BLACK LAKE RESTORATION PROJECT: PHASE II

Final Report on Sediment Coring, Jar Testing and Alum Dosing

HAB AquaticSolutions

JANUARY 2, 2018

1 Project Understanding

HAB Aquatic Solutions (HAB) understands that for Phase I of the Black Lake Alum Treatment Project, two deep water sediment cores were collected, sectioned and analyzed for labile phosphorus (P), iron bound-P, aluminum bound-P, calcium bound-P and organic bound-P. Biogenic-P was not measured, but rather estimated as a fraction of the organic P. Herrera Environmental Consultants conducted this study and used the results to calculate an aluminum sulfate (alum) dose for Black Lake. The 2016 dose was based on the sum of sediment mobile P (labile + iron bound-P), estimated sediment biogenic-P and water column P. However, this dose did not account for water column interference from organic and other negative compound/particles within the water column. In April 2016, HAB applied the recommended alum dose to the lake in accordance with the Phase I project specifications.

HAB understands that water quality improvements were noted in the summer of 2016 following the alum application. However, the improvements were below expectations and the duration of the benefits were questioned. HAB considers the Phase I dose to be very light (relative to other HAB projects) and the observed water quality improvements are encouraging and suggest that additional alum could further enhance the duration of benefits.

1. Phase II (the current study) builds upon the previous work by collecting additional sediment cores and adding biogenic-P to the list of measured parameters (rather than estimating it). The additional cores and tests better characterize the potential internal loading of P across the entire lake and refine the total required alum dose. In addition to the coring, HAB conducted jar tests to determine if there are any chemical, dissolved or particulate (i.e. humics), interferences to aluminum availability to bind with phosphorus during alum floc formation and P binding in the water column and sediment of Black Lake. The Phase II results and recommendations are included in this report. The study, alum doses and application strategy were reviewed and supported by an independent lake management expert (Appendix B).

2 Jar Tests on Alum Phosphorus Removal Efficiency

HAB conducted a jar test to determine if any interferences to alum floc formation and P binding capacity exist in the water column. The jar test was conducted at the Black Lake boat launch on June 2, 2017by titrating a range of alum volumes into plastic containers filled with water from Black Lake. For each dose, the P removal was measured and used to determine the optimal water column alum dose. Table 1 shows the individual aluminum doses and the total-P, total alkalinity and pH measurements collected 30 minutes after aluminum addition. Figures1 (see page 10) presents a graphical representation of these results. The jar test replicated a buffered alum application (alum:sodium aluminate = 2:1) and Table 2 lists the volumes of aluminum sulfate and sodium aluminate added to 10 gallons (38 L) of Black Lake water for each dose.

Table 1. Jar test aluminum doses and results 30 minutes after dosing.

Dose	Volumetric Al Dose (mg Al/L)	Aerial Al Dose (g Al/m^2)	Total-P* (µg/L)	Total-P* (% Change)	pH*	Total Alkalinity* (mg $CaCO_3$/L)
0	0	0	12	0%	7.67	270
1	0.81	4.21	13	+8%	7.66	267
2	2.03	10.54	12	0%	7.66	260
3	2.84	14.75	13	+8%	7.61	253
4	4.05	21.07	5	-58%	7.61	250
5	8.11	42.14	4	-67%	7.40	230
6	24.32	126.42	4	-67%	7.21	200
7	40.54	210.70	4	-67%	6.84	145
8	60.81	316.05	3	-75%	6.35	90
9	81.08	420.40	3	-75%	5.92	40

Table 2. Jar test dose volumes of aluminum sulfate and sodium aluminate in 30 gallons (38 L) of lake water.

Dose	Volumetric Al Dose (mg Al/L)	Aerial Al Dose (g Al/m^2)	Aluminum Sulfate Dose (ml/10 gal*)	Sodium Aluminate Dose (ml/10 gal*)
0	0	0	0	0
1	0.81	4.21	0.23	0.11
2	2.03	10.54	0.57	0.28
3	2.84	14.75	0.80	0.40
4	4.05	21.07	1.14	0.57
5	8.11	42.14	2.28	1.14
6	24.32	126.42	6.84	3.42
7	40.54	210.70	11.39	5.70
8	60.81	316.05	17.01	8.55
9	81.08	420.40	22.79	11.39

*10 gallons = 37.85 liters

**alum:sodium aluminate = 2:1

As anticipated, jar test results indicate that a higher than normal interference to alum floc formation and P binding exists in Black Lake's water column. This can be offset by adding the correct amount of alum during applications. The amount of alum required to offset the interference is called the "water column alum demand" and is incorporated into the total alum dose (water column demand + sediment demand) for a lake. Lakes typically have a water column demand of 0.5 to 2.4 mg Al/L.

