Quality Assurance Project Plan

Horseshoe Lake

Grant ID: WQC-2015-CwCoHH-00129

Grant Name: Water Quality Testing & Improvement at Two Cowlitz County Lakes

Picture of Horseshoe Lake taken by Noel Johnson.

Date: January 2016
For: Washington State Department of Ecology
By: Hilarie Larson, REHS/RS
Cowlitz County Environmental Health Unit
207 4th Ave North, Kelso, WA 98626
Phone: (360) 414-5599

1.0 Title Page, Table of Contents, and Distribution List

Quality Assurance Project Plan for Water Quality Testing at Horseshoe Lake

______________________________	Date: __________
Tammy Riddell, Nonpoint Grant/Loan Project Specialist, Water Quality Program, Washington State Department of Ecology	
______________________________	Date: __________
Hilarie Larson, REHS, Author/Project Lead, Cowlitz County Environmental Health Unit	
______________________________	Date: __________
Season Long, EHS III, Environmental Health Unit Lead, Cowlitz County Environmental Health Unit	
______________________________	Date: __________
Chris Bischoff, REHS, Environmental Health Manager, Cowlitz County Health Department	
______________________________	Date: __________
Greg Salato for Christine Leaf, Project Manager, ALS Global Laboratory	

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Distribution List

Chris Bischoff
Environmental Health Program Manager
Cowlitz County Health Department
207 4th Ave North, Kelso WA 98626
Email: bischoffc@co.cowlitz.wa.us
Phone: (360) 414-5599 x 6445

Chris Leaf
Project Manager
ALS Global Laboratory
Email: chris.leaf@alsglobal.com
Phone: (360) 501-3275

Hilarie Larson
Environmental Health Specialist /
Project Lead
Cowlitz County Health Department
207 4th Ave North, Kelso, WA 98626
Email: larsonh@co.cowlitz.wa.us
Phone: (360) 414-5599 x 6428

Bart Step
City of Woodland Public Works Director
and Horseshoe Lake Management
Committee Member
Email: steppb@ci.woodland.wa.us
Phone: (360) 225-7999

Jody Bartkowski Herz
City of Woodland Engineering Technician
and Horseshoe Lake Management
Committee Member
Email: bartkowskij@ci.woodland.wa.us
Phone: (360) 225-7999

Season Long
Environmental Health Specialist Lead
Cowlitz County Health Department
207 4th Ave North, Kelso, WA 98626
Email: longs@co.cowlitz.wa.us
Phone: (360) 414-5599 x 6446

Tom Golik
President
Horseshoe Lake Management Committee
Email: goliktom@yahoo.com

2.0 Abstract

Water Quality at Horseshoe Lake in Washington State is one of two projects included in Water Quality Testing and Improvement at Two Cowlitz County Lakes, a grant program that also addresses Silver Lake and is funded in part by a Washington State Department of Ecology (Ecology) grant awarded to Cowlitz County Health Department (CCHD). The long-term goal is to improve the water quality of two major lakes in Cowlitz County for the public's health and recreational benefit by minimizing the health risks posed by toxic algae growth events and controlling non-native noxious weeds that limit the recreational potential of each lake.

The first objective is to establish a reliable data bank with a sufficient number of data points to enable future evaluation and long term planning actions to improve the water quality of Horseshoe Lake. Current improvements needed include the reduction of phosphorus levels (which is a factor in the cyanobacteria blooms that occur during some years), and control of the milfoil infestation. This ambient water quality monitoring program includes a two-year period of record with a project completion goal of December, 2017. The study target for Horseshoe Lake includes 4 testing sites for lab samples and in-situ tests. Success of the study will be determined by the completion of at least 31 of the 32 (95% or greater) sampling events. The result of a successful study will be current and reliable data appropriate and available for use in professional and citizen planning.

Another objective is to encourage local discussion and improve understanding of how individuals can have a positive effect on their lake water quality. This work will coincide with the time period of the first objective and is targeted to Horseshoe Lake Management Committee (HSLMC) and the general public. Results will be improved individual understanding and sense of empowerment regarding Horseshoe Lake water quality issues. The measure of success will be the existence of a public website that conveys a description and the results of this program, and includes messages that encourages individual responsibility and action.

The CCHD will work closely with HSLMC to develop a lake specific Quality Assurance Project Plan (QAPP), to select and purchase a water monitoring probe and other equipment, to ensure that volunteers are trained and audited, to conduct sampling for lab analysis and to perform in-situ testing, to compile and analyze results, conduct annual public meeting, and develop a public website. The outcome will be a reliable data bank presented in a usable format and publicly displayed so that water quality professionals and stakeholders can later analyze it to help plan long-term mitigation, education, and restoration efforts.

3.0 Background

3.1 Study area and surroundings

Horseshoe Lake is an oxbow lake located in the city of Woodland, Washington, formed by isolation of a bend in the North Fork Lewis River during construction of Interstate 5 (I-5) in 1940, then known as US 99. Washington Department of Transportation (DOT) oversees operation of the pump that controls flow into the lake, and is obligated to ensure that the lake does not become stagnant. It works on a float system, continually running unless river levels are too low. The outflow, owned by Washington Department of Fish and Wildlife (WDFW), is monitored by Woodland Public Works. During the summer months, the outlet is always many feet above water level. In the winter, the outlet valve is opened from a range of 5 – 20- turns, or fully opened, dependent on lake water levels. If the fully opened position still results in too high of lake level, then Public Works will ask DOT to turn the inlet pump off. The addition of water from North Fork Lewis River serves to dilute Horseshoe Lake water and thereby, in theory, improve lake water quality. See Figure 1. Map of Horseshoe Lake by Entranco (1999) in Section 16, which indicates the location of the inlet and outlet structures. See also Appendix A. Pictures of Horseshoe Lake.

The border between Clark and Cowlitz counties runs down the middle of the lake. The lake has a surface area of 34.7 hectares, a volume of 12.1 x 10^5 cubic meters (980 acre-feet), an average depth of 3.5 meters (11.5 feet), and a maximum depth of 7.2 meters (23.5 feet) (Welch et al. 1992). See Figure 2. Horseshoe Lake Depth (Somers 1989).

