Report

Lake Study Summary

Little St. Germain Lake Protection District

Project I.D.: 05L001

Little St. Germain Lake Protection District

May 2006

Lake Study Summary
Little St. Germain Lake Protection District

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1. Sediment Phosphorus Evaluation

Lake studies done by USGS in 2001 and 2005 produced a phosphorus budget for the Little St. Germain Lake. The phosphorus budget included input values for precipitation, stream inflow, groundwater inflow, and septic tanks. USGS identified internal sediment loading as a potential source of phosphorus but had no input values available to use with the phosphorus budget. Internal loading occurs as phosphorus contained in the sediment is released back into the water column. This release takes place under aerobic and anoxic conditions.

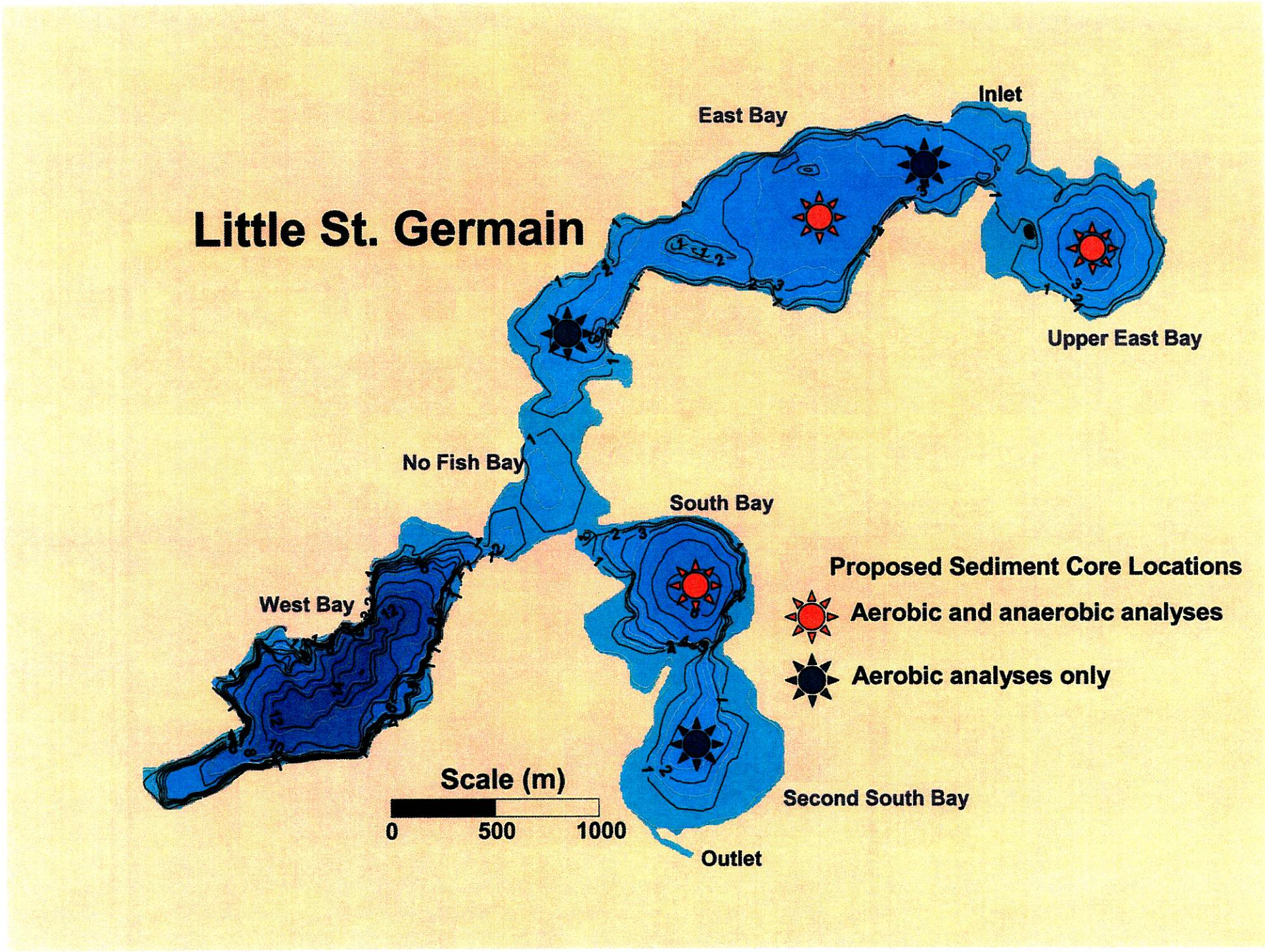
The Little St. Germain Lake Protection District received a WDNR Lake Planning Grant to study internal phosphorus loading to the lake. This work was completed by the United States Geological Survey (USGS) in 2005. The intent of this work was to identify the internal phosphorus loading to the lake and determine if this loading would reduce the effectiveness of chemical treatment to remove phosphorus.

Sediment core samples were collected in the summer of 2005. Figure 1 shows the sample locations. The core samples were sent to the State Lab of Hygiene for analysis. Core samples were incubated under aerobic or anoxic conditions. The water above the sediment cores was sampled for soluble reactive phosphorus on a daily basis. The results were calculated in a phosphorus release rate ($mg/m^2/day$).

The sediment core test results are shown in Attachment 1. USGS found the maximum phosphorus release rate to be 1 $mg/m^2/day$ and occurred under anoxic conditions. This release rate was applied to the upper East Bay in the area that experiences anoxic conditions (below 10 feet water depth). This area is 44,000 square meters. Over a 60 day period (approximately equal to a winter anoxic period) the phosphorus release from the Upper East Bay is estimated at 5.8 pounds. The measured aerobic release rate was near zero.

The result of the study shows that with a total lake phosphorus input budget of over 1,000 pounds of phosphorus per year, the relative input from sediment release is small. With the Upper East Bay as a model for the other three bays that experience anoxic conditions, the total internal phosphorus release is approximately 25 pounds per year.

Based on this study, the internal phosphorus loading is less than 3% of the overall phosphorus loading. Chemical treatment to remove phosphorus in Muskellunge Creek can be effective and internal phosphorus loading will have little impact on the effectiveness of the chemical treatment.