The total-P jar test reduction curve (Figure 1, page 10) shows that the optimal dose to overcome the water column demand, and achieve a desired P reduction, was dose #4 (Table 1). This dose of 4.05 mg Al/L or 21.07 g Al/m^2 resulted in a decrease of total-P to 5 μg/L. Higher doses reduced to total-P to 3-4 mg/L, but the relatively insignificant greater reduction is not justified by the increased costs associated with these higher doses. Dose #4 is the most cost-effective dose to overcome the water column demand and was used to calculate the total alum dose for Black Lake. The jar tests also show that Dose #4 is an environmentally safe dose, with only minor reductions in pH and alkalinity (Figure 1; Table 1).

3 Sediment Coring and Alum Dosing

3.1 Sediment Coring

3.1.1 Core Collection Methodology

A single sediment core was collected from an anchored boat on June3, 2017 from seven locations in Black Lake. Undisturbed cores were collected using a Piston Interface Corer (www.aquaticresearch.com/piston_sediment_corer). The locations were representative of the lake conditions, included various lake depths and captured spatial variation in sediment chemistry across Black Lake. The coring locations are shown in Figure 2 and the exact site locations (latitude and longitude) are described in Table 3.

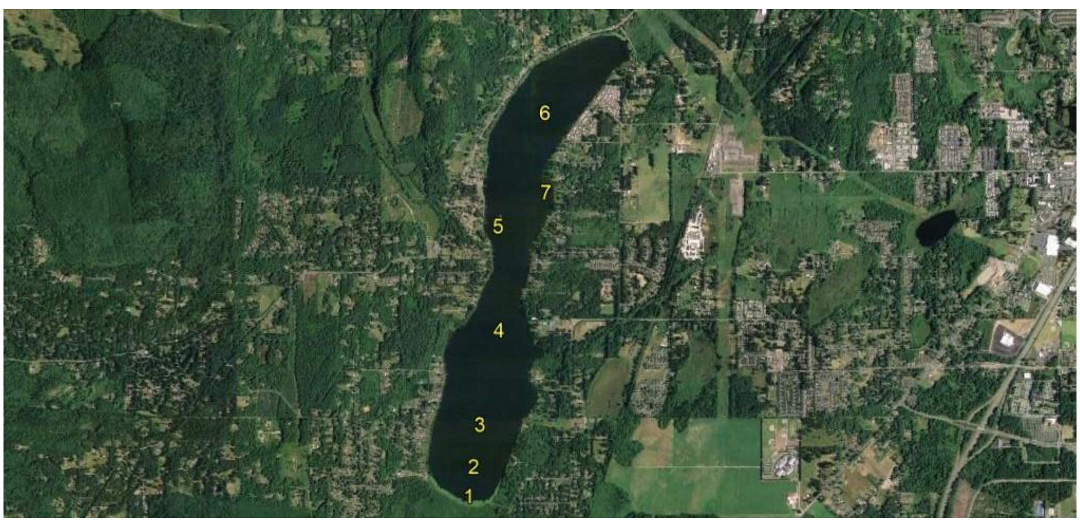


Figure 2. Black Lake Sediment Coring Locations

Table 3. Description of the coring locations and core characteristics.

Site	Latitude/Longitude	Water Depth (ft)	Core Length (cm)	Core Type
1	46.9759/-122.9825	8	25	Shallow Water
2	46.9772/-122.9825	13	25	Shallow Water

3	46.9812/-122.9813	20	20	Shallow Water
4	46.9882/-122.9792	26	20	Deep Water
5	46.9959/-122.9793	25	20	Deep Water
6	47.0043/-122.9742	25	25	Deep Water
7	46.9984/-122.9741	6.5	8	Shallow Water

Immediately after collecting the core (in the boat), each of the seven cores were sectioned at 2-5 cm intervals to the bottom of the core (see Table 3 for core lengths). The core depths were determined by the by the consistency/texture of the lakebed and the penetration depths of the gravity coring device. The coring depths were satisfactory to adequately define the zone of bioavailable phosphorus.

3.1.2 Lab Testing

The coring and subsequent sectioning resulted in 49 sediment samples. The samples were kept on ice and delivered on June 3, 2017 to IEH Analytical Laboratories (IEH) in Seattle, WA. IEH analyzed each sample for the following required parameters:

- Percent Water & Percent Solids
- Total Organic Carbon
- Total Phosphorus
- Phosphorus Fractions: Total Organic Phosphorus, Biogenic Phosphorus, Mobile Phosphorus (iron-bound phosphorus plus loosely sorbed phosphorus), Aluminum-bound Phosphorus & Calcium-bound Phosphorus
- Aluminum, Iron & Calcium

3.1.3 Results

The laboratory results are presented in Appendix A. All requested analyses were performed and the data quality was reviewed for precision and accuracy. The detection limits were acceptable, and all analytes were detected in all samples with the exception of loosely bound phosphorus. The loosely bound fraction was not detected in any samples at a detection limit of 2 mg/kg dry weight. Accuracy was acceptable based on recoveries ranging from 100 to 101% for quality control check samples.

