping scenario, the pump will operate approximately 12 hours per day mid-April through mid-November when water levels are higher than or within 3.6 inches of the existing control elevation. Based on this scenario, approximately 52% of the flow between Swimming Pool Pond and North Cornelia between mid-April and mid-November will be treated, on average. A three-chamber filtration vault is proposed to test three different filtration media types, with a goal of assessing and ultimately using the filtration media that most effectively removes phosphorus. The estimated total phosphorus removal efficiency for the proposed filtration vault is approximately 63%, based on the anticipated removal efficiencies of the proposed filtration media. Based on this and the estimated volume of water filtered, the filtration vault is anticipated to remove 22 pounds of phosphorus on an average annual basis, with a range of 12 – 28 pounds for evaluated years, dependent on climatic conditions.

A feasibility-level design cost estimate was developed for the Rosland Park filtration vault and is shown in Table 8-1. The opinion of probable cost provided generally corresponds to standards established by the Association for the Advancement of Cost Engineering (AACE). A class 3 feasibility-level opinion of cost was used based on the level of project definition (between 10% and 40%), wide-scale use of parametric models to calculate estimated costs (i.e., making extensive use of order-of-magnitude costs from similar projects), and uncertainty with an acceptable range of between -15% and +20% of the estimated project cost. The estimated annualized cost per pound of total phosphorus removed is also summarized in Table 4-7.

Table 8-1 Rosland Park Treatment Vault Feasibility-Level Cost Estimate

BMP	Feasibility-Level Cost Estimate[1]	Feasibility-Level Cost Range (-15% - +20%)	Estimated Life of Project	Estimated Annualized Cost per Pound TP Removed[2]
Rosland Park Treatment Vault	$744,000	$632,000–$892,000	30 years	$2,200

[1] Feasibility-level cost estimate does not include annual costs for operations and maintenance. Cost does include engineering and design estimate

[2] Feasibility-level estimated annualized cost per pound total phosphorus removed assumes an annual maintenance cost of approximately $11,000 and an inflation rate of 3%.

Based on preliminary discussions with staff from the MnDNR, the proposed pumping from Swimming Pool Pond will require a water appropriations permit. A Work in Public Waters permit will likely not be necessary since the proposed pumping draw down depth is less than one half foot. Notification of impacted riparian landowners and an accounting of support will be required as part of the permitting process. While it is not anticipated that a permit will be necessary from MPCA for the proposed filtration vault, discussions with MPCA staff regarding the proposed BMP and proposed filtration media is recommended prior to or early in the design process to confirm.

NMCWD will need to obtain the necessary rights to construct the proposed filtration vault on property owned by the City of Edina. It is anticipated that NMCWD and the City of Edina will enter into a cooperative agreement upon ordering of the project. A permit for construction of the proposed filtration vault will also be required from NMCWD.

Prior to design and construction, it is recommended that testing of the proposed filtration media be considered, including evaluating the hydraulic conductivity of the CC17 and iron-enhanced CC17 media and conducting bench scale testing of the media for phosphorus removal effectiveness.

8.2 Other Watershed BMP Opportunities

As part of the 2019 UAA study, several watershed best management practices (BMPs) were evaluated to assess their effectiveness in reducing phosphorus loading to Lake Cornelia and Lake Edina, including watershed-wide infiltration, a BMP in Rosland Park, and street sweeping. This feasibility study expanded on previous analyses to include a high-level evaluation of other potential BMP opportunities in the Lake Cornelia and Lake Edina watersheds, including consideration of retrofit stormwater BMPs on publicly-owned land in the Lake Edina watershed and treatment opportunities in ponds upstream of Lake Cornelia (Point of France Pond, Lake Otto, Lake Nancy).

8.2.1 Stormwater BMP Retrofit Opportunities in Lake Edina Watershed

Watershed runoff comprises a significant portion of the external phosphorus loading to Lake Edina, ranging from 35% to 45% of annual phosphorus sources in modeled years (Reference (1)). A high-level watershed analysis was conducted as part of this study to identify potential opportunities to implement stormwater BMPs in the Lake Edina watershed, with a focus on partnership projects on publicly-owned lands. Two properties were identified for the potential to incorporate infiltration-based BMPs: Cornelia Elementary School, owned by Edina Public Schools, and the open green space area between Lynmar Lane and Bristol Boulevard owned by the City of Edina (from this point forward referred to as Lynmar basin). Three rain gardens proposed at Cornelia Elementary School would collect and infiltrate stormwater runoff from approximately 2.6 acres of primarily school parking lot. A stormwater infiltration feature within the Lynmar Basin would collect and infiltration runoff from an 18-acre residential watershed.

Concept-level opinions of probable cost were developed for the two potential BMP projects and are shown in Table 8-2. The opinions of probable cost are generally correspond to standards established by the AACE. Class 5 opinions of cost were used based on the limited project definition, wide-scale use of parametric models to calculate estimated costs (i.e., making extensive use of order-of-magnitude costs from similar projects), and uncertainty with an acceptable range of between -30% and +50% of the estimated project cost.

The estimated annual total phosphorus removals are approximately 3.6 and 20.5 pounds from the Cornelia Elementary School basins and the Lynmar Basin, respectively. The estimated annualized cost per pound of total phosphorus removed is also summarized in Table 8-2.

Table 8-2 Lake Edina Watershed Infiltration-BMP Concept-Level Cost Estimates

Location	Concept-Level Cost Estimate[1]	Concept Level Cost Range (-30% – +50%)	Estimated Life of Project	Estimated Annualized Cost per Pound TP Removed[2]
Cornelia Elementary School (3 Infiltration BMPS)	$332,000	$233,000–$498,000	30 years	$5,500
Lynmar Basin (1 Infiltration BMP)	$512,000	$359,000–$768,000	30 years	$1,500

[1] Concept-level cost estimates do not include annual costs for operations and maintenance. Costs do include engineering and design estimates.
[2] Concept-level estimated annualized cost per pound total phosphorus removed assumes an annual maintenance cost of approximately 10% of estimated construction costs and an inflation rate of 3%.

If the NMCWD is interested in pursuing implementation of stormwater BMPs on these sites, the next step would be to contact the property owners to discuss partnership opportunities. The City of Edina has indicated potential interest in preliminary discussions. Edina Public Schools has not been contacted yet. It is recommended that the NMCWD consider preparing some sketches/renderings of the proposed rain gardens and infiltration basin prior to meeting with Edina Public Schools and City of Edina.

8.2.2 Opportunities for Treatment of Ponds Upstream of Lake Cornelia

Internal P loading in stormwater ponds has been increasingly identified as an issue in the Twin Cities area. There are generally two causes of internal P loading in ponds: (1) high phosphorus in pond bottom sediment resulting from years of sediment accumulation and the occurrence of low oxygen during the summer months, and (2) an abundant population of fish such as carp, bullheads, and other fish such as goldfish which disturb bottom sediments and cause phosphorus to release into the water column. In many cases ponds are afflicted by both problems, they have high phosphorus in bottom sediments as well as an abundant population of bottom foraging fish such as carp and goldfish.

Given the root cause of internal loading in ponds, there are three viable approaches to reducing internal phosphorus loading in ponds: (1) remove and eliminate the bottom feed fish such as goldfish and carp, (2) bind the phosphorus in the pond bottom sediment by adding aluminum (alum), iron (e.g., iron filings per the studies conducted by the University of Minnesota, or calcium (e.g., spent lime (calcium carbonate) is currently being studied), and (3) aerate to improve oxygen concentrations. Removing fish such as carp has been shown to be successful in the in the Ramsey Washington Metro Watershed District with carp removal leading to reduced phosphorus concentrations within the pond water column at the pond outlet. Lower turbidity, but also increased aquatic plant abundance, occurs in conjunction with carp removal. The use of alum (aluminum is the main component) is a well-established method for reducing internal phosphorus loading and this approach is being used for Lake Cornelia. The use of iron and spent lime are also potentially viable approaches but are more experimental. Spent lime is a waste material and repurposing of that material to treat phosphorus is attractive. However, there are potential challenges in identifying an approach to apply spent lime as spent lime is a solid material that is largely insoluble in water and would have to be ground and spread in some manner. Iron has potentially similar application challenges. The short- and long-term benefits of treatment using spent lime and iron in a waterbody are still unknown. Aeration may also help by increasing oxygen in the water column and reduce the rate of phosphorus release from bottom sediments. The appropriate aeration approach such as a fountain or forced air bubbler would need to be evaluated on a pond-by-pond basis.

The first step before committing to a management action is to determine if a pond is exporting phosphorus as a consequence of internal P loading by monitoring at the ponds' inlet and outlet (or within the water column). Once it is established that a pond or series of ponds are releasing phosphorus, then appropriate mitigation approaches can be identified and applied if the magnitude of phosphorus export justifies the action. A 2018 monitoring analysis conducted by the University of Minnesota concluded that minimal internal phosphorus release was occurring in Swimming Pool Pond and Point of France Pond upstream of Lake Cornelia. Water quality data has not been collected from Lake Nancy or Lake Otto, but should be considered in the future to better understand whether internal loading from sediment phosphorus release is occurring.

It is expected that carp and goldfish management efforts at Lake Cornelia will also benefit upstream ponds if there is a connection (e.g., active fish passage) between Lake Cornelia and these ponds. If there is a connection then it will be necessary to reduce or eliminate carp and goldfish populations in those ponds as well as in Lake Cornelia. The 2018 fishery survey noted an abundant goldfish population in Lake Nancy, which is connected to North Cornelia via a storm sewer under Highway 62. Before other management activities are considered in Lake Nancy, it is recommended that we wait to realize the benefits of carp and goldfish control at Lake Cornelia. No fisheries information is currently available for Lake Otto.

8.3 Curly-leaf Pondweed Management

The presence of curly-leaf pondweed and its mid-summer die-off negatively impacts the water quality of Lake Cornelia. Accordingly, management of curly-leaf pondweed is an important component of a long-term management plan for Lake Cornelia. Effective control of aquatic invasive species can require long-term management. While a long-term curly-leaf pondweed management goal of reducing presence of the invasive plant until neither curly-leaf pondweed nor turions are observed in the lake would be most protective of Lake Cornelia and downstream lake ecosystems, it would require intensive treatment that may not be sustainable for the duration needed to be successful. As such, a more immediate curly-leaf management goal is to reduce the extent and density of the invasive plant throughout Lake Cornelia so it doesn't significantly hinder growth of native plants and so mid-summer die off of curly-leaf pondweed does not cause reduced water quality.

Two alternatives for curly-leaf pondweed management were evaluated as part of this study: annual herbicide treatment (current approach) and a lake drawdown.

8.3.1 Annual Herbicide Treatments

The City of Edina has been conducting annual herbicide treatments in Lake Cornelia since 2017 to reduce the impact of curly-leaf pondweed die-back on water quality in Lake Cornelia and downstream Lake Edina and to help promote a healthy native aquatic plant population. Spring pre-treatment plant surveys since 2017 indicate annual treatments are having some level of effectiveness in reducing the presence and density of curly-leaf pondweed throughout the lake. While annual herbicide treatments can reduce the extent and density of curly-leaf pondweed, this approach may necessitate long-term annual herbicide treatments.

The planning-level opinion of probable cost for herbicide treatment of the curly-leaf pondweed in Lake Cornelia is approximately $28,000 per year of treatment, with a range of $26,000 to $34,000 (-10% to +20%). This estimate includes preparation of contract documents, permitting, and herbicide application. The cost estimate also includes potential costs related to monitoring that may be deemed appropriate or required by the MnDNR as part of permitting, including temperature measurements, herbicide residue monitoring, and aquatic plant monitoring.

The City of Edina anticipated conducting an herbicide treatment of Lake Edina in 2020 to manage curly-leaf pondweed. However, a pre-treatment survey in spring of 2020 found little or no curly-leaf pondweed in the lake.

8.3.2 Lake Drawdown

Another potential method to control curly-leaf pondweed is to draw down water levels in a lake to allow the lake bed to freeze over the winter. Curly-leaf pondweed primarily propagates through 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 kill the turions, thus disrupting curly-leaf pondweed's reproductive cycle.

A high-level evaluation of a drawdown in Lake Cornelia to control curly-leaf pondweed was included as part of this feasibility study due to the success of this approach in other lakes, including several in the NMCWD, and the desire to avoid recurring management activities. Results of the analysis indicate that while it would be feasible to draw the lake down, the project is cost prohibitive. The drawdown would require a pumping capacity of 3,000 gallons per minute (gpm) to have a reasonable likelihood of drawing down lake levels within the timeframe required by MnDNR and keeping lake levels drawn down throughout the winter months. In addition, three separate 3,000 gpm pumps would be necessary to pump water from the several deeper holes throughout North and South Cornelia.

Conducting a lake drawdown would require approval from the MnDNR through a Work in Public Waters Permit. Under Minnesota Statute Section 103G.408, 75 percent of the riparian landowners must authorize a drawdown. The City of Edina owns all of the property adjacent to North Lake Cornelia and approximately half of the shoreline property around South Lake Cornelia. South Lake Cornelia has 31 private, riparian landowners.

8.3.3 Curly-Leaf Management Recommendation

Given that the annual herbicide treatments are having some level of effectiveness in reducing the presence and density of curly-leaf pondweed throughout Lake Cornelia, it is recommended that this management approach be continued. Additional monitoring to compare year-to-year effectiveness in reducing the presence and density of curly-leaf pondweed is recommended. Because of the high cost, intensive permitting requirements, and uncertainty regarding the likelihood of maintaining a drawn down condition throughout the winter months, a lake draw down is not recommended at this time.

8.4 Fishery Management

A 2018 fish survey identified a large population of goldfish in Lake Cornelia and upstream Lake Nancy. Similar to carp, goldfish have the potential to negatively impact water quality by increasing in-lake turbidity due to benthic feeding habits and increase in-lake nutrient levels from nutrient cycling through the fish gut. With the high numbers of goldfish in the Lake Cornelia system and their potential to reduce water quality, management options to reduce the goldfish population were considered as part of this feasibility study. While carp were found in lesser numbers in Lake Cornelia, they were more abundant in Point of France Pond and are being included in consideration of management options.

While a relatively large amount of research has been conducted on common carp and their impact on water quality in Minnesota, limited research is available regarding goldfish and goldfish/carp hybrids. A literature review was conducted as part of this feasibility study to better understand the characteristics of goldfish and goldfish/carp hybrids, their role and movements within lake systems, and potential goldfish control methods.

8.4.1 Fish Management Recommendations

Based on the literature review of goldfish in lake systems and currently-available information regarding the fishery in Lake Cornelia, an integrated approach to goldfish and carp management using a combination of management actions is anticipated to be the most successful option. The following management approach is recommended:

1) **Conduct removal of goldfish and carp in combination with mitigation of recurrent winterkill through the use of winter aeration**
   As identified in the literature review, there are several potential methods for goldfish and carp removal, including biological control, lake drawdown, physical removal and chemical control. A combination of physical removal and biological control (predation) is the preferred approach at this time (versus lake drawdown and/or chemical treatment), as removal efforts can be selective/targeted to goldfish to reduce impacts to other fish and wildlife. However, additional information is needed to assess the potential effectiveness of removal efforts, including monitoring of the goldfish and carp populations in the Lake Cornelia system to understand their movements (assess feasibility of targeted removals) and assess the efficacy of baited box nets for removal of goldfish.

2) **Stock native fish following removal of large numbers of goldfish and winterkill mitigation.** Stocking of native fish such as bluegill, largemouth bass and/or pike is likely to reduce success of goldfish following initial removal of a large biomass of the existing goldfish and carp populations and mitigation of winterkill to allow for native fish populations to survive for more than just a few seasons. Stocking of native fish may be affected by availability of disease free fish stocks in the region.

8.4.2 Winter Aeration

A comprehensive evaluation was conducted by Barr's subconsultant, Gantzer Water, to evaluate the feasibility of installing a winter aeration system that could be used in either North or South Cornelia, or both basins, to prevent periodic winter fish kill, promote the establishment of a self-sustaining native fish population, and reduce the carp and goldfish population in Lake Cornelia. Several different types of aeration systems were considered and evaluated according to effectiveness, aesthetic effects, potential impacts on winter ice thickness (safety consideration), and ease of maintenance.

A side stream saturation system was identified as the preferred approach as it will be most capable of meeting the criteria identified for this project, which include efficiency, minimal aesthetic disturbance (the piping and other aeration equipment should not be visible to lake users), and this system is not anticipated to affect usage of the lake by residents (i.e., winter ice thickness should not be measurably impacted).

Two separate systems would be required to aerate both North and South Cornelia. It is recommended that an aeration system be installed only in South Cornelia at this time. Installation of the system in South Cornelia will allow the system to be tested and refined prior to potential future installation of a system in North Cornelia. It is expected that the aeration system in South Cornelia may be more effective than North Cornelia, as there is greater potential for North Cornelia to freeze to the bottom due to its shallow nature.

The side stream saturation aeration system in South Cornelia will include an intake located in one bay of and an outlet in the other bay, pulling water in a circular pattern in the west part of South Cornelia. A pump and the oxygen injection system components would be housed in an approximately 8-foot by 8-foot equipment storage building on the City-owned property on the south side of South Cornelia. The proposed system would operate from January until about mid-March.

The planning-level opinion of probable cost for designing and installing a side stream aeration system in South Cornelia is $202,000, with a range of $172,000 to $243,000 (-15% to +20%). The opinion of probable cost is based on engineering judgement, and experience with similar projects. The opinion of cost includes costs for specialty design services and technical support from Gantzer Water during project installation and system start-up including follow-up site visits, as needed.

8.4.3 Goldfish and Carp Removal

A combination of physical removal and biological control (predation) is the preferred approach to remove goldfish and carp from the Lake Cornelia system. While information is limited regarding effective goldfish removal techniques, there is hope that the baited box net approach that has been successful with carp will also be effective in catching and removing goldfish. NMCWD intends to test the baited box net approach in 2020 and 2021 as part of their goldfish monitoring project.

8.4.4 Stocking

Stocking of native fish such as bluegill, largemouth bass and/or pike is recommended to reduce success of goldfish following initial removal of a large biomass of the existing goldfish population and mitigation of winterkill (aeration) to allow for native fish populations to survive for more than just a few seasons. Future stocking schedules, species and rates should be determined in conjunction with MnDNR fisheries West Metro management and could include approaches such as:

a) Stocking 3-5" size disease free bluegills at a rate of 100/surface acre. This should be conducted in combination with largemouth bass in a planned management option.

b) Alternatively, initially stocking up to 420 sexually mature bluegill adults from disease-free sources equally split between male and female.

c) Stocking at rates similar to the past history of MNDNR management from disease-free sources that include bluegill, largemouth bass and northern pike.

8.4.5 Additional Monitoring

As compared with carp, limited research is available regarding goldfish and goldfish/carp hybrids. As such, it is important to gather additional information on goldfish in the Lake Cornelia system. The proposed monitoring program, beginning in summer of 2020, will help confirm goldfish and carp populations and will include analysis of age structure of a goldfish sample to better understand the environmental conditions that drive goldfish movements to connected water bodies. The monitoring program will also track movement of goldfish and carp, which is important in better understanding their mobility, spawning patterns and likelihood to travel/spread within a system. Finally, a possible goldfish removal method (baited box net trapping) will be tested to determine effectiveness with goldfish (this method has shown to be successful with carp).

9 References

1. **Barr Engineering Co.** *Report Summary Lake Cornelia and Lake Edina Water Quality Study Use Attainability Analysis for Lake Cornelia (updated from 2010) and Lake Edina (first version).* July 2019.

2. **Nine Mile Creek Watershed District.** *Water Management Plan.* October 2017 (Amended April 2018, April 2019).

3. **Natarajan, Poornima and Gulliver, John.** *Assessment of Internal Phosphorus Loading in Swimming Pool Pond and Point of France Pond, City of Edina.* s.l. : College of Science & Engineering, University of Minnesota, 2019.

4. **Berg, Matt.** Personal email communication to Jessica Vanderwerff Wilson at City of Edina. s.l. : Endangered Resources Services LLC, April 20, 2020.

5. **Maxwell, Joshua.** *Lake Cornelia System Fisheries Assessment.* s.l. : Riley Purgatory Bluff Creek Watershed District, 2018.

6. *Turbidity Generation and Biological Impacts of an Exotic Fish Carassius auratus, Introduced into Shallow Seasonally Anoxic Ponds.* **Richardson, M, Whoriskey, F and Roy, L.** 4, 1995, Journal of Fish Biology, Vol. 47.

7. *Effects of Adult Common Carp (Cyprinus carpio) on Multiple Trophic Levels in Shallow Mesocosms.* **Parkos, Joseph, Santucci, Victor and Wahl, David.** 2, 2003, Canadian Journal of Fisheries and Aquatic Sciences, Vol. 60, pp. 182-192.

8. **Morgan, David, Beatty, Stephen and McLetchie, Heather.** *Control of Feral Goldfish (Carassius auratus) in the Vasse River: Report to the Vasse-Wonnerup LCDC.* s.l. : Centre for Fish and Fisheries Research, Murdoch University, 2005.

9. *Growth and Potential Photosynthesis of Cyanobacteria are Stimulated by Viable Gut Passage in Crucian Carp.* **Kolmakov, Vladimir and Gladyshev, Michail.** s.l. : Kluwer Academic Publishers, 2003, Aquatic Ecology, Vol. 37, pp. 237-242.

10. *Hypoxia.* **Richards, Jeffrey.** 2009, Fish Physiology, Vol. 27.

11. *Simultaneous Direct and Indirect Calorimetry or Normoxic and Anoxic Goldfish.* **Van Waversveld, J, Addink, A and Van Den Thillart, G.** 1989, Journal of Experimental Biology, Vol. 142, pp. 325-335.

12. **Safer, Martin.** Aquatic Invaders of the Pacific Northwest: Carassius Auratus auratus (Common Goldfish). 2014.

13. **Penttinen, O and Holopainen, I.** Seasonal Feeding Activity and Ontogenetic Dietary Shifts in Crucian Carp. [book auth.] W Wieser, et al. *Environmental Biology of European Cyprinids: Developments in Environmental Biology of Fishes.* s.l. : Springer, Dordrecht, 1992, Vol. 13.

14. *Effects of Summer Drawdown on Cyprinid Fish Larvae in Lake Biwa, Japan.* **Yamamoto, Toshiya, Kohmatsu, Yukihiro and Yuma, Masahide.** s.l. : The Japanese Society of Limnology, June 2006, Vol. 7, pp. 75-82.

15. *Chemical Foraging Stimulation in the Omnivorous Species Crucian Carp, Carassius carassius (Linnaeus 1758).* **Olsen, K, et al.** 2018, Aquaculture Reports, Vol. 12, pp. 36-42.

16. *Feeding Habits of Carassius carassius (Cyprinidae) in Beni Haroun Dam (Northeast of Algeria).* **Khelifi, Naima, et al.** 6, s.l. : AACL Bioflux, 2017, Vol. 10, pp. 1596-1609.

17. *Nonnative Fishes Inhabiting the Streams and Lakes of Illinois.* **Laird, Christopher and Page, Lawrence.** 1, 1996, Illinois Natural History Survey Bulletin, Vol. 35, pp. 1-51.

18. *Minimal Dissolved Oxygen Requirements of Aquatic Life with Emphasis on Canadian Species: A Review.* **Davis, John.** 12, s.l. : Journal of the Fisheries Research Board of Canada, 1975, Vol. 32, pp. 2295-2332.

19. *Aspects of Growth and Feeding in Golden Carp, Carassius auratus, from South Australia.* **Mitchell, B.** 6, 1979, Transactions of the Royal Society of South Australia, Vol. 103, pp. 137-144.

20. *Direct and Indirect Effects of Predation on a Fish Community: A Whole-Lake Experiment.* **He, Xi and Kitchell, James.** s.l. : American Fisheries Society, 1990, Transactions of the American Fisheries Society, Vol. 119, pp. 825-835.

21. *Interspecific Hybridization between Carp (Cyprinus carpio L.) and Goldfish (Carassius auratus L.) from Victorian Waters.* **Hume, DJ, Morison, Alexander and Fletcherb, Andrea.** January 1983, Australian Journal of Marine and Freshwater Research, Vol. 34, pp. 915-919.

22. *Koi x Goldfish Hybrid Females Produce Triploid Progeny When Backcrossed to Koi Males.* **Gomelsky, Boris, Schneider, Kyle J and Plouffe, Debbie.** 2012, North American Journal of Aquaculture, Vol. 74, pp. 449-452.

23. *Reproductive Biology of Carassius carassius (Cyprinidae) in Beni Haroun Dam, Algeria.* **Khelifi, Naima, et al.** 3, s.l. : AACL Bioflux, 2019, Vol. 12, pp. 822-831.

24. *Some Aspects of Reproductive Biology of the Crucian Carp Carassius Carassius in Lake Ziway, Ethiopia.* **Dadebo, Elias and Tugie, Daba.** 2, s.l. : The Biological Society of Ethiopia, 2009, Ethiopian Journal of Biological Science, Vol. 8, pp. 109-121.

25. **Hart, Steven, et al.** *Integrated Pest Management for Nuisance Exotics in Michigan Inland Lakes.* s.l. : Michigan State University Extension, 2000.

26. **Huber, T and Dawson, V.** Developing and Integrated Pest Management Strategy. [ed.] V Dawson and C Kola. *Integrated Pest Management Techniques to Control Nonnataive Fishes.* s.l. : U.S. Geological Survey, Upper Midwest Environmental Sciences Center, 2003, pp. 81-86.

27. **Dawson, V and Kolar, C.** *Integrated Management Techniques to Control Nonative Fishes.* LaCrosse, Wisconsin : U.S. Geological Survey, Upper Midwest Environmental Sciences Center, 2003.

28. **Bartodziej, William, et al.** A Minnesota Story: Urban Shallow Lake Management. *LakeLine.* s.l. : North American Lake Management Society, 2017. Vol. Winter, pp. 23-29.

29. **Sorensen, Peter, Bajer, Przemek and Headrick, Mary.** *Development and Implementation of a Sustainable Strategy to Control Common Carp in the Purgatory Creek Chain of Lakes.* 2015.

30. *Attracting Common Carp to a Bait Site with Food Reveals Strong Positive Relationships between Fish Density, Feeding Activity, Environmental DNA, and Sex Pheromone Release That Could be Used in Invasive Fish Management.* **Ghosal, Ratna, et al.** 2018, Ecology and Evolution, Vol. 8.

31. *Feeding Stimulants in an Omnivorous Species, Crucian Carp Carassius carassius (Linnaeus 1758).* **Olsen, K and Lundh, T.** November 2016, Aquaculture Reports, Vol. 4, pp. 66-73.

32. *An Evaluation of Attractants to Increase Catch Rates and Deplete Age-0 Common Carp in Shallow South Dakota Lakes.* **Carl, Dray, Weber, Michael and Brown, Michael.** s.l. : American Fisheries Society, 2016, North American Journal of Fisheries Management, Vol. 36, pp. 506-513.

33. *Relative Size Selectivity of Trap Nets for Eight Species of Fish.* **Laarman, Percy and Ryckman, James.** 1982, North American Journal of Fisheries Management, Vol. 2, pp. 33-37.

34. *The Chemical Sensitivity and Electrical Activity of Individual Olfactory Sensory Neurons to a Range of Sex Pheromones and Food Odors in the Goldfish.* **Sato, Koji and Sorensen, Peter.** 2018, Chemical Senses, Vol. 43, pp. 249-260.

35. *Nonnative Fishes Inhabiting the Streams and Lakes of Illinois.* **Laird, Christopher and Page, Lawrence.** 1, March 1993, Illinois Natural History Survey Bulletin, Vol. 35.

36. *A Review of Fish Control Projects.* **Meronek, Thomas, et al.** s.l. : American Fisheries Society, 1996, North American Journal of Fisheries Management, Vol. 16, pp. 63-74.

37. *Variation in Native Micro-Predator Abundance Explains Recruitment of a Mobile Invasive Fish, the Common Carp, in a Naturally Unstable Environment.* **Bajer, Przemyslaw, et al.** 2012, Biological Invasions, Vol. 14, pp. 1919-1929.

38. *Bluegill Recruitment, Growth, Population Size Structure, and Associated Factors in Minnesota Lakes.* **Tomcko, Cynthia M and Pierce, Rodney B.** 2005, North American Journal of Fisheries Management, Vol. 25, pp. 171-179.

39. *Role of Aquatic Vegetation Coverage on Hypoxia and Sunfish Abundance in Bays of a Eutrophic Reservoir.* **Miranda, LE and Hodges, KB.** 2000, Hydrobiologia, pp. 51-57.

40. *Bluegill (Lepomis macrochirus) Spawning Periodicity and Hatching Duration in the Northern Great Plains, USA.* **Jolley, Jeffrey C, Edwards, Kris R and Willis, David W.** 1, March 2009, Journal of Freshwater Ecology, Vol. 24, pp. 29-38.

41. *Dynamics of Quality Bluegill Populations in Two Michigan Lakes with Dense Vegetation.* **Schneider, James C.** 1, 1999, North American Journal of Fisheries Management, Vol. 19.

42. *Recruitment and Abundance of an Invasive Fish, the Common Carp, is Driven by its Propensity to Invade and Reproduce in Basins That Experience Winter-Time Hypoxia in Interconnected Lakes.* **Bajer, Przemyslaw and Sorensen, Peter.** 2009, Biological Invasions, Vol. 12, pp. 1101-1112.

43. **Clearwater, Susan J, Hickey, Chris W. and Martin, Michael L.** Overview of Potential Piscicides and Molluscicides for Controlling Aquatic Pest Species in New Zealand. Wellington : Science and Technical Publishing, Department of Conservation, New Zealand, 2008.

44. *Potential Distribution of the Viral Haemorrhagic Septicaemia Virus in the Great Lakes Region.* **Escobar, L E, et al.** 2016, Journal of Fish Diseases, pp. 1-18.

45. **Minnesota Department of Natural Resources.** MnDNR Lakefinder. [Online] [Cited: 03 31, 2020.] https://maps1.dnr.state.mn.us/lakefinder/mobile/.

46. —. Personal communication. December 4, 2018.

47. *A Re-Evaluation of U.S. State Fish-Stocking Recommendations for Small, Private, Warmwater Impoundments.* **Dauwalter, Daniel and Jackson, John.** 8, August 2005, Fisheries, Vol. 30, pp. 18-28.

48. **Schneider, James A.** A Fish Management Guide for Northern Prairie Farm Ponds. s.l. : Minnesota Department of Natural Resources, Section of Fisheries, August 1983.

49. **Minnesota Department of Natural Resources Fisheries Division.** *Lake Management Planning Guide.* 1982.