Little St. Germain
Inlet
East Bay
Upper East Bay
No Fish Bay
South Bay
West Bay
Second South Bay
Outlet
Proposed Sediment Core Locations
Aerobic and anaerobic analyses
Aerobic analyses only
Scale (m)
0
500
1000

August 2005
Little St. Germain Lake Phosphorus Release Rate Study
Summary

WSLH #	Sample Description/Core ID	Aerobic or Anerobic	Release Rate mg/m2/day	Regression Fit, r	Average Release mg/m2/day	% Relative Difference
IQ003580	Core S-1	Aerobic	1.534	0.98	1.2255	50%
IQ003581	Core S2	Aerobic	0.917	0.964		
IQ003582	Core S3	Aerobic	1.208	0.934	1.2955	14%
IQ003583	Core S4	Aerobic	1.383	0.997		
IQ003584	Core SS1	Aerobic	0.054	0.827	0.065	34%
IQ003585	Core SS2	Aerobic	0.076	0.954		
IQ003586	Core E1	Aerobic	-0.104	0.794	-0.0015	13667%
IQ003587	Core E2	Aerobic	0.101	0.661		
IQ003588	Core M1	Aerobic	-0.05	0.736	-0.033	103%
IQ003589	Core M2	Aerobic	-0.016	0.322		
IQ003590	Core M3	Anaerobic	1.061	0.956	0.966	20%
IQ003591	Core M4	Anaerobic	0.871	0.951		
IQ003592	Core N1	Aerobic	0.035	0.936	0.0555	74%
IQ003593	Core N2	Aerobic	0.076	0.783		
IQ003594	Core UE1	Aerobic	-0.383	0.969	-0.2885	66%
IQ003595	Core UE2	Aerobic	-0.194	0.798		
IQ003596	Core UE3†	Anaerobic	0.898	0.909	-0.033	5642%
IQ003597	Core UE4†	Anaerobic	-0.964	0.823		
IQ003598	Lake Water Blank*	Aerobic	0.431	0.987	NA	NA
IQ003599	Lake Water Blank*	Anaerobic	0.149	0.984	NA	NA

†The raw data are being re-checked to confirm that the cores were analyzed under the same conditions.

* Blank studies were performed without sediment. Consequently, the rubber stopper was in direct contact with the lake water for the entire experiment. We believe phosphorus leached from the stopper. However, in the actual sediment release studies, the stopper is isolated from the lake water by a layer of sediment. Therefore, the release rates observed in the blank studies may not be used to evalute the sample studies.

	NE Basin	UE Basin			11.4828	
Ave. Aerobic	0.007	-0.2885				
Ave Anoxic	0.966	-0.033				
UE/NE Anoxic		0.4665				
	NE Basin	UE Basin	UE Basin		UE Basin	
Anoxic Area m2	0	3.5 m - 11.	44000		44000	
Days	0	60	60		60	
Rate		Low	0.4665	High	1	
mgs			1,231,560		2,640,000	
kgs			1.23		2.64	
lbs			**2.71**		**5.808**	

Report

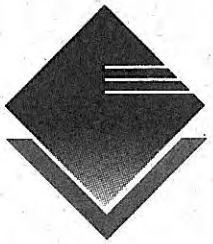
Phosphorus Removal Study

Little St. Germain Lake

Scope I.D.: 00L007

Little St. Germain Lake Protection and Rehabilitation District

November 2004



Foth & Van Dyke

Little St. Germain Lake Protection & Rehabilitation District
Phosphorus Removal Study

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Appendix A Phosphorus Removal Testing
Appendix B Project Cost Analysis

1. Introduction

The Little St. Germain Lake Protection and Rehabilitation District (District) completed a Lake Management Plan in January 2001. The report identified Muskellunge Creek as a source of 53% to 61% of the phosphorus input to Little St. Germain Lake on an annual basis. A model was used to evaluate the impact of a reduction in phosphorus from Muskellunge Creek. The model evaluated phosphorus reduction levels in Muskellunge Creek of 50%, 75%, and 100% and the impact on the East Bay of Little St. Germain Lake (the mouth of Muskellunge Creek). The measured total phosphorus concentration in East Bay averages 0.046 mg/l. The model predicted a reduction in total phosphorus of 0.012, 0.019, and 0.021 mg/l respectively in the East Bay. The impact on the lake would be expected to increase the average summer Secchi depth reading by 0.7, 1.0, and 2.0 ft respectively. As a result of the phosphorus reduction, the frequency of blue-green algae blooms was also expected to decrease.

The lake management plan recommended that chemical phosphorus removal from Muskellunge was the best technology but that further evaluation was needed due to the potentially high cost. To accomplish the phosphorus removal evaluation, a lake protection grant was applied for in the spring of 2000. The District was successful in obtaining a Lake Protection Grant from the Wisconsin Department of Natural Resources (WDNR) to do preliminary engineering work related to phosphorus removal.

The preliminary engineering work scope is as follows:

A. Phosphorus Removal Preliminary Design
B. Preliminary Lagoon Design
C. Land Acquisition Assistance
D. Permitting

This report focuses on items A and B. If the preliminary concepts and costs are feasible to the District and upon your authorization, items C and D will be completed.

2. Phosphorus Removal Testing

2.1 Jar Testing for Alum Dosage

Jar testing was done to determine the approximate dosage of alum that could be used to remove phosphorus from Muskellunge Creek water. Jar testing is a chemical simulation of a treatment process. Water samples are placed in jars and chemicals added to provide treatment. Various concentrations are used to determine which concentration would be best. Foth & Van Dyke has facilities in their office to complete the jar testing.

Alum is the common name for aluminum sulfate. This chemical is commonly used in water and wastewater treatment as a coagulant (settling aid) and for phosphorus removal. Many lakes have applied alum to the entire lake for phosphorus removal. Alum separates in water into aluminum ions and sulfate ions. The aluminum reacts with dissolved phosphates to produce a precipitate. This precipitate makes the reacted phosphorus unavailable to plants and algae.

A sample of water from Muskellunge Creek was collected by Foth & Van Dyke. Foth & Van Dyke added varying alum dosages to the test samples. The samples were mixed and allowed to settle. The supernatant (clear liquid above the settled solids) was collected from each jar and analyzed for total phosphorus, dissolved phosphorus and total suspended solids. The results are shown below:

Alum Dose – mg/l	Total P – mg/l	Dissolved P – mg/l	Total Suspended Solids – mg/l
0	0.032	0.022	4
10	0.026	0.014	7
20	0.018	0.008	10
30	ND	0.008	3
40	ND	0.007	6

The results showed that a dose of 20 mg/l had reacted with almost all the dissolved phosphorus and a dose of 30 mg/l had removed almost all the total phosphorus. Note that the raw water sample without the alum dose had a relatively low phosphorus concentration compared to the long term Muskellunge Creek average concentrations of 0.050 mg/l.

The best floc (chemical precipitate) was formed at an alum dose of 30 mg/l or higher. The floc settled to the bottom of the jar with some smaller particles remaining suspended.

2.2 Laboratory Settling Column Testing

A laboratory settling column is a useful tool in determining the speed at which a particle settles and simulates actual conditions more closely than a jar test. The settling column used is 7 feet tall and 8 inches in diameter. The column is clear plastic with sample ports located at one foot increments. Foth & Van Dyke has a settling column at their office and used this apparatus for the test.

Alum was added to the raw water as the water was added to the settling column. This procedure simulated field conditions. Samples were taken after 4 hours, 8 hours, and 24 hours. At each sample collection time, samples were collected at 1 foot intervals for a total of 18 samples per test period.

The first test was conducted at an alum dose of 3 mg/l. The second test was done at a higher concentration of 29 mg/l. The test at 3 mg/l alum dosage was done to see if the larger scale test could demonstrate improved performance at a lower alum dosage.

