Final Report for:
Agreement: WQC-2018-CwCoHH-00092

Project Name: Silver Lake Sediment and Water Quality Testing

Recipient: Cowlitz County Health & Human Services

Total Cost of Project: $173,468

Grant Amount: $120,101

Project Start Date: 2/1/2018

Project End Date: 12/31/2022

Subproject: Engagement Project

_____   _____

Authorized Signatory / Date   Project Manager / Date

1.0   Title Page and Table of Contents

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2.0 Executive Summary

2.1 Project Description

There were two primary objectives of this project: to sample sediment at the bottom of Silver Lake (in hopes of facilitating a potential dredging project) and to continue with lake water quality measurements; with the addition of sampling the inlet creeks. The specific sediment sampling goal was to determine if sediment extracted or dredged from the bottom of the lake would likely meet the parameters of the Dredged Material Management Program (DMMP) Contaminants of Concern (COCs) for disposal. Water quality goals included ongoing sampling from the lake and two inlet creeks, Sucker Creek, and Hemlock Creek. Samples from each creek were to be taken above and below potential influences (referred herein as "upper" and "lower" sample sites).

This project attempted to determine if the potential influences at Sucker Creek included the Headquarters Landfill and any forestry activities occurring between the upper and lower sample sites. Unfortunately, an upper Sucker Creek sample site could not be accessed and was therefore eliminated during the planning phase. The lower Sucker Creek sample site, located below the landfill and through the Weyerhaeuser gate about a mile down the road at the bridge (which was reconstructed during the project), was retained.

Two adequate sample sites were located on Hemlock Creek. The upper sample site could be accessed through a Weyerhaeuser gate approximately a mile and ½ up the 4730 road. The lower sample site was located near the two culverts that deliver water into the lake, on the canal side, of Canal Rd.

Overall, the water quality sampling schedule was completed as outlined in Figure 3. Grab samples were collected for total phosphorus, chlorophyll *a*, and *E. coli,* and analyzed. During the sampling a digital handheld multi-parameter probe was used to gather field data on water temperature, pH, dissolved oxygen, and turbidity. Secchi depths were determined at the lake's Deep East, Deep West, and Outlet Creek sampling sites in conjunction with the grab sampling. Sampling for *E. coli* during the summer demonstrated that the swim areas met EPA primary recreation standards.

Goal achievement success varied. The sediment sampling goal was met, a quality assurance project plan was developed, and composite samples were taken and analyzed. The water sampling goal was only partially executed as the Inlet Creek upper and lower sample sites were compromised; however, greater community outreach was accomplished by providing an educational postcard to the residents living in the larger watershed area as well as digitizing and updating the watershed management plan, allowing greater access to this information.

While not part of the original project description, the Silver Lake Diking District received permission to flush the lake in September of 2018. This event took place between Cowlitz County's two water quality grants with Ecology. SLWAC and the surrounding community

expressed a high level of interest regarding the effectiveness of the lake flushing project, and therefore, the result of the flushing event has been included in this report.

2.2 Project Accomplishments

In May of 2019 the Quality Assurance Project Plan – Silver Lake (QAPP) and the Standard Operating Procedures (SOPs) were approved by Ecology. Volunteers reviewed the SOPs and were trained by County staff. The project's design included sampling at three designated lake locations, 5 stream locations and 4 swim beaches during the months June- September (Figure 3). These sites were accessed by boat. Sampling frequency was monthly from May 2019 – April 2021. A Secchi disc was used at these locations to determine Secchi visibility. Water, temperature, pH, dissolved oxygen, and turbidity was measured in-situ using a digital sampling handheld multiparameter meter that was funded by this project. An accredited lab determined total phosphorus, chlorophyll *a*, and *E. coli*. Samples were collected per Ecology approved protocols as outlined in the QAPP. The mean, variance, and standard deviation of the results were calculated. The results were graphed, and trends and patterns were identified, where possible.

Accomplishments:
1) Collected 189 total phosphorus samples from streams.
2) Took 37 chlorophyll *a* sample from lake
3) Took 213 *E. coli* samples from both the lake and the streams.
4) Collected the following data points: 201 temperature, 201 dissolved oxygen, 185 pH, and 185 turbidity measurements with the probe in the lake, and in the streams.
5) Conducted a one-time sampling event for testing total phosphorus and standard fresh-water COCs that were collected from three locations of the lake. The samples were then homogenized, composited and analyzed as one sample. See *Figure 13* for detailed list of COCs.
6) Measured water temperature, dissolved oxygen, pH, and turbidity concurrently during all sediment sampling at each sample location. These measurements are covered via the Silver Lake Water Quality Testing QAPP published in May 2019.
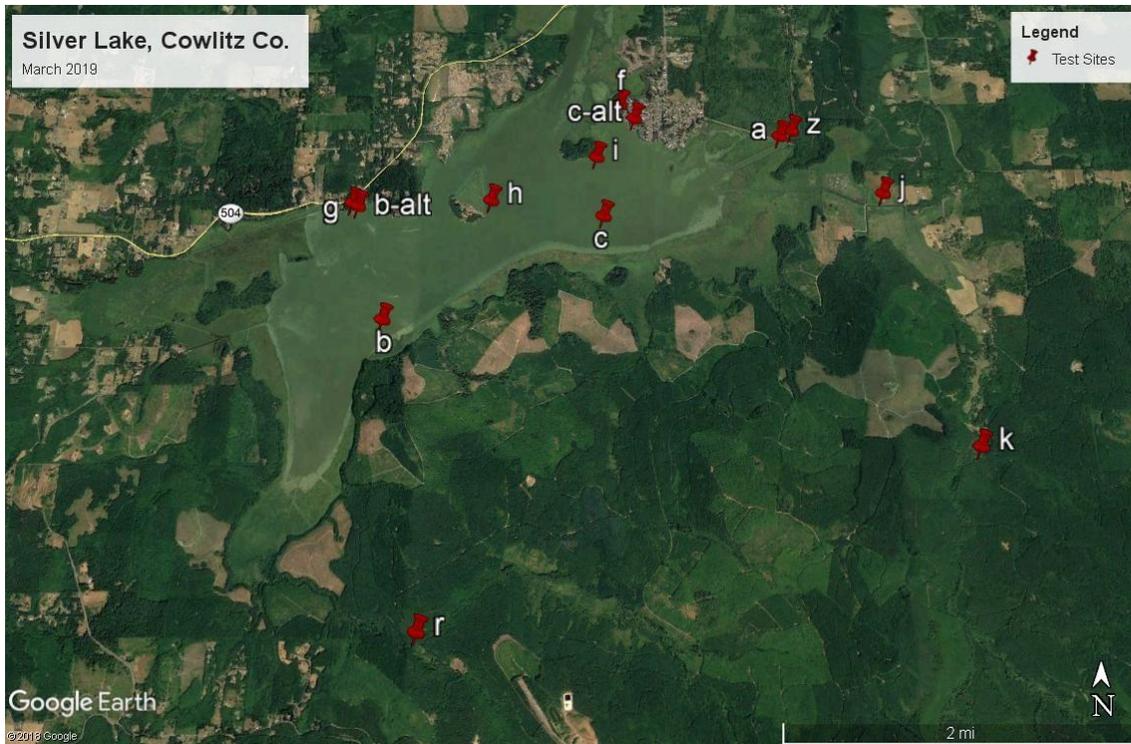
Figure 1: All Water Sampling Sites

Lake Sites – Main Monthly: a. Outlet Creek, b. Deep West, c. Deep East
Lake Sites – Seasonal Swim: f. Streeters, i. Tree House, g. Silver Resort, h. Walen
Creek Sites – z. Outlet Gate, r. Sucker Creek Upper, j. Hemlock Canal Rd, k. Hemlock Rd 1390
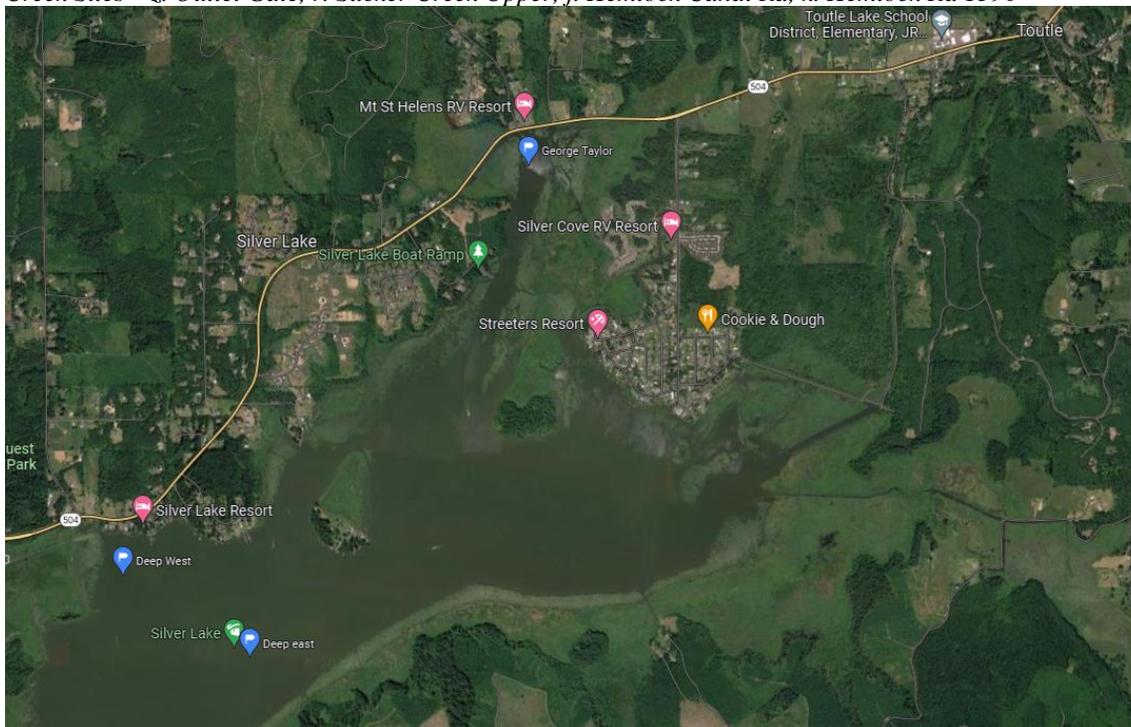

Figure 2: Sediment sampling sites

Lake Sites – one time sampling event: George Taylor, Deep West, Deep East

2.3   The Next Step for Continued Success

The Diking District should continue to fund water quality testing in the lake and inlet streams. SLWAC should engage stakeholders, including the US Army Corps of Engineers to discuss the possibility of dredging using the sediment data collected in this study.

SLWAC is also considering the value and possibility of increasing the influence of Hemlock Creek, in which the upper section had the least amount of phosphorus reported. However, the lower section of Hemlock Creek had relatively high levels of phosphorus, which may correlate to the sampling location being influenced by the lake inflow and outflow at this sight. Prior to any action this discrepancy should be further investigated.

CCHD will continue to work with residents to identify cyanobacteria blooms and post warning signs and beach closures when appropriate. Additionally, the Silver Lake Watershed Management Plan also recommends stream shading, both shoreline and road erosion control, fenced aquatic nurseries, and the management of riparian zones. CCHD supports this recommendation being explored.

2.4   Lessons Learned

Lessons learned:

- Consult with other agencies early (The Dredged Material Management Program turned out to be immensely helpful!)
- Confirm access to sample sites in planning stage
- Search for like projects during planning stage – if none exist, then plan for more time to complete (QAPP, etc)

Complications:
- Probe was sent back to the factory in June for the following repairs: USB connection and cord needed to be replaced along with replacement of the DO, turbidity, and temperature/conductivity sensors.
- Sucker Creek sample site underwent bridge replacement (even though it was remote!)
- Hemlock Creek culvert sample site was not always representative of Hemlock Creek – sometimes the lake would flow up the dike waterway, likely dependent on lake and stream levels.

3.0 Overview Description of Project

3.1 General Project Description

This project provided useful data for evaluating the overall health of Silver Lake and in planning long-term actions. The immediate goal of this project was to provide the data and site-specific results necessary to plan, execute, and evaluate continuous improvement projects. One measurement of success included the completion of 24 water sampling events in addition to a one-time analysis of a sediment sample. A key goal of this project was accomplished by updating the watershed management plan and digitizing it. This will allow greater access by community and agency members to use the information already published on Silver Lake. Another metric of success was the mailing of 800educational and outreach postcards to residents living in the Silver Lake watershed.

The Silver Lake QAPP, written by CCHD, was approved by Ecology and a water quality probe was purchased. This study then generated a reliable databank that includes 189 data points for total phosphorus, 37 data points for chlorophyll *a*, and 213 data points for *E. coli*. These data points supported trend analysis regarding each constituent. The water quality probe provided four additional parameters, generating 185 data points for pH and turbidity as well 201 data points for DO and temperature. The data was collected following the approved QAPP protocols.

