Alum Treatment of Lake Cornelia

Feasibility Analysis

Prepared for
Nine Mile Creek Watershed District

July 2019

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1 Introduction

The Nine Mile Creek Watershed District (NMCWD) recently completed a Use Attainability Analysis (UAA) for Lake Cornelia (updated from 2010) and Lake Edina (first version) to assess the water quality and prescribe management activities to improve lake water quality (see Barr Engineering Co., 2019). One of the recommendations of the study was to conduct an alum treatment of Lake Cornelia (North and South Basins) to bind (or immobilize) the phosphorus in lake bottom sediments and prevent release of the phosphorus into the water column during summer months. All lakes accumulate phosphorus (and other nutrients) in the sediments from the settling of particles and dead algae. This reservoir of phosphorus can be reintroduced or recycled to the lake water and be used by plants and algae for growth. The recycling of nutrients from the sediments to the lake water is known as "internal loading". The process of internal loading is complex and can be affected by temperature, oxygen, pH, wind mixing, and bioturbation by organisms such as bottom-feeding fish species.

Significant reductions in internal phosphorus loading in Lake Cornelia are an integral part of the overall strategy to reduce phosphorus concentrations as well as the magnitude and frequency of algal blooms in Lake Cornelia. The lake water quality modeling conducted as part of the UAA demonstrated that internal release of phosphorus from lake bottom sediments is a significant source of phosphorus to Lake Cornelia, contributing an estimated 14%-40% of the annual phosphorus loading to North Cornelia during modeled years, and an estimated 14%-19% of the annual phosphorus loading to South Cornelia. The lake water quality modeling also demonstrated that an alum treatment will be highly effective in reducing the summer-average phosphorus concentration in Lake Cornelia. Based on these findings, we recommend conducting an alum treatment of Lake Cornelia (north and south basin).

Internal loading often occurs during time periods when flows into and out of Lake Cornelia are lower, and the phosphorus tends to remain in the lake water column (i.e., is not flushed out). Since Lake Cornelia is quite shallow, the effects of these internal loads are enhanced compared to deeper lakes. One of the reasons to conduct an alum treatment now rather than after the other management activities have been implemented is to improve summertime clarity and promote native aquatic plant growth. The City of Edina is currently engaged in an effort to control invasive curly-leaf pondweed by treating with endothall in the spring. Alum treatment is expected to promote aquatic plant community growth and subsequently promote competition with curly-leaf pondweed. We expect that the alum treatment will enhance the overall curly-leaf pondweed control efforts.

This study provides the results of sediment coring and phosphorus fraction analysis, alum (aluminum) dosing, cost-benefit analysis of the treatment, site access, permitting requirements, and timing/schedule of the application for Lake Cornelia. As part of this effort, the potential benefit of treating Swimming Pool Pond with alum was evaluated using findings of a study conducted by University of Minnesota Saint Anthony Falls Laboratory (Natarajan and Gulliver, 2019). Using sediment collected from the bottom of Swimming Pool Pond, the study showed a low internal loading rate. This was confirmed with phosphorus measurements within the pond. While there is some internal loading in Swimming Pool Pond, the benefit of treating the pond with alum is expected to be minimal.

The sediment core analysis and lake water quality modeling conducted as part of the UAA demonstrated that internal loading is not a major source of phosphorus to the Lake Edina. Therefore, we do not recommend an alum treatment on Lake Edina at this time.

2 Internal Loading Background

2.1.1 Internal Loading in Lakes

Internal loading is a natural process in lakes and is mainly driven by temperature and oxygen availability. Traditionally, internal loading has been attributed to deep lakes with warm surface waters and cooler deep waters that mix infrequently and develop low oxygen conditions in bottom waters. In shallow lakes like Lake Cornelia, stable, summer-long stratification due to temperature differences does not usually occur. Instead, weak temperature gradients are formed during daytime hours and calm periods. This weak stratification can cause small microzones or pockets of low oxygen just above the sediment surface. These microzones are difficult to detect during periodic sampling because they are usually limited to a small water layer above the sediment and exist for short periods. Oxygen depletion over-night can be significant as algae respire (use oxygen) during this period instead of producing oxygen as they do during daylight hours. Phosphorus is released from the sediment under these low oxygen conditions and since the lake is shallow this phosphorus is immediately available for uptake by algae and plants the following day. In shallower areas, algae will actually grow on the sediment surface and directly uptake nutrients from the sediment. In some cases, pH can increase due to algae and macrophyte growth and phosphorus can be released from the sediment if pH is high enough (greater than 9.5) for an extended period.