Each sample was analyzed for total phosphorus and total suspended solids. The complete test results are shown in Appendix A. A summary of the test is shown below:

Test 1 – Alum Addition – 3 mg/l

Sample	Total P – mg/l	Total Suspended Solids – mg/l
Raw Water	0.061	10
Average – 4 hours	0.044	13.0
Average – 8 hours	0.032	10.8
Average – 24 hours	0.025	7.7

Test 2 – Alum Addition – 29 mg/l

Sample	Total P – mg/l	Total Suspended Solids – mg/l
Raw Water	0.061	10
Average – 4 hours	0.019	10.7
Average – 8 hours	0.017	5.3
Average – 24 hours	0.017	3.2

The results show that the alum concentration of 29 mg/l was more effective than the lower dose of 3 mg/l. The alum dose of 29 mg/l removed 72% of the phosphorus after 24 hours while the 3 mg/l dose removed 59%. However, the additional cost of the alum at higher dosages should be considered when evaluating chemical cost versus phosphorus removal effectiveness. The above data is shown in graphical form below.

The results also show that the total suspended solids continued to decline from 4 hours to 24 hours. The floc particles apparently move slowly through the water column and quiescent settling of 24 hours or enhanced settling will be needed to provide good particulate removal. Enhanced settling could be accomplished with the aid of a polymer to form larger particles and speed the particulate settling.

