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BCWMC 9-19-13

Feasibility Report for Water Quality Improvements in Twin Lake

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February 2013

Feasibility Report for Water Quality Improvements in Twin Lake CIP Project TW-2

Engineer's Report to the Bassett Creek Watershed Management Commission

February 2013

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the Laws of the State of Minnesota.

Karen L. Chandler

Karen L. Chandler
Reg. No 19252 Date 2-14-2013

Prepared by
Barr Engineering Company
4700 West 77th Street • Minneapolis, MN 55435-4803
Phone: 952-832-2600 • Fax: 952-832-2601

Feasibility Report for Water Quality Improvements to Twin Lake
CIP Project TW-2
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Executive Summary

In 2008, phosphorus concentrations began to increase significantly in the surface waters of Twin Lake. Again in 2009, phosphorus increased significantly. A study was conducted (the Twin Lake Phosphorus Internal Loading Investigation, Barr Engineering Co., March 2011) to determine the cause of these increased phosphorus levels. Increased release of phosphorus from lake sediments (internal phosphorus loading) and enhanced transport of phosphorus from bottom waters to the surface were identified as the causes of increased phosphorus levels in Twin Lake surface waters. Warming of Twin Lake waters, likely due to recent warm climatic conditions, was the likely trigger for these recent changes.

This feasibility study evaluated six management options to address increasing phosphorus and algae in Twin Lake. These management options either: (1) tie up or bind phosphorus in lake sediment, (2) physically remove phosphorus from the lake, or (3) reduce algal growth. The six options include hypolimnetic withdrawal, sediment phosphorus inactivation (alum treatment), biomanipulation, barley straw, aeration, and dredging.

Alum treatment was identified as the most feasible option based upon cost, probability for success, and maintenance. Alum treatment is the low cost option ($148,000). It has a high probability of success, defined as reducing phosphorus in Twin Lake surface water to levels experienced prior to 2008. Alum treatment requires no maintenance.

1.0 Background

Twin Lake is an inland lake with a 20-acre surface area located in Golden Valley, Minnesota (Figure 1). Twin Lake is located directly east of Sweeney Lake and is partially within Theodore Wirth Regional Park. It is within the Bassett Creek Watershed and is managed by the Bassett Creek Watershed Management Commission (BCWMC). During 2008 and 2009, water quality at Twin Lake failed to meet Minnesota water quality standards and the water quality goals established by the BCWMC. The lake was “eutrophic” due to high phosphorus concentrations and dense algae growth seen in the lake. The Twin Lake Phosphorus Internal Loading Investigation (Barr Engineering Co., March 2011) was conducted to identify the cause of significantly increasing phosphorus levels in surface waters in recent years. It was determined that increasing internal phosphorous loading (triggered by a warming of lake water temperature and subsequent dissolved oxygen depletion) from lake bottom sediments was responsible for the significant increase in phosphorus concentrations in surface waters (see Figure 2 for sediment sampling locations). Phosphorus is held in lake sediment by iron. When oxygen is reduced in the lake water column and depleted in sediments, iron can no longer hold phosphorus. Although there are other elements that can hold phosphorus in the sediment (e.g., calcium, magnesium, and aluminum), these elements are not available at adequate levels to bind phosphorus and prevent internal phosphorus loading.

There are essentially three general approaches to address the high levels of phosphorus and algae in Twin Lake:

1. ***Tie up the phosphorus*** in the lake sediment by adding phosphorus-binding elements such as calcium or aluminum (alum treatment, see Section 2.2) or by increasing oxygen to enhance iron binding (see Section 2.5).

2. ***Physically remove phosphorus*** by withdrawal of water from the lake bottom (hypolimnetic withdrawal, see Section 2.1) or by dredging phosphorus-laden sediments from the lake bottom (see Section 2.6).

3. ***Reduce algal growth*** and concentrations by promoting a more balanced fishery (biomaniption, see Section 2.3) or by inhibiting algal growth with a natural algaecide (barley straw, see Section 2.4).

This report makes a recommendation, based on cost, maintenance considerations, environmental considerations, and potential for success.

2.0 Management Options

Six management options were analyzed and are discussed below. For each option, a description is provided, along with costs (including capital, operation, engineering, and permitting), benefits of the approach, drawbacks of the approach, and identification of permitting agency. Table 1 includes a feasibility level opinion of cost for each option.

