Appendices

Appendix A

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

Rosland Park Stormwater BMP Conceptual Designs

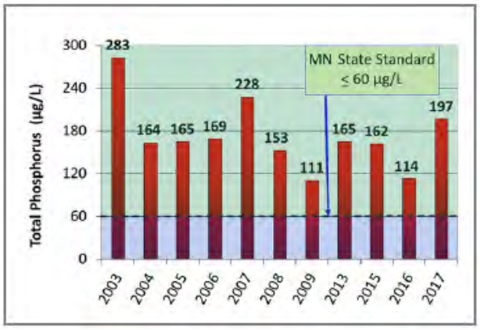
Summary for Nine Mile Creek Watershed District

December 18, 2019 Board Meeting

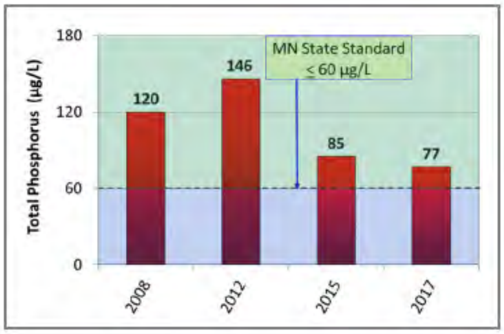
BARR

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.

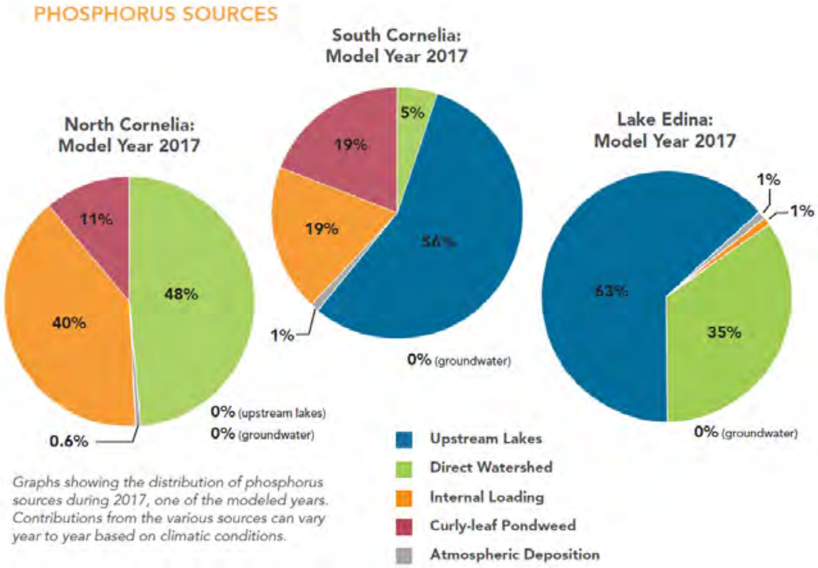


Summer average phosphorus concentrations in Lake Edina have historically been above the state standard for shallow lakes.

Motivations-
Periodic blue green algal blooms

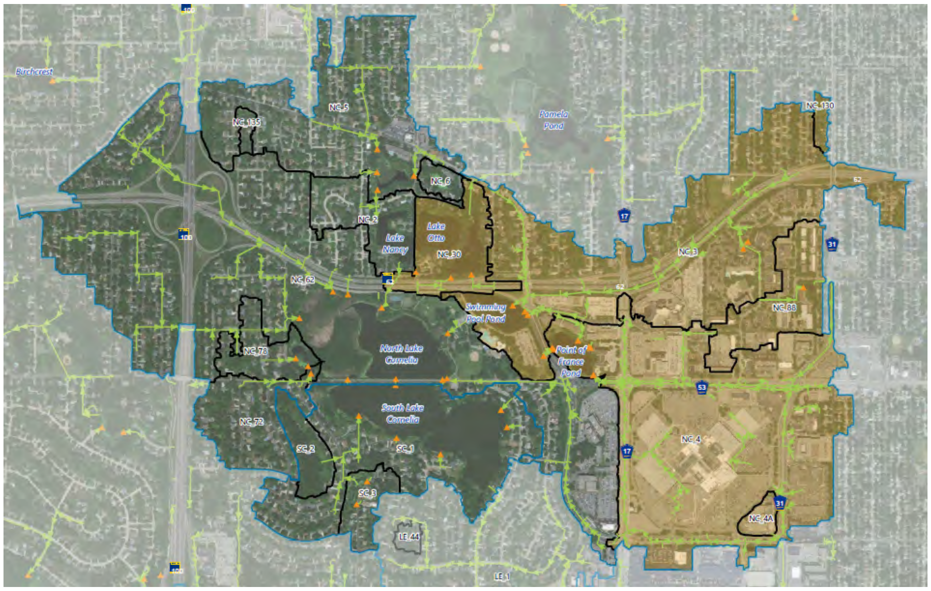
Cornelia Blue Green Algae Blooms

Water quality study results



Graphs showing the distribution of phosphorus sources during 2017, one of the modeled years. Contributions from the various sources can vary year to year based on climatic conditions.

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)

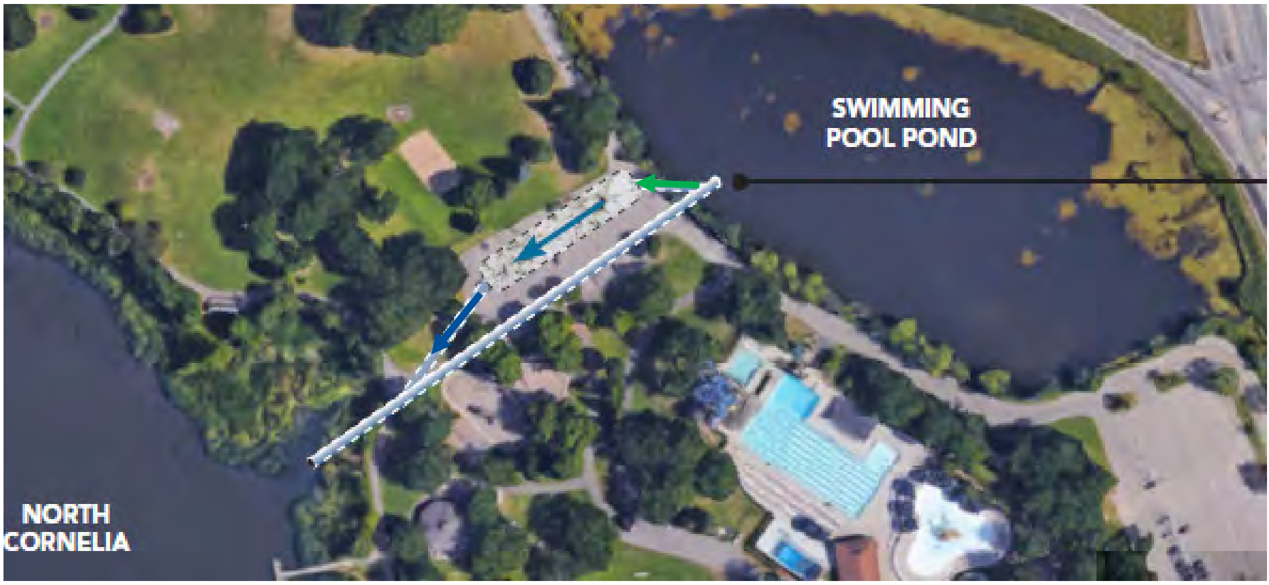
- Located at the edge of the north parking lot

Preferred concept

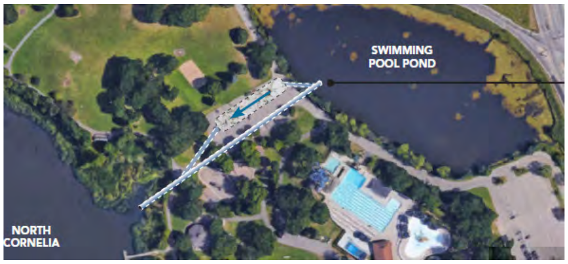
Filtration Treatment Vault – example

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)

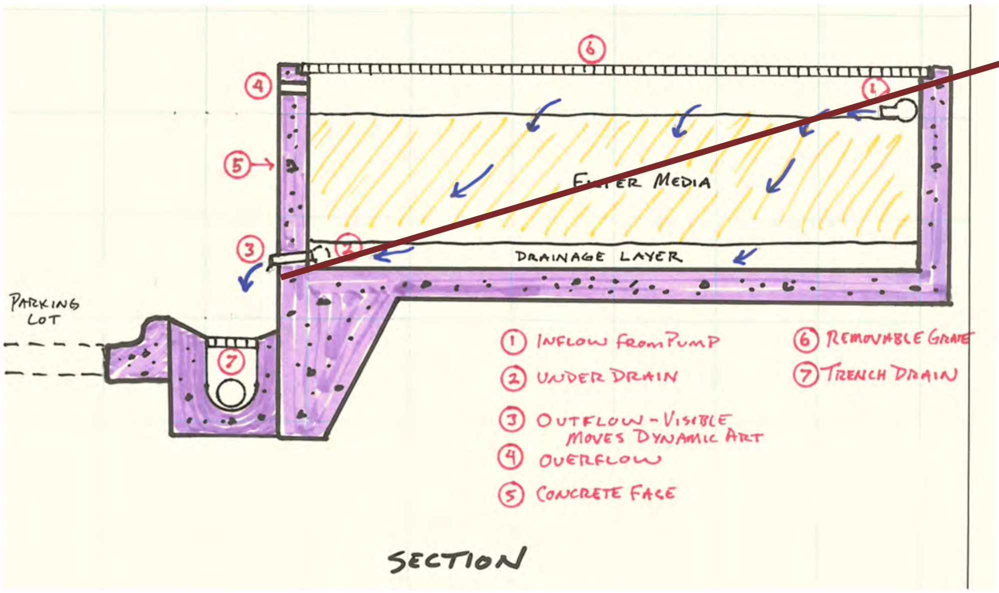
- Adds visual interest to park and Frisbee golf
- Plants help maintain filtration capacity
- High visibility for education

Concept 2 (cons)

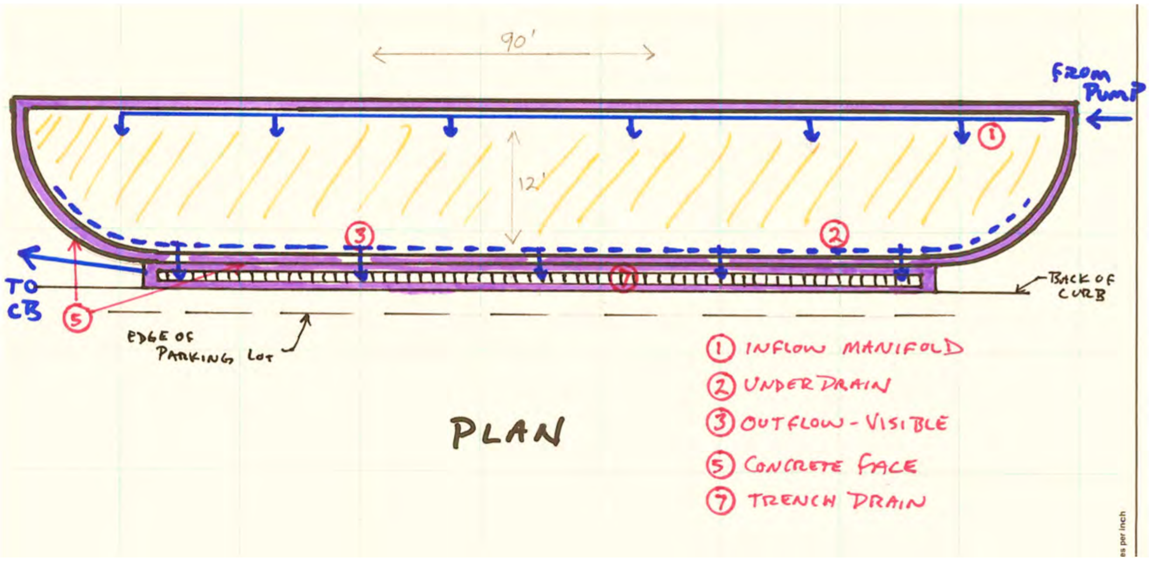
- Loss of park open space and could be in conflict with future park plans
- Difficult access for maintenance and maybe more maintenance required because of plants
- Concerns about trampling of plants
- Pumping – power consumption and O&M