Figure 2-1 Settling Column Phosphorus - 3 mg/l Alum

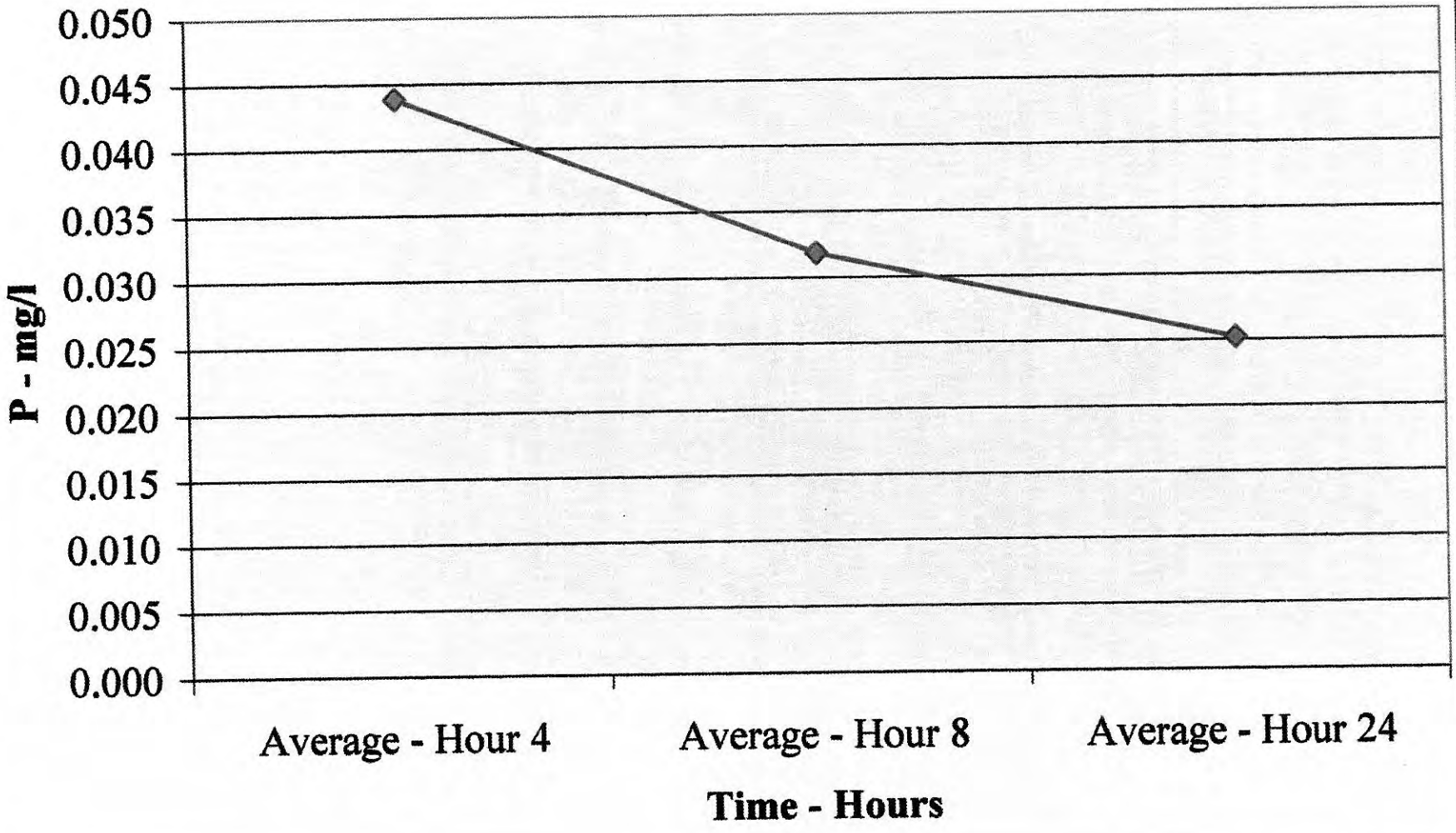


Figure 2-2 Settling Column TSS - 3 mg/l Alum

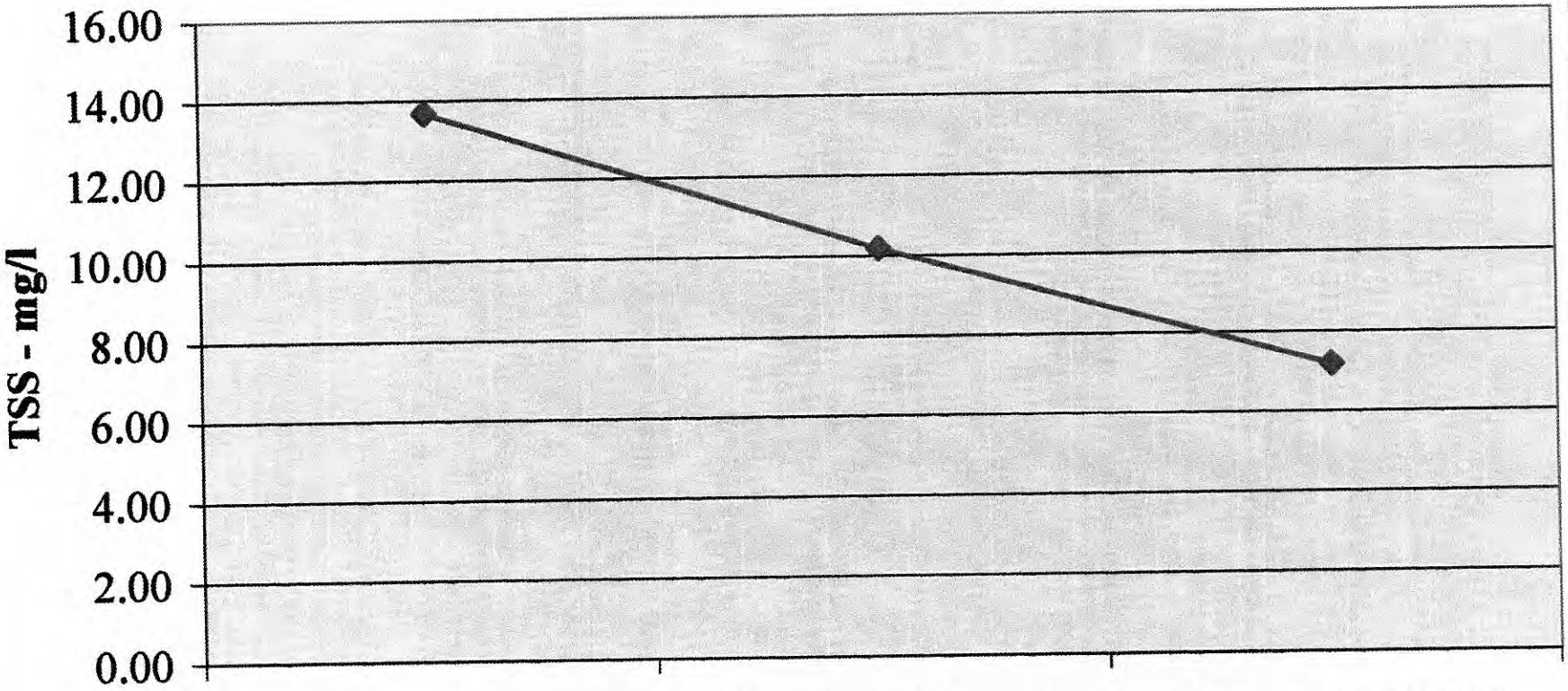
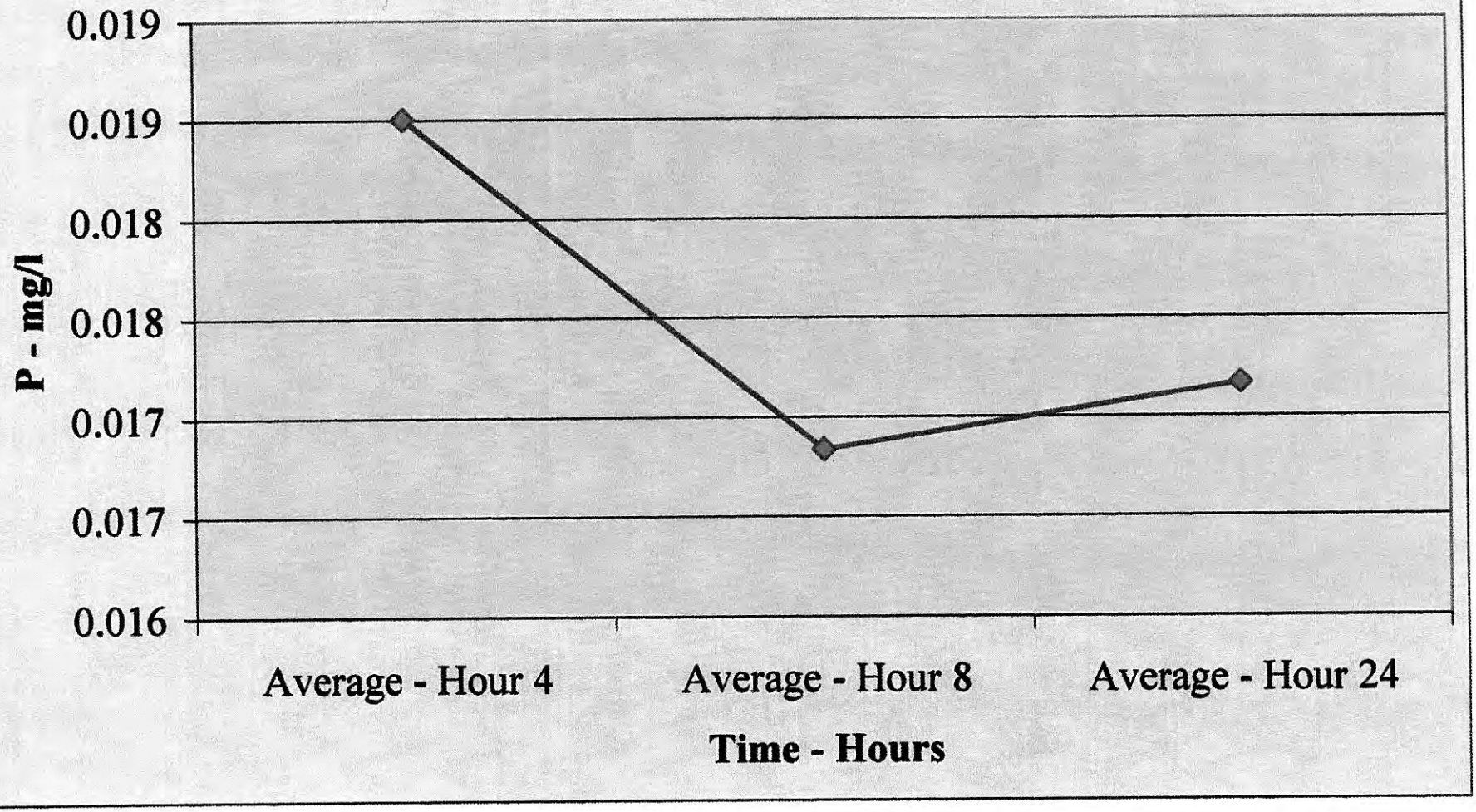