Appendices

Appendix A

December 18, 2019 Presentation to NMCWD Board of Managers on Rosland Park BMP Conceptual Design

Rosland Park Stormwater BMP Conceptual Designs

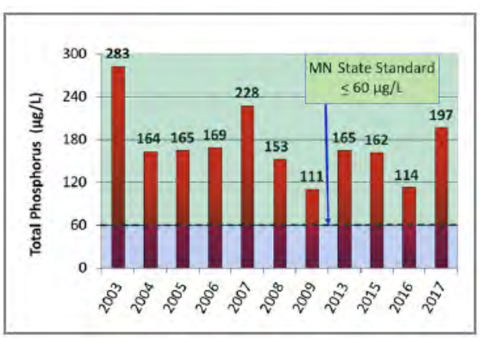
Summary for Nine Mile Creek Watershed District

December 18, 2019 Board Meeting

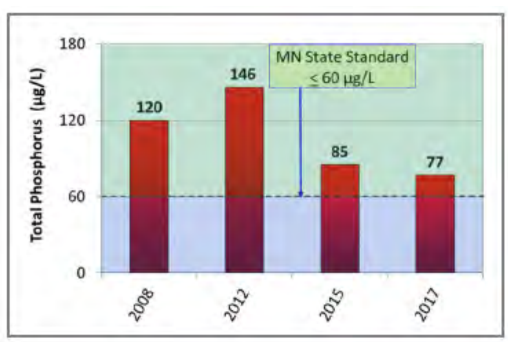
BARR

Motivations-

Lake Cornelia and Lake Edina do not meet State water quality standards



Summer average phosphorus concentrations in Lake Cornelia (North Basin) have historically been well above the state standard for shallow lakes.

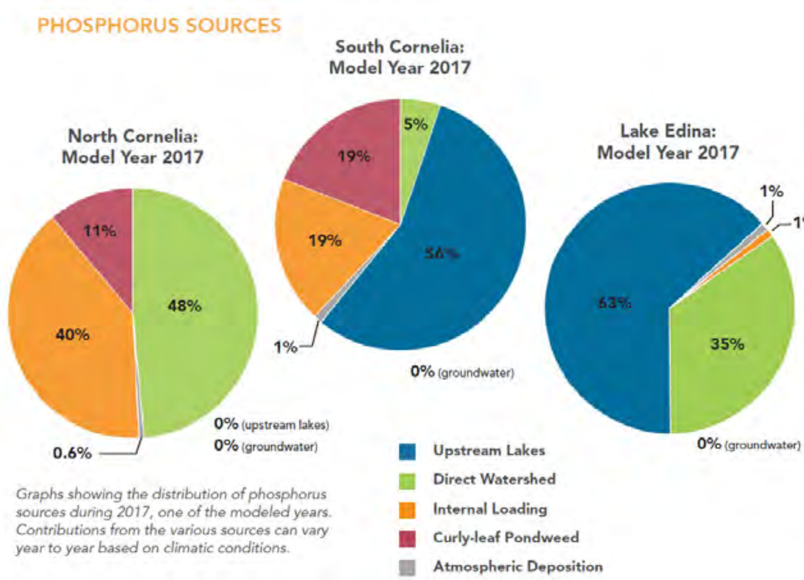


Summer average phosphorus concentrations in Lake Edina have historically been above the state standard for shallow lakes.

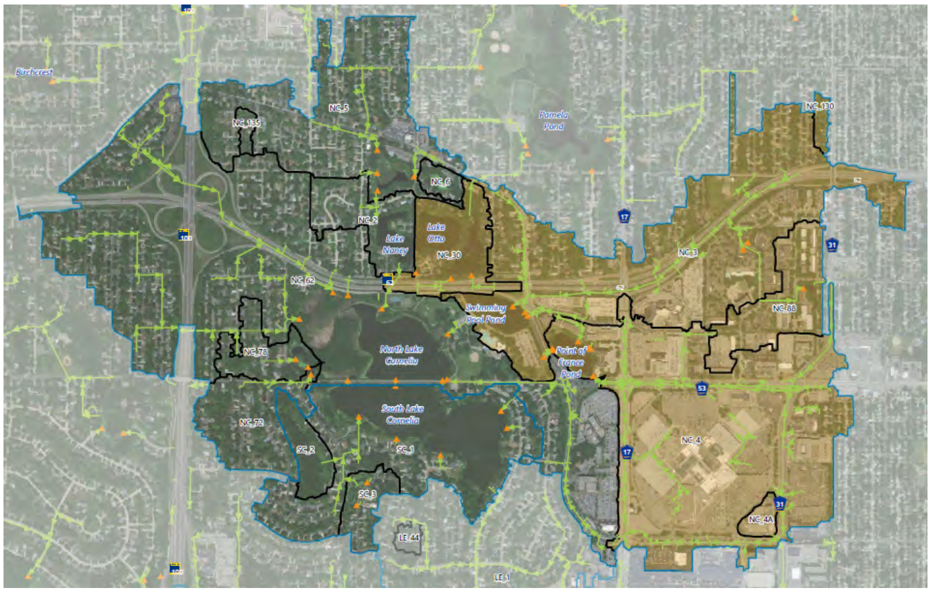
Motivations-
Periodic blue green algal blooms

Cornelia Blue Green Algae Blooms

Water quality study results



Why stormwater treatment in Rosland Park?



Large drainage area (shown in orange) flows to Swimming Pool Pond in Rosland Park before reaching Lake Cornelia.

Stormwater treatment design goals/criteria

- ***Treat as much stormwater as possible.*** Using ponds as storage allows us to treat more water (versus trying to capture the runoff from nearby parking lots/roads/buildings as it happens)
- ***Target dissolved phosphorus removal.*** Much of the particulate phosphorus is already removed by the ponds.
- ***Minimize footprint/park disruption***

Conceptual Designs

Concept #1:
Underground Filtration Treatment Vault (Gravity flow)

- Located in north parking lot

Concept #2:
Filtration Stream with Bioretention Pools (Pumped)

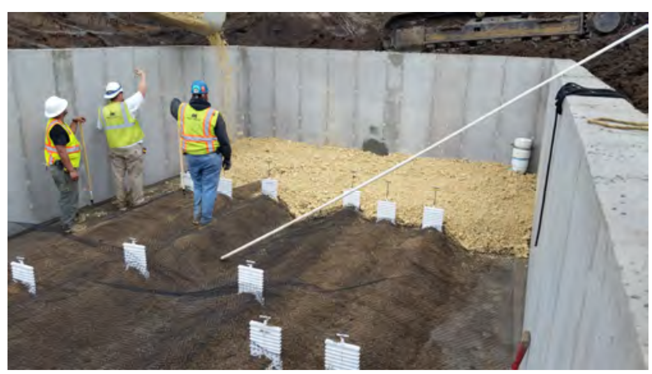
- Located in green space northwest of north parking lot

Concept #3:
Filtration Treatment Vault (Pumped)

- Located at the edge of the north parking lot

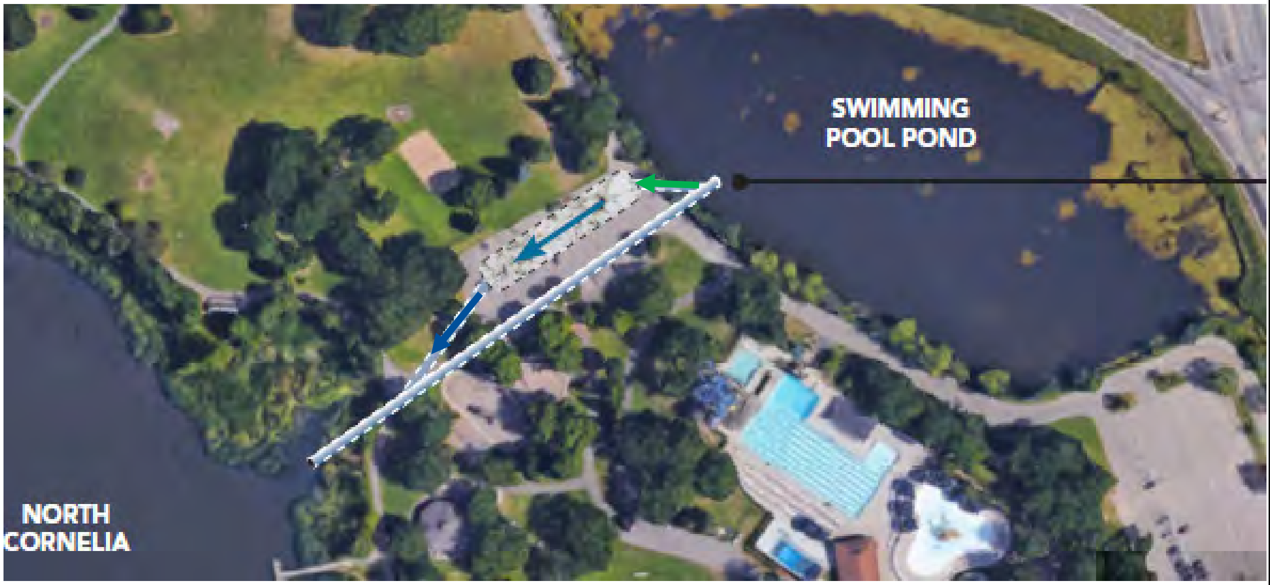
Preferred concept

Filtration Treatment Vault – example

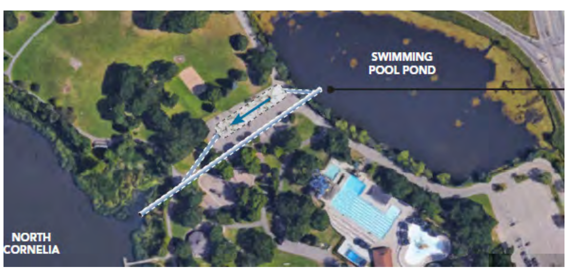


Ramsey-Washington Metro Watershed District
Frost-Kennard Spent Lime Vault Filter

Concept #1: Underground Filtration treatment vault – (gravity flow)



Concept #1: Underground Filtration treatment vault – (gravity flow)



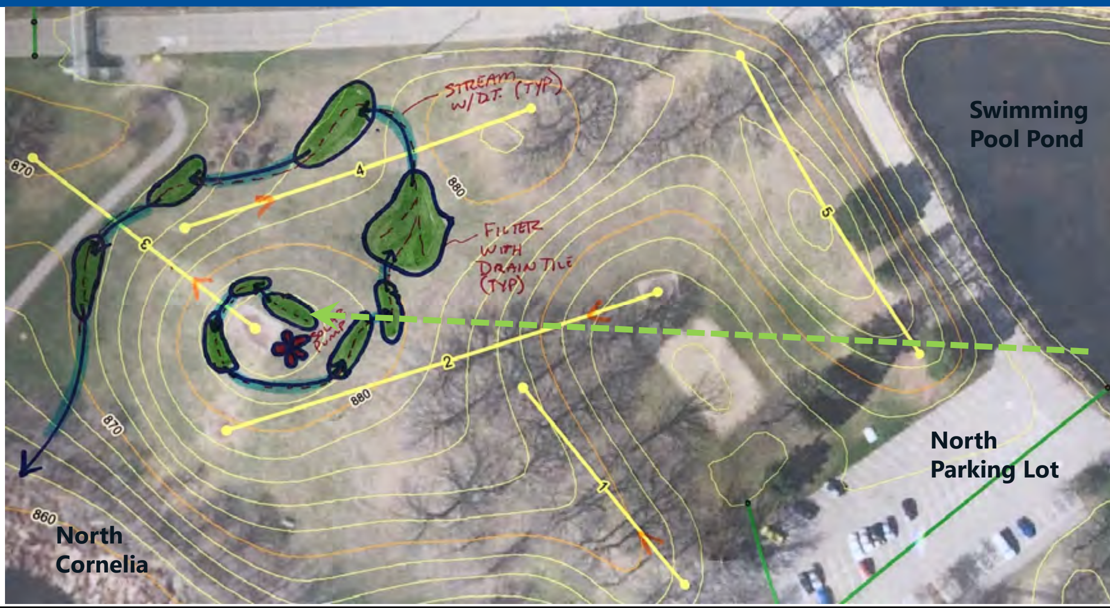
Concept 1 (pros)

- Gravity system – no pumping required
- Easily accessible for maintenance
- No loss of park space or parking

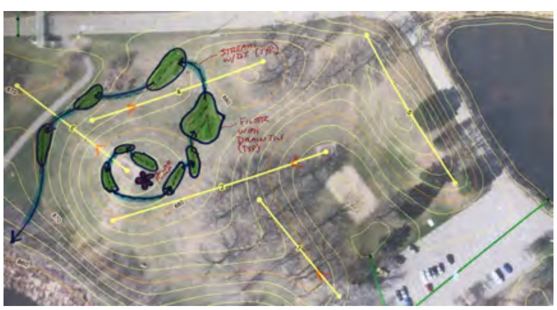
Concept 1 (cons)

- Larger footprint
- Concerns about walking and driving on grate
- Concerns about difficulty maintaining gravity flow when N. Cornelia is high
- Concerns about inundating the filter when N. Cornelia is high

Concept #2: filtration stream w/bioretention pools – pumped



Concept #2: filtration stream w/bioretention pools – pumped



Concept 2 (pros)

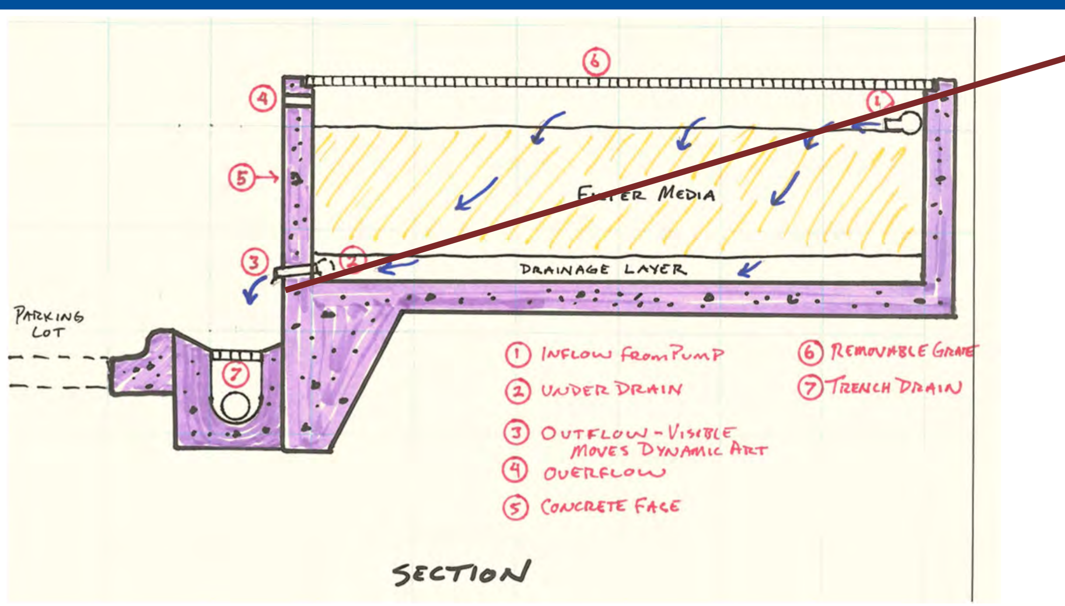
- Adds visual interest to park and Frisbee golf
- Plants help maintain filtration capacity
- High visibility for education

Concept 2 (cons)

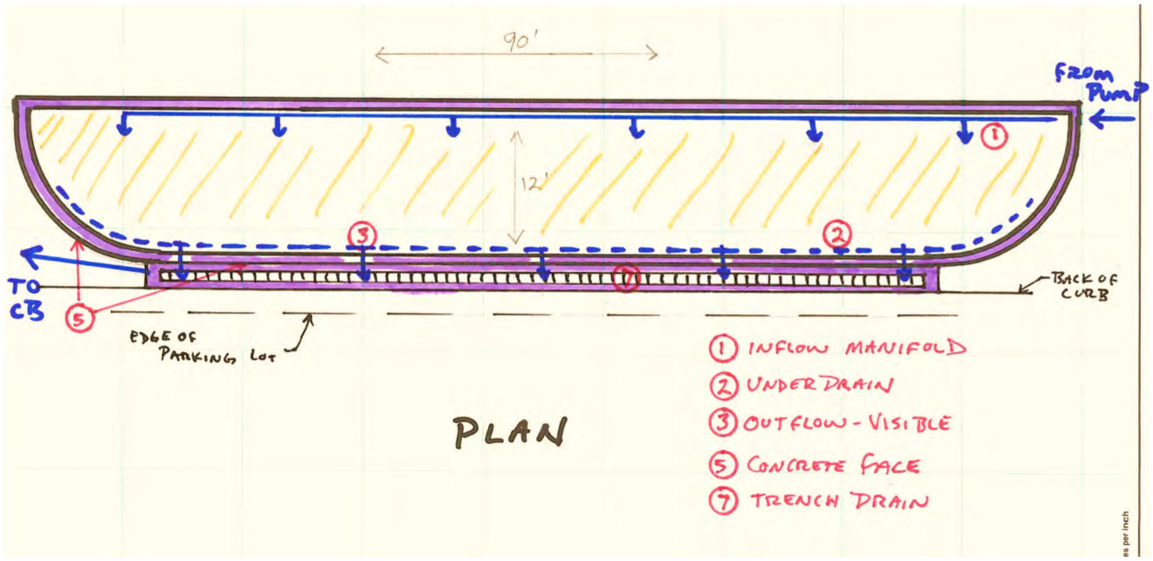
- Loss of park open space and could be in conflict with future park plans
- Difficult access for maintenance and maybe more maintenance required because of plants
- Concerns about trampling of plants
- Pumping – power consumption and O&M

Concept #3: Filtration Treatment Vault – pumped

Concept #3: Filtration Treatment Vault – pumped
Cross section

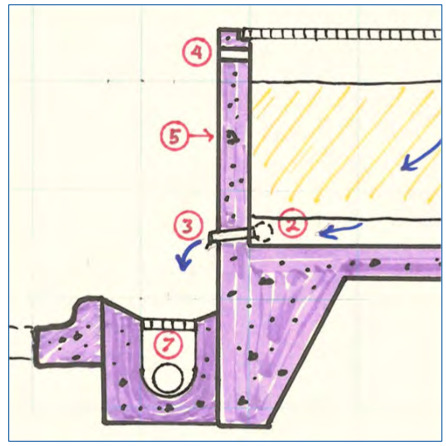


Concept #3: Filtration Treatment Vault – Plan view



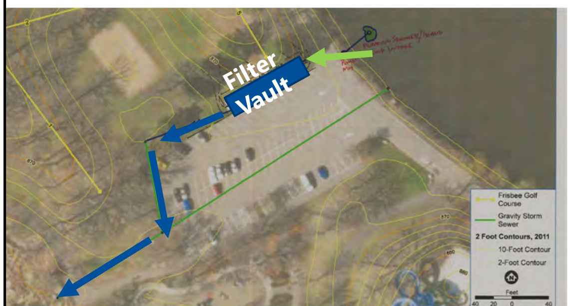
Concept #3: Filtration Treatment Vault – Example grates

Concept #3: Filtration Treatment Vault – filtered water is visible



Concept #3: Filtration Treatment Vault – sketch

Concept #3: Filtration Treatment Vault – pumped



Concept 3 (cons)

- Pumping – power consumption and O&M
- Aesthetics?
- Small loss of park space

Concept 3 (pros)

- Easily accessible for maintenance
- Minimal loss of park space
- Adds visual interest to park
- Visible to public—education and public art opportunities
- Eliminates concerns about walking and driving on grate
- Eliminates design challenges associated with a gravity system
- Treatment even when its not raining, constant flow rate

Option: Offset pump's power consumption with solar

Image source above: Woodford Country Journal and Smart Flower Solutions

Image to the left: Timber frame and SunCommon's Solar Canopy.
Source: The Beetle Blog: Snapshots and Stories from New Energy Works.

Opportunities to integrate stormwater education and public art

Opportunities to Improve the Appearance of the Exposed Vault

Decorative Railings - examples

Other considerations

- Maintenance- City would operate and maintain
- Quasi-experimental nature of stormwater feature (potential to experiment with alternative filtration media)

Planning Level Costs – Construction, Engineering, 30% Contingency

Concept 1: $590,000

Concept 2: Cost was not calculated

Concept 3: $650,000

Add:

- Decorative Facing on the concrete wall ~ $15,000
- Solar Power Generation Back to the Grid ~ $75,000
- Public Art and Education ~$25,000 to $100,000+

General Comparison of the Concepts

- All concepts treat a similar annual volume and have similar removal rates
- Concept 1 and Concept 3 have similar construction costs
- Edina staff prefer Concept 3
- Edina Parks Commission seemed to favor Concept 3

Next Steps

- Present preferred conceptual design to Edina City Council
- Feasibility analysis/preliminary design on **preferred** concept– **January - April**

Appendix B

University of Minnesota Report: Assessment of Internal Phosphorus Loading in Swimming Pool Pond and Point of France Pond

ST. ANTHONY
FALLS LABORATORY

Project Report No. 587

Assessment of Internal Phosphorus Loading in Swimming Pool Pond and Point of France Pond, City of Edina

Final Report

By

Poornima Natarajan
John S. Gulliver
St. Anthony Falls Laboratory
University of Minnesota
2 Third Avenue SE Minneapolis, MN 55455

Prepared for:
City of Edina
7450 Metro Blvd. Edina, MN 55439

March 2019
Minneapolis, Minnesota

COLLEGE OF
Science & Engineering
UNIVERSITY OF MINNESOTA

Acknowledgements

This project was a contract between the City of Edina and the University of Minnesota St. Anthony Falls Laboratory (SAFL). Support from the City of Edina including Ross Bintner and Jessica Vanderwerff Wilson, and the Nine Mile Creek Watershed District is greatly appreciated. The assistance from Peter Corkery, Peter Olson, Vinicius Taguchi and Robert Gabrielson with field sampling and laboratory analysis at SAFL is greatly appreciated.

Table of Contents

List of Figures

List of Tables

1. Introduction

Stormwater ponds are widely implemented stormwater control measures (SCMs) for runoff quantity and quality control in urban areas. They are primarily used to remove solids and associated pollutants such as phosphorus from runoff. There is increasing evidence, however, that some ponds are no longer retaining phosphorus, and have become potential source of phosphorus (Song et al. 2015). In the Twin Cities area, a water quality survey conducted in 98 stormwater ponds in the Riley Purgatory Bluff Creek Watershed District (RPBCWD) showed <0.010 mg/L to 8.1 mg/L total phosphorus in the ponds (Forster et al. 2012; RPBCWD 2014). Further examination of the data showed that 39% of the 98 ponds contained median TP greater than 0.38 mg/L, the 95% confidence interval (CI) of expected TP in the Twin Cities Metro Area (Janke et al. 2017; Taguchi et al. 2018b). The high phosphorus level in the ponds above typical runoff concentration was hypothesized to be due to internal phosphorus release from the sediments. Laboratory sediment cores and field-scale monitoring of phosphorus mass inputs and outputs in five ponds provided evidences of internal loading in those ponds (Olsen 2017; Taguchi et al. 2018b). Since ponds are part of the watershed network that delivers runoff with phosphorus to lakes and streams, high phosphorus load and algae in ponds present increased risks of harmful algal bloom occurrences and water quality degradation in the receiving waterbodies. Therefore, there is a need to assess stormwater ponds so that management strategies to control phosphorus pollution from ponds can be developed.

This project was originally proposed as a two-part study to assess and treat internal phosphorus loading in two stormwater ponds in the City of Edina, the Swimming Pool Pond and the Point of France Pond. The objective of the first part of the study was to investigate internal phosphorus release from the pond sediments by measuring phosphorus release from pond sediment cores incubated in the laboratory and monitoring the *in situ* water quality. If internal loading was found to be substantial, the objective of the second part of the study was to chemically-inactivate the sediment phosphorus by treatment. This report presents results of the first part of the study, i.e., internal phosphorus loading assessment in the two ponds, and provides recommendations for pond phosphorus treatment.

2. Methods

2a. Site description

The Swimming Pool Pond (area = 0.0125 km^2; depth = 0.305 – 2.13 m) and the Point of France Pond (area = 0.0257 km^2; depth = 0.305 – 2.44 m) are located south of Hwy 62 in the City of Edina (Figure 1). The ponds are located in a heavily-urbanized area, consisting of commercial and high-density residential land use, in the north Lake Cornelia watershed (part of Lower Minnesota River watershed), in the Nine Mile Creek Watershed District. Outflows from the Point of France Pond are routed to the Swimming Pool Pond, which in turn discharges into north

Lake Cornelia, a 303(d) list impaired lake due to eutrophic conditions. Toxic algae were reported in the lake in summer 2016 and 2017.

Figure 1. Locations of the Swimming Pool Pond and Point of France Pond in the City of Edina, Hennepin County, MN. (source: <www.maps.google.com>)

2b. Laboratory phosphorus (P) release study

i. Pond sediment coring

Sediment cores were collected from the Swimming Pool Pond in February 2018. Six intact cores, containing approximately 0.2 m sediment and 0.8 m overlying pond water, were collected by driving a piston corer through holes drilled in ice (Figure 2a). Five sediment cores from the Point of France Pond were collected from a canoe in July 2018 (Figure 2b). The P release study on the Point of France Pond sediments was conducted based on the Swimming Pool Pond study results, hence the sediment coring was performed in the later part of summer.

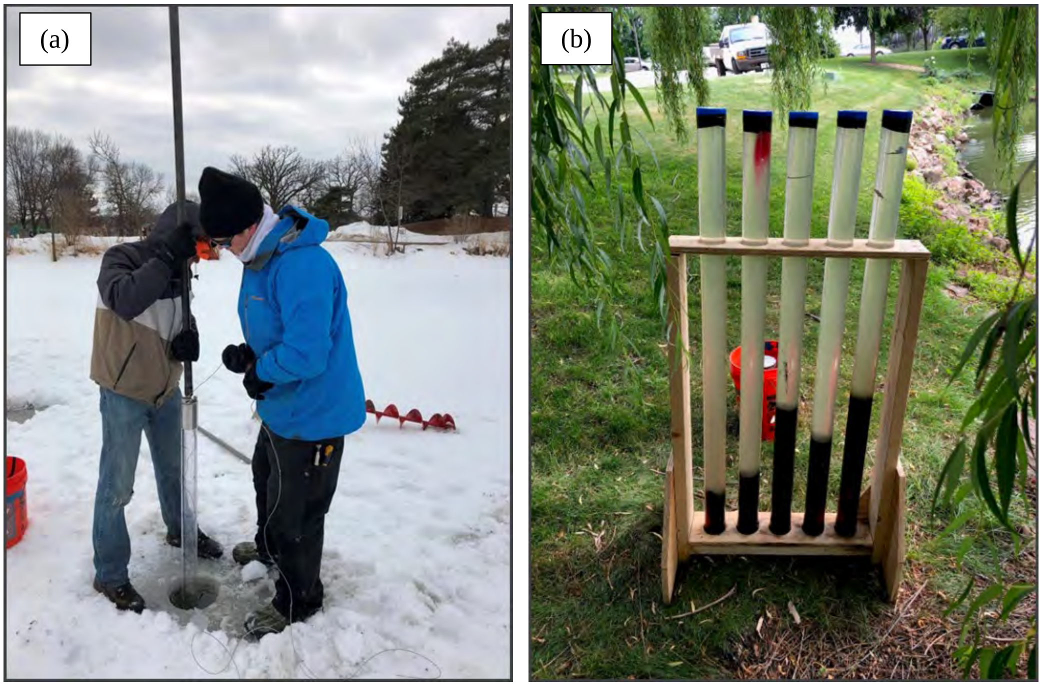


Figure 2. Sediment core collection from the (a) Swimming Pool Pond in February 2018, and (b) Point of France Pond in July 2018.

ii. Sediment-water columns

The cores collected from the ponds were incubated at 20 °C at the St. Anthony Falls Laboratory (SAFL). The water column above the sediment was drained, filtered to remove particulates and refilled into the columns. In the first phase of the P release experiments, the water column was mixed by air bubbling to determine if oxic P release occurred from the sediments. Then, air bubbling was switched off, and the dissolved oxygen (DO) concentration in the water 8 cm above the sediment, and the concomitant P release were monitored. In the final phase, P release was measured under an anoxic water column created by bubbling ultrapure nitrogen gas (DO < 1 mg/L). When the water column was kept mixed with air or nitrogen gas, water samples for P measurements were drawn from the center of the water columns, on an approximately weekly basis. In the unmixed phase (air off), one water sample was taken ~8 cm above the sediment and a second sample at the center of the total water column height. Two sampling points were necessary because a concentration gradient can develop during unmixed state, and the two measurements were used to estimate the average P concentration in the entire water column. The frequency of water sampling was adjusted from 1 day to 7 days during the unmixed phase to observe the rate of change of P mass in the water column. The increase in ortho-phosphorus (ortho-P) mass (where, mass = concentration × water volume) during a given incubation period was used to determine the P release rate ($mg/m^2/day$, i.e., P mass per sediment surface area of the core per time). P flux during the unmixed phase was determined using data from the first 15 days. The mean P release and 67% confidence interval (CI) of the mean was calculated for each phase. As a measure of the sediment oxygen demand (SOD), the Michaelis-Menten kinetic model was fit to the DO levels in the unmixed water column (air off phase) (Olsen 2017):

$$S = \frac{S_{max}[C_{O2}]}{K_M + [C_{O2}]}$$

where S is the substrate consumption rate, S_{max} is the maximum dissolved oxygen consumption rate, C_{O2} is the substrate (oxygen) concentration, and K_M is the half-consumption concentration. A constant K_M of 1.4 mg/L was used for all cores. The assumption is that all DO reduction comes from the microbial oxygen demand of the sediments, so K_M represents the surface of the sediments.

iii. Sediment phosphorus fractionation

At the end of core incubation, the top 10 cm of the sediments was extruded from the columns and analyzed for P species using the sequential chemical extraction procedure (Engstrom 2010). The amounts of loosely-bound P, iron-bound P, aluminum-bound P, mineral-bound P, labile organic P and residual organic P in the sediments were determined at 1-cm interval for the 0 – 5 cm depth and at 2- or 3-cm interval for the 5 – 10 cm depth. The P forms were used to understand the potential for P release under changing environmental conditions (loosely-bound P is dissolved or easily disassociated from a solid; iron-bound P is attached to an iron compound in the sediments; aluminum-bound P is attached to an aluminum compound in the sediments; mineral-bound P is attached to other minerals (typically calcium) in the sediments; labile organic P is the organic P that is available for microbial degradation, and residual organic P is not available for microbial degradation). Water content and organic matter content (loss on ignition at 550 °C) were also determined in the sediment samples.

2c. *In-situ* water quality sampling

Water quality of the ponds was sampled on a bi-weekly basis from May through September 2018. Surface grab water samples were collected from 5 to 6 locations (Figure 3) using a Van Dorn sampler, and analyzed for total phosphorus, dissolved phosphorus, and soluble reactive phosphorus concentrations (Standard Methods 4500-P, APHA AWWA, WPCF 1995) using a spectrophotometer (detection limit = 10 µg/L P). If stratification was detected, an additional water sample was collected below the stratification depth. The surface to bottom profiles of DO, temperature and conductivity were also taken at 25-cm intervals using a Hach WQ40D handheld meter with DO and conductivity sensors.