The area is characterized by cool summers and mild, wet winters. The average daily January low temperature is 33.5° F, and the average daily July high temperature is 82° F. Average annual precipitation for the area is 43.3 inches, with most precipitation occurring as rainfall between October and March. (www.bestplaces.net/climate/city/washington/woodland).

Previous fish surveys have identified rainbow trout, brown trout, large-mouth bass, large-scale suckers, brown bullhead, yellow bullhead, carp, squawfish, goldfish, sculpin, and yellow perch in the lake (Welch et al. 1992). The lake also contains sturgeon and steelhead, and many birds are found in the area including ducks, geese, cranes, seagulls, osprey, bald eagles, and goldfinches (Horseshoe Lake Committee 2000).

A city park on the lake offers a public boat ramp, which results in regular and moderately heavy public use. The lake hosts recreational activities including swimming, no-wake boating, fishing, and bird watching. A meat packaging plant is in operation on one of the shoreline properties.

3.1.1 Logistical problems

The lake is easily accessible. Inclement weather could interfere with sampling events, but should be of short enough duration to reschedule within the same month.

Depending on water levels and milfoil density, the southern sampling site could possibly be difficult to reach during the summer months. During the planning process, we did make an adjustment to sample site 4 to increase the likelihood of accessibility. The south arm comprises a significant portion of the lake, and thus avoiding it altogether does not seem prudent. The sampling plan addresses alternatives should the south arm site still become unavailable.

3.1.2 History of study area

A city park on the lake offers a public boat ramp, which results in regular and moderately heavy public use. In September 2010, the lake became a No Wake Body of Water due to residents' concerns about erosion and safety. Personal watercraft were prohibited about 10 years prior to that. Currently, the lake hosts recreational activities including swimming, no-wake boating, fishing, and bird watching.

There is a meat packing plant located on a lot adjacent to the lake. "Levels of fecal coliform were highest along the south shore of the south arm adjacent to the meat packing plant" in 1988 (Somers 1989). Although "fecal coliform levels in the whole of Horseshoe Lake did not exceed state water quality standards…at any time during the study." The summary of the same document also noted that Horseshoe Lake is undergoing the natural process of aging, or eutrophication, which is being accelerated by activities such as farming and urban development.

Horseshoe Lake was studied extensively during a one year period from 1991-1992 (Welch et al. 1992). This study's report it titled Phase I Diagnostic Study of Horseshoe Lake. Three recommendations from this study included enlargement of the pump that delivers Lewis River water to Horseshoe Lake in order to increase dilution, whole lake buffered alum treatment of the lake to improve turbidity and decrease total phosphorus levels, and development of a watershed management plan.

In 1999, The Final Report Horseshoe Lake Restoration Project Phase II Implementation was issued (Entranco Inc and Gibbs & Olson Inc 1999). Herein it was noted that "the greatest water quality benefit seemed to result from the buffered alum treatment," while "the dilution program provided mixed results" because the Lewis River actually had higher phosphorus levels than the lake sometimes. It was also revealed that as much as 50 percent of the dilution water flows directly from the lake back to the Lewis River through groundwater seepage. Also notable, lake level lower than groundwater can result in higher phosphorus levels in the lake.

HSLMC currently estimates that 50% of the 85-acre lake is milfoil infested. While the Committee is currently researching additional ways to control milfoil, they have been working for several years to install enough sterile grass carp to help eradicate the milfoil. In May 2009, 250 carp were installed. Due to their small size, it is believed that most of them fell prey to birds. In October 2011, 100 more carp were installed. In September 2015, 160 additional carp were put in. WDFW estimates that 22 fish are needed per acre. Using this formula, the Committee's goal is to have 935 live grass carp.

3.1.3 Contaminants of concern

This study will measure the most commonly studied water quality parameters including total phosphorus, chlorophyll *a*, and Secchi depth. Nitrogen will also be measured because nitrogen lake levels are unknown. Testing for bluegreen algae toxins is not within the scope of this study. If a bloom occurs during the study's timeframe, HSLMC will conduct testing through Ecology's citizen testing program.

3.1.4 Results of previous studies

In 1989 Sheldon Somers with Cowlitz County Conservation District authored a study that noted natural eutrophication was being accelerated by human activities. At that time, levels of fecal coliform were highest along the south arm adjacent to the meat packing plant, and that "the owner has been contacted and is working with the soil conservation service to reduce the amount of fecal material coming into the lake." (Somers 1989). Neither the Lewis River or Horseshoe Lake were in violation of state standards for fecal coliform. River fecal levels were much higher than lake fecal levels. It was also noted that Secchi depth averaged 3.0 feet over the entire lake, a decrease of approximately one half since 1975. Problems identified included:

1) Periodic high levels of fecal coliform in the river water
2) Blue-green algae impacting water clarity
3) Lack of flow through the lake
4) Disposal of garbage and lawn clippings in the lake and along the river

In 1992 the University of Washington completed a Phase I lake restoration study for the City of Woodland. Welch et al. (1992) recommended three major actions:

1) Whole lake buffered alum treatment
2) Increased dilution from the Lewis River
3) A watershed management plan

Between June 1997 and October 1998, these recommendations were implemented. The Phase II report by Entranco indicated that the alum treatment was most effective, as predicted (Entranco Inc and Gibbs & Olson Inc 1998). Results are summarized in the below chart. Current 12 month averages from HSLMC testing are included for comparison purposes.

Table 3.1.4 (A)

Horseshoe Lake Water Quality Treatment Results					
Parameter	Pre-Tx Range 1991/1997	Post-Tx Summer 1998	% Improvement(1)	Water Quality Goals (2)	Current 12 month average (by HSLMC)
Total Phosphorus (µg/l)	23.0 to 29.9	18.3	20 to 39	13.0 to 18.0	18.6
Chlorophyll *a* (µg/L)	14.0 to 15.0	8.5	39 to 43	5.4 to 8.3	Unknown
Secchi Depth (meters)	1.2 to 1.8	2.1	17 to 75	1.8 to 2.4	2.1
(1) The range of values is based on a comparison of 1998 post-treatment summer average values with pre-treatment summer average values for 1991 (Welch et al. 1992) and 1997 (this study).					
(2) Water quality goals established by the University of Washington (Welch et al. 1992).					