2.1 Hypolimnetic Withdrawal

Hypolimnetic withdrawal involves the direct removal of phosphorus-laden lake bottom waters. Because of the small watershed of Twin Lake, treated water must be returned to the lake to maintain lake levels. A hypolimnetic withdrawal system includes a pipe and perforated riser that is installed along the lake bottom, near the deepest point, and connects to a shoreline treatment system consisting of pumps, tanks to hold chemicals, and a clarifier to settle treated water.

The primary benefit of hypolimnetic withdrawal is the prevention of phosphorus accumulation in bottom waters and the potential transport of high phosphorus bottom waters to the surface of Twin Lake. The other benefit is that treatment is conducted out of the lake water column (i.e., not in the lake itself).

The primary drawbacks to this method include:

- Water removed from the hypolimnion has a strong odor (rotten egg smell caused by hydrogen sulfide) and systems often need to be shut down during summer (when internal loading is highest) due to complaints from lake users or neighboring residents.

- Hypolimnetic withdrawal followed by treatment and discharge back to the lake is an inefficient approach to removing phosphorus compared to a whole-lake treatment, given the high cost (capital and operation and maintenance) of such a system.

- Potential warming of the lake water as bottom waters are exposed to surface temperatures during treatment. This warmed water will need to be returned to the lake at the appropriate depth to avoid triggering lake mixing.

For this study, construction costs were estimated at $400,000 and annual operation and maintenance costs (includes electricity, chemical cost, and settled flocculent disposal) were estimated at $40,000. Engineering and design costs were assumed to be 20% of the total capital cost and a contingency of 25% of capital cost was applied. For a 20-year design life, and after including permitting cost, this results in a total cost of $1,330,000. A national pollutant discharge elimination system (NPDES) permit will be required from the MPCA to construct and operate this system. A work in public waters permit will also be required from the Minnesota Department of Natural Resources.

2.2 Sediment Phosphorus Inactivation (Alum Treatment)

Twin Lake is largely a net “sink” for phosphorus, meaning, phosphorus that goes into the lake stays in the lake and accumulates in bottom sediments. If the sediments contain high levels of phosphorus-binding elements that resist the effects of low oxygen (oxygen resistant elements include calcium, magnesium, and aluminum), then this phosphorus will remain in the lake bottom sediments, even if oxygen is low. If phosphorus increases to high concentrations in lake-bottom waters when dissolved oxygen is low, this indicates that phosphorus is primarily bound to iron instead of calcium, magnesium, and aluminum. This is the case for Twin Lake. To immobilize phosphorus in Twin Lake sediment, additional calcium, magnesium, or aluminum must be added. Of these three elements, aluminum most readily binds phosphorus (and displaces iron) at the pH conditions found in lake sediments. Calcium can also bind phosphorus in lake sediments (lakes limed for pH control in Sweden have shown increased calcium phosphate binding), however, this would be considered an experimental approach and permitting would be more complicated and more expensive.

Addition of aluminum (in the form of alum) to bind excess phosphorus in lake sediments is the most widely-accepted and well-understood approach, largely because it is effective (e.g., it bind phosphorus even at lower pH levels found in lake sediment), and it is not affected by low oxygen levels in the lake bottom waters. When alum is added to a lake, it forms a white floc that then settles through the water column and deposits on the sediment surface. The alum floc then mixes into the sediment and binds available phosphorus. Until recently, dosing methods were crude and many lakes (especially shallow lakes) were under-dosed, causing short lived treatment longevity in some cases. Better dosing methods have been developed recently, reducing the chance for under-dosing. Treatment longevity has ranged from 4 to 21 years in stratified lakes, and from less than 1 year to 11 years in shallow lakes (Welch and Cooke 1999). It is expected that treatment longevity could range from 10 to 20 years for Twin Lake because of the limited watershed size, and the lake is deep and protected from wind. The treatment is anticipated to reduce the internal phosphorus load by 242 pounds per year. An indirect benefit resulting from sediment phosphorus inactivation is increased dissolved oxygen in the hypolimnion. This occurs because productivity in the lake (algal growth) is lower after treatment, and less organic matter is deposited on sediments, all of which cause oxygen depletion.