The sediment phosphorus data are presented in Figure 3 on pages 12-13. Total phosphorus and biogenic-P was consistently high at all coring locations. The phosphorus fractions generally decreased with core depth until reaching stable background concentrations.

The total amount of P in the sediments is high and a significant pool of P exists in the Black Lake sediments that is contributing to available P in the water column via internal loading. The internal loading source of P from the sediments is two fold. The first source is organic-P. The concentration of organic-P is very high relative to the other P fractions. The biogenic-P represents the portion of the organic-P that is most readily available for dissolution into the water column, the biogenic-P concentrations are also very high. Internal loading from the organic-P pool is controlled by biological activity in the sediments, rather than stoichiometric REDOX chemistry.

The second internal loading source is the P that is bound to iron. Iron bound-P is controlled by stoichiometric REDOX chemistry and internally loading from this source generally occurs when the sediments are anoxic. There is significant iron bound-P in the Black Lake sediments (as represented by core #6) and it is an internal loading source of concern.

3.2 Alum Application Strategy and Plan

3.2.1 Alum Dosing

The method of alum dose calculation for Black Lake is summarized below:

2. Assumed a ratio of aluminum added to aluminum bound P formed of 20:1 for mobile P (labile + Fe-P) and water column demand and 9:1 for biogenic-P.
3. Assumed the liable-P concentration of 1 mg/kg dry wet when results were below the detection limit of 2 mg/kg dry weight.
4. Estimated the mass of aluminum required to inactivate water column phosphorus (jar test study indicates a dose of 21.07 g Al/m^{2}to meet the water column demand)(Table 1).
5. Estimated the mass of aluminum required to inactivate bioavailable sediment phosphorus for each core.
    a. Determined the depth of mobile phosphorus (Labile-P + Fe-P + biogenic-P) in the lakebed at all coring sites. Fe-P, biogenic-P, organic-P, total-P and total organic carbon generally decreased with core depth and stabilized at a background concentration at depths of 8-15 cm (Figure 3).
    b. Converted the volume of targeted sediment to mass by multiplying the sediment bulk density by percent dry matter.
    c. Determined the mass of mobile phosphorus by multiplying the targeted mobile phosphorus concentration by the mass of targeted sediment.
    d. Determined the aluminum dose in g Al/m^2 by the product of the mass of mobile phosphorus and the ratio of aluminum added to aluminum bound phosphorus formed.
6. Averaged the aluminum dose for the shallow water cores and the deep water cores (Table 3)to determine total sediment dose for lake depths of 2-20 feet and >20 feet.
7. Summed the total sediment dose for each depth zone and water column dose to determine the overall aluminum dose for the lake.
8. Compared the overall aluminum dose to the buffering capacity of the lake and determined the total aluminum dose cannot be supplied solely by alum, and an aluminum-based pH buffer (sodium aluminate) is necessary. Determined the required ratio of alum to buffer to be 2:1.
9. Converted the total aluminum dose mass to gallons of alum and sodium aluminate.
10. A dose of 21.07 g Al/m^{2}is required to meet the water column demand.
11. A dose of 50.29 g Al/m^2 is required to inactivate available sediment P at lake depths of 2-20 ft.
12. A dose of 72.86g Al/m^{2}is required to inactivate available sediment P at lake depths >20 ft.
13. A total dose of 71.36 g Al/m^2 (21.07 + 50.29 g Al/m^2) is required for lake depths of 2-20 ft.

14. A total dose of 93.93 g Al/m^2 (21.07 + 72.86 g Al/m^2) is required for lake depths > 20 ft.
15. The doses and application strategy were reviewed and supported by an independent lake management expert (Appendix B).

3.2.2 Alum Application Strategy and Plan

3.2.2.1 Option 1

- Apply a **half** dose of alum and sodium aluminate in year one to inactivate the targeted sediment and water column P throughout the entire lake at water depths greater than 2 ft. This results in a dose of 234,382 gallons of alum and 117,191 gallons of sodium aluminate.

- Additional sediment and water samples would be collected 6 months after the first application to confirm the dose for the second application. This allows for adjustments if needed. The testing will not need to be as extensive and costly as the recently completed study. Fewer cores and samples will be required to confirm the second dose. Our previous project experience (e.g., Green Lake, WA, Bald Eagle Lake, MN, Cedar Lake, WI) has shown that this approach increases the effectiveness and cost-efficacy of the alum applications.

- Apply a second **half** dose of alum and sodium aluminate 2-3 years after the first half dose to the same application zones used in the first application. It is anticipated that the second dose will also be 234,382 gallons of alum and 117,191 gallons of sodium aluminate.

- The estimated cost for ***each*** half dose application is $1,130,000. This cost includes all contractor services required for the applications; including alum, sodium aluminate, taxes, labor, mobilization, demobilization, water quality monitoring, and reporting.