Phosphorus released from the sediment through internal loading processes is considered immediately available because it is in a dissolved form that algae and plants can use directly. Watershed phosphorus loading is generally 35-45% dissolved (on average in Minnesota) while the remaining portion is in the form of particles (either soil or organic matter) that become part of lake sediment. The particulate form of phosphorus cannot be directly used by algae or plants until it is released from the particles or organic matter.

Phosphorus taken up by organisms in lakes (including algae and plants) is returned to the sediment when the organisms die. Once in the sediment, much of this phosphorus can then be released again after the organic matter breaks down, continuing the internal loading process. While this is a natural process in all lakes, additional inputs of phosphorus due to human activity have caused increases in both the total amount and the rate of internal phosphorus loading in lakes.

2.1.2 Mixing Effects of Benthivorous (Bottom-feeding) Fish

A 2018 fishery survey of Lake Cornelia identified a large population of benthivorous (bottom-feeding) fish, specifically black bullhead and goldfish. Benthivorous fish species increase mixing of lake sediments, which in turn can increase the rate (or speed) of internal loading in lakes. In addition, species like black bullhead and goldfish can actually increase the depth of sediment mixing in lakes. This means that a greater amount of phosphorus can be transported from the sediment to the water. Because there is little to no oxygen in lake sediment just below the sediment water interface, the pool of phosphorus that might not be available under 'normal' conditions without bottom-feeding species is physically pushed out of the sediment due to mixing. It should be noted that benthivorous fish do not cause internal loading but they may increase that rate of internal loading and they may increase transport of phosphorus from bottom to surface waters.