Concept #3: Filtration Treatment Vault – pumped

Concept #3: Filtration Treatment Vault – pumped
Cross section

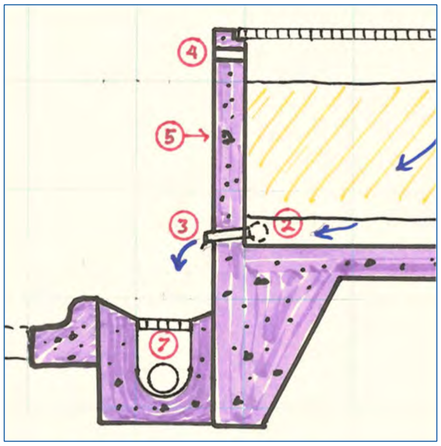


Concept #3: Filtration Treatment Vault – Plan view



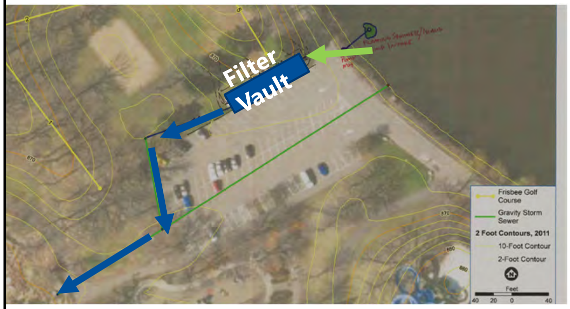
Concept #3: Filtration Treatment Vault – Example grates

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

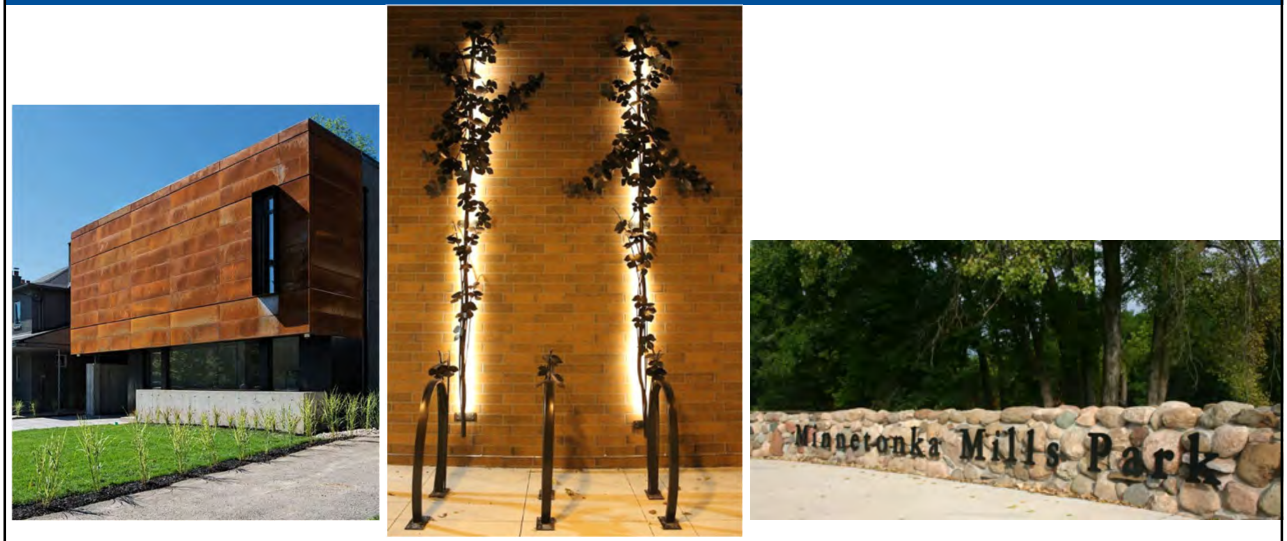
Option: Offset pump's power consumption with solar

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

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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.

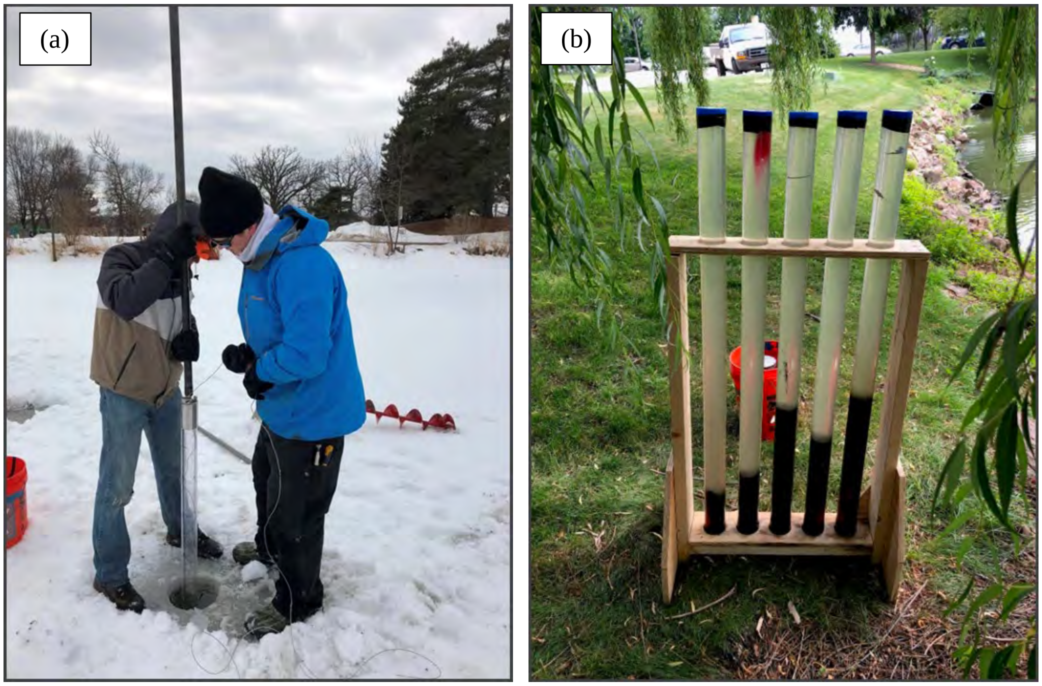

Figure 2. Sediment core collection from the (a) Swimming Pool Pond in February 2018, and (b) Point of France Pond in July 2018.

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.

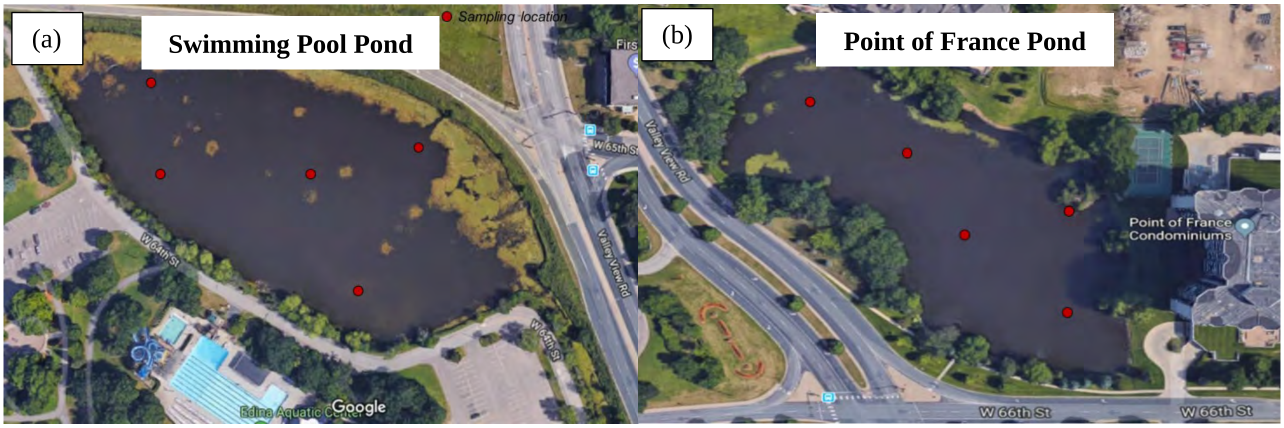

Figure 3. Locations of water sample collection and DO, temperature and conductivity profile monitoring (red circles) in the (a) Swimming Pool Pond and (b) Point of France Pond.

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.

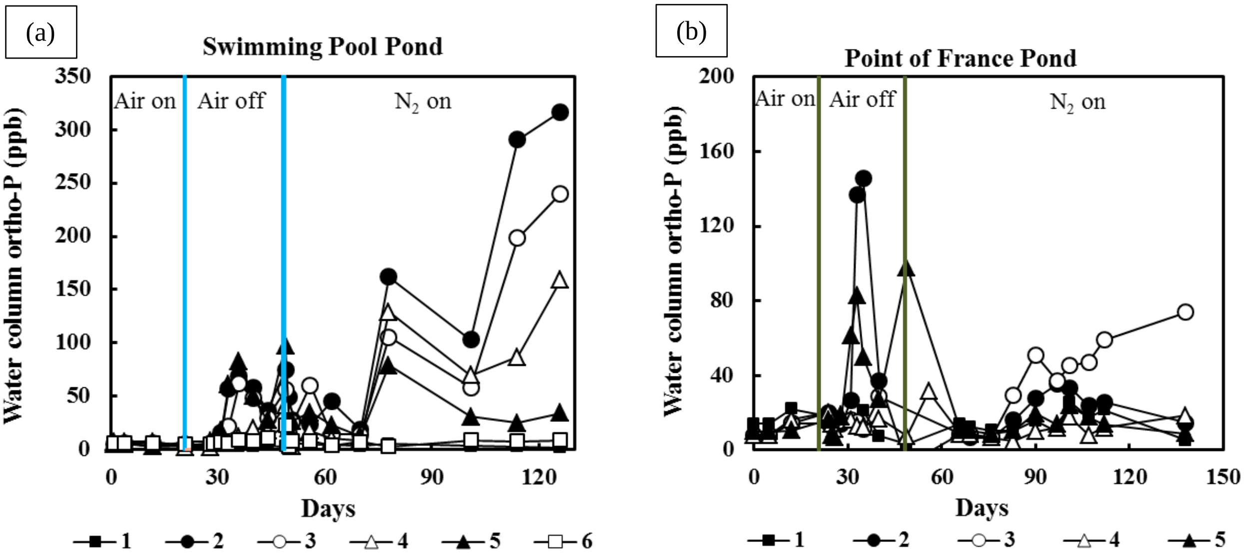

Figure 4. Phosphorus (ortho-P) release from the (a) Swimming Pool Pond and (b) Point of France Pond sediment cores under oxic (air bubbling), air off, and anoxic (N_2 bubbling) phases at 20 °C. Solid lines separate the three phases of the P release study.

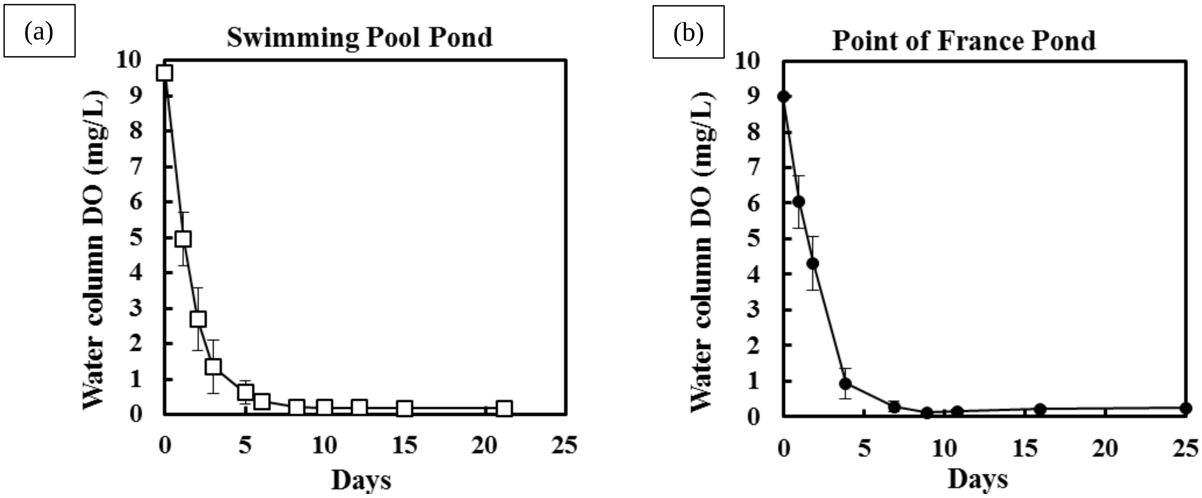

Figure 5. Average water column dissolved oxygen (DO) concentrations after air supply was switched off in the sediment cores from the (a) Swimming Pool Pond and (b) Point of France Pond. Measurements were taken at 8 cm above the sediment surface. Error bars are 67% confidence interval (CI) of the mean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