Entranco Inc and Gibbs & Olson Inc (1999), noted that with the improved water clarity facilitated by the alum treatment, aquatic plant growth may increase. Today, excessive milfoil is considered the priority problem by HSLMC.

Testing conducted by HSLMC in conjunction with the City of Woodland shows regular intermittent phosphorus levels over goal level of 0.025 mg/L, as indicated in yellow in the below chart.

Table 3.1.4 (B)

HSLMC Phosphorus Test Results (µg/L)					
Jan-13	ND	0.004	0.005	0.002	ND
Feb-13	0.002	0.006	ND	ND	ND
Mar-13	0.003	0.004	0.005	0.005	0.009
Apr-13	0.009	0.011	0.011	0.010	0.014
May-13	0.003	0.010	0.012	0.012	0.012
Jun-13	0.005	0.005	0.004	0.006	0.006
Jul-13	0.018	0.010	0.012	0.006	0.010
Aug-13	0.007	0.007	0.007	0.006	0.014
Sep-13	0.012	0.014	0.012	0.013	0.014
Oct-13	0.032	0.030	0.017	0.028	0.013
May-14	0.03	0.120	0.045	0.140	0.049
Jun-14	0.011	ND	ND	0.026	0.220
Jul-14	ND	ND	ND	ND	ND
Aug-14	0.026	0.017	0.014	0.019	0.019
Sep-14	0.019	0.022	0.018	0.021	0.014
Oct-14	0.027	0.027	0.025	0.024	0.018

Nov-14	0.013	ND	ND	0.013	0.010
Dec-14	0.018	0.019	0.027	0.019	0.15
Jan-15	ND	0.022	ND	ND	ND
Feb-15	0.043	0.042	0.032	0.028	0.035
Mar-15	0.016	0.014	0.015	0.014	0.015
Apr-15	0.017	0.016	0.017	0.017	0.019
May-15	0.019	0.019	0.017	0.018	0.018
Jun-15	0.014	0.014	0.012	0.016	0.015

In 1989, the average pH was 8.3, an increase from 1975 levels of 7.3. Current testing also shows high (alkaline) pH levels, in the 9 and 10 range. Therefore, pH levels measured with the County's YSI ProDSS water quality sonde will be of special interest, to see if indeed there has been a continual increase in alkalinity over the years.

3.1.5 Regulatory criteria or standards

This study will not be used to determine compliance with regulatory standards or criteria. However, the following criteria will be considered and commented upon in the analysis of the final results.

Washington Administration Code (WAC) 173-201A-200 sets aquatic life criteria for indigenous warm water species, as described below.

> For Aquatic Life:
> Temperature: Highest 7-DADMax 20°C (68°F)
> DO: Lowest 1 Day Minimum of 6.5 mg/L
> Turbidity: Shall not exceed 10 NTU over background when the background is 50 NTU or less; or a 20 percent increase in turbidity when the background turbidity is more than 50 NTU.
> pH: shall be within the range of 6.5 to 8.5 with a human-caused variation within the above range of less than 0.5 units.

Also, Washington Administrative Code 173-201A-230 indicates that lake specific studies may be initiated to set specific ambient total phosphorus range for values over 20 µg/L in Puget Lowlands Ecoregion.

4.0 Project Description

This project will provide the data necessary to evaluate the health of Horseshoe Lake, and to plan long-term actions by the Horseshoe Lake community.

4.1 Project goals

The long-term project goal is to improve the water quality of Horseshoe Lake for the public's health and recreational benefit, minimizing the health risks posed by toxic algae growth events, and controlling non-native noxious weeds that limit the recreational potential of the lake.

The immediate goal of this project is to provide the data and site-specific results necessary to plan, execute, and evaluate continuous improvement actions. Public access via a public website to the study process and training developed for the lake, and all data collected, is another key goal of this project.

4.2 Project objectives

The first objective is to establish a reliable data bank with a sufficient number of data points to enable future evaluation and long-term planning actions to improve the water quality of Horseshoe Lake. This study will generate a data bank that includes 128 data points for total phosphorus, 128 data points for chlorophyll *a*, and 128 data points for Secchi depth, which will support conclusions and trend analysis regarding the constituent itself as well as a calculation of the trophic state index. In addition, 96 data points of total nitrate-nitrite will be established. A water quality probe will provide 6 water quality parameters, generating 128 data points for each. To ensure this objective, the project's goal is to accomplish 95% or more of the sampling events following the approved QAPP. Upon completion, numerical and trending analysis of the data will be completed.

The second objective is to encourage local discussion and improve understanding of how individuals can have a positive effect on their lake water quality. To ensure this objective, the project's data will be cataloged, made available to the public via the internet, and submitted to Ecology through the Environmental Information Management (EIM) database. Public understanding and discussion will be facilitated via annual informational public meetings.

4.3 Information needed and sources

No additional information is needed before the study may commence.

4.4 Target population

The target populations of this study include the chosen water quality constituents of Horseshoe Lake. Ambient air temperature will also be measured. Specific targeted constituents are:

- Lab-determined values of total phosphorus, chlorophyll *a*, and total nitrate-nitrite.
- In-situ lake characterizations including Secchi disk depth and Ysi ProDSS measurements of air and water temperature, pH, conductivity, dissolved oxygen, and turbidity.

The segment of the general public that is concerned about or has influence over Horseshoe Lake and its watershed is another target population, as public education and publishing of results is a component of the project.

4.5 Study boundaries

Horseshoe Lake is located in Woodland, Washington on the Willamette Meridian in Township 5 North. (Welch et al. 1992).