The project also encouraged local discussion and improved the understanding of individuals' effect on lake water quality. The project's data was cataloged and submitted to Ecology through the Environmental Information Management (EIM) database. It was also made available to the public via the County's public website

3.2 Sampling Schedule (Done 12-20-22)

Water Quality Sample Schedule with QC						
April 2019 – March 2021						
#	**Target Date**	Lake TP	Lake Secchi	**Stream TP**	**Lake chlor *a***	*E. coli* *Lake + stream + swim + QC*
1	May 2019	3	3	5	3	3 lake + 5 stream
2	Jun 2019	3 + Q	3	5 + Q	3	3 lake + 5 stream + 4 swim + Q
3	July 2019	3	3	5	3 + Q	3 lake + 5 stream + 4 swim
4	Aug 2019	3 + B	3	5 + B	3 + B	3 lake + 5 stream + 4 swim + B
5	Sep 2019	3 + Q	3	5 + Q	3	3 lake + 5 stream + 4 swim + Q
6	Oct 2019	3	3	5	3 + Q	3 lake + 5 stream
7	Nov 2019	3	3	5	None	3 lake + 5 stream
8	Dec 2019	3 + Q	3	5 + Q	None	3 lake + 5 stream + Q
9	Jan 2020	3	3	5	None	3 lake + 5 stream
10	Feb 2020	3	3	5	None	3 lake + 5 stream
11	Mar 2020	3 + Q	3	5 + Q	None	3 lake + 5 stream + Q
12	Apr 2020	3	3	5	None	3 lake + 5 stream

13	May 2020	3	3	5	3	3 lake + 5 stream
14	Jun 2020	3 + Q	3	5 + Q	3	3 lake + 5 stream + 4 swim + Q
15	July 2020	3	3	5	3 + Q	3 lake + 5 stream + 4 swim
16	Aug 2020	3 + B	3	5 + B	3 + B	3 lake + 5 stream + 4 swim + B
17	Sep 2020	3 + Q	3	5 + Q	3	3 lake + 5 stream + 4 swim + Q
18	Oct 2020	3	3	5	3 + Q	3 lake + 5 stream
19	Nov 2020	3	3	5	None	3 lake + 5 stream
20	Dec 2020	3 + Q	3	5 + Q	None	3 lake + 5 stream + Q
21	Jan 2021	3	3	5	None	3 lake + 5 stream
22	Feb 2021	3	3	5	None	3 lake + 5 stream
23	Mar 2021	3 + Q	3	5 + Q	None	3 lake + 5 stream + Q
24	Apr 2021	3	3	5	None	3 lake + 5 stream
total		82	72	130	42	234

QC = Quality Control
Q = QC Sample (Field Duplicate or Replicate)   **B** = Field Blank

Sample Sites Specified:
3 lake points = a. Outlet, b. Deep West, c. Deep East
4 swim points = f. Streeters, i. Tree House, g. Silver Resort, h. Walden
5 stream points = q. Easy St, z. Outlet Gate, r. Sucker Upper, j. Hemlock Canal rd., k.
Hemlock Rd 1390

Table 1

4.0   Tasks Accomplished

- Collaborated with SLWAC technical advisors in project planning and implementation.
- Developed and wrote a lake specific QAPP for water quality testing which was approved by Ecology.
- Developed and wrote a lake specific QAPP for sediment testing which was approved by Ecology.
- Compared previously used sampling methods with Ecology-approved Standard Operating Procedures (SOP) and provided training and training documents.
- Provided oversight and audits of volunteers during field testing. CCHD presided over every sampling event.
- Collected the following data: 189 total phosphorus from the lake, 37 data points for Chlorophyll *a*, 213 data points for *E. coli* from both lake and stream.
- 81 Secchi, 201 temperature, 185 pH, 201 D.O. and 185 turbidity samples were collected.
- Determined Secchi disk depth at 3 locations monthly.
- The year-round water sampling was conducted at 3 lake sites and 5 stream sites with an addition of 4 swim sites added during the summer months (June- September).
- Determined probe measurements at 3' water depth monthly: water temperature, pH, dissolved oxygen, and turbidity at 3 lake locations and 5 stream locations monthly.
- Sediment sampling at 3 locations for COC's and total phosphorus

- Input water quality monitoring data into Ecology's EIM system annually. In situ water testing will be performed concurrently at each of the five sites, measuring water temperature, pH, turbidity, and dissolved oxygen
- 800 educational postcards were sent to the resident living within the Silver Lake watershed
- Compiled and published all data on County website.
- Submitted quarterly progress reports and billings to Ecology.
- Conducted technical audit and submitted report to Ecology.
- Conduct numerical and trending analysis of the study's data.
- Submitted a report to Ecology Project Manager summarizing data results and data analysis.

5.0   Quality Assurance Measures

Quality control measures as outlines in the approved QAPP were achieved. Field duplicates were taken quarterly. Field blanks were taken annually, and all came back below the detection limits. Probe measurements were taken in duplicate, and the average of the two readings were recorded as the result. More information can be found in the QAPP on approved methods.

6.0 Results – Secchi Depth

Secchi depth of the lake, including sites Deep West, Deep East, and Outlet Creek were measured over 23 events by the same person during all events on the shaded side of the boat between 9am and 12pm. Results through the duration of the project averaged 2.2 ft (variance of 0.56 and SD 0.75).

Year 1 averaged 2.7 feet (variance of 0.462 and SD 0.679) while year 2 was average depth of 2.26 ft, (variance 0.701 and SD 0.837). The Year 3 including only 4 events, which were not as good as Year 1 or Year 2 with an average of 1.9 ft, (variance 0.259 and SD 0.509). These results are consistent with our last study in which water clarity improved in the winter and decreased during the summer. This also correlates with the seasonal increase in Chlorophyl-*a* and summer algae blooms seen on the lake

Additionally, we also tested 4 bathing beaches in the summer months (June- September) in Y1, the average was 1.5 feet (variance 0.10 and SD 0.31).
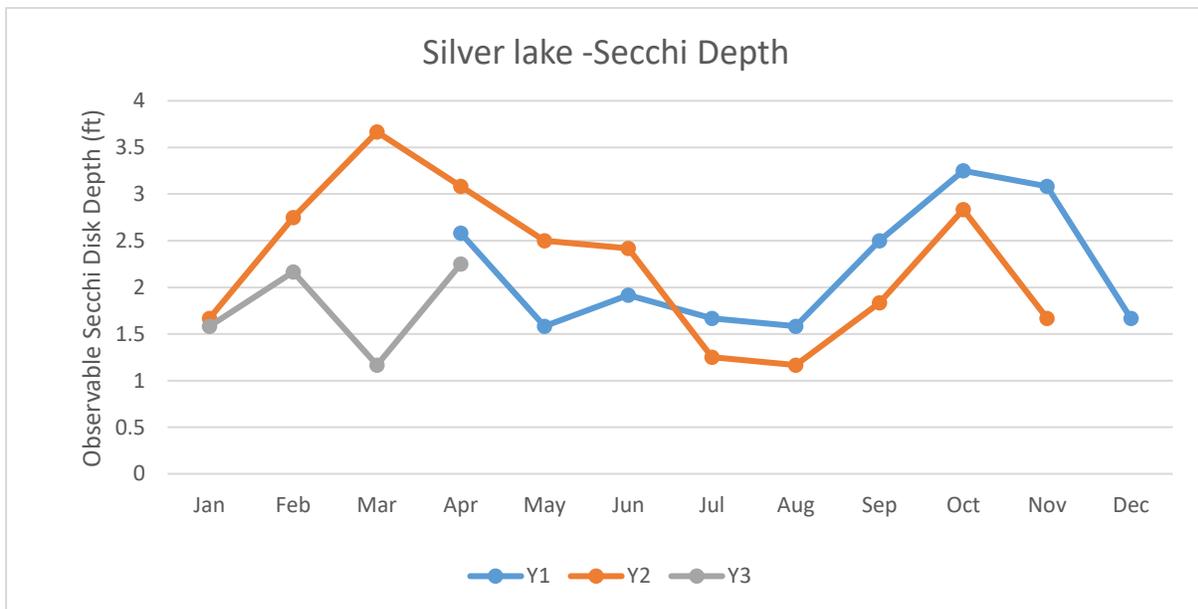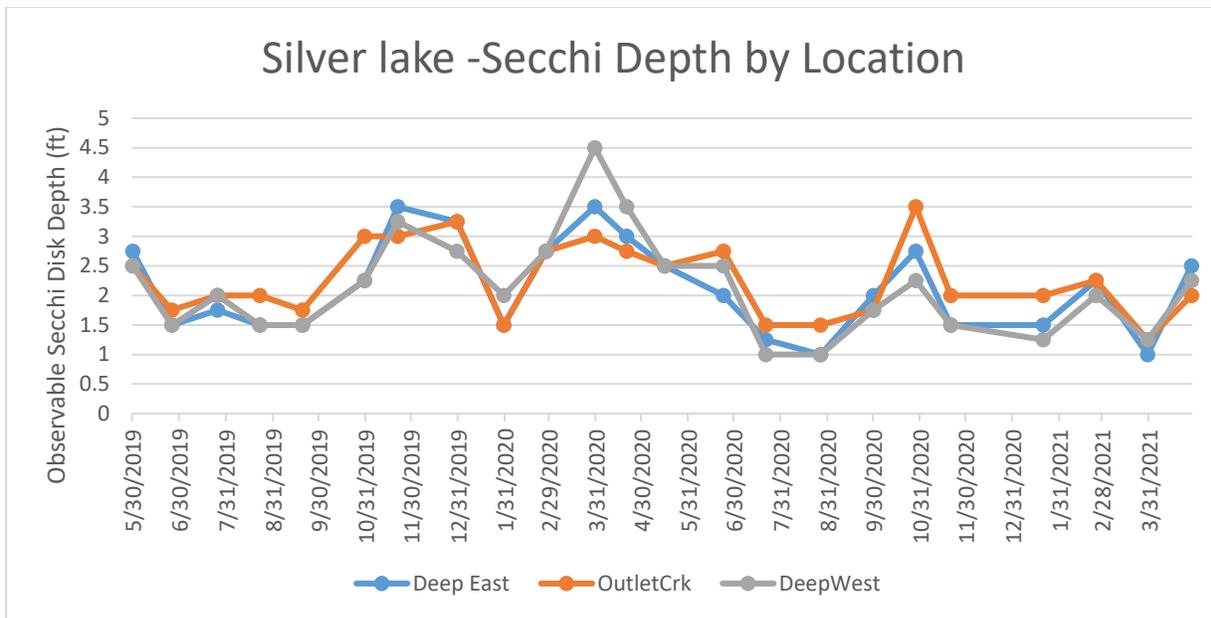

Figure 3

Figure 4

7.0 Results – Lab Analytes

7.1 Total Phosphorus

The average total phosphorus levels in Silver Lake are double that of the state action level and the EPA criteria. Washington Administrative Code 173-201A-230 indicates that lake specific studies may be initiated for values over 20 µg/L, or 0.020 mg/L in Puget Lowlands Ecoregion. The EPA (1987) water criteria for total phosphorus is 25 µg/L, or 0.025 mg/L.

The average total phosphorus over the course of the study was 0.058 mg/L (variance 0.00003 and SD of 0.0193). Year 1 average was 0.063 mg/L (variance 0.00004 and SD 0.021). Year 2 was slightly lower with an average of 0.053 mg/L (variance 0.0007 and SD 0.027).