The primary drawback with an alum treatment is that it likely will need to be conducted again in the future. None of the mitigation approaches outlined in this document can be considered permanent; however, alum is often viewed differently because the source of the aluminum is an ore which is a non-renewable resource. Although a thorough discussion is beyond the scope of this review, there is an ongoing debate about the potential human health effects (i.e., Alzheimer's) of aluminum. It should be noted that aluminum does not remain in the water column of an alum-treated lake and in some cases alum treatments have led to a reduction in the long-term concentration of aluminum in the water column. Over the long term, aluminum that settles in the sediment becomes an inert mineral called gibbsite. For shallow lakes, aluminum may cause the pH to drop and cause a fish kill. This will not happen in Twin Lake because it is deep and the pH effects will be minimal. Also, it is recommended that the treatment be split and applied in subsequent years; this will reduce potential pH effects.

The aluminum (alum) application for Twin Lake is estimated to cost $148,000, including engineering and design (20%), a contingency (25%), and permitting. Engineering and design includes time to develop maps to guide the contractor where to apply alum (the aluminum compound), develop contract documents, and selection of a contractor. This cost estimate does not include time to monitor the alum treatment. Permitting consists of a request to the MPCA to conduct an alum treatment. Typically the MPCA provides a letter giving approval of the treatment with monitoring requirements. A work in public waters permit will also be required from the Minnesota Department of Natural Resources.

2.3 Biomanipulation

Biomanipulation usually involves the removal of rough fish such as carp and introduction of piscivores (for example, bass and northern pike). In lakes with low populations of piscivores, small planktivorous fish reduce zooplankton populations that graze on algae. Although zooplankton cannot entirely control excess algae growth, they can notably reduce algal populations in lakes that have moderate populations of algae (e.g., mesotrophic lakes). When piscivores are added, they reduce the planktivorous fish population, allowing zooplankton to graze algae more effectively.

The benefits of this method are its comparatively low cost, improved fishery, and reduced algal populations. This method is not invasive (e.g., compared to dredging) and may be defined as "natural." The primary disadvantage of this method is that even if successful, meaning, the zooplankton population increases and algae are more heavily grazed, algae populations will not be reduced significantly given that algae populations are quite high in Twin Lake. Also, surface water phosphorus concentrations may not meet the BCWMC water quality goals or State water quality standards, even though algae are reduced.

The cost of biomanipulation as a management method includes three tasks. First, rough fish such as carp must be removed. In Twin Lake, this removal process must be done while there is open water, using a combination of seining (netting) and electrofishing. The approximate cost of this task is $8,000; there is some uncertainty in this estimate given that the size of the carp population in Twin Lake is not well understood. Second, the lake would be stocked with pike and bass. Because Twin Lake has an existing fish population, stocking efforts must consist entirely of full grown individuals, not young fishes (fingerlings) due to their low survival rate. This stocking would be done in the fall months and would consist of 3 northern pike individuals per surface acre and 100 largemouth bass individuals per surface acre. The cost to purchase fish for stocking from a retail outfitter would be $6,000 for the pike stocking and $39,000 for the bass stocking.

Finally, since fish can migrate freely between Sweeney and Twin Lakes, the fish populations would have to be monitored yearly, at a cost of $1,000 per year. If monitoring results suggest that the stocking has not been successful, repeat stocking efforts would be needed. The cost estimate for this option includes up to three repeat stocking efforts, in years 2, 4, and 6. If, after four stocking efforts, carp populations have returned or pike and bass populations have not stabilized, alternative management methods would need to be considered. The total cost for four stocking efforts, monitoring, permitting, and contingency (25%) is $270,000. The Minnesota Department of Natural Resources Fisheries Department issues permits for fish stocking.

2.4 Barley Straw

Barley straw is added to the shoreline of small water bodies to limit the growth of algae. The barley straw is placed into mesh bags and staked along the shore so it is partially submerged in water. Recent research shows that during the breakdown of barley straw in lake water, chemicals are produced that prevent the growth of some algae during the summer. For barley straw to be effective, it must be added every year, otherwise conditions are likely to return to the way they were before treatment.