4.6 Tasks required

- Develop and write a lake-specific QAPP for Ecology approval.
- Collaborate with HSLMC technical advisors in project planning and implementation.
- Compare current sampling methods with Ecology-approved Standard Operating Procedures (SOP), and provide training and documents to eliminate any discrepancies.
- Provide oversight and audits of volunteers during field testing.
- Conduct total phosphorus, chlorophyll *a* sampling for lab analysis at 4 locations monthly from October-May and bi-monthly from June-September. 128 data points will be established for each analyte over the two year study.
- Conduct total nitrate-nitrite sampling for lab analysis at 4 locations monthly. 96 data points will be established for this constituent over the two year study.
- Determine Secchi disk depth at four locations twice each month during the summer months of June – September and once a month from October - May. 128 data points will be established for Secchi depth.
- Determine probe measurements for ambient air temperature, water temperature at 1' water depth, and the following measurements at 3' water depth: water temperature, pH, dissolved oxygen and turbidity at four locations twice each month during the summer months of June – September and once a month from October - May. 128 data points will be established for each of these measurements.
- Conduct annual public meetings to help educate the public on specific activities that they can do to have a positive effect on the lake, as well as activities that they can refrain from that have a potentially negative effect on the lake.

- Input water quality monitoring data into Ecology's EIM system annually.
- Compile and publish all data on public website.
- Submit quarterly progress reports and billings.
- Conduct Technical Audit within 90 days commencement and submit report.
- Annually, in January, submit grant load reductions report.
- Conduct numerical and trending analysis of the study's data.
- Submit a report to Ecology Project Manager summarizing data results and data analysis.
- Submit recipient closeout report.

4.7 Practical constraints

The lake is easily accessible. Inclement weather could interfere with sampling events, but should be of short enough duration to reschedule within the same month.

The southern most sampling site may be difficult to reach during the summer months, due to shallow water depths and the excessive milfoil growth. This sample site has been strategically placed so it is representative of the south arm but has a greater chance of remaining accessible. The sample plan is designed to accommodate the possibility that inaccessibility may still occur.

4.8 Systematic planning process

This document serves as the systematic planning process for this project.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 5.1 Key Individuals

Personnel	Title	Responsibility	Phone
Chris Bischoff	Environmental Health Manager	Supervision	360-414-5599
Season Long	Environmental Health Specialist Lead	Project Oversight	360-414-5599
Hilarie Larson	Environmental Health Specialist	Project Lead	360-414-5599
Jody Bartkowski Herz	Engineering Technician	Project Planning	360- 225-7999
Chris Leaf	Project Manager at ALS Global	Manage Lab Tasks	360-501-3275

5.2 Special training and certifications

The Cowlitz County Health Department - Environmental Health Unit (CCHD-EHU) and the HSLMC will provide personnel for this project.

CCHD-EHU:

Chris Bischoff is the Environmental Health Manager and will serve as the overall supervisor for this project. He earned his Bachelor of Science in Biology and is a Registered Sanitarian by the National Environmental Health Association.

Hilarie Larson, Environmental Health Specialist, is also a Registered Sanitarian. She has a Bachelor of Science from Pacific University and six years of experience in local and state environmental health programs. She conducted water quality sampling previously in Tillamook County and administered the shellfish safety program, along with other environmental health work experiences in city, county and state health departments.

Season Long, Environmental Health Specialist Lead, has a Bachelor of Science in Biology and a Master of Science in Marine Resource Management. She worked on multiple research teams and focused much of her work on collecting and analyzing water quality samples, including ground water monitoring at Columbia Ridge Landfill for Oregon Department of Environmental Quality, and wetland/watershed water quality assessment for Earth Design Consultants.

Megan Erickson, Environmental Health Specialist, earned a Bachelor of Science in Food Science and Human Nutrition. Before working for the County she spent two years at Columbia Analytical Services/ALS where she performed microbiological testing including: total coliform, fecal coliform, *E. coli*, BOD, CBOD, DO, pH, and turbidity.

Jeremiah Maschmann has a Bachelor of Science in Biology and a total of nine years working in water quality programs. Prior to working for the County, he spent seven years with the Federal Bureau of Reclamation Water Quality Lab and two years with Columbia Analytical Services/ALS, conducting various forms of analytical testing in both places.

HSLMC:

The City of Woodland Public Works Department is responsible for Horseshoe Lake and Park. Bart Stepp, Public Works Director, works with the Washington State Department of Transportation to maintain Lake levels and water quality. Jody Bartkowski Herz, Engineering Technician, acts as Committee Secretary. She has also coordinated and conducted pre-grant sampling and complied the results of all sampling and testing.

HSLMC is comprised of eight appointed community representatives. Seven of eight members are active and include:

Tom Golik has been a member of the HSLMC since its establishment in 1989 and is the Chairperson. He currently represents the Committee at City Council meetings, prepares correspondence, and volunteers for sampling activities.

Pat Rychel was appointed as a Committee member in 2008 when the group reconvened after a several year hiatus. He offers the Committee a resource for historical information and data research.

Terry Jones lives on the Lake. He and Neil Van Horn joined the Committee shortly after 2008 and both volunteer for testing when available.

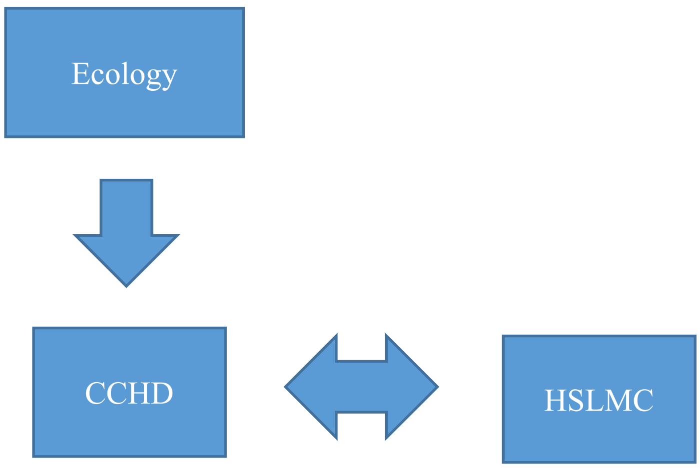
Mike Curry lives on Horseshoe Lake and is an avid swimmer and paddle boarder. He gathers water level, temperature, and clarity data weekly from his dock, and volunteers for sampling activities.