Year 3 averaged 0.057 mg/L (variance 0.0002 and SD 0.015). Seasonal trends noted in the previous study were consistent during this project period including total phosphorus concentrations increasing during the summer and into the fall months.
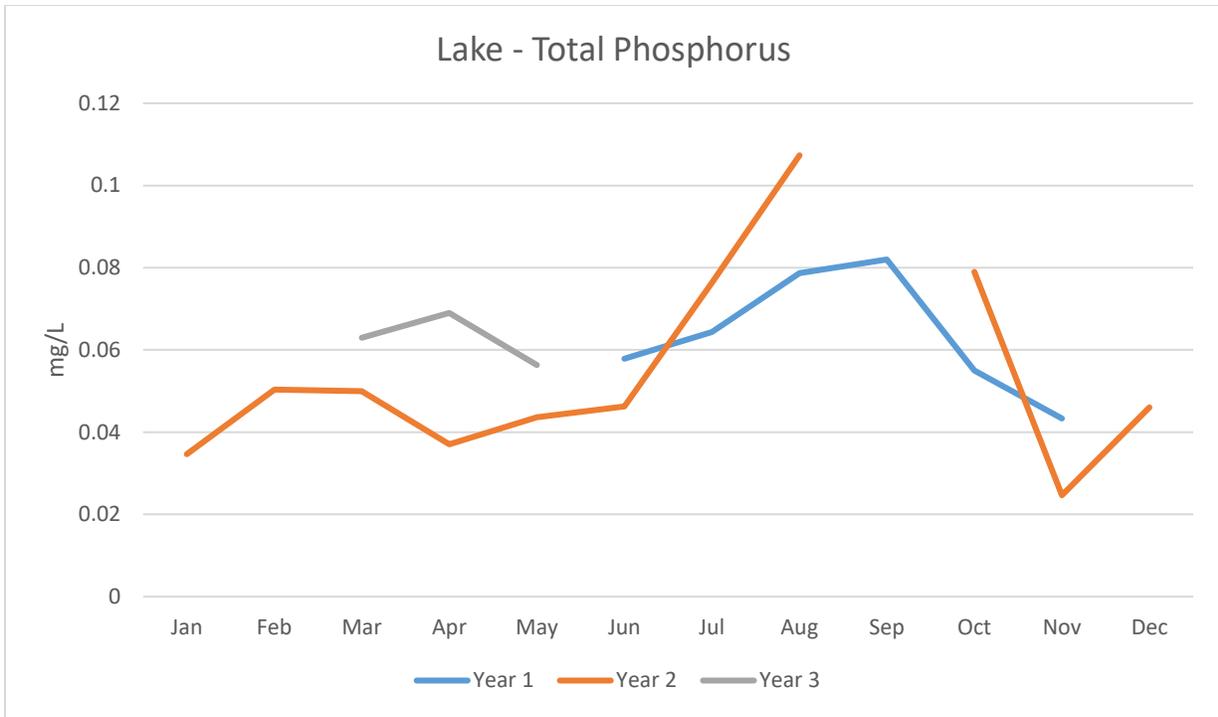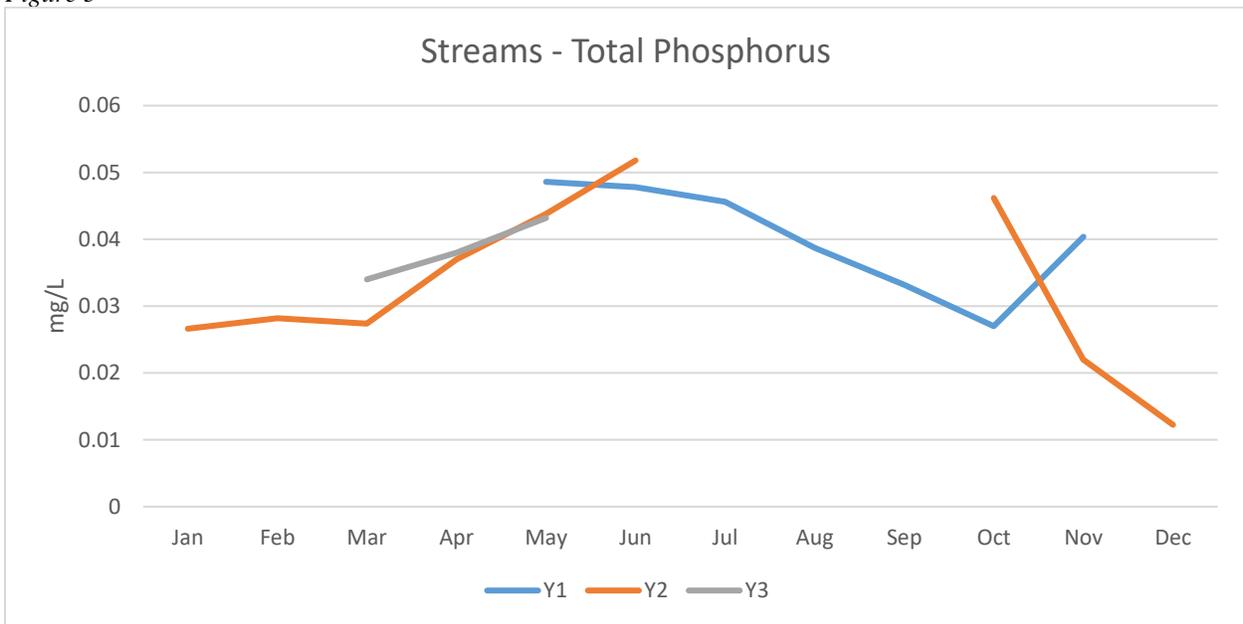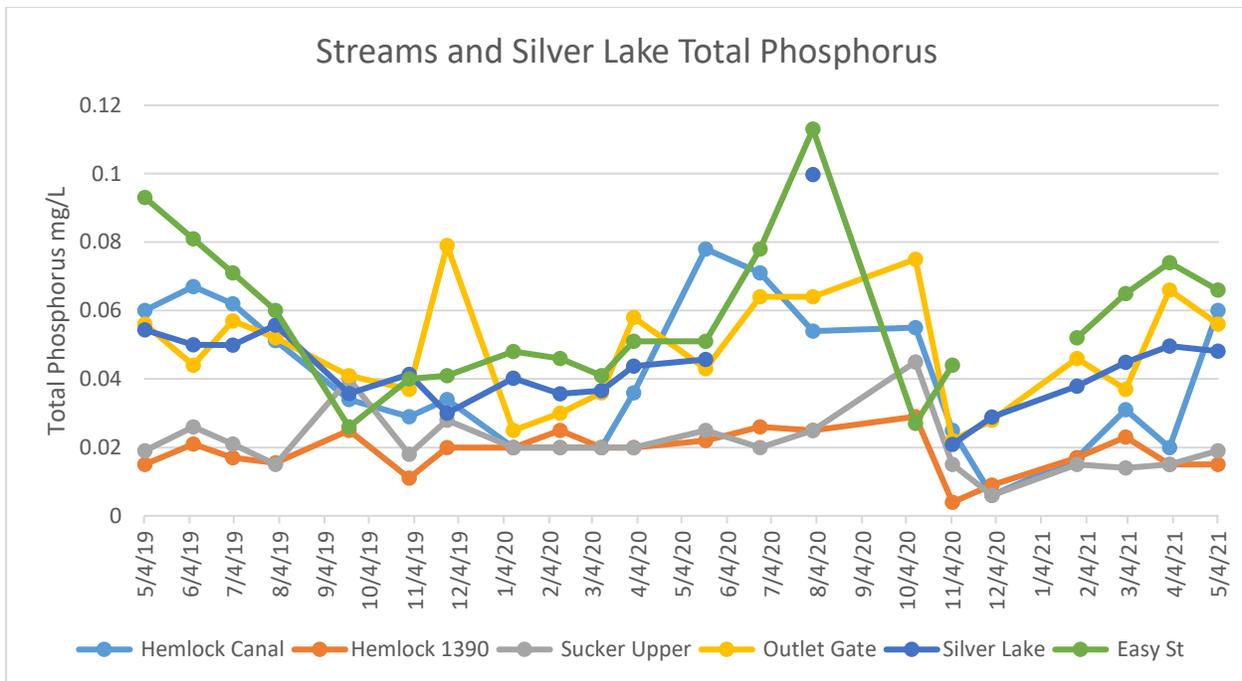
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Figure 5

Figure 6

Figure 7

Overall, the streams phosphorus was 0.037 mg/L, (variance 0.037 and SD 0.023) which was lower than Silver Lake levels. Year 1 average was 0.041 mg/L (variance 0.0004 and SD 0.018). Year 2 was lower with an average of 0.037 mg/L (variance 0.0005 and SD 0.020). Year 3 averaged 0.038 mg/L (variance 0.0004 and SD 0.020).

Hemlock 1390 and Upper Sucker had less total phosphorus throughout the course of the study average total phosphorus level of 0.019 mg/L, (variance 0.0000, SD 0.006). Upper Sucker had an average of 0.021 mg/L, (variance 0.0000 and SD 0.009), followed by Hemlock Canal 0.041 mg/L, (variance 0.0004 and SD 0.021), and Outer Gate 0.048 mg/L, (variance 0.0003 and SD 0.016). Easy street had the highest average 0.058 mg/L, (variance 0.0005 and SD 0.023). The upper section of the watershed has lower total phosphorous levels, however, the results were still relatively close to meeting the threshold for initiating a study per the WAC.

7.2 Chlorophyll-*a*

Average chlorophyll-*a* concentration throughout the sampling period was 21.9 ug/L with a range between 2.7 - 87.7 ug/L depending on the location and time of year. The annual averages show an increase from Year 1 to Year 2. Year 1 averaged 18.8 ug/L while Year 2 was 27.1 ug/L. Notably, Outlet Creek was the lowest with an average of 13.9 ug/L while Deep West was the highest at 26.8 ug/L and Deep East was the second highest 25.1 ug/L.
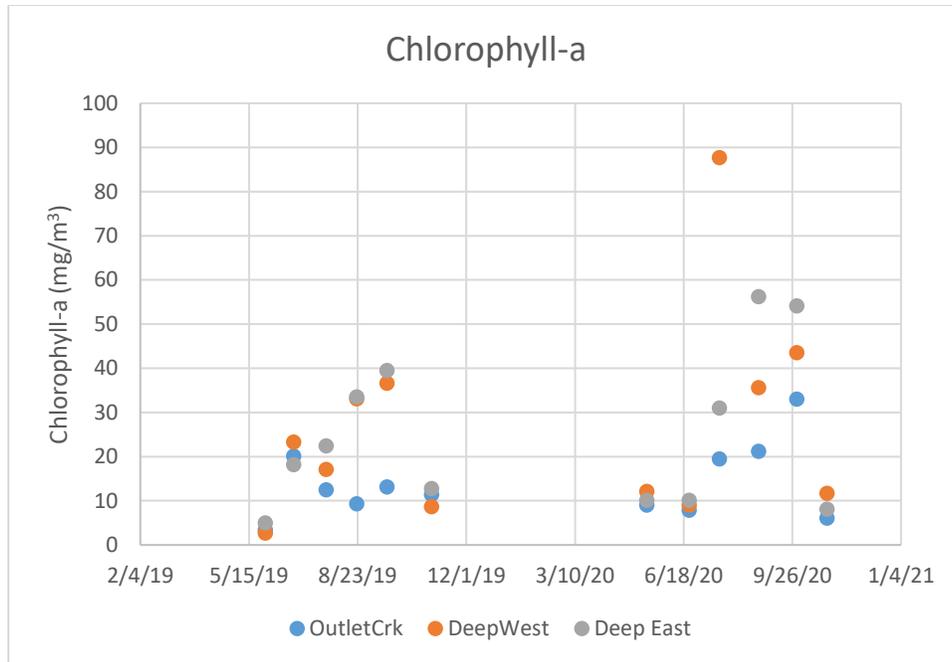
Figure 8

7.3 E. coli

E.coli was tested at all locations throughout the study period on a monthly basis. Four swim areas were added to the sampling during the summer months of June-September. Overall, Silver Lake averaged was 5.18 MPN/100mL. While Year 1 was 6.60 MPN/100mL, Year 2 was 4.69 MPN/100mL, and Year 3 was 3.82 MPN/100mL.

Overall, streams averaged higher then Silver lake with an average of 29.2 MPN/100mL over the study. While Year 1 was 31.3 MPN/100mL, Year 2 was 31.3 MPN/100mL, and Year 3 was 10.3 MPN/100mL.

Individual stream results varied: Sucker Creek averaged 33.79 MPN/100mL, Outer Gate 23.50 MPN/100mL, Hemlock 1390 43.62 MPN/100mL, Hemlock Canal 20.81 MPN/100mL, and Easy Street 25.12 MPN/100mL. Sucker Creek, Hemlock 1390, and Easy Street all had a spike event. In May of 2020 at Hemlock 1390 we collected a sample that was 346 MNP/ 100 mL and in July of 2020 we collected a sample at Sucker Creek that was 249 MNP/ 100mL. These high hits skewed the average stream sample seen in *Figure 10* below. When these events are removed from the overall data, the average is closer to the other sampling locations: Hemlock 1390 28.55 MPN/100mL, Sucker Creek 23.54 MPN/100mL, and Easy Street 18.93 MPN/100mL.

