Technical Pre-Proposal

Assessment and treatment of internal phosphorus loading in Shoreview Commons Pond, City of Shoreview

Part I: Pre-treatment study

Part II: Iron filings treatment and assessment study

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Proposal Summary

Project activities

The proposed project is a two-part study to (i) investigate the internal phosphorus release in a stormwater pond in the City of Shoreview (Part I), and (ii) implement an iron filings treatment in the pond and assess the post-treatment phosphorus water quality in the pond (Part II). The Part I pre-treatment study will measure the sediment phosphorus release using laboratory mesocosms of pond sediment-water columns, and measure the *in situ* water quality in the pond. If internal loading is substantial in the pond, the results will be utilized in the Part II study to chemically-inactivate the sediment phosphorus using iron filings, and then monitor the phosphorus water quality in the pond to assess the treatment effectiveness. The overall goal is to mitigate phosphorus pollution from the stormwater pond, and eventually minimize impacts on the downstream water quality.

Relevance

The US EPA has listed ~3000 surface water impairments due to excess phosphorus and eutrophication problems (US EPA 2016). Stormwater ponds are one of the widely implemented stormwater control measures (SCMs) for runoff quantity and quality control in urban areas. In Minnesota, there are over 30,000 stormwater treatment ponds that are used to remove pollutants such as solids, nutrients, metals and hydrocarbons from runoff. There is increasing evidence, however, that some ponds are no longer retaining phosphorus, and have become potential phosphorus sources due to the release of phosphorus from the bottom sediments (i.e., internal phosphorus loading). Since ponds are part of the watershed network that delivers runoff with

phosphorus to lakes and streams, the high phosphorus load and corresponding algae and floating plants in ponds present increased risks of harmful algal bloom occurrences and water quality degradation in the receiving waterbodies. Internal loading in stormwater ponds is not a well-researched topic, and methods to identify ponds that are providing poor phosphorus retention and requiring maintenance have not been thoroughly investigated. There is a need to understand the significance of internal loading in stormwater ponds, and develop management tools including effective treatment strategies to improve the water quality not only in ponds but also in lakes and streams.

Project outcomes

The proposed project will assess the importance of internal phosphorus loading in one stormwater pond, and determine the effectiveness of iron filings treatment in accomplishing the goals of reducing phosphorus loading and improving the water quality in the pond. The project will be one of the first field implementation of iron filings treatment as a sediment phosphorus inactivation method in ponds. If successful, iron filings application can be a viable tool for treating ponds to reduce the net phosphorus load discharged from the ponds. Given that a large number of ponds can experience eutrophication due to high internal loading, a decrease in pond phosphorus loading will greatly benefit the waterbodies receiving the pond outflows. Ultimately, this can lead to adaptive management of stormwater ponds, which can have important implications for Total Maximum Daily Load (TMDL) implementation plans for impaired waters.

Background

Stormwater ponds are primarily designed to detain and treat urban stormwater runoff. Phosphorus is one of the critical pollutants in runoff because phosphorus is the limiting nutrient for primary production in temperate freshwaters (Schindler 1977). Ponds typically act as sinks for phosphorus washed off from lawn fertilizers, degrading organic matter, animal wastes and other non-point sources in the surrounding watershed area. However, under certain environmental conditions, ponds can become a source of phosphorus due to the recycling of phosphorus accumulated in the bottom sediments. The increased phosphorus concentrations due to internal loading mechanisms can negate the intended purpose and diminish the overall efficacy of ponds. Internal loading is a known, significant summertime phenomenon in lakes. Reduction in internal phosphorus load is often necessary to improve the lake water quality and satisfy TMDL allocation goals.