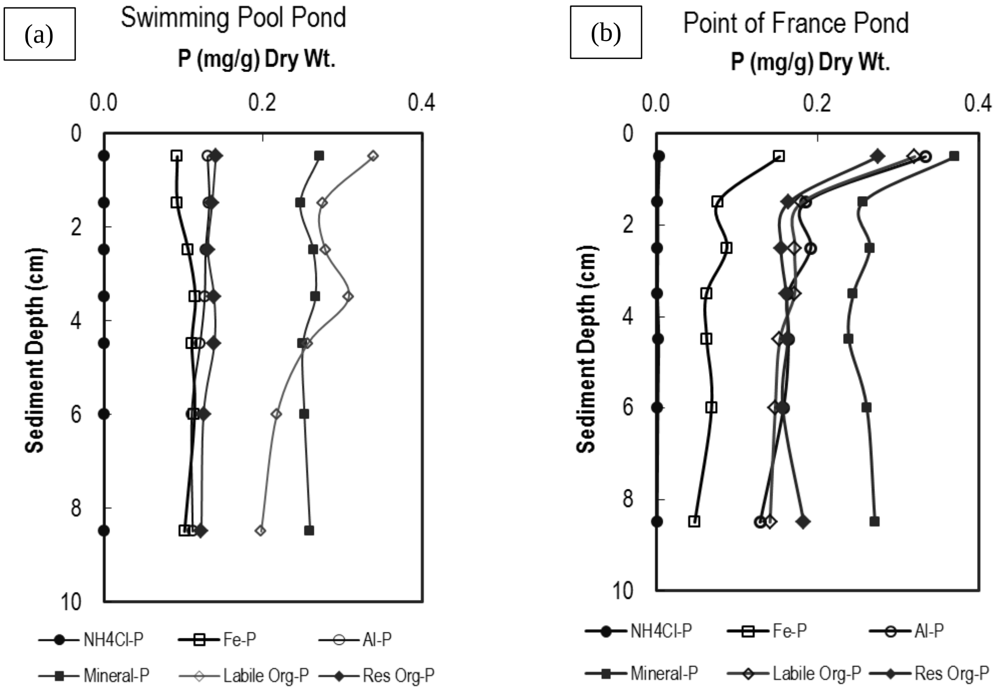

Figure 6. Phosphorus fractions in the upper 10 cm of sediments in the (a) Swimming Pool Pond and (b) Point of France Pond sediment cores. Average concentrations in five sediment cores are plotted. For each depth interval, concentration is plotted at the mid-point of the depth interval (for example, concentration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

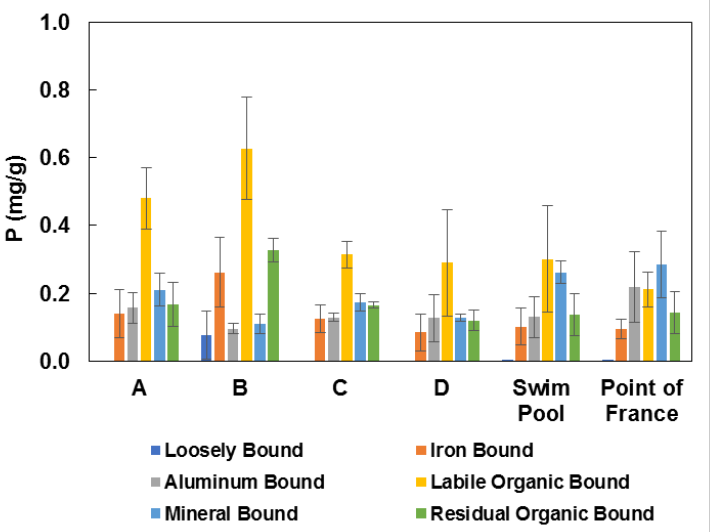

Figure 7. Sediment phosphorus fractions in the upper 4 cm of sediment cores collected from the Swimming Pool Pond and Point of France Pond along with other stormwater ponds in the Twin Cities Metro area (data from Taguchi et al. 2018b) (Error bars are standard deviations). Loosely-bound P is primarily 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.

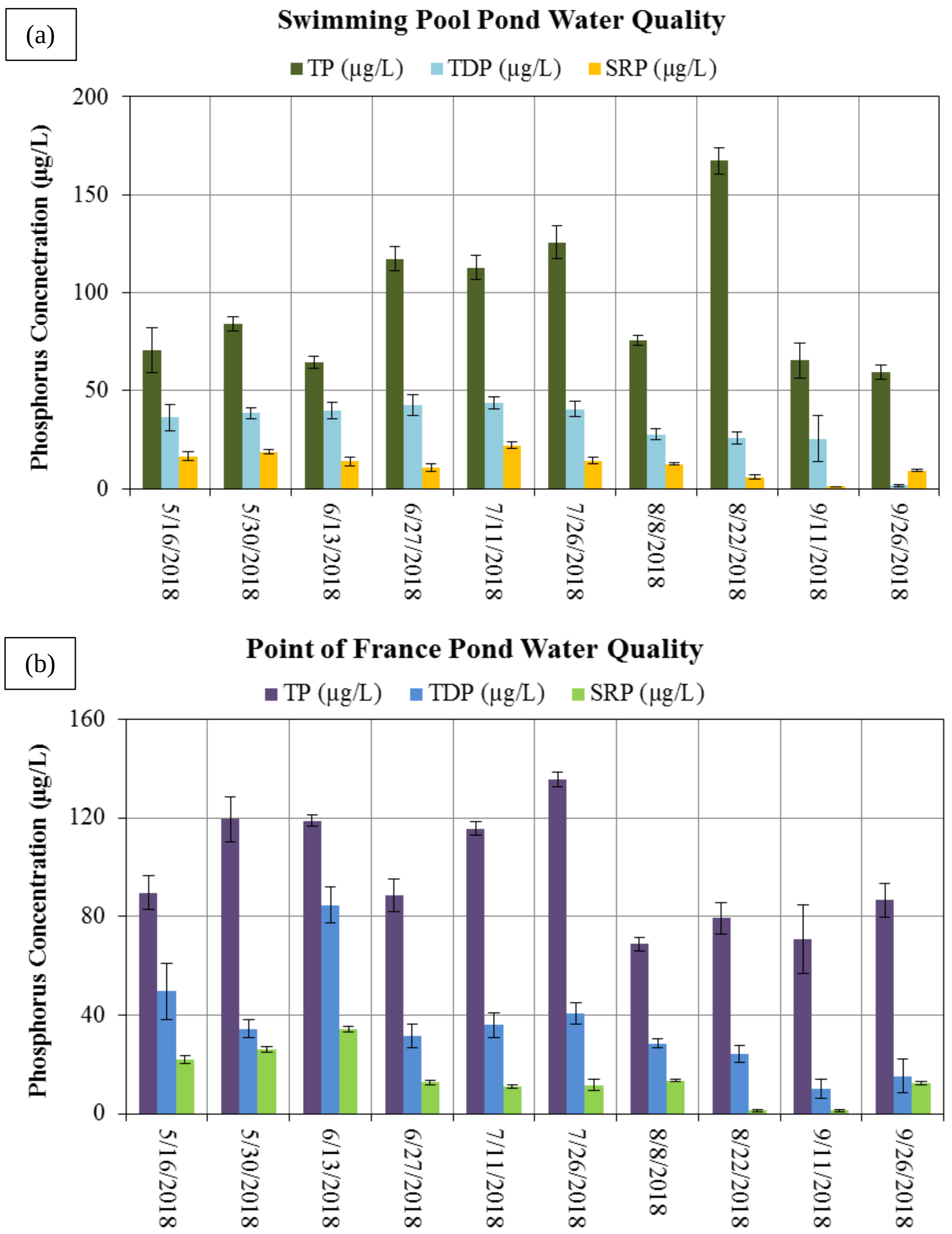

Figure 8. *In situ* phosphorus water quality from May to September 2018 in the (a) Swimming Pool Pond and (b) Point of France Pond. Average phosphorus concentrations in the epilimnion water samples collected from five locations in the pond are shown. Error bars are 67% CI of the mean measurements. Water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

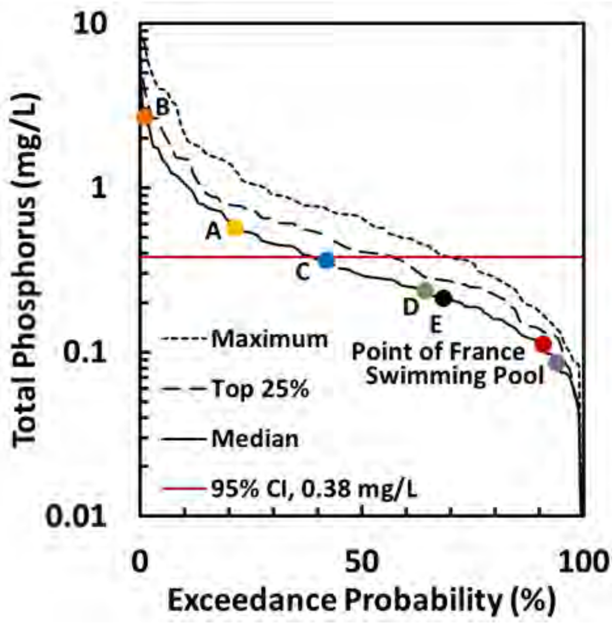

Figure 9. Median epilimnion grab sample values in the Swimming Pool Pond and Point of France Pond plotted along with stormwater ponds monitored by Taguchi et al. (2018b) (colored circles) in the exceedance probability distribution of total phosphorus concentrations in the RPBCWD ponds (figure adapted 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.

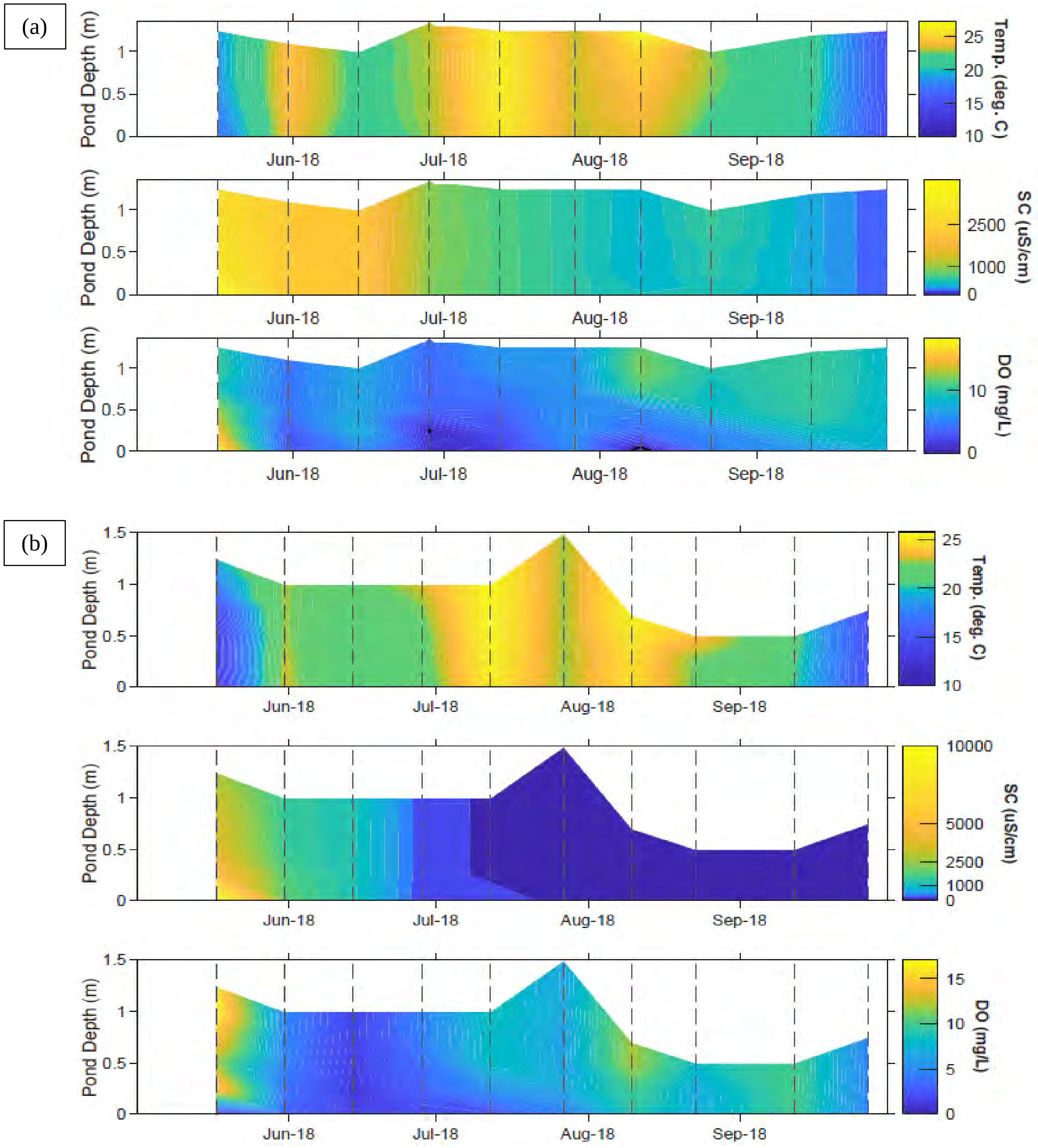

Figure 10. Time series contour plots of temperature, specific conductivity (SC), and dissolved oxygen (DO) concentrations in the (a) Swimming Pool Pond and (b) Point of France Pond from May to September 2018. Vertical lines show times when profiles were taken at the ponds; linear interpolation is used 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

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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