When the swim sites were tested during the remaining months, the results were all below EPA's Primary Recreation Standard.
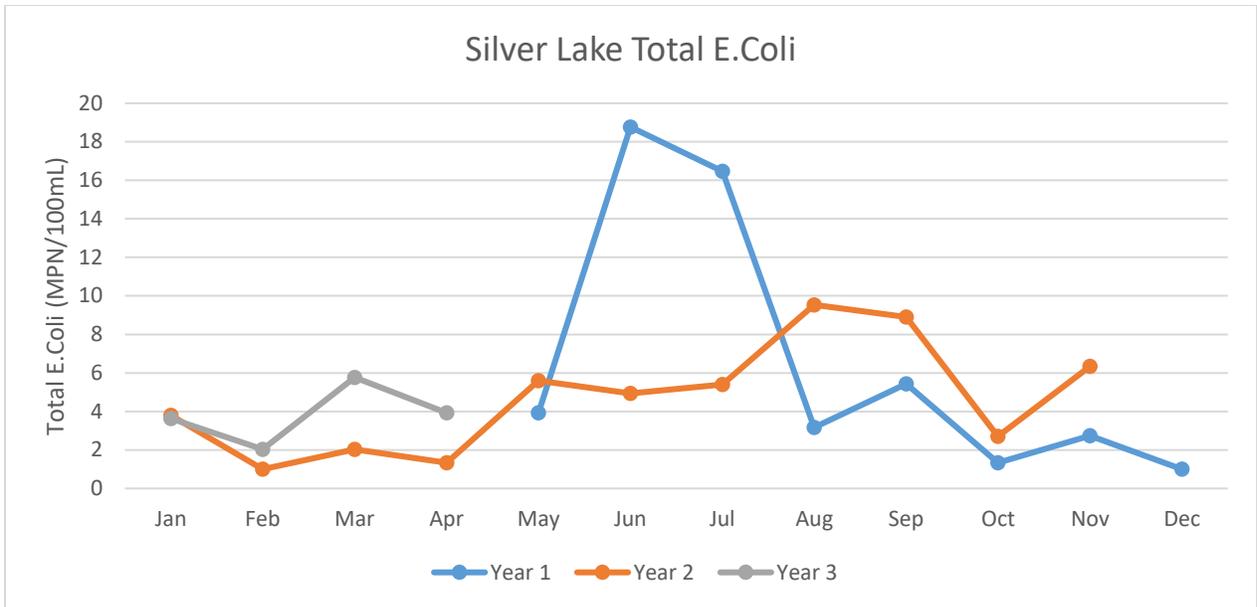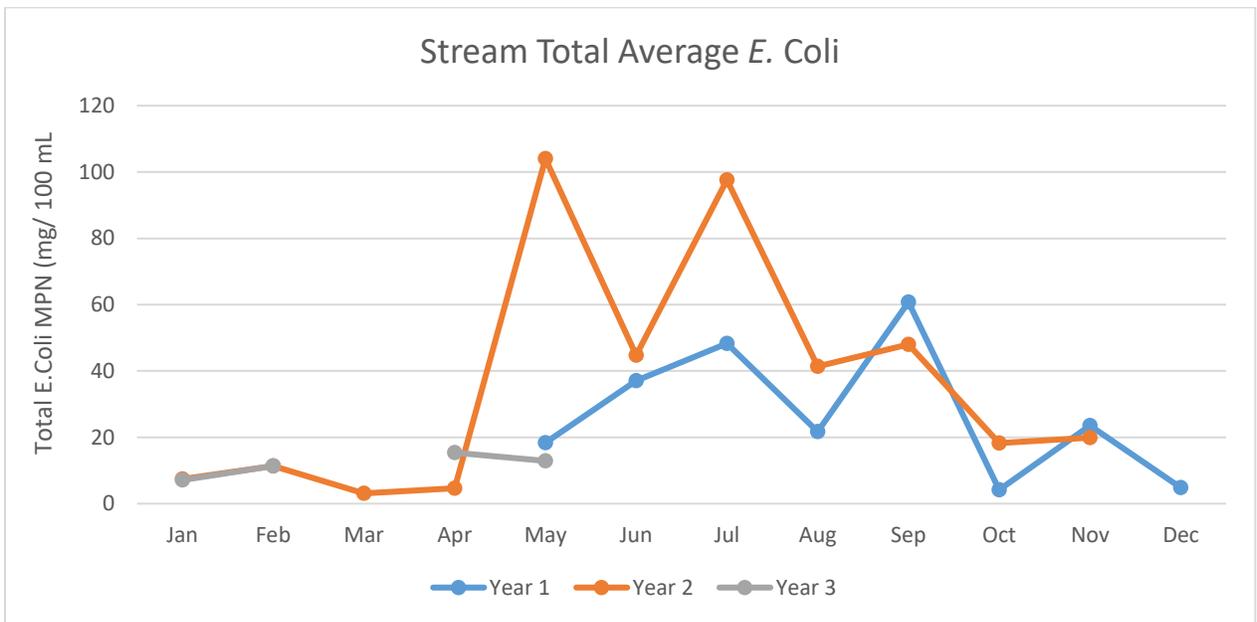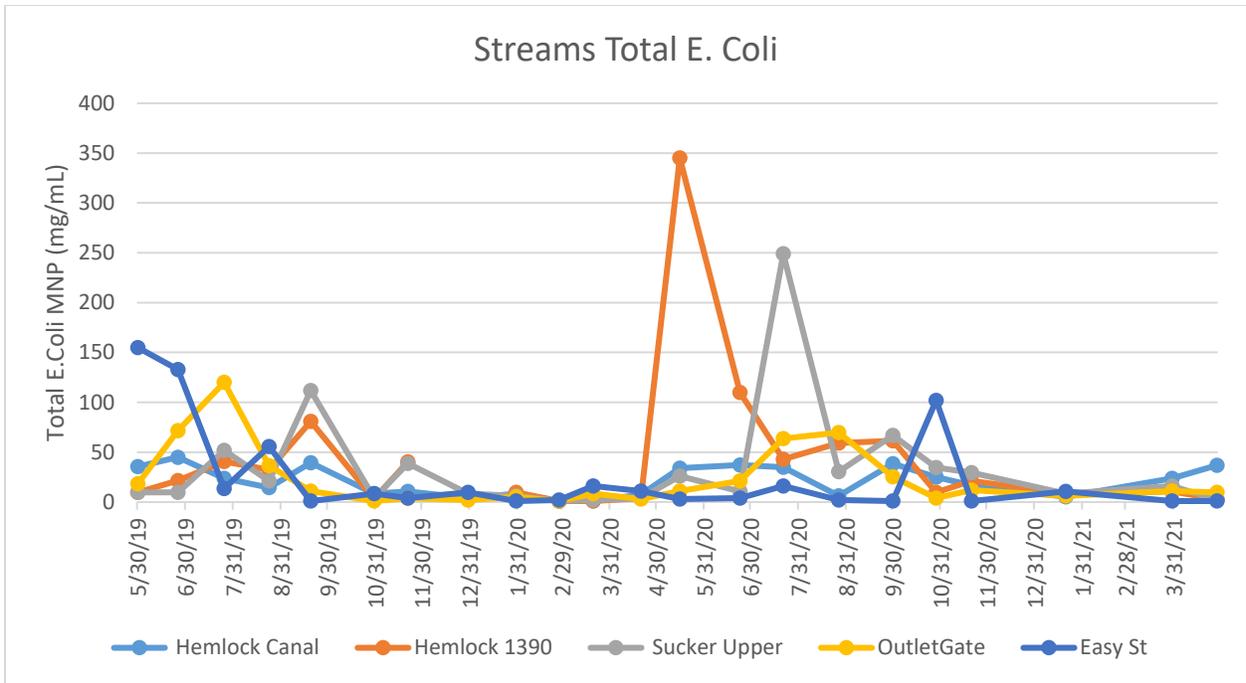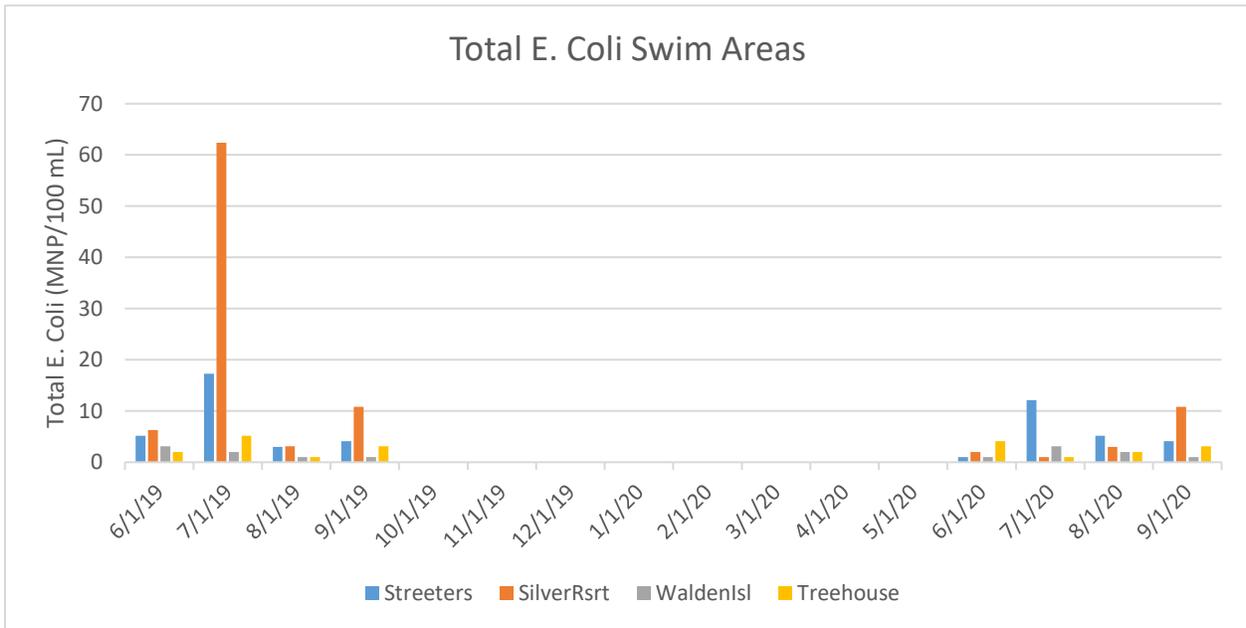
Figure 9

Figure 10

Figure 11

Figure 12

7.4 Sediment Results

The samples were collected in 3 locations and then homogenized to form one sample that was processed at an accredited lab. The sample was tested for the COCs as designated by the DMMP. All constituents fell below DMMP recommended standards. See *Figure 13* for more details.

ANALYTES		METHOD	Results K2205476-001	SL1 value	MDL	MRL	UNITS
Sediment Conventional							
Total solids		PSEP (1986)/ SM2540G	*65.5*		NA	NA	%
Total volatile solids (TVS)		PSEP (1986)/ SM2540G	*1.60*		NA	NA	%
Particle Size Distribution		PSEP (1986)/ASTM D-422* modified sieve sizes)	**		NA	NA	grams
Total organic carbon (TOC)		EPA 9060A	*5.99*		0.02	0.1	%
Sulfide		EPA 9030 B	*1.52*		0.28	0.70	mg/kg
Ammonia		Plumb (1981)/SM4500-NH3	*21.7*		0.06	0.68	mg/kg
METALS (mg/kg dry weight)	CSS						
Arsenic	7440-38-	6010D	**ND**	14	2.7	5.5	mg/kg
Cadmium	7440-43-9	6010D	ND	2.1	0.12	0.27	mg/kg
Chromium	7440-47-3	6010D	7.8	72	0.4	1.1	mg/kg
Copper	7440-50-8	6010D	14.8	400	0.4	1.4	mg/kg
Lead	7439-92-1	6010D	6.7	360	1.0	2.7	mg/kg
Mercury	7439-97-6	7471B	0.01	0.66	0.003	0.025	mg/kg
Nickel	7440-02-0	6010D	**4.6**	38(2)	0.4	1.1	mg/kg

Analyte	CAS	Method	Result				Units
Selenium	7782-49-2	6020B	0.2	11	0.1	1.4	mg/kg
Silver	7440-22-4	6020B	NA	0.57	0.004	0.02	mg/kg
Zinc	7440-66-6	6010D	13.5	3200	0.5	1.4	mg/kg
ORGANOMETALLIC COMPOUNDS[3] (µg/kg dry weight)							
Naphthalene	91-20-3	8270ESVO LL	**ND**		16	450	µg/Kg
Acenaphthylene	208-96-8	8270E SVO LL	ND		9.7	450	µg/Kg
Acenaphthene	83-32-9	8270E SVO LL	ND		13	450	µg/Kg
Fluorene	86-73-7	8270E SVO LL	ND		18	450	µg/Kg
Phenanthrene	85-01-8	8270E SVO LL	ND		16	450	µg/Kg
Anthracene	120-12-7	8270E SVO LL	ND		12	450	µg/Kg
2-Methylnaphthalene[5]	91-57-6	8270E SVO LL	ND		16	450	µg/Kg
Total LPAH	---						
Fluoranthene	206-44-0	8270E SVO LL	ND		17	450	µg/Kg
Pyrene	129-00-0	8270E SVO LL	ND		14	450	µg/Kg
Benzo(a)anthracene	56-55-3	8270E SVO LL	ND		13	450	µg/Kg
Chrysene	218-01-9	8270E SVO LL	ND		20	450	µg/Kg
Benzo(b)fluoranthene	205-99-2	8270E SVO LL	ND		17	450	µg/Kg
Benzo(j)fluoranthene *	205-82-3	8270E SVO LL	NA				
Benzo(k)fluoranthene	207-08-9	8270E SVO LL	ND		20	450	µg/Kg
*Benzo(a)pyrene	50-32-8	8270E SVO LL	ND		22	450	µg/Kg
Indeno(1,2,3-c,d)pyrene	193-39-5	8270E SVO LL	ND		16	450	µg/Kg
Dibenz(a,h)anthracene	53-70-3	8270E SVO LL	ND		20	450	µg/Kg
Benzo(g,h,i)perylene	191-24-2	8270E SVO LL	ND		16	450	µg/Kg
CHLORINATED HYDROCARBONS (µg/kg dry weight)							
beta-BHC		8081B LL	NA	7.2	0.18	1.0	µg/Kg
PHTHALATES (µg/kg dry weight)				`			
Di-n-butyl Phthalate	84-74-2	8270D SVO LL	**ND**	380	21	450	µg/Kg
Di(2-ethylhexyl) Phthalate	117-81-7	8270D SVO LL	ND	500	9.7	450	µg/Kg
Di-n-octyl Phthalate	117-84-0	8270D SVO LL	ND	39	14	450	µg/Kg
PHENOLS (µg/kg dry weight)							
Phenol		8270D SVO LL	**ND**	120	26	450	µg/Kg
m + p Cresol		8270D SVO LL	NA	260	4.5	10	µg/Kg