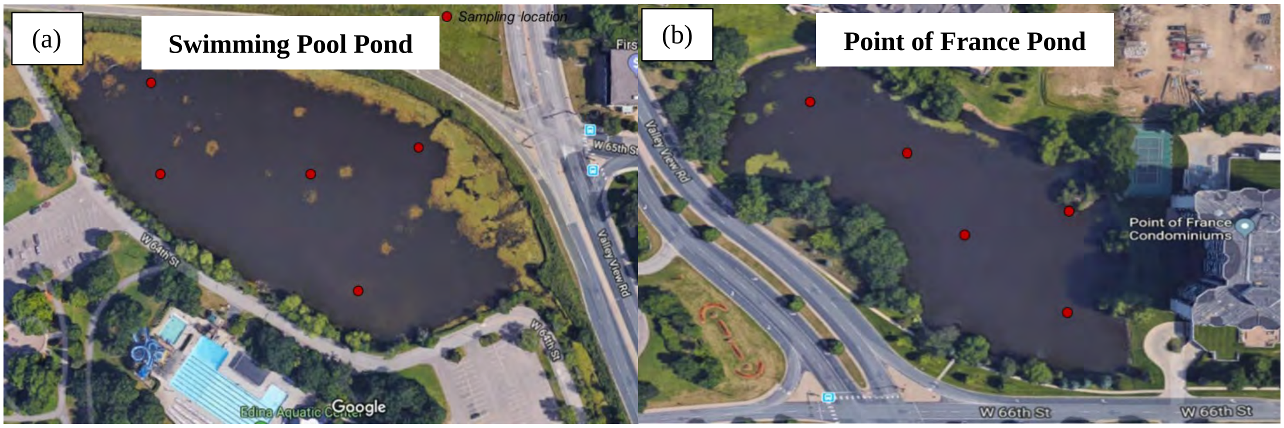


Figure 3. Locations of water sample collection and DO, temperature and conductivity profile monitoring (red circles) in the (a) Swimming Pool Pond and (b) Point of France Pond.

3. Results

3a. Oxic and anoxic phosphorus release rates

Under aerated (oxic) conditions, the Swimming Pool Pond sediment cores maintained low ortho-P levels in the water columns (Figure 4a). The average P release rate of -0.14 ± 0.08 (67% CI) mg/m^2/day suggested a small decrease in the water column ortho-P concentration occurred under oxic conditions. Once the air supply was switched off, the water column DO levels started decreasing due to the sediment oxygen demand (Figure 5a). The DO concentrations dropped below 1 mg/L after ~5 days in most cores. S_{max}, the maximum oxygen consumption by the biologically active sediments, ranged between 1.76 and 4.2 g/m^2/day in the six cores. As DO was consumed, the pond sediments started releasing P resulting in increased ortho-P concentrations in the water columns. However, measurable P increase occurred in only three out of the six cores. The average P release from the six cores was thus relatively small at 1.16 ± 0.45 mg/m^2/day during the first 15 days of the 22-day unmixed phase. In the next phase with an anoxic mixed water column, ortho-P release continued to occur at 1.09 ± 0.36 (67% CI) mg/m^2/day. The sediment cores that appeared to be sandy (collected near the pond inlets) showed minimal P release under the two anoxic phases.

Similar results were obtained for the Point of France Pond sediment cores (Figure 4b). A very small release of sediment P occurred under oxic conditions (0.83 ± 0.23 mg/m^2/day), which can be attributed to the mineralization of labile organic phosphorus in the sediments (Jensen and Andersen 1992). After the air supply was turned off, it took almost 7 days for the DO levels to reach below 1 mg/L, and the S_{max} ranged between 2.0 and 4.9 g/m^2/day in the five cores (Figure 5b). Once again, responses to low DO conditions were highly variable among the five cores, yielding an average P release rate of 4.09 ± 3.21 mg/m^2/day during the air off phase (note the 67% CI). This average P release under anoxic conditions is relatively high. In contrast, the following phase with an anoxic mixed water column had an anoxic P release from these sediments that was relatively low at 0.39 ± 0.17 mg/m^2/day.

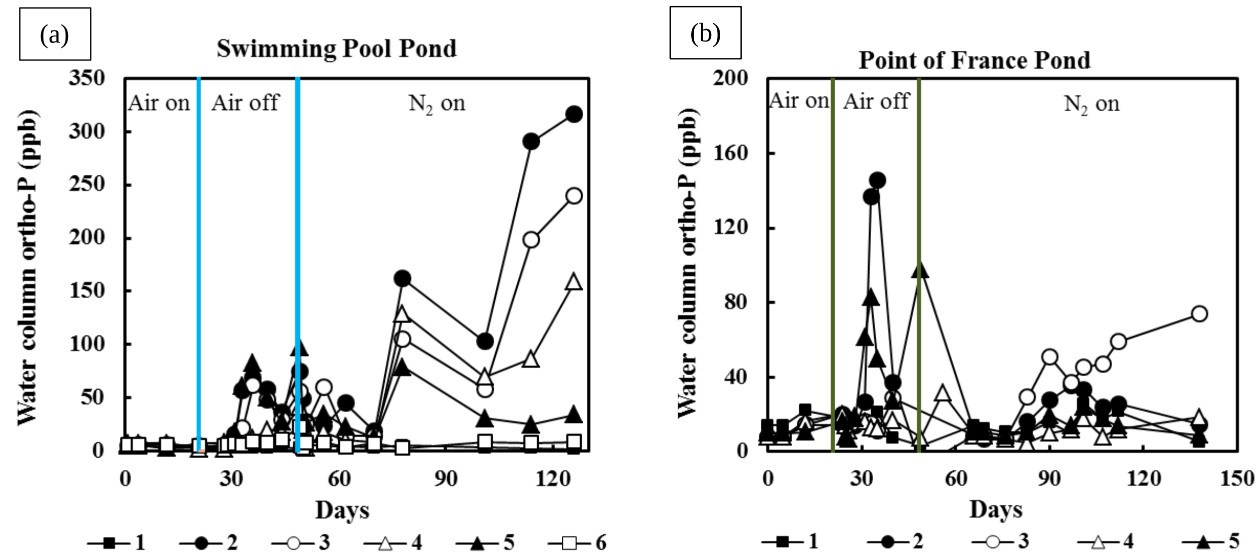


Figure 4. Phosphorus (ortho-P) release from the (a) Swimming Pool Pond and (b) Point of France Pond sediment cores under oxic (air bubbling), air off, and anoxic (N_2 bubbling) phases at 20 °C. Solid lines separate the three phases of the P release study.

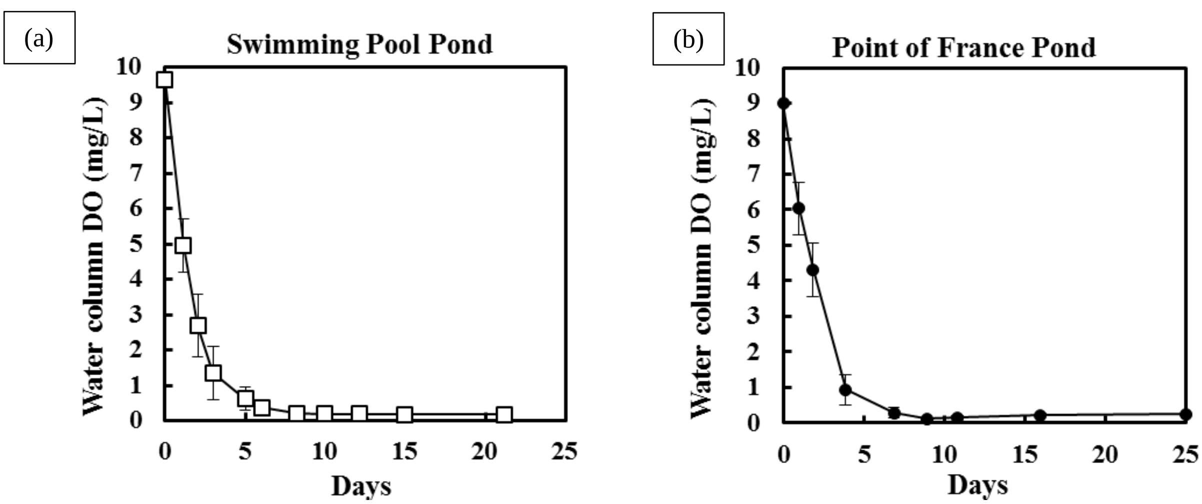


Figure 5. Average water column dissolved oxygen (DO) concentrations after air supply was switched off in the sediment cores from the (a) Swimming Pool Pond and (b) Point of France Pond. Measurements were taken at 8 cm above the sediment surface. Error bars are 67% confidence interval (CI) of the mean measurements.

The P release rates for the two Edina pond sediments were compared to other ponds in the Twin Cities Metro area (Table 1; Taguchi et al. 2018b). The anoxic P release rates and the DO depletion rates for the Swimming Pool Pond and Point of France Pond are relatively low when compared to some of the high P release-ponds. Low sediment microbial activity, which is supported by the lower sediment oxygen demand and organic matter content, is related to the P release rate from the sediments. This is because oxygen demand is indicative of opportunistic aerobic respiration by microbes and organic matter present a source of microbial food (Taguchi et al. 2018b).

Table 1. Comparison of internal phosphorus release from sediments of the Swimming Pool Pond and Point of France Pond with other stormwater ponds in the Twin Cities Metro area (data from Taguchi et al. 2018b).

Pond	Oxic Flux Rate ($mg/m^2/day$)	Anoxic Flux Rate ($mg/m^2/day$)	S_{max} ($g/m^2/day$)	Organic matter content (%)*
A	-1.27 ± 0.71	7.51 ± 2.93	4.21 ± 0.47	30%
B	-0.14 ± 0.76	5.62 ± 1.80	4.23 ± 0.95	86%
C	-4.38 ± 2.89	1.09 ± 0.26	1.94 ± 0.19	15%
D	-5.80 ± 1.94	2.27 ± 0.49	1.85 ± 0.63	16%
E	-19.78 ± 3.37	3.18 ± 2.76	5.19 ± 0.59	27%
Swimming Pool Pond	-0.14 ± 0.08	1.16 ± 0.45	3.07 ± 0.48	19%
Point of France Pond	0.83 ± 0.23	4.09 ± 3.21	2.51 ± 0.53	24%

*upper 11 or 10 cm sediments

3b. Sediment phosphorus fractions

The water content in the Swimming Pool Pond sediments ranged from 71 – 91% in the four cores analyzed, and these cores contained an average of 23% dry weight organic matter content in the upper 10 cm depth. One core, which was collected near the pond inlet, was predominantly sandy in appearance and contained 15% moisture content and 2% organic matter content. The sediment core collected near the inlet in the Point of France contained 40% moisture content and 7% organic matter content. The other sediment core samples contained 66 – 91% water content and an average of 27% organic matter content.

The sediment P pool in the Swimming Pool Pond and Point of France Pond cores provided an indication of the relationship between the observed P release in the laboratory cores and the releasable phosphorus fractions. The average concentrations of the various phosphorus species in the upper 10 cm sediment depth of the cores from the two ponds is plotted in Figure 6. In the Swimming Pool Pond, the average total P pool in the top 4 cm of sediments was composed of <0.05% loosely-bound P, 11% iron-bound P, 14% aluminum-bound P, 28% mineral-bound P, 32% labile organic P and 15% residual P. The Point of France Pond sediment's total P fractionation consisted of 0.18% loosely-bound P, 9.3% iron-bound P, 22% aluminum-bound P, 29% mineral-bound P, 21% labile organic P and 19% residual P, on average. The cores with sandier appearance varied from other cores in the P composition; they generally contained a large fraction of mineral-bound P and were low in organic P (data not shown). Overall, more P was tied up in the relatively unavailable forms in the sediments (i.e., Al- and mineral-bound) than the P present in the easily-releasable forms (i.e., loosely-bound and iron-bound). Labile organic P, that has the potential to become bioavailable after being broken down by microbacteria, was the more substantial mobile P form in the pond sediments.

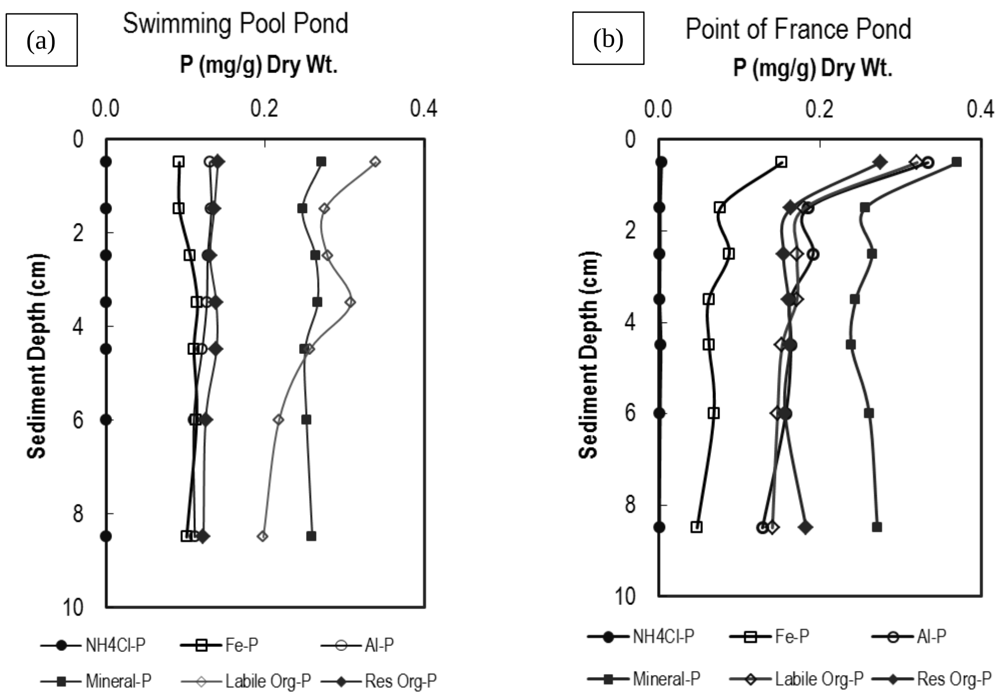


Figure 6. Phosphorus fractions in the upper 10 cm of sediments in the (a) Swimming Pool Pond and (b) Point of France Pond sediment cores. Average concentrations in five sediment cores are plotted. For each depth interval, concentration is plotted at the mid-point of the depth interval (for example, concentration for 0 – 1 cm depth is plotted at 0.5 cm).

Comparison to other stormwater ponds sampled by Taguchi et al. (2018) provides a perspective on the mobilization of phosphorus from the pond sediments (Figure 7). The upper 4 cm of sediments from the Edina ponds contained relatively low amounts of the redox-sensitive forms of phosphorus, i.e., the loosely-bound and iron-bound fractions. The potentially-releasable labile organic P in the Edina pond sediments was lower than ponds A and B that exhibited high anoxic P release rates (Table 1). Phosphorus was mostly associated with aluminum and calcium in the Edina pond sediments, and this phosphorus is not influenced by changes in oxygen conditions.

The low anoxic P releases measured from the Edina ponds are thus explained by the relatively low concentrations of redox-P and organic P species.

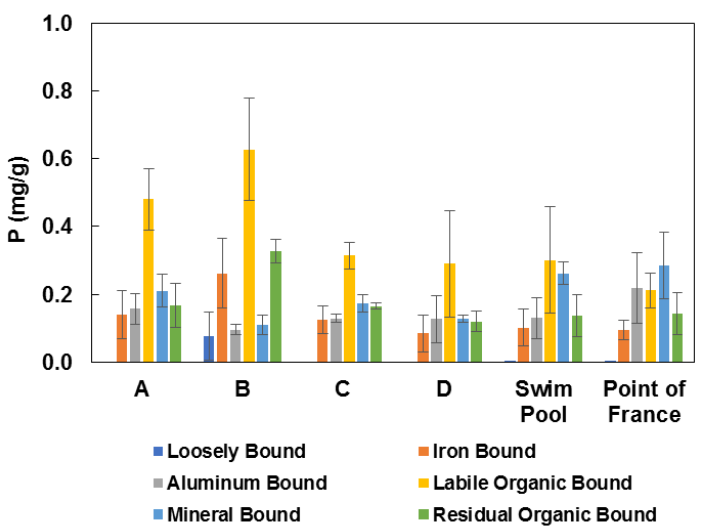


Figure 7. Sediment phosphorus fractions in the upper 4 cm of sediment cores collected from the Swimming Pool Pond and Point of France Pond along with other stormwater ponds in the Twin Cities Metro area (data from Taguchi et al. 2018b) (Error bars are standard deviations). Loosely-bound P is primarily dissolved P in the pore water, labile organic bound P can be converted into ortho-P over time, mineral-bound is primarily associated with calcium, and residual organic bound P is considered refractory.

3c. *In situ* water quality

The water quality data collected in 2018 are provided in Appendix A (Table A- 1 and Table A-2). The phosphorus concentrations in the pond water were generally in the low to moderate range during the growing season (Figure 8). In the Swimming Pool Pond, the average concentrations in the epilimnion grab water samples contained 59 – 167 µg/L total phosphorus, 10 – 44 µg/L dissolved phosphorus and 1 – 22 µg/L soluble reactive phosphorus. Concentrations in the Point of France Pond were in a similar range; 69 – 135 µg/L total phosphorus, 10 – 85 µg/L dissolved phosphorus and 1 – 34 µg/L soluble reactive phosphorus. The May to September average was 94 ± 35 (Std. Dev.) µg/L total phosphorus, 32 ± 11 µg/L dissolved phosphorus and 13 ± 6 µg /L soluble reactive phosphorus in the Swimming Pool Pond. Point of France Pond contained 97 ± 23 µg/L total phosphorus, 36 ± 21 µg/L dissolved phosphorus and 15 ± 10 µg /L soluble reactive phosphorus during summer.

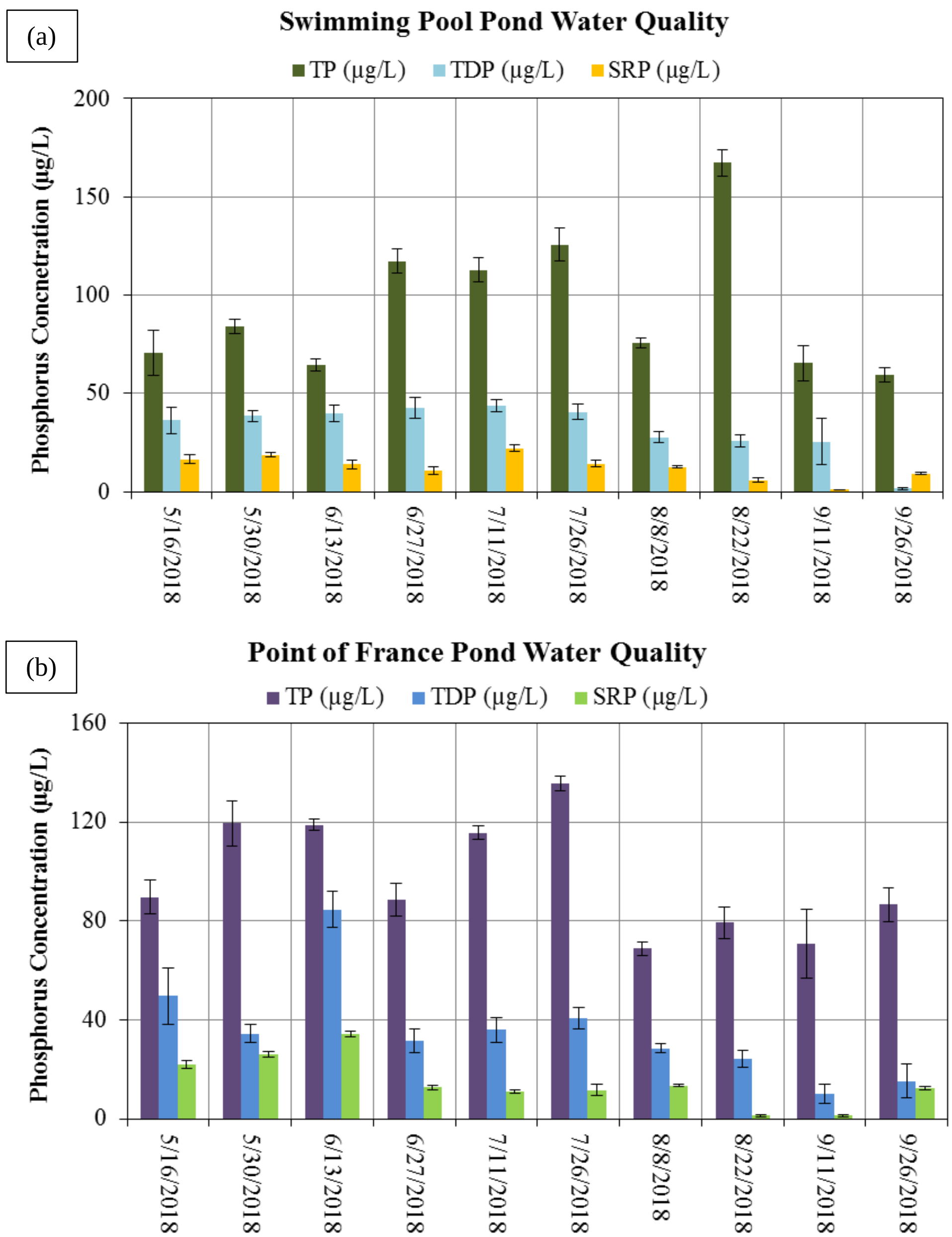


Figure 8. *In situ* phosphorus water quality from May to September 2018 in the (a) Swimming Pool Pond and (b) Point of France Pond. Average phosphorus concentrations in the epilimnion water samples collected from five locations in the pond are shown. Error bars are 67% CI of the mean measurements. Water samples were collected on a biweekly basis.

The median TP concentrations in the Swimming Pool Pond and Point of France Pond are compared to five other stormwater ponds intensively monitored by Taguchi et al. (2018b), who also developed the probability exceedance distribution of TP concentrations in the RPBCWD ponds (Figure 9). The TP concentrations in the Swimming Pool Pond and Point of France Pond were much lower than 0.38 mg/L, the upper 95% CI of expected runoff TP in the Twin Cities

Metro Area (Janke et al. 2017). The TP levels were also much lower than the median concentrations monitored in other stormwater ponds in the area.

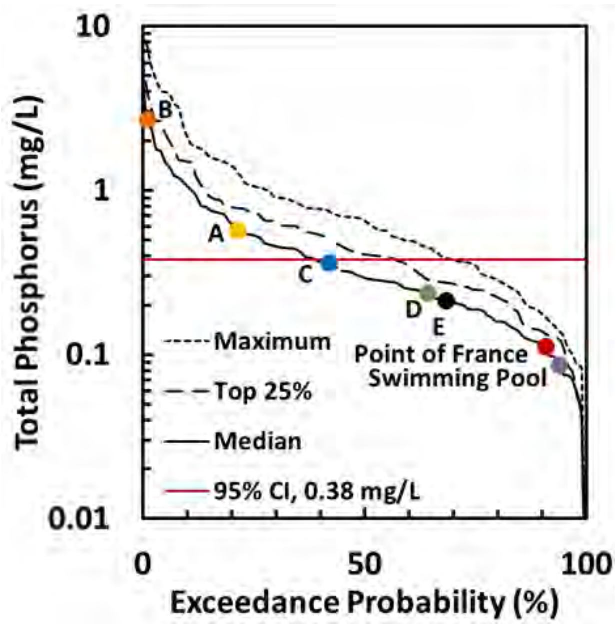


Figure 9. Median epilimnion grab sample values in the Swimming Pool Pond and Point of France Pond plotted along with stormwater ponds monitored by Taguchi et al. (2018b) (colored circles) in the exceedance probability distribution of total phosphorus concentrations in the RPBCWD ponds (figure adapted from Taguchi et al. 2018b). Red line is the upper 95% confidence interval (CI) of the expected TP in runoff in the Twin Cities Metro area.

The DO, temperature, and conductivity measured in the ponds over the entire summer period are summarized in Appendix A (Table A- 3 and Table A- 4). The *in situ* DO concentrations and water temperature presented evidence of mixed water column conditions in the ponds, which could be a reason for the low to moderate phosphorus levels in the pond water. The Swimming Pool Pond was mixed and oxic during most of the summer (Figure 10a). Bottom DO lower than 1 mg/L was detected only during two instances in August 2018 (see 8/8/18 and 8/22/18 data in Table A- 3), although it is possible that the DO probe was in the sediments at those low depths and recorded very low DO concentration. In the Point of France Pond, thermal stratification and low bottom DO were observed intermittently (Figure 10b), although DO less than 1 mg/L was not recorded anytime (Table A- 4). Nonetheless, strong thermal stratification that could cause the pond bottom to turn anoxic was not observed in both pond during summer 2018.

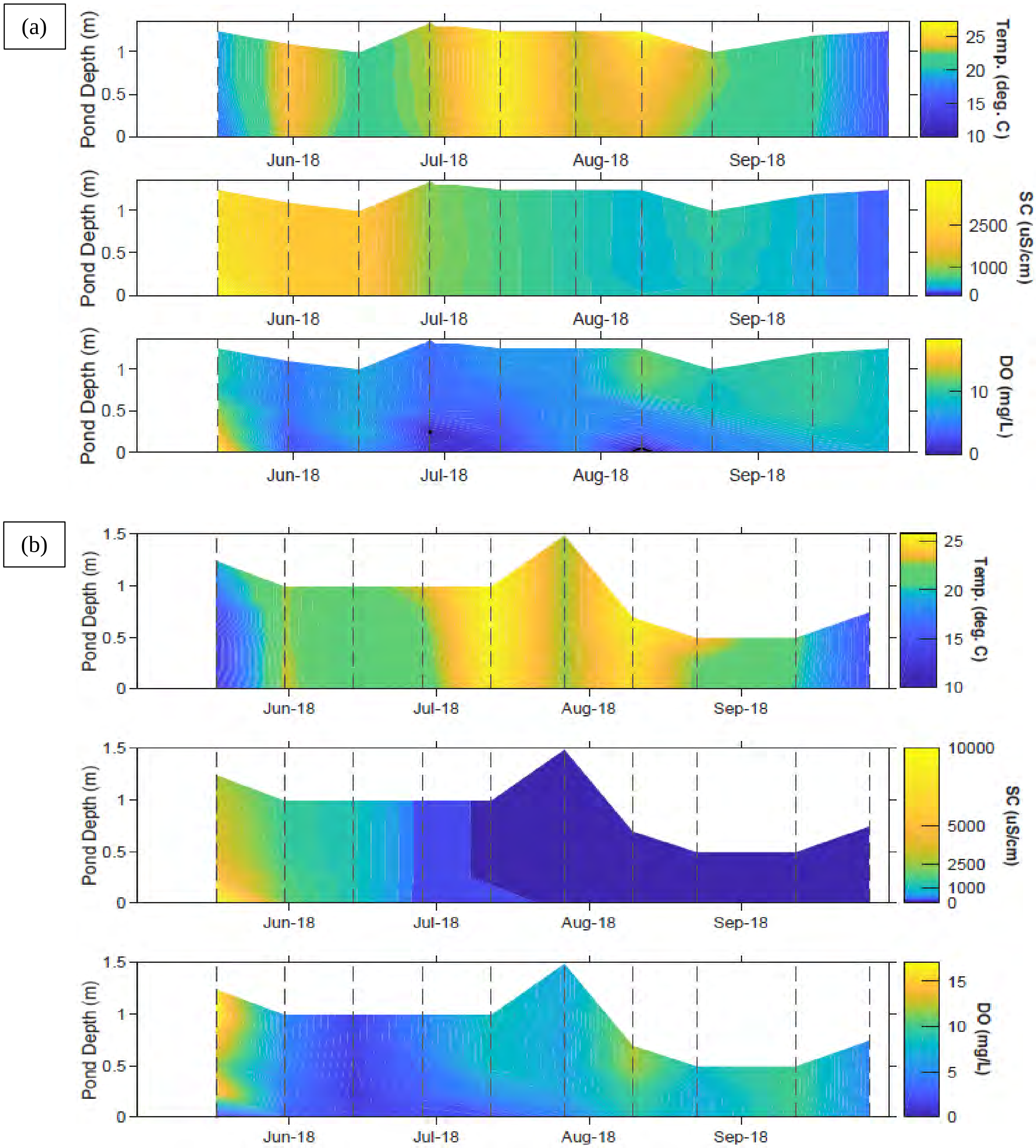


Figure 10. Time series contour plots of temperature, specific conductivity (SC), and dissolved oxygen (DO) concentrations in the (a) Swimming Pool Pond and (b) Point of France Pond from May to September 2018. Vertical lines show times when profiles were taken at the ponds; linear interpolation is used to fill the time series between pond visits. A 1 mg/L DO threshold is indicated by black line, which is visible only in the DO plot for the Swimming Pool Pond during August 2018.

High conductivity was measured from the beginning of monitoring in May 2018, and was likely high prior to May sampling. Such high specific conductivity values are attributed to chlorides contributed by road salt input (Taguchi et al. 2018b). Conductivity gradually decreased from May through August as chloride was flushed out of the pond, although it took longer for the chloride levels to drop in the Swimming Pool Pond, which is downstream of the Point of France Pond. Chemostratification is a phenomenon that has been observed in some ponds that exhibited strong summertime stratification and low bottom DO (Taguchi et al. 2018b). However, such stratification due to high chloride concentrations did not appear to be strong and impact DO levels in the Edina ponds.

The maintenance of primarily oxic and well-mixed water column *in situ* suggests that conditions are less favorable for internal P release to occur from the sediments during the warmer months. Under oxic conditions, the sediments exhibited very low or no release of P (Table 1), which means P contribution from internal loading can be expected to be negligible in both ponds. In addition to mixing due to stormwater inflows, it is hypothesized that low sheltering from trees around the ponds was a factor in aiding wind mixing of the pond water column and thus preventing a sustained stratification that could have led to anoxia.