The use of barley straw has decreased the growth of algae in approximately 50% of the cases studied. Dosing methods are variable, so it is difficult to determine why some cases are successful and others are not. The main benefit of barley straw is reduced algae growth. The primary disadvantage of barley straw is that its effectiveness is uncertain and the degree to which it may reduce algal growth (if effective) is hard to predict. The use of barley straw will not reduce phosphorus levels in Twin Lake. Barley straw may also have an unintended consequence of adding organic matter and reducing dissolved oxygen in the lake.

Barley straw is applied at a rate of 300 pounds per acre of lake surface. At a cost of $12 per 45-pound bale of barley straw, the yearly cost for barley straw for Twin Lake will be $1,680. Additional costs include $1,000 for delivery, $500 for materials (bags and stakes) and $8,000 for labor to apply barley straw to the shoreline. The total annual cost of a barley straw application would be $11,180. Since barley straw must be applied annually, the cost to apply barley straw for the 20-year design period is $279,500 (including a 25 percent contingency and permitting). The MPCA's general permit program for pesticides covers barley straw application. A notice of intent must be filed with the MPCA prior to barley straw application.

2.5 Aeration

Aeration involves the addition of oxygen to the hypolimnion (e.g., the lake bottom waters). For Twin Lake, the purpose of installing an aeration system would be to reduce the release of phosphorus from lake sediment. There are a number of ways to aerate bottom waters in lakes:

1. Pure oxygen can be pumped to the bottom of the lake where oxygen then diffuses into the water.

2. Air can be pumped to the bottom of a lake to induce mixing and exposure of bottom waters with low oxygen to air at the lake surface.

3. Hypolimnetic water can also be pumped to the surface, run through a baffle system where oxygen can diffuse into the water, and then be returned to the hypolimnion or the lake surface.

In several applications, aeration has been successful at increasing dissolved oxygen in bottom waters. In some of these cases, however, lake water quality did not improve (and in a few cases worsened) because it is difficult to force aerated water to move downward in the lake column and contact the lake sediments. Aerated water has a tendency to move upward with increased buoyancy, and water along the sediment-water interface is difficult to disturb without disturbing sediment. Phosphorus that continues to release from lake sediments (even with aeration) is quickly transported to the lake surface where algae are growing. Thus, design of aeration systems is challenging. The sediment must also contain adequate iron levels to bind phosphorus to prevent the release of phosphorus, even under oxygenated conditions. In lakes with high internal loading, the sediment-binding capacity is often low relative to the amount of mobile phosphorus, and iron would need to be added to improve phosphorus binding with aeration.

Two types of aeration systems were studied for this report. The first is a bubbler system. Although there can be several approaches to diffusing air into lake water, the approach that was evaluated for cost-estimating purposes consists of flexible tubing (soaker hoses) installed at the lake bottom and pumps that provide compressed air to the tubing. The second system evaluated is a Solar Bee solar-powered mixing system. This proprietary system consists of a tube with an impeller that pulls water from the bottom of the tube to the surface. The colder water then plunges on the outside of the tube, causing the lake to destratify and presumably improve dissolved oxygen. The tube can be placed at a depth below the thermocline to access cold water.

Costs for a bubbler system were estimated based on a past lake aeration project. The length of the aeration system, consisting of parallel soaker hoses deployed in Twin Lake (total length 1,800 feet) was assumed to be ¾ of the lake length, or 1,350 feet. The cost/foot of bubbler system was estimated at $120/foot, resulting in a total installation cost of $160,000. The yearly maintenance cost, including power for the compressor, is estimated at $35,000. Including engineering and design (20%), a contingency (25%), and permitting cost, the total cost of a bubbler installation for a 20-year design life is $935,000. The Minnesota Department of Natural Resources Fisheries Department issues permits for aeration systems.

Because they are solar-powered, the costs of a Solar Bee system are for initial purchase only; there are no operation costs. However, storage will be required in the winter and some labor costs will be incurred with spring placement and fall removal (estimated annual cost of $5,000). These systems are under warranty for 10 years on the motor and 25 years on the photo-voltaic panels. This report assumes that the purchase of two SB10000 v10 models (the manufacturer’s recommendation for a lake the size of Twin Lake) will be sufficient for a 20-year design life. The total cost for purchase of two SB10000 v18s is $102,000. The total cost of the Solar Bee system for a 20-year design life with a 25% contingency and permitting cost is $240,700. It is assumed that engineering and design costs will be minimal. The Minnesota Department of Natural Resources Fisheries Department issues permits for aeration systems.

