Lake Hicks

Alum Treatment Report

April 2006

Photo by Tom Smayda

King County

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Thanks to Tricia Shoblom of Washington Department of Ecology Bellevue Regional Office for her assistance with reviewing the IPMP and obtaining the NPDES permit.

Finally, special thanks to the members of the White Center community for their efforts to improve Lake Hicks and Lakewood Park for the benefit of all who visit the park. The Friends of Hicks Lake, and in particular long-time resident Dick Thurnau, have been vocal proponents of restoration and improvement projects at Lake Hicks.

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INTRODUCTION

On April 11, 2005, King County performed an alum treatment at Lake Hicks, a four-acre lake just south of Seattle in the White Center neighborhood of unincorporated King County. Water quality monitoring prior to the treatment determined that water and sediments of the lake were very high in phosphorus and that internal loading from hypolimnetic anoxia was a primary source of phosphorus loading. High concentrations of phosphorus in the lake were leading to frequent dense cyanobacteria blooms, which created unsightly conditions at the lake and posed a potential health threat to humans, pets, and wildlife. An alum treatment was determined to be the most appropriate and cost effective management technique to lower phosphorus concentrations in the lake and reduce the frequency and severity of the cyanobacteria blooms. Post-treatment monitoring results have shown the treatment to be successful.

There are several other documents that discuss water quality and past projects at Lake Hicks. A recent management plan, the *Lake Hicks Integrated Phosphorus Management Plan* (IPMP) was completed just prior to implementation of the alum treatment. The IPMP outlines past and present conditions at the lake and recommends an alum treatment. The IPMP is cited throughout this report. Printed copies of the IPMP are available from the King County Department of Natural Resources and Parks (KCDNRP); the IPMP is online at http://dnr.metrokc.gov/wlr/waterres/smlakes/reports.htm.

BACKGROUND INFORMATION

Watershed and Lake Characteristics

Lake Hicks' watershed is located between the cities of Burien and Seattle in unincorporated King County. The 678-acre watershed is within the 1200-acre Salmon Creek sub-basin of the Duwamish/Green River WRIA 9 as defined by the Washington State Department of Ecology (Ecology). The majority of the watershed is developed. The IPMP discusses watershed features in further detail.

The lake is entirely within King County's 32-acre Lakewood Park. The lake is mainly fed by urban surface runoff, although groundwater also contributes water to the lake (Lake Hicks IPMP). The water and sediments in the lake are extremely rich in nutrients – phosphorus being of primary concern.

During periods of normal precipitation, the lake ranges from four to five meters deep, with a surface area of about 4-acres. Generally water levels at Lake Hicks follow the same pattern as most other lakes in the Puget Sound lowlands of lower water levels in summer and higher levels in winter. Because the lake is relatively small compared to the size of the watershed, and the watershed has a high percentage of impermeable surface, the depth and surface area of the lake vary a great deal depending on rainfall patterns. The lake has no natural outlet, but there is a pump system that operates when the water

level reaches a certain elevation. Capacity of the outlet pump is limited by a choke point downstream, so heavy sustained rains can and do flood the lake.

History of Problem

In recent years, cyanobacteria blooms have become more frequent and dense. In 2004 samples were collected from three different blooms, and in each case tested positive for toxins. Without relatively expensive toxicity tests, there is no way of knowing whether a particular bloom is toxic. Given the frequency and severity of cyanobacteria blooms in the lake, and the risks posed to humans, pets, and wildlife by blooms that produce toxins, King County staff decided to take actions that would result in decreased phosphorus concentrations in the lake and thus control nuisance blooms.

Past Management Efforts

Water quality problems have existed at Lake Hicks for many years. The IPMP outlines the water quality studies and improvement projects completed in the last 30 years by King County DNRP and its predecessor agencies. This is the first time alum has been used at Lake Hicks for phosphorus control.

2004 WQ Characterization

Bi-Weekly Monitoring

Water quality was monitored prior to the alum treatment to establish baseline conditions and verify that high phosphorus concentrations existed. Baseline samples were collected monthly from May through October. Parameters measured during baseline monitoring included total phosphorus (TP), total nitrogen, total suspended solids (TSS), chlorophyll *a*, pH, dissolved oxygen (DO), conductivity, and temperature, not all of which is included in this report. Other data can be obtained upon request.

After storms in which an inch or more of rain fell at nearby SeaTac airport in a 24-hour period, storm samples were collected. Additional parameters measured for storm samples included orthophosphate and fecal coliform concentrations. Analysis of near-bottom water during the summer months showed very low concentrations of dissolved oxygen and phosphorus concentrations that were much higher than samples collected at a depth of one-meter. Anoxic conditions at the water-sediment interface allow a chemical reaction to take place, pulling phosphorus from the sediment into the water which becomes available to algae in the euphotic zone when the lake mixes.

Monitoring results show that TP concentrations remained high in the lake throughout the sampling period. Further, chlorophyll *a* concentrations also were high during the summer months, representing large algae populations which likely led to the poor water clarity (Table 1).

Table 1. 2004 Water Quality Data at 1 m depth

Date	Secchi (m)	Chlorophyll-a	Total P (mg/L)	Total N (mg/L)	Fecal Coliform (cfu/100ml)
5/19/2004	2.2	11.2	0.0288	0.6390	8
6/2/2004	1.8	13.5	0.0453	0.7390	34
6/17/2004	1.6	18.6	0.0297	0.5740	100
6/30/2004	1.2	7.37	0.0400	1.4500	60
7/13/2004	0.9	36.8	0.0410	1.2500	120
7/27/2004	0.4	195	0.0910	2.7100	6
8/10/2004	0.15	126	0.1020	1.7100	230
8/24/2004	0.4	30.4	0.1230	1.9100	690
9/7/2004	0.8	76.7	0.1080	1.8400	83
9/21/2004	0.6	54.2	0.0995	1.4100	130
10/5/2004	0.6	51.6	0.1160	1.5000	74
10/20/2004	0.6	62.9	0.0998	1.4300	460

These data are shown graphically and compared with post-treatment monitoring results on pages 12-13 of this report. Appendix A contains monitoring results for other parameters, storm events, and results of the phytoplankton monitoring, which showed that potentially toxic cyanobacteria species were the predominant phytoplankton species through much of the summer.

Toxic Cyanobacteria Blooms

During summer 2004, King County staff and community residents noticed dense cyanobacteria blooms through much of the summer (B. Cullen, pers. comm.). Seven water samples tested positive for the presence of microcystin, a hepatotoxin found in certain species of cyanobacteria. Although toxin levels did not exceed safety standards of 1μg/L set by the World Health Organization, toxins were detected in each of the samples as shown in Figure 4. Different methods were used to evaluate toxin amounts over the period, and actual amounts of some samples may have been under-reported (IPMP).