3.2.2.2 Option 2

- Apply a **half** dose of alum and sodium aluminate in year one to inactivate the targeted sediment and water column P throughout the entire lake at water depths greater than 2 ft. This results in a dose of 234,382 gallons of alum and 117,191 gallons of sodium aluminate.

- Additional sediment and water samples would be collected 6 months after the first application to confirm the dose for the second application. This allows for adjustments if needed.

- Apply a **quarter** dose of alum and sodium aluminate 2-3 years after the first half dose to the same application zones used in the first application. It is anticipated that the second dose will also be 162,203 gallons of alum and 81,101 gallons of sodium aluminate.

- Additional sediment and water samples would be collected 6 months after the first quarter dose application to confirm the dose for the second quarter dose application. This allows for adjustments if needed.

- Apply a second **quarter** dose of alum and sodium aluminate 2-3 years after the first quarter dose to the same application zones used in the first two applications. It is anticipated that the second quarter dose will also be 162,203 gallons of alum and 81,101 gallons of sodium aluminate.

- The estimated cost for the half dose application is $1,130,000. The estimated cost for ***each*** quarter dose is $800,000. These costs include all contractor services required for the applications; including alum, sodium aluminate, taxes, labor, mobilization, demobilization, water quality monitoring, and reporting.

- Option 2 spreads the project costs over multiple fiscal years and could be an advantage, depending on availability of funds.

4 Funding Strategy Considerations

4.1 Washington Department of Ecology

4.1.1 Freshwater Algae Program (FAP) Grants

- The maximum grant amount for freshwater algae program grants is $50,000

- Eligible activities include, but may not be limited to the following:
    - Education and outreach
    - Freshwater algae control and management
    - Freshwater algae management plans
    - Freshwater algae monitoring programs
    - Freshwater algae pilot projects
    - Freshwater algae research
    - Freshwater algae sampling equipment
    - Nutrient reduction activities

- Priority is given to lakes in which harmful freshwater algae have occurred within the past three years.

4.1.2 Centennial Grant

- Centennial Grants represent a larger funding source and should be considered for a potential Black Lake alum project.
- Typically, a match of 25% for non-point source pollution grants are required.

- Eligible Project Types:
    - Wastewater facility construction (financial hardship communities only)

- Onsite repair and replacement
- Agricultural best management practices
- Education and stewardship
- Water quality monitoring
- Lake water quality planning
- Riparian and wetlands habitat restoration and enhancement
- Stream restoration
- TMDL plan development and implementation
- Wellhead protection

- It is our understanding that these grants are large and could be used for an alum application project.

- It is our understanding that having received a previous FAP grant may be viewed favorably in the Centennial Grant process. The FAP grant can be viewed as a planning grant and the Centennial Grant can be viewed as a project implementation grant.

- It is our understanding that Centennial Grant applications that have political support may have a better chance of being funded. We recommend that local representatives be identified and educated on the needs of Black Lake in hopes of gaining support for a successful Centennial Grant application. Such educational efforts should include meetings and presentations with representatives about the problem and recommended solutions. HAB is interested in having conversations with Black Lake about assisting with these efforts.

4.1.3 Self-funded

- HAB is working with a lake community in Wisconsin on an alum application project. The total cost of the project is approximately $2.5M. They are receiving some state grants, but are funding a considerable amount of the project themselves.

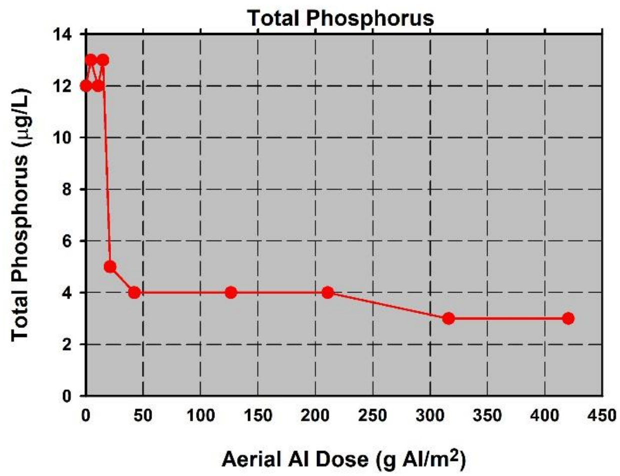
- They already had taxing district in place that collected a small property tax each year based on a mil rate that is established annually.

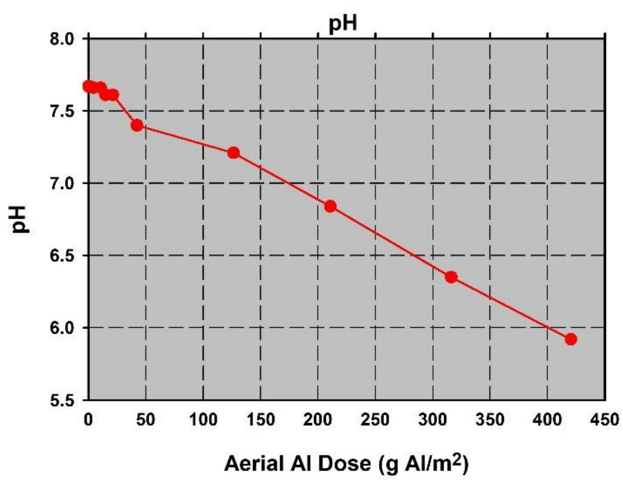
- They created a Special Assessment through the taxing district to fund the alum project.