3 Sediment Coring

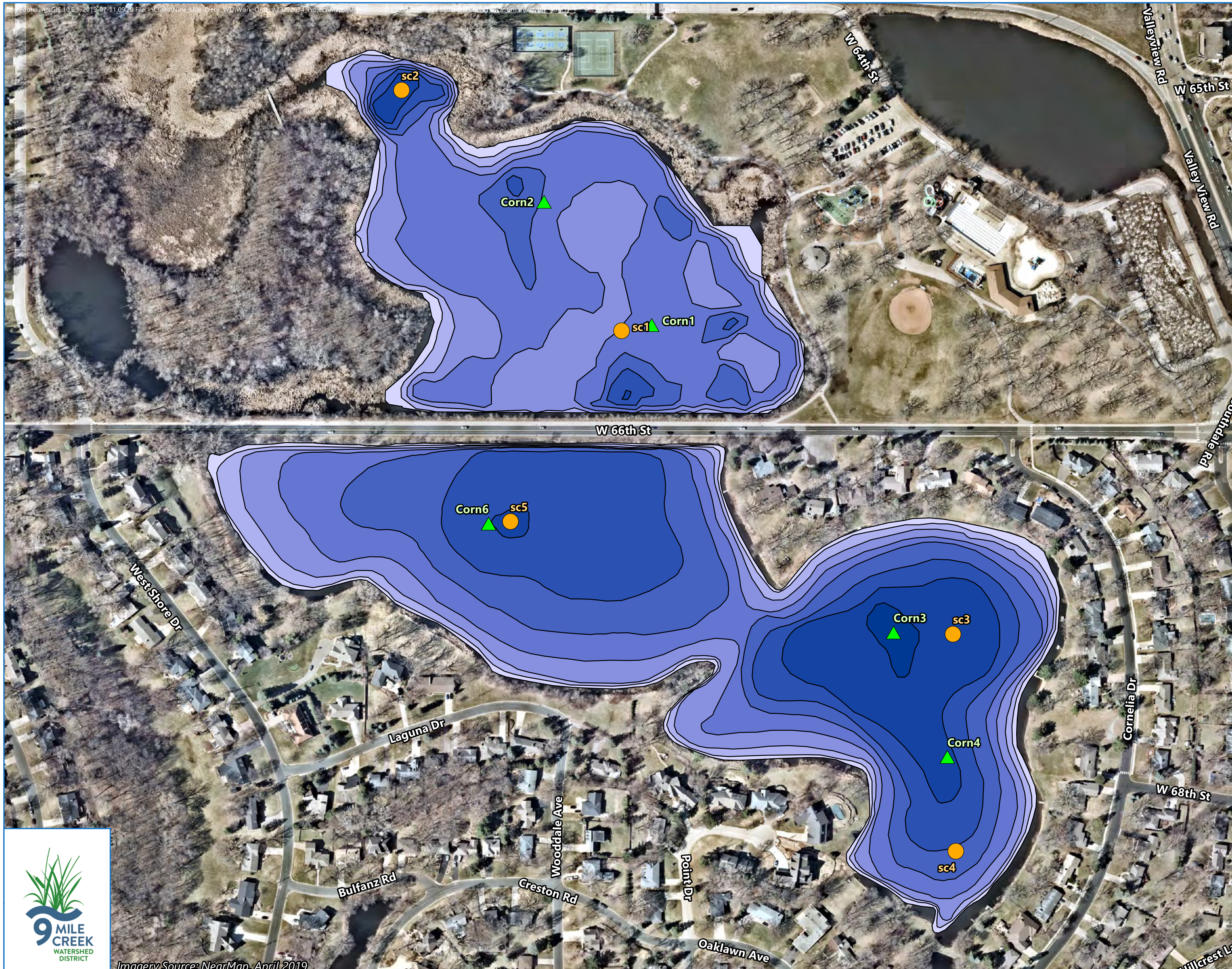
Sediment cores were collected to determine the different fractions of phosphorus in the sediment (i.e. phosphorus fractionation). Some forms of sediment phosphorus contribute to internal loading while others remain in the sediment. Conducting phosphorus fractionation of the lake-specific sediments helps maximize effectiveness and longevity of an alum treatment through development of a targeted application and dosing plan. The sediment cores were analyzed for mobile phosphorus (mobile-P) (iron-bound and loosely-sorbed phosphorus), aluminum-bound phosphorus, organically-bound phosphorus, and calcium-bound phosphorus (calcium-P). The sediment was also analyzed for percent water and percent organic carbon to calculate the density of the sediment. Mobile phosphorus is the phosphorus fraction that that causes internal loading during the summer months when oxygen is low. This fraction is also used to calculate alum (aluminum) doses necessary to prevent internal loading. Organically-bound phosphorus slowly decays over time and this fraction is also important as it will eventually become mobile phosphorus and lead to future internal loading. Aluminum-bound and calcium-bound phosphorus also provide information about sediment mixing, the layer of sediment actively releasing phosphorus, and historical phosphorus inputs.

A total of five sediment cores were collected from the lake bottom in 2008 and five cores were collected in June 2019 (see Figure 1). A few differences were noted between the sediment collected in 2008 and the sediment collected in 2019. The sediment was less dense in 2019 and the concentration of organic phosphorus (organic-P) was higher in 2019. This is perhaps an outcome of the dense curly-leaf pondweed growth and die-off in recent years. Curlyleaf growth and die-off could lead to a build-up of a more organic sediment with higher organically-bound phosphorus. A summary of the sediment chemistry is provided in Table 1 below.

Table 1 Average phosphorus concentrations in sediment cores collected in Lake Cornelia in 2008 and in 2019

Units are mg phosphorus per gram of dry sediment.