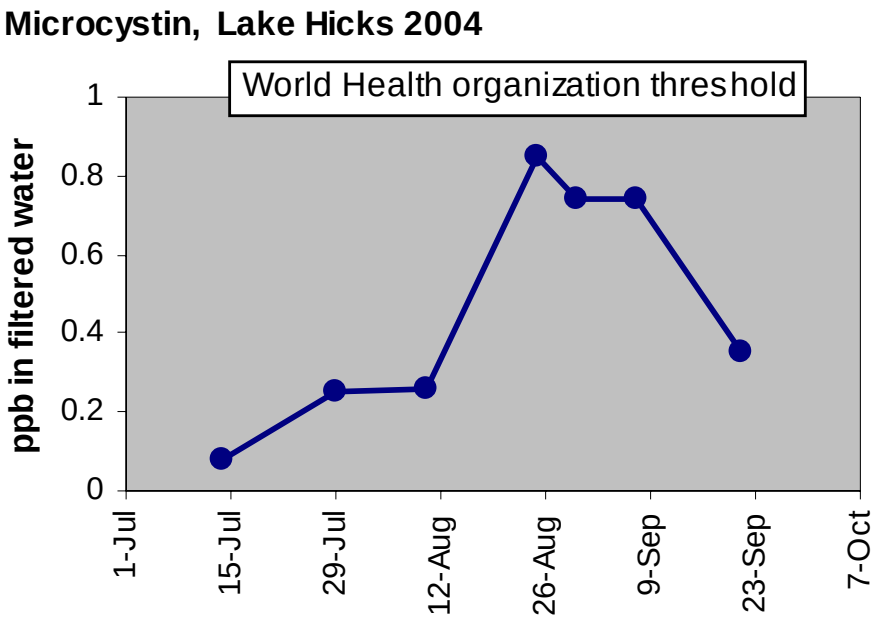


Figure 1. Lake Hicks 2004 Toxicity Test Results

The dense cyanobacteria blooms posed potential risk to people and animals coming into contact with the water. The blooms also detracted from the aesthetic value of the lake and park.

Figure 2.Cyanobacteria Bloom in Lake Hicks, Summer 2004

PUBLIC INVOLVEMENT AND PERMITS

Public Meetings

Prior to the alum treatment, King county hosted two public meetings to discuss with the community the water quality problems occurring at the lake and the potential solutions to the problem. Comments and suggestions from community members at the January 12th meeting were incorporated into the IPMP. Nine community members attended the meting on January 12. The meeting on March 24 was attended by 13 community members.

Announcements of the meetings were sent to all members of the Friends of Lake Hicks, and to all businesses and homes within ¼ mile of the watershed; ArcView GIS software was used to determine the parcels and mailing addresses within ¼ mile of the lake.

Copies of the meeting announcements and agendas for each meeting are included in Appendix B.

SEPA Checklist and Determination of Non-significance

As required by the NPDES permit, a State environmental Policy Act (SEPA) checklist was completed for the proposed project. After reviewing the Checklist, King County, the lead agency, determined that the alum treatment would not have a significant adverse impact on Lake Hicks, earning the project a Determination of Non-significance (DNS). Notice of the DNS was distributed to all residents within ¼ mile of the lake as well as required agencies and organizations. A copy of the SEPA checklist and the DNS are included in Appendix C of this report.

Public Notice and Press releases

In addition to public meeting announcement notices sent to residents in the Lake Hicks area, there were also three announcements published in the in the local newspaper, *The White Center News*. The announcements were a requirement of the NPDES permit, and were published according to the schedule required by the permit; the notices were published on
March 2, 2005.
March 9, 2005, and
March 16, 2005. Copies of the announcements are included in Appendix C.

Approximately one-week prior to the planned alum treatment, a press release was sent to local and regional media. The press release outlined the plan for the alum treatment and highlighted the predicted benefits of the alum treatment to the water quality in Lake Hicks.

PRE-TREATMENT TASKS

Budget Secured through KC Capital Projects Group

King County's Capital Projects and Open Space Acquisitions (CPOSA) group in the Water and Land Resources Division agreed to provide funding for the project. This funding enabled staff from the Lake Stewardship Program to manage the pre-treatment monitoring, the alum treatment, and post-treatment monitoring.

Phosphorus Reduction Options Examined; Alum Recommended

King County Lake Stewardship Program staff considered available management techniques that would lower phosphorus concentrations in the lake (IPMP). Options included alum treatment, dilution, stormwater retention and treatment, sediment oxidation techniques, aeration, dredging, and instituting a watershed education campaign. Lake Stewardship Program staff determined that an alum treatment would be most likely to succeed in achieving immediate relief from phosphorus-related cyanobacteria blooms at Lake Hicks. Stormwater controls and an education of watershed residents were also recommended in the IPMP for longer-term results.

Permit Requires Phosphorus Management Plan

In 2005, alum treatments in Washington required coverage under the National Pollution Discharge Elimination System (NPDES) permit, a permit required by the Clean Water Act (1972) and administered by the state of Washington. Typically, before granting NPDES permit coverage for using herbicides to control nuisance aquatic weeds the Washington Department of Ecology required an Integrated Aquatic Vegetation Management Plan (IAVMP). For lack of a separate classification, alum treatments were grouped with nuisance weed control projects, and therefore, required an Integrated Phosphorus Management Plan (IPMP).

The *Lake Hicks IPMP*, completed in March 2005, compiles watershed and lake history, outlines the sources of phosphorus, examines the phosphorus control options, and recommends using aluminum sulfate (alum) and sodium aluminate (buffer) to control internal phosphorus loading at Lake Hicks. The IPMP also discusses other treatment strategies to be incorporated; the Friends of Hicks Lake intends to initiate a watershed education campaign, and the King County CPOSA group has other projects underway upstream of Lake Hicks that are intended to improve water quality of the surface waters flowing to Lake Hicks. The IPMP is available online at: http://dnr.metrokc.gov/wlr/-waterres/smlakes/reports.htm.

Buffer Chosen

In lakes with relatively low alkalinity, such as Lake Hicks, using a "buffering agent" during the alum treatment is required to prevent the pH in the lake from decreasing to a point that would threaten aquatic life. Of the several different substances that could have been used to buffer the alum treatment, sodium aluminate was determined to be the most cost-effective because it also contributes a high weight of aluminum by volume. Other

buffering solutions considered included slaked lime and calcium carbonate, neither of which adds any aluminum to the lake during the alum treatment.

Jar Tests Determine Correct Amounts of Alum and Buffer

To estimate the correct ratio of aluminum sulfate (alum) to sodium aluminate (buffer), staff at the King County Environmental Lab performed several "jar tests." The goal was to identify the amount of alum and buffer equaling a dose of 25mg aluminum per liter of lake water, while maintaining pH in the lake just above 6.5, a condition of the NPDES permit. The sodium aluminate has a higher content of aluminum per unit weight than the alum, so it contributed more aluminum to the lake. This was a primary consideration in using this buffer rather than other available buffering substances such as calcium carbonate.