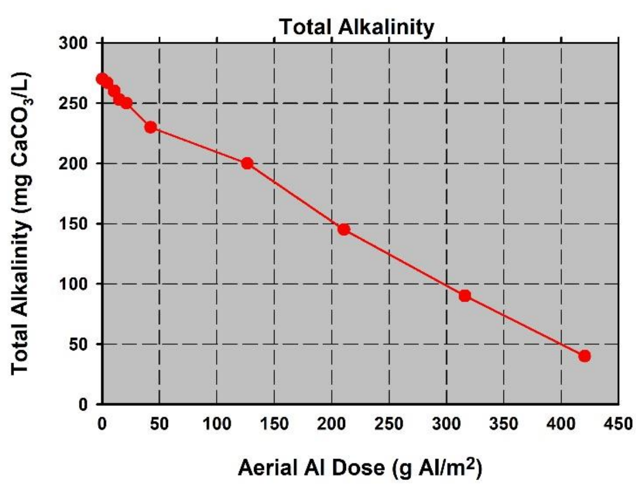
- They chose to do the Special Assessment each year until the project was complete (basically pay as they go). Other options include a longer-term assessment (~10-15 years) and obtain a loan to pay for the alum application. The annual Special Assessment funds are then used to pay the loan back.

- Determine if Black Lake has a current taxing district in place. Some lake taxing districts have been recently established around Seattle. If Black Lake has a taxing district, some restructuring may be required to allow the funding of alum projects. HAB can provide more information, if needed.

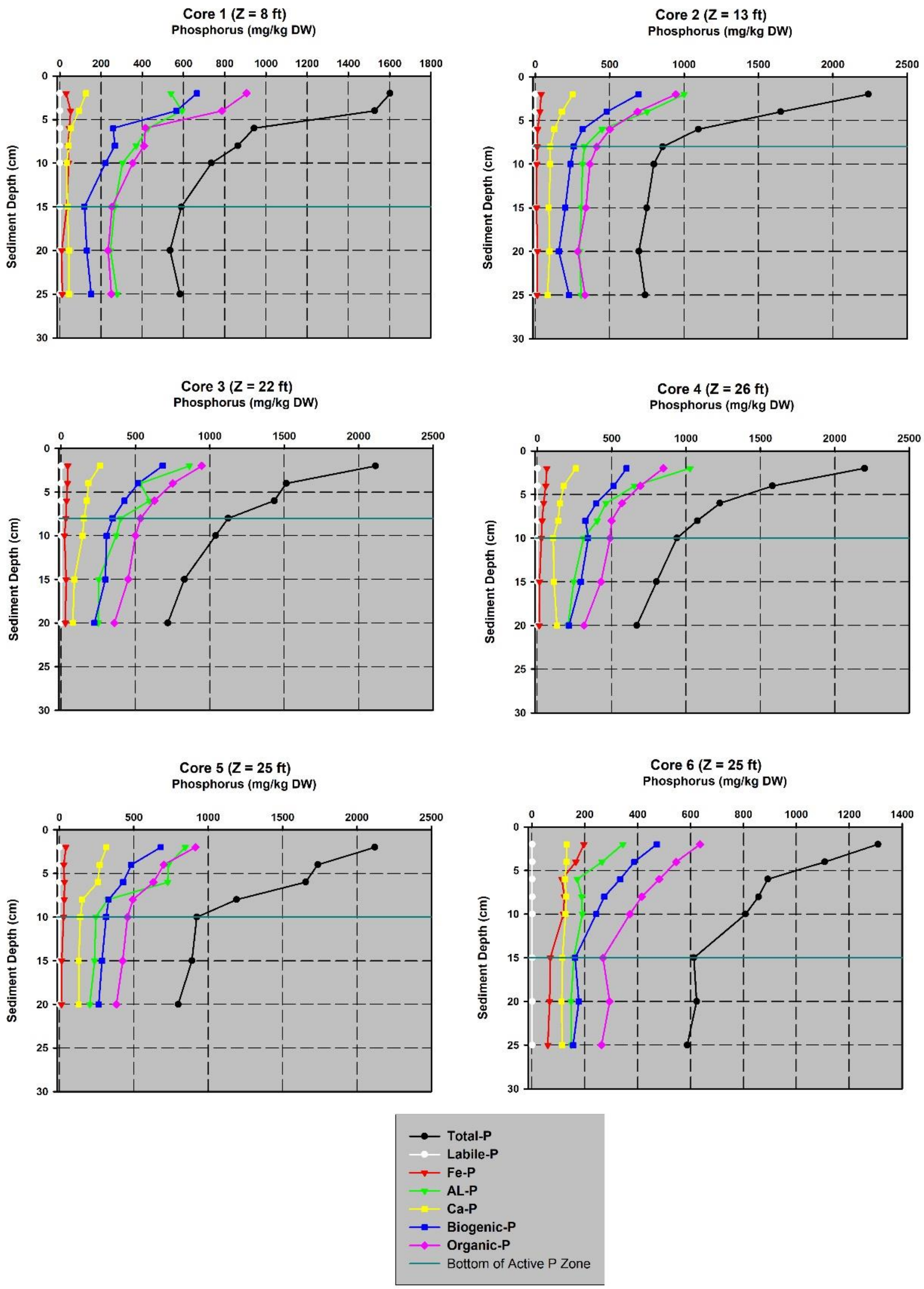
5 Figure 1. Effects of Jar Test Alum Doses on Total-P, pH and Total Alkalinity