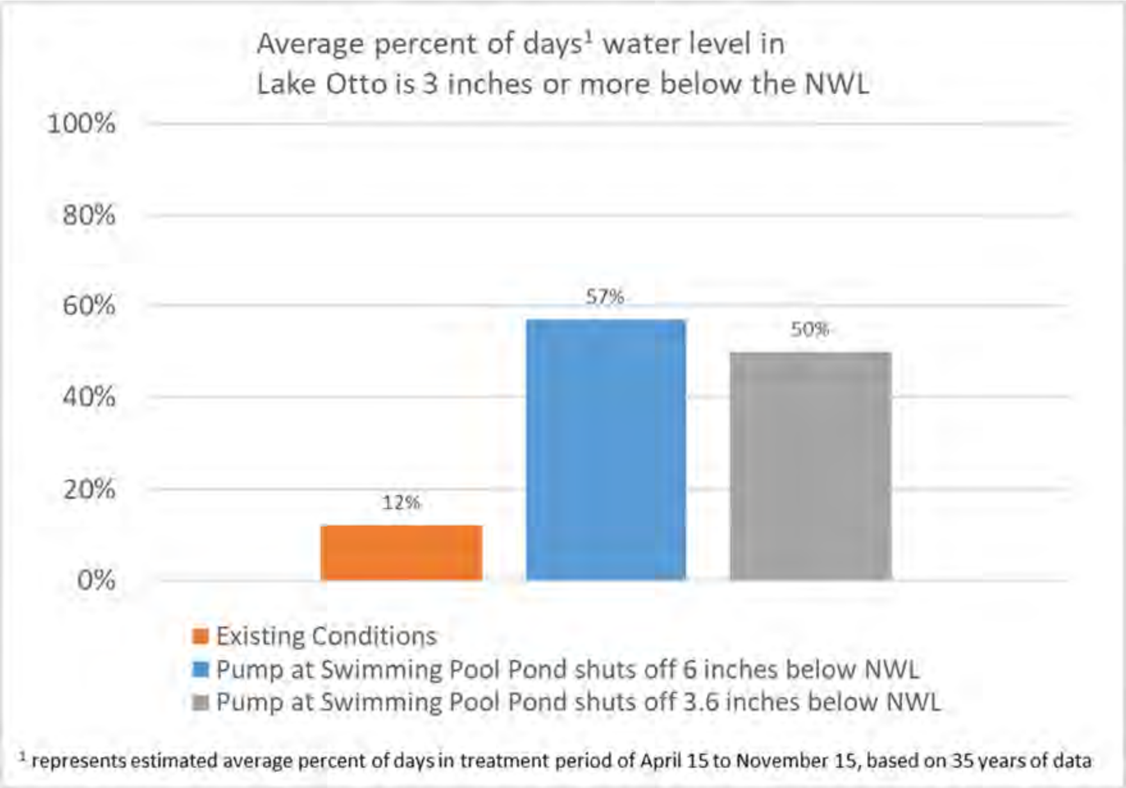
Scenario		Average Annual Pumped Volume (ac-ft)[1]	Range Annual Pumped Volume (ac-ft)[1]	% of Discharge from Swimming Pool Pond Treated[3]	Average days/treatment period[1] Lake Otto >3 inches below existing NWL	Average days/treatment period[1] Lake Otto >6 inches below existing NWL
1	Pump shuts off 6 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

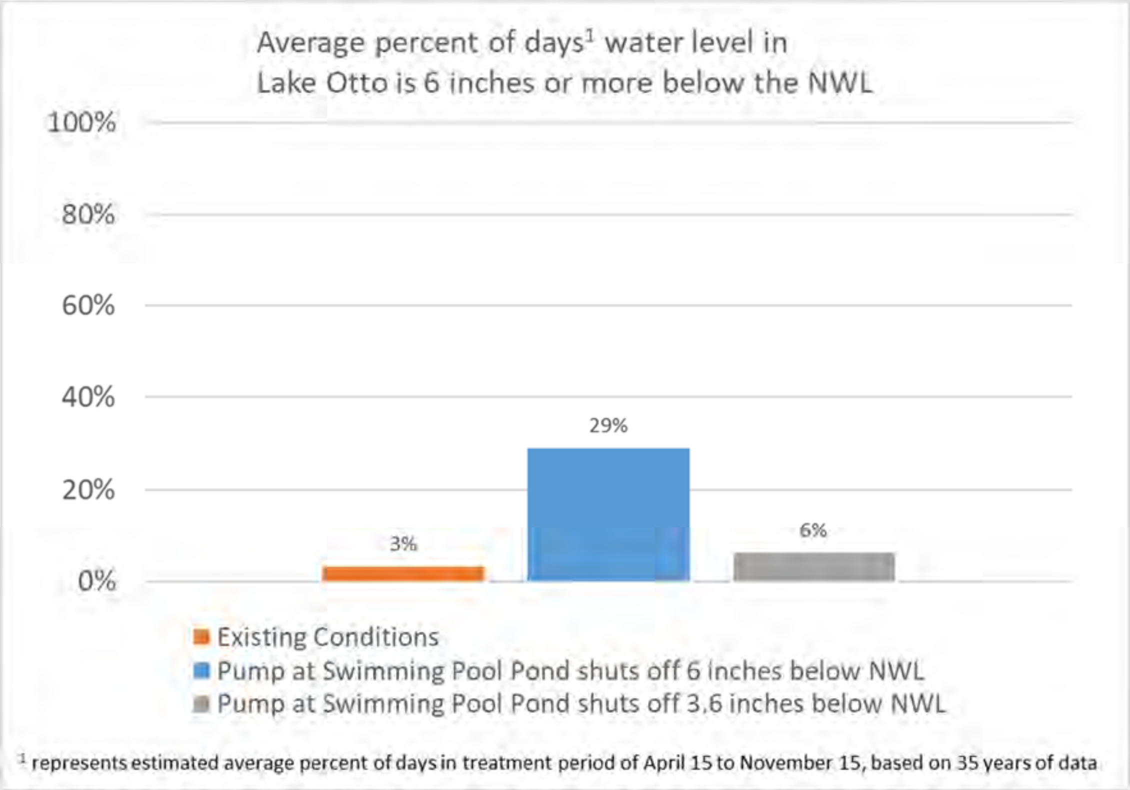
[3] % of discharge based on treatment period of April 15 through November 15

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.



[1] represents estimated average percent of days in treatment period of April 15 to November 15, based on 35 years of data

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



[1] represents estimated average percent of days in treatment period of April 15 to November 15, based on 35 years of data

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
APPROVED BY:		DATE:	
ISSUED:		DATE:	
ISSUED:		DATE:	
ISSUED:		DATE:	
ISSUED:		DATE:	

ENGINEER'S OPINION OF PROBABLE PROJECT COST

PROJECT: 2019 Rosland Park Feasibility Design
LOCATION: Nine Mile Creek Watershed District
PROJECT #: 23/27-1725.01

OPINION OF COST - SUMMARY

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

ENGINEER'S OPINION OF PROBABLE PROJECT COST
PROJECT: Lake Edina Retrofit BMPs - Cornelia Elementary
LOCATION: City of Edina
PROJECT #: 23271725.01
OPINION OF COST - SUMMARY

SHEET:	1	OF	
CREATED BY:	KJN2	DATE:	3/18/2020
CHECKED BY:	KAL	DATE:	6/1/2020
APPROVED BY:	JMK2	DATE:	6/1/2020
ISSUED:		DATE:	
ISSUED:		DATE:	
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

ENGINEER'S OPINION OF PROBABLE PROJECT COST
PROJECT: Lake Edina Retrofit BMPs - Lynmar Basin
LOCATION: City of Edina
PROJECT #: 23271725.01
OPINION OF COST - SUMMARY

SHEET:	1	OF	
CREATED BY:	KJN2	DATE:	3/18/2020
CHECKED BY:	KAL	DATE:	6/1/2020
APPROVED BY:	JMK2	DATE:	6/1/2020
ISSUED:		DATE:	
ISSUED:		DATE:	
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

ENGINEER'S OPINION OF PROBABLE PROJECT COST

PROJECT: Lake Cornelia Drawdown
LOCATION: City of Edina
PROJECT #: 23271725.01

OPINION OF COST - SUMMARY

SHEET:	1	OF	
CREATED BY:	JAH	DATE:	5/20/2020
CHECKED BY:	JMK2	DATE:	6/1/2020
APPROVED BY:		DATE:	
ISSUED:		DATE:	
ISSUED:		DATE:	
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
APPROVED BY:		DATE:	
ISSUED:		DATE:	
ISSUED:		DATE:	
ISSUED:		DATE:	
ISSUED:		DATE:	

ENGINEER'S OPINION OF PROBABLE PROJECT COST

PROJECT: Lake Cornelia Aeration System

LOCATION: Nine Mile Creek Watershed District

PROJECT #: 23/27-1725.01

SUMMARY OF MORE DETAILED VERSION

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**	

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[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.

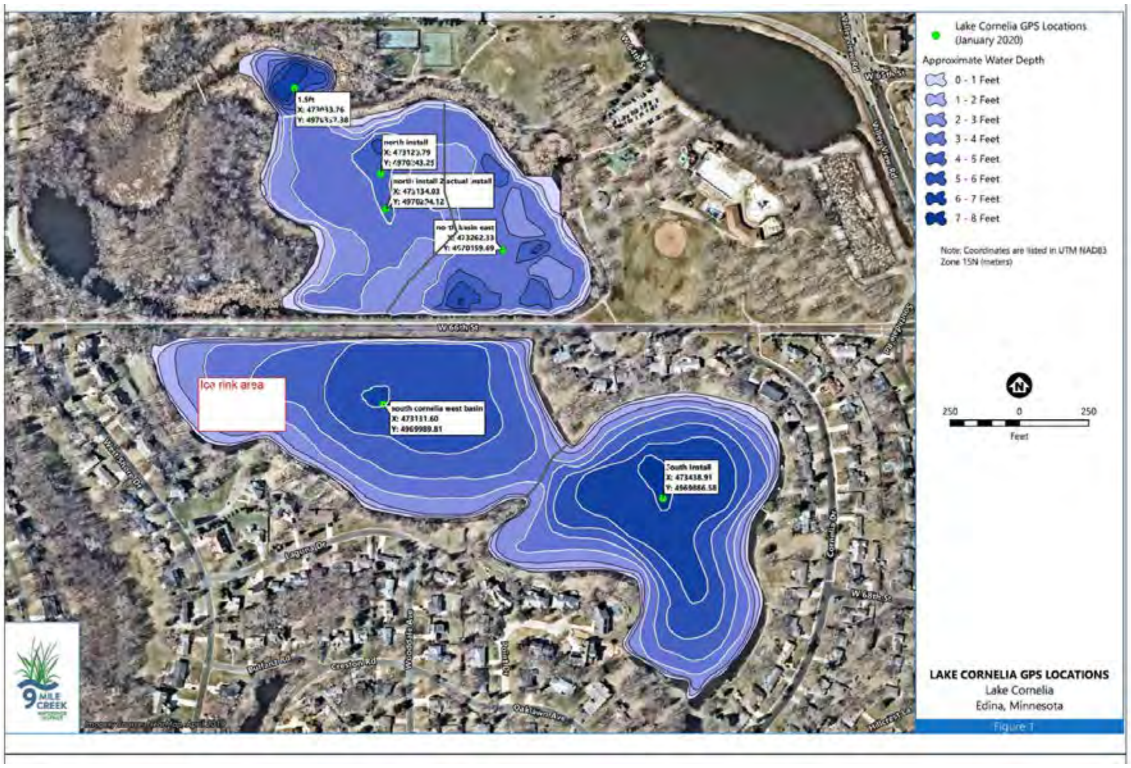


Figure 3: Topographic map of North and South Lake Cornelia showing location of water column profiles and remote sensor deployment labeled as "North actual install" and "South Install".

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.