Figure 2-3 Settling Column Phosphorus - 29 mg/l Alum



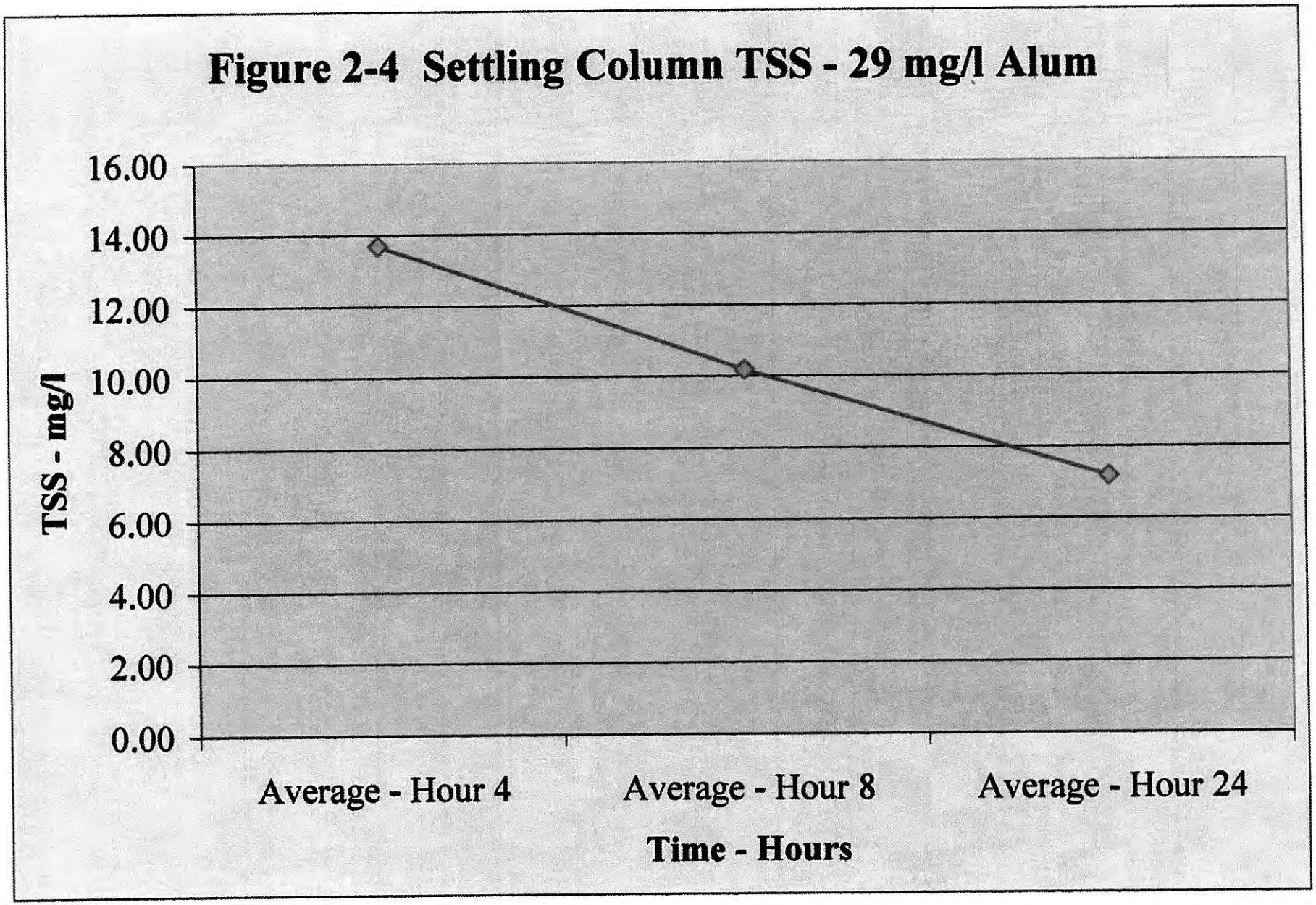


Figure 2-4 Settling Column TSS - 29 mg/l Alum
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
TSS - mg/l
Average - Hour 4
Average - Hour 8
Average - Hour 24
Time - Hours

3. Phosphorus Removal Alternatives

The Lake Management Plan evaluated biological and chemical phosphorus removal alternatives. In the Plan, the biological phosphorus removal alternative was eliminated due to cost, unproven performance, and seasonal operation. Chemical phosphorus removal using alum was considered to be technically feasible. Three options were identified; chemical addition directly to the creek, stream diversion with side stream treatment, and partial lake treatment.

3.1 Direct Chemical Addition to Muskellunge Creek

3.1.1 Process Description

Alum can be applied as a liquid and directly fed to Muskellunge Creek. The alum will react with the phosphorus in the stream to form a precipitate. The precipitate will bind the phosphorus making it unavailable to algae and plants in the lake. Phosphorus precipitate will settle to the bottom of the creek and lake. Figure 3-1 shows sites A and B that are potential sites for adding chemical for phosphorus removal.

3.1.2 Capital Cost

The facilities for this process are relatively simple. A chemical feed system to pump liquid alum into the creek is all that is required. The chemical feed system includes a chemical storage tank and chemical feed pumps. A building will be required to maintain the chemical storage tank above freezing and to protect equipment from the weather and vandalism.

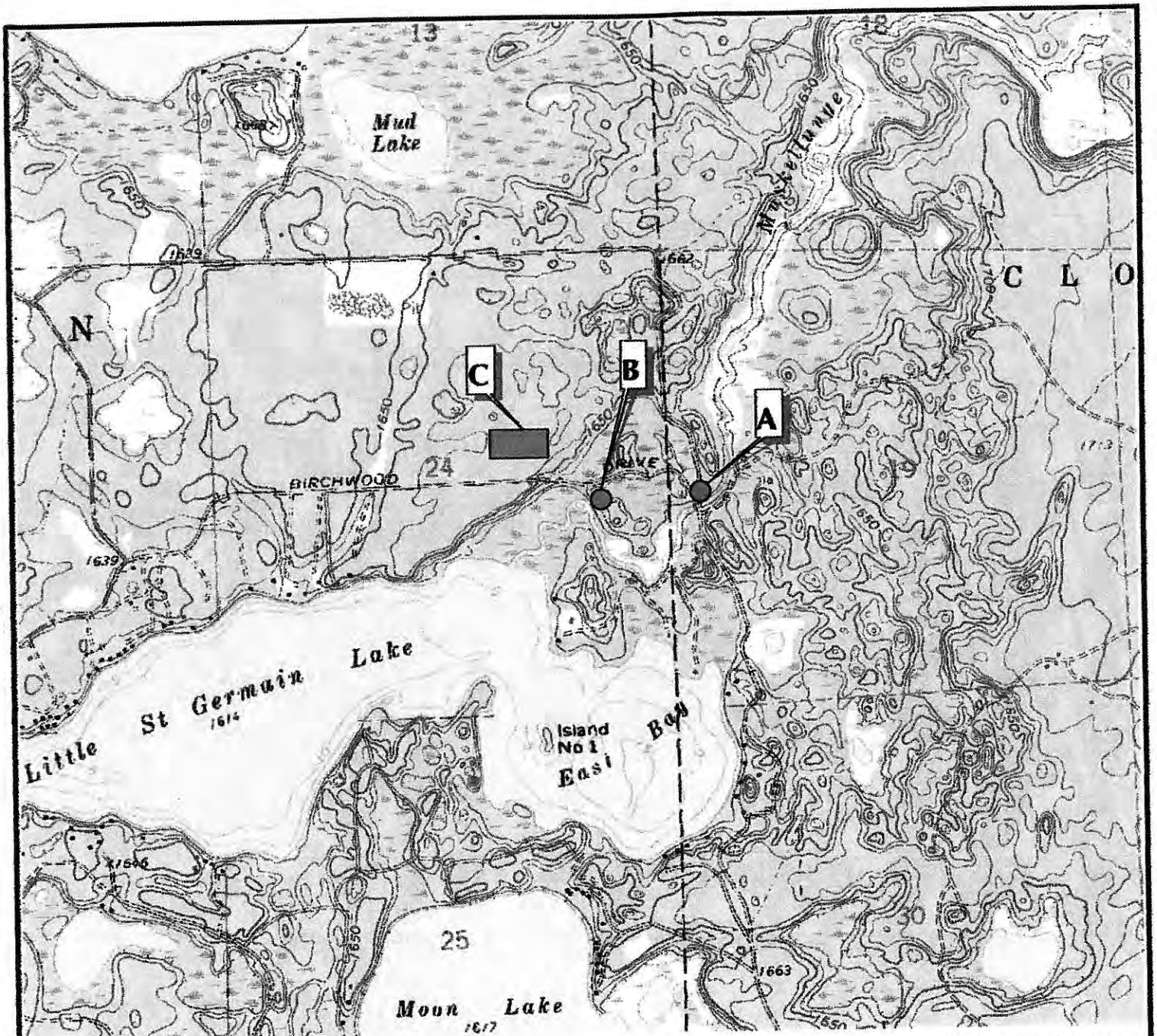
The chemical can be added to the stream through a small diameter pipe (1 inch size). The pipe can be placed on the stream bed and the alum distributed through evenly spaced orifices to get a well mixed process.