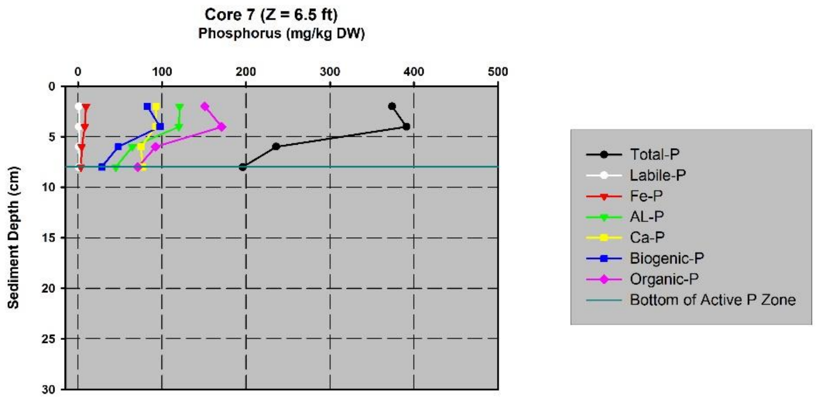

Total Phosphorus
Total Phosphorus (μg/L)
0
2
4
6
8
10
12
14
0
50
100
150
200
250
300
350
400
450
Aerial Al Dose (g Al/m2)


pH
pH
5.5
6.0
6.5
7.0
7.5
8.0
0
50
100
150
200
250
300
350
400
450
Aerial Al Dose (g Al/m2)


Total Alkalinity
Total Alkalinity (mg CaCO3/L)
0
50
100
150
200
250
300
0
50
100
150
200
250
300
350
400
450
Aerial Al Dose (g Al/m2)

6 Figure 3: Sediment P-Fraction Profiles for the Seven Black Lake Cores


Core 1 (Z = 8 ft)
Phosphorus (mg/kg DW)
Core 2 (Z = 13 ft)
Phosphorus (mg/kg DW)
Core 3 (Z = 22 ft)
Phosphorus (mg/kg DW)
Core 4 (Z = 26 ft)
Phosphorus (mg/kg DW)
Core 5 (Z = 25 ft)
Phosphorus (mg/kg DW)
Core 6 (Z = 25 ft)
Phosphorus (mg/kg DW)
Sediment Depth (cm)
Total-P
Labile-P
Fe-P
AL-P
Ca-P
Biogenic-P
Organic-P
Bottom of Active P Zone


Core 7 (Z = 6.5 ft)
Phosphorus (mg/kg DW)
0
100
200
300
400
500
Sediment Depth (cm)
0
5
10
15
20
25
30
Total-P
Labile-P
Fe-P
AL-P
Ca-P
Biogenic-P
Organic-P
Bottom of Active P Zone

7 Appendix A. P-Fractionation Lab Results

IEH ANALYTICAL LABORATORIES
LABORATORY & CONSULTING SERVICES
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PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER:	MIS048-37B	PAGE	1
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DATE SAMPLED:	06/03/17	DATE RECEIVED:	06/04/17

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON SEDIMENT SAMPLES FROM HAB AQUATIC SOLUTIONS

CASE NARRATIVE

Forty nine sediment samples were received by the laboratory in good condition and analyzed according to the chain of custody. Phosphorus fractions were determined according to the method of Rydin and Welch.. Successive extractions with NH4Cl, Bicarbonate/Dithionate, NaOH, and HCL were performed and analyzed for phosphorus. One part of Organic P was determined by digesting the residue after the inorganic fractions were extracted. Organic P includes the P after the inorganic fractions plus Biogenic P. Total P is the sum of all fractions minus Biogenic P, which is part of the Organic P fraction. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows, while QA/QC data is contained on subsequent pages.