Basin	Average-Top 6 cm							
	Mobile P (mg/g dry)		Aluminum-P (mg/g dry)		Organic-P (mg/g dry)		Calcium-P (mg/g dry)	
	2008	2019	2008	2019	2008	2019	2008	2019
North Cornelia	0.29	0.23	0.09	0.05	0.18	0.71	0.25	0.21
South Cornelia	0.13	0.05	0.07	0.05	0.19	0.72	0.23	0.22



Sediment Core - 2008

Sediment Core - 2019

Approximate Water Depth

- 0 - 1 Feet
- 1 - 2 Feet
- 2 - 3 Feet
- 3 - 4 Feet
- 4 - 5 Feet
- 5 - 6 Feet
- 6 - 7 Feet
- 7 - 8 Feet

N

250 0 250

Feet

SEDIMENT CORING LOCATIONS

Lake Cornelia

Edina, Minnesota

Figure 1

4 Alum Application and Dosing Plan

Collecting sediment cores and conducting phosphorus fractionation of the lake-specific sediments is important in developing a targeted application and dosing plan that will maximize effectiveness and longevity of an alum treatment. One of the purposes of sediment coring and phosphorus fractionation is the calculation of an alum dose that can bind the mobile phosphorus fraction and prevent internal loading (the mobile phosphorus fraction is the fraction that releases during low oxygen conditions). Another purpose is to understand and plan for the fraction of organically- bound phosphorus in the sediments, as that fraction decays over time (e.g., 10% a year) and becomes part of the mobile P pool.

Sediment analysis results indicate the concentration of organically-bound phosphorus is high in North and South Lake Cornelia and hence a split alum (aluminum) application is recommended. Half of the alum (aluminum) would be applied followed by another treatment 5 years after the initial treatment. This would allow the organic-P to decay into mobile phosphorus and then the second application would bind the decayed/new mobile phosphorus. It should be noted that alum (aluminum) cannot directly bind and immobilize the organically-bound aluminum. Finally, it should also be noted that mobile P was lower in 2019. This is likely due to the timing of sediment collection, cores were collected in the first week in June in 2019 (some phosphorus likely had already released from the sediment thereby reducing the concentration of phosphorus in the sediment) while the cores from 2008 were collected the last week of October (phosphorus should have settled back down into the sediments). Sediment chemistry data from both 2008 and 2019 were used to calculate alum doses.

Using the mobile-P data collected from North and South Lake Cornelia and the methods of Pilgrim et al., 2007, alum doses were calculated to achieve an approximately 85 percent internal phosphorus loading reduction (Table 2). This target was used for the 2018 UAA update, as internal load reduction targets greater than 85 percent often lead to significantly higher doses and costs and the additional benefit is negligible and not cost efficient. The total alum dose was calculated to immobilize mobile phosphorus in the top six centimeters of sediment. Because Lake Cornelia is shallow, it will be necessary to apply both alum and sodium aluminate to buffer pH in a near neutral (pH 7.0) range that is safe for fish and aquatic life. The application area includes all areas within both basins with water depths greater than two feet.

The recommended dose for 2019 for North Cornelia is 55 grams of aluminum per square meter of lake-bottom and 22 grams of aluminum per square meter of lake-bottom for South Cornelia. For comparison purposes, the alum dose for the 2019 alum treatment at Normandale Lake was approximately 30 grams per square meter of lake bottom. For the recommended dose in 2019, a comparison to Normandale Lake shows that a higher dose is being applied to North Cornelia while a slightly lower dose is being applied to South Cornelia (see Table 2). These differences are based upon the concentration of mobile-P in the sediments of these lakes. The collection of sediment cores is recommended one year prior to the application of the second dose to North and South Cornelia to confirm that the second application is warranted and to update the dose, as necessary, based on mobile-P concentrations.

Table 2 **Recommended alum and sodium aluminate application dose for 2019 and the total application dose after a second application**

Bay	Treatment Area (ac)	Mobile-P ($g\ m^{-2}\ cm^{-1}$)[1]	Aluminum Dose ($g\ m^{-2}$)	Gallons per Acre		Total Gallons	
				Alum	Sodium Aluminate	Alum	Sodium Aluminate
Recommended Dose for 2019							
North Cornelia	15.6	0.33	55	439	220	6,850	3,425
South Cornelia	27.7	0.13	22	174	87	4,817	2,409
Total						11,667	5,834
Full Dose: Amount of Alum Application Applied in Total After Second Application[2]							
North Cornelia	15.6	0.33	110	878	439	13,700	6,850
South Cornelia	27.7	0.13	44	348	174	9,634	4,817
Total						23,335	11,667

[1] Mobile phosphorus concentration consists of the iron-bound and loosely-sorbed phosphorus concentration. Value is the average of the top 6 cm of sediment which was used for dosing purposes.
[2] Total application dose assumes the second application will be at a dosing rate consistent with the recommended 2019 dose. Additional sediment core collection and analysis is recommended prior to second application to confirm dosing rate.