Bill Dunlap lives on Horseshoe Lake and is currently developing lakefront property. He owns and operates the boat used for sampling activities.

Scott Perry lives on Horseshoe Lake and is a past City Council member. He is active with milfoil management, and volunteers his time and boat for backup testing.

5.3 Organization chart

Three organizations are involved with this project: Ecology, CCHD, and HSLMC. Ecology has awarded a task-specific grant to CCHD. CCHD is responsible for administering and managing the project, and must meet Ecology administrative and technical requirements and documentation. Per Ecology's Scope of Work document, Cowlitz County is to retain ownership of equipment purchased with the grant. The grant was awarded because of demonstrated volunteerism of HSLMC members, and is dependent on their involvement in sampling tasks.



5.4 Project schedule

Table 5.4 Project Schedule

Date	Task or Accomplishment
Jul 30, 2015	Ecology Quarter Report due
Aug early 2015	Complete procurement of Probe
Sept 28, 2015	QAPP submitted to Ecology
Oct late 2015	QAPP returned to CCHD - approved by Siana Wong with required edits
Oct 31, 2015	Ecology Quarter Report due
Nov 18, 2015	QAPP sent to Ecology with edits and signatures
Dec 1, 2015	Volunteer Training
Dec 15, 2015	Betsey Dickes provides further QAPP review
Jan 11, 2016	QAPP resubmitted to Siana Wong
Jan early 2016	Sample Set 2 + Quarterly Probe Blanks + Quarterly Lab Replicate (1 site)
Jan 13, 2016	QAPP returned to CCHD - approved by Siana Wong with required edits
Jan 21, 2016	QAPP sent to Ecology with edits and signatures
Jan late 2016	ALS to receive accreditation for chlorophyll *a*
Jan 31, 2016	Ecology Quarter Report due
Feb 1, 2016	Sample Set 1 (with chlorophyll *a* if accredited, and without if not accredited)
Mar early 2016	Sample Set 2 + quarterly field replicate (1 site)
Apr 1, 2016	Sample Set 3
Apr 30, 2016	Ecology Quarter Report due + Technical Systems Audit per 12.1 due
May early 2016	Sample Set 4 + quarterly field replicate (1 site) & Website Launch
Jun early 2016	Sample Set 5 & Field Audit
Jun late 2016	Sample Set 6 & Duplicate Sample
Jul early 2016	Sample Set 7 + quarterly field replicate (1 site)
Jul late 2016	Sample Set 8 & Field Audit + Ecology Quarter Report Due
Aug early 2016	Sample Set 9
Aug late 2016	Sample Set 10 + Quarterly Probe Blanks + Quarterly Lab Replicate (1 site)
Sep early 2016	Sample Set 11 & Field Audit
Sept late 2016	Sample Set 12 + Ecology Quarter Report Due
Oct 1, 2016	Sample Set 13
Oct late 2016	Ecology Quarter Report Due + Conduct annual public meeting
Nov 1, 2016	Sample Set 14 & website update
Nov mid 2016	Compile data & submit to EIM
Dec 1, 2016	Sample Set 15 & website update
Jan 1, 2017	Sample Set 16 & Field Audit
Jan late 2017	Ecology Quarter Report Due
Feb 1, 2017	Sample Set 17 & Quarterly Probe Blanks + Quarterly Lab Replicate (1 site)
Mar 1, 2017	Sample Set 18 + input data into Ecology EIM
Apr 1, 2017	Sample Set 19
Apr late 2017	Ecology Quarter Report Due
May 1, 2017	Sample Set 20 & Field Audit
Jun early 2017	Sample Set 21 + Quarterly Probe Blanks + Quarterly Lab Replicate & Website

	Update
Jun late 2017	Sample Set 22
Jul early 2017	Sample Set 23
Jul late 2017	Sample Set 24 + Quarterly Probe Blank + Quarterly Lab Replicate (1 site) & Field Audit + Ecology Quarter Report Due
Aug early 2017	Sample Set 25
Aug late 2017	Sample Set 26
Sep early 2017	Sample Set 27 + Quarterly Probe Blank + Quarterly Lab Replicate (1 site)
Sept late 2017	Sample Set 28 & Field Audit
Oct 1, 2017	Sample Set 29 + Ecology Quarter Report Due
Nov 1, 2017	Sample set 30
Dec 1, 2017	Sample set 31 + Compile data & submit to EIM
*Jan early 2018	Sample Set 32 + Quarterly report due
*Jan mid 2018	Compile data & submit to EIM, analyze data
*Jan 31, 2018	Ecology Quarter Report due
*Feb early 2018	Draft Final Report, Conduct annual public meeting + update website
*Mar early 2018	Submit final report
*	indicates activity beyond grant expiration date; extension requested.

5.5 Limitations on schedule

There are no anticipated limitations on schedule. The above schedule in section 5.4 provides enough flexibility to recover from a cancelled sampling event due to weather conditions. If a volunteer experiences boating equipment problems, or a conflict in schedule, Cowlitz County Public Works has indicated that we can use their boat. If the water sample probe experiences a malfunction or mechanical problem, then a gap in data of some water quality parameters could occur.

5.6 Budget and funding

Budget is described below for the grant in its entirety, which also includes the Horseshoe Lake project. The total eligible cost for this dual project is $143,028.00 Of that, Ecology will fund $107,271.00 and Cowlitz County will fund $35,757.00. See below charts for delineation of budget funds.