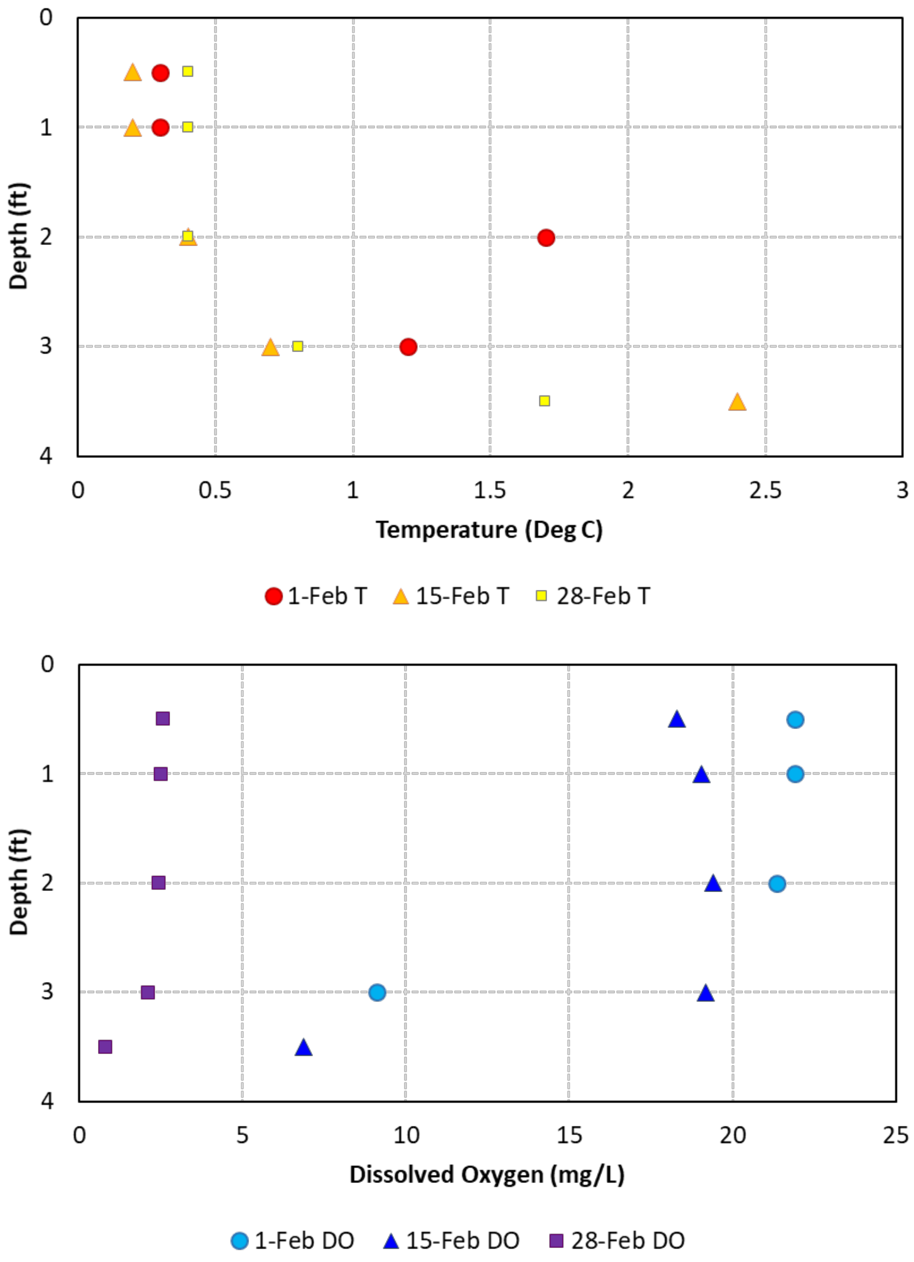


Figure 2: Sample temperature (top) and DO (bottom) data collected during February 2019 on North Lake Cornelia.

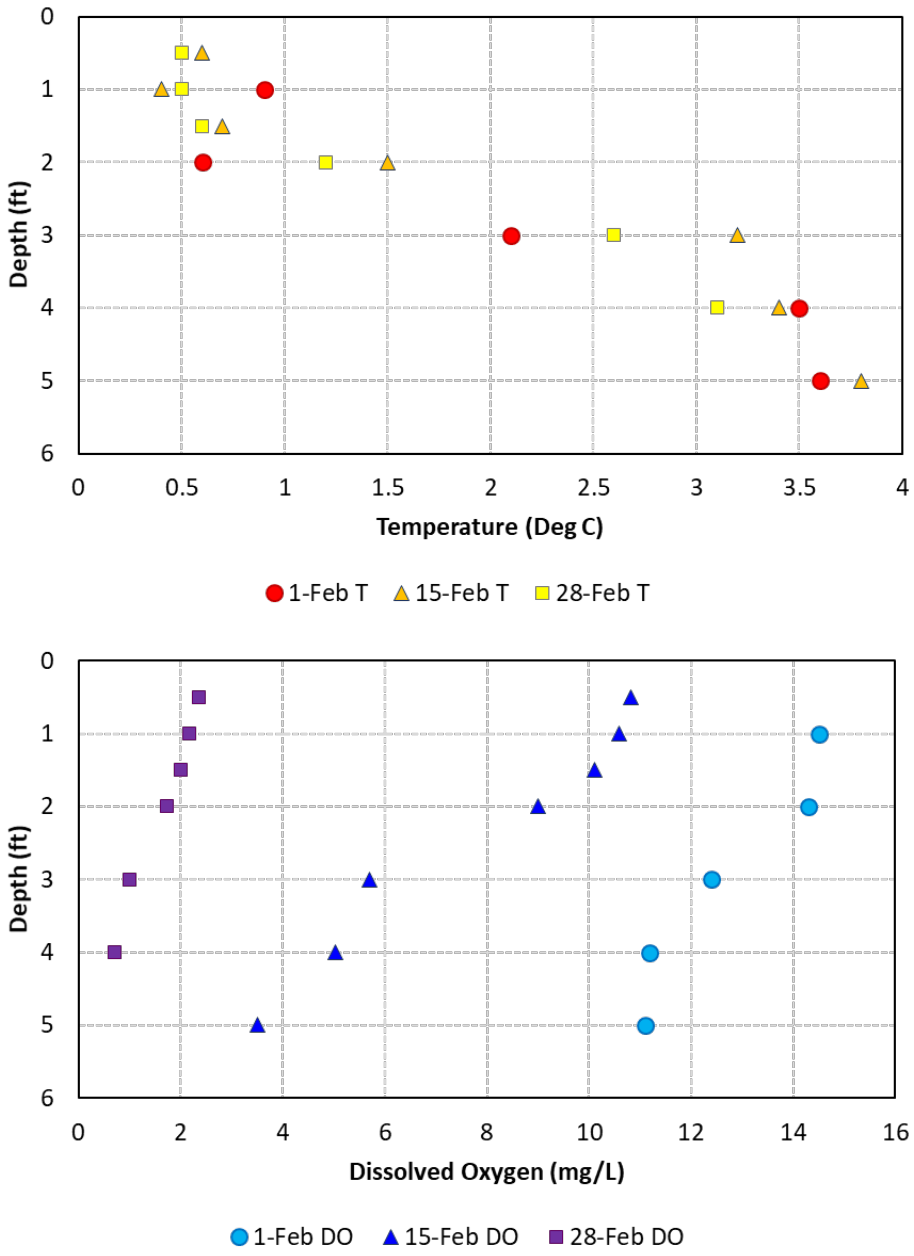
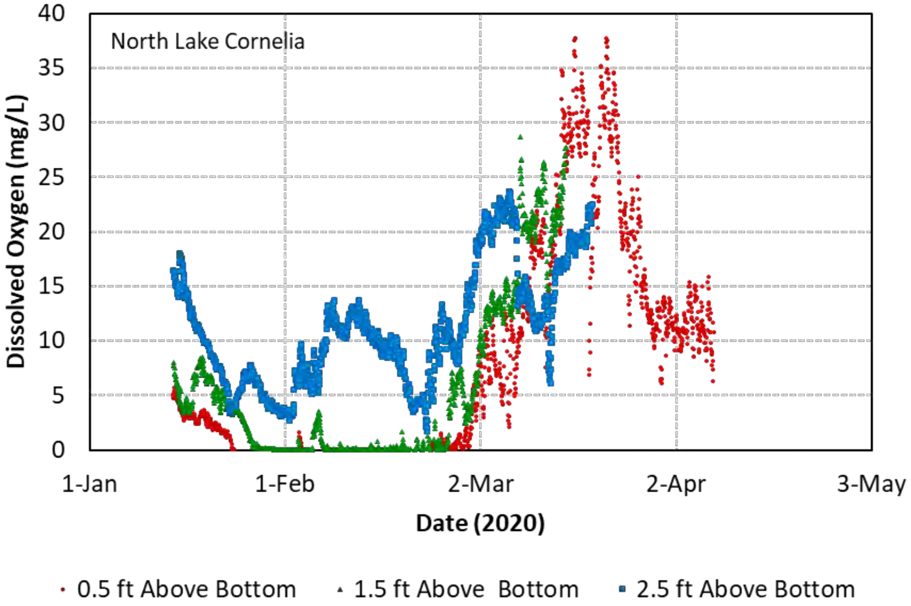


Figure 3: Sample temperature (top) and DO (bottom) data collected during February 2019 on South Lake Cornelia.



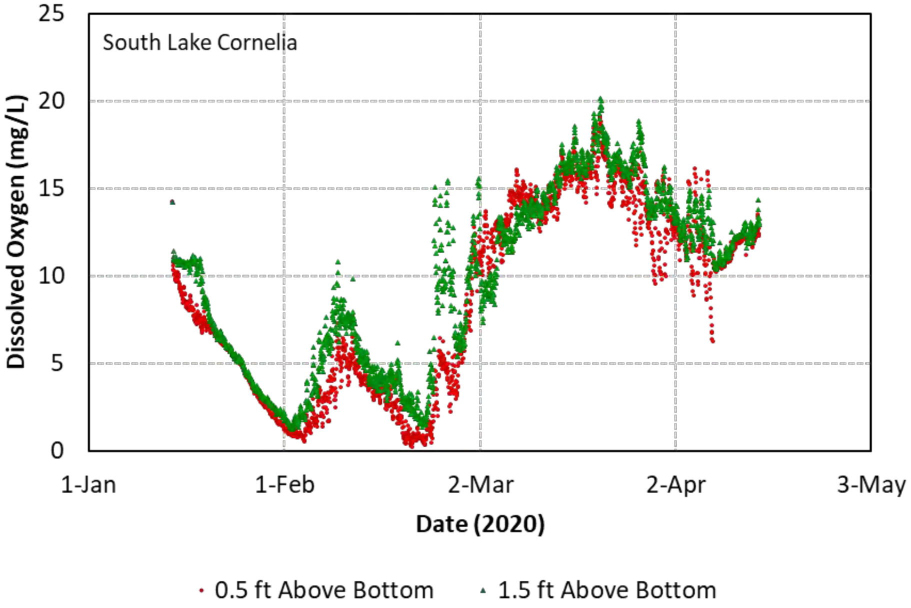


Figure 4: Remote dissolved oxygen data collected in North (top) and South (bottom) Lake Cornelia, showing linear depletion rates occurring mid-January and early February.

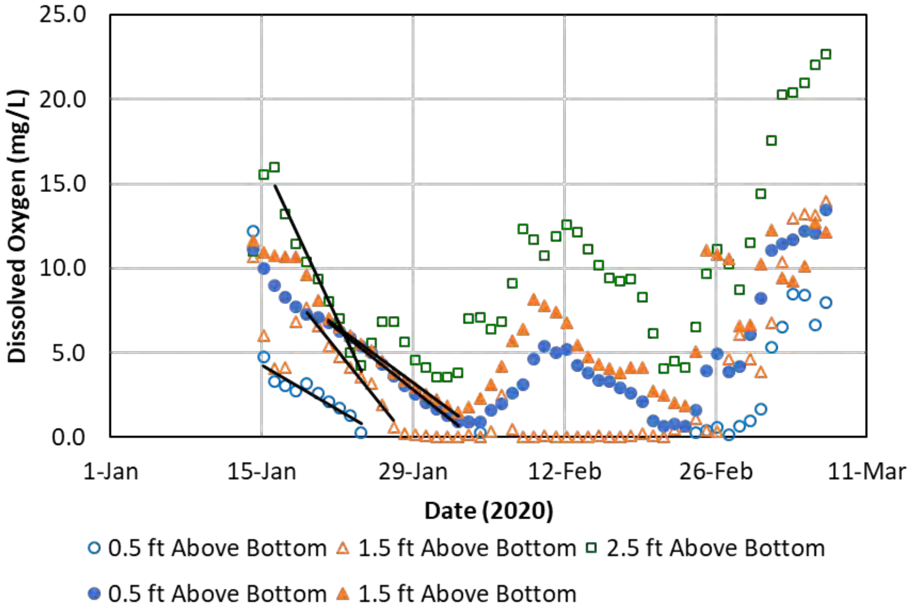


Figure 5: Aggregated remote DO data collected on North (open symbols) and South (closed symbols) Lake Cornelia with black lines showing data used to determine depletion rates.