Lab personnel performed quick tests prior to the full 24-hour treatment tests to determine the approximate ratios of alum to buffer to use in the 24-hour jar test. Three ratios were applied, with two sample sets for each ratio of alum to buffer (Table 2).

Table 2. Ratios of Alum and Buffer Used in Jar Tests

Replicate number	mg Al from alum	mg Al from buffer
1	12.02	12.98
2	12.02	12.98
3	11.74	13.26
4	11.74	13.26
5	12.32	12.68
6	12.32	12.68

For each set of replicates, lab personnel, measured the initial pH initially, after the alum was applied, after the buffer was applied, and at one hour after treatment, four hours after treatment, and just before and after 24-hours post-treatment (Figure 3).

Replicate tests 3 and 4 yielded the pH endpoint closest to 6.5, so that ratio was chosen as the most appropriate from the ratios tested. However, the alum and sodium aluminate products used in the jar tests were supplied by different vendors than the products used in the treatment, so some changes in proportions were made to ensure that volumes of alum to buffer were in the correct ratio to each other, and that the chemicals were in the correct ratio to the lake water. After estimating the lake volume and analyzing data from the jar tests, staff determined the optimal ratio of alum to buffer from Cascade Columbia Distributors to be 2418 gal aluminum sulfate (48% solution) to 985 gal sodium aluminate (43% solution).

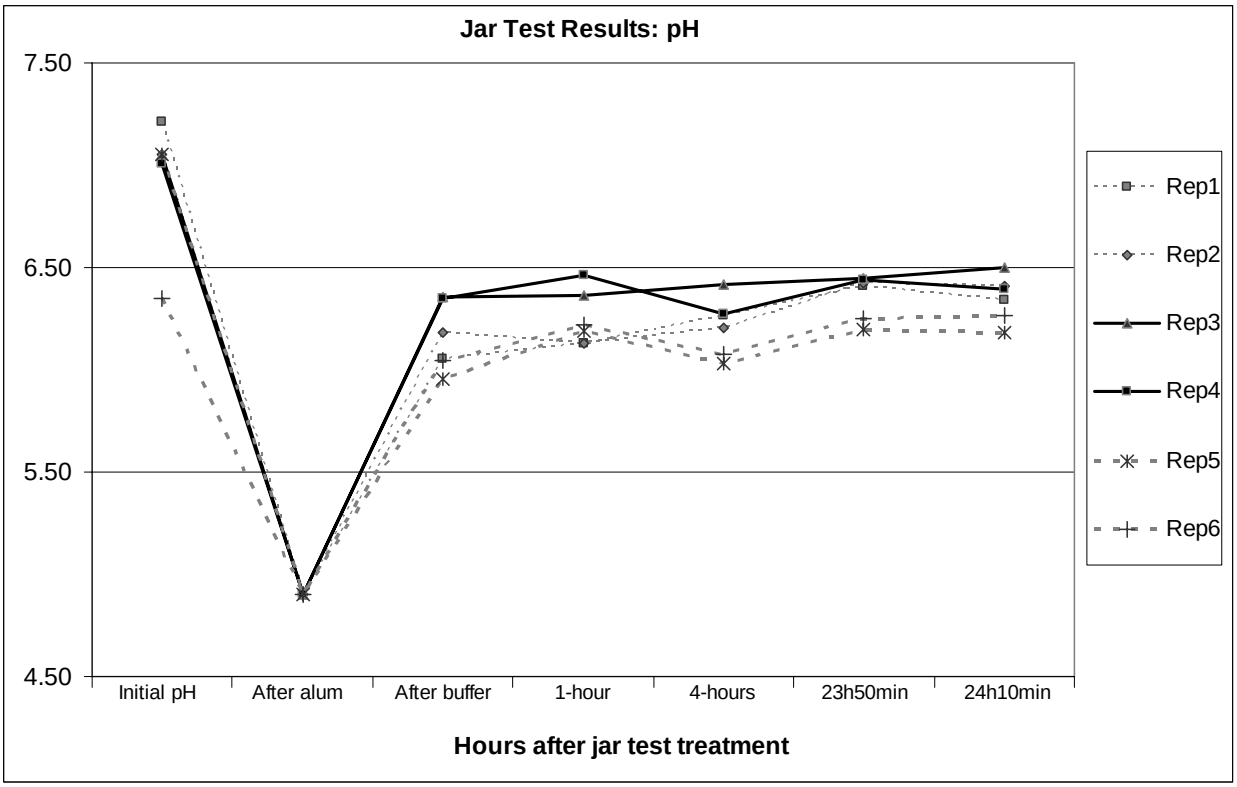


Figure 3. Jar Test Results: pH

In addition, the water used in the jar test was analyzed for orthophosphate, total phosphorous, and alkalinity. These results were not integral to determining the dose of alum and buffer necessary for the treatment, but showed that the treatment would be effective in removing phosphorus. The results from the pH tests and analysis of other parameters are shown in Appendix D.

Chemicals Purchased from Local Supplier

Suppliers were sought who could provide both of the chemicals. After reviewing three bids, the company chosen to provide the chemicals was Cascade Columbia Distributors, a chemical distributor located in south Seattle.

Consultant and Applicator Hired

None of the King County staff working on the project had previous experience with alum treatments, so a consultant with relevant experience was hired to advise King County staff during the project. King County hired Tom Smayda of Smayda Environmental Consultants.

The applicator hired was AquaTechnex, the lowest bidder among several aquatic herbicide applicators with the necessary equipment for the job.

DAY OF TREATMENT

Chemicals delivered to site

The alum was contained in a tanker truck that remained on site throughout the day. The tanker truck was equipped with an air-pressure system that could force the alum out of the truck and through the hoses.

The sodium aluminate was delivered to the site in four 250-gallon plastic tanks, or “totes” (Figure 4). Each tote had an air vent at the top and a “cam-lock” fitting at the bottom where the drain hose could be attached. The totes were not rated for increased pressure, so filling the tanks relied upon the totes being at a higher elevation than the tanks on the boats so gravity and the weight of the sodium aluminate would allow the fluid to flow through the hoses.

Figure 4. Sodium aluminate totes

Staff and assignments

There were several King County staff members on site during the alum treatment, each with one or more tasks (Table 3).

Table 3. Staff Assignments on Day of Treatment

Staff	Affiliation	Tasks
Sally Abella	KC DNRP	Water sampling, photos
Beth Cullen	KC DNRP	Water sampling
Michael Murphy	KC DNRP	Project Manager
Ben Budka	KC DNRP	Water sampling, photos
Terry Siebens	KC DNRP	Alkalinity titrations
Tom Smayda	Smayda Environmental Consultants	Water sampling, photos
Chris Clinton	AquaTechnex	Treatment boat/tank operator
Terry McNabb	AquaTechnex	Treatment boat/tank operator
Kyle Langan	AquaTechnex	Treatment boat/tank operator
CCD Truck driver	CCD	Chemical tanks and hoses

Tricia Shoblom from the Washington State Department of Ecology was at the site for part of the day to ensure that the application was going according to the NPDES permit conditions.