4. Summary and Recommendations

a) The Swimming Pool Pond sediments did not release P under oxic conditions. Low P release occurred under anoxic conditions, at a rate of 1.16 ± 0.45 mg/m^2/day.
b) In the Point of France Pond, very low oxic P release was measured (0.83 ± 0.23 mg/m^2/day). Anoxic P release rate was relatively low and highly variable among the sediment cores, at 4.09 ± 3.21 mg/m2/day.
c) The impact of water column dissolved oxygen concentrations on the P release behavior was variable among the sediment cores, indicating the influence of sediment microbial activity and sediment characteristics on the potential for sediment P release.
d) Characterization of the sediment P fractions showed majority of P in the redox insensitive aluminum- and mineral-bound pool, i.e., not releasable under low oxygen conditions. The readily-mobile form of redox-P and potentially-mobile organic P were present in low (redox-P) to moderate (labile organic P) concentrations when compared to other stormwater ponds in the Twin Cities. The sediment P composition supports the low anoxic P release rates measured in the laboratory cores.
e) *In situ* monitoring showed low to moderate total phosphorus concentrations in the ponds during the growing season.
f) Surface to bottom profiles of DO and temperature were indicative of a mixed water column in the ponds during most of summer 2018, with intermittent stratification that lasted only for a brief amount of time.
g) High conductivity was measured in the ponds in May 2018, likely due to chlorides from road salt input. Gradual decrease in conductivity was noticed due to the mixing of pond water and flushing out of chloride in the pond discharge.

h) Together, these data suggest that conditions in the ponds are such that the water columns are mixed and primarily oxic during warmer months, indicating little to no internal P release and a minor impact on the pond water column phosphorus concentration.

i) Present conditions in the Swimming Pool Pond and Point of France Pond suggest that the ponds are providing treatment of phosphorus. Thus, chemical treatment of sediment to reduce internal phosphorus loading is currently not recommended.

j) Should conditions change to favor the development of anoxia in the pond, the potential for internal P release from the pond sediments could increase. One scenario would be increase in sheltering around the ponds that would result in poor mixing and stronger stratification causing low DO in the bottom of the pond. It is recommended that the sheltering around the pond be kept minimal to allow wind mixing of the pond.

References

APHA, AWWA, WPCF (1995), *Standard methods for the examination of water and wastewater*, 19th Ed., American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF, former Water Pollution Control Federation or WPCF), Washington, D.C.

Engstrom, D. (2010). Sediment phosphorus extraction procedure high sample throughput. Modified by Robert Dietz and Michelle Natarajan (2015).

Forster, P., Austin, D., Scharf, R., Carroll, J., and Enochs, M. (2012). Rethinking stormwater pond nutrient removal. Oral presentation at the 2012 Minnesota Water Resources Conference. St. Paul, MN.

Janke, B. D., Finlay, J. C., and Hobbie, S. E. (2017). “Trees and streets as drivers of urban stormwater nutrient pollution.” *Environmental Science & Technology*, 51(17), 9569-9579.

Jensen, H.S., and Andersen, F.O. (1992). Importance of Temperature, Nitrate, and pH for Phosphate Release from Aerobic Sediments of Four Shallow Eutrophic Lakes. *Limnology and Oceanography*, 37(3), 577-589.

Olsen, T. (2017). Phosphorus dynamics in stormwater ponds. Master’s Thesis, University of Minnesota, Minneapolis, MN.

Riley Purgatory Bluff Creek Watershed District (2014). Stormwater pond project: 2013 Report, 1-54. <http://rpbcwd.org/news/2013-stormwater-pond-report/> (accessed January 2016).

Song, K., Xenopoulos, M. A., Marsalek, J., and Frost, P. C. (2015). “The fingerprints of urban nutrients: dynamics of phosphorus speciation in water flowing through developed landscapes.” *Biogeochemistry*, 125, 1-10.

Taguchi, V., Olsen, T., Natarajan, P., Janke, B., Finlay, J., Stefan, H. G., Gulliver, J.S., and Bleser, C.S. (2018a.) Urban stormwater ponds can be a source of phosphorus. UPDATES Newsletter, 13(2), St. Anthony Falls Laboratory, University of Minnesota, Minneapolis, MN.

Taguchi, V., Olsen, T., Janke, B., Stefan, H. G., Finlay, J., and Gulliver, J.S. (2018b). Phosphorus release from stormwater ponds, Chapter in Stormwater Research Priorities and Pond Maintenance, Final Report, Minnesota Pollution Control Agency, St. Paul, MN.

Appendix A

Table A- 1. Phosphorus water quality data for the Swimming Pool Pond from May to September 2018.

	5/16/18	5/16/18	5/16/18	5/30/18	5/30/18	5/30/18	6/13/18	6/13/18	6/13/18	6/27/18	6/27/18	6/27/18	7/11/18	7/11/18	7/11/18
	TP (µg/L)	TDP (µg/L)	SRP (µg/L)	TP (µg/L)	TDP (µg/L)	SRP (µg/L)	TP (µg/L)	TDP (µg/L)	SRP (µg/L)	TP (µg/L)	TDP (µg/L)	SRP (µg/L)	TP (µg/L)	TDP (µg/L)	SRP (µg/L)
Site 1 Epi	57	42	13	74	45	19	58	29	8	131	58	16	115	37	20
Site 1 Hypo				71	34	19									
Site 2 Epi	61	39	17	83	42	21	68	36	14	126	53	16	110	34	18
Site 2 Hypo				90	32	21				134	51	6	120	45	18
Site 3 Epi	84	53	13	89	45	19	66	53	23	99	25	6	100	42	22
Site 3 Hypo	76	6	13	67	22	15									
Site 4 Epi	117	17	27	94	40	19	53	38	16	132	38	12	127	52	20
Site 4 Hypo				85	44	23				117	35	10			
Site 5 Epi	57	20	13	74	32	21	71	48	10	107	40	8	130	50	22
Site 5 Hypo				126	49	17									
Site 6 Epi	47	49	17	91	29	15	71	33	12	109	40	6	96	47	30
Site 6 Hypo				76	29	21									
	7/26/18	7/26/18	7/26/18	8/8/18	8/8/18	8/8/18	8/22/18	8/22/18	8/22/18	9/11/18	9/11/18	9/11/18	9/26/18	9/26/18	9/26/18
	TP (µg/L)	TDP (µg/L)	SRP (µg/L)	TP (µg/L)	TDP (µg/L)	SRP (µg/L)	TP (µg/L)	TDP (µg/L)	SRP (µg/L)	TP (µg/L)	TDP (µg/L)	SRP (µg/L)	TP (µg/L)	TDP (µg/L)	SRP (µg/L)
Site 1 Epi	108	40	14	86	27	13									
Site 1 Hypo				102	24	14									
Site 2 Epi	110	45	10	76	27	14	169	32	6	64	38	1	70	10	10
Site 2 Hypo															
Site 3 Epi	158	53	18	76	39	11	181	32	3	84	12	1	54	10	9
Site 3 Hypo															
Site 4 Epi	128	43	14	71	21	13	158	22	5	83	9	1	54	10	10
Site 4 Hypo				89	27	13									
Site 5 Epi	136	33	18	72	29	13	150	27	6	42	61	1	63	10	9
Site 5 Hypo				101	31	14	152	20	1						
Site 6 Epi	116	30	12	71	24	13	180	17	10	55	6	1	56	10	9

Table A- 2. Phosphorus water quality data for the Point of France Pond from May to September 2018.

	5/16/18	5/16/18	5/16/18	5/30/18	5/30/18	5/30/18	6/13/18	6/13/18	6/13/18	6/27/18	6/27/18	6/27/18	7/11/18	7/11/18	7/11/18
	TP	**TDP**	**SRP**	**TP**	**TDP**	**SRP**	**TP**	**TDP**	**SRP**	**TP**	**TDP**	**SRP**	**TP**	**TDP**	**SRP**
Site 1 Epi	83	33	25	106	27	27	120	83	35	91	10	10	118	50	10
Site 1 Hypo	207	22	27	118	27	23									
Site 2 Epi				109	32	23	115	118	35	73	40	10	125	37	10
Site 2 Hypo										86	56	12	133	34	14
Site 3 Epi	100	63	21	136	34	25	128	76	37	78	38	12	116	40	12
Site 3 Hypo	67	14	19	95	25	25	133	73	37				137	32	12
Site 4 Epi				91	25	25	115	78	37	81	35	14	114	45	14
Site 4 Hypo							138	78	35				167	37	18
Site 5 Epi	86	53	21	142	44	30	120	71	35	94	35	16	117	26	10
Site 5 Hypo	96	33	17	84	59	28	135	73	31	101	33	18			
Site 6 Epi				133	44	28	116	83	29	115	30	14	105	19	10
Site 6 Hypo				91	47	27	133	83	38	84	45	21	127	29	12

	7/26/18	7/26/18	7/26/18	8/8/18	8/8/18	8/8/18	8/22/18	8/22/18	8/22/18	9/11/18	9/11/18	9/11/18	9/26/18	9/26/18	9/26/18
	TP	**TDP**	**SRP**	**TP**	**TDP**	**SRP**	**TP**	**TDP**	**SRP**	**TP**	**TDP**	**SRP**	**TP**	**TDP**	**SRP**
Site 1 Epi	133	43	8	73	29	13	99	17	1	68	6	3	78	38	12
Site 1 Hypo				72	24	18	87	25	1						
Site 2 Epi	143	33	14	76	29	14	82	25	3	61	1	1	80	16	12
Site 2 Hypo				64	26	16									
Site 3 Epi	132	48	16	61	36	14	70	34	1	120	22	1	109	12	14
Site 3 Hypo															
Site 4 Epi	145	55	8	64	24	14	66	18	1	58	9	1	92	10	10
Site 4 Hypo				81	24	14									
Site 5 Epi	132	38	18	71	27	13									
Site 5 Hypo															
Site 6 Epi	128	28	6	67	26	13	80	27	1	48	12	1	75	9	12
Site 6 Hypo															

Table A- 3. Dissolved oxygen (DO), temperature (T), and specific conductivity (SC) data for the Swimming Pool Pond from May to September 2018. H is the depth of sampling in the water column.

	SITE 1				SITE 2				SITE 3			
Sampling date	H (m)	DO (mg/L)	T °C	SC (µs/cm)	H (m)	DO (mg/L)	T °C	SC (µs/cm)	H (m)	DO (mg/L)	T °C	SC (µs/cm)
5/16/18	0.00	9.6	18.8	2972	0.00	10.4	18.7	2969	0.00	10.1	19.1	2955
	0.25	12.7	18.1	2992	0.25	10.4	18.9	2964	0.25	10.2	19.0	2953
	0.50	15.7	17.0	3263	0.50	10.3	19.0	2959	0.50	10.4	19.0	2963
	0.75				0.75	10.5	19.0	2961	0.75	15.1	18.5	2952
	1.00								1.00	18.3	18.2	3379
	1.25											
5/30/18	0.00	4.4	23.9	2430	0.00	4.2	24.2	2350	0.00	5.3	24.2	2210
	0.25	3.9	24.3	2430	0.25	4.0	24.1	2153	0.25	5.1	24.3	2199
	0.50	2.8	23.8	2040	0.50	4.1	24.3	2160	0.50	5.1	24.3	2200
	0.60	1.4	23.8	2067	0.75	3.5	24.2	2290	0.75	5.0	24.3	2200
					1.00	4.3	24.2	2037	1.00	2.9	24.3	2220
									1.05	2.57	24.4	2220
6/13/18	0.00	6.4	21.5	2200	0.00	6.8	21.8	2230	0.00	8.1	21.7	2230
	0.25	6.7	21.4	2163	0.25	6.8	21.8	2230	0.25	7.3	21.7	2220
	0.40	6.6	21.3	2154	0.50	7.4	21.7	2210	0.50	6.9	21.6	2220
					0.75	5.6	21.7	2230	0.75	6.6	21.6	2220
									1.00	5.5	21.5	2220
6/27/18	0.00	3.7	22.8	949	0.00	3.3	23.2	1044	0.00	4.3	23.2	1001
	0.25	3.4	22.9	939	0.25	3.4	23.2	1058	0.25	4.3	23.2	980
	0.50	2.8	22.9	929	0.50	3.5	23.2	1061	0.50	4.4	23.1	977
	0.60	1.7	22.7	914	0.75	1.7	22.9	975	0.75	4.4	23.2	972
					1.00	1.1	22.9	987	1.00	3.2	23.0	975
									1.10	2.8	23.0	833
7/11/18	0.00	5.3	25.8	726	0.00	5.4	26.1	723	0.00	5.7	26.2	730
	0.25	5.0	26.1	724	0.25	5.3	26.3	722	0.25	5.7	26.3	729
	0.50	3.6	25.8	719	0.50	5.0	26.2	722	0.50	5.6	26.3	727
	0.60	3.1	25.9	725	0.75	4.7	26.1	719	0.75	5.5	26.3	721
					1.00	1.8	25.9	657	1.00	4.8	26.2	724
7/26/18	0.00	5.5	22.5	554	0.00	5.5	23.0	547	0.00	6.1	23.3	557
	0.25	5.3	22.9	550	0.25	5.5	23.2	546	0.25	6.0	23.6	556
	0.50	5.2	22.9	549	0.50	5.6	23.1	545	0.50	5.9	23.5	555
					0.75	5.4	23.2	545	0.75	5.9	23.5	555
									1.00	5.8	23.5	553
8/8/18	0.00	8.5	25.1	368	0.00	11.7	25.6	384	0.00	12.2	25.8	385
	0.25	6.1	24.1	359	0.25	11.6	25.5	384	0.25	12.3	25.4	382
	0.47	6.1	23.9	358	0.50	8.9	24.5	382	0.50	9.6	24.6	382
					0.75	10.6	24.9	382	0.75	7.2	24.4	386
					1.00	7.9	24.2	384	1.00	5.2	24.3	393
8/22/18					0.00	9.5	22.8	683	0.00	9.4	23.1	687
					0.25	9.5	23.0	683	0.25	7.8	22.7	598

	SITE 1				SITE 2				SITE 3			
Sampling date	**H (m)**	**DO (mg/L)**	**T °C**	**SC (µs/cm)**	**H (m)**	**DO (mg/L)**	**T °C**	**SC (µs/cm)**	**H (m)**	**DO (mg/L)**	**T °C**	**SC (µs/cm)**
					0.50	8.9	22.7	607	0.50	5.3	22.4	542
					0.75	6.0	22.1	520	0.75	5.0	22.3	531
					1.00	5.7	22.1	516				
9/11/18					0.00	10.6	21.1	331	0.00	10.7	21.1	331
					0.25	10.5	21.1	331	0.25	10.7	21.0	331
					0.50	10.5	21.1	331	0.50	10.4	21.0	331
					0.75	10.5	21.1	330	0.75	10.3	20.9	331
									0.95	10.6	20.9	333
9/26/18					0.00	8.8	15.7	147	0.00	8.9	15.2	149
					0.25	8.8	15.6	147	0.25	8.8	15.4	148
					0.50	8.8	15.5	147	0.50	8.7	15.4	148
									0.75	8.5	15.3	148
									1.00	8.5	15.3	148

Table A- 4. Continued: Data for sampling sites 4, 5 and 6 in the Swimming Pool Pond.

	SITE 4				SITE 5				SITE 6			
Sampling date	**H (m)**	**DO (mg/L)**	**T °C**	**SC (µs/cm)**	**H (m)**	**DO (mg/L)**	**T °C**	**SC (µs/cm)**	**H (m)**	**DO (mg/L)**	**T °C**	**SC (µs/cm)**
5/16/18	0.00	10.3	19.1	2960	0.00	10.8	19.0	2973	0.00	9.7	19.6	2984
	0.25	10.5	19.0	2957	0.25	10.8	19.0	3017	0.25	10.2	19.4	2964
	0.50	9.5	19.0	2971	0.50	11.8	18.8	3053	0.50	11.8	19.1	3070
	0.75	12.8	18.6	3116	0.75	15.3	18.9	3148	0.75	14.2	18.9	3161
	1.00	14.8	17.8	3250	1.00	16.9	18.0	3267				
	1.25	18.3	17.1	4075	1.25	17.6	17.3	3507				
5/30/18	0.00	4.4	24.4	2340	0.00	5.1	24.6	2420	0.00	4.3	25.0	2670
	0.25	4.5	24.5	2310	0.25	5.0	24.8	2400	0.25	2.9	25.2	2680
	0.50	4.7	24.5	2300	0.50	5.0	24.7	2410	0.50	3.0	25.1	2840
	0.75	4.5	24.5	2300	0.75	4.3	24.7	2700	0.75	1.5	25.1	2830
	1.00	3.2	24.4	2350	1.00	3.9	25.1	2770	0.85	0.53	25.1	2840
	1.10	2.9	24.2	2350	1.25	1.3	24.9	2860				
6/13/18	0.00	7.6	22.0	2230	0.00	6.9	22.3	2230	0.00	9.5	22.4	2220
	0.25	7.4	22.1	2230	0.25	8.2	21.8	2220	0.25	8.9	22.0	2220
	0.50	7.4	22.1	2230	0.50	7.9	21.8	2230	0.50	6.5	21.7	2220
	0.75	8.0	22.0	2230	0.75	7.1	21.7	2240	0.73	4.3	21.5	2230
	1.00	5.7	21.6	2230	1.00	7.0	21.6	2240				
					1.25	6.0	21.7	2240				
6/27/18	0.00	4.3	23.3	953	0.00	5.9	23.2	960	0.00	5.5	23.6	1115
	0.25	4.2	23.2	948	0.25	5.0	23.2	960	0.25	4.3	23.5	1154
	0.50	4.0	23.1	950	0.50	4.3	23.1	956	0.50	2.2	23.4	1251
	0.75	4.1	23.1	958	0.75	4.0	23.1	968	0.75	1.9	23.2	1250
	1.00	3.8	23.0	967	1.00	2.8	23.2	954				
	1.25	1.0	23.0	932	1.25	1.1	23.3	1230				

	SITE 4				SITE 5				SITE 6			
Sampling date	**H (m)**	**DO (mg/L)**	**T °C**	**SC (µs/cm)**	**H (m)**	**DO (mg/L)**	**T °C**	**SC (µs/cm)**	**H (m)**	**DO (mg/L)**	**T °C**	**SC (µs/cm)**
	1.35	1.5	22.9	931	1.35	0.9	23.3	1100				
7/11/18	0.00	6.51	26.4	726	0.00	5.3	26.5	726	0.00	5.84	26.4	725
	0.25	6.15	26.4	724	0.25	5.6	26.5	727	0.25	5.21	26.6	723
	0.50	4.94	26.4	730	0.50	5.6	26.6	725	0.50	3.67	26.5	723
	0.75	3.87	26.4	734	0.75	4.7	26.5	725	0.75	4.76	26.6	724
	1.00	2.86	26.3	733	1.00	3.1	26.5	727				
	1.25	1.95	26.1	733	1.13	2.6	26.5	729				
7/26/18	0.00	6.4	23.3	552	0.00	5.8	23.4	560	0.00	5.6	23.5	553
	0.25	6.3	23.4	552	0.25	5.7	23.5	560	0.25	5.4	23.5	554
	0.50	6.3	23.4	552	0.50	5.7	23.6	569	0.50	5.5	23.5	552
	0.75	6.3	23.4	552	0.75	5.6	23.6	569	0.75	5.4	23.5	553
	1.00	6.3	23.4	552	1.00	5.7	23.6	559				
	1.25	5.7	23.4	552	1.15	5.5	23.6	559				
8/8/18	0.00	11.8	27.2	385	0.00	13.2	26.2	384	0.00	12.7	26.7	393
	0.25	12.4	25.3	375	0.25	13.4	25.3	384	0.25	11.7	25.4	392
	0.50	11.2	24.9	375	0.50	11.3	24.8	388	0.50	10.5	25.0	391
	0.75	5.9	24.4	369	0.75	9.3	24.5	396	0.75	7.8	24.6	395
	1.00	4.1	24.2	371	1.00	4.7	24.3	402				
	1.25	0.2	23.8	462	1.25	0.5	24.0	426				
8/22/18	0.00	9.7	22.8	628	0.00	8.3	23.1	677	0.00	9.8	23.2	701
	0.25	9.1	22.9	621	0.25	7.6	22.8	665	0.25	6.7	22.8	625
	0.50	8.9	22.7	550	0.50	6.2	22.6	637	0.50	4.2	22.7	628
	0.75	5.8	22.4	554	0.75	5.6	22.4	621				
	1.00	5.0	22.0	497	1.00	4.9	22.3	608				
					1.20	0.2	22.3	639				
9/11/18	0.00	10.8	21.1	331	0.00	9.9	21.1	332	0.00	9.8	21.4	332
	0.25	10.8	21.0	331	0.25	10.2	21.1	331	0.25	9.6	21.2	333
	0.50	10.8	21.0	331	0.50	10.3	21.0	331	0.50	9.4	21.2	332
	0.75	10.5	20.9	331	0.75	8.7	21.0	332				
	1.00	9.3	20.6	333	1.00	7.9	20.8	334				
	1.20	6.6	20.4	336	1.20	6.9	20.6	337				
9/26/18	0.00	8.8	15.4	147	0.00	8.8	15.3	148	0.00	9.0	15.2	149
	0.25	8.7	15.5	147	0.25	8.8	15.4	148	0.25	9.0	15.4	148
	0.50	8.7	15.5	147	0.50	8.8	15.4	148	0.50	8.9	15.4	148
	0.75	8.5	15.5	147	0.75	8.3	15.4	148	0.75	8.9	15.4	149
	1.00	8.3	15.4	147	1.00	8.2	15.4	148				
	1.25	8.1	15.4	148	1.25	8.2	15.5	148				

Table A- 5. Dissolved oxygen (DO), temperature (T), and specific conductivity (SC) data for the Point of France Pond from May to September 2018. H is the depth of sampling in the water column.

		SITE 1				SITE 2				SITE 3		
Sampling date	**H (m)**	**DO (mg/L)**	**T °C**	**SC (µs/cm)**	**H (m)**	**DO (mg/L)**	**T °C**	**SC (µs/cm)**	**H (m)**	**DO (mg/L)**	**T °C**	**SC (µs/cm)**
5/16/18	0.00	16.2	19.9	2826					0.00	16.1	19.7	2827
	0.25	15.7	16.7	3250					0.25	17.1	17.8	3350
	0.50	14.9	15.1	3501					0.50	14.8	14.5	3661
	0.75	13.8	13.7	4037					0.75	12.1	13.5	3921
	1.00	13.2	13.1	4875					1.00	15.8	13.5	5137
	1.25	0.85	13.1	>10,000					1.25	0.93	13.1	10,000
	1.50	0.19	11.4	>10,000								
	1.75	0.11	9.7	>10,000								
	1.95	0.08	8.4	>10,000								
5/30/18	0.00	5.0	22.8	1535	0.00	5.01	22.8	1640	0.00	5.17	23.0	1591
	0.25	4.9	22.9	1587	0.25	4.78	23.0	1659	0.25	5.1	23.0	1599
	0.50	4.1	22.8	1554	0.50	4.36	23.0	1655	0.50	4.9	23.0	1625
	0.75	3.0	22.8	1587	0.75	4.46	23.2	1800	0.75	4.2	23.3	1930
	1.00	1.6	22.5	2000	1.00	3.16	23.0	1860	1.00	3.65	23.4	2057
	1.25	0.97	22.3	2000								
	1.50	0.51	21.9	2520								
	1.75	0.06	21.4	3330								
	2.00	0.02	20.3	4300								
6/13/18	0.00	2.5	22.8	1329	0.00	2.39	22.3	1334	0.00	2.0	22.2	1327
	0.25	2.3	22.3	1326	0.25	2.29	22.2	1329	0.25	1.9	21.5	1317
	0.50	2.0	21.6	1310	0.50	1.7	21.3	1320	0.50	1.8	21.2	1313
	0.75	1.4	21.0	1300	0.75	1.56	20.9	1323	0.75	1.6	20.9	1311
	1.00	1.2	20.7	1250	1.00	1.5	20.6	1306	1.00	1.9	20.7	1321
	1.25	0.34	19.9	1145	1.12	1.43	20.6	1270				
	1.50	0.12	19.3	1110								
6/27/18	0.00	5.1	23.1	365	0.00	4.86	23.1	361	0.00	4.9	23.4	362
	0.25	5.1	22.7	365	0.25	5.23	22.7	365	0.25	4.9	22.8	367
	0.50	3.8	22.4	368	0.50	4.36	22.4	365	0.50	4.0	22.4	366
	0.75	3.4	22.2	369	0.75	3.91	22.3	360	0.75	3.5	22.3	364
	1.00	2.8	21.6	326	1.00	1.83	22.0	358	1.00	2.4	21.9	332
	1.25	2.5	21.4	317								
	1.50	2.2	20.9	299								
7/11/18	0.00	7.6	25.4	265	0.00	8.7	25.8	263	0.00	8.8	25.9	265
	0.25	7.6	25.5	265	0.25	8.2	25.7	264	0.25	8.4	25.7	264
	0.50	6.7	25.6	265	0.50	8.1	25.7	265	0.50	8.4	25.7	264
	0.75	5.4	25.4	272	0.75	3.9	25.4	273	0.75	5.9	25.6	264
	1.00	3.6	25.1	291	1.00	2.3	25.2		1.00	2.8	25.4	366
7/26/18	0.00	7.6	22.3	251	0.00	7.2	22.8	249	0.00	6.8	23.0	257
	0.25	7.5	22.6	249	0.25	7.1	22.9	249	0.25	6.8	23.0	250
	0.50	7.4	22.7	249	0.50	7.0	22.9	249	0.50	6.9	23.0	250

		SITE 1				SITE 2				SITE 3		
Sampling date	**H (m)**	**DO (mg/L)**	**T °C**	**SC (μs/cm)**	**H (m)**	**DO (mg/L)**	**T °C**	**SC (μs/cm)**	**H (m)**	**DO (mg/L)**	**T °C**	**SC (μs/cm)**
	0.75	7.3	22.8	249	0.75	7.0	22.9	249	0.75	6.7	23.0	250
	1.00	7.2	22.9	249	1.00	7.0	22.9	249	1.00	6.7	23.0	249
					1.25	6.4	22.9	250	1.25	6.87	23.0	249
									1.50	4.73	22.9	251
8/9/18	0.00	11.2	25.2	215	0.00	11.7	25.3	214	0.00	12.2	25.6	214
	0.25	11.7	25.3	217	0.25	11.4	25.2	214	0.25	12.2	25.2	214
	0.50	10.6	25.2	221	0.50	10.2	25.2	214	0.50	10.3	24.9	216
	0.75	4.86	24.3	260	0.75	5.7	24.1	239	0.70	9.1	24.9	217
					1.00	2.8	23.6	246				
8/22/18	0.00	7.5	23.3	298	0.00	8.6	23.4	292	0.00	8.3	24.1	295
	0.25	7.0	22.6	296	0.25	7.2	22.7	292	0.25	7.1	22.7	291
	0.50	5.5	22.2	295	0.50	5.7	22.3	293	0.50	7.1	22.6	291
	0.75	4.6	22.1	295	0.75	5.3	22.2	293				
	1.00	4.1	22.1	299	0.95	4.9	22.1	294				
	1.25	3.8	22.1	302								
	1.50	3.6	22.0	299								
	1.75	3.5	22.0	297								
	2.00	0.14	22.0	330								
9/11/18	0.00	9.8	21.0	188	0.00	9.7	20.4	187	0.00	10.4	21.1	183
	0.25	9.6	20.6	187	0.25	9.7	20.4	187	0.25	10.5	20.8	183
	0.50	9.4	20.1	187	0.50	9.5	20.4	187	0.50	10.1	20.5	182
	0.75	8.8	20.1	192	0.75	9.0	20.3	186				
	1.00	7.4	19.8	200	1.00	7.1	20.1	187				
	1.25	6.5	19.7	208								
9/26/18	0.00	5.0	15.2	101	0.00	5.0	15.1	101	0.00	5.2	15.1	100
	0.25	4.9	15.2	101	0.25	5.0	15.1	101	0.25	5.1	15.2	100
	0.50	4.9	15.2	101	0.50	5.0	15.1	101	0.50	5.1	15.2	100
	0.75	4.8	15.2	101	0.75	4.9	15.1	101	0.75	5.0	15.2	100
	1.00	4.5	15.2	101	0.90	4.8	15.1	102				
	1.25	4.4	15.2	101								
	1.50	4.3	15.2	102								
	1.75	4.3	15.2	102								

Table A- 6. Continued: Data for sampling sites 4, 5 and 6 in the Point of France pond.

		SITE 4				SITE 5				SITE 6		
Sampling date	**H (m)**	**DO (mg/L)**	**T °C**	**SC (μs/cm)**	**H (m)**	**DO (mg/L)**	**T °C**	**SC (μs/cm)**	**H (m)**	**DO (mg/L)**	**T °C**	**SC (μs/cm)**
5/16/18					0.00	17.7	19.3	2806				
					0.25	18.6	18.1	3275				
					0.50	20.6	15.3	3910				
					0.75	15.6	14.0	4278				
5/30/18	0.00	5.22	22.9	1609	0.00	6.6	23.1	1813	0.00	5.25	23.2	1724

		SITE 4				SITE 5				SITE 6		
Sampling date	**H (m)**	**DO (mg/L)**	**T °C**	**SC (μs/cm)**	**H (m)**	**DO (mg/L)**	**T °C**	**SC (μs/cm)**	**H (m)**	**DO (mg/L)**	**T °C**	**SC (μs/cm)**
	0.25	5.12	22.9	1594	0.25	5.6	23.3	1808	0.25	5.09	23.3	1729
	0.50	4.87	22.9	1588	0.50	5.4	23.3	1798	0.50	5.14	23.3	1732
	0.75	4.64	22.9	1594	0.75	4.7	23.3	1796	0.75	4.56	23.3	1786
									1.00	3.86	23.3	1830
6/13/18	0.00	2.19	22.6	1330	0.00	1.8	22.4	1350	0.00	1.88	23.0	1330
	0.25	2.08	22.7	1327	0.25	1.6	21.7	1331	0.25	1.1	21.7	1316
	0.50	2.11	22.5	1325	0.50	1.4	21.3	1331	0.50	1.45	21.3	1325
	0.75	1.96	21.3	1310					0.75	1.94	21.0	1320
6/27/18	0.00	5.18	22.9	362	0.00	4.5	23.5	366	0.00	4.77	23.5	366
	0.25	4.48	22.6	363	0.25	3.5	22.8	366	0.25	2.53	22.7	367
	0.50	4.02	22.4	360	0.50	2.4	22.5	367	0.50	2.53	22.4	357
	0.75	2.89	22.2	357	0.75	0.1	22.3	354	0.75	1.62	22.1	332
	0.90	2.24	22.1	357								
7/11/18	0.00	8.0	26.3	266	0.00	10.4	26.5	262	0.00	10.0	26.8	262
	0.25	8.0	25.9	266	0.25	9.9	26.4	261	0.25	10.1	26.7	262
	0.50	7.1	25.7	265	0.50	9.8	26.3	261	0.50	9.5	26.5	262
	0.75	3.9	25.4	273	0.65	8.8	26.2	261	0.75	6.7	25.8	262
	1.00	3.7	25.3	300					1.00	5.52	25.6	495
7/26/18	0.00	7.4	22.9	250	0.00	7.6	23.0	248	0.00	8.1	23.2	247
	0.25	7.5	23.0	250	0.25	7.5	23.1	248	0.25	6.8	23.1	248
	0.50	7.5	23.0	249	0.50	7.5	23.1	248	0.50	6.7	23.1	248
	0.75	7.4	22.9	249	0.65	7.4	23.1	247	0.75	6.3	23.0	248
8/9/18	0.00	11.9	25.5	214	0.00	10.6	25.9	212	0.00	11.1	26.7	213
	0.25	10.8	25.4	213	0.25	14.2	25.5	214	0.25	13.4	25.7	215
	0.50	11.1	25.2	216	0.50	13.8	25.2	214	0.50	14.3	25.4	215
	0.75	9.1	24.3	220	0.75	10.7	24.6	218	0.70	10.5	25.0	367
	1.00	1.5	23.7	228								
8/22/18	0.00	9.6	23.5	292					0.00	9.7	23.4	291
	0.25	9.3	22.9	290					0.25	9.6	22.7	289
	0.50	8.1	22.3	290					0.50	8.8	22.4	289
	0.75	5.9	22.1	291					0.75	6.0	22.0	291
	0.76	5.3	22.0	292					1.00	5.4	22.0	292
9/11/18	0.00	10.3	21.0	186					0.00	10.3	21.5	184
	0.25	10.3	20.9	185					0.25	10.2	21.2	183
	0.50	10.3	20.7	184					0.50	10.3	21.1	183
	0.75	10.3	20.5	183.9					0.75	10.2	20.7	183
	1.00	9.7	20.3	182.9					1.00	8.3	20.2	184
9/26/18	0.00	5.2	15.1	101					0.00	5.2	15.2	101
	0.25	5.1	15.1	101					0.25	4.9	15.1	100
	0.50	5.0	15.1	101					0.50	4.9	15.1	101
	0.75	5.0	15.1	101					0.75	4.8	15.1	101
	1.00	4.3	15.1	101					1.00	4.4	15.1	101

Appendix C

Summary of Hydraulic Modeling Analysis for Rosland Park Stormwater Treatment BMP

Technical Memorandum

To: Project File
From: Katie Turpin-Nagel and Janna Kieffer
Subject: Rosland Park Proposed Filtration BMP- Summary of Hydraulic Analysis
Date: June 10, 2020
Project: 23271725.01

The proposed stormwater Best Management Practice (BMP) in Rosland Park is an above-ground filtration vault that will treat water from Swimming Pool Pond prior to discharge to North Lake Cornelia. Because the filtration vault is above ground and there is minimal drop in elevation between Swimming Pool Pond and North Cornelia, use of a pump is necessary to get water from Swimming Pool Pond into the above-ground filtration vault. After passing through the filtration system, treated water would be conveyed to Lake Cornelia through existing stormwater infrastructure.