Internal loading in ponds, as such, is poorly understood and has been a less-researched topic, although very high phosphorus levels, algal blooms, and low phosphorus retention are being observed in ponds. For example, in the Twin Cities area, 98 stormwater ponds surveyed between 2010 and 2013 contained <0.010 mg/L to 8.1 mg/L total phosphorus (Riley Purgatory Bluff Creek Watershed District 2014). As a reference, the MPCA's total phosphorus water quality standard for lakes in the North Central Hardwood Forest ecoregion is set at 0.060 or 0.040 mg/L

to prevent eutrophic conditions. Export of dissolved phosphorus (i.e., output > input) has also been observed in some urban ponds (Song et al. 2015), indicating failure to provide adequate phosphorus treatment. In a recent study on five stormwater ponds in the Twin Cities area (Olsen 2017), laboratory mesocosms of pond sediments demonstrated phosphorus release from the sediments back into the water column under low dissolved oxygen (or anoxic conditions). The phosphorus (primarily orthophosphate) release rates were between 2.27±0.44 and 7.50±2.94 $mg/m^2/day$, which can substantially increase pond phosphorus concentrations. Sediment oxygen demand measured in the mesocosms and water column dissolved oxygen concentrations measured *in situ* in the ponds confirmed that the ponds are susceptible to developing anoxic conditions during no-flow periods, which in turn can induce internal phosphorus release.

Thus, there is a need to assess more stormwater ponds and develop management strategies to control the net phosphorus release from ponds so that the impacts to downstream waterbodies can be minimized. Sediment dredging is a common pond rehabilitation measure, but the associated costs and regulatory needs for proper sediment disposal in case of PAH presence can sometimes make dredging a less favorable option. In lakes, one of the techniques to reduce internal loading is chemical inactivation of sediment phosphorus, commonly using alum, iron chloride, or activated-clay. There are some known applications of alum and iron chloride treatment of phosphorus in pond inflows.

The addition of zero-valent iron metal filings to lake sediments as a measure for internal load reduction was investigated in a recent research project (Natarajan et al. 2017). Sediment cores from two eutrophic Minnesota lakes (Rush Lake in Chisago County and Ann Lake in Wright County) were subject to experimental doses of iron filings in a laboratory-scale mesocosm setup. The anoxic phosphate release from the natural (unamended) lake sediments were approximately five times the oxic phosphate release at 20 °C. The addition of > 0.05 g iron/cm^2 sediment area significantly reduced the anoxic phosphate release. Detailed analysis of the sediment phosphorus species revealed that the iron-dosed sediments contained very low mobile phosphorus in the porewater, which resulted in the decreased phosphate flux across the sediment-water interface and the very low phosphate concentrations (<0.050 mg/L) in the water overlying the sediments. The placement of an appropriate dose of iron filings is a potential sediment phosphorus inactivation tool that can be applied in stormwater ponds.

Proposal Narrative

Part I: Pre-treatment study

Objectives

The main objective of the Part I pre-treatment study is to determine the internal phosphorus loading in the Shoreview Commons stormwater pond. Using laboratory-scale mesocosms of pond sediment-water columns, the phosphorus release rates will be measured under varying

environmental conditions. Periodic field measurements of dissolved oxygen (DO), temperature, conductivity and total phosphorus in the pond water column will also be taken to verify the environmental conditions of the pond. The water quality data and mesocosm study results will be used to assess the importance of internal phosphorus loading in the pond. The Part I study will provide the information necessary for recommending the iron filings dose required to reduce phosphorus release from the pond sediments. The dosing requirements developed in a lake sediment mesocosm study (Natarajan et al. 2017) will be used as reference. If possible, a second stormwater pond in the City of Shoreview will be sampled for water quality (DO, temperature, conductivity, and phosphorus) to serve as a "control" for part II of this proposal.

Proposed site

The Shoreview Commons pond, located north of Highway 96 in the Shoreview Commons Park, Shoreview (Ramsey County, MN) (Figure 1 and Table 1), is the proposed site for the internal phosphorus assessment and treatment studies. The drainage area to the pond (0.583 km^2; 35% impervious) consists of residential and park/institutional land. Inflow to the pond is through a storm sewer along with overland flow, and the pond outflow is routed into Snail Lake.