2.6 Dredging

Due to space limitations around Twin Lake, on-site disposal of dredged materials was deemed infeasible; therefore the opinion of probable cost consisted of a review of on-site dewatering and off-site disposal. This process involves construction and operation of an on-site dewatering facility, using chemical flocculants to minimize the size of the facility, and shipping dewatered solids to a landfill for disposal. Preliminary cost estimates indicate that the cost of dredging could exceed $100/CY of dredged materials generated. Removing 15 cm (approximately 6 inches) of sediment from the bottom of Twin Lake would yield about 17,500 CY of dredged materials, for a total capital cost of approximately $1.7 million dollars. With the inclusion of engineering and design (20%), contingency (25%), and permitting the total cost is $2,570,000.

Several permits would be required for dredging activities, including local, state, and federal permits.

3.0 Recommendations

3.1 Recommended Management Strategy

Sediment phosphorus inactivation by treatment of lake sediments with aluminum (alum) is the recommended management strategy because it is the most feasible, it is the lowest cost option, and it has the greatest probability of reducing phosphorus and algal concentrations to levels monitored in 2005. At that time phosphorus levels spiked from approximately 15 ug/L in 2005 to 40 ug/L in 2008 and then 70 ug/L in 2009. Although modeling has not been conducted, it is expected that with alum treatment, phosphorus concentrations will likely settle around 20 ug/L.

It is recommended that alum be applied to 19 acres of the lake surface. The total alum dose of 1,840 gallons per acre (total volume of 34,957 gallons) should be applied (e.g., split) into two different years (920 gallons per acre for each treatment, or 17,479 gallons total volume per treatment) to increase the treatment longevity. A period of 3 years should pass from the time that the first alum application is conducted to the second application. With these applications, it is expected that 92 percent of the potentially releasable phosphorus (the mobile phosphorus form, which is responsible for internal loading) will be bound by aluminum and no longer available for internal phosphorus loading. The treatment is anticipated to reduce the internal phosphorus load by 242 pounds per year and the treatment is expected to last 10 to 20 years.

3.2 Funding Sources

The City of Golden Valley proposes to use BCWMC capital improvement program (CIP) funds to pay for its portion of the project costs. BCWMC water quality improvement projects are funded through the BCWMC's CIP and are paid for via an ad valorem tax levied by Hennepin County over the entire Bassett Creek watershed.

3.3 Detailed Cost Estimate

The total cost to apply alum (split into two applications) in Twin Lake is estimated to cost $148,000, including engineering and design (20%), contingency (25%), and permitting cost. Engineering and design includes time to develop maps to guide the contractor where to apply alum (the aluminum compound), contract documents, and selection of a contractor. This cost estimate does not include time to monitor the alum treatment.

3.4 Project Schedule

This project is proposed as a 2014 CIP project. Assuming the BCWMC orders this project, the design for this project will begin in late 2013 or early 2014, which will include gathering public input and obtaining permits. Alum application is proposed for 2014 and 2017.

3.5 Permits

The recommended alum treatment will require an approval letter (with monitoring requirements) from the MPCA and a work in public waters permit from the Minnesota Department of Natural Resources. The project will also require coordination with the Minneapolis Park and Recreation Board (MPRB), as the lake is partially located on MPRB parkland. Other local permits will also likely be required.