5 Cost Estimate

5.1 Opinion of Probable Cost

A planning-level opinion of probable cost was developed for the alum treatment based on previous project applications and communication with an alum application contractor. The cost estimate includes individual and total costs for a split dose in 2019 and 2024, in 2019 dollars. The opinion of cost is intended to provide assistance in planning and budgeting, but should not be assumed as an absolute value. The estimated costs are summarized in Table 3.

Table 3 Engineer's opinion of probable cost

Basin	Treatment Cost[1] ($)	Treatment Cost Range[2]($)		Estimated Life of Project
		Low	High	
2019 Alum Treatment- 1st Dose	$116,000	$104,000	$139,000	5 years
2024 Alum Treatment- 2nd Dose	$116,000	$104,000	$139,000	5 years
Total (combination of two treatments)	$232,000	$208,000	$278,000	10 years

[1] Treatment cost includes mobilization cost estimate ($15,300), alum application cost estimate ($69,700), engineering costs for bidding, contracting, pH monitoring and contractor oversight ($20,000), and 10% overall contingency.
[2] Opinion of probable cost is considered a Class 2 cost estimate corresponding to standards established by the Association for the Advancement of Cost Engineering (AACE), with a range between -10% and +20%.

5.2 Cost-Benefit Analysis

A cost-benefit analysis of potential management activities in Lake Cornelia and its tributary watershed was conducted as part of the recently completed Use Attainability Analysis (UAA) for Lake Cornelia (updated from 2010) and Lake Edina (first version). Results of the analysis showed that the cost-benefit ratio for the alum treatment is low in comparison with other watershed management practices, indicating a high benefit per dollar spent. Published literature supports the conclusion that alum treatment costs are often low compared to the benefit that is received in terms of phosphorus reductions (see Bartodziej et al., 2017). As part of this analysis, the cost-benefit ratio was recomputed based on the estimated alum treatment costs identified in Section 5.1. The methodology and results are summarized below.

Estimated costs for the alum treatment were annualized to help compare the cost-benefit ratio. The annualized cost for each management alternative is based on anticipated maintenance, replacement costs, and anticipated useful life-span of the projects/treatments. A 3% interest rate was assumed. The annualized cost was calculated as the value of 'n' equal, annual payments, where 'n' is the anticipated useful life-span of the project or treatment.

For the cost-benefit analysis, two approaches were considered to quantify the benefits of each of the evaluated management activities. The first approach quantifies the benefit in terms of phosphorus removed (in pounds) during the time period of April through September (i.e., phosphorus that did not enter the lake system as a result of the management practice). Table 4 summarizes the annualized costs per pound of phosphorus removed in North and South Cornelia. The second approach quantifies the benefit in terms of reduced summer average total phosphorus concentration in North and South Cornelia (June through September). Table 5 summarizes the annualized costs per unit reduction in in-lake summer average total phosphorus concentration (µg/L) from conducting an alum treatment.