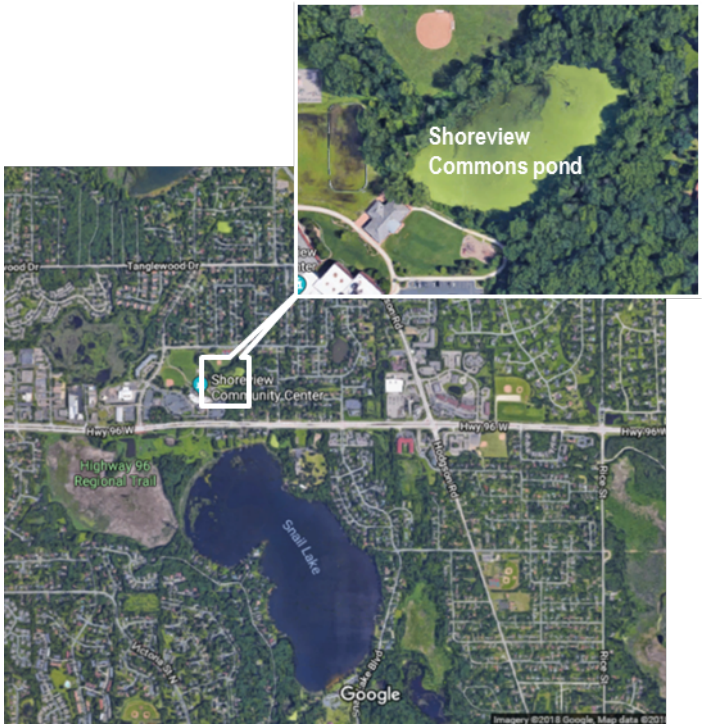

Figure 1. Map showing the location of Shoreview Commons pond in the City of Shoreview, Ramsey County, MN. (source: <www.maps.google.com>)

Table 1. Characteristics of Shoreview Commons pond, MN (data source: Stantec 2017)

Shoreview Commons pond	Characteristics
Surface area	0.0117 km^2 (2.9 ac)
Depth	0.61-1.22 m (2-4 ft); mean depth = 0.61 m (2 ft)
Volume	7154 m^3 (5.8 ac-ft)
Drainage area	0.583 km^2 (144 ac)
Drainage area: Pond area	50

The Shoreview Commons pond has been experiencing strong odor problems, low water clarity, and a heavy surface cover of duckweed especially during summer. The low water column dissolved oxygen (1.7-2.4 mg/L), and black and mucky bottom sediments indicate the presence of decomposing organic matter and reducing conditions in the pond. The 2016 water quality survey measured high concentrations of total phosphorus (0.221 mg/L) and chl-*a* (21.4 mg/L) in the pond (Stantec 2017).

Methods

The laboratory mesocosm systems will consist of pond sediment cores placed with overlying water from the Shoreview Commons pond. The dissolved oxygen (DO) levels in the water columns will be manipulated to create oxic (high DO) and anoxic (low DO) conditions, and the phosphorus release from the sediments to the overlying water will be measured. The oxic and anoxic phosphorus release rates will be quantified as the linear change in phosphorus mass in the water column over the respective experimental duration. DO, temperature and conductivity profiles will be taken at select locations in the pond during the growing season. Water samples for total phosphorus will also be collected. If the pond is found to be stratified, water samples will be collected at the surface and below the stratified layer. The laboratory data and field conditions will be related to evaluate the internal loading potential in the pond. The *in situ* water quality (DO, temperature, conductivity and phosphorus) in a second stormwater pond in the City of Shoreview will likely be collected, for use as control data for part II of this proposal.

Task 1. Sediment core collection (Shoreview Commons pond)

Six intact sediment cores with overlying water column, spatially distributed across the pond area, will be collected through ice or from a boat. DO, temperature, and conductivity measurements will also be taken at the coring locations.

Task 2. Laboratory mesocosm studies (Shoreview Commons pond)

The six sediment-water columns will be set up at 20 °C at the St. Anthony Falls Laboratory (SAFL). Bubblers will be placed above the sediment-water interface to simulate oxic (by air bubbling) or anoxic (by nitrogen gas bubbling) conditions in the water column. The

concentrations of soluble reactive phosphorus (primarily phosphate) in the water will be monitored throughout the experimental duration, and the oxic and anoxic phosphate release rates determined.