3.1.3 Operation Cost

The main operation costs are chemical addition and sludge removal. To determine the cost of these items, an analysis of the processes must be made. The items below describe the potential costs and impacts for each item.

3.1.3.1 Chemical Usage

The settling column test showed 72% of the phosphorus was removed after 24 hours with an alum dose of 29 mg/l. When the alum dose was reduced to 3 mg/l, the test showed 59% of the phosphorus. The USGS report estimated a 50% phosphorus reduction in the stream would decrease the East Bay phosphorus concentration by 0.012 mg/l. A 75% phosphorus reduction would decrease the East Bay phosphorus concentration by 0.019 mg/l. The test results from the settling column were between the two model predictions. Through interpolation, it is estimated that if 59% of the phosphorus were removed from the stream, the impact on East Bay would be a phosphorus reduction of 0.015 mg/l. If 72% of the phosphorus were removed from the stream, the impact on East Bay would be a phosphorus reduction of 0.018 mg/l.



A -Stream Diversion or Chemical Addition Site

B -Stream Diversion or Chemical Addition Site

C -Treatment Lagoon - Potential Site

SOURCE: U.S.G.S. 7.5-MINUTE TOPOGRAPHIC
QUADRANGLE - ST. GERMAIN (1970)
VILAS COUNTY, WISCONSIN

N

0 700 1400 2100 2800 3500 Feet

FIGURE 3-1
STREAM TREATMENT SITE LOCATION
Little St. Germain Lake
Vilas County, Wisconsin

DATE:		
9/1/2004	Foth & Van Dyke	m:\99l005\ apr\little_sg_1.apr

The above analysis shows that a 10-fold increase in chemical addition resulted in a reduction in lake phosphorus concentration of only 17%. The addition of higher amounts of chemical will result in greater phosphorus removal but the additional cost and solids production may outweigh the benefits.

The average stream flow for Muskellunge Creek at the Birchwood Drive road crossing is 7.3 cubic feet per second. This is equivalent to about 4.7 million gallons of water per day. The amount of alum needed to produce 29 mg/l for this amount of water is approximately 227 gallons per day at a concentration of 5 lbs alum/gallon. At a cost of $1.5 per gallon, the daily cost for alum addition is $340 or $124,300 annually.

If the chemical dosage is reduced to 3 mg/l, the amount of liquid alum required is 23.5 gallons per day. The daily cost for this dosage is $34 or $12,900 annually.

3.1.3.2 Solids Production

The use of alum will form a precipitate when it reacts with phosphorus and other compounds in the water. Some of these solids will eventually settle to the bottom of the river but most will settle in the lake. The area where solids will settle will depend on the settling rate of the solids. From the settling column testing, solids settled consistently over a 24 hour period. This leads to a conclusion that the area where solids will settle will be relatively large. Wind, currents, and boating traffic near the mouth of Muskellunge Creek could disperse the light solids formed from alum addition to the creek water. It is estimated that an area of 70 acres (the upper portion of the 336 acre East Bay) may be impacted from solids deposition. Over time the solids that settle will compress and become part of the sediment. The initial solids concentration may be 2% but over time the concentration may increase to 5% to 10%.

The solids production can be estimated from the settling tube testing. When the higher dose of 29 mg/l was added, some solids quickly settled to the bottom of the settling column. The remainder settled slowly over the 24 hour period until a low level of suspended solids remained. It is estimated that 30 mg/l of suspended solids were precipitated in this test. At a concentration of 2% solids, this volume would be 343,000 cubic feet. Over a 70 acre area, the annual increase in sediment would be 0.11 feet (1.3 inches).

The lower dose of alum produced lighter solids that settled slowly. The solids increased to 13.67 mg/l after 4 hours but dropped to 7.17 mg/l by the end of the test. After 24 hours, it is estimated that 6.5 mg/l of suspended solids were precipitated. At a concentration of 2% solids, this volume would be 75,000 cubic feet. Over a 70 acre area, the annual increase in sediment would be 0.025 feet (0.3 inches).

3.1.3.3 Solids Removal

Solids can accumulate in a lake to an extent that causes navigational problems or becomes a nuisance. Dredging is the method used to remove sediment from a lake. The technique for a large body of water is to use a barge and a pump. The pump suction is connected to an auger that removes sediment from the lake bottom. The solids are pumped to shore through a flexible pipe.

Solids disposal can be done in a variety of ways. Liquid sediment can be trucked to a disposal area. Solids can also be dewatered near the dredging site and hauled as a cake to a disposal area.

3.1.4 Risk Issues

While alum has been used extensively in lake rehabilitation and water treatment, there are several unknowns related to continuous use to precipitate phosphorus from a stream. The rate of solids deposition is difficult to predict and could impact the potential of future sediment removal. The area of the lake impacted by the solids deposition is also unknown and will vary depending on the amount of chemical added, the rate at which the chemical settles, and the water movement near the mouth of Muskellunge Creek.

The addition of alum (aluminum sulfate) has no known toxicity issues but the long term affect from aluminum or sulfate is not known. Sulfate has been linked to an increase in mercury concentration by means of chemical reactions in the sediment releasing mercury into the water column. If Little St. Germain Lake has adequate sulfate concentration naturally, then additional sulfate will not cause more mercury release.

3.1.5 Seasonal Operation

A consideration should be made to operating a chemical feed system on a seasonal basis. If an objective of the chemical phosphorus removal is to reduce the weed growth and algae blooms in the East Bay, then reducing the phosphorus concentration in East Bay during the summer growing season may be all that is required.

East Bay is the largest bay in the lake and covers 336 acres. The maximum depth is 16 feet but over half the bay is less than 10 feet deep. It is estimated that the upper half of East Bay is most affected by Muskellunge Creek. If ½ of East Bay is targeted and is calculated to be 170 acres at 10 feet of depth, the volume of this water is 74 million cubic feet. With an average flow rate of 8 cfs, Muskellunge Creek would replace that amount of water in 107 days. If chemical treatment of Muskellunge Creek began at the beginning of March, by early June, much of the upper ½ of East Bay would have been displaced and the phosphorus concentration would be significantly lower. Treatment could continue until late August for a seven month treatment period.

Seasonal treatment may accomplish most goals at a lower operational cost and reduced risk.

3.2 Sidestream Chemical Phosphorus Removal

3.2.1 Process Description

This alternative diverts a portion of Muskellunge Creek to a treatment lagoon where alum is added and the solids settle in the lagoon. The treated water is then returned to Muskellunge Creek before it discharges into Little St. Germain Lake. This process is complex and includes a diversion structure in the creek, a pumping system capable of about 5,000 gpm, a treatment lagoon, and a return flow structure to discharge water back into Muskellunge Creek. Figure 3-1 shows sites A and B as potential for stream diversion locations. Site C is identified as a potential lagoon site for treatment and settling of the solids.