Pentachlorophenol		8270D SVO_LL	ND	1200	87	2700	µg/Kg
MISCELLANEOUS EXTRACTABLES (µg/kg dry weight)							
Benzoic Acid	65-85-0	8270D SVO LL	ND	2900	200	2700	µg/Kg
Dibenzofuran	132-64-9	8270D SVO LL	ND	200	14	450	µg/Kg
Carbazole	86-74-8	8270D SVO LL	NA	900	3.8	10	µg/Kg
PESTICIDES & PCBs (µg/kg dry weight)							
2,4'-DDD		8081B LL	**ND**	310	0.31	1.1	µg/Kg
4,4'-DDD		8081B LL	ND	310	0.68	2.3	µg/Kg
2,4'-DDE		8081B LL	3.4	21	0.54	1.1	µg/Kg
4,4'-DDE		8081B LL	ND	21	*0.46*	1.1	µg/Kg
2,4'-DDT		8081B LL	ND	100	0.55	1.1	µg/Kg
4,4'-DDT		8081B LL	ND	100	0.69	2.3	µg/Kg
Dieldrin	60-57-1	8081B LL	ND	4.9	0.34	1.1	µg/Kg
Endrin Ketone	53494-70-5	8081B LL	ND	8.5	0.51	1.1	µg/Kg
Total PCBs (Arclors) including:				110			
Aroclor 1016		8082A LL	ND	-	0.74	3.0	µg/Kg
Aroclor 1221		8082A LL	ND	-	0.74	3.0	µg/Kg
Aroclor 1232		8082A LL	ND	-	0.74	3.0	µg/Kg
Aroclor 1242		8082A LL	ND	-	0.74	3.0	µg/Kg
Aroclor 1248		8082A LL	ND	-	0.74	3.0	µg/Kg
Aroclor 1254		8082A LL	ND	-	0.74	3.0	µg/Kg
Aroclor 1260		8082A LL	ND	-	0.74	3.0	µg/Kg
Aroclor 1262		8082A LL	NA	-	0.74	3.0	µg/Kg
Aroclor 1268		8082A LL	NA	-	0.74	3.0	µg/Kg
Bulk Petroleum Hydrocarbons (mg/kg)							
Diesel Range Organics (DRO)		NWTPH-Dx	**2.5**	340	1.8	25	mg/kg
Gasoline Range Organics (GRO)		NWTPH-Dx	NA	3600	2.9	100	mg/kg
Voluntary Additional Tests							
Barium (for potential landfill disposal)		6020B	31.6		0.027	0.068	mg/kg
Phosphorus, Total	7723-14-0	365.3 Mod	222	NA	7	33	mg/kg

Table 2
NA= Not Applicable
ND= Non-Detect

Description	Phi Size	Dry Weight (Grams)	Percent of Total Weight Recovered
Gravel (>2.00 mm)	<-1 Ø	0.2219	2.90
Sand, Very Coarse (1.00 mm to 2.00 mm)	-1 to 0 Ø	0.2690	3.51
Sand, Coarse (0.500 mm to 1.00 mm)	0 to 1 Ø	0.3409	4.45
Sand, Medium (0.250 mm to 0.500 mm)	1 to 2 Ø	0.4463	5.83
Sand, Fine (0.125 mm to 0.250 mm)	2 to 3 Ø	0.4912	6.42
Sand, Very Fine (0.0625 mm to 0.125 mm)	3 to 4 Ø	0.4313	5.64
Silt (0.0039 mm to 0.0625 mm)	4 to 8 Ø	3.2050	41.87
Clay (< 0.0039 mm)	> 8 Ø	2.3650	30.90
	Total	7.7706	101.52

Figure 13

8.0 Results - Sonde

In-situ data was collected using a Ysi ProDSS sonde. Calibration and use of the sonde was performed according to the manufacturer's instructions (https://www.ysi.com/ProDSS). Calibration occurred at least every 30 days, and drift was noted in a calibration log. All data was collected 3 ft from water surface. The results are the average of two field duplicate readings.

During June 2021, the probe was out for repair.

Figure 14 – YSI ProDSS Sonde with calibration solutions

8.1 Temperature

The average temperature for the duration of the project at the Deep West, Deep East, and Outlet Creek was 56.9°F, (variance 130.48 and SD 11.42). Year 1 (May-December 2019) average temperature was just 62.3 ° F (variance 132.45and SD 10.01). Year 2 (January-November 2020) average temperature was 57.3°F (variance 112.63 and SD 10.56). Year 3 (January and February 2021) the average temperature was 42.7 F° (variance 0.819 and SD 0.905).

Overall streams averaged slightly lower temperatures then the lake 53.3°F, (variance 108.859 and SD 10.43). Year 1 (May-December 2019) average temperature was just 55.7 ° F (variance 126.390 and SD 11.242). Year 2 (January-November 2020) average temperature was 53.56°F (variance 91.55 and SD 9.57). Year 3 (January and February 2021) the average temperature was 42.3 F° (variance 1.759 and SD 1.326).

Stream specific temperatures also varied: Hemlock Canal averaged 51.2 F° (variance 94.49 and SD 9.72), Hemlock 1390 averaged 49.97 F° (variance 70.69 and SD 8.41), Sucker Creek averaged 51.22 F° (variance 77.55 and SD 8.81), and Outlet Gate averaged 56.91 F° (variance 136.01 and SD 11.66). Easy St. was the warmest averaging 57.05 F° (variance of 136.69 and SD 11.69).

Bathing beaches were constantly warmer than the lake and streams. Year 1, they averaged 68.78 F° and Year 2 they averaged 70.76 F°.
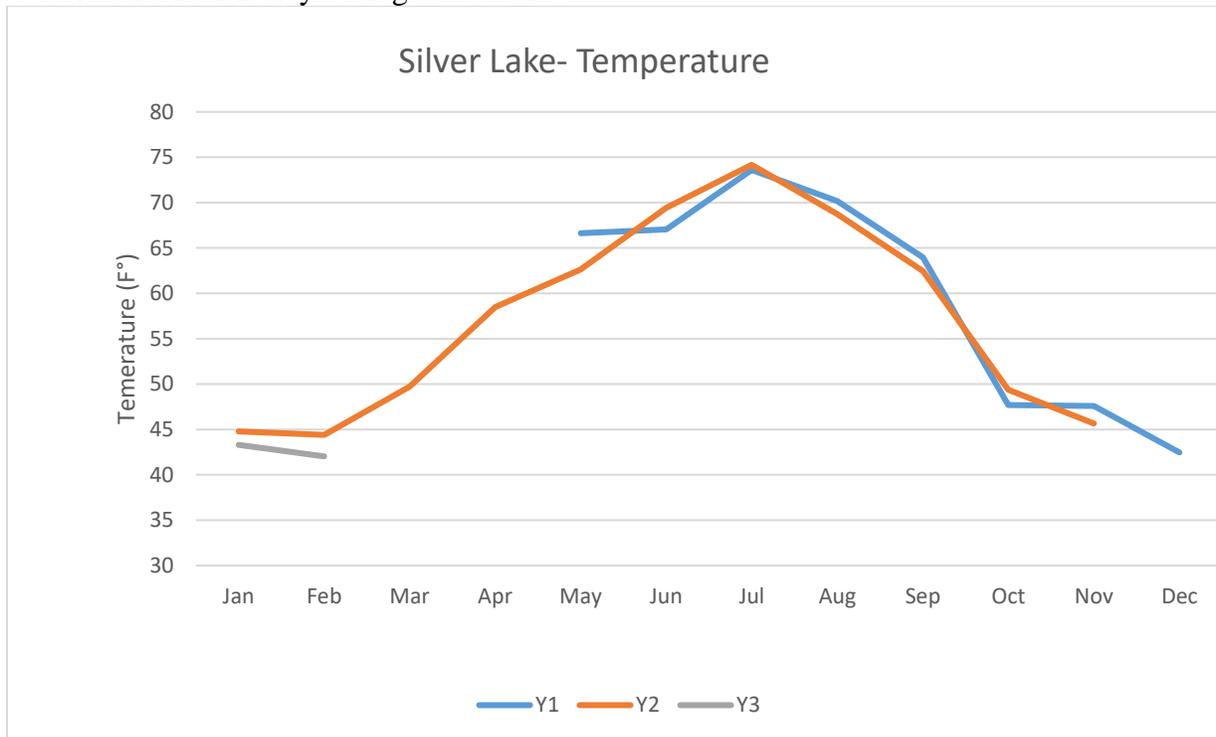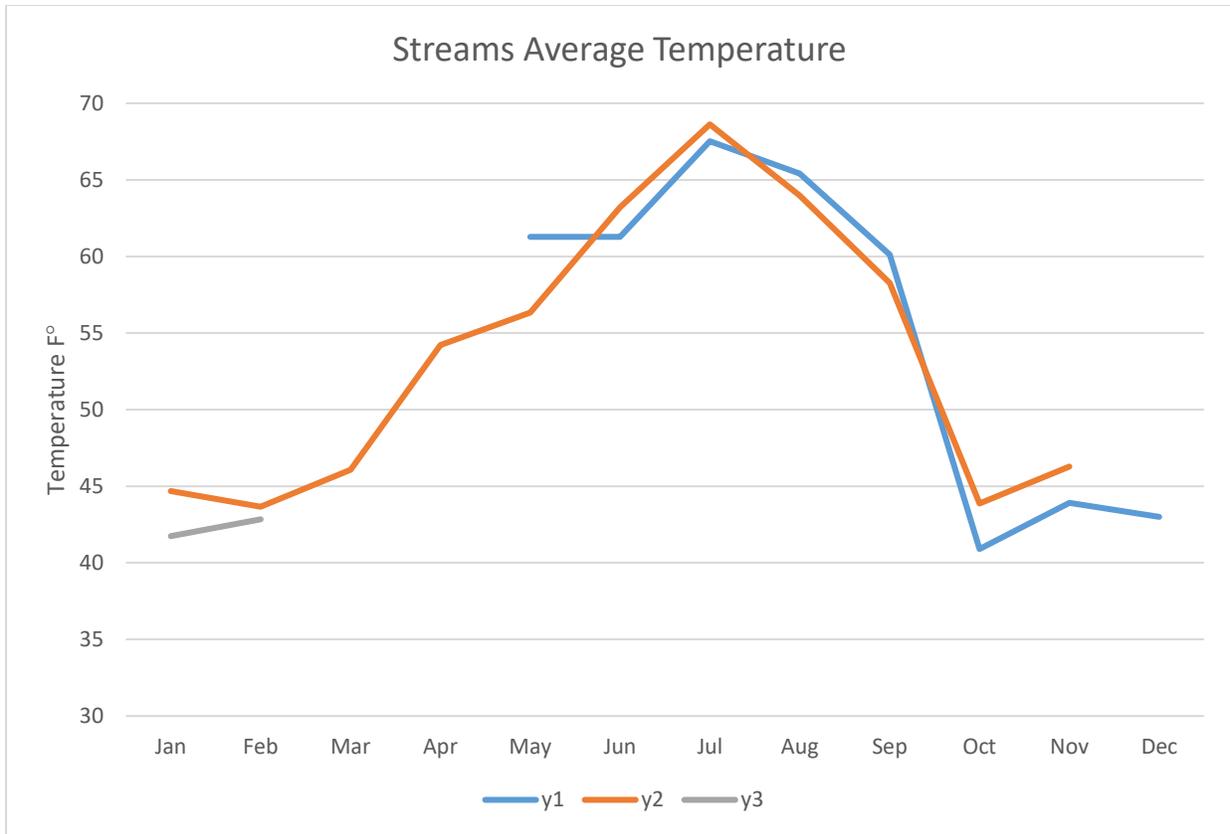

Figure 15

Figure 16

8.2 pH

The average pH throughout the project at Deep West, Deep East, and Outlet creek was 7.6 (variance 0.417 and SD 0.646), with a range of 9.31- 6.57. The pH during Year 1 was 7.6 (variance 0.372 and SD 0.610). The pH during Year 2 was 7.57 (variance 0.495 and SD 0.703). Year 3 had one data point pH 7.41.