Table 4 Summary of annualized cost per pound of total phosphorus removed from conducting an alum treatment in Lake Cornelia

Basin	Estimated Treatment Cost[1] ($)		Annualized Estimated Treatment Cost ($/year)		Current TP Load[2] (lb)		Average TP Load Removed (lb)[2,3]		Annualized Cost per Pound of TP Removed ($/lb)	
	Low	High	Low	High	Low	High	Low	High	Low[6]	High[6]
North Cornelia	$61,000	$82,000	$13,745	$18,370	456	673	54	222	$340	$62
South Cornelia[4]	$43,000	$57,000	$9,665	$12,918	442	525	86	169	$150	$57
Both	$104,000	$139,000	$23,411	$31,289	898	1,198	140	391	$223	$60

[1] Estimated cost range reflects -10% to +20% of point cost estimate for each lake.
[2] Range from the 2018 Lake Cornelia UAA for modeling years 2015, 2016, and 2017. Load for modeling period early-to mid-April through September 30.
[3] Load reduction for modeling period early to mid-April through September 30.
[4] Part of the load reduction in South Cornelia is a result of the load reduction in North Cornelia.
[5] Cost-benefit calculation assumes that the longevity of the alum treatment is 5 years.
[6] High estimate assumes the low annual phosphorus load reduction and the high cost and the low estimate assumes high annual phosphorus load reduction and the low cost.

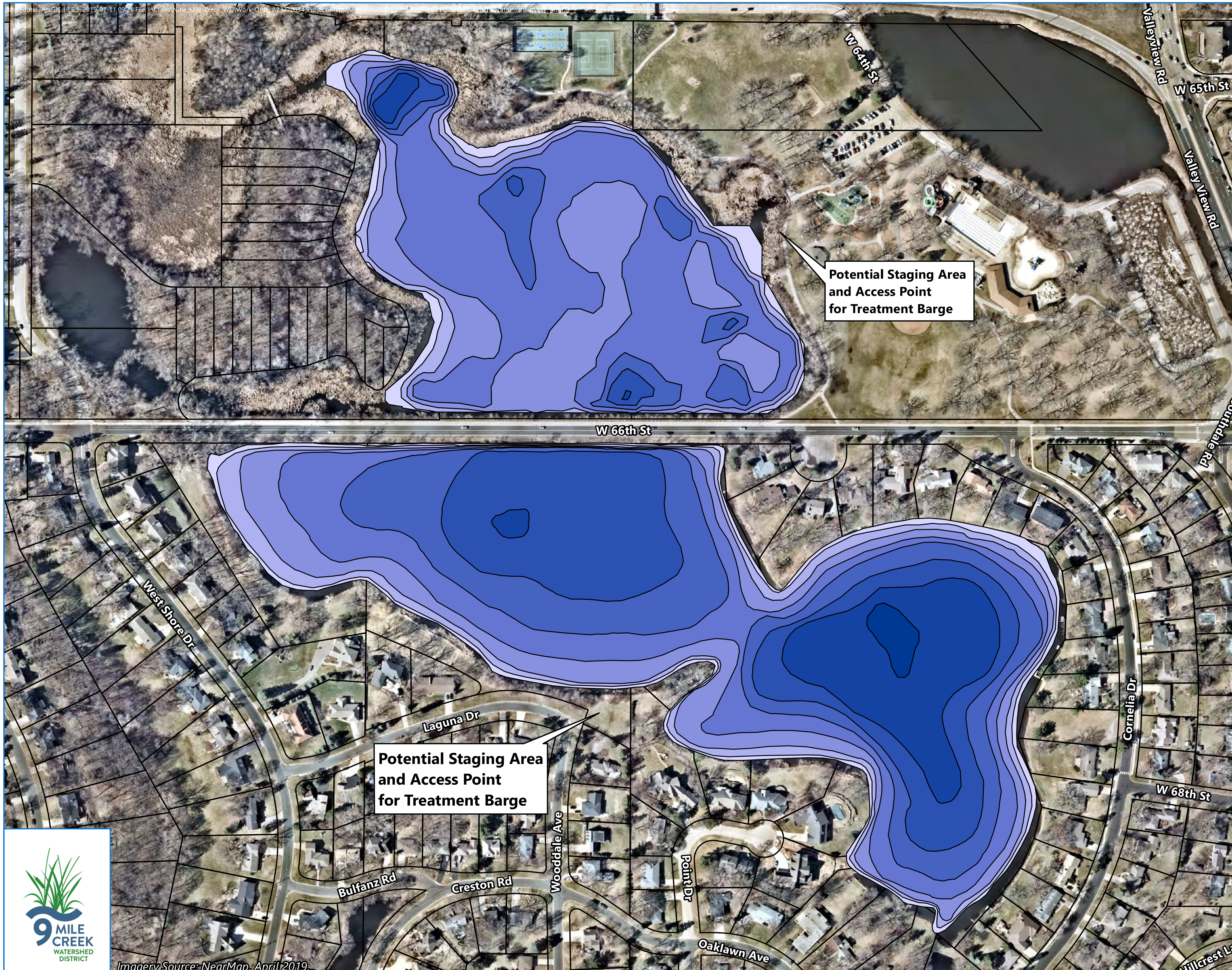
Table 5 Summary of annualized cost per unit reduction (µg/L) in summer-average total phosphorus concentration.