Task 3. In situ water quality sampling (Shoreview Commons pond and a control pond)

The DO, temperature and conductivity profiles will be measured in the water column, and water samples for total phosphorus concentrations will be taken in selected locations in the pond. Data collection will be done a few times during the growing season.

Task 4: Project report

A final project report, summarizing the results of the laboratory mesocosm studies and the *in situ* water quality observations, will be prepared.

The budget subtotal for Tasks 1 to 4 is $8,780.

Task 5. Sediment analysis (optional; recommended for Part II study)

Task 5 is included as an optional task in the Part I study, but is highly recommended considering the scope of the Part II study. The pond sediments will be analyzed for phosphorus and associated metal concentrations. The available (redox-sensitive and labile organic phosphorus) and unavailable (aluminum- and mineral-bound) forms of phosphorus in the pond sediments will be determined by the sequential phosphorus extraction method. Concentrations of metals (Fe, Al, Ca) in the sediments will be measured. The data will be related to the phosphorus release rates measured in the mesocosms. The main purpose of Task 5 is to gather pre-treatment sediment quality data, so that future comparisons with iron-treated sediments can be made. The phosphorus forms in the sediments can be expected to change because of iron filings addition. The sediment data will help understand the impacts of iron dosing on the phosphorus retention (or release) in the pond.

The budget subtotal for Task 5 is $5,615.

Results and deliverables

The Part I pre-treatment study will determine the significance of internal loading in the Shoreview Commons pond under different environmental conditions. The phosphorus release rate data and pond water quality will help interpret the phosphorus release vis-à-vis retention ability of the pond. A project report summarizing the results will be final deliverable for this study. The iron filings dose recommended for future treatment of the Shoreview Commons pond will also be included in the report.

Budget and timetable

The proposed Part I study has four tasks. The budget subtotal for Tasks 1 to 4 is $8,648. Task 5 is recommended to be included in the Part I study; the budget subtotal for Task 5 only is $5,615. The timeline listed for each task is approximate.

Part I: Pre-treatment study				
	Tasks	**~Start by**	**~End before**	**Budget**
1	Sediment core collection (one pond)	4/1/2018	5/1/2018	$1,022
2	Laboratory mesocosm studies (one pond)	4/1/2018	8/31/2018	$3,857
3	*In situ* water quality sampling (two ponds)	5/1/2018	8/31/2018	$2,765
4	Project report		10/31/2018**	$1,136
			Task 1 to 4 subtotal	**$8,780**
5*	Sediment analysis (one pond)	4/1/2018	8/31/2018	$5,615
			Task 1 to 5 total	**$14,395**

*optional, highly recommended
** subject to change depending on the water quality sampling duration

Part II: Iron filings treatment and assessment study

Objectives

The main objectives of the proposed Part II study are to implement iron filings treatment in the Shoreview Commons stormwater pond (City of Shoreview), monitor the phosphorus water quality in the pond to measure the treatment effectiveness, and identify factors affecting phosphorus release/retention based on detailed sediment analysis. The iron filings treatment is proposed to chemically-inactivate the sediment phosphorus and reduce the internal phosphorus release in the pond. It is proposed to include a "control" stormwater pond (i.e., not treated with iron filings) to allow comparisons with the treated pond.

Proposed sites

The Shoreview Commons pond (area = 0.0117 km^2; mean depth = 0.61 m), assessed for internal loading in the Part I pre-treatment study, is the proposed candidate for iron filings treatment. If feasible, a second pond in the area will be proposed as the control (i.e., no iron treatment) for this project. The objective is to compare the treated and control ponds to evaluate the impact of treatment on the phosphorus water quality.

Methods

The iron filings dose for the Shoreview Commons pond will be determined based on the Part I study and Natarajan et al. (2017) study. Iron filings will be applied on the surface of pond sediments. Water quality in the iron-treated (Shoreview Commons pond) and control ponds will be concurrently monitored by grab sampling technique over a one-year period. Sediments from the iron-treated pond will be analyzed to explain the pond phosphorus levels.