For streams, pH overall was slightly lower with an average of 7.44 (variance 0.220 and SD 0.47), with a range of 9.34 -6.49. Year 1 had a pH of 7.53 (variance 0.153 and SD 0.391). Year 2 was 7.37 (variance 0.069 and SD 0.262). Year 3 only had one data point pH 7.53.

The bathing beaches had a slightly higher overall average then the lake 8.47 (variance 0.278 and SD 0.590), and a range of 7.24 – 9.39. Year 1 had a pH of 8.45 (variance 0.431 and SD 0.656). Year 2 was 8.47 (variance 0.281 and SD 0.530).
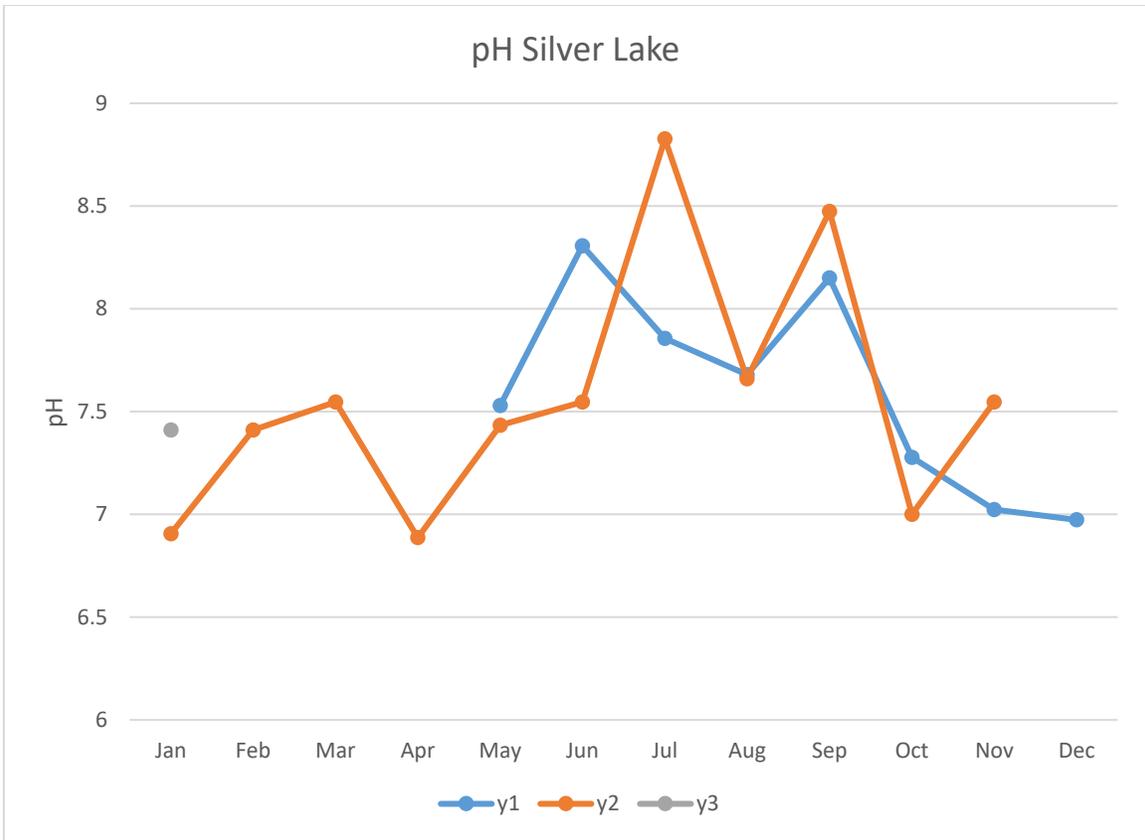
Figure 17
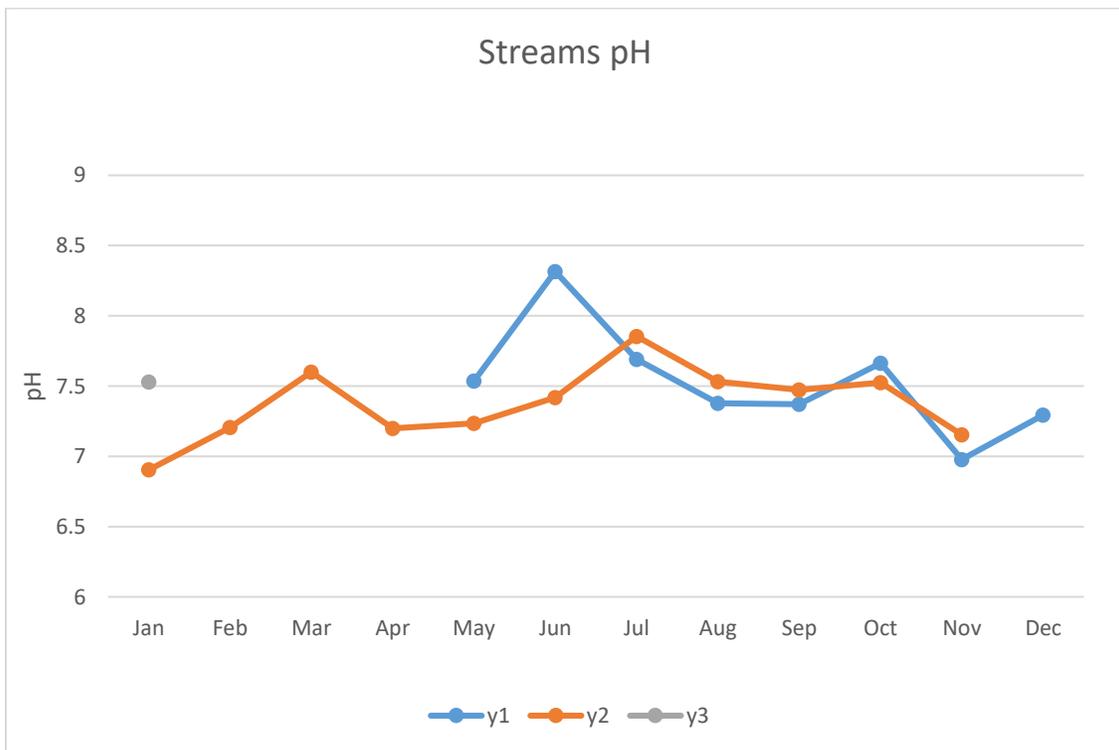
Figure 18

8.3 Dissolved Oxygen

The average DO measurement throughout the project at Deep West, Deep East, and Outlet Creek was 9.40 mg/L (variance 2.0 and SD 1.42). Year 1 was lower than year 2 at 9.49 mg/L (variance 1.217 and SD 1.103) vs 9.82 mg/L (variance 2.580 and SD 1.606). Year 3 was the lowest at 8.90 mg/L (variance 1.764 and SD 1.328).

Overall, the streams DO average was 9.29 mg/L (variance 5.01 and SD 2.24), which was slightly lower than in the lake over the length of the project. Year 1 stream DO was 9.37 mg/L (variance 3.707 and SD 1.925). Year 2 stream DO was 9.12 mg/L (variance 6.177 and SD 2.485), and Year 3 was 9.97 mg/L (variance 3.955 and SD 1.989).

The overall average for the bathing beaches was 9.90 mg/L (variance 1.705 and SD 1.306). Year 1 was 9.86 mg/L (variance 2.449 and SD 1.565). Year 2 was 9.95 mg/L (variance 0.976 and SD 0.988).

Fish do best in waters with 5 mg/L of DO or more, while our earlier work noted DO levels varied between 8.52 - 10.6 mg/L in July of 2020, this study showed lake levels between 6.46 - 12.29 mg/L while streams ranged 3.42 – 13.69 mg/L.
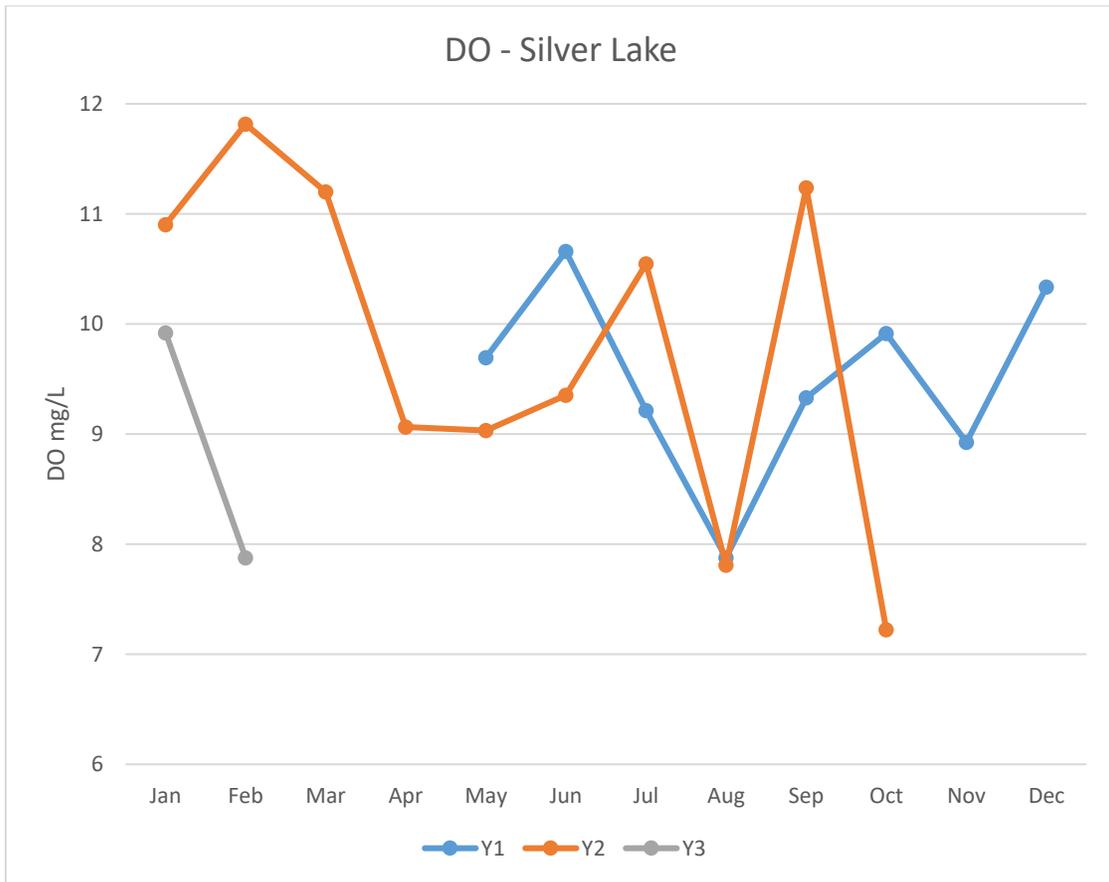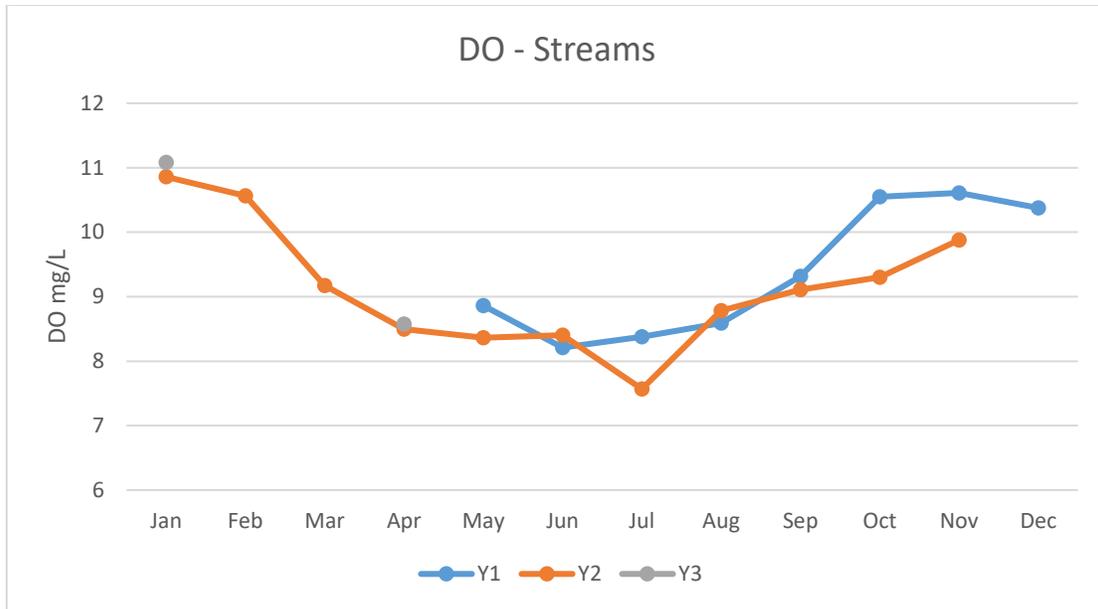

Figure 19

22

Figure 20

8.4 Turbidity

The average turbidity in the Lake for the project was 8.73 NTU (variance of 21.06 and SD 4.589). The average turbidity in Year 1 was higher at 8.03 NTU (variance 14.008 and SD 3.74) while the average in Year 2 was higher at 8.85 NTU (variance 25.432 and SD 5.043). Year 3 had one data point at 13.07 NTU.