Table 5.6 (A)

Total Project Budget for Both Lakes				
Task ID	**Task Description**	**Budget**	**Ecology Share 75%**	**Project Match 25%**
1	Project Administration	28,392	21,294	7,098
2	Water Lab Sampling & Testing	114,636	85,977	28,659
	Total	143,028	107,271	35,757

Table 5.6 (B)

Project Budget for Task 1 Specific Activities for Both Lakes							
Task ID	**Task Description**	**Hours**	**Cost/hr**	**Total**	**Budget**	**Ecology Share**	**Project Match**
1A		80	52.88	4230.4		3172.80	1057.6
1B		157	52.88	8302.16		6226.62	2075.54
1B		79.92	52.88	4226.17		3169.63	1056.54
1B		220	52.88	11633.60		8725.20	2908.40
					rounded:	rounded:	rounded:
		536.92		28,392.33	28,392	21,294	7,098

Table5.6(C)

Project Budget for Task 2 Specific Activities for Both Lakes							
Task ID	**Task Description**	**#**	**Unit**	**Price /unit**	**Event**	**Ecology Share 75%**	**Project Match 25%**
2G	County Mobilization	1.33	hr	52.88	64	4501.15	
2G	Volunteer Mobilization	1	hr	22.69	64		1452.16
2C	Data entry	1	hr	22.69	64		1452.16
2A	QAPPs	306	hr	52.88	1	16181.3	
2B	training	10	hr	52.88	9	4759.2	
2H	Public meetings	16	hr	52.88	2	1692.16	
2G	Boat value - Silver	4	hr	16.95	32		2169.6
2G	Boat value - Horseshoe	1.5	hr	16.95	32		813.6
2G	Sampling volunteers - Silver	9	hr	22.69	32		6534.72
2G	Sampling volunteers - Horseshoe	3	hr	22.69	32		2178.24
2G	Mileage costs - Silver	78	miles	0.57	32	1422.72	
2G	Mileage costs – Horseshoe	48	miles	0.57	32	875.52	
2G	Transport samples - Horseshoe	1.25	hr	22.69	32		907.6
2G	Transport samples - Silver	1.5	hr	22.69	32		1089.12
2G	Lab charges Silver Lake	1	event	788	32	25216	
2G	Lab charges Horseshoe Lake	0.625	event	788	32	15760	
2E	Website update - Silver	1	hr	22.69	32		726.08
2E	Website update - Horseshoe	0.5	hr	22.69	32		363.04
2G	temp, level and outflow	1		22.69	208		4719.52

2G	weather and data entry	0.5		22.69	208		2359.76
2G	boat costs	1		16.95	208		3525.6
2F	Probe Purchase	1		9500	1	9,500	
2F	other equipment purchase	1		3400	1	3400	
2C	website creation	60	hr	22.69	1		1361.4
2E	Stat analysis	50	hr	52.88	1	2644	
	Project Total					85,952	29,652.6
	Target: 114,636 x 75% and 25%					85,977	28,659
	Difference Project Total & Target					-25	933.6
	% of Total Budget (114, 636)					0.75	0.26
	% of Project Total (115,604.60)					0.74	0.26

Table 5.6 (D)

Laboratory Budget for Horseshoe Lake							
Lab Test	Locations	X per year	# of years	Total test #	Test # + quarterly QC	Price per test	Total lab costs
Budget							**15760**
Phosphorus	4	16	2	128	138	28	3864
Chlorophyll *a*	4	16	2	128	138	55	7590
Turbidity for probe QC	1	12	2	NA	24	10	240
Total Nitrate-Nitrite	4	12	2	96	106	22	2332
Total							**14,026**
Under Budget (This will be used for Ecology's addition of 10% fecal coliform samples to Silver Lake study for QC purposes per Bill Ward.)							**(-) 1,734**

6.0 Quality Objectives

6.1 Decision Quality Objectives (DQOs)

N/A

6.2 Measurement Quality Objectives

Table 6.2 (A)

MQOs – Precision & Bias in Field Constituents				
Analyte	**Accuracy (deviation of % deviation from true value**	**Precision (% RSD)**	**Bias (% deviation from true value)**	**Required Reporting Limit**
Secchi Depth	NA	+/- 0.5m	NA	NA
Temperature	+/- 0.2 ° C	0.1° F	NA	NA
pH	+/- 0.2 pH units	0.01 pH units	NA	NA
Conductivity	0-100 mS/cm: +/- 0.5% of reading or 0.001mS/cm, whichever is greater. 20-50 mg/L: +/- 1.0% of reading	0.001, 0.01, or 0.1µS/cm (range dependent)	NA	NA
Dissolved Oxygen	0 to 20 mg/L: +/- 0.1 mg/L or 1% of reading, whichever is greater. 20 to 50 mg/L: +/- 8% of reading	0.01 mg/L and 0.1%, or 0.1 mg/L and 1% (user selectable)	NA	NA

Table 6.2 (B)

MQOs – ALS Global Lab Constituents Analysis Method, Detection and Quantitation Limits, Lab Quality Control Limits							
Analyte	**Method**	**MDL**	**MRL**	**Units**	**Accuracy LCS %Rec**	**Matrix Spike %Rec**	**Precision % RPD**
Phosphorus, Total	EPA 365.3	0.004	0.01	mg/L	85-115	70-130	20
Chlorophyll-*a*	SM10200 H	0.3	0.8	mg/m3	88-113	NA	20
Total nitrate-nitrite	EPA 353.2	0.02	0.05	mg/L	90-110	90-110	20

6.2.1 Targets for Precision, Bias, and Sensitivity

6.2.1.1 Precision

At concentrations near the lowest concentration of interest, it will not be possible to meet the percentage MQOs indicated above because errors expressed as a percentage increase at lower concentrations. However, at lower concentrations, the acceptable error is generally greater. The precision MQO is in line with MEL's historic performance for most constituents. Chlorophyll, which is inherently more variable, has a less stringent MQO.

The above MQO table is intended to indicate the quality of the result from a particular sample (or pooled set of samples) and therefore to apply to lab or field *splits*. Quarterly field duplicate samples (i.e., sequentially collected), which include some environmental variability, may be used to determine if MQOs have been met; however, some judgment may be required regarding the amount of environmental variability in the sample.

6.2.1.2 Bias

Sampling bias will be minimized by strictly adhering to the protocols discussed and referenced herein. This QAPP provides procedures for collecting representative and valid samples. However, as is true for all sampling, some sampling bias is likely present in the results even if not measurable or confirmed. Assessment and management of bias will occur mostly at the laboratory. We expect that bias in the chemical analyses will be corrected so that long-term bias will not occur within a single method. Measurement Quality Objectives for bias are listed in the MQO table above.