Task 1. Iron filings treatment (Shoreview Commons pond)

Iron filings will be spread on the entire pond sediment surface with the assistance of the City of Shoreview personnel. One method is to spread iron filings over a frozen pond surface in winter so that the iron filings will eventually settle to the pond bottom as the ice thaws. An alternate option is to apply the iron filings using a spreader device attached to a boat during early Spring. Iron filings units (lb) and costs may change depending on Part I mesocosm study results ($2000/acre est.), and variability of iron filings costs.

Task 2. Year 1 pond water quality sampling (Shoreview Commons and control ponds)

Total phosphorus concentrations, and DO, temperature and conductivity profiles in the water column will be measured at various sampling frequencies during the growing season. Frequent sampling will be conducted during select wet-weather periods. One possibility is to take daily *in situ* measurements during a period before and after a major storm. The goal will be to follow an adaptive assessment method based on the field measurements.

Task 3. Sediment analysis (Shoreview Commons pond)

Five to six sediment cores will be collected from the treated pond area. The upper 10 cm of sediments will be subject to sequential phosphorus extraction to determine the concentrations of available (redox-sensitive and labile organic phosphorus) and unavailable (aluminum- and mineral-bound) forms of phosphorus in the sediments. The concentrations will be compared to the pre-treatment sediment data (Task 5, Part I study). Metal (Fe, Al, Ca) concentrations in the sediments will be measured.

Task 4: Project report

A final project report, summarizing the effectiveness of iron filings treatment in improving the phosphorus water quality in the pond, will be prepared.

The budget subtotal for Part II, Tasks 1 to 4 is $25,340.

Results and deliverables

The Part II study will provide the effectiveness of iron filings treatment in improving phosphorus retention in the Shoreview Commons pond. The water quality measured in the treated vis-à-vis untreated pond will indicate the success of the treatment method. A project report summarizing the Part II study results will be the final deliverable.

Add scope to Part II study

It is possible that weather conditions during the first-year monitoring could create unusual conditions in terms of phosphorus release from the sediments and hence affect the phosphorus dynamics in the pond. Water quality monitoring in the two stormwater ponds may be continued for a second year, if necessary.

Task 5. Year 2 pond water quality sampling (Shoreview Commons and control ponds)

Total phosphorus concentrations, and DO, temperature and conductivity profiles in the water column will be measured at various sampling frequencies during the growing season. Frequent sampling will be conducted during select wet-weather periods. One possibility is to take daily *in situ* measurements during a period before and after a major storm. The goal will be to follow an adaptive assessment method based on the field measurements.

Task 5 will add $5,638 to the project cost. The budget subtotal for Tasks 1 through 5, including cost for Year 2 data analysis and report writing, is $30,978.

Budget and timetable

The timeline listed for each task is approximate. The Part II study will encompass one or two years following one year of pre-treatment study. Iron filings treatment and one-year water quality monitoring is estimated to cost $25,340. Conducting a second-year monitoring is estimated to add $5,638 to the budget (hence, total = $25,340 + $5,638 = $30,978). As noted under Part II, Task 1, iron filings units (lb) and costs may change depending on Part I mesocosm study results ($2000/acre est.), and variability of iron filings costs.

Part II: Iron filings treatment and assessment study				
	Tasks	**~Start by**	**~End before**	**Budget**
1*	Iron filings treatment (one pond)	2/1/2019	5/1/2019	$ 6,883
2	Year 1 *in situ* water quality sampling (two ponds)	5/1/2019	8/31/2019	$ 2,915
3	Sediment analysis (treated pond)	5/1/2019	8/31/2019	$ 6,113
4	Data analysis and project report		10/31/2019***	$ 9,428
			Tasks 1 to 4 subtotal	**$25,340**
5a-d**	Year 2 *in situ* water quality monitoring (two ponds)	5/1/2020	8/31/2020	$ 2,915
5e.**	Data analysis (Year 2 data) and project report		10/31/2020	$ 2,723
			Task 5 subtotal	**$ 5,638**
			Task 1 to 5 total	**$30,978**

* cost subject to change depending on the results of Part I
**additional scope
*** schedule subject to change depending on the water quality sampling duration

References

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