A spill and accident response plan was developed and on site during the treatment. This plan is included as Appendix E.

Boats on the water

AquaTechnex staff arrived at the lake in the morning and launched two boats into the lake, using the beach on the east side of the lake as a ramp.

Filling the tanks on the boats

To maintain stable pH, the two chemicals must be added to the water simultaneously. Because alum and sodium aluminate are both very heavy liquids, putting two tanks on a single boat would have required using small tanks and refilling them very often. Instead, tanks for each chemical were placed on separate boats – a 150 gallon tank on a larger boat for the alum, and a 75 gallon tank on a smaller boat for the sodium aluminate.

Two-inch (inside diameter) hoses were attached to the outlet ports of the tanker truck and the totes using cam-lock fittings. The hoses ran from the tanker truck and the totes down hill to the boats on the lake, a drop of approximately 10 feet (Figure 5.)

Figure 5. Loading Tanks on the Boats

The alum flowed relatively easily through the hoses, and the tank on the boats could be filled in several minutes. Additionally, the tanker truck could pressurize the tank, allowing the alum to be forced through the hose to the tank on the boat. The pressurized tank of the truck was useful in accelerating the fill rate as fluid pressure decreased as volume in the truck decreased through the day.

The sodium aluminate product was a viscous fluid, with a consistency at room temperature similar to corn syrup. The cool weather on the day of the treatment (air temperature ~10°C) increased the viscosity of the liquid, making it very slow to flow through the hose from the totes to the tanks on the boats. The first tank took about 30 minutes to fill. To reduce the friction between the fluid and the inside of the hose, the hose leading from the sodium aluminate totes to the tank on the boat was shortened as much as possible. With the shorter hose, the tank for the second run filled in approximately 15 minutes. However, it was clear that in order to finish the treatment in a single day as hoped, the sodium aluminate tank would need to be filled more quickly.

To further increase the flow of the sodium aluminate through the hose, a diaphragm pump was connected in-line between the sodium aluminate totes and the hoses leading to the tanks on the boats. The pump increased the rate of flow, but the process proved to be very hard on the pump. Two older pumps failed to in quick succession, due to insufficient horsepower to pump the viscous fluid. Two additional, more powerful pumps were rented from a local rental shop. One of these pumps blew a gasket after filling several tanks. The second rented pump made it through the remainder of the day. The tanks enabled the sodium aluminate tank to be filled in less than 10 minutes.

This problem could have been prevented by using a four-inch inside-diameter hose from the pumps to the tank, and by having the sodium aluminate stored in a heated room prior to the treatment so the liquid would have been less viscous.

Application process

The alum tank held 150 gallons and the buffer tank held with 62 gallons, which was very close to the proper ratio determined by the jar tests; during treatment, the pumping rates were adjusted so the two tanks were emptied at approximately the same time.

At 9am the alum and buffer tanks filled and treatment began. The boat delivering alum led the way, and the second boat applying the buffer followed closely behind. The boats crossed the lake from north to south and back, progressing from the west end of the lake toward the beach at the eastern shore of the lake. Each run across the lake slightly overlapped the area covered in the previous cross, ensuring that the entire bottom of the lake was blanketed with alum. The two boats were within 20 feet of one another at all times, and traveled at slow speeds during the treatment.

Figure 6. Alum treatment boats at Lake Hicks

When filling the tanks for the fourteenth trip onto the lake, the alum in the tanker truck ran dry. The truck driver opened the top hatch of the tank and discovered that less alum had been delivered than the requested amount, leaving approximately 150 gallons of sodium aluminate that could not be used; adding buffer only to the lake could have caused undesirable dramatic increases in pH.

Treatment finished just before 4pm.

Because of the short supply of alum, the supplier only charged for the alum and sodium aluminate that was used in treatment. However, the treatment did not deliver the target concentration of 25mg aluminum per liter of lake water. Total amounts of alum and buffer added to the lake were:

~ 2040 gallons of 48% aluminum sulfate (alum)
~ 850 gallons of 43% sodium aluminate (buffer)

Because the alum ran out when the tank was partially filled on the 14th treatment trip, the exact volume of the alum and sodium aluminate added to the lake is not known. However, based on the amount of sodium aluminate left in the fourth tote (~150gal), and knowing that alum and buffer were added in a ratio of 2.4:1, it is possible to estimate the treatment volume of alum and buffer. Estimated treatment volume was 2040 gallons of 48% aluminum sulfate to 850 gallons of 43% sodium aluminate. Based on the estimated volume of chemicals applied and the estimated volume of the lake on the day of treatment, the estimated treatment concentration was approximately 22 mg aluminum per liter of water in the lake.

Monitoring during Treatment

During treatment King County staff were taking physical measurements and collecting samples from the lake. Physical measurements included pH and Secchi; water samples were analyzed for alkalinity.

Ongoing measurements were taken to ensure that conditions in the lake were remaining relatively constant so as not to cause harm to plants and animals living in the lake. Maintaining pH above 6.5 was a requirement of the NPDES permit. No specific values were given, but the permit required monitoring alkalinity during the treatment. Data collected during the alum treatment show that conditions remained stable during most of the treatment. At about 10 A.M. pH values fell below 6.5, but were quickly brought up by adding additional buffer to the area (Figure 7).

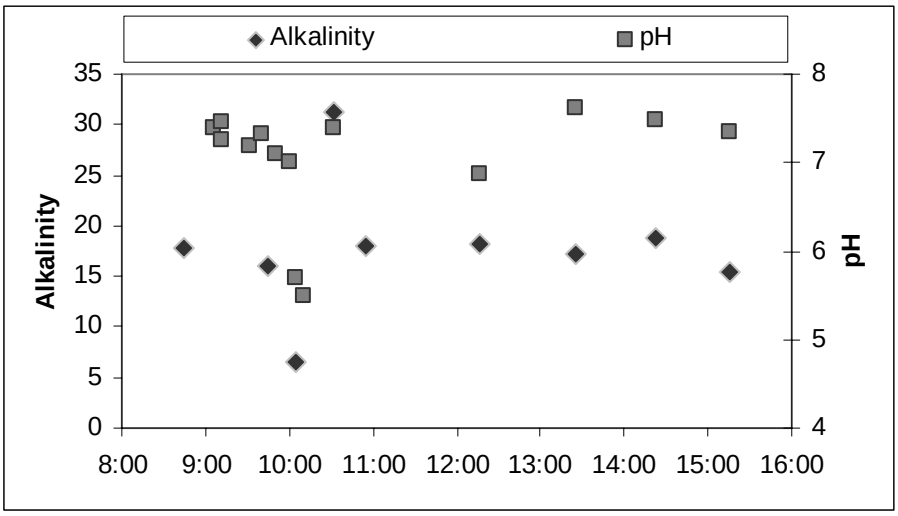


Figure 7. Alkalinity and pH During Treatment

POST-TREATMENT MONITORING RESULTS

Post-treatment monitoring began just after the treatment, and continued through the December 2005. 2005 data are included in Appendix A. King County plans to measure phosphorus concentrations and other parameters several times during 2006 and 2007 to determine if the alum treatment continues to prevent phosphorus release from the sediments.