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

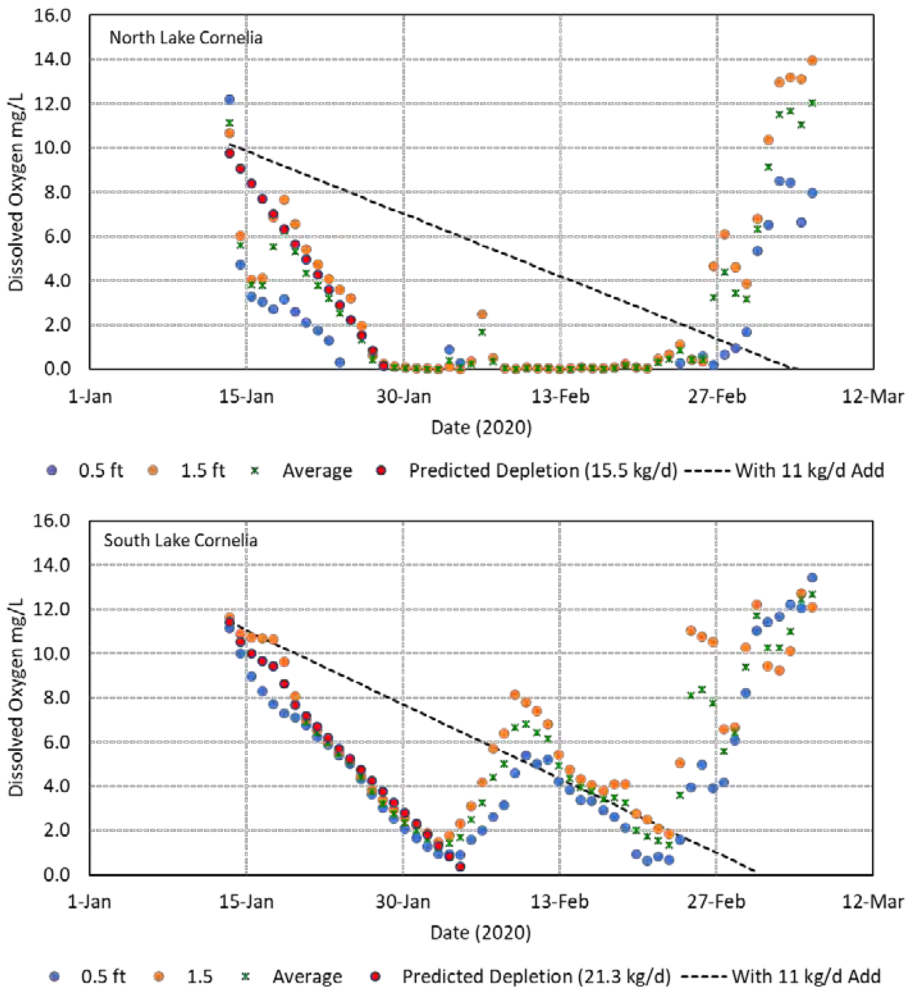


Figure 6: Aggregated remote dissolved oxygen (DO) data for North (top) and South (bottom) Lake Cornelia showing predicted depletion rates (red circles) to match the observed rate of depletion and predicted DO (dashed black line) and corresponding time of anoxia from an oxygen supplement of 11 kg/d.

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).

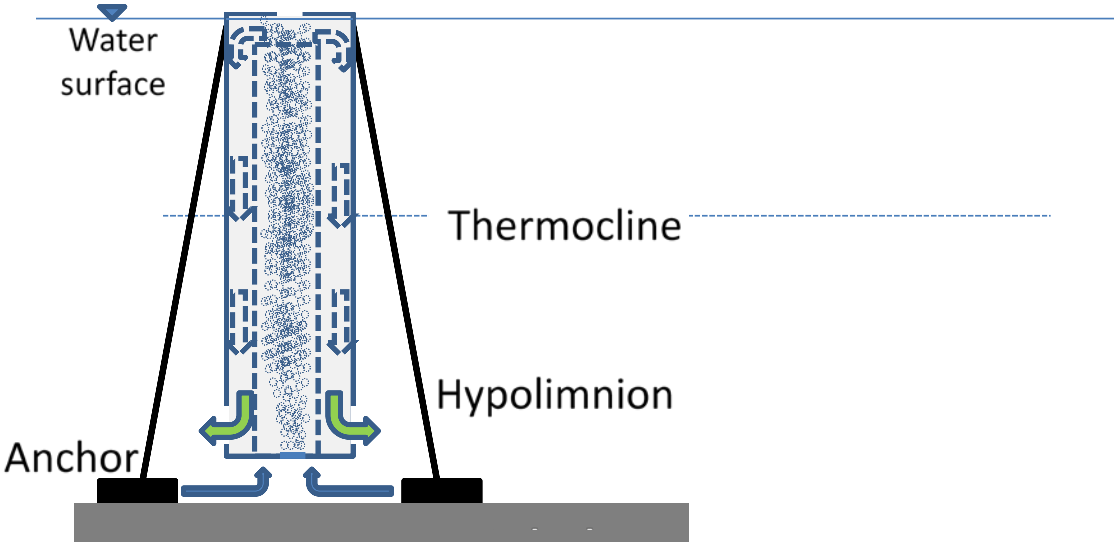


Figure 7: Full-Lift diagram

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.

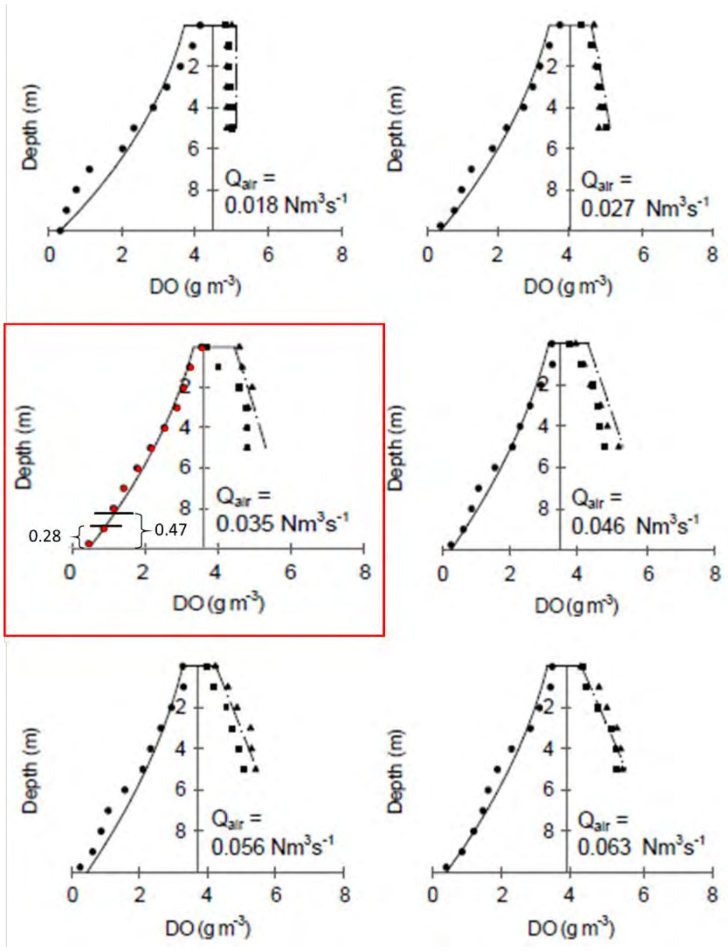


Figure 8: Experimental and model DO profiles for a range of air flow rates for full lift aerators (Burris et al (1998)) with predicted DO increases for North (0.28 mg/L) and South (0.47 mg/L) overlaid on 0.035 Nm^3/s, a mid-range applied gas flow rate.

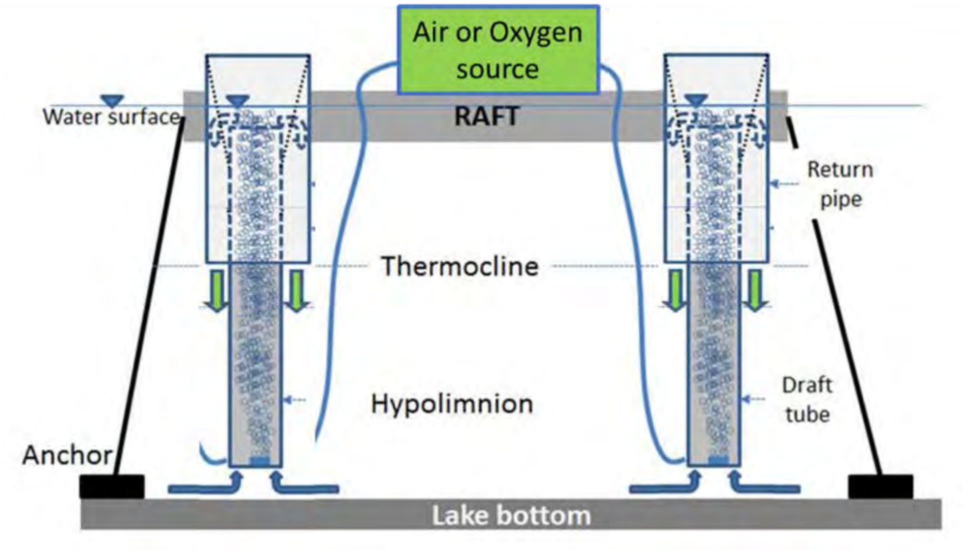


Figure 9: Full-lift aeration/oxygenation schematic showing relative position in the water column, entraining water from near the lake bottom and discharging to hypolimnion depth. For winter deployment, thermocline depth becomes ice depth.

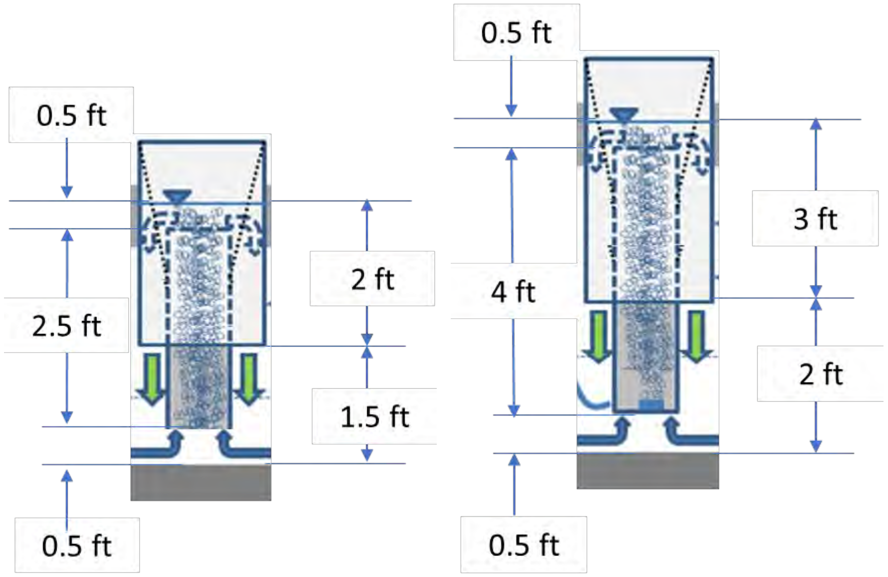


Figure10: Sketch showing recommended riser and down comer lengths with approximate position in the water column for North (left) and South (right) Cornelia Lakes.

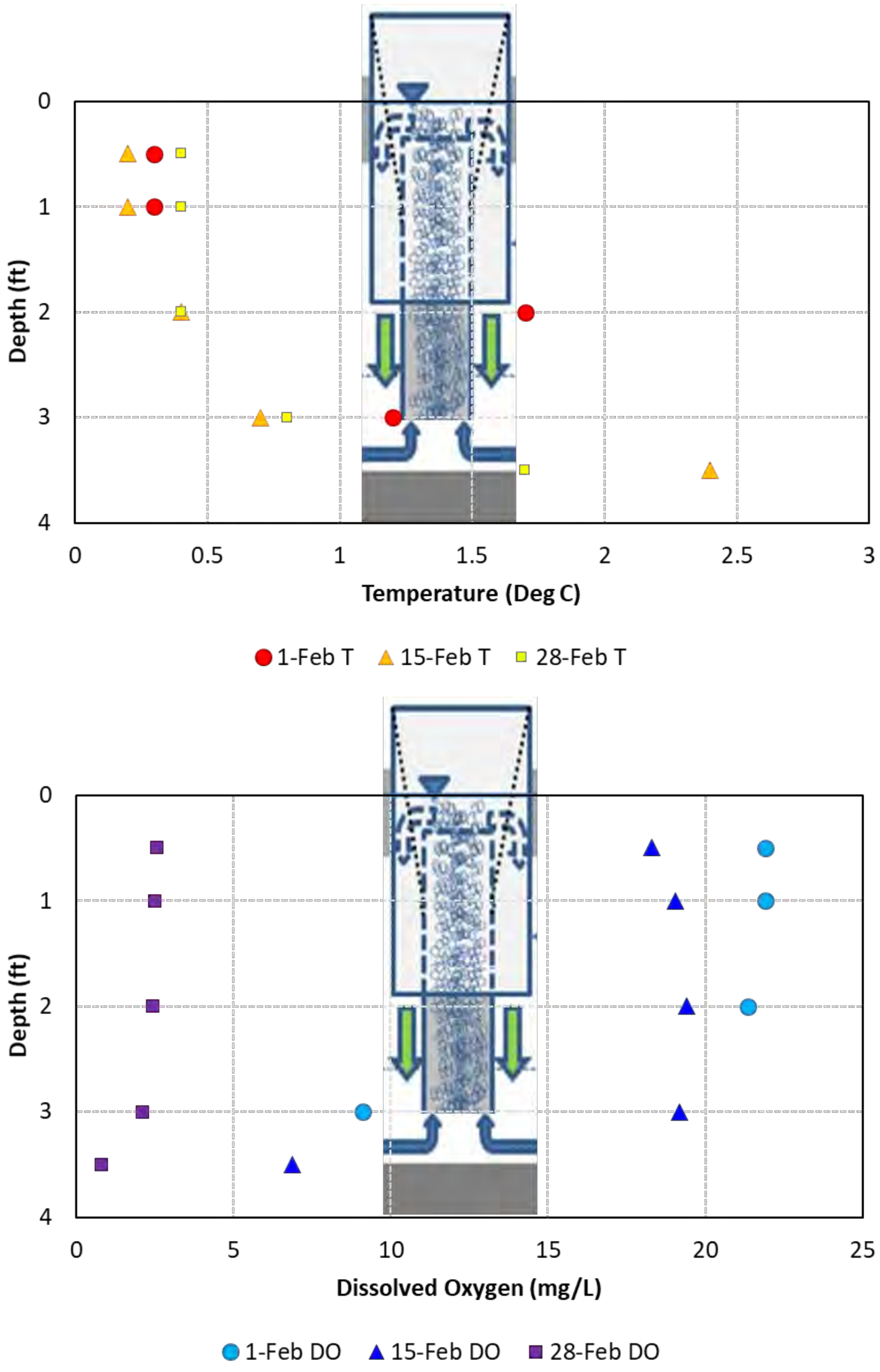


Figure 11: Temperature (top) and DO (bottom) profiles with full-lift apparatus overlaid to show water column positioning and circulation pattern in North Cornelia Lake.