SAMPLE DATA - SEDIMENTS (DRY WT. BASIS)

SAMPLE ID	% SOLIDS	% WATER	TOC (%)	TOTAL-P (mg/kg)	LOOSELY BOUND P (NH4CL) (mg/kg)	FE BOUND P (DITHIONATE) (mg/kg)	AL BOUND P (NAOH) (mg/kg)	BIOGENIC P (mg/kg)	CA BOUND P (HCL) (mg/kg)	ORGANIC P (mg/kg)
BL1 0-2	5.84%	94.2%	PENDING	1602	<2.00	30.1	539	664	127	906
BL1 2-4	6.25%	93.7%	PENDING	1527	<2.00	52.6	593	565	94.4	787
BL1 4-6	7.04%	93.0%	PENDING	943	<2.00	46.3	427	259	54.1	416
BL1 6-8	8.12%	91.9%	PENDING	863	<2.00	41.1	370	267	43.7	409
BL1 8-10	8.54%	91.5%	PENDING	735	<2.00	42.3	304	221	34.2	354
BL1 10-15	9.93%	90.1%	PENDING	590	<2.00	34.2	266	119	37.7	253
BL1 15-20	11.3%	88.7%	PENDING	535	<2.00	9.1	246	131	44.3	235
BL1 20-25	11.3%	88.7%	PENDING	583	<2.00	11.2	278	152	44.5	250
BL2 0-2	5.83%	94.2%	PENDING	2238	<2.00	39.3	1000	695	253	945
BL2 2-4	6.41%	93.6%	PENDING	1650	<2.00	30.7	752	481	179	688
BL2 4-6	7.77%	92.2%	PENDING	1096	<2.00	15.7	449	319	128	502
BL2 6-8	8.89%	91.1%	PENDING	857	<2.00	13.0	330	260	101	413
BL2 8-10	9.71%	90.3%	PENDING	797	<2.00	10.6	318	237	101	367
BL2 10-15	10.6%	89.4%	PENDING	750	<2.00	8.2	310	202	91.3	341
BL2 15-20	11.9%	88.1%	PENDING	697	<2.00	14.7	298	159	96.7	287
BL2 20-25	12.1%	87.9%	PENDING	738	<2.00	12.6	308	228	83.2	334
BL3 0-2	6.80%	93.2%	PENDING	2115	<2.00	44.5	862	682	262	946
BL3 2-4	7.70%	92.3%	PENDING	1513	<2.00	43.5	532	519	185	752
BL2 4-6	8.38%	91.6%	PENDING	1434	<2.00	37.8	595	426	174	628
BL3 6-8	9.14%	90.9%	PENDING	1123	<2.00	33.1	401	347	154	535
BL3 8-10	9.83%	90.2%	PENDING	1039	<2.00	22.5	370	306	145	501
BL3 10-15	10.9%	89.1%	PENDING	829	<2.00	33.5	254	298	89.6	452
BL3 15-20	12.0%	88.0%	PENDING	717	<2.00	29.3	250	225	79.6	358
BL4 0-2	7.63%	92.4%	PENDING	2201	<2.00	65.4	1026	601	260	849
BL4 2-4	8.52%	91.5%	PENDING	1581	<2.00	56.6	654	514	178	693
BL4 4-6	9.60%	90.4%	PENDING	1229	<2.00	44.2	462	397	153	570
BL4 6-8	9.55%	90.5%	PENDING	1076	<2.00	32.9	403	324	141	499
BL4 8-10	13.7%	86.3%	PENDING	938	<2.00	28.6	311	343	108	490
BL4 10-15	12.3%	87.7%	PENDING	802	<2.00	15.1	245	293	113	429
BL4 15-20	13.3%	86.7%	PENDING	670	<2.00	13.9	207	213	133	316
BL5 0-2	8.66%	91.3%	PENDING	2121	<2.00	43.1	846	682	317	915
BL5 2-4	10.1%	89.9%	PENDING	1737	<2.00	30.4	732	484	272	702
BL5 4-6	10.6%	89.4%	PENDING	1655	<2.00	34.3	729	429	259	632
BL5 6-8	11.8%	88.2%	PENDING	1191	<2.00	32.9	325	331	154	494
BL5 8-10	12.5%	87.5%	PENDING	923	<2.00	28.6	245	314	140	459
BL5 10-15	13.8%	86.2%	PENDING	891	<2.00	15.1	237	287	130	426
BL5 15-20	14.6%	85.4%	PENDING	798	<2.00	13.9	204	265	130	383
BL6 0-2	8.70%	91.3%	PENDING	1309	<2.00	196.4	344	473	132	636
BL6 2-4	10.3%	89.7%	PENDING	1108	<2.00	166.4	265	387	131	546
BL6 4-6	11.1%	88.9%	PENDING	892	<2.00	112.9	171	334	125	482
BL6 6-8	11.9%	88.1%	PENDING	857	<2.00	122.3	189	274	130	416
BL6 8-10	12.3%	87.7%	PENDING	808	<2.00	119.5	191	243	127	371
BL6 10-15	14.4%	85.6%	PENDING	612	<2.00	69.1	158	163	116	269
BL6 15-20	15.5%	84.5%	PENDING	623	<2.00	66.8	148	178	113	294
BL6 20-25	15.0%	85.0%	PENDING	587	<2.00	60.2	149	156	114	264
BL7 0-2	52.0%	48.0%	PENDING	374	<2.00	9.5	121	82.6	93.2	151
BL7 2-4	52.4%	47.6%	PENDING	391	<2.00	7.9	120	97.5	92.5	171
BL7 4-6	66.4%	33.6%	PENDING	236	<2.00	4.2	64.5	47.8	75.0	92.4
BL7 6-8	71.9%	28.1%	PENDING	196	<2.00	3.4	45.0	28.3	76.6	71.2