Operation of the proposed pump for the filtration vault at Rosland Park will be dependent on water levels in Swimming Pool Pond; the pump will operate when water levels are higher than or slightly below the control elevation. The depth of pumped drawdown below the control elevation of Swimming Pool Pond (and Lake Otto, north of Highway 62 and connected to Swimming Pool Pond via two 60-inch culverts) was given much consideration as part of this feasibility and preliminary design analysis, with the goal of balancing the maximization of water pumped to the filtration system with minimizing impacts of pumping on riparian land owners adjacent to Swimming Pool Pond and Lake Otto. A hydraulic modeling analysis was conducted to help determine how much water would be treated under various pumping scenarios and climatic conditions and what impacts the pumping scenarios would have on water levels. Methodology and results of the hydraulic modeling analysis are summarized in this memo.

Discussion of Model Set-up

The XP-SWMM hydrology and hydraulics modeling software was used to assess the impacts of pumping based on various drawdown depths from the normal water level (NWL) of Swimming Pool Pond and upstream Lake Otto. A long-term continuous simulation was conducted because it allows for evaluation of water fluctuations under a variety of climatic conditions. For the continuous modeling analysis, the City of Edina's existing XPSWMM model was simplified for the Lake Cornelia watershed, and then run for several pumping scenarios using 35-years of 15-minute precipitation data. The pumping scenarios analyzed included:

1) Pump shuts off 6 inches below the NWL, lowering Swimming Pool Pond and Lake Otto
2) Isolating Lake Otto-- Pump shuts off 6 inches below the NWL, lowering only Swimming Pool Pond
3) Pump shuts off 3.6 inches below the NWL, lowering Swimming Pool Pond and Lake Otto

All of the modeled scenarios assumed a design pumping rate of 1.0 cfs that would run 12 hours per day during April 15 through November 15.

The model results were used to assess the volume of water that could be treated each year on average by the filtration vault. Table 1 summarizes the results for each modeled scenario.

Table 1. Summary of amount of water treated and impacts to Lake Otto water levels under evaluated pumping scenarios

Scenario		Average Annual Pumped Volume (ac-ft)[1]	Range Annual Pumped Volume (ac-ft)[1]	% of Discharge from Swimming Pool Pond Treated[3]	Average days/treatment period[1] Lake Otto >3 inches below existing NWL	Average days/treatment period[1] Lake Otto >6 inches below existing NWL
1	Pump shuts off 6 inches below the NWL, lowering Swimming Pool Pond and Lake Otto	125	71 - 163	58%	122 (57%)	62 (29%)
2	Isolating Lake Otto-- Pump shuts off 6 inches below the NWL, lowering only Swimming Pool Pond	102	60 - 130	49%	25 [2] (12% [2])	5 [2] (3% [2])
3	Pump shuts off 3.6 inches below the NWL, lowering Swimming Pool Pond and Lake Otto	108	61 - 143	52%	108 (50%)	13 (6%)

[1] Treatment season is April 15 through November 15.
[2] Reflects existing conditions in Lake Otto
[3] % of discharge based on treatment period of April 15 through November 15

The continuous simulation hydraulic model was also used to determine how often lake levels in Lake Otto would be below the normal water level by greater than 3 inches (0.25 feet) and greater than 6 inches (0.5 feet). Figures 1 and 2 show the average percentage of days during the treatment period that water levels would be 3 inches or more below the normal water level and 6 inches or more below the normal water level, as compared with existing conditions.

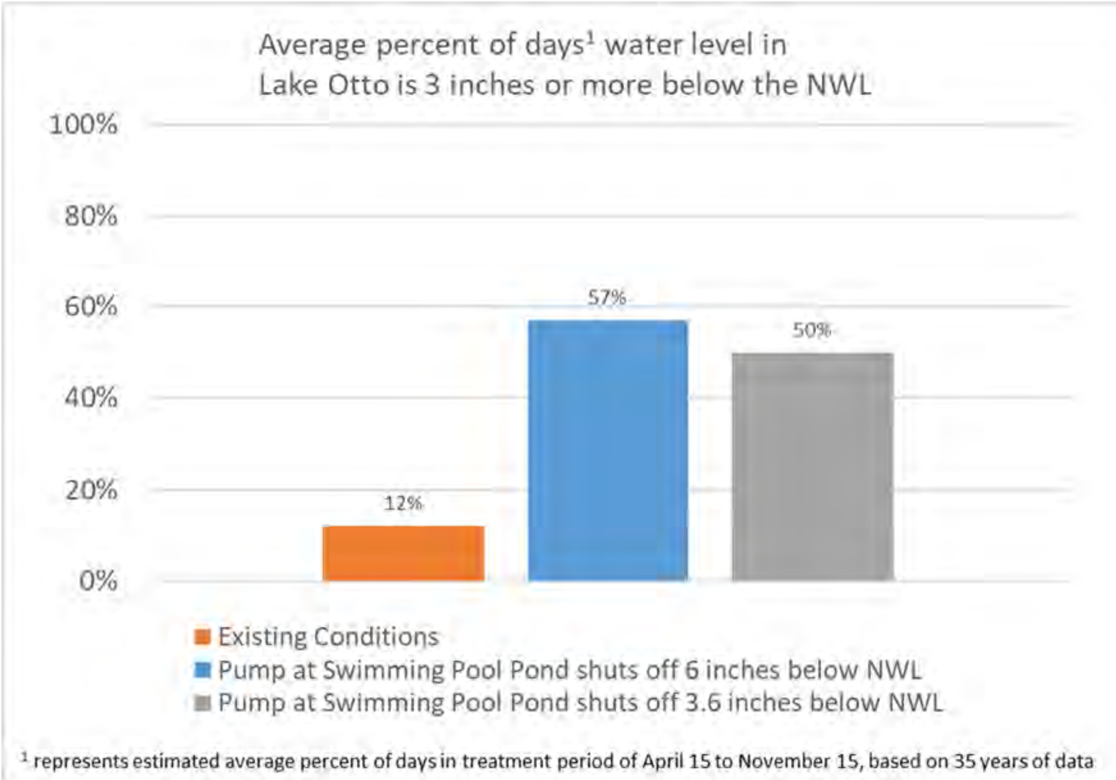


Figure 1. Average percent of days water level in Lake Otto is 3 inches or more below the NWL

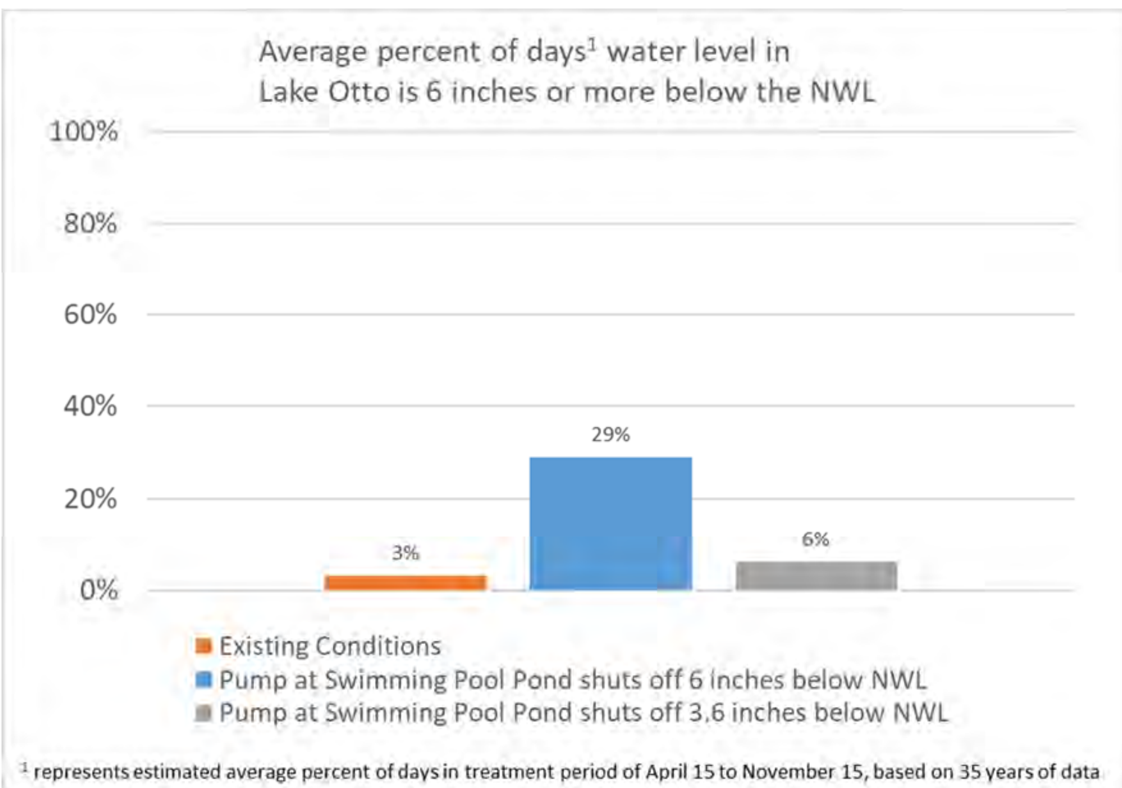


Figure 2. Average percent of days water level in Lake Otto is 6 inches or more below the NWL

Discussion of Modeling Results

Scenario 1, pumping until the water level in Swimming Pool Pond is 6 inches below the NWL, results in an average annual pumped/treated volume of 125 acre-feet, which represents approximately 58% of the discharge from Swimming Pool Pond to North Cornelia during the treatment period (April 15 – November 15). As shown in Figures 1 and 2, this pumping scenario does result in an increased number of days that the water level in Lake Otto is below the normal water level. On average, under Pumping Scenario 1, water levels would be 3 inches or more below the existing NWL approximately 57% of the days during the treatment period (April 15 through November 15), as compared to 12% under existing conditions. Water levels would be 6 inches or more below the NWL approximately 29% of the days during the treatment period, on average, as compared with 3% under existing conditions.

Scenario 2, isolating Lake Otto and pumping until Swimming Pool Pond is 6 inches below the NWL, results in an average annual treatment volume of 102 acre-feet (approximately 23 acre-feet less than the Scenario 1). This treated volume represents approximately 49% of the flow from Swimming Pool Pond to North Cornelia during the treatment period (April 15 – November 15). Isolating Lake Otto from Swimming Pool Pond to prevent lowering of water levels due to pumping would require a weir or alternate control structure be installed at the Lake Otto outlet. A site investigation found that construction of a weir at the Lake Otto outlet or inlet to Swimming Pool Pond would be challenging due to steep slopes, the depth of the fully-submerged pipes, and the length of weir that would need to be constructed to cross two 60-inch diameter storm sewer pipes. The considerable construction constraints and associated costs make this option undesirable.

A third scenario was analyzed to attempt to balance the advantages of Scenarios 1 and 2. The goal of Scenario 3 was to minimize the number of days that Lake Otto has reduced water surface elevations, while maximizing the amount of water treated from Swimming Pool Pond. In Scenario 3, water is pumped until the water level in Swimming Pool Pond is 3.6 inches (0.3 feet) below the NWL. This scenario results in an average annual treatment volume of 108 acre-feet, approximately 52% of the discharge volume from Swimming Pool Pond to North Cornelia during the treatment period (April 15 – November 15). Reducing the depth of pumping from 6 inches to 3.6 inches results in reduced water level impacts to Lake Otto residents (see Figures 1 and 2). On average, the number of days during the treatment period that water levels would be 3 inches or more below the NWL is approximately 50%, in comparison with 57% under Scenario 1. The average number of days during the treatment period that water levels would be 6 inches or more below the NWL is approximately 6%, which is significantly lower than under Scenario 1 (29%) and only slightly higher than under existing conditions (3%).

Scenario 3, turning the pump off when the water level in Swimming Pool Pond drops 3.6 inches below the normal water level, balances the desire to pump/treat a substantial portion of the flow from Swimming Pool Pond to Lake Cornelia while minimizing impacts to water levels for riparian land owners adjacent to Swimming Pool Pond and Lake Otto. A benefit of periodic lower water levels is reduced flood risk for adjacent properties.

Appendix D

Opinions of Probable Cost

PREPARED BY: BARR ENGINEERING COMPANY		SHEET:	1	OF	2
		BY:	KAL	DATE:	5/15/2020
		CHECKED BY:	JMK2	DATE:	5/15/2020
ENGINEER'S OPINION OF PROBABLE PROJECT COST		APPROVED BY:		DATE:	
PROJECT:	2019 Rosland Park Feasibility Design	ISSUED:		DATE:	
LOCATION:	Nine Mile Creek Watershed District	ISSUED:		DATE:	
PROJECT #:	23/27-1725.01	ISSUED:		DATE:	
OPINION OF COST - SUMMARY		ISSUED:		DATE:	

Engineer's Opinion of Probable Project Cost
Rosland Park Above Ground Filter
Feasibility Design

Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
A	Mobilization/Demobilization (10%)	LS	1	$40,000.00	$40,000.00	1,2,3,4,5,6
B	Traffic Control	LS	1	$5,000.00	$5,000.00	1,2,3,4,5,6
C	Inlet Protection	Each	4	$250.00	$1,000.00	1,2,3,4,5,6
D	Orange Construction Fencing	LF	500	$5.00	$2,500.00	1,2,3,4,5,6
E	Silt Fence	LF	250	$4.00	$1,000.00	1,2,3,4,5,6
F	Street Sweeping	HR	20	$175.00	$3,500.00	1,2,3,4,5,6
G	Utility Relocation	LS	1	$5,000.00	$5,000.00	1,2,3,4,5,6
H	Clearing and Grubbing	LS	1.0	$4,000.00	$4,000.00	1,2,3,4,5,6
I	Excavation for Vault & Placement as Fill on site	CY	150	$20.00	$3,000.00	1,2,3,4,5,6
J	5 HP Pump, MH structure, electrical panel, and controls	Each	1	$100,000.00	$100,000.00	1,2,3,4,5,6
K	Power supply for pump	LF	350	$25.00	$8,750.00	
L	Aeration MH with internal pipes - 72" dia., 8' deep	LS	1	$10,000.00	$10,000.00	1,2,3,4,5,6
M	Area Drains,pipe and river rock for filter discharge (Nyloplast)	Each	3	$2,000.00	$6,000.00	1,2,3,4,5,6
N	Shallow Area Drain downstream of Area Drains (Nyloplast)	Each	1	$1,500.00	$1,500.00	1,2,3,4,5,6
O	SPP Pump Intake Floating Island skimmer (Biohaven)	SF	250	$70.00	$17,500.00	1,2,3,4,5,6
P	12" Flexible Pump Intake Pipe in SPP	LF	40	$100.00	$4,000.00	1,2,3,4,5,6
Q	12" Pump Intake pipe under road	LF	40	$40.00	$1,600.00	1,2,3,4,5,6
R	Pump Discharge pipe to aertion MH	LF	100	$35.00	$3,500.00	1,2,3,4,5,6
S	12" Pipe from Aeration MH to Flow Distribution weir	LF	20	$35.00	$700.00	1,2,3,4,5,6
T	Flow spreader Weir/pipes into Vault	LS	1	$5,000.00	$5,000.00	1,2,3,4,5,6
U	Pipe to Ex CB - 12" PVC	LF	180	$30.00	$5,400.00	1,2,3,4,5,6,7
V	Connect to Existing CB	Each	1	$1,000.00	$1,000.00	1,2,3,4,5,6
W	3/4" Crushed Rock with Geotextile under vault (2 ft thick)	CY	150	$50.00	$7,500.00	1,2,3,4,5,6
X	Reinforced Concrete - Slab (1200sf x 8")	CY	30	$1,000.00	$30,000.00	1,2,3,4,5,6
Y	Reinforced Concrete - 6" Walls (6' deep vault)	CY	24	$1,000.00	$24,000.00	1,2,3,4,5,6
Z	Reinforced Concrete - Footing	CY	20	$1,000.00	$20,000.00	1,2,3,4,5,6
AA	Vault Grate cover-FRP and cross supports	SF	1,200	$40.00	$48,000.00	1,2,3,4,5,6
BB	Vault Railing	LF	100	$150.00	$15,000.00	1,2,3,4,5,6
CC	6" CPEP underdrain and outlet pipe for Filter Cell	Each	3	$2,000.00	$6,000.00	1,2,3,4,5,6
DD	Drainage layer under filter- 6" depth Granular Filter Aggregate	CY	20	$80.00	$1,600.00	1,2,3,4,5,6
EE	Cell 1-CC17 Filter media (2 ft depth)	CY	27	$100.00	$2,700.00	1,2,3,4,5,6
FF	Cell 2-CC17 and Iron Filter media (2 ft depth)	CY	27	$120.00	$3,240.00	1,2,3,4,5,6
GG	Cell 3-Spent Lime (3 ft depth)	CY	40	$100.00	$4,000.00	1,2,3,4,5,6
HH	Concrete Wall Facing (105' x 5')	SF	525	$50.00	$26,250.00	1,2,3,4,5,6
II	Curb and Gutter Installation	LF	100	$50.00	$5,000.00	1,2,3,4,5,6
JJ	Remove and replace bituminous and agg base	SY	160	$60.00	$9,600.00	1,2,3,4,5,6
KK	Pond Shoreline Restoration	LS	1.0	$4,000.00	$4,000.00	1,2,3,4,5,6
LL	Turf Re-Establishment (Restoration)	SY	200	$5.00	$1,000.00	1,2,3,4,5,6
MM	Erosion Control Blanket	SY	200	$4.00	$800.00	1,2,3,4,5,6
				CONSTRUCTION SUBTOTAL	$439,000.00	1,2,3,4,5,6,7,8
				CONSTRUCTION CONTINGENCY (30%)	$132,000.00	1,2,3,4,5,6,7,8
				ENGINEERING AND DESIGN (30%)	$172,000.00	1,2,3,4,5,6,7,8
				ESTIMATED TOTAL CONSTRUCTION COST	**$743,000.00**	1,2,3,4,5,6,7,8
	ESTIMATED ACCURACY RANGE	**-15%**			**$632,000.00**	5,8
		20%			**$892,000.00**	5,8

NN	Public Art	LS	1	$100,000.00	$100,000.00	1,2,3,4,5,6
				ADDITIONAL ITEMS SUBTOTAL	**$100,000.00**	1,2,3,4,5,6,8

Notes

[1] Limited design work completed (feasibility level)

[2] Quantities Based on Design Work Completed.

[3] Unit Prices Based on Information Available at This Time.

[4] Minimal Soil and Field Investigations Completed.

[5] This Design Level (Class 3, 10 - 40% design completion per ASTM E 2516-116) cost estimate is based on screening/conceptual discussion. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Construction Cost as the project is defined is -15% to +20%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and maintenance costs are not included.

[6] Estimated costs are for construction and do not include maintenance, monitoring, or additional tasks following construction.

[7] Furnish and Install pipe cost per linear foot includes all trenching, bedding, backfilling, compaction, and disposal of excess materials

[8] Estimated costs are reported to nearest thousand dollars.

PREPARED BY: BARR ENGINEERING COMPANY		SHEET:	1	OF	
BARR		CREATED BY:	KJN2	DATE:	3/18/2020
ENGINEER'S OPINION OF PROBABLE PROJECT COST		CHECKED BY:	KAL	DATE:	6/1/2020
PROJECT: Lake Edina Retrofit BMPs - Cornelia Elementary		APPROVED BY:	JMK2	DATE:	6/1/2020
LOCATION: City of Edina	ISSUED:			DATE:	
PROJECT #: 23271725.01	ISSUED:			DATE:	
OPINION OF COST - SUMMARY	ISSUED:			DATE:	

Engineer's Opinion of Probable Project Cost

Lake Edina Retrofit BMPs - Cornelia Elementary

Three Rainwater Gardens

Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
A	Mobilization	LS	1	$18,000	$18,000	1,2,3,4,5,6,7
B	Temporary Erosion Control	LS	1	$5,000	$5,000	1,2,3,4,5,6,7
C	Tree Removal	EA	16	$1,000	$16,000	1,2,3,4,5,6,7
D	Remove and Dispose of Sewer Pipe	LF	24	$30	$720	1,2,3,4,5,6,7
E	Remove and Dispose of Storm Structures	EA	2	$750	$1,500	1,2,3,4,5,6,7
F	Sawcut Pavement	LF	100	$10	$1,000	1,2,3,4,5,6,7
G	Remove and Dispose Pavement	SY	70	$5	$350	1,2,3,4,5,6,7
H	48" Diameter RC Drainage Structure, Complete	EA	2	$4,000	$8,000	1,2,3,4,5,6,7
I	Storm diversion structure (manhole + weir)	EA	1	$15,000	$15,000	1,2,3,4,5,6,7
J	Storm sewer pipe (RCP)	LF	175	$115	$20,125	1,2,3,4,5,6,7
K	Storm sewer FES (RCP)	EA	1	$600	$600	1,2,3,4,5,6,7
L	Tie-In to Existing Storm Structure	EA	1	$2,000	$2,000	1,2,3,4,5,6,7
M	Replace Pavement	SY	70	$35	$2,450	1,2,3,4,5,6,7
N	Splashblock Assemblies	EA	4	$1,400	$5,600	1,2,3,4,5,6,7
O	Rain Garden(s)	SF	6,669	$15	$100,035	1,2,3,4,5,6,7,8
	CONSTRUCTION SUBTOTAL				$196,000	1,2,3,4,5,6,7,9
	CONSTRUCTION CONTINGENCY (30%)				$59,000	1,5,9
	ESTIMATED CONSTRUCTION COST				$255,000	1,2,3,4,5,6,7,9
	PLANNING, ENGINEERING & DESIGN (30%)				$77,000	1,2,3,4,5,9
	ESTIMATED TOTAL PROJECT COST				$332,000	1,2,3,4,5,7,11
	ESTIMATED ACCURACY RANGE	**-30%**			**$233,000**	5,7,11
		50%			**$498,000**	5,7,11

Notes

[1] Limited Design Work Completed (1-15%).

[2] Quantities Based on Design Work Completed.

[3] Unit Prices Based on Information Available at This Time.

[4] Limited Soil Boring and Field Investigation Information Available.

[5] This concept-level (Class 5, 1-15% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -30% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[6] Estimate assumes that projects will not be located on contaminated soil.

[7] Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following constuction.

[8] Estimate costs are to install a rainwater garden, including subsurface removals, and installation of planting soil, plants, and shrubs.

[9] Estimate costs are reported to nearest thousand dollars.

PREPARED BY: BARR ENGINEERING COMPANY		SHEET:	1	OF	
BARR		CREATED BY:	KJN2	DATE:	3/18/2020
ENGINEER'S OPINION OF PROBABLE PROJECT COST		CHECKED BY:	KAL	DATE:	6/1/2020
PROJECT: Lake Edina Retrofit BMPs - Lynmar Basin		APPROVED BY:	JMK2	DATE:	6/1/2020
LOCATION: City of Edina	ISSUED:			DATE:	
PROJECT #: 23271725.01	ISSUED:			DATE:	
OPINION OF COST - SUMMARY	ISSUED:			DATE:	

Engineer's Opinion of Probable Project Cost

Lake Edina Retrofit BMPs - Lynmar Basin

Infiltration Basin

Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
A	Mobilization	LS	1	$28,000	$28,000	1,2,3,4,5,6,7
B	Temporary Erosion Control	LS	1	$5,000	$5,000	1,2,3,4,5,6,7
D	Tree Removal	EA	30	$700	$21,000	1,2,3,4,5,6,7
E	Install cast-in-place weir in existing FES	LS	1	$6,000	$6,000	1,2,3,4,5,6,7
M	Infiltration Basin	SF	24,341	$10	$243,410	1,2,3,4,5,6,7,8
	CONSTRUCTION SUBTOTAL				$303,000	1,2,3,4,5,6,7,9
	CONSTRUCTION CONTINGENCY (30%)				$91,000	1,5,9
	ESTIMATED CONSTRUCTION COST				**$394,000**	1,2,3,4,5,6,7,9
	PLANNING, ENGINEERING & DESIGN (30%)				$118,000	1,2,3,4,5,9
	ESTIMATED TOTAL PROJECT COST				$512,000	1,2,3,4,5,7,11
	ESTIMATED ACCURACY RANGE	**-30%**			**$359,000**	5,7,11
		50%			**$768,000**	5,7,11

Notes

[1] Limited Design Work Completed (1-15%).

[2] Quantities Based on Design Work Completed.

[3] Unit Prices Based on Information Available at This Time.

[4] Limited Soil Boring and Field Investigation Information Available.

[5] This concept-level (Class 5, 1-15% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -30% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[6] Estimate assumes that projects will not be located on contaminated soil.

[7] Estimate costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following constuction.

[8] Estimate costs are to install a rainwater garden, including subsurface removals, and installation of planting soil, plants, and shrubs.

[9] Estimate costs are reported to nearest thousand dollars.

Lake Cornelia Curly-leaf Pondweed Herbicide Treatment (Endothall) Cost Estimate

Item Description	Unit	Estimated Quantity	Unit Cost	Cost Per Year
Prepare Bids/Specs/Form of Agreement	LS	1	$3,000	$3,000
Treatment design	LS	1	$2,000	$2,000
MnDNR Permitting	LS	1	$1,000	$1,000
Temperature Measurements	LS	1	$3,000	$3,000
Herbicide Residue Monitoring	LS	1	$2,300	$2,300
Data Processing/Reporting	LS	1	$2,000	$2,000
Barr costs for Macrophyte surveys (contract preparation, coordination, and data QA)	LS	2	$300	$600
Subcontractor Cost of Macrophyte Surveys and Analyses	LS	2	$1,300	$2,600
Subcontractor Cost of Endothall Treatment	Gallons	114	$75	$8,540
Contingency (10%)				$3,000
Total				**$28,100**
Range (-15%)				$24,000
Range (+20%)				$34,000
Total				**$24,000 to $34,000**

Assumptions:

Includes treatment of North and South Cornelia

Includes one pre-treatment and post-treatment plant survey completed by Endangered Resource Services,

Assumes the Nine Mile Creek Watershed District prepares Bids/Specs and conducts all coordination, including monitoring and reporting that may be required as part of permitting (e.g., temperature monitoring, herbicide residual monitoring, post-treatment aquatic plant survey) and contracting (herbicide applicator and aquatic plant survey subcontractor)

Assumes NMCWD engineer will process data and prepare a memo summarizing treatment results

Assumes water quality monitoring, if required, is completed by the NMCWD as a part of the District lake monitoring program or by CAMP and cost is not included in this program.

Assumes UPL will provide free analyses of endothall residue samples following treatment.

PREPARED BY: BARR ENGINEERING COMPANY		SHEET:	1	OF	
		CREATED BY:	JAH	DATE:	5/20/2020
ENGINEER'S OPINION OF PROBABLE PROJECT COST		CHECKED BY:	JMK2	DATE:	6/1/2020
PROJECT: Lake Cornelia Drawdown		APPROVED BY:		DATE:	
LOCATION: City of Edina	ISSUED:			DATE:	
PROJECT #: 23271725.01	ISSUED:			DATE:	
OPINION OF COST - SUMMARY	ISSUED:			DATE:	

Engineer's Opinion of Probable Project Cost

Lake Cornelia Drawdown

Cat. No.	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
A	Mobilization/demobilization	LS	1	$5,000	$5,000	1,2,3,4,5,6,7
B	Pump set-up, rental, and removal (3,000 gpm pump)	LS	3	$169,100	$507,300	
C	Daily servicing (including refueling and maintenance) during initial 30-day drawdown period1	LS	3	$45,800	$137,400	
D	Periodic servicing[8] (including refueling and maintenance) to maintain drawdown)	LS	3	$129,600	$388,800	
E	Site Restoration	LS	3	$2,500	$7,500	1,2,3,4,5,6,7
F	HDPEP Inlet and Outlet Pipes for All Three Pipes (2,400 Feet Total)	LF	2,400	$15	$36,000	1,2,3,4,5,6,7
	CONSTRUCTION SUBTOTAL				$1,082,000	1,2,3,4,5,6,7,9
	CONSTRUCTION CONTINGENCY (30%)				$325,000	1,5,9
	ESTIMATED CONSTRUCTION COST				**$1,407,000**	1,2,3,4,5,6,7,9
	PLANNING, ENGINEERING & DESIGN (30%)				$422,000	1,2,3,4,5,9
	ESTIMATED TOTAL PROJECT COST				$1,829,000	1,2,3,4,5,7,11
	ESTIMATED ACCURACY RANGE	**-30%**			**$1,281,000**	5,7,11
		50%			**$2,744,000**	5,7,11

Notes

[1] Limited Design Work Completed (1-15%).

[2] Quantities Based on Design Work Completed.

[3] Unit Prices Based on Information Available at This Time.

[4] Limited Soil Boring and Field Investigation Information Available.