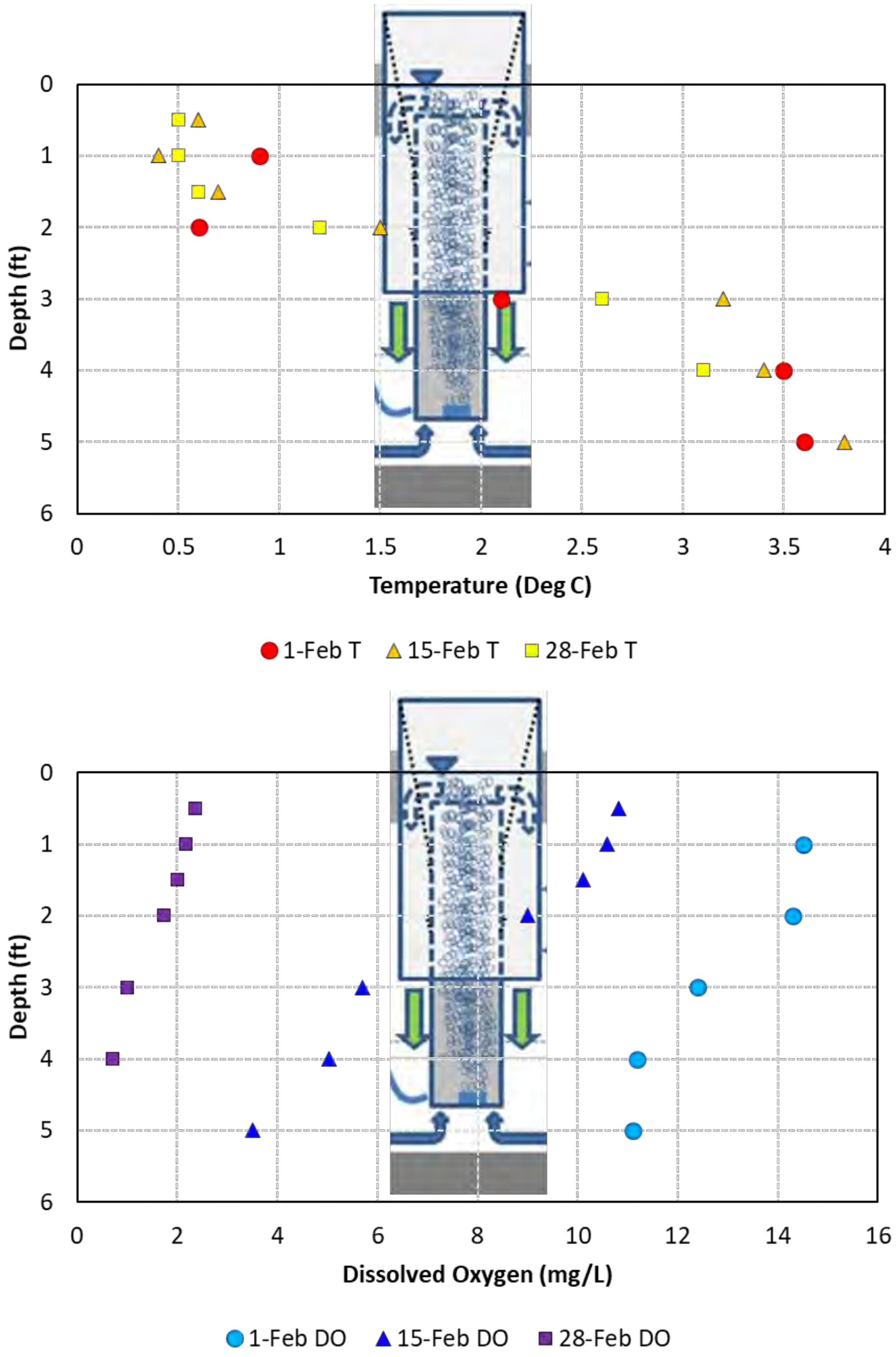


Figure 12: Temperature (top) and DO (bottom) profiles with full-lift apparatus overlaid to show water column positioning and circulation pattern in South Cornelia Lake.

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

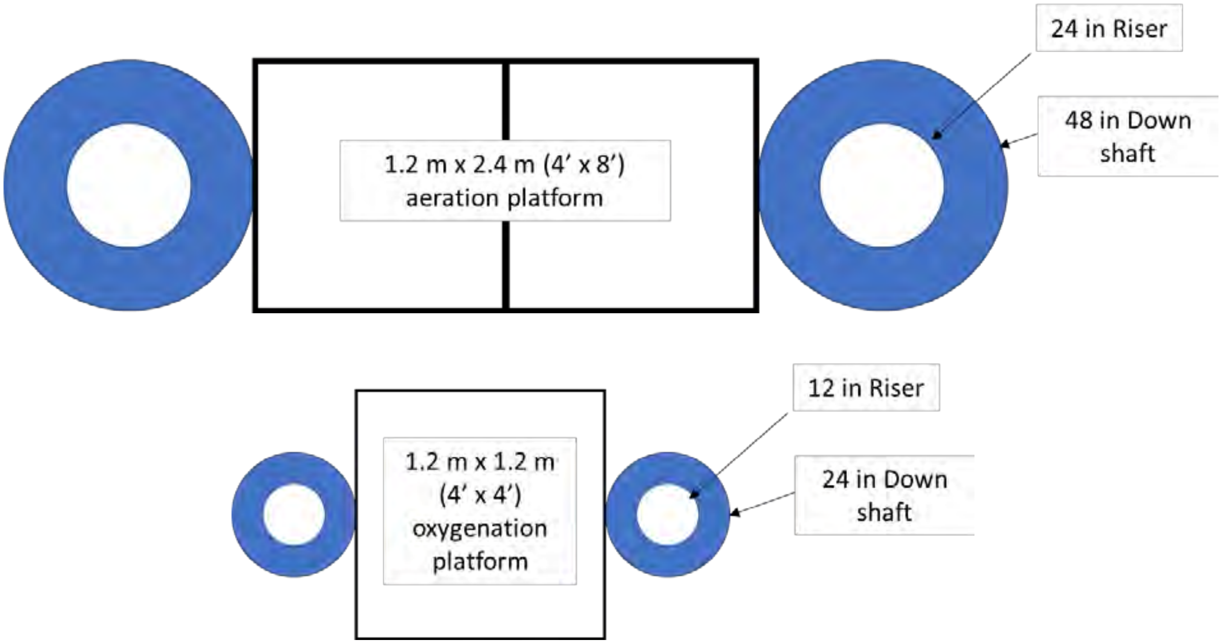
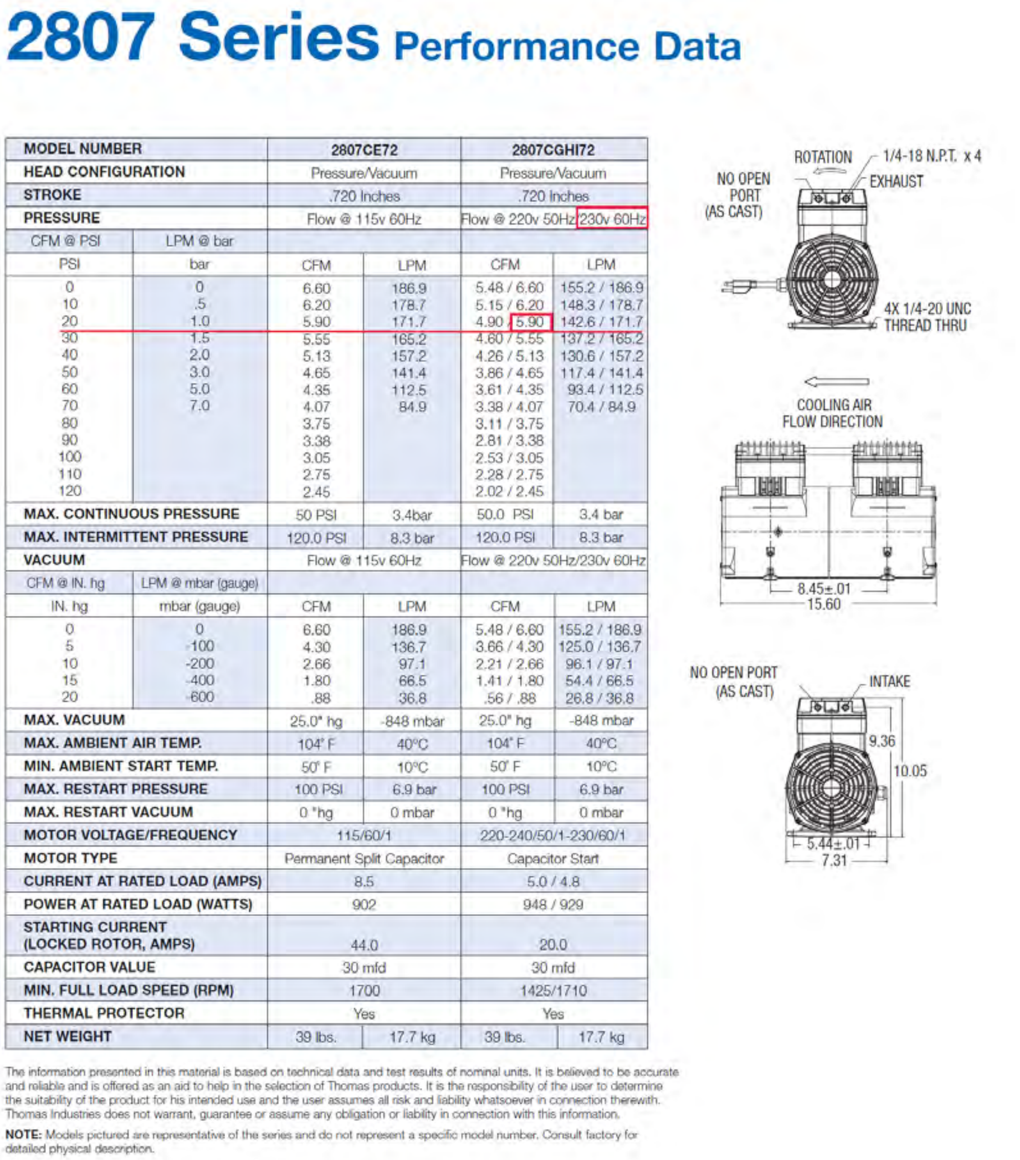


Figure 14. Approximate platform sizes for 24/48 (top) and 12/24 (bottom) riser to downcomer ratio.

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

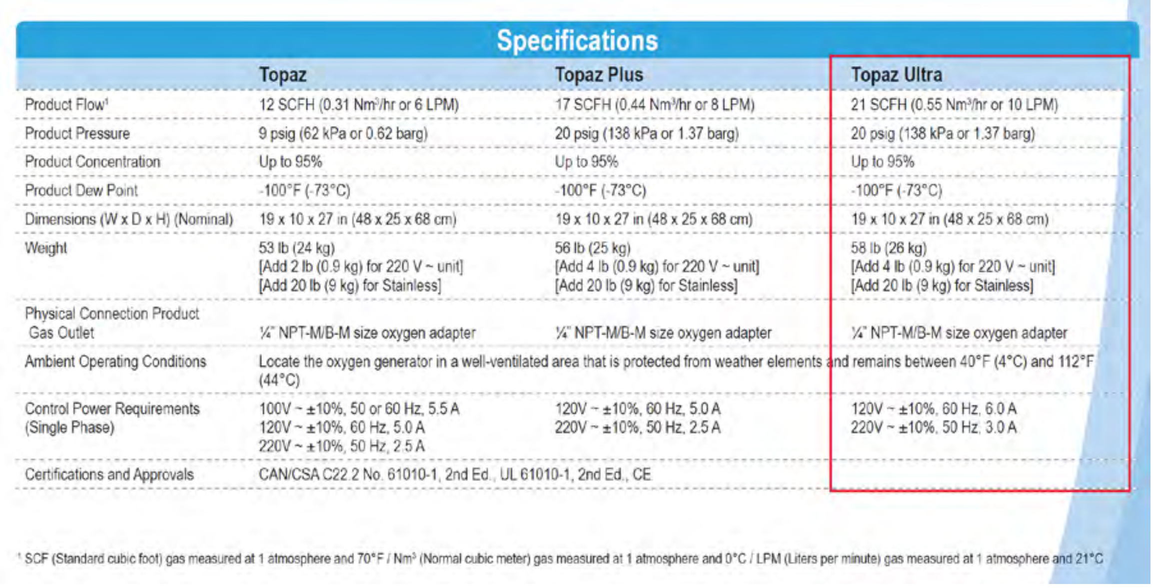
The information presented in this material is based on technical data and test results of nominal units. It is believed to be accurate and reliable and is offered as an aid to help in the selection of Thomas products. It is the responsibility of the user to determine the suitability of the product for 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 Nm^3/hr or 6 LPM)	17 SCFH (0.44 Nm^3/hr or 8 LPM)	21 SCFH (0.55 Nm^3/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 / Nm^3 (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.