6.2.1.3 Sensitivity

Table 6.2.1.3

MQOs – Sensitivity				
Water Quality Parameter	**Measurement Range**	**Accuracy**	**Resolution**	**Instrument or method**
Water clarity	0-30 feet	NA	NA	Secchi disk
Turbidity	0-4000 FNU	0-999 FNU: 0.3 FNU or 3% (whichever is greater), 1000 to 4000 FNU: +/- 5% of reading	0.1 FNU	ProDSS
Temperature	-5 to 70 °C	+/- 0.2°C	+/- 0.1°C or 0.1°F	ProDSS
pH	0 to 14 pH units	+/- 0.2 pH units	0.01 pH units	ProDSS
Dissolved Oxygen	0 to 50 mg/L	0 to 20 mg/L +/- 0.1mg/L or 1%, whichever is greater. 20 to 50 mg/L +/-8%	0.01 mg/L and 0.1% or 0.1 mg/L and 1% (user selectable)	ProDSS
Total phosphorus	0.01 to 100 mg/L	0.01 mg/L +/- 10%	0.004 mg/L	EPA 365.3
Chlorophyll *a*	0.2 to 1000 mg/L	0.2 µg/L +/- 10%	0.08 mg/L	SM 10200H

Total Nitrate-Nitrite	0.05 – 5 mg/L (higher with dilution)	+/- 10%	0.05 mg/L	EPA 353.2

6.2.2 Targets for Comparability, Representativeness, and Completeness

6.2.2.1 Comparability

All measurement and analytical procedures are documented so that the data will be comparable with samples collected and analyzed in a like manner according to attached SOPs.

6.2.2.2 Representativeness

The study will span over two years, and conditions of sampling are expected to vary. Samples will be collected monthly from October – April, and bimonthly from May – September. Because the lake is shallow, grab samples taken at 3 feet water depth are considered to be representative. Grab samples will be shaken before poured into lab containers per Horseshoe Lake SOPs to aid in representativeness.

The four sampling sites for total phosphorus, chlorophyll *a* and total nitrate-nitrite were chosen to represent general geographical locations of the lake, (1) the inlet, (2) the swim beach / north arm, (3) the midpoint / bend, and (4) the south arm. The south arm site was also chosen with summer season accessibility in mind.

6.2.2.3 Completeness

There are no legal or compliance uses anticipated for the Horseshoe Lake data. In addition, there is no fraction of the planned data that must be collected in order to fulfill statistical criteria. It is expected that at least 95% of the sampling events will occur unless unanticipated and prolonged inclement weather conditions prevent sampling.

7.0 Sampling Process Design (Experimental Design)

7.1 Study Design

Four sites will be sampled at a frequency ranging from monthly to bi-monthly. The study includes three different lab tests, Secchi depth determination, and several in-situ tests. Two of the labs (chlorophyll *a* and phosphorus) and Secchi depth will be used to independently determine Carlson's trophic state index.

7.1.1 Sampling location and frequency

Table 7.1.1

Horseshoe Lake Sample and Test Schedule (per Calendar Year) by Site #					
Month / Week	Total Phosphorus	Chlorophyll *a*	Nitrate - Nitrite	In-Situ	Secchi Depth
Jan wk 1	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4
Feb wk 1	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4
Mar wk 1	1,2,3,4 + Q	1,2,3,4 + Q	1,2,3,4 + Q	1,2,3,4	1,2,3,4
Apr wk 1	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4
May wk 1	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4
Jun wk 1	1,2,3,4 + Q	1,2,3,4 + Q	1,2,3,4 + Q	1,2,3,4	1,2,3,4 + Q
Jun wk 3	1,2,3,4 + B	1,2,3,4 + B	1,2,3,4 + B	1,2,3,4	1,2,3,4
Jul wk 1	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4
Jul wk 3	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4
Aug wk 1	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4
Aug wk 3	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4
Sep wk 1	1,2,3,4 + Q	1,2,3,4 + Q	1,2,3,4 + Q	1,2,3,4	1,2,3,4
Sep wk 3	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4
Oct wk 1	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4
Nov wk 1	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4
Dec wk 1	1,2,3,4 + Q	1,2,3,4 + Q	1,2,3,4 + Q	1,2,3,4	1,2,3,4

1,2,3,4 = sampling sites
Q = Quality Control Duplicate Sample (to be taken at one of the 4 sites)
B = Blank Sample submitted to Lab (annually)

7.1.2 Parameters to be determined

The three most common constituents for the assessment of lakes will be determined in this study including phosphorus, chlorophyll *a*, and Secchi depth. The results of chlorophyll *a* will be used to independently calculate Carlson's Trophic State Index (TSI). Total phosphorus and Secchi depth will be also be used to calculate trophic state, but used as supporting calculations and not considered independently, since "neither transparency or phosphorus are independent estimators of trophic state. Using transparency or phosphorus as an estimator of chlorophyll is very different from assuming equal and independent status of the variables." (Carlson 1983, as cited in Osgood 1983).

Total nitrate-nitrite will also be determined, as it has not been measured in the previous studies and its levels are unknown.

YSI ProDSS sonde measurements of temperature, pH, turbidity, and dissolved oxygen will be obtained at all sites upon each sample event.

Calculating the TSI

North American Lake Management Society (2015) publishes the following information on the secchi dip-in website, http://www.secchidipin.org/index.php/monitoring-methods/trophic-state-equations/:

> The index is relatively simple to calculate and to use. Three separate equations are used: Secchi disk, TSI(SD); chlorophyll pigments, TSI(CHL); and total phosphorus, TSI(TP).
>
> The simplified equations are:
>
> $TSI(SD) = 60 – 14.41 \ln(SD)$
>
> $TSI(CHL) = 9.81 \ln(CHL) + 30.6$
>
> $TSI(TP) = 14.42 \ln(TP) + 4.15$

In the Horseshoe Lake study, the three variables will not be averaged. Carlson (1983) emphasizes that the index is predicated on the idea that it is predicting algal biomass. Chlorophyll is a better predictor than either of the other two indices. There is no logic in combining a good predictor with two that are not (Carlson 1983).