[5] This concept-level (Class 5, 1-15% design completion per ASTM E 2516-11) cost estimate is based on feasibility-level designs, alignments, quantities and unit prices. Costs will change with further design. Time value-of-money escalation costs are not included. A construction schedule is not available at this time. Contingency is an allowance for the net sum of costs that will be in the Final Total Project Cost at the time of the completion of design, but are not included at this level of project definition. The estimated accuracy range for the Total Project Cost as the project is defined is -30% to +50%. The accuracy range is based on professional judgement considering the level of design completed, the complexity of the project and the uncertainties in the project as scoped. The contingency and the accuracy range are not intended to include costs for future scope changes that are not part of the project as currently scoped or costs for risk contingency. Operation and Maintenance costs are not included.

[6] Estimate assumes that projects will not be located on contaminated soil.

[7] Estimated costs are to design, construct, and permit each alternative. The estimated costs do not include maintenance, monitoring or additional tasks following constuction.

[8] Cost estimate assumes one month of continuous pumping (August 15 through September 15) followed by 6.5 months of intermittent pumping (September 15 through March 1) to keep the lake drawn down. The cost estimate assumes pumping 50% of the time during the intermittent period but this could vary widely depending on precipitation and climate conditions.

[9] Estimate costs are reported to nearest thousand dollars.

PREPARED BY: BARR ENGINEERING COMPANY	SHEET: 1	OF	2
	BY: KMP	DATE:	5/28/2020
	CHECKED BY: JMK2	DATE:	6/1/2020
ENGINEER'S OPINION OF PROBABLE PROJECT COST	APPROVED BY:	DATE:	
PROJECT: Lake Cornelia Aeration System	ISSUED:	DATE:	
LOCATION: Nine Mile Creek Watershed District	ISSUED:	DATE:	
PROJECT #: 23/27-1725.01	ISSUED:	DATE:	
SUMMARY OF MORE DETAILED VERSION	ISSUED:	DATE:	

Engineer's Opinion of Probable Project Cost
Lake Cornelia Aeration System

ITEM #	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT COST	ITEM COST	NOTES
	Mobilization/Demobilization (10%)	LS	1	$9,665	**$9,664.50**	
A	Inlet Protection	Each	2	$250	$500	
B	Orange Construction Fencing	LF	100	$5	$500	
C	Silt Fence	LF	100	$4	$400	
D	Street Sweeping	HR	20	$175	$3,500	
E	Electrical Installation (110V)	LS	1	$10,000	$10,000	
F	Clearing and Grubbing	LS	1.0	$1,000	$1,000	
	Safety, Erosion Control, and Site Prep				**$15,900.00**	
G	Pump (Aquaculture Pump Rated 60 gpm/ 60 ft Head)	Each	1	$2,450	$2,450	
H	Topz Ulta (10 lpm) Oxygen Supply	Each	1	$4,375	$4,375	
I	Flow Control Unit (Alicat)	Each	1	$2,550	$2,550	
J	Contact Chamber (24" Base Speece Cone or Equivalent)	Each	1	$2,570	$2,570	
K	Environmental Control (Heater, Dehumidifier)	Each	1	$2,000	$2,000	
L	Piping	Each	1	$15,000	$15,000	
M	Building and Distribution System Prep	Each	1	$10,000	$10,000	
N	Building (6'x6' Precast Concrete)	Each	1	$12,500	$12,500	
O	System Assembly, In-Lake Piping Assembly and Deploy	Each	1	$25,000	$25,000	
	Aeration System - Complete				**$76,445.00**	
P	Lake Shoreline Restoration	Each	1.0	$2,500.00	$2,500.00	
Q	Turf Re-Establishment (Restoration)	SY	200	$5.00	$1,000.00	
R	Erosion Control Blanket	SY	200	$4.00	$800.00	
	Site Restoration				**$4,300.00**	
	Construction Contingency (30%)				$31,892.85	
				CONSTRUCTION SUBTOTAL	$138,202.35	
				Gantzer Water Design and Commissioning Support[1]	$22,000.00	
				ENGINEERING AND DESIGN (30%)	$41,460.71	
				ESTIMATED TOTAL CONSTRUCTION COST	**$202,000.00**	
	ESTIMATED ACCURACY RANGE	**-15%**			**$172,000.00**	
		20%			**$243,000.00**	

[1] Gantzer Water design and commissioning support includes engineering and design support, start-up testing, O&M manual and training, and two years of start-up support.

Appendix E

Lake Cornelia Winter Oxygenation Design Considerations

Lake Cornelia Winter Oxygenation Design Considerations

PREPARED FOR:	Keith Pilgrim (Barr Engineering)
PREPARED BY:	Paul Gantzer
DATE:	April 21, 2020

Proposed Scope of Work: Lake Cornelia Winter Oxygenation Design Considerations

The focus of this work was to identify the oxygen demand in North and South Lake Cornelia and then use those values to recommend an ice-preserving oxygen management strategy that can operate during winter to prevent fish kills.

Five sets of water column profile data were provided from January 18 to March 18, 2019 that were collected at east and west locations on North and South Lake Cornelia. Additionally, two strings of dissolved oxygen (DO) probes were deployed in each basin and collected data hourly between January 14 and April 14, 2020. Probes were positioned 0.5, 1, 2, and 3 feet above the bottom.

Following review and analysis of the water quality data, four remediation strategies were evaluated, full-lift aeration, full-lift oxygenation, oxygen enhanced full-lift aeration, and side-stream saturation (SSS) oxygenation. In summary, it is recommended to deploy SSS systems in each basin. The following report summarizes details supporting this recommendation.

Data Analysis and DO Demand

A topographical map was provided with the water column profiles collected during winter 2019. The topo was imported into AutoCadLT to scale and the contours were traced to create an approximate volume table for each basin. Both North and South Lakes were divided into two sub basins representing east and west. The division is shown as a heavy black line on the topographic map (Figure 1). For this study, the surface contours were excluded because they represent the area and volume covered with the ice. The estimated volumes of interest were summarized in Table 1.

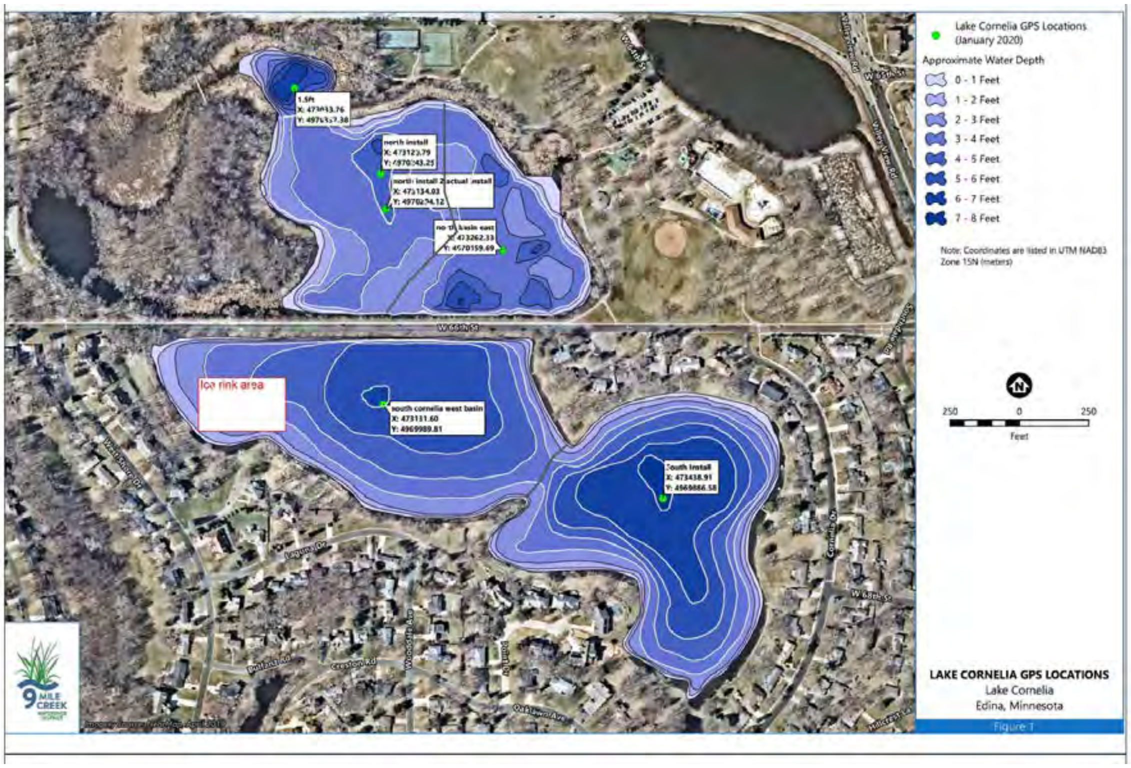


Figure 3: Topographic map of North and South Lake Cornelia showing location of water column profiles and remote sensor deployment labeled as “North actual install” and “South Install”.

Table 1: Summary of lake and corresponding basin volumes.

Lake	Basin	Volume	
		ft^3	m^3
North	East	377,666	10,694
	West	415,737	11,772
Total		793,403	22,467
South	East	795,730	22,533
	West	740,052	20,956
Total		1,535,782	43,488

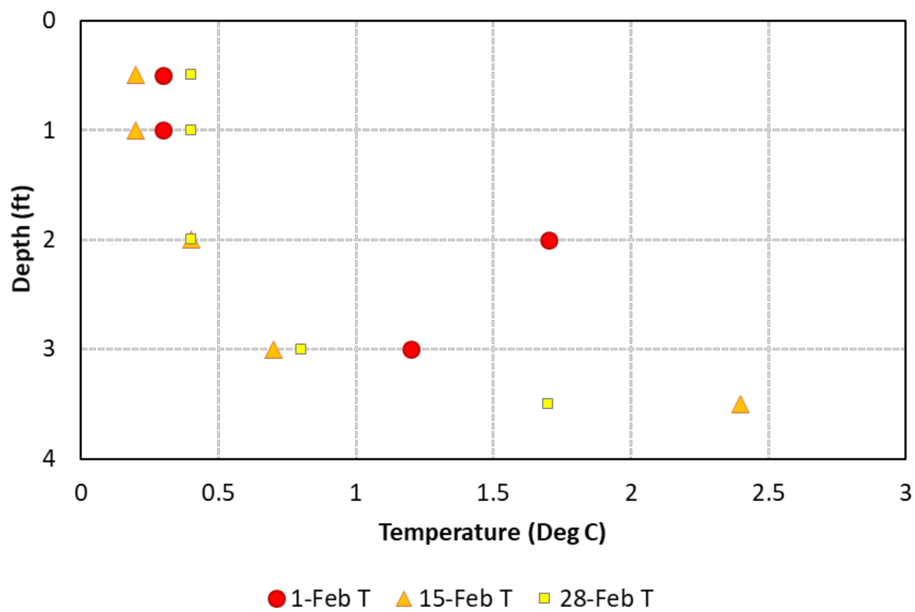
Both water column profiles and remote data were used to estimate DO depletion rates. An example of the water column profiles collected during February 2019, which were also used to determine DO depletion rates are shown in Figures 2 and 3 for North and South Lake Cornelia respectively.

Although remote probes were deployed at four depths, only partial data sets were available for analysis. Bottom probes were believed to have sunken into the sediment. This is based on this depth recording 0 mg/L as soon as the probes were deployed and then reading ambient once the sensors were recovered. This meant that the other probes positions were approximately 6 inches below the original estimate. Data was therefore shifted downward to reflect this offset. For North, the remaining three probes collected data throughout the deployment (Figure 4 top). For South, only the two middle probes collected data (Figure 4 bottom). The top probe appeared to have been damaged in shipping for it did not have data beyond the test data point prior to shipping in December. All remote data were aggregated to consolidate the data to daily averages for analysis (Figure 5). Both lakes showed linear DO depletion in late January through early February, which is denoted by black lines on the aggregated data (Figure 5) and is summarized in Table 2. Review of the remote data revealed prolonged anoxic conditions in North and recovery in mid-February but then depleting again until spring ice melt occurred in South.

The volume table was used to determine oxygen (mass) content for the various data sets. In summary DO depletion rates from water column profiles were calculated to be 20.4 (8.0 east, 12.4 west) and 17.5 (10.4 east, 7.1 west) kg/d for North and South Lake Cornelia respectively. Analysis of the remote data resulted in DO depletion rates to be 15.5 and 21.3 kg/d for North and South Lake Cornelia respectively. Although there are limitations in each data set, these values provide a baseline to establish and oxygen supplement strategy.

Traditional oxygen management would consider the maximum depletion rate and then design a system to meet up to three times that demand throughout a determined time period, typically six months. This is done because of increased DO demand from oxygenation system operation coupled with increased DO demand throughout the summer as detritus enters the lower waters from settling organics growing throughout the summer. For winter oxygenation, the strategy is modified to sustain adequate DO long enough to reach ice melt in the spring. Based on this modification, the oxygenation system can be scaled back to prolong the onset of anoxia for one and half to two months compared to maintaining a desired oxygen concentration for six months. This concept is shown graphically with the remote data, in which the estimated DO was calculated by offsetting the depletion with oxygen addition (Figure 6). The resulting analysis showed that supplementing the oxygen content in each lake with 11 kg/d offset the time of anoxia several days after the observed ice melt and subsequent natural DO recovery.

Because there are several caveats with the data and corresponding data analysis (e.g. estimated water volumes, uncertainty of actual remote probe position, and only having two water column profiles that showed decreased DO), it would be recommended to have an oxygen addition strategy that can add upwards of 17 kg/d, which is approximately 150% of the 11 kg/d estimate.



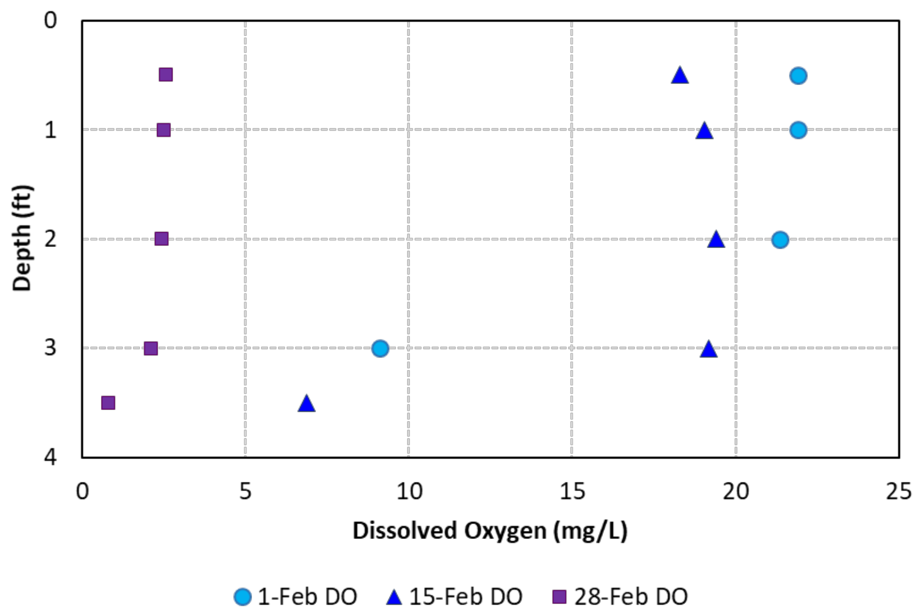


Figure 2: Sample temperature (top) and DO (bottom) data collected during February 2019 on North Lake Cornelia.

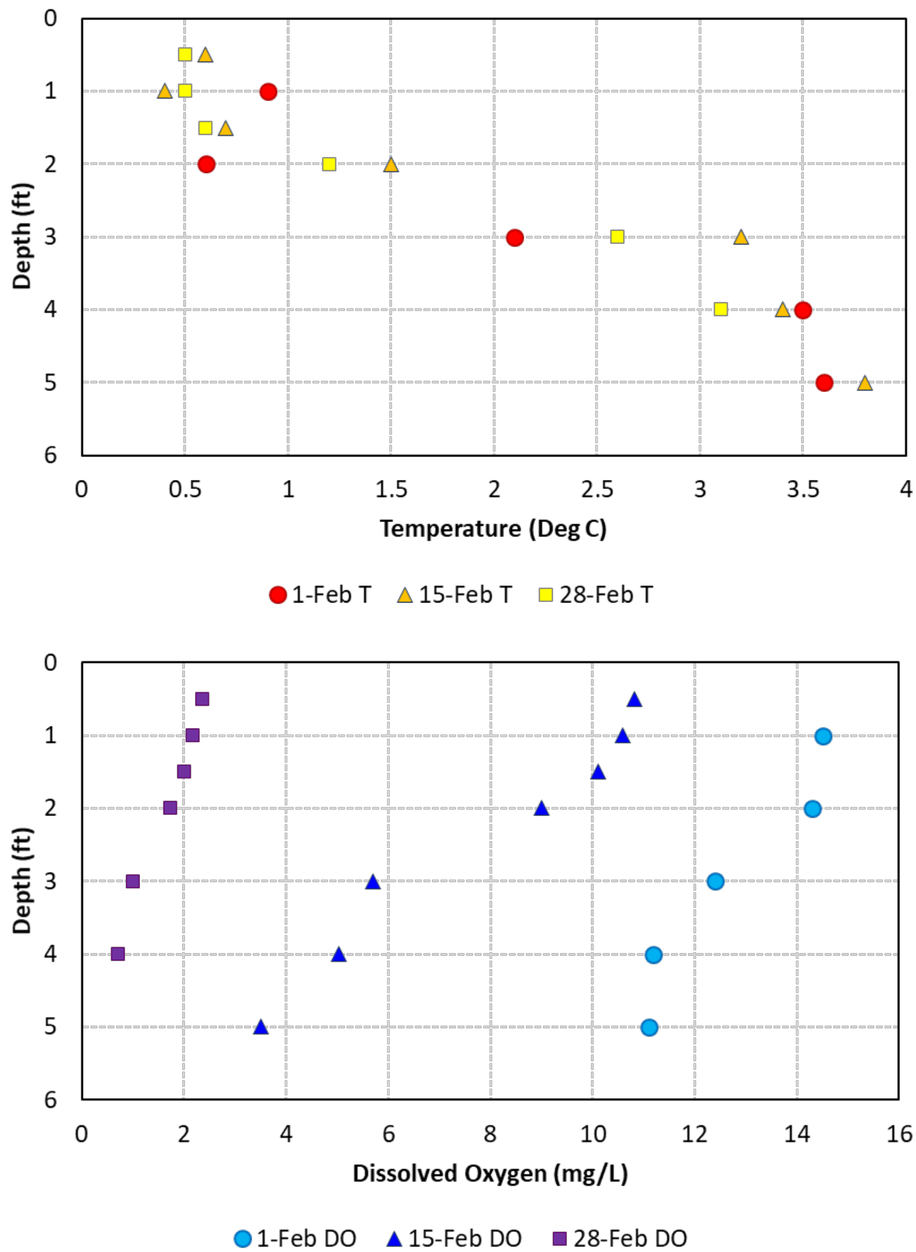


Figure 3: Sample temperature (top) and DO (bottom) data collected during February 2019 on South Lake Cornelia.

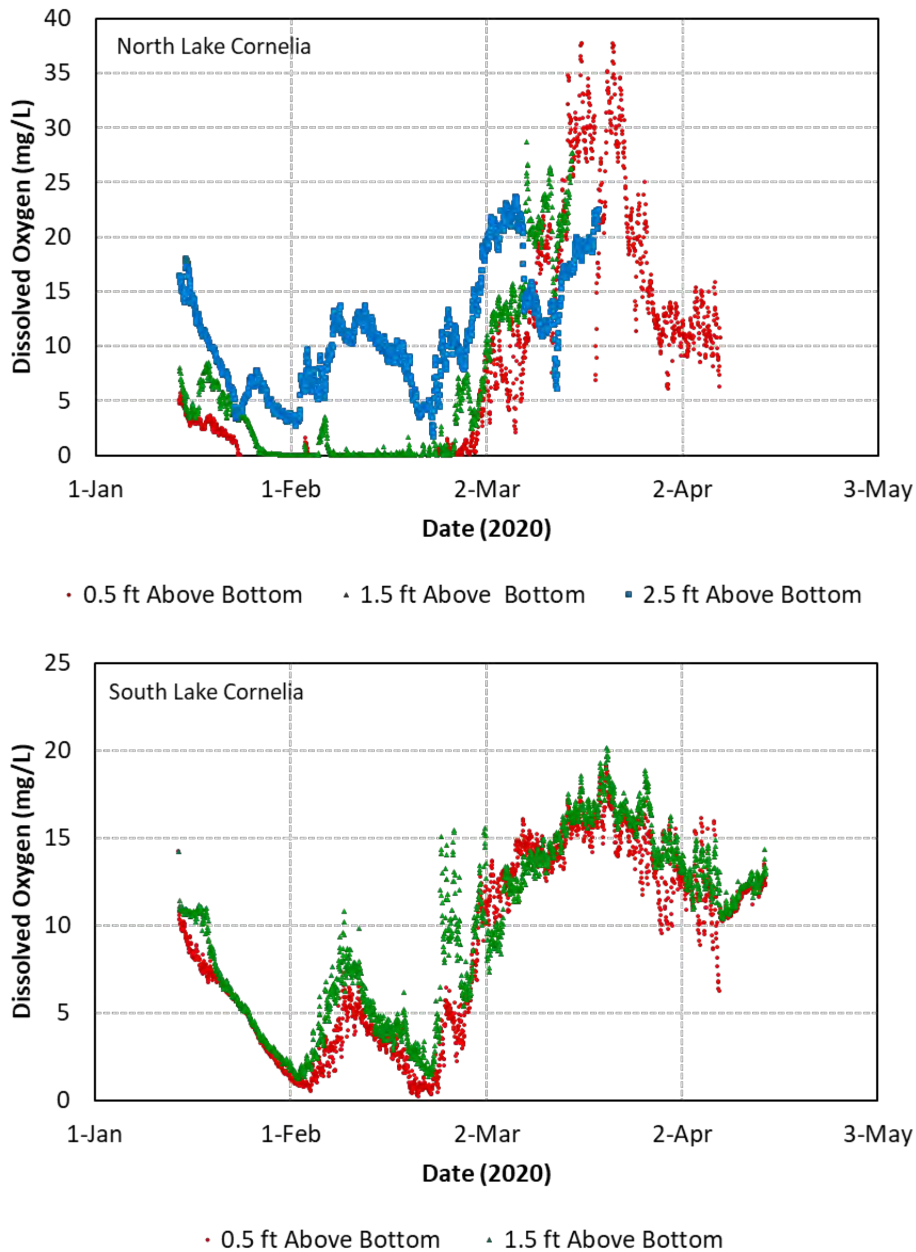


Figure 4: Remote dissolved oxygen data collected in North (top) and South (bottom) Lake Cornelia, showing linear depletion rates occurring mid-January and early February.

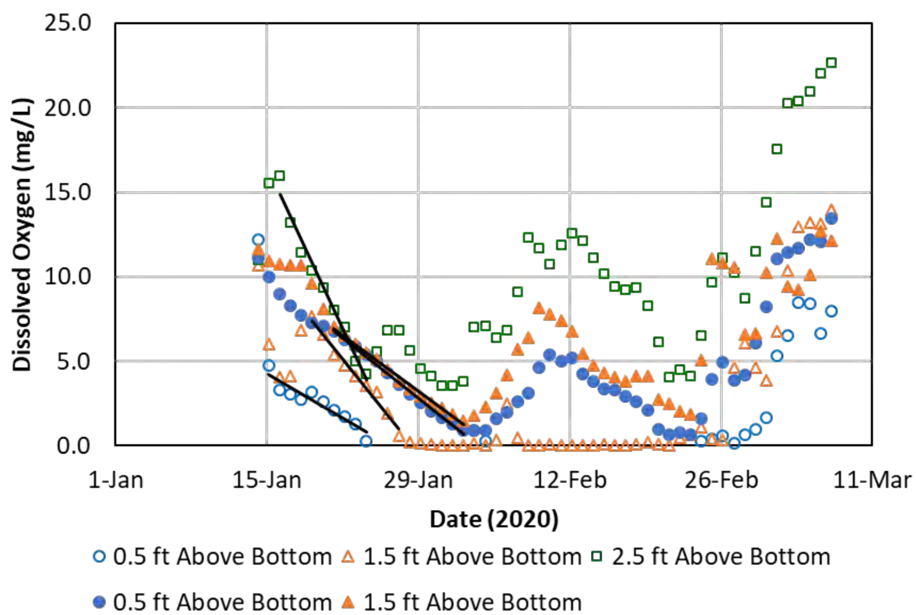
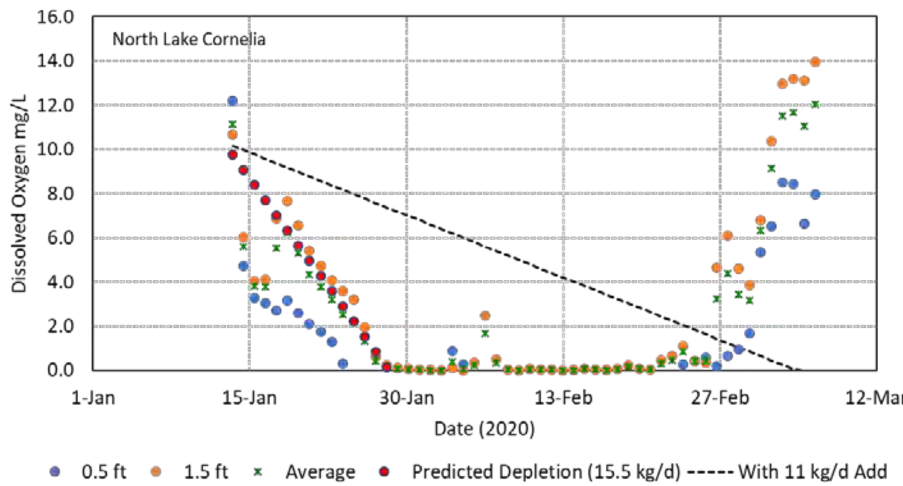


Figure 5: Aggregated remote DO data collected on North (open symbols) and South (closed symbols) Lake Cornelia with black lines showing data used to determine depletion rates.

Table 2: Summary of aggregated dissolved oxygen (DO) data used to determine remotely deployed sensor DO depletion rates

Date	North			South	
	0.5	1.5	2.5	0.5	1.5
	ft above bottom			ft above bottom	
	mg/L				
16-Jan			16.0		
17-Jan			13.2		
18-Jan			11.4		
19-Jan	3.2		10.4		
20-Jan	2.6		9.3		
21-Jan	2.1	5.4	8.1	6.8	7.0
22-Jan	1.8	4.7	7.0	6.2	6.5
23-Jan	1.3	4.1	5.0	5.9	6.0
24-Jan	0.3	3.6	4.3	5.4	5.5
25-Jan		3.2		5.0	5.2
26-Jan		1.9		4.3	4.5
27-Jan		0.6		3.6	3.8
28-Jan		0.2		3.1	3.4
29-Jan				2.6	2.9
30-Jan				2.1	2.6
31-Jan				1.7	2.2
1-Feb				1.3	1.9
2-Feb				0.9	1.5
Rate (mg/L d)	-0.53	-0.76	-1.37	-0.51	-0.47



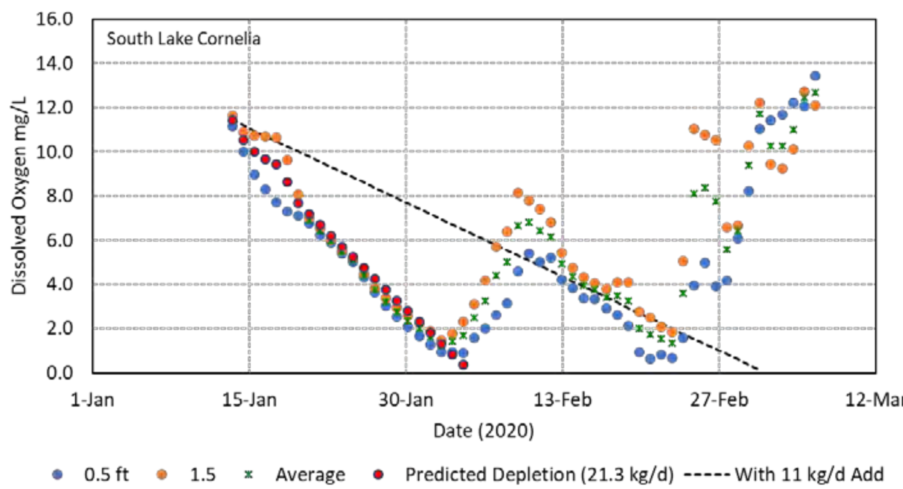


Figure 6: Aggregated remote dissolved oxygen (DO) data for North (top) and South (bottom) Lake Cornelia showing predicted depletion rates (red circles) to match the observed rate of depletion and predicted DO (dashed black line) and corresponding time of anoxia from an oxygen supplement of 11 kg/d.

Oxygenation Overview

Winter oxygenation injects oxygen into the bottom of a lake. The goal of this technology is to prevent the onset of anoxia until ice melts and the DO can recover naturally. For winter projects, the primary goal is ice preservation and then ensuring enough oxygen exists to extend the potential longest time period of historical anoxic conditions.

This method of lake water quality reclamation is becoming standard practice in drinking and hydroelectric reservoirs. Adapting this technology to recreational lakes requires scaling down existing technology or developing a new hybrid technology.

This section presents common methods to increase the oxygen content in the water column, aeration and oxygenation that are applicable to Lake Cornelia.

Aeration and Oxygen Strategies

Aeration injects air to a location deep in the lake. Oxygen sparging is similar but uses pure oxygen instead of air. Air is only 20% oxygen. Use of pure (95%) oxygen instead of air increases the rate of oxygen transfer to water from gas by a factor up to ten compared to air in deep, cold locations.

There are several technologies that aerate or inject pure oxygen to lakes (Table 1) that are all conceptually simple from a mechanical perspective. These technologies have traditionally been used for oxygen transfer in drinking-water reservoirs to improve raw water quality. Full lift aeration, partial lift aeration, destratification, and linear diffusers are common aeration technologies.

TABLE 1

Summary of applicable In Lake Oxygen Management Methods

Method	Description
Full Lift Aeration	• Uses air • Water travels the full depth of the lake • Does not cause destratification • Increase in dissolved oxygen concentration varies between 0.5 – 5.0 mg/L depending on sediment chemistry and depth
Full Lift Oxygenation	• Uses oxygen • Water travels the full depth of the lake • Does not cause destratification • Increase in dissolved oxygen ranges from 2 mg/L to 8 mg/L depending on sediment chemistry and depth
Oxygen Enhanced Full Lift Aeration	• Same features as full lift aeration • Uses oxygen injection in down flow chamber

	• Does not cause destratification • Increase in dissolved oxygen ranges from 2 mg/L to 8 mg/L depending on sediment chemistry and depth
Side-stream Saturation (SSS)	• Uses oxygen • Requires pump to circulate water • Does not cause destratification • Increase in dissolved oxygen ranges from 2 mg/L to 20 mg/L

1. Full Lift Aeration

Full lift aeration has been used for oxygen transfer in lakes for several decades. Air is pumped to diffusers in the bottom of a draft or riser tube. The essential idea is that these systems are made of a large pipe inside a larger pipe. The inner pipe (draft tube) extends to just above the lake bottom. Air injected into the pipe entrains large volumes of water into the bottom of the pipe and the bubble water mixture rises to the top of the pipe near the water surface. Water flowing out the top of the inner pipe hits the edges of the outer return pipe, sending the water back down to mid-lake level. Because the water is cold, it falls back to the bottom.