3.2.2 Capital Cost

The facilities for this process are much more extensive than the in-stream chemical addition alternative. A water diversion structure will be required to intercept water from Muskellunge Creek. This structure is proposed to be concrete and be located in the stream channel. Water from Muskellunge Creek will be diverted to a pump station. The pump station will transfer water to the treatment lagoon. The pump station will be sized for about 5,000 gpm and will have controls to allow about 75% of the creek water to be pumped to the lagoon. At high flows, the amount of water bypassing the pumps will be greater.

At the lagoon, alum will be added to the pumped water and discharged into the lagoon. The lagoon will be sized for a minimum retention time of 24 hours. The required volume is 7.2 million gallons with an additional million gallons reserved for sediment storage. The dimensions of the lagoon will be approximately 280 feet by 520 feet with a water depth of about 10 feet. Solids will settle in the lagoon and clear water discharged back to Muskellunge Creek.

A chemical feed system to pump liquid alum into the treatment lagoon will be required. The chemical feed system includes a chemical storage tank and chemical feed pumps. A building will be required to maintain the chemical storage tank above freezing and to protect equipment from the weather and vandalism.

3.2.3 Operation Cost

The main operation costs are chemical addition and solids removal. To determine the cost of these items, an analysis of the processes must be made. The items below describe the potential costs and impacts for each item.

3.2.3.1 Chemical Usage

The settling column test showed 72% of the phosphorus was removed after 24 hours with an alum dose of 29 mg/l. When the alum dose was reduced to 3 mg/l, the test showed 59% of the phosphorus. The USGS report estimated a 50% phosphorus reduction in the stream would decrease the East Bay phosphorus concentration by 0.012 mg/l. A 75% phosphorus reduction would decrease the East Bay phosphorus concentration by 0.019 mg/l. The test results from the settling column were between the two model predictions. Through interpolation, it is estimated that if 59% of the phosphorus were removed from the stream, the impact on East Bay would be a phosphorus reduction of 0.015 mg/l. If 72% of the phosphorus were removed from the stream, the impact on East Bay would be a phosphorus reduction of 0.018 mg/l.

The above analysis shows that a 10-fold increase in chemical addition resulted in a reduction in lake phosphorus concentration of only 17%. The addition of higher amounts of chemical will result in greater phosphorus removal but the additional cost and solids production may outweigh the benefits.

The average stream flow for Muskellunge Creek at the Birchwood Drive road crossing is 7.3 cubic feet per second. This is equivalent to about 4.7 million gallons of water per day. The pump station will pump about 75% of the stream flow (3.5 million gallons per day). The amount of alum needed to produce 29 mg/l for this amount of water is approximately 169 gallons per day

at a concentration of 5 lbs alum/gallon. At a cost of $1.5 per gallon, the daily cost for alum addition is $253 or $92,300 annually.

If the chemical dosage is reduced to 3 mg/l, the amount of liquid alum required is 17.5 gallons per day. The daily cost for this dosage is $26 or $9,500 annually.

3.2.3.2 Solids Production

The use of alum will form a precipitate when it reacts with phosphorus and other compounds in the water. These solids will eventually settle to the bottom of the treatment lagoon. From the settling column testing, solids settled consistently over a 24 hour period.

The solids production can be estimated from the settling tube testing. When the higher dose of 29 mg/l was added, some solids quickly settled to the bottom of the settling column. The remainder settled slowly over the 24 hour period until a low level of suspended solids remained. It is estimated that 30 mg/l of suspended solids were precipitated in this test. At a concentration of 2% solids, this volume would be 256,000 cubic feet per year. Over a 3 acre area, the annual increase in lagoon solids would be 2.0 feet.

The lower dose of alum produced lighter solids that settled slowly. The solids increased to 13.67 mg/l after 4 hours but dropped to 7.17 mg/l by the end of the test. After 24 hours, it is estimated that 6.5 mg/l of suspended solids were precipitated. At a concentration of 2% solids, this volume would be 55,000 cubic feet per year. Over a 3 acre area, the annual increase in lagoon solids would be 0.42 feet.

3.2.3.3 Solids Removal

Solids that accumulate in the lagoon will need to be removed on a regular basis. Excessive solids in the bottom of the lagoon can reduce detention time and treatment capacity. Dredging is the method used to remove solids from a lagoon. The technique for a large body of water is to use a barge and a pump. The pump suction is connected to an auger that removes solids from the lagoon bottom. The solids are pumped to shore through a flexible pipe. An alternative to dredging is to drain the lagoon and allow the solids to dry. The solids could then be removed as a dry product. To facilitate operation and removal, the treatment lagoon could be divided into two cells and one cell remains in operation while one cell is drained and the solids removed.

Solids disposal can be done in a variety of ways. Liquid sediment can be trucked to a disposal area. Solids can also be dewatered near the dredging site and hauled as a cake to a disposal area. Solids removed as a cake have a lower disposal cost due to lower transportation costs.

Because dredging or dry solids removal is an expensive process with a large portion of the cost tied up in mobilization, solids removal should be delayed until a large enough amount of solids is in the lagoon

3.2.4 Risk Issues

This alternative reduces the risk issues associated with phosphorus precipitation in the lake. Implementation is a large risk with this alternative for the following reasons:

- WDNR strives to maintain natural streams and navigable waterways. A large diversion structure in the stream bed, while technically feasible, may be difficult to get permitted for construction.

- Land will need to be acquired near Muskellunge Creek and Birchwood Drive. Because the land requirements are quite specific, if the land is not available, is located in an environmentally sensitive area, or is too expensive, there are no other alternatives available to locate a lagoon and treatment system.

- The cost of the system including operation may be prohibitive.

3.3 Partial Lake Chemical Phosphorus Removal

3.3.1 Process Description

This alternative chemically treats the majority of Little St. Germain Lake. This process applies alum to the lake where the water depth is greater than five feet. The phosphorus in the water column is removed and settles to the bottom. In addition, the alum precipitate reacts with phosphorus released from the sediment preventing it from entering the water column.

The alum is applied to the lake through a special barge designed to apply liquid alum to the lake surface or injected below the surface. The barge can carry several thousand gallons of liquid alum at a time.

3.3.2 Capital Cost

There is no capital cost for this alternative. All costs are incurred by contracting with a company for phosphorus treatment.

3.3.3 Operation Cost

The operation cost is the cost for contracting a company to do the phosphorus removal. Preliminary estimates of a cost for treating approximately 650 acres (excluding West Bay and Upper East Bay) are about $60,000. If the West Bay and Upper East Bay are included, the cost would be greater. The question relating to operating cost is the frequency that total lake treatment is needed.

The volume of water in the 650 acres impacted by Muskellunge Creek (between mouth of the creek and the outlet stream) is about 250 million cubic feet. The annual input from Muskellunge Creek and groundwater is about 350 million cubic feet as determined by the USGS hydrology report from October 2000. These numbers show that there is a water exchange of about 260 days. If chemical treatment is applied in June each year, by March of the following year, the water from the creek and groundwater would have replaced the treated lake water. With phosphorus concentrations in the creek and groundwater at levels higher than normal lake water, the chemical treatment will have little impact on lake phosphorus concentrations for more than 12 months. To maintain low levels of phosphorus in the lake, chemical treatment will be required each year.