Tables

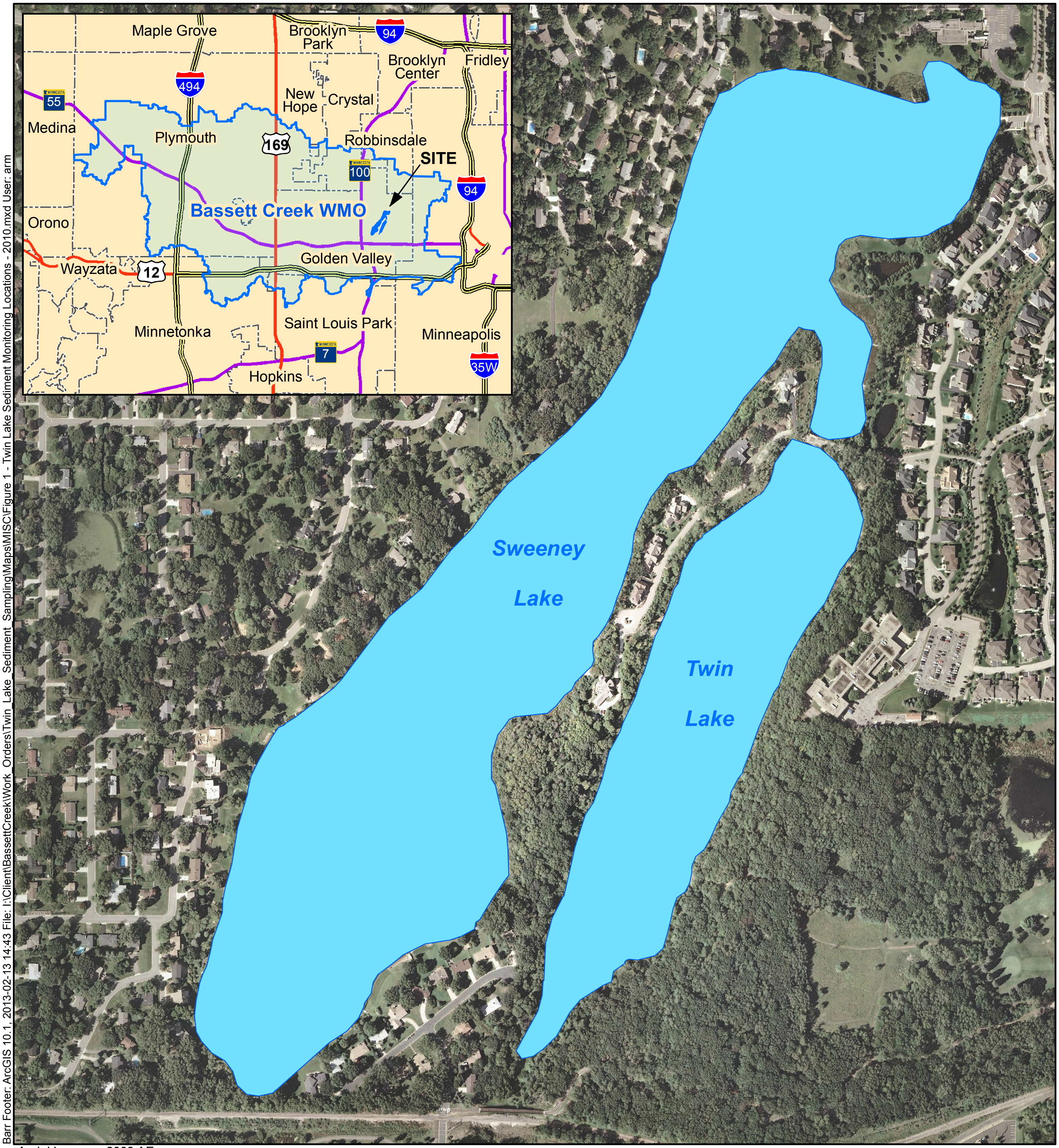
Table 1. Opinion of probable cost

Management Option	Costs					
	Capital	Engineering and Design (20%)	Contingency (25%)	Annual Operation and Management	Permitting	Total Cost over 20 Years
Biomanipulation[1]	$216,000	$ -	$54,000	$ -	$ 3,000	$ 273,000
Hypolimnetic Withdrawal	$ 400,000	$ 80,000	$ 100,000	$ 40,000	$ 10,000	$ 1,330,000
Alum Treatment	$ 100,000	$ 20,000	$ 25,000	$ -	$ 3,000	$ 148,000
Barley Straw	$ 223,600	$ -	$ 55,900	$ -	$ 3,000	$ 282,500
Aeration-Bubbler	$ 160,000	$ 32,000	$ 40,000	$ 35,000	$ 3,000	$ 935,000
Aeration-Solar Bee	$ 102,000	$ -	$ 35,700	$ 5,000	$ 3,000	$ 240,700
Dredging	$ 1,700,000	$ 425,000	$ 425,000	$ -	$ 20,000	$ 2,570,000

Notes:

(1) Biomanipulation assumes a total of four stockings conducted in years 1, 2, 4, and 6.