A full-lift aeration system entrains water near the bottom and transports it to the surface before it drops back down to the bottom (Figure 7).

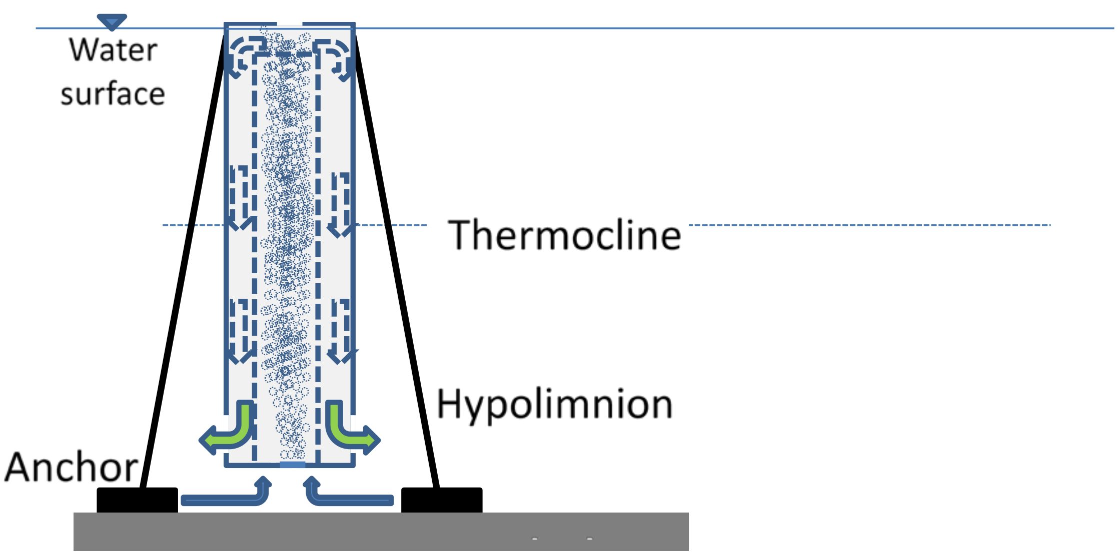


Figure 7: Full-Lift diagram

The increase in oxygen through a hypolimnetic aerator system can be small, sometimes no more than 0.5 mg/L to 1 mg/L. The reason for this problem has two parts:

1. High chemical oxygen demand. When the hypolimnion loses oxygen, bacteria strip oxygen from iron and manganese. When oxygen is introduced back into the hypolimnion, there is a chemical reaction between oxygen and manganese of iron that strips dissolved oxygen from the water.
2. Limited oxygen transfer capacity of air. Air contains only 20% oxygen. As a result, oxygen saturation in water in the presence of air is only about 11 mg/L. The saturation concentration places a ceiling on how much oxygen can go from air to water and slows down the rate at which oxygen can dissolve from oxygen to air. Often, the rate of chemical oxygen demand in water can exceed the oxygen transfer from air to water.

Use of pure oxygen solves both problems, provided there is sufficient water depth as discussed below.

2. Full Lift Oxygenation

Full lift oxygenation is a modified air lift aerator technology. The difference is that it would have a longer draft tube to reach to the lake bottom and it would use a pure oxygen generator instead of an air compressor.

In general terms, it is like a full-lift aeration system that uses pure oxygen instead of air. That advantage over air is five to tenfold increase in oxygen transfer efficiency (kg O_2 transferred / m^3 diffused gas). As a result, the system moves much less water than an aeration system. There is far less movement of water that could increase oxygen demand by inducing currents along the sediment surface.

In full lift oxygenation, minimum oxygen gain ranges from 2 to 4 mg/L; however, this is contingent on water depth. Compared to an equivalent aeration design, full lift oxygenation uses 80% less gas flow. As a result, flow of water through the system is much less than an aerated system, reducing currents across sediments.

Full lift oxygenation can be constructed as a raft mounted system with lighter equipment than full-lift aeration. Consequently, repairs and maintenance can be made from the surface, rather than requiring divers.

3. Oxygen enhanced Full-Lift Aeration

Oxygen enhanced full lift aeration is a hybrid technology. This is configured exactly like a full lift aerator as described above but would have pure oxygen gas injected just below the surface in the down flow chamber.

In general terms, it is a full-lift aeration system that uses air in the riser and pure oxygen in the down flow chamber (downcomer). The advantages are similar to full lift oxygenation but have the benefit of water circulation of the full lift aerator and have potentially increased oxygen input above full lift oxygenation from longer contact time between the oxygen gas and the water.

Full-lift aeration has been studied extensively by Burris et al (1998) and applied in several water-supply reservoirs in the United States. Using the theories and dimensional relationships studies by Burris, the larger full-lift systems were scaled down and applied to the Lake Cornelia project. Burris et al (1998) tested a range of flow rates and established a relationship between applied gas flow rate and riser cross section. For a series of tests performed it was found that for a fixed riser cross section, as flow rates increased bubbles were carried over to the down comer (return portion) in which oxygen transfer continued (Figure 8). The winter application of full lift technology follows the same configuration as summer applications during stratification where the downcomer extends to the thermocline (Figure 9). The main difference is the thermocline represents the ice depth.

Applying these results to North and South Lake Cornelia full lift aeration would result in an oxygen increase of 0.28 and 0.47 mg/L respectively, which translates to 1.1 and 1.8 kg/d. Based on the 2 and 3% oxygen transfer efficiency of the full lift aeration it would be impractical for Lake Cornelia.

Applying these results to North and South Lake Cornelia full lift oxygenation would result in an oxygen increase slightly higher; however, the resulting oxygen input would top out at 5 and 6 kg/d for North and South respectively. Even though this is slightly better than full lift aeration it still only results in approximately 8 – 10 % oxygen transfer efficiency. Just as the full lift aeration was impractical, full lift oxygenation is also not applicable based on the size that would be needed to meet the minimum 11 kg/d let alone 17 kg/d.

The third option using full lift technology is the oxygen enhanced full lift aerator. This set up would negate the oxygen addition from the air lift itself and solely be based on the oxygen input capacity applied to the downcomer. Smaller size full lift aerators were sized using a 12" riser and 24" downcomer with an applied air flow rate of 6 scfm to each aerator. For this set up, the downward velocity is estimated to be 0.81 ft/sec. The corresponding upward (oxygen) bubble velocity is 0.72 ft/sec. This would result in oxygen bubbles being in contact with the water for approximately 30 seconds, increasing the predicted oxygen transfer efficiency to 40%.

The full lift technology applied to Lake Cornelia is shown in Figure 10 and superimposed on water column profiles for North and South in Figures 11 and 12 respectively. This technology has been proven to preserve ice during winter operation (Figure 13) but requires apparatus (Figure 14) to be present on the ice during operation. This set up provides the flexibility to house all equipment on the raft and run power to the raft or house all equipment on shore and plumb air and oxygen lines to each system. Both are viable set ups; however, although this configuration could be sized to meet the 11 kg/d oxygen requirement, it would be challenging to scale up to 17 kg/d.

To meet the 11 kg/d minimum oxygen input it would require a bank of oxygen generators plus additional flow control to split the flow between 2 and 4 full lift aerators mounted in the lake. Additionally, each full lift aerator requires either its own air supply or a distinct air control manifold to distribute air appropriately.

To put this into perspective, each full lift aerator requires a 1 Hp compressor rated at ~6 scfm and an oxygen supply rated at 0.3 scfm (17 kg/d). Each air lift system would have an estimated oxygen input capacity of 5 – 6 kg/d. If the equipment is mounted on the raft, each aerator would require its own dedicated power cable because of the length of run (~ 600 ft) to the desired deployment location and corresponding power draw.

Despite the full lift technology being known to preserve ice during winter operation, there is concern about the amount of apparatus mounted on a raft on the lake and/or equipment mounted on shore and plumbed to a raft system.

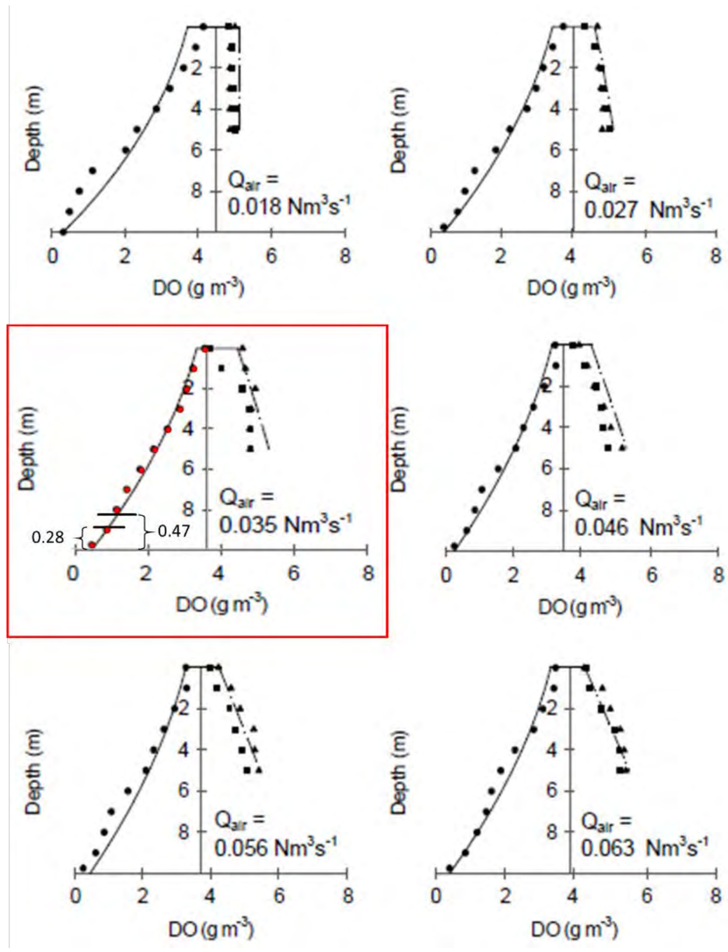


Figure 8: Experimental and model DO profiles for a range of air flow rates for full lift aerators (Burris et al (1998)) with predicted DO increases for North (0.28 mg/L) and South (0.47 mg/L) overlaid on 0.035 Nm3/s, a mid-range applied gas flow rate.

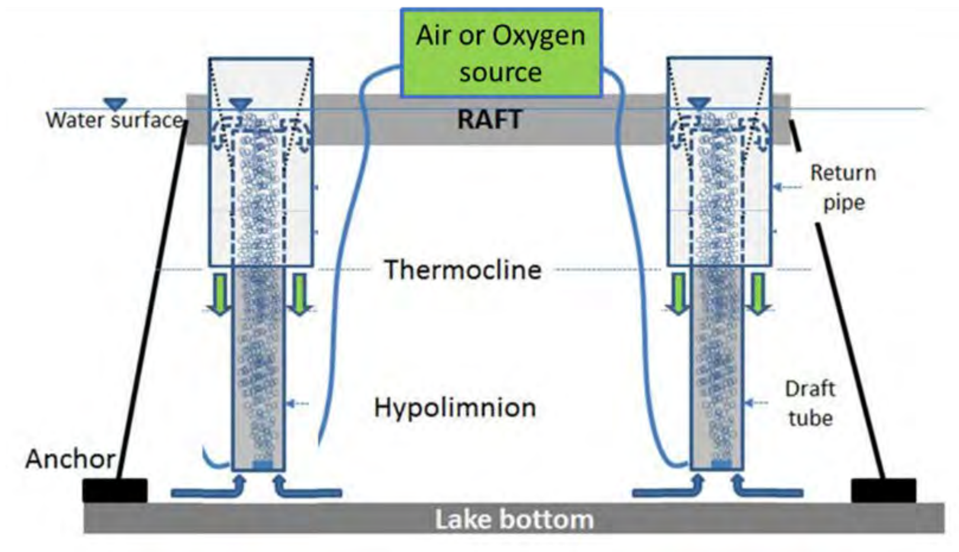


Figure 9: Full-lift aeration/oxygenation schematic showing relative position in the water column, entraining water from near the lake bottom and discharging to hypolimnion depth. For winter deployment, thermocline depth becomes ice depth.

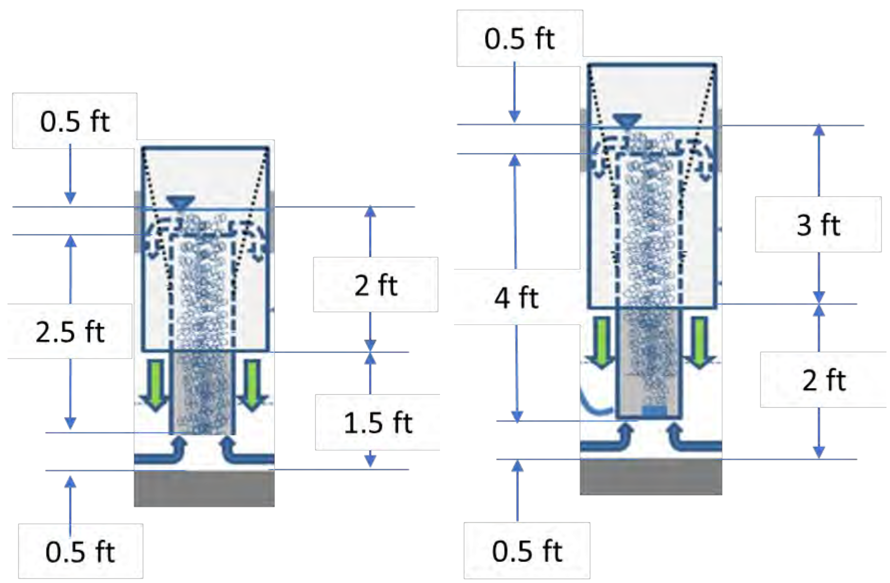


Figure10: Sketch showing recommended riser and down comer lengths with approximate position in the water column for North (left) and South (right) Cornelia Lakes.

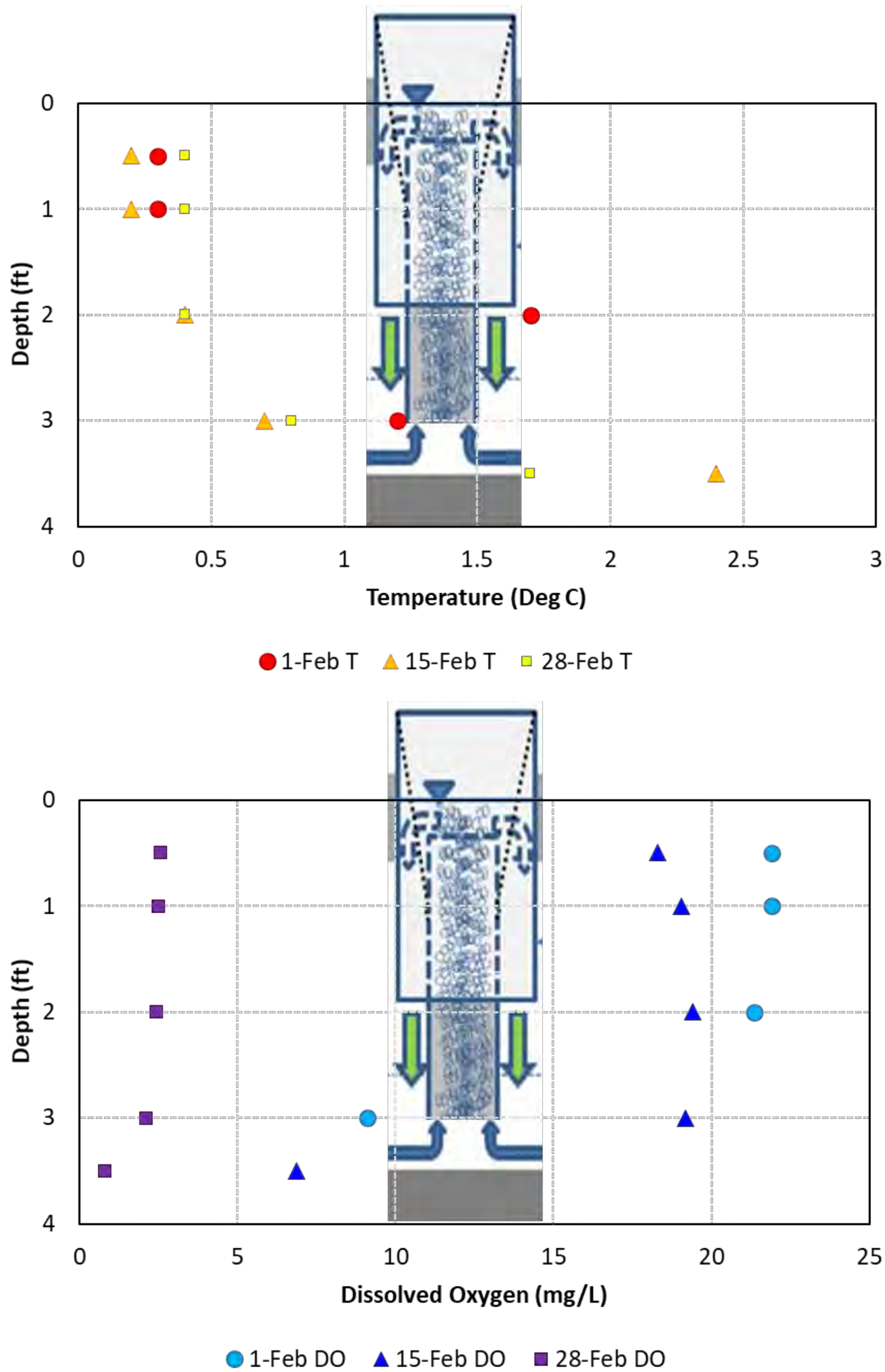


Figure 11: Temperature (top) and DO (bottom) profiles with full-lift apparatus overlaid to show water column positioning and circulation pattern in North Cornelia Lake.

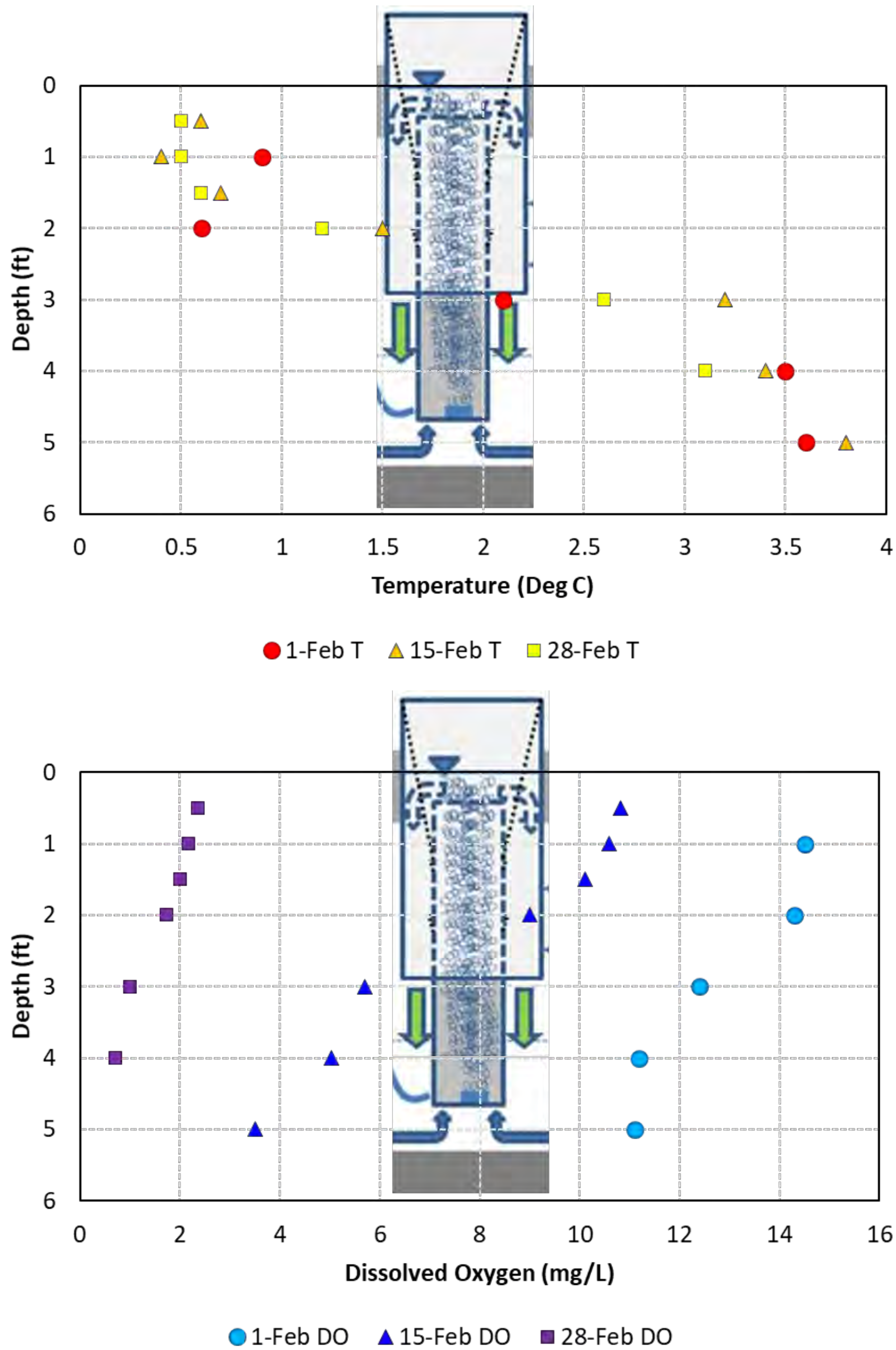


Figure 12: Temperature (top) and DO (bottom) profiles with full-lift apparatus overlaid to show water column positioning and circulation pattern in South Cornelia Lake.

Figure 13: Photos of 24″ riser and 48″ downcomer being assembled/deployed (top) and in operation (bottom).

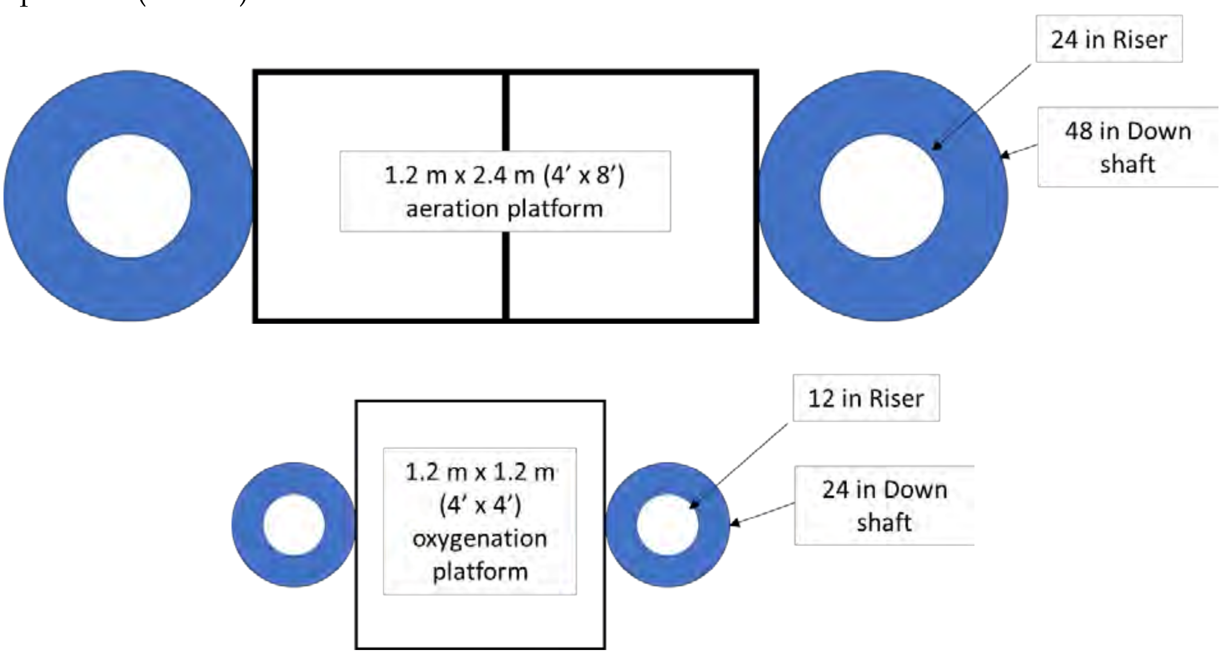


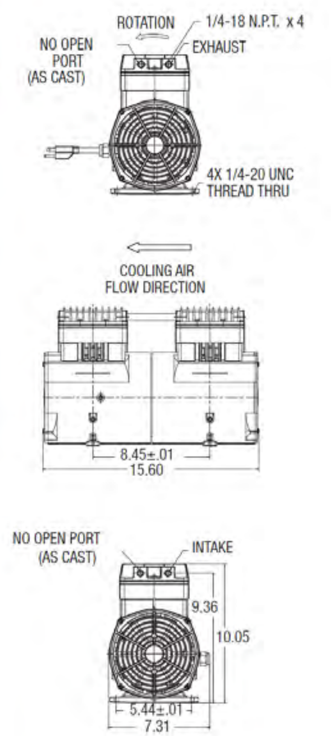
Figure 14. Approximate platform sizes for 24/48 (top) and 12/24 (bottom) riser to downcomer ratio.

Air supply

In order to move the required volume of water in the oxygen enhanced full lift aerator, each 12" rise would need an applied air flow rate of 6 scfm, which can be supplied by a 1 Hp piston air compressor such as the Thomas 2807 WOB-L series oilless piston compressor (Figure 15).

2807 Series Performance Data

MODEL NUMBER		2807CE72		2807CGHI72	
HEAD CONFIGURATION		Pressure/Vacuum		Pressure/Vacuum	
STROKE		.720 Inches		.720 Inches	
PRESSURE		Flow @ 115v 60Hz		Flow @ 220v 50Hz/230v 60Hz	
CFM @ PSI	LPM @ bar				
PSI	bar	CFM	LPM	CFM	LPM
0	0	6.60	186.9	5.48 / 6.60	155.2 / 186.9
10	.5	6.20	178.7	5.15 / 6.20	148.3 / 178.7
20	1.0	5.90	171.7	4.90 / 5.90	142.6 / 171.7
30	1.5	5.55	165.2	4.60 / 5.55	137.2 / 165.2
40	2.0	5.13	157.2	4.26 / 5.13	130.6 / 157.2
50	3.0	4.65	141.4	3.86 / 4.65	117.4 / 141.4
60	5.0	4.35	112.5	3.61 / 4.35	93.4 / 112.5
70	7.0	4.07	84.9	3.38 / 4.07	70.4 / 84.9
80		3.75		3.11 / 3.75	
90		3.38		2.81 / 3.38	
100		3.05		2.53 / 3.05	
110		2.75		2.28 / 2.75	
120		2.45		2.02 / 2.45	
MAX. CONTINUOUS PRESSURE		50 PSI	3.4bar	50.0 PSI	3.4 bar
MAX. INTERMITTENT PRESSURE		120.0 PSI	8.3 bar	120.0 PSI	8.3 bar
VACUUM		Flow @ 115v 60Hz		Flow @ 220v 50Hz/230v 60Hz	
CFM @ IN. hg	LPM @ mbar (gauge)				
IN. hg	mbar (gauge)	CFM	LPM	CFM	LPM
0	0	6.60	186.9	5.48 / 6.60	155.2 / 186.9
5	-100	4.30	136.7	3.66 / 4.30	125.0 / 136.7
10	-200	2.66	97.1	2.21 / 2.66	96.1 / 97.1
15	-400	1.80	66.5	1.41 / 1.80	54.4 / 66.5
20	-600	.88	36.8	.56 / .88	26.8 / 36.8
MAX. VACUUM		25.0" hg	-848 mbar	25.0" hg	-848 mbar
MAX. AMBIENT AIR TEMP.		104° F	40°C	104° F	40°C
MIN. AMBIENT START TEMP.		50° F	10°C	50° F	10°C
MAX. RESTART PRESSURE		100 PSI	6.9 bar	100 PSI	6.9 bar
MAX. RESTART VACUUM		0 "hg	0 mbar	0 "hg	0 mbar
MOTOR VOLTAGE/FREQUENCY		115/60/1		220-240/50/1-230/60/1	
MOTOR TYPE		Permanent Split Capacitor		Capacitor Start	
CURRENT AT RATED LOAD (AMPS)		8.5		5.0 / 4.8	
POWER AT RATED LOAD (WATTS)		902		948 / 929	
STARTING CURRENT (LOCKED ROTOR, AMPS)		44.0		20.0	
CAPACITOR VALUE		30 mfd		30 mfd	
MIN. FULL LOAD SPEED (RPM)		1700		1425/1710	
THERMAL PROTECTOR		Yes		Yes	
NET WEIGHT		39 lbs.	17.7 kg	39 lbs.	17.7 kg



The information presented in this material is based on technical data and test results of nominal units. It is believed to be accurate and reliable and is offered as an aid to help in the selection of Thomas products. It is the responsibility of the user to determine the suitability of the product for his intended use and the user assumes all risk and liability whatsoever in connection therewith. Thomas Industries does not warrant, guarantee or assume any obligation or liability in connection with this information.

NOTE: Models pictured are representative of the series and do not represent a specific model number. Consult factory for detailed physical description.

Figure 15: Specification for the 2807 WOB-L compressor.