The following charts shows the baseline data collected during 2004 compared with data collected in 2005 after the alum treatment (Figures 8-9-10).

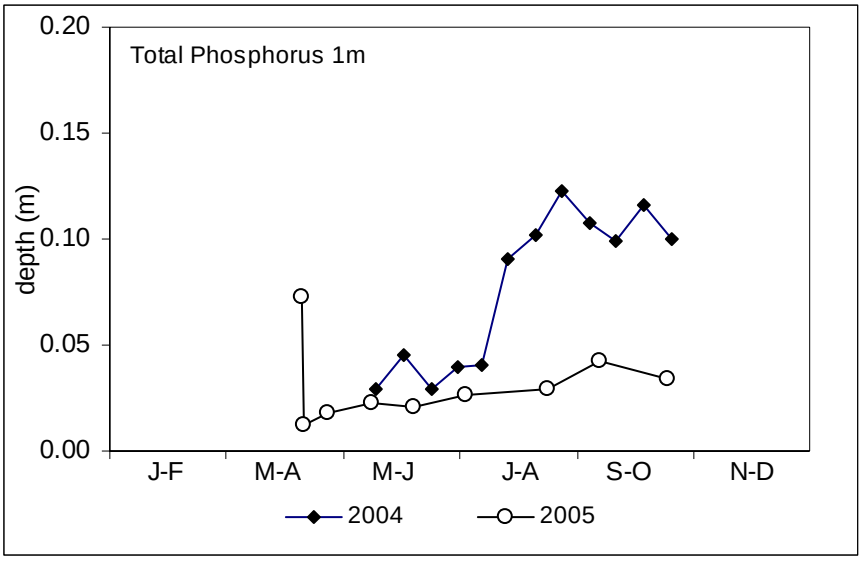


Figure 8. Total Phosphorus Values in 2004 and 2005

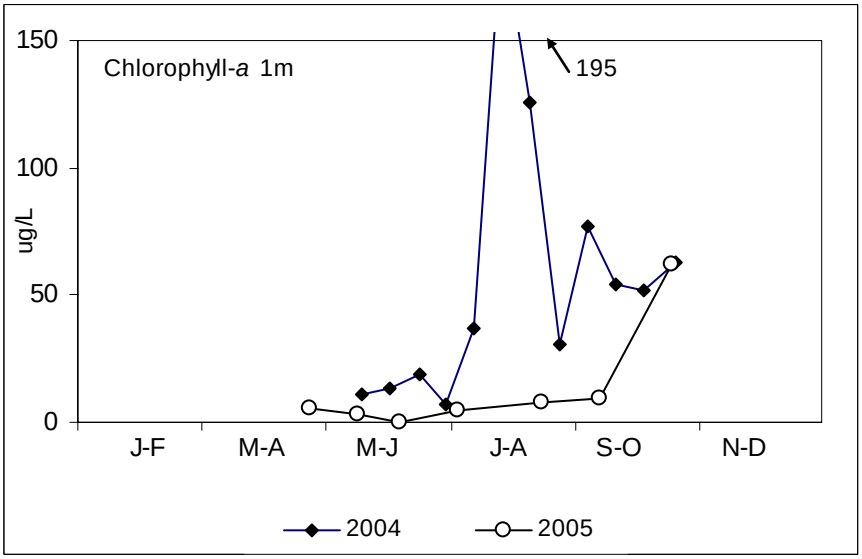


Figure 9.Chlorophyll *a* Values in 2004 and 2005

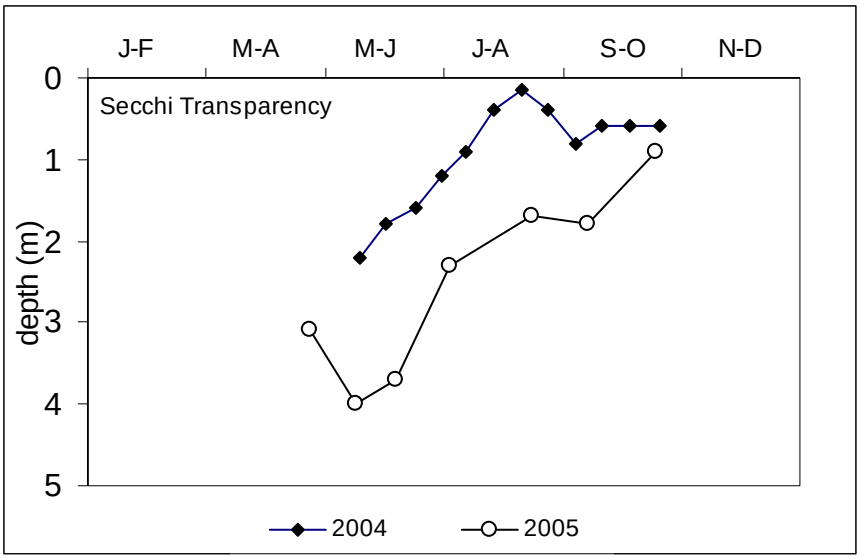


Figure 10. Secchi Values in 2004 and 2005

The data from 2005 illustrate clearly that the alum treatment was successful in sequestering phosphorus in the sediment of the lake. Phosphorus levels were lower in 2005 (Figure 8), and likely led to decreased algae growth evidenced by lower chlorophyll *a* values in 2005 (Figure 9). Decreased algae growth likely resulted in the deeper Secchi transparencies (Figure 10).

NEXT STEPS

In October 2005, the Capital Projects, Open Space and Acquisitions (CPOSA) group in King County's Water and Land Resources Division completed construction of a bio-swale just upstream of Lake Hicks, which reconfigured the outlet of the detention pond to the east of the parking lot on the west side of Lakewood Park. The bio-swale is designed to retain a large volume of water in addition to the pond, slow the flow of the inlet to the lake, and allow some of the sediment to settle out, while roots of the plants along the banks of the bio-swale take up some of the nutrients that would otherwise flow directly to the lake.

Staff from the King County Lake Stewardship program will continue to work with members of the White Center community in efforts to educate residents in the Lake Hicks watershed about phosphorus reduction measures, Best Management Practices, and other ways they can help maintain the health and beauty of Lake Hicks.