Basin	Treatment Cost[1] ($)		Annualized Estimated Treatment Cost ($/year)		Current In-Lake Summer-Average Phosphorus Concentration (µg/L)		In-Lake Phosphorus (µg/L) Reduction[2]		Cost Benefit ($/µg/L P Reduction)[3]	
	Low	High	Low	High	Low	High	Low	High	Low[4]	High[4]
North Cornelia	$61,000	$82,000	$13,745	$18,370	126	185	21	42	$875	$327
South Cornelia[4]	$43,000	$57,000	$9,665	$12,918	118	178	25	85	$517	$114

[1] Estimated cost range reflects -10% to +20% of point cost estimate.
[2] From the 2018 Lake Cornelia UAA for modeling years 2015, 2016, and 2017.
[3] Cost-benefit calculation assumes that the longevity of the alum treatment is 5 years.
[4] High estimate assumes the low annual phosphorus benefit and the high cost and the low estimate assumes high annual phosphorus benefit and the low cost.

6 Site Access

Site access options were evaluated as part of this study, which included review of land use and topographic conditions adjacent to the lake and communications with City of Edina staff and an alum application contractor. Direct access to the lake for barge access, rather than using a crane to place the treatment barge on the water, is preferable and would likely be more cost effective. A staging area near the lake where temporary tanks can be placed to hold alum and sodium aluminate will be necessary. These tanks are used to refill the alum treatment barge. Potential site access locations are shown in Figure 2, based on these considerations. A city-owned parcel at the intersection of Laguna Drive and Wooddale Avenue has been identified as a potential barge launching and staging area for treatment of South Cornelia. The area just north or south of the fishing pier in Rosland Park has been identified as a potential barge launching and staging area for treatment of North Cornelia. The fishing pier would be useful for barge refilling as it would allow the barge to remain in the deeper part of the lake during refilling and hence there would be reduced sediment disturbance. Both of these sites have been discussed with the City of Edina as potential boat launching and staging areas with use by the contractor contingent upon written approval by the City of Edina Parks Department.



Parcel Boundaries

Approximate Water Depth

- 0 - 1 Feet
- 1 - 2 Feet
- 2 - 3 Feet
- 3 - 4 Feet
- 4 - 5 Feet
- 5 - 6 Feet
- 6 - 7 Feet
- 7 - 8 Feet

N

250 0 250

Feet

9 MILE CREEK WATERSHED DISTRICT

POTENTIAL STAGING LOCATIONS

Lake Cornelia

Edina, Minnesota

Figure 2

7 Permitting

With the exception of a written letter of approval by the City of Edina Parks Director for site access, no additional local permitting requirements have been identified for the alum application. The Minnesota Pollution Control Agency (MPCA) typically requires submittal of a notification letter regarding the planned alum treatment. This letter typically includes a basis of the need for the alum treatment, dosing, and application timing. The MPCA provides a written notification to proceed.

8 Timing

The effectiveness of an alum treatment can be influenced by the timing of application. Typically, alum treatments are conducted in the spring or fall to avoid alum floc getting caught up on vegetation and to avoid floc settling impedance during an algal bloom (the floc can get stuck to buoyant algae). The alum treatment in Lake Cornelia is tentatively planned for October 2019. During the fall, the primary limitations for treatment are ice formation and water temperature (temperature needs to be approximately 42 degrees Fahrenheit or greater).

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