Oxygen supply

For simplicity and expandability, self-contained oxygen generators are recommended. These units operate on 120VAC and are designed to operate 24-7. In order to increase the oxygen capacity for larger requirements, these systems are split into a separate compressor and oxygen generator. The recommended oxygen supply is a Topaz Ultra (Figure 16) from Airsep, a Chart Industries company. https://www.caireinc.com/commercial/products/oxygen-products/self-contained-o2-generators/

Specifications

	Topaz	Topaz Plus	Topaz Ultra
Product Flow[1]	12 SCFH (0.31 Nm³/hr or 6 LPM)	17 SCFH (0.44 Nm³/hr or 8 LPM)	21 SCFH (0.55 Nm³/hr or 10 LPM)
Product Pressure	9 psig (62 kPa or 0.62 barg)	20 psig (138 kPa or 1.37 barg)	20 psig (138 kPa or 1.37 barg)
Product Concentration	Up to 95%	Up to 95%	Up to 95%
Product Dew Point	-100°F (-73°C)	-100°F (-73°C)	-100°F (-73°C)
Dimensions (W x D x H) (Nominal)	19 x 10 x 27 in (48 x 25 x 68 cm)	19 x 10 x 27 in (48 x 25 x 68 cm)	19 x 10 x 27 in (48 x 25 x 68 cm)
Weight	53 lb (24 kg) [Add 2 lb (0.9 kg) for 220 V ~ unit] [Add 20 lb (9 kg) for Stainless]	56 lb (25 kg) [Add 4 lb (0.9 kg) for 220 V ~ unit] [Add 20 lb (9 kg) for Stainless]	58 lb (26 kg) [Add 4 lb (0.9 kg) for 220 V ~ unit] [Add 20 lb (9 kg) for Stainless]
Physical Connection Product Gas Outlet	¼" NPT-M/B-M size oxygen adapter	¼" NPT-M/B-M size oxygen adapter	¼" NPT-M/B-M size oxygen adapter
Ambient Operating Conditions	Locate the oxygen generator in a well-ventilated area that is protected from weather elements and remains between 40°F (4°C) and 112°F (44°C)		
Control Power Requirements (Single Phase)	100V ~ ±10%, 50 or 60 Hz, 5.5 A 120V ~ ±10%, 60 Hz, 5.0 A 220V ~ ±10%, 50 Hz, 2.5 A	120V ~ ±10%, 60 Hz, 5.0 A 220V ~ ±10%, 50 Hz, 2.5 A	120V ~ ±10%, 60 Hz, 6.0 A 220V ~ ±10%, 50 Hz, 3.0 A
Certifications and Approvals	CAN/CSA C22.2 No. 61010-1, 2nd Ed., UL 61010-1, 2nd Ed., CE		

[1] SCF (Standard cubic foot) gas measured at 1 atmosphere and 70°F / Nm³ (Normal cubic meter) gas measured at 1 atmosphere and 0°C / LPM (Liters per minute) gas measured at 1 atmosphere and 21°C

Figure 16: Specifications from AirSep for Topaz Ultra oxygen generator.

4. Side-Stream Oxygenation

The fourth oxygenation system evaluated was a side-stream saturation (SSS) oxygenation system. A SSS withdraws water from near the lake bottom, oxygenates it, and then returns it to the near the lake bottom (Figure 17). There are a few side-stream oxygenation technologies available in the market. The primary difference between these units is the pressure in the oxygen saturation chamber. According to Henry's Law, as the partial pressure of oxygen rises in the saturation chamber the oxygen concentration in the water also increases.

The SSS oxygenation system is summarized in the flow diagram shown in Figure 17. An intake is placed near the bottom of the lake with a screen to prevent debris from damaging the downstream equipment. A pump is used to pull water from the bottom of the lake and push it through the oxygen contact chamber and back into the lake. The oxygenated water is injected near the bottom via a distribution header.

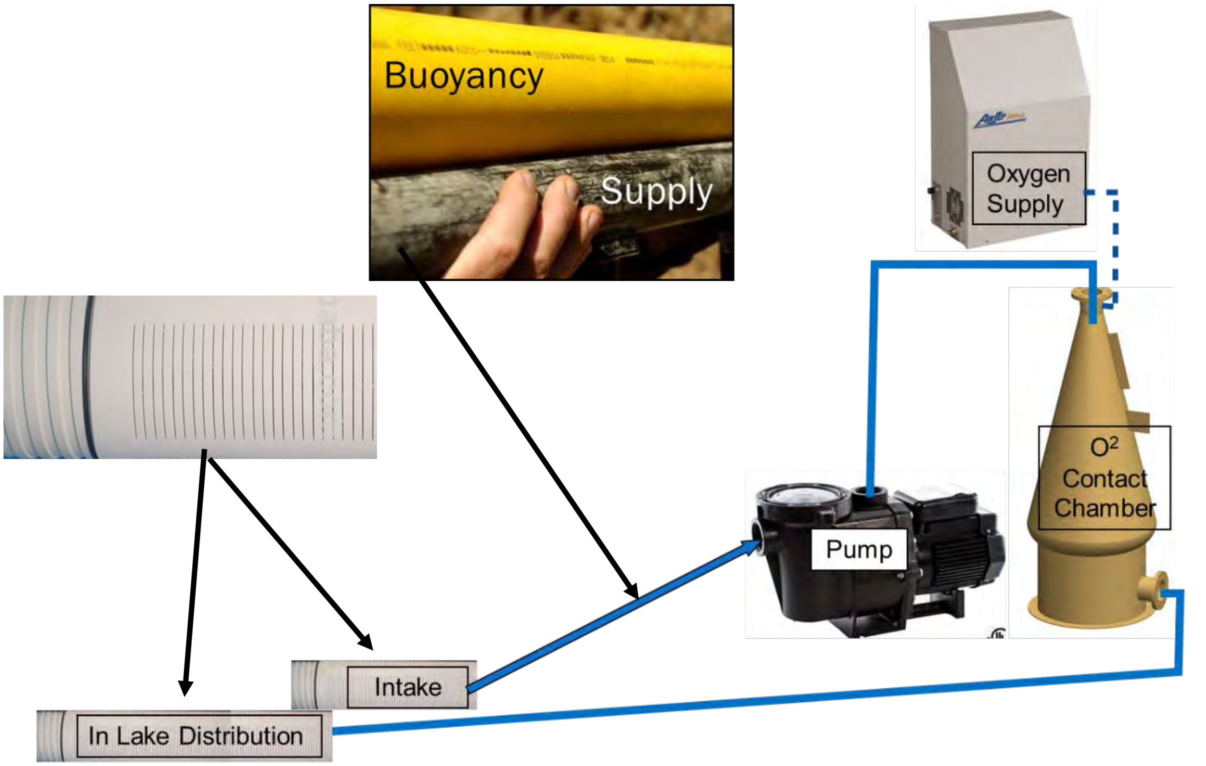


Figure 17: Side-stream saturation (SSS) oxygenation process flow diagram showing the main components of the system; in-lake distribution and intake (slotted well screen), pump, oxygen supply, oxygen contact chamber, and corresponding (HDPE) piping (2-pipe system)

Side-stream saturation oxygenation systems are designed to achieve 100% oxygen transfer efficiency and ensure the oxygen discharge does not exceed saturation conditions at depth. This ensures the water does not de-gas at discharge depth, which would create a rising bubble and induce undesirable water circulation.

Recommended Strategy

Side stream saturation oxygenation strategy has the highest oxygen transfer efficiency, would have the least amount of equipment, and provides the least visual impact to the lake. It is therefore the recommended strategy for this project.

With any oxygenation system design, there is a level of complexity behind the calculations, layout, and recommendations. It is the focus of this proposal to provide an overview of GWRE recommendations with the intention of providing full detail, if awarded. The following section covers the system design, which includes all the required components to ensure:

1. A minimum of 11kg/d can be delivered to water under the ice,
2. 100% oxygen transfer efficiency is achieved in the oxygen contact chamber,
3. Uniform distribution of oxygenated water
4. Minimal disruption to the water column and corresponding ice structure, and
5. No sediment re-suspension.

Key design criteria include the following:

1. Oxygen demand per DO analysis is satisfied,
2. Conditions in the oxygen contact chamber (Speece Cone) do not exceed 70% DO saturation,
3. System operating pressure is below the output pressure of the oxygen supply, and
4. Discharge concentration does not exceed 100% DO saturation conditions at discharge depth and temperature.

The SSS design, outlined above is accomplished by use of the following system components:

- Oxygen supply to provide at minimum 11 kg/d
    - Topaz Ultra by AirSep, which is a complete self-contained oxygen concentrator
    - Rated at 10 lpm (up to 17 kg/d)
    - Outlet pressure of 20 psig (~34.7 psia)
    - Nominal oxygen purity of 93%
    - Noise decibal rating of 55 dba
- Environmental controls
    - An exhaust fan to ensure proper air circulation to the oxygen concentrator and
    - A dehumidifier in the room housing the oxygen concentrator to reduce moisture content to the air flow entering the oxygen concentrator.
- A 1.5 Hp pump
    - Capable of maintaining flow rate at 60 GPM and 50 psia, the recommended water flow rate and pressure of the system,
    - With built in strainer basket, and
    - No published noise rating but estimated to be as high as 70 dba.
- A Speece Cone oxygen contact chamber
    - Designed to accommodate 60 GPM
    - Achieve 100% oxygen transfer efficiency at 12 kg/d oxygen addition requirement; however, capable of up to 17 kg/d to match

output capacity of the oxygen supply.

- Digital flow control to provide accurate oxygen flow rates to increase or decrease oxygen input as necessary.
- Suction line
  - o Large enough to minimize head loss and corresponding net positive suction head (NPSH) at the pump inlet to prevent cavitation,
  - o Long enough to reach deepest part of the lake in either east or west basin, and
  - o With slotted well screen.
- Distribution Header:
  - o Designed to distribute oxygenated water uniformly along the entire length (100 ft),
  - o Use slotted well screen (same as suction),
  - o Designed to dissipate energy associated with water flow rate as quickly as possible while preserving ice structure, and
  - o Prevent sediment re-suspension

Specific details supporting design recommendations

Oxygen supply

Oxygen supply being rated higher than required. 11 kg/d was identified as the oxygen demand of the system. This is understood to be the minimum oxygen input capacity to prevent formation of anoxic conditions by the time ice begins to melt in the spring. It is therefore recommended to provide a slightly larger design capacity to accommodate potential shortcomings in operation.

Dehumidifier and moisture control

During prior installations, GW has worked with several different oxygen concentrator sizes. The most important factor in sustained operation of these units is to provide clean dry air to the unit. For larger systems that have a separate air supply, this is accomplished with refrigerated dryers and moisture coalescing filters. For smaller, self-contained units, this is more difficult to achieve because the air supply is contained within the unit. As a result, the smaller units are more sensitive to moisture content in feed air. A way to counter this design limitation is to house the unit in an isolated enclosure with environmental controls. For this application, it is recommended to isolate the oxygen concentrator in a small room ~ 3′ x 4′ and use a reliable dehumidifier in parallel with good air circulation.

Distribution piping

The in-lake distribution piping design applies the same characteristics that has been key to success with line diffusers; robust, essentially maintenance free, and accessible for repair if needed without the use of divers. This consist of a two- pipe system, a supply pipe and a buoyancy pipe, with all connections fusion welded. The two-pipe system can be fabricated on land and extruded to the lake, where it floats on the surface until it is ready to be pulled into position and deployed. To deploy the system on the bottom, the buoyancy line is flooded, which causes the system to sink to the bottom

Piping and fittings

All piping designed to carry water are proposed to be of HDPE construction, with the exception of the suction and discharge headers which are sch 80 pvc. All fittings to transition between components such as the pump and the oxygen contact chamber will be 304 stainless steel. Oxygen supply line between the oxygen concentrator (Topaz) and the oxygen contact chamber (Speece Cone) will be flexible copper with brass fittings as necessary. An example of the flow control piping is shown in Figure 18.

Figure 18: Example of Alicat flow control header with braided SS supply line from oxygen supply, brass fittings, and flexible copper out the outflow side to an oxygen contact chamber.

System layout

Suction and discharge header

The intake and discharge headers use slotted well screen, which are designed to have minimal velocities, which is important for Lake Cornelia to ensure sediment and debris are not entrained in the intake and the exit velocity does not induce mixing to disturb ice. The basic layout of the piping in the lake is to position the distribution header along the deepest part of the water column in one basin and have the suction header also in the deepest part of the water column but position in the other basin, which are shown as a red lines at the end of the black distribution lines (Figure 19).

Shore-based equipment

The shore-based equipment was laid out using approximate spacing for adequate working conditions. Based on this approximate layout, all equipment would require a minimum of an 8′ X 8′ footprint. This allowed for enough space between the pump and contact chamber as well as the required offset for piping and air flow around the pump (Figure 20). Additionally, a small section ~3′ X 4′ is shown in one corner with a 30″ access door for the Topaz oxygen concentrator. A standard height ceiling would be enough, which is based on the maximum height being less than six feet (Figure 21).

Although it is difficult to recommend system layouts for a site unseen, it would be recommended to house the equipment in a structure that compliments the area surroundings. Beyond the structure, the only component that would be visible to the public would be the pipe(s) at the water edge. It would be recommended to install all shore-based piping in a suitable trench and then covered and reseeded to minimize disruption to the environment. Additionally, trenching and covering would be essential to install the pipes below the frost line with adequate insulation for piping coming above grade.

With regards to the building and the noise concern it is recommended to use a noise attenuation material such as acoustiblok, https://www.acoustiblok.com/.

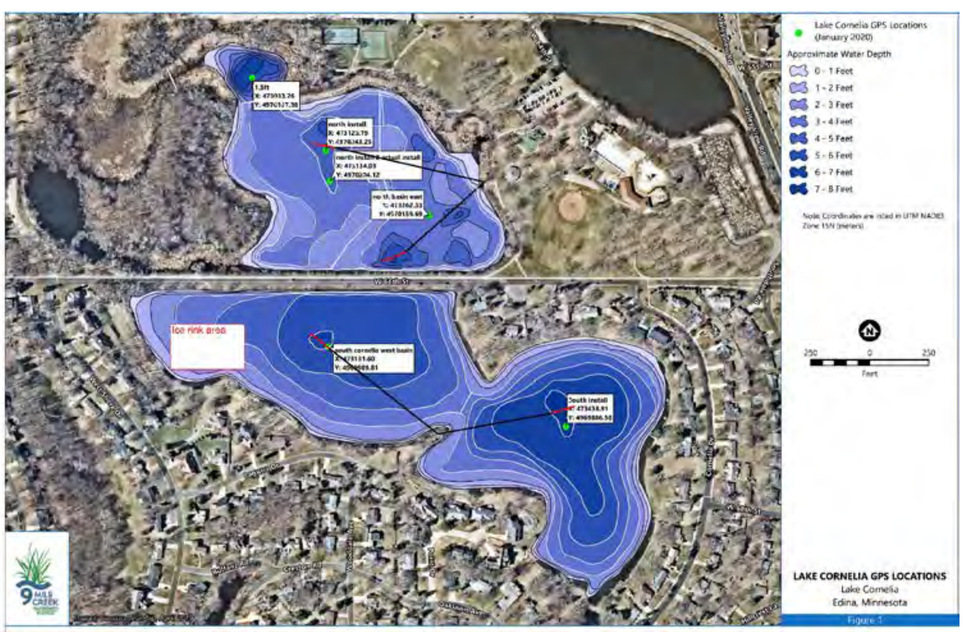


Figure 19: Proposed SSS layout for North and South Lake Cornelia. Each lake would have intakes from one basin and discharge header in the other basin.

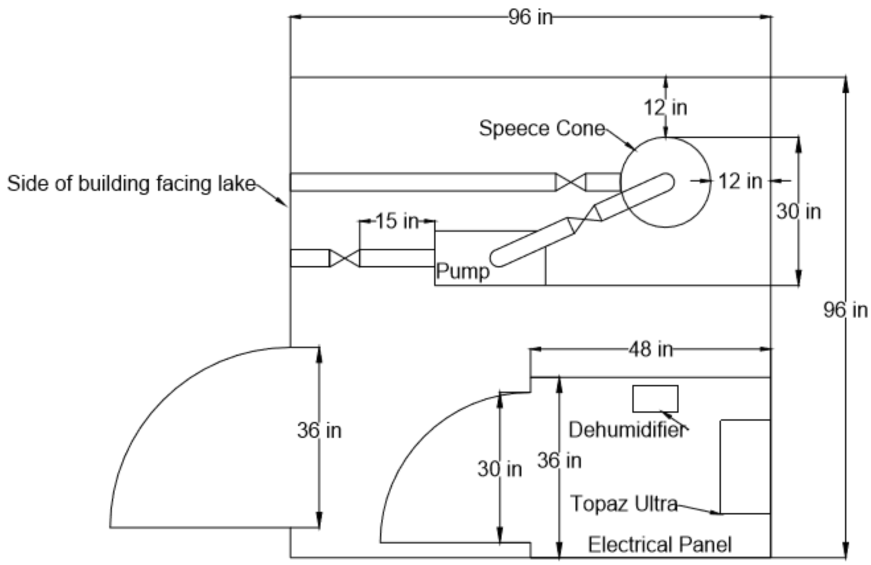


Figure 20: Proposed system layout showing 8′ x 8′ building footprint, estimated equipment layout and recommended offsets. Note the oxygen concentrator (Topaz) located in a 3′ x 4′ sectioned off room for improved environmental control.

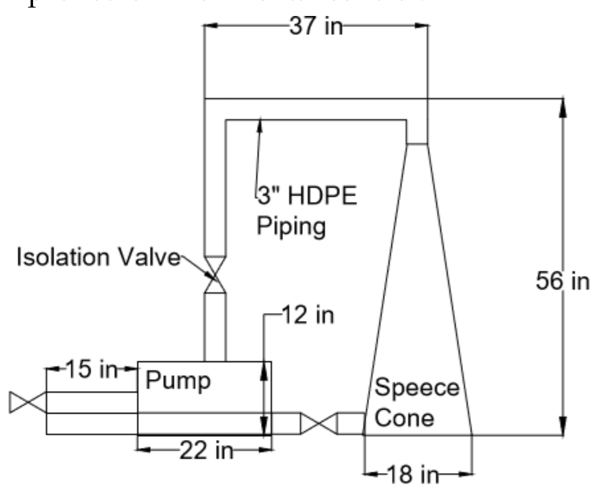


Figure 21: Sketch showing pump and oxygen contact chamber to demonstrate approximate height of equipment.

Side-Stream Saturation Oxygenation Cost Estimate

Monitoring Considerations

Hypolimnetic Aerators: Characterizing and Optimizing Performance
Final Report to City of Norfolk and CH2M Hill; Vickie Burris and John Little; Virginia Polytechnic Institute & State University; January 1998 (Personal Communication)

Hypolimnetic Aerators: Predicting Oxygen Transfer and Water Flow Rate
Vickie Burris;1998; Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University (http://scholar.lib.vt.edu/theses/available/etd-011399-122244/unrestricted/ETD1.PDF)

Bubble dynamics and oxygen transfer in a hypolimnetic aerator
Vickie L. Burris and John C. Little; Water Science and Technology **Vol. 37 No 2 pp 293–300**
© IWA Publishing 1998

Appendix F

WSB Carp and Goldfish Monitoring Scope

GOLDFISH AND COMMON CARP POPULATION AND INTER-WATERBODY MOVEMENT ASSESSMENT IN LAKE CORNELIA SYSTEM

Proposal for the Nine Mile Creek Watershed District

March 2, 2020

wsb

Prepared by:

Jordan Wein, Environmental Scientist

WSB, 178 East 9th Street, Suite 200, St. Paul, MN 55101

INTRODUCTION

Invasive goldfish have just been added to the MAISRC priority list for investigation. They are being released into lakes around the Twin Cities Metro. Clearly, education is needed to prevent initial infestations. But little is known about the risk of spread of this invasive species to other connected water bodies if an infestation has been confirmed. The results of this study and education initiative will work to prevent introductions as well as guide planning and management of watersheds to take rapid action to stop the spread of goldfish in this system and others in Hennepin County.

In addition to goldfish, common carp are well-known to be a significant driver of poor water quality parameters. While foraging, they root around in lake sediments where nutrients like phosphorous can be locked up in an inactive form. When disturbance occurs from an overabundance of carp, large amounts of phosphorous is reintroduced to the water column where it becomes available for algae. This in turn promotes green algae blooms as well as turbid water conditions. Both North and South Cornelia are on the Minnesota Pollution Control Agency's Impaired Waters list due to excess nutrient loads. The main parameters that are measured to decide if a water body belongs on this list are total phosphorous (TP), chlorophyll-a (algae abundance), and clarity (measured by secchi depth). Goldfish and common carp can contribute significantly to the internal loading of TP and management of their populations below a threshold of 100kg/ha (Bajer et al, 2009) is generally considered to be an inexpensive method of managing internal loading (Bartodziej et al, 2017).

In 2018, surveys completed by Riley Purgatory Bluff Creek Watershed District for Nine Mile Creek Watershed District identified carp in Cornelia Lake and surrounding potential nursery lakes. Goldfish and carp were found in numbers that warranted more rigorous assessment and understanding of inter-lake spatial usage in order to guide future long-term management. To properly assess for goldfish and carp biomass levels and the presence of YOY, WSB recommends that electrofishing surveys be properly completed as deemed by protocols in Bajer and Sorensen (2012).

It is also important to know the movement capabilities and patterns between and within lakes in the Cornelia system. WSB would utilize passive integrated transponder (PIT) tags to track movement via antennas at strategic locations in the Cornelia system. To understand the history of recruitment in this system, an age structure will be developed for goldfish and carp to connect past environmental conditions in which the lake system was at risk. That structure will also help determine how often biomass reduction efforts are needed over the long-term time scale moving forward. Finally, WSB will test a system for biomass reduction that has been found to be effective at species specific capture of carp. It will be tested in Nancy Lake where the population of goldfish was found to be very high.

This test will allow the watershed district to plan for the future of removals (if needed) and costs associated with that effort. In general, the data collected in this work will serve as the scientific baseline to determine if/what population reduction is needed to meet biomass goals, understand important pathways to movement, and strategize if/what management of goldfish and/or carp should be planned for the future in order to improve water quality and promote the health of the lake ecosystems.

To obtain approval of the Minnesota DNR Fisheries, a small amount of time has been included to account for this process. Any administrative expenditures to manage the accounting of this project will be covered by the project management line item. The following is a detailed description of the recommended work plan:

ELECTROFISHING SURVEYS TO ESTIMATE POPULATION AND IMPLANT PIT TAGS

To reduce cost, this effort will be coupled with electrofishing surveys for the project submitted to the Hennepin County Aquatic Invasive Species grant. A small amount of time will be added to the goldfish surveys in order to simultaneously collect data about the carp biomass and implant PIT tags while the carp are in hand. These surveys are best done between the months of July and September while carp are more evenly distributed around the lake. WSB would conduct at least three 20-minute transects in randomized sections of shoreline in each water body. We would conduct these surveys on three different days at least one week apart. This is to account for differences in environmental conditions that may bias the catch rate. We would use the catch per unit effort (CPUE) model described in Bajer and Sorensen (2012) to quickly determine the carp density, average size/weight and scale that to the lake for an overall goldfish and carp biomass (kg/ha).

We will measure, weigh, implant a PIT tag and give a pelvic fin clip before releasing back to the lake. In subsequent capture events, if enough individuals are recaptured, we will be able to calculate a mark/recapture population estimate. This is generally more reliable but requires more effort and cost.

From these data, we will report on the size structure of the populations in each lake with the CPUE data and a calculated carp biomass.

INSTALLING PIT ANTENNAS TO MONITOR CARP MOVEMENT BETWEEN LAKES

Antennas would be constructed, installed and tested to monitor the movements of goldfish and carp in the Cornelia Lake system. Four locations (Figure 1) would have antennas installed to determine which water bodies are important in the recruitment of carp in the system. It will determine what time of year, what proportion of the population is moving and how often use the pathway between bodies.

These antennas will be in place before PIT tags are implanted during the electrofishing surveys described above. The antennas will run for one year in order to capture the unbiased movement in the spring of 2021, when spawning migrations are anticipated to occur. Long term PIT monitoring data is very valuable, so we recommend considering further monitoring of these locations for the future.

If the results show a sizeable movement of tagged fish through one or more pathways, consideration and planning of barriers to impede movement and/or a trap to target the migrations for biomass removal can be built into a management plan.

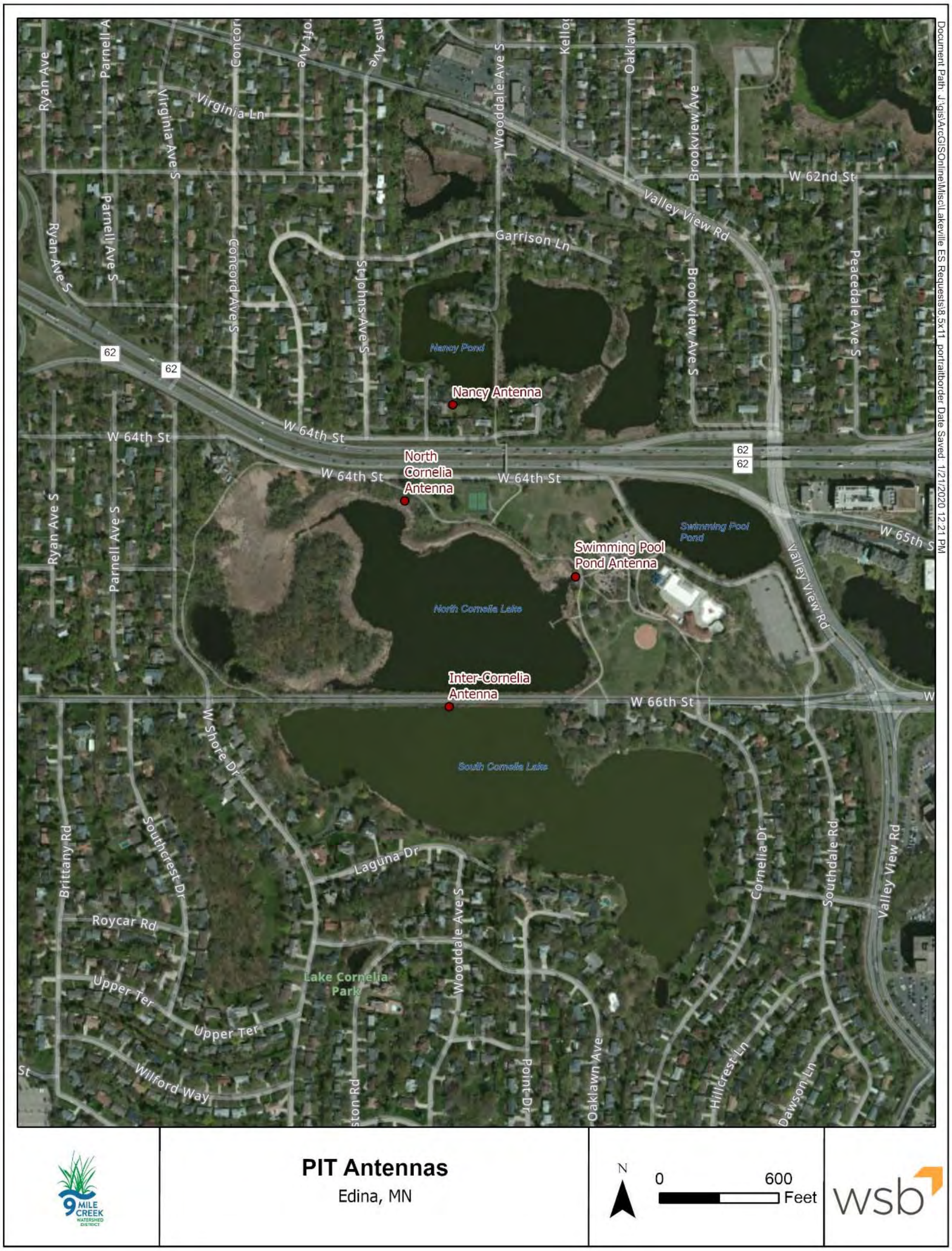


Figure 1: Illustration of locations of PIT antennas strategically placed in potential fish pathways.

TESTING RAPID MANAGEMENT ACTION TO ADDRESS LOCALIZED INFESTATIONS

We will employ a technique found to be successful in small water bodies with common carp to determine efficacy with goldfish. A box net trap refers to a mesh net that lays on the lake bottom with attached walls around the outside. These walls are attached to vertical metal pipes that extend above the water surface. The walls are attached to ropes that are run to shore and when the ropes are pulled in, the walls quickly rise above the surface trapping the fish within the trap area inside. The fish are corralled to a corner and removed with a dip net.

A modified baited-box-net trap (one with a mesh size appropriate for goldfish instead of adult carp) will be deployed in Nancy Lake and baited with cracked corn (or another bait seen to be effective). A bait bag will be placed on top of the net in order to draw in goldfish. Lake residents will tend the bait, filling it if the bag is empty, once per day for up to seven days of baiting and report to WSB. After the first removal attempt, we will drop the walls and bait for an additional week in order to test the trap a second time. This method has been found to be over 98% selective for carp. All fish captured will be counted and measured. All goldfish will be removed from the lake.

Figure 2: A box net trap with walls raised

UNDERSTANDING RECRUITMENT STATUS IN THE LAKE COMPLEX

WSB recommends that a sample of fish be euthanized during electrofishing surveys or the baited box net tests and examined to determine age. We would do this by removing the inner ear bones called otoliths and cross sectioning them under a microscope to document the growth rings (annuli). If otoliths are not able to be sampled with goldfish, we will also collect scales to examine. The ages will be grouped and examined to determine past year classes of recruitment.

Altogether, this helps gain a history of recruitment that impacted the current overall population. Using that history, we would draw insight into a long-term management plan for reduction of biomass and the "lifespan" of the work. The larger the sample the better, since low recruitment years can be missed with a small sample size. We recommend at least a sample of 50.

BUDGET TABLE:

	Cornelia Lake System Goldfish and Carp Assessment 2020	Expenses	Env. Scientist V hours	Env. Scientist VI hours	Line item total
	Hourly rate		$90	$97	
Overhead	Permitting and project management		7		$630
Part 1: Goldfish assessment	Electrofishing surveys and PIT tagging goldfish	$849	52	52	$10,573
	Construction and installation of PIT antennas		27	16	$3,982
	Testing baited box net trap for capture of goldfish ($500 for net, $350 for corn)	$850	24	16	$4,562
	Annual PIT antenna rental ($1,500/system)	$6,000			$6,000
	Age structure for goldfish (sample of 50)		34		$3,060
	Data analysis and reporting		24		$2,160
Part 2: Additional carp objectives	Additional surveying time to implant carp tags while electrofishing	$400	7	7	$1,709
	PIT antenna installs and monitoring		0	0	$0
	Ageing structure for carp (sample of 50)		30	4	$3,088
	Additional time for data analysis and reporting		6		$540
	Goldfish population and interwater body movement assessment				**$30,967**
	Carp specific additional objectives				**$5,337**
	Overall Project total				**$36,304**

TIMELINE:

	2020						2021				
	July	August	September	October	November	December	January	February	March	April	May
Construction and installation of PIT antennas											
Electrofishing surveys for population assessment and PIT tag implantation											
Ageing structure for goldfish and carp (sample of 50)											
Testing of baited box net trap in Nancy Lake											
Data analysis and reporting (preliminary and final)											

REFERENCES:

Bartodziej, W., Sorensen, P.W., Bajer, P.G., Pilgrim, K. and Blood, S. 2017. A Minnesota story: Urban shallow lake management. *NALMS Lakeline*. 23-29.

Bajer, P.G., and Sorensen, P.W. 2012. Using boat electrofishing to estimate the abundance of invasive common carp in small midwestern lakes. *North American Journal of Fisheries Management.* 32:5, 817-822.

Bajer, P.G., Sullivan, G., and Sorensen, P.W. 2009. Effects of a rapidly increasing population of common carp on vegetative cover and waterfowl in a recently restored midwestern shallow lake. *Hydrobiologia.* 632: 235-245.