Appendices

Appendix A	Water Quality Data
Appendix B	Public Meeting Documentation
Appendix C	SEPA Documents
Appendix D	Jar Test Results
Appendix E	Emergency Response Plan

2004-2005 Lake Hicks Hand-held Meter Data

station	date	depth (m)	Time	Secchi	Temp degC YSI550	Temp degC YSI 63	Temp degC hydro	DO YSI550	DO hydrolab	pH YSI63	pH hydrolab	Cond. YSI63	Cond. hydrolab	Lake level
A745	19-May-04	1	10:30		19.1	19.1		8.10		6.99		49.7		
A745	19-May-04	2.5	10:45		17.1	16.6		2.60		6.26		51.5		
A745	19-May-04	4.5	10:50			11.9				6.19		56.3		
A745A	19-May-04	surface	11:20		19.7	19.7		8.35		6.76		50.2		
A745	2-Jun-04	1	11:38		19.0	19.0		10.23		7.9		48		
A745A	2-Jun-04	surface	11:00		20.1	20.2		10.17		7.52		50.3		
A745	17-Jun-04	1	11:40		21.3	21.5		9.26		8.24		47.5		
A745	17-Jun-04	3.3			16.3			1.50						
A745	17-Jun-04	4.8			13.8			0.74		5.93				
A745A	17-Jun-04													
A745	30-Jun-04	1	11:33		23.6	23.7		7.35		7.9		55.3		
A745	30-Jun-04	3.5	11:40		19.6	20.0		0.15		6.67		53.2		
A745	30-Jun-04	4.5	11:44			13.1		0.13		6.29		129.9		
A745A	30-Jun-04	surface	11:05		24.1	24.2		7.85		8.21		56.4		
A745	13-Jul-04	1	9:30			22.0		9.42		8.93		53.6		
A745	13-Jul-04	3.5	9:40			17.1		0.04		6.16		65.7		
A745	13-Jul-04	4.9	9:45			13.9				6.14		119.7		
A745A	13-Jul-04	surface	9:20		22.2	22.2		9.78		8.82		54.2		
A745	27-Jul-04	1	12:28			23.6		8.57		8.6		53.4		
A745	27-Jul-04	2				21.1		0.05		6.99		61.1		
A745	27-Jul-04	**2.5**				18.1		0.04		6.48		136		
A745A	27-Jul-04	surface	12:28			27.6		13.06		10.03		86.3		
A745	10-Aug-04	1	9:45		21.4	21.4		5.58		7.29		0		
A745	10-Aug-04	2.5	9:55		19.5	19.4		0.06		6.42		0		
A745	10-Aug-04	3	10:05			17.7		0.00		6.42		0		
A745A	10-Aug-04	surface	9:10		23.0	23.2		11.50		9.77		62.9		
A745	24-Aug-04	surface			20.7			1.38		6.35				
A745	24-Aug-04	1m			20.4			2.66		6.06				
A745	24-Aug-04	2.5m			20.2			2.21		5.96				
A745	24-Aug-04	3.5m			18.2			0.19		6.24				
A745A	24-Aug-04	surface	~9:45											
A745	7-Sep-04	surface												

2004-2005 Lake Hicks Hand-held Meter Data

station	date	depth (m)	Time	Secchi	Temp degC YSI550	Temp degC YSI 63	Temp degC hydro	DO YSI550	DO hydrolab	pH YSI63	pH hydrolab	Cond. YSI63	Cond. hydrolab	Lake level
A745	7-Sep-04	1m			19.5			5.25		7.03		55		
A745	7-Sep-04	2.5			19.5			4.43		6.83		53.6		
A745	7-Sep-04	4			18.9			0.00		6.17		60.6		
A745A	7-Sep-04	surface	10:00		19.6	19.6		5.10		6.75		54.8		
A745	21-Sep-04	1m	10:10		16.6	16.5		5.94		6.98		44.3		
A745	21-Sep-04													
A745	21-Sep-04													
A745A	21-Sep-04	surface	10:00		17.1	17.1		6.81		6.74				
A745	5-Oct-04	surface			15.2	15.1		6.29		7.04				
A745	5-Oct-04	1												
A745	5-Oct-04													
A745	5-Oct-04	3.5												
A745A	5-Oct-04	surface	9:29		15.1	15.2		6.37		7.51				
A745	20-Oct-04	surface	11:00		13.1	13.2		6.85		6.94				
A745	20-Oct-04	1m												
A745A	20-Oct-04	surface	10:35		13.3	13.3		4.87		7.25		36.875		
A745	25-Apr-05	1		3.1	16.4	16.6		9.05		7.12				160
A745	25-Apr-05	1.5			14.9	15.0		9.65		7.08				
A745	25-Apr-05	2			13.6	13.7		10.59		7.01				
A745	25-Apr-05	2.5			12.8	12.7		10.27		6.48				
A745	25-Apr-05	3			12.1	12.1		9.16		6.56				
A745	25-Apr-05	3.5				11.7				6.93				
A745	25-Apr-05	4				11.4				6.07				
A745	25-Apr-05	4.5				11.1				6.07				
A745	25-Apr-05	5				10.9				6.16				
A745	18-May-05	0	AM	4.0		18.0		7.90		6.81		68.6		156
A745	18-May-05	1	AM			17.9		7.92		6.59		68.4		
A745	18-May-05	1.5	AM			17.9		7.88		6.55		68.4		
A745	18-May-05	2	AM			17.7		7.22		6.56		66.9		
A745	18-May-05	2.5	AM			17.5		7.16		6.43		65.3		
A745	18-May-05	3	AM			17.3		6.08		6.37		68.8		
A745	18-May-05	3.5	AM			16.9				6.33		69.2		