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CASE FILE NUMBER:	MIS048-37B	PAGE	2
REPORT DATE:	PRELIMINARY REPORT 08/13/17		
DATE SAMPLED:	06/03/17	DATE RECEIVED:	06/04/17
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON			
SEDIMENT SAMPLES FROM HAB AQUATIC SOLUTIONS			

QA/QC DATA- SEDIMENTS

QC PARAMETER	% SOLIDS	TOC (%)	TOTAL-P (mg/kg)	LOOSELY BOUND P (NH4CL) (mg/kg)	FE BOUND P (DITHIONATE) (mg/kg)	AL BOUND P (NAOH) (mg/kg)	BIOGENIC P (mg/kg)	CA BOUND P (HCL) (mg/kg)	ORGANIC P (mg/kg)
METHOD	SM18 2540B	EPA 9060	CALCULATED	SM18 4500PF	SM18 4500PF	SM18 4500PF	EPA 365.1	SM18 4500PF	EPA 365.1
DATE PREPARED	08/03/17		08/07/17	08/07/17	08/07/17	42954.0	08/07/17	08/07/17	08/07/17
DATE ANALYZED	1.00%	0.01	5.00	2.00	2.00	2.0	2.00	2.00	2.00
DETECTION LIMIT									
DUPLICATE									
	BL7 6-7.5		BL7 6-7.5	BL7 6-7.5	BL7 6-7.5	BL7 6-7.5	BL7 6-7.5	BL7 6-7.5	BL7 6-7.5
SAMPLE ID	71.9%		196	<2.00	3.44	45.0	28.3	76.6	71.2
ORIGINAL	71.6%		204	<2.00	3.46	44.8	29.0	78.6	77.2
DUPLICATE	0.37%	#DIV/0!	3.89%	NC	0.69%	0.0	2.31%	2.56%	8.06%
RPD									
SPIKE SAMPLE									
SAMPLE ID									
ORIGINAL									
SPIKED SAMPLE									
SPIKE ADDED	NA	NA	NA	NA	NA	NA	NA	NA	NA
% RECOVERY									
QC CHECK (mg/l)									
FOUND				0.039	0.039	0.0	0.095	0.039	0.095
TRUE		3.35		0.039	0.039	0.0	0.094	0.039	0.094
% RECOVERY	NA	0.00%	NA	100.00%	100.00%	1.0	101.06%	100.00%	101.06%
BLANK	NA	<0.01	NA	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

8 Appendix B. Independent Review of Study and Report

To: John Holz, PhD, HAB Aquatic Solutions
From: Harry Gibbons, PhD
Date: January 1, 2018

Subject: Black Lake Restoration: Phase II Review

Thanks for the opportunity to review your draft report on Black Lake alum dose. Basically, this is great work and I agree with your approach, finding and recommendations. The following is a summary of review comments and report concurrences.

Section 2
The approach to and assessment of the jars test for alum phosphorus removal efficiency is correct. The recommend dose for water column of 4.05 mg Al/L is correct.

Section 3.1
The approach and assessment of the results of sediment coring is correct.

Section 3.2.1
The alum dosing approach and calculations are correct and within the range to be expected for this type of lake.

Section 3.2.2
Both option 1 and 2 are valid approaches to treating Black Lake to maximize effectiveness and to give funding options.

The only issue that is beyond the current scope of this study, is that without a current and update phosphorus mass balance to help define the impact of external phosphorus loading to the recharging of sediment phosphorus and internal loading; a prediction of longevity of effectiveness in preventing harmful algal blooms is between 5 to 20 years after the last current proposed option 1 or 2 treatments. This means that regardless of option 1 or 2 the lake will need another alum treatment due to external watershed loading of phosphorus. Although the dose for that future treatment will probably be significantly lower than currently needed, because the proposed alum treatment dose would control the legacy sediment phosphorus that is currently driving internal phosphorus loading. For examples, Long Lake in Kitsap County needs an alum treatment every 5 years; Green Lake in Seattle is on a 10 to 15 year treatment cycle; and Long Lake (main lake) in Thurston County is on a 20 plus year cycle.

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