Stream turbidity for the project was quite a bit lower than the lake with an overall of 5.50 NTU with a variance of 19.74 and a SD of 4.44. The average turbidity in Year 1 was 5.47 NTU (variance 20.43 and SD 4.520) while the average in Year 2 was higher at 5.43 NTU (variance 19.430 and SD 4.408). Year 3 had one data point at 6.56 NTU.

Overall beach turbidity was 13.75 NTU (variance 6.86 and SD 47.07) which was higher than the other sampling sites. Year 1 was 12.05 NTU (variance 18.70 and SD 4.32) while the average in Year 2 was higher at 15.92 NTU (variance 18.70 and SD 8.91). Year 3 had one data point at 6.56 NTU.
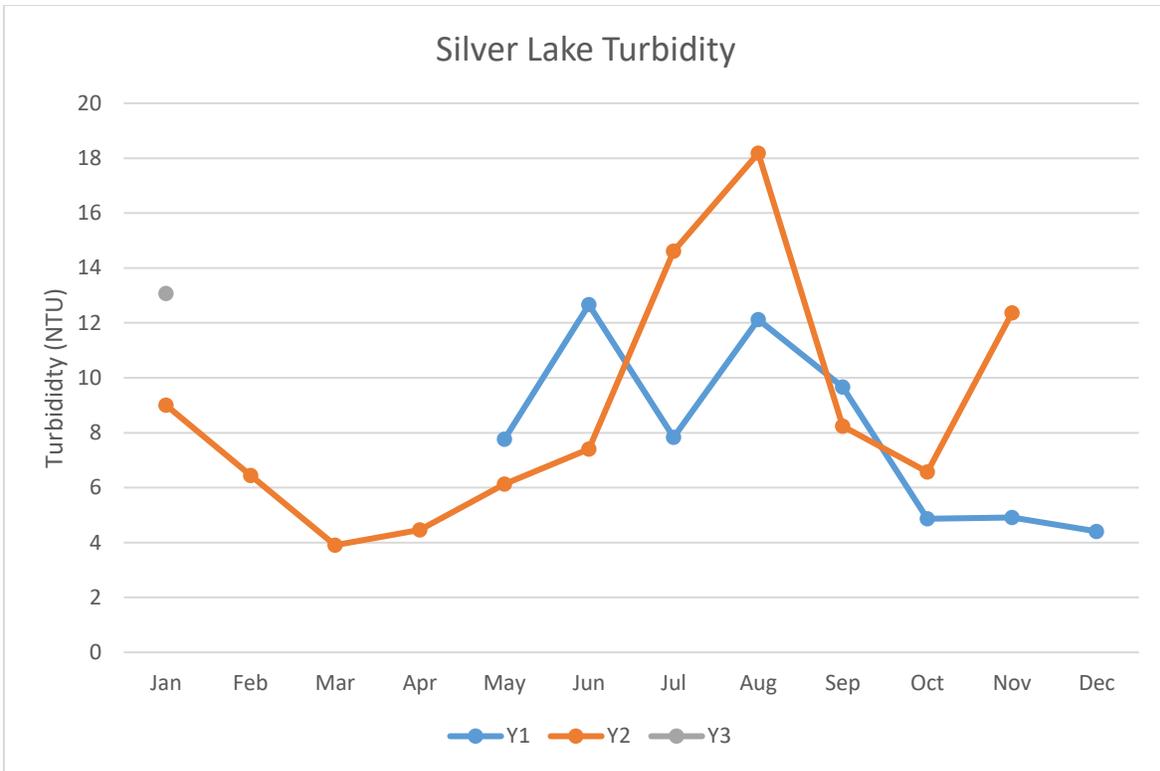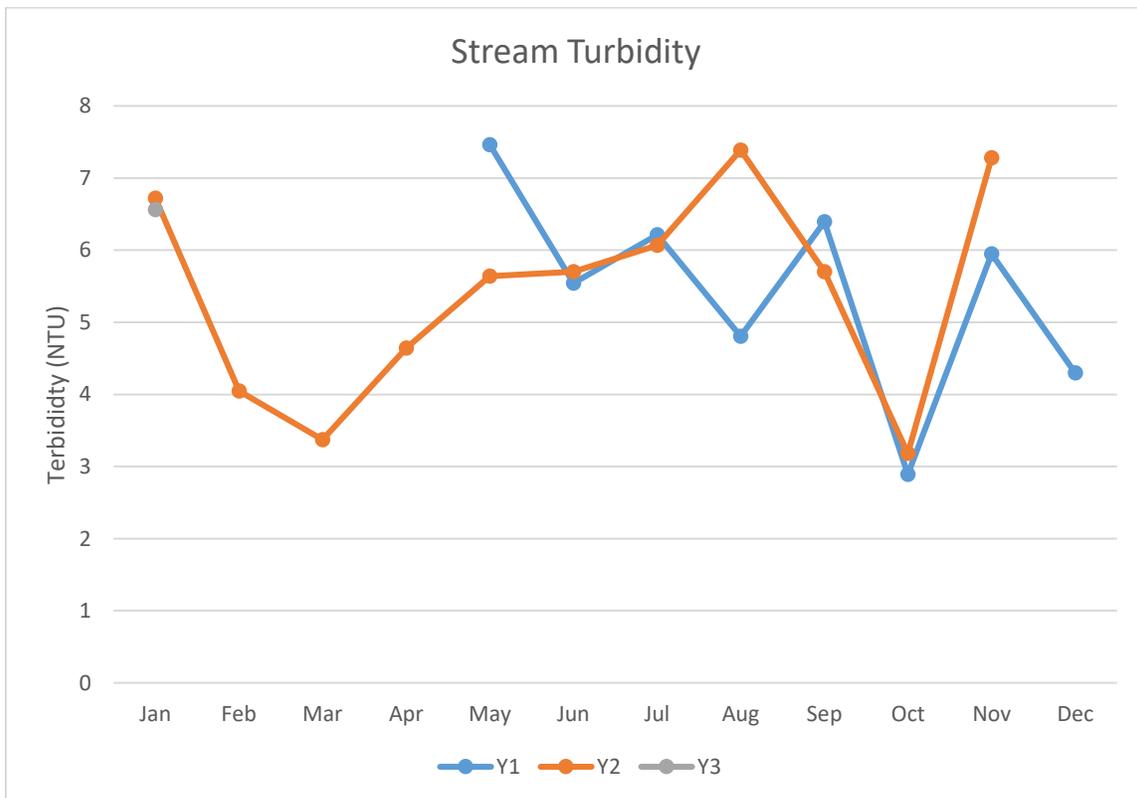
Figure 21

Figure 22

9.0   Supporting Data

9.1 Silver Lake Flushing Event September 2018

The Silver Lake Flood Control District monitored the daily lake levels over a 4-year period. The lake dropped more than usual in 2015 and this was followed by a drop in the concentration of lake phosphorus. While not an official study this data was used by SLWAC to promote the flushing project which occurred during September of 2018.

Historically the lake levels drop between 12 and 17 inches each year due to evaporation. During the flushing event of 2018 the radial gates of the dam were opened, and the lake was drained at a rate of 2 inches per day until it reached 36 inches below the dam level.
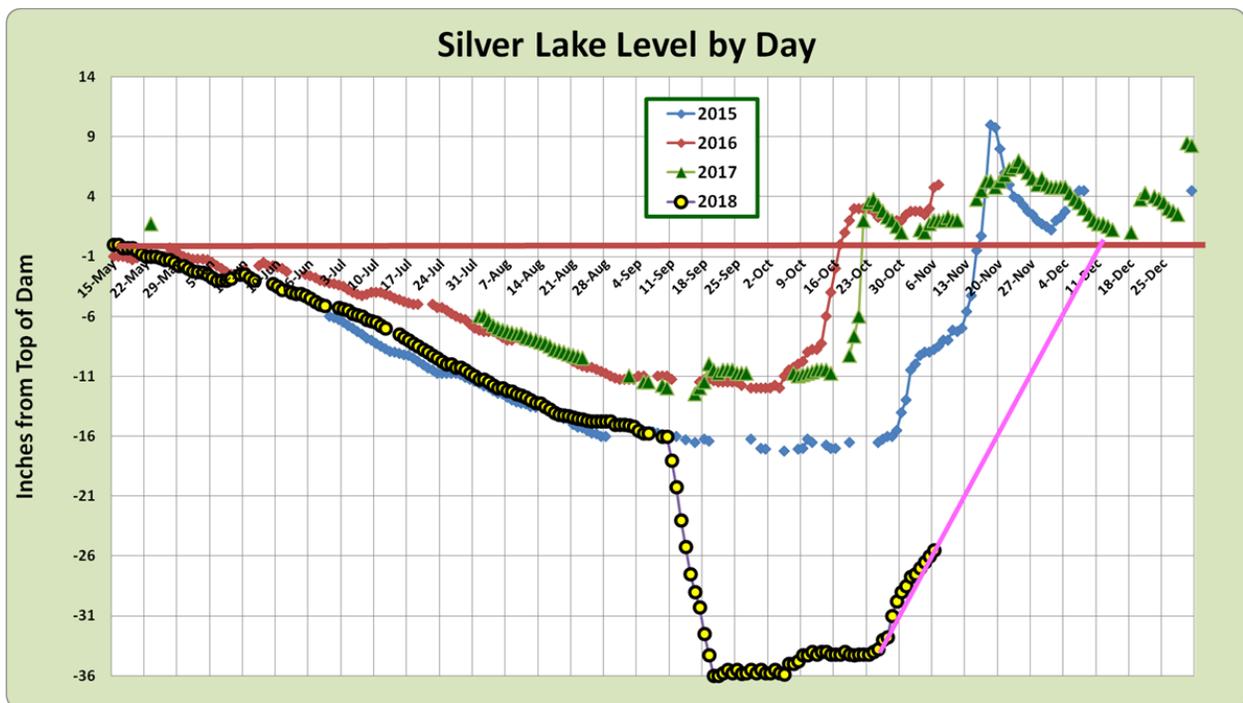