2004-2005 Lake Hicks Hand-held Meter Data

station	date	depth (m)	Time	Secchi	Temp degC YSI550	Temp degC YSI 63	Temp degC hydro	DO YSI550	DO hydrolab	pH YSI63	pH hydrolab	Cond. YSI63	Cond. hydrolab	Lake level
A745	18-May-05	4	AM			16.6				6.35		70.4		
A745	18-May-05	4.5	AM			15.8				6.66		70.5		
A745	18-May-05	5	AM			15.0				6.66		76.4		
A745	18-May-05	5.5	AM			14.9		2.35						
A745	8-Jun-05	0.1	AM	3.6			18.85		6.71		7.29		70.2	115
A745	8-Jun-05	0.5	AM				18.83		7.11		7.3		70.1	
A745	8-Jun-05	1	AM				18.81		6.88		7.33		70.1	
A745	8-Jun-05	1.5	AM				18.8		6.87		7.33		70.4	
A745	8-Jun-05	2	AM				18.74		6.57		7.29		69.9	
A745	8-Jun-05	2.5	AM				18.62		5.33		7.16		70.9	
A745	8-Jun-05	3	AM				18.26		2.97		6.98		72.2	
A745	8-Jun-05	3.5	AM				17.21		0.7		6.85		75.4	
A745	8-Jun-05	4	AM				16.31		0.23		6.75		75.8	
A745	8-Jun-05	4.5	AM				15.38		0.16		6.88		96.7	
A745	6-Jul-05	0.5	AM	2.3		22.5	22.35		7.88	7.47	7.58	66.5	67.5	129
A745	6-Jul-05	1	AM			22.4	22.24		7.98	7.39	7.54	66.2	67.4	
A745	6-Jul-05	1.5	AM			22.2	22.13		7.84	7.36	7.51	62.0	67.1	
A745	6-Jul-05	2	AM			21.9	21.73		7.98	7.33	7.55	62.4	67.8	
A745	6-Jul-05	2.5	AM			21.5	21.14		6.95	7.29	7.39	62.4	68.2	
A745	6-Jul-05	3	AM			20.8	20.43		2.65	6.72	6.96	62.7	70.5	
A745	6-Jul-05	3.5	AM			20	19.37		0.58	6.51	6.79	63.7	72.9	
A745	6-Jul-05	4	AM			19.1	17.83		0.21	6.44	6.67	63.3	78.6	
A745	6-Jul-05	4.5	AM			17.3	16.68		0.19	6.39	6.66	71.5	91.9	
A745	17-Aug-05	0.5		1.7	22.5	22.5	22.45	7.47	7.62	7.66	7.65	80.6	48.1	90
A745	17-Aug-05	1			22.5	22.6	22.45	7.47	7.56	7.62	7.63	80.3	48.2	
A745	17-Aug-05	1.5			22.5	22.6	22.45	7.39	7.81	7.6	7.57	80.5	48.1	
A745	17-Aug-05	2			22.5	22.6	22.45	7.4	7.61	7.59	7.61	80.6	48	
A745	17-Aug-05	2.5			22.5	22.6	22.42	7.45	7.32	7.58	7.56	80.5	48.2	
A745	17-Aug-05	3			22.5	22.5	22.26	6.96	5.96	7.42	7.31	81	48.6	
A745	17-Aug-05	3.5				22.3	21.75		1.57	7.08	6.61	81.2	45.6	
A745	17-Aug-05	4				20.5	19.63		1.50	6.43	6.47	77	66.7	
A745	17-Aug-05	4.5				18.5	17.4		1.29	6.48	6.3	136.5	115	

2004-2005 Lake Hicks Hand-held Meter Data

station	date	depth (m)	Time	Secchi	Temp degC YSI550	Temp degC YSI 63	Temp degC hydro	DO YSI550	DO hydrolab	pH YSI63	pH hydrolab	Cond. YSI63	Cond. hydrolab	Lake level
A745	14-Sep-05	0.2	10:00	1.8			18.74		6.19		7.1		71.4	77
A745	14-Sep-05	1	10:00				18.75		6.35		7.21		71	
A745	14-Sep-05	1.5	10:00				18.74		6.26		7.11		70.8	
A745	14-Sep-05	2	10:00				18.72		6.33		7.06		71	
A745	14-Sep-05	2.5	10:00				18.7		5.93		7.01		71	
A745	14-Sep-05	3	10:00				18.68		6.05		6.98		71.1	
A745	14-Sep-05	3.5	10:00				18.62		5.47		7.01		71.2	
A745	14-Sep-05	4	10:00				18.57		4.96		7.01		71.4	
A745	14-Sep-05	4.5	10:00				18.44		3.78		6.91		73.4	
A745	19-Oct-05	0.2		0.9			14.29		9.86		7.35		70.2	86
A745	19-Oct-05	1					14.28		9.75		7.45		70.5	
A745	19-Oct-05	1.5					14.28		9.5		7.43		70.5	
A745	19-Oct-05	2					14.2		9		7.33		70.8	
A745	19-Oct-05	2.5					14.14		8.6		7.28		70.9	
A745	19-Oct-05	3					14.12		8.45		7.24		70.8	
A745	19-Oct-05	3.5					14.1		8.45		7.22		70.9	
A745	19-Oct-05	4					14.09		8.25		7.18		71.1	
A745	19-Oct-05	4.5					14.08		8.25		7.13		71	
A745	19-Oct-05	5					14.07		7.13		6.97		72.1	

2004-2005 Lake Hicks Nutrient and Fecal Coliform Data

Date	Secchi (m)	Chlor-a (µg/L)	Total P (µg/L)	Total N (µg/L)	FC (CFU/100mL)
19-May-04	2.2	11.2	0.0288	0.6390	8
2-Jun-04	1.8	13.5	0.0453	0.7390	34
17-Jun-04	1.6	18.6	0.0297	0.5740	100
30-Jun-04	1.2	7.37	0.0400	1.4500	60
13-Jul-04	0.9	36.8	0.0410	1.2500	120
27-Jul-04	0.4	195	0.0910	2.7100	6
10-Aug-04	0.15	126	0.1020	1.7100	230
24-Aug-04	0.4	30.4	0.1230	1.9100	690
7-Sep-04	0.8	76.7	0.1080	1.8400	83
21-Sep-04	0.6	54.2	0.0995	1.4100	130
5-Oct-04	0.6	51.6	0.1160	1.5000	74
20-Oct-04	0.6	62.9	0.0998	1.4300	460
11-Apr-05			0.0723		430
12-Apr-05			0.0124		22
25-Apr-05	3.1	5.61	0.0178	0.379	33
18-May-05	4.0	3.45	0.0226	0.523	34
8-Jun-05	3.7	**0.05**	0.0212	0.554	26
6-Jul-05	2.3	4.44	0.0260	0.724	40
17-Aug-05	1.7	8.23	0.0289	0.625	35
14-Sep-05	1.8	9.20	0.0427	0.859	5
19-Oct-05	0.9		0.0341		92

APPENDIX B:

PUBLIC MEETING DOCUMENTATION

This appendix contains documents related to two public meetings held prior to the alum treatment.

January 12, 2005

- Meeting Flyer
- Meeting Agenda
- Sign-in sheet

March 24, 2005

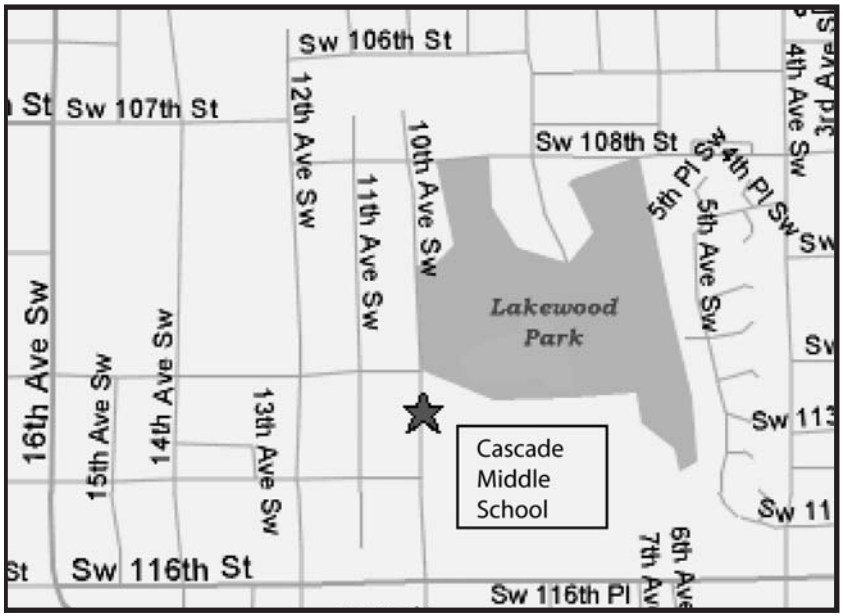
- Meeting Flyer
- Meeting Agenda
- Sign-in sheet