3.3.3.1 Solids Production

The amount of alum used for partial lake treatment is similar to the option of adding 30 mg/l to Muskellunge Creek. The amount of precipitate will be spread out over 650 acres and will accumulate at a rate of 0.13 inches per year assuming in settles to 2% solids concentration.

3.3.3.2 Solids Removal

Solids can accumulate in a lake to an extent that causes navigational problems or becomes a nuisance. Dredging is the method used to remove sediment from a lake. The technique for a large body of water is to use a barge and a pump. The pump suction is connected to an auger that removes sediment from the lake bottom. The solids are pumped to shore through a flexible pipe.

Solids disposal can be done in a variety of ways. Liquid sediment can be trucked to a disposal area. Solids can also be dewatered near the dredging site and hauled as a cake to a disposal area.

3.3.4 Risk Issues

This alternative includes risk issues associated with phosphorus precipitation in the lake. These issues were discussed in Section 3.1.4. The cost of annually treating the lake for phosphorus may be prohibitive.

3.4 Lake Aeration Impact

Lake aerators are used in winter to provide oxygen to areas of the lake that typically become anoxic. There are three aerator locations in Little St. Germain Lake; South Bay, Upper East Bay and near the mouth of Muskellunge Creek. The aerators are operated for approximately 3 months in winter beginning in January and ending in late March.

Phosphorus precipitation from addition to the stream or lake will settle near the aerators located at the bottom of the lake in South Bay and near the mouth of Muskellunge Creek. Areas near the aerators may have velocities great enough (approximately 1 foot per second) to re-suspend settled particles. This is true of phosphorus precipitates as well as other lighter sediments. These light particles will settle in other areas of the lake that have less turbulence.

The lake aerators are not operated when the seasonal phosphorus treatment system is operated. This is true for the in-stream treatment alternative and the partial lake treatment alternative. The phosphorus precipitate will settle under natural lake conditions before the lake aerators are started up in winter. The only impact the aerators will have on phosphorus precipitates is in areas adjacent to the aerators where velocities are high enough to suspend light sediment. The total area impacted by the aerators will be less than 1 acre.

4. Phosphorus Removal Cost Analysis

4.1 General

A cost-effectiveness analysis will be performed on the three phosphorus removal alternatives. The cost-effectiveness analysis is based on a 20 year project life. Each phosphorus removal alternative uses the present worth analysis method to compare total costs over a 20-year period. The interest rate used in this evaluation is 6%. The analysis includes capital costs and operation and maintenance costs.

4.2 Direct Chemical Addition to Muskellunge Creek

The capital cost for this alternative includes:

- Chemical feed building
- Chemical feed equipment
- Piping
- Site work
- Electrical
- Land
- Technical, administrative
- Contingency

The estimated project cost is $279,000. Appendix B contains detailed information on the project cost.

The operation cost was calculated for a 12 month operational period and a 6 month operational period. The cost for operation over a 6 month period is $13,700 while the cost of operation over a 12 month period is $24,800. These costs assume an alum feed rate of about 3 mg/l.

4.3 Sidestream Chemical Phosphorus Removal

The capital cost for this alternative includes:

- Stream diversion structure
- Pump Station
- Treatment Lagoon
- Chemical feed building
- Chemical feed equipment
- Piping
- Site work
- Electrical
- Land
- Technical, administrative
- Contingency

The estimated project cost is $1,632,000. Appendix B contains detailed information on the project cost.

The operation cost was calculated for a 12 month operational period and a 6 month operational period. The cost for operation over a 6 month period is $49,100 while the cost of operation over a 12 month period is $98,100. These costs assume an alum feed rate of 3 mg/l.

4.4 Partial Lake Chemical Phosphorus Removal

There are no capital costs for this alternative. The annual operation and maintenance cost is estimated at $60,000 for a chemical application to the main lake channel.

4.5 Present Worth Summary

The following table summarizes the cost-effective analysis for the phosphorus removal alternatives:

Alternative	Capital Cost	Annual O&M Cost	Total Present Worth
In-stream Treatment	$279,200	$13,700	$436,300
Treatment Lagoon	$1,632,000	$49,100	$2,195,000
Partial Lake Treatment	$0	$60,000	$688,200

The above table shows the in-stream treatment alternative to be the most cost-effective. This analysis assumed that seasonal phosphorus removal would be implemented to reduce the annual operation cost.

5. Internal Phosphorus Loading

The USGS report dated October 2000 included a phosphorus budget for Little St. Germain Lake. Sources of phosphorus identified in the report included precipitation, stream inflow, groundwater, and septic tanks.

An additional phosphorus source not previously identified is internal loading. This occurs as phosphorus contained in the sediment is released back into the water column. This release takes place under aerobic and anaerobic conditions.

At this time it is unknown what impact the internal loading has on the overall phosphorus budget in Little St. Germain Lake. Before the District evaluates phosphorus removal alternatives, the impact of internal phosphorus loading should be considered. If the internal loading is a relatively large portion of the phosphorus budget, then chemical treatment of the stream may be less effective in lowering the phosphorus concentration in the lake. Therefore, an analysis of internal phosphorus loading should be done before a decision is made on chemical phosphorus treatment.

6. Conclusions and Recommendations

6.1 Conclusions

- Muskellunge Creek contributes 53% to 61% of the total phosphorus to Little St. Germain Lake.
- Removing phosphorus from Muskellunge Creek will improve water clarity and reduce phosphorus concentrations up to 46%.
- Little St. Germain Lake will remain a eutrophic lake if all the phosphorus is removed from Muskellunge Creek.
- Laboratory tests showed alum can remove phosphorus from Muskellunge Creek.
- A laboratory settling column test showed that significant phosphorus removal (59% removal) occurred with an alum dose of 3 mg/l provided that 24 hours of settling occurred.
- An alum dose of 29 mg/l provided more rapid settling and greater phosphorus removal (72% removal).
- Direct chemical addition to Muskellunge Creek is a feasible alternative with risk issues regarding solids settling in the lake.
- Sidestream chemical addition and treatment will eliminate most solids settling in the lake but has a higher cost and may not be permitted due to impacts on the stream habitat.
- Seasonal chemical treatment should be considered to reduce operational cost and minimize solids build-up.
- Partial lake treatment is a feasible alternative to reducing phosphorus concentrations in the lake. To keep phosphorus concentrations low, partial lake treatment will need to be repeated each year. The water entering the lake from the inlet stream and groundwater has an average residence time of less than one year.
- Internal phosphorus loading has an unknown impact on the lake.
- Lake aeration will have a negligible impact on phosphorus precipitation.

6.2 Recommendations

- Determine the impact of internal phosphorus loading in the summer of 2005. Contact USGS to prepare a work plan and apply for a lake planning grant to conduct the work.
- Evaluate the feasibility of implementing the direct chemical treatment in Muskellunge Creek alternative by doing the following:

A. Determine location of treatment facilities and the possibility of obtaining land and easements.
B. Review permitting issues with WDNR.
C. Consider model of lake phosphorus based on seasonal operation.
D. Prepare financing plan including WDNR Lake Protection Grant.
E. Obtain property owner comments with educational flyer and survey.