Figures



Aerial Imagery: 2009 AE

N

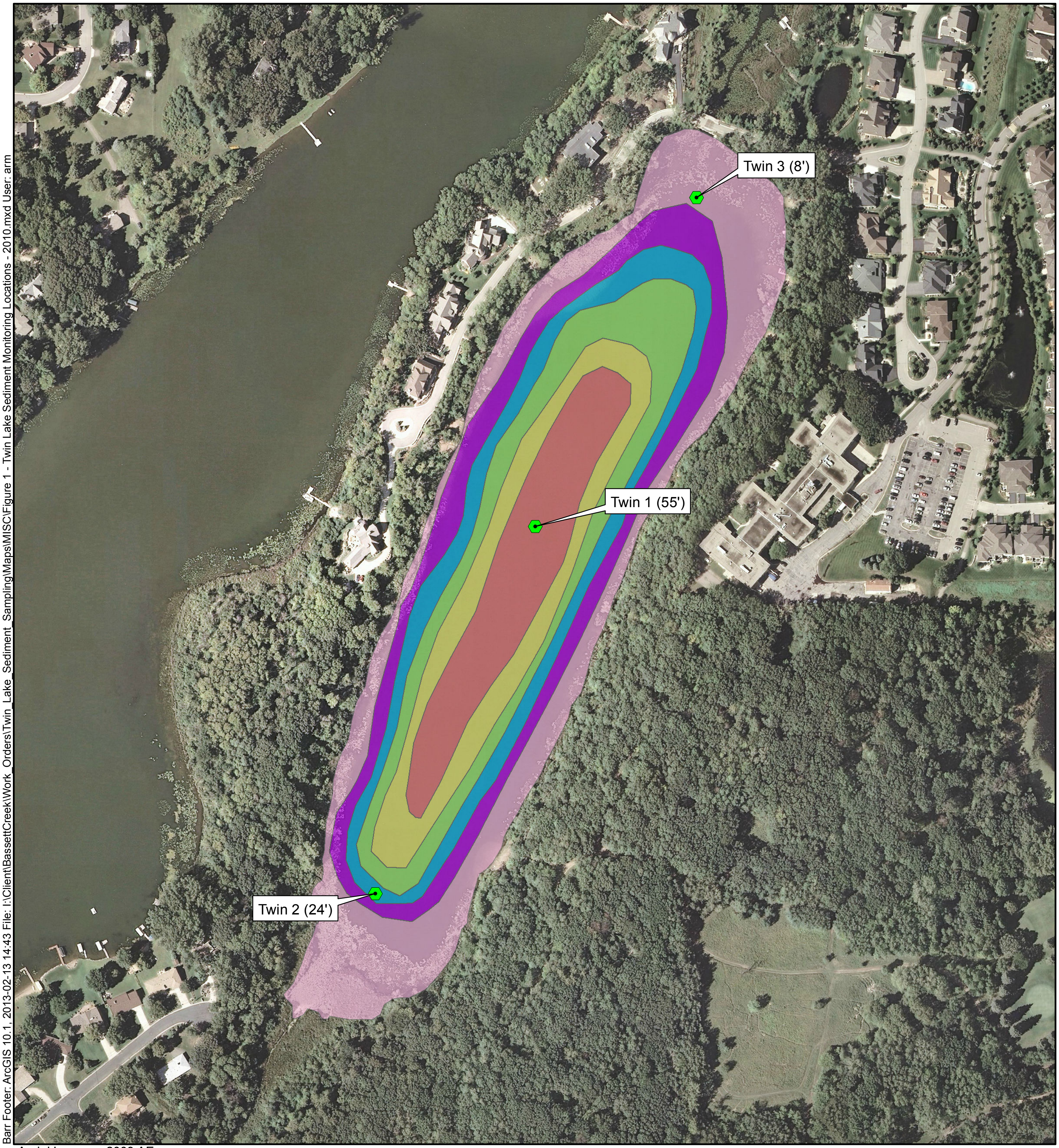
Legend

Twin and Sweeney Lakes

500 250 0 500 Feet

Figure 1

Location Map



Aerial Imagery: 2009 AE

Twin Lake (Depth in feet)

- 0-10
- 10-20
- 20-30
- 30-40
- 40-50
- >50
- Sediment Monitoring Locations

N

0 150 300 600 Feet

Figure 2

2010 Twin Lake
Sediment Monitoring Locations