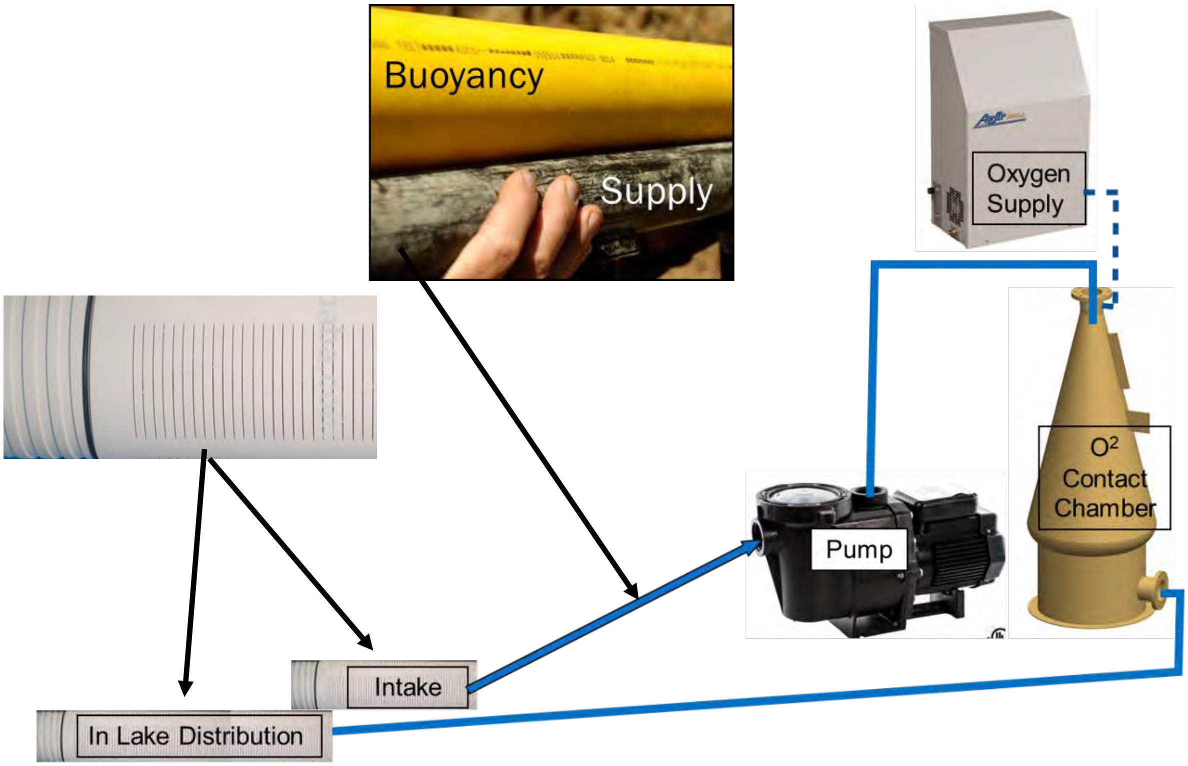


Figure 17: Side-stream saturation (SSS) oxygenation process flow diagram showing the main components of the system; in-lake distribution and intake (slotted well screen), pump, oxygen supply, oxygen contact chamber, and corresponding (HDPE) piping (2-pipe system)

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
    - Large enough to minimize head loss and corresponding net positive suction head (NPSH) at the pump inlet to prevent cavitation,
    - Long enough to reach deepest part of the lake in either east or west basin, and
    - With slotted well screen.
- Distribution Header:
    - Designed to distribute oxygenated water uniformly along the entire length (100 ft),
    - Use slotted well screen (same as suction),
    - Designed to dissipate energy associated with water flow rate as quickly as possible while preserving ice structure, and
    - 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/.

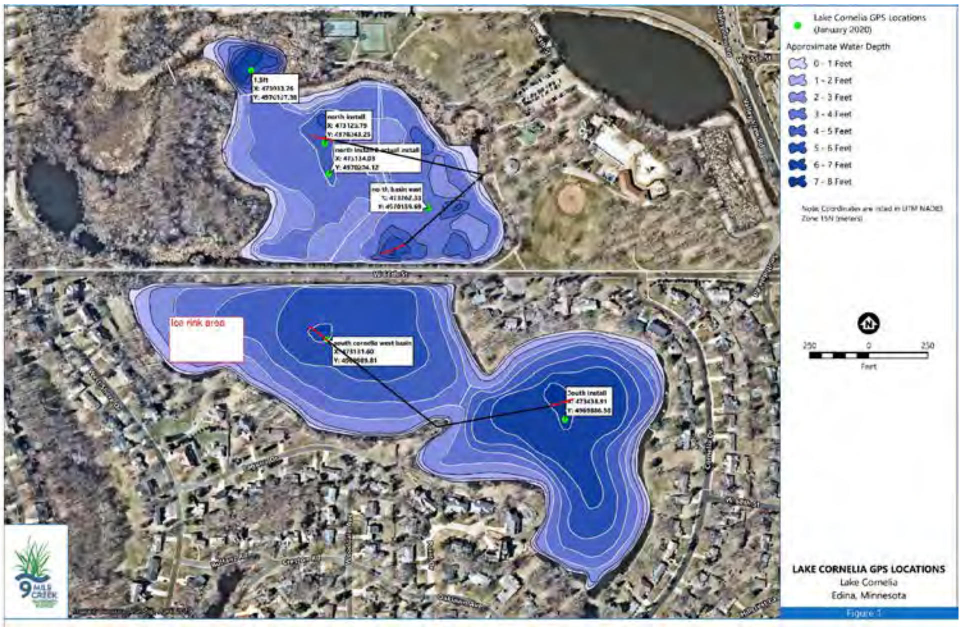


Figure 19: Proposed SSS layout for North and South Lake Cornelia. Each lake would have intakes from one basin and discharge header in the other basin.

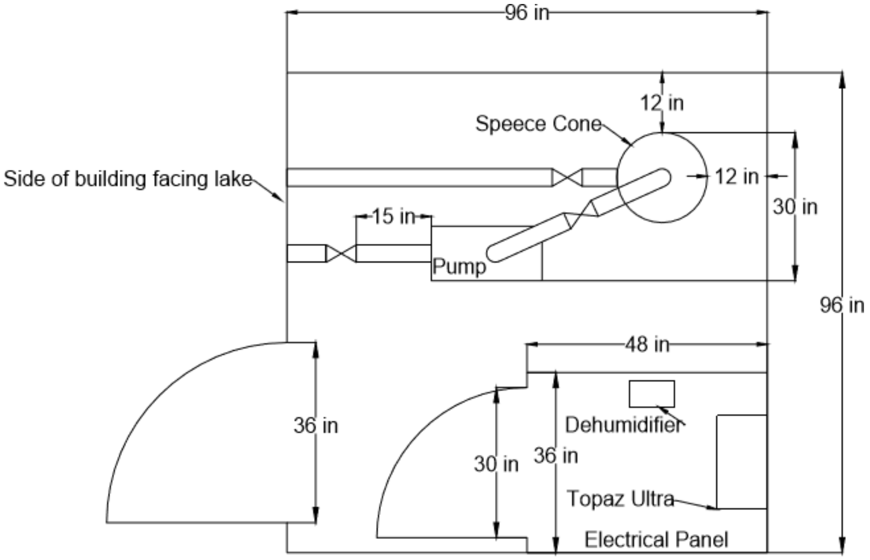


Figure 20: Proposed system layout showing 8′ x 8′ building footprint, estimated equipment layout and recommended offsets. Note the oxygen concentrator (Topaz) located in a 3′ x 4′ sectioned off room for improved environmental control.

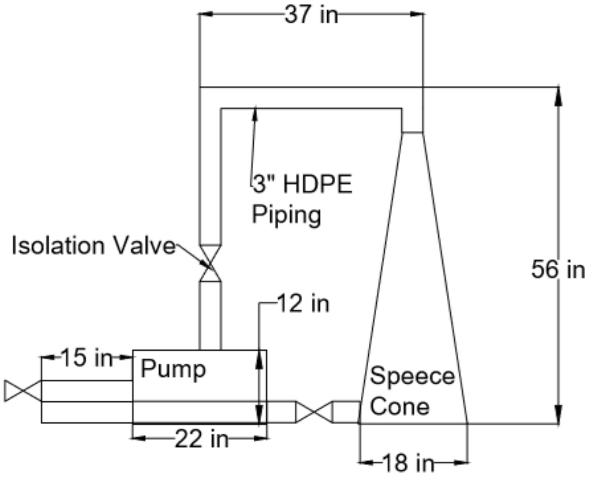


Figure 21: Sketch showing pump and oxygen contact chamber to demonstrate approximate height of equipment.

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**
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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

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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.

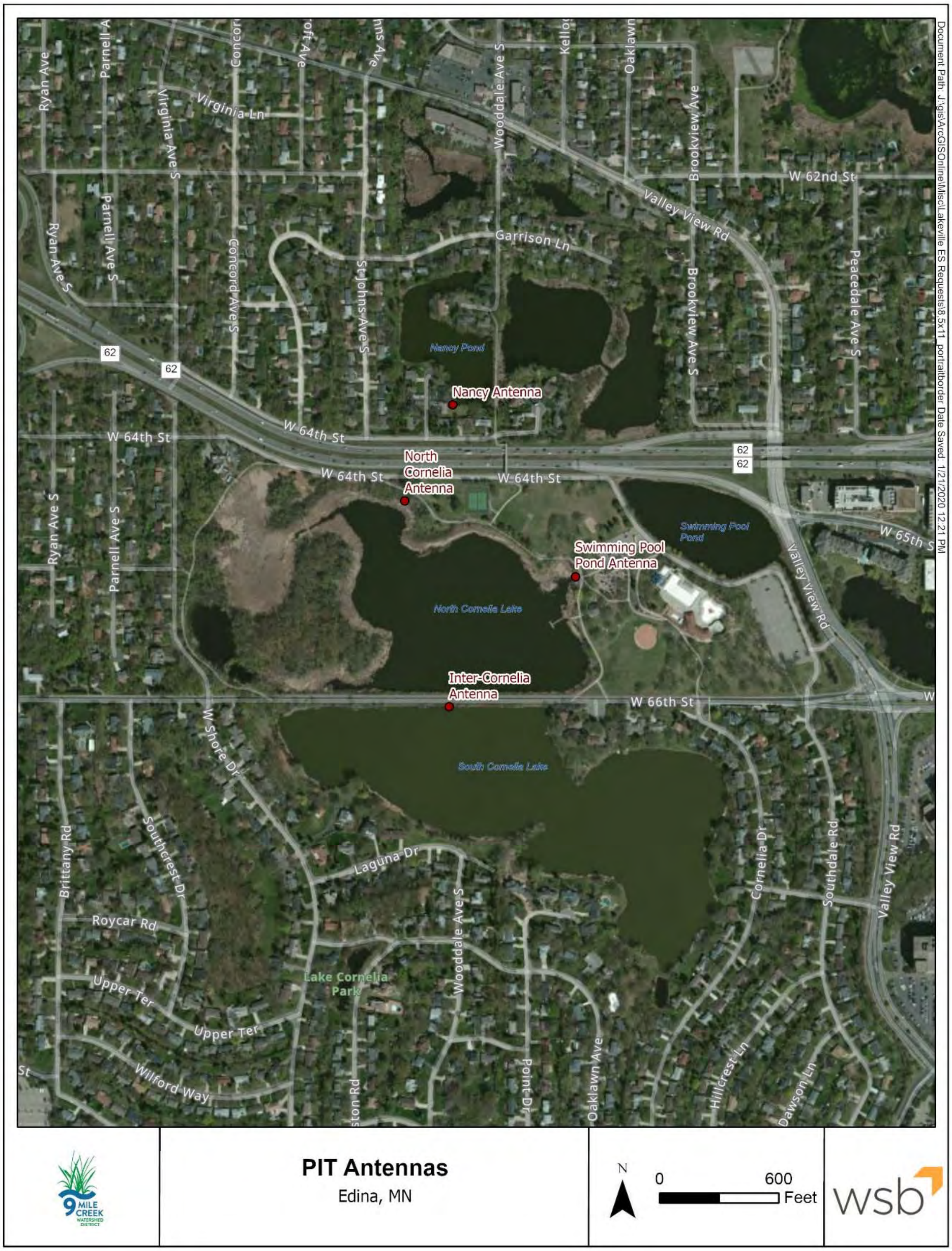

Figure 1: Illustration of locations of PIT antennas strategically placed in potential fish pathways.

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.