Figure 23 The above chart was provided by the Silver Lake Flood Control District. This chart shows the lake level in relation to the top of the dam indicated by the red line.
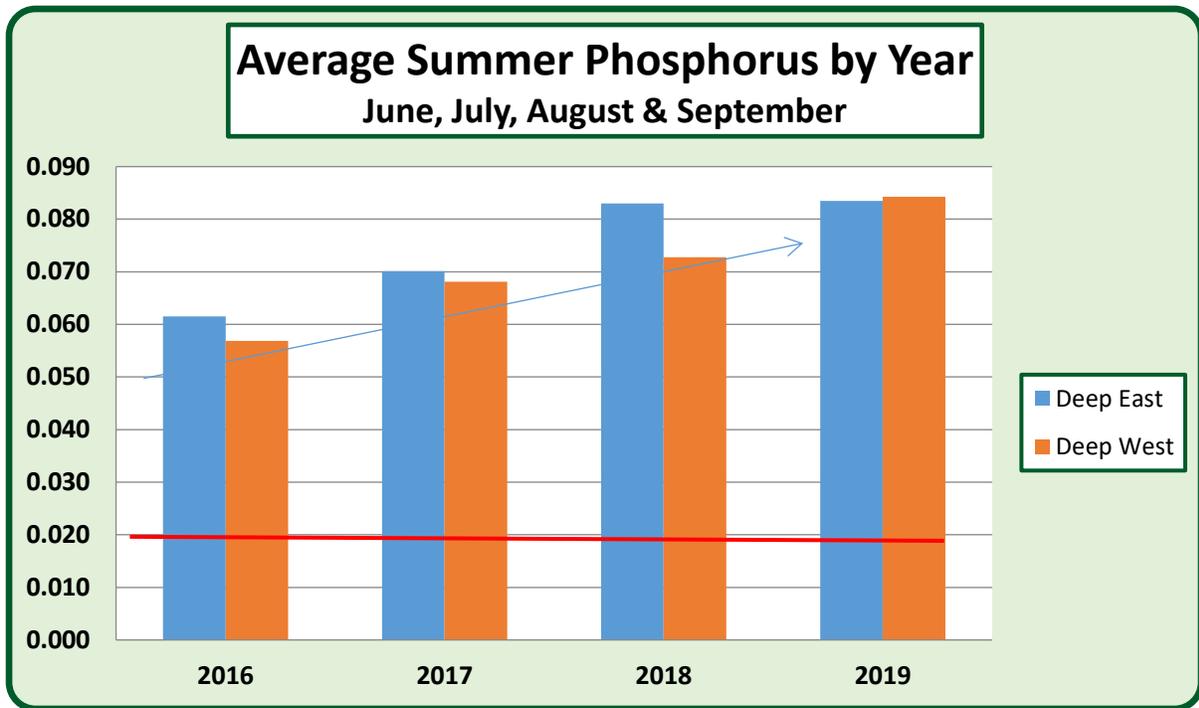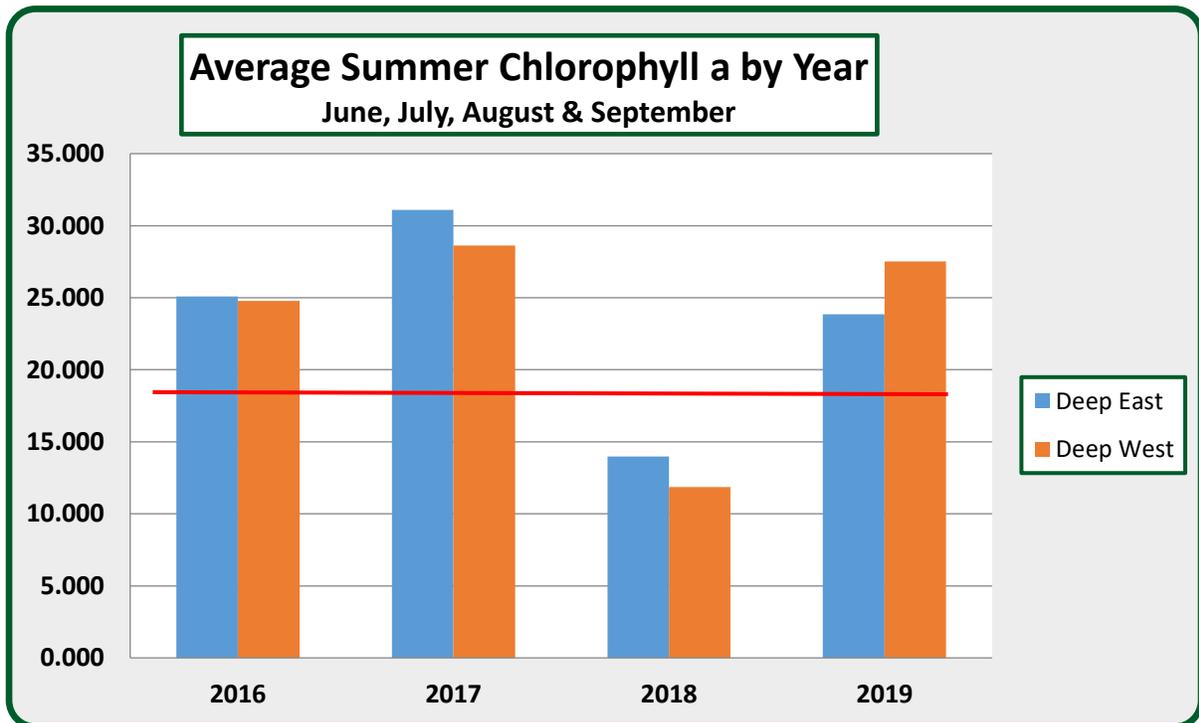
Figure 24

Figure 25

The overall effects of drawdown did not show a reduction in total phosporus however Chlorophyll *a* was lower then previous years.

9.2 Silver Lake Drainage Boundary

The drainage basin charts below are provided by Silver Lake Flood Control District.
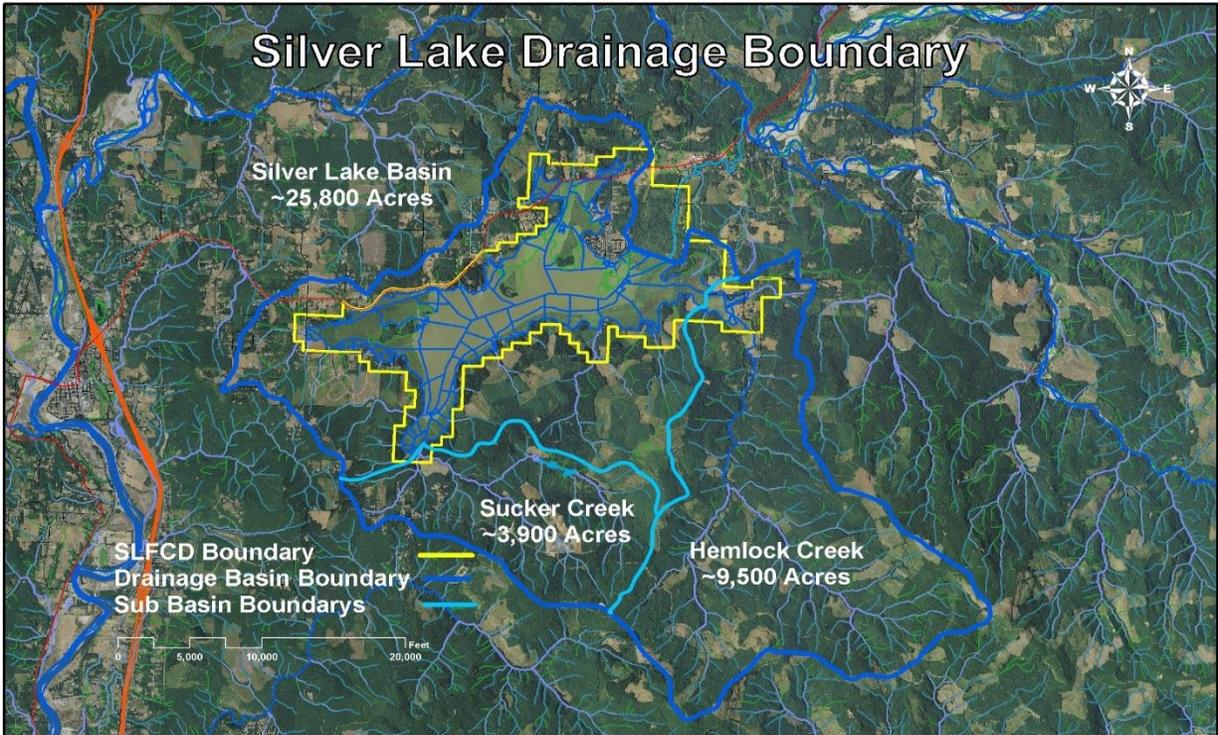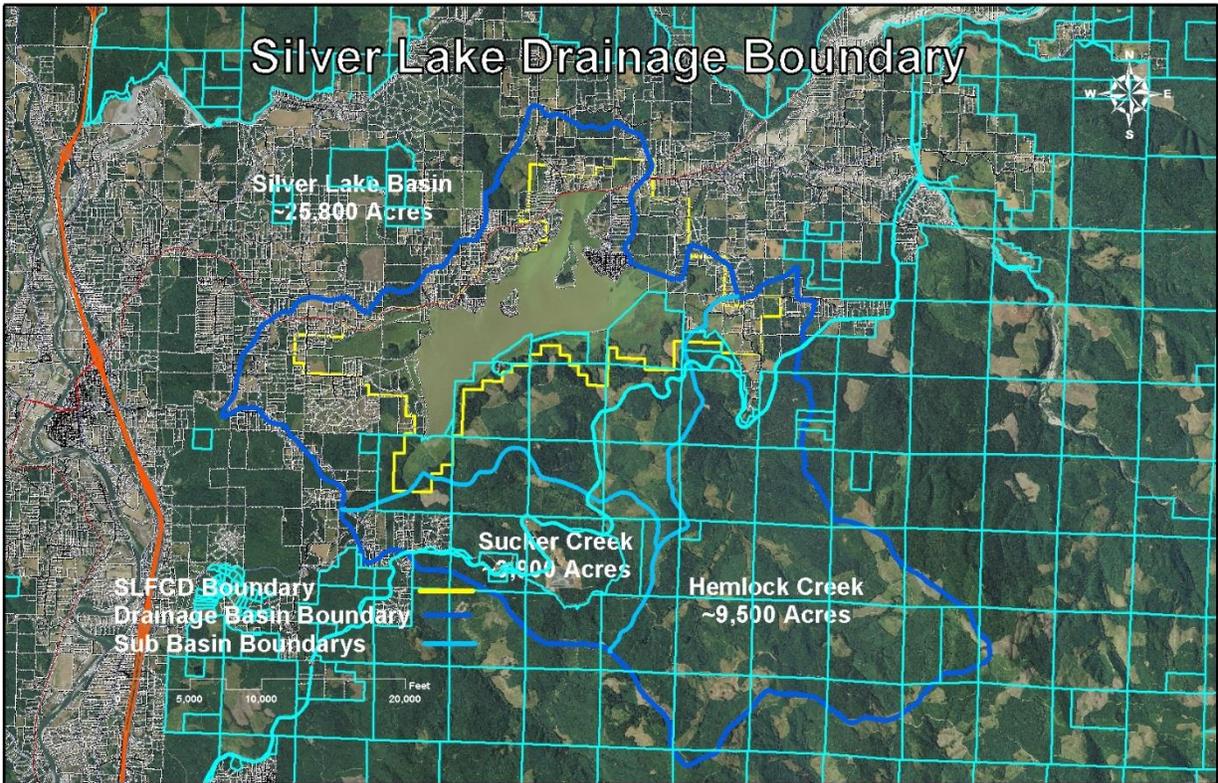

Figure 26

Figure 27

Figure 28

10.0 Evaluation

Silver Lake has a long history of phosphorus research including The Cowlitz County Silver Lake Phase II Restoration Monitoring report (June 1998) which noted that the 1997 weighted mean for total phosphorus was 0.034 mg/L. The first Washington State University (WSU) study (Bhagat, 1975) reported a mean of about 0.030mg/L.

SLWAC monitoring occurred in August 2012 and May 2015, and annual data was collected in 2013 and 2014. The average total phosphorus in 2013 was 0.046 mg/L, while in 2014 the average was higher at 0.063 mg/L.

These previous projects created a base of work to build on. The County became involved in the water quality monitoring of Silver Lake in 2015 when CCHD was awarded the following grant: *Agreement WQC-2015-CwCoHH-00129 Water Quality Testing & Improvement at Two Cowlitz County Lakes* between September 2015 and September 2018. The average total phosphorus over the course of the study was 0.053 mg/L. The average summer chlorophyll-*a* concentration during 2016 and 2017 was 26.9 mg/m^3. Year-round Secchi measurements averaged 2.0 ft. deep.

The QAPP identified the goal of completing 23 out of the 24 scheduled sampling events for water quality. This was accomplished and included 1 sediment sampling event. Some data was initially rejected due to quality assurance issues. The QAPP was followed, and a high-quality databank was established that is helpful in planning, executing, and evaluating improvement actions.

Contaminants of concern were not found in the sediment sample at any actionable level and indeed met the criteria established in the Dredged Material Management Program. Additionally, we learned how the streams change as they go through the watershed and how this might influence lake levels. The average total phosphorus over the course of the study for the lake was 0.058 mg/L while streams had 0.037 mg/L. Secchi values varied seasonally as we have seen in past studies. Dissolved oxygen in the streams had clear seasonal trends with higher levels in the winter then summer. Silver Lake had similar trends but with more variability across the lake. Stream temperatures, while slightly lower than the Silver Lake average, mirrored the annual pattern. Stream pH more consistently hovered around 7.4 while lake pH was slightly higher 7.5.

Overall, this project adds to the long-standing body of work and reinforces the need to maintain water quality testing. SLWAC continues to strive toward their long-term goal to improve the water quality of Silver Lake for the public's health and recreational benefit. This should help minimize the health risks posed by toxic algae growth events.

11.0   Follow Up

SLWAC continues to meet regularly to consider possible remediation activities. The sediment data results are of particular interest to the group as they look to dredging as a possible means to improve water quality. SLWAC is also considering the value and possibility of increasing the influence of Hemlock Creek.

Additionally, the Silver Lake Flood Control District has approved SLWAC's request to flush the lake beginning in February 2023. SLWAC should continue water quality sampling pre and post event to determine short- and long-term effects of this action.

CCHD and SLWAC have continued to work together to engage stakeholders and the public for future planned remediation actions. CCHD has regularly attended SLWAC meetings and has encouraged the planning of long-term remediation actions including the possibility of dredging, a key focus of this grant. It should be noted that without SLWAC this study would not have been successful.