Lake Hicks Alum Treatment Public Meeting

Wednesday January 12, 2005
6:30 – 8 p.m.
Cascade Middle School, in the choir room (directions and map on back)
11212 10th Ave SW, Seattle 98146

Please join us to discuss plans for improvements to Lake Hicks (Garrett). The Washington State Department of Ecology considers Lake Hicks to be impaired by excessively high phosphorus levels that contribute to frequent algae blooms. King County is applying for a permit to treat the lake next spring with aluminum sulfate (alum), which will lower phosphorus concentrations in the water and "cap" the phosphorus rich sediments. County staff and community leaders will be present to answer questions about the alum treatment and other planned improvements at Lake Hicks and Lakewood Park.

King County
Department of
Natural Resources and Parks
Water and Land Resources Division



DIRECTIONS **to Cascade Middle School: From SW 116th Street, head north on 10th Ave SW.**

Cascade Middle School will be on your right, just south of Lakewood Park.

Park in the lot and follow the signs to the choir room (toward the back of the school).

0412LakeHicksAlumFlyer.p65 mdev

Lake Hicks Alum Treatment 2nd Public Meeting

Thursday, March 24, 2005
6:30 – 8 p.m.
Cascade Middle School, in the choir room (directions and map on back)
11212 10th Ave SW, Seattle 98146

Please join us to discuss plans for improvements to Lake Hicks (Garrett). The Washington State Department of Ecology considers Lake Hicks to be impaired by excessively high phosphorus levels that contribute to frequent algae blooms. King County is applying for a permit to treat the lake next spring with aluminum sulfate (alum), which will lower phosphorus concentrations in the water and "cap" the phosphorus rich sediments. County staff and community leaders will be present to answer questions about the alum treatment and other planned improvements at Lake Hicks and Lakewood Park.

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Park in the lot and follow the signs to the choir room (toward the back of the school).

0412LakeHicksAlumFlyer.p65 mdev

APPENDIX D: Jar Test Results

3/8/05 Lake Hicks tests with Univar buffer

Beaker	Aluminum (mg/L)				Product (mg/L)			Product (ml/L)					pH (continuous stirring)				T (°C)	
	Total Al dose	buffer Al/ alum Al	Al from alum	Al from buffer	alum	buffer	buffer/ alum	alum	buffer	buffer/ alum	**alum 10%**	**buffer 10%**		after alum	after buffer			
#	(mg/L)	w/w (k)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	w/w	(ml/L)	(ml/L)	v/v	**(ml/L)**	**(ml/L)**	initial			**time**	initial	final
1	25	1.08	12.02	12.98	276.94	134.10	0.48	0.209	0.117	0.561	**2.086**	**1.170**	7.209	4.9	6.053	11:50	10.7	10.7
2	25	1.08	12.02	12.98	276.94	134.10	0.48	0.209	0.117	0.561	**2.086**	**1.170**	7.050	4.9	6.179	12:02	10.5	10.6
3	25	1.13	11.74	13.26	270.44	137.01	0.51	0.204	0.120	0.587	**2.037**	**1.196**	7.050	4.9	6.353	12:17	10.4	10.5
4	25	1.13	11.74	13.26	270.44	137.01	0.51	0.204	0.120	0.587	**2.037**	**1.196**	7.009	4.9	6.351	12:29	10.6	10.6
5	25	1.03	12.32	12.68	283.76	131.04	0.46	0.214	0.114	0.535	**2.137**	**1.144**	7.056	4.9	5.953	12:47	10.5	10.5
6	25	1.03	12.32	12.68	283.76	131.04	0.46	0.214	0.114	0.535	**2.137**	**1.144**	6.352	4.9	6.042	13:03	10.7	10.8

Beaker	**pH record** (top only, no stirring)													
#	alum (mg/L)	Buffer (mg/L)	Time	time 1 h	pH	time 4 h	pH	time 24 h -10 min	pH	time 24 h +10 min	pH	**mean 24 h pH**	T (°C)
1	12.02	12.98		12:51	6.129	15:52	6.268	11:40	6.407	12:00	6.339	**6.37**	10.1
2	12.02	12.98		13:05	6.131	16:04	6.206	11:52	6.421	12:16	6.407	**6.41**	9.8
3	11.74	13.26		13:17	6.363	16:18	6.416	12:02	6.445	12:25	6.500	**6.47**	10.2
4	11.74	13.26		13:30	6.464	16:26	6.276	12:23	6.440	12:42	6.393	**6.42**	9.8
5	12.32	12.68		13:46	6.186	16:46	6.031	12:35	6.198	12:58	6.182	**6.19**	10.1
6	12.32	12.68		14:03	6.223	17:01	6.077	12:52	6.252	13:13	6.267	**6.26**	10.1

5 min soak on all 24 h measurements

Beaker #	Sample record	Lims #	Sample date / time		orthoP	total P (mg/L)	Alk
1	24 h sample	L34910-1	3/9/2005	12:05	<mdl	0.0059	5.6
2	24 h sample	-2	3/9/2005	12:20	<mdl	0.0063	5.8
3	24 h sample	-3	3/9/2005	12:30	<mdl	0.0056	7.0
4	24 h sample	-4	3/9/2005	12:45	<mdl	<mdl	6.9
5	24 h sample	-5	3/9/2005	13:00	<mdl	<mdl	4.5
6	24 h sample	-6	3/9/2005	13:15	<mdl	0.0058	4.9
Alum (Cascade)		-7	3/9/2005	10:00			
Alum, 10%		-8	3/9/2005	10:00			
Sodium Aluminate (Univar)		-9	3/9/2005	10:00			
Sodium Aluminate 10%		-10	3/9/2005	10:00			
Lake Hicks water		L34903-1	3/7/2005		<mdl	0.0553	17.5

Al from alum (mg) = 25 /(1+k), where k = buffer-Al / alum-Al w/w ratio
Al from buffer (mg) = 25 - Al from alum (mg)

Alum	**based on USALCO 48.2%**	
w/w ratio Al_2/product	0.04340	
Product weight	11.1	lbs/gal
	5,045,455	mg/gal
	1328	mg/ml

Buffer	**Univar 30%**	
w/w ratio Al_2/product	0.0968	
Product weight	9.58	lbs/gal
	4,354,545	mg/gal
	1146	mg/ml

APPENDIX E:

EMERGENCY RESPONSE PLAN

This appendix contains a copy of the Emergency Response Plan developed to guide staff in the event of a spill or medical emergency during the alum treatment.