7.1.3 Field measurements

Field measurements include Secchi depth and sonde measurements of air temperature, surface water temperature, and at 3': water temperature, pH, DO and turbidity. See table 7.1.3 Horseshoe Lake Sampling Plan for locations of Secchi and In-situ measurements.

Table 7.1.3

Site Information for Field Measurement and Lab Samples			
Number	Name	Latitude	Longitude
1	Inlet	45° 54' 2.265"N	122° 44' 27.509"W
2	Swim Beach	45° 54' 1.379"N	122° 44' 42.077"W
3	Midpoint	45° 53' 43.419"N	122° 44' 57.656"W
4	South	45° 53' 33.831"N	122° 44' 40.109"W

7.2 Maps or diagram

Please see map of Horseshoe Lake and sampling sites below.

Sample Site 1:	Lake Inlet	45° 54’ 2.265” N	122° 44’27.509” W
Sample Site 2:	Swim Beach	45° 54’ 1.379” N	122°44’42.077”W
Sample Site 3:	Midpoint (bend)	45° 53’ 43.419” N	122° 44’ 57.656”W
Sample Site 4:	South(garbage dump)	45° 53’ 33.831”N	122° 44’ 40.109”W

7.3 Assumptions underlying design

N/A

7.4 Relation to objectives and site characteristics

The long-term project goal is to improve the water quality of Horseshoe Lake for the public’s health and recreational benefit by minimizing the health risks posed by toxic algae growth events and controlling non-native noxious weeks that limit the recreational potential of the lake.

The first objective is to establish a reliable data bank with a sufficient number of data points to enable future evaluation and long-term planning actions to improve the water quality of Horseshoe Lake. The result will be current and reliable data appropriate and available for use in professional and citizen planning. The sampling plan supports this objective.

Another objective is to encourage local discussion and improve understanding of how individuals can have a positive effect on their lake water quality. Results will be improved individual understanding and sense of empowerment regarding Horseshoe Lake water quality issues. The sampling plan supports this objective as well.

The study design supports the final outcome of the project by creating a reliable data bank presented in a usable format. This will be publically displayed so that water quality professionals and stakeholders can later analyze it to help plan long-term mitigation, education, and restoration efforts.

7.5 Characteristics of existing data

Sampling from August of 2012 to June of 2015, sponsored by HSLMC, has included only total phosphorus and *E. coli*. This sampling was conducted by a City of Woodland engineer technician (also a HSLMC member) following a field manual developed by WDFW. The data has allowed stakeholders to have confidence in continued low *E. coli* levels, and therefore this study offers no further examination of *E. coli*. Total phosphorus has risen above the EPA (1987) water quality criteria of 25 µg/L and the Washington State action value of 20 µg/L (WAC 173-201A-230) on several occasions, and thus remains an important constituent. Nitrogen levels are unknown, as are cholorphyll *a* levels.

Field measurements during the last six months have been taken consistently by WDFW, and before that to a much more limited degree. Measurements of pH by WDFW's Hydrolab probe has been quite high; into the 10 and 11s. There is some anticipation to see if CCHD's ProDSS probe will confirm such a high pH.

8.0 Sampling Procedures

8.1 Field measurement and field sampling SOPs

Procedures and task for measuring phosphorus, nitrogen, chlorophyll *a*, and Secchi depth are developed from Ecology EAP015 Version 1.2, and EPA Office of Water Volunteer Lake Monitoring document 440491002.

See Appendix B. Horseshoe Lake SOP, separate attachment.

All field measurements taken via Ysi ProDSS including ambient air temperature, water temperatures, pH, conductivity, dissolved oxygen, and turbidity will strictly follow the ProDSS User Manual Document #626973-01 REF (https://www.ysi.com/ProDSS). Probe calibration will be conducted utilizing the above referenced document and furthermore adding the rinse "rules of threes." Staff conducting calibration should also utilize PRODSS Quick Start Guide and Probe Tutorial Notes 8/27/15. Calibration of pH shall be within 2 weeks of each sampling event, and calibration of all other parameters shall be within 30 days of each sampling event.

8.2 Containers, preservation methods, holding times

Please see table below:

Table 8.2

Sample Volume, Container, Preservation, Storage, & Hold Time Requirements			
Analyte(s)	**Container**	**Preservation Technique**	**Analysis Holding Time**
Total Phosphorus	500 mL Plastic H_2SO_4	9N H_2SO_4: Cool to 4± 2ºC	28 days
Total nitrite-nitrate	500 mL Plastic H_2SO_4	9N H_2SO_4: Cool to 4+/- 2°C	28 days
(Analysis of) Chlorophyll *a* (Preparation)	Unfiltered: 1 L unpreserved opaque plastic container	Unpres.; Cool to 4± 2ºC, no light exposure	Filter within 48 Hrs.
		Frozen	28 days

8.3 Invasive species evaluation

Horseshoe Lake is not listed in Washington's 303(d) list of impaired waters for invasive species. However, it is significantly affected by the overabundance of milfoil, and the same precautions will be used as if it was on the list. Per EAP070 section 6.1, field activities will be conducted to minimize the contact between equipment and potential sources of invasive species, particularly aquatic plants, sediment and fish. Methods of minimization include (sections 6.1.4.1 – 6.1.4.5); sampling from areas of less weed growth to more dense weed growth, avoid running boat onto sediment, avoid getting plants, sediment and fish inside boats or other sampling gear, avoid driving or walking through areas of mud and high weed growth. The sampling team will not wear felt soles.

Per EAP070 section 6.2, after field work all equipment will be inspected, cleaned and drained. The sampling team will inspect and clean all equipment that contacted (terrestrial or aquatic) soil, vegetation, or water. They will remove any visible vertebrates, invertebrates, plants, algae or sediment. If necessary, they will use a scrub brush and rinse with clean water either from the site or brought for that purpose, until the equipment is clean. In addition, the sampling team will drain water in bilges, samplers or other equipment that could hold water from the site. Since no hose is available at the launch, the sampling team will ensure that no debris will leave the equipment and potentially spread invasive species during transit or cleaning.

8.4 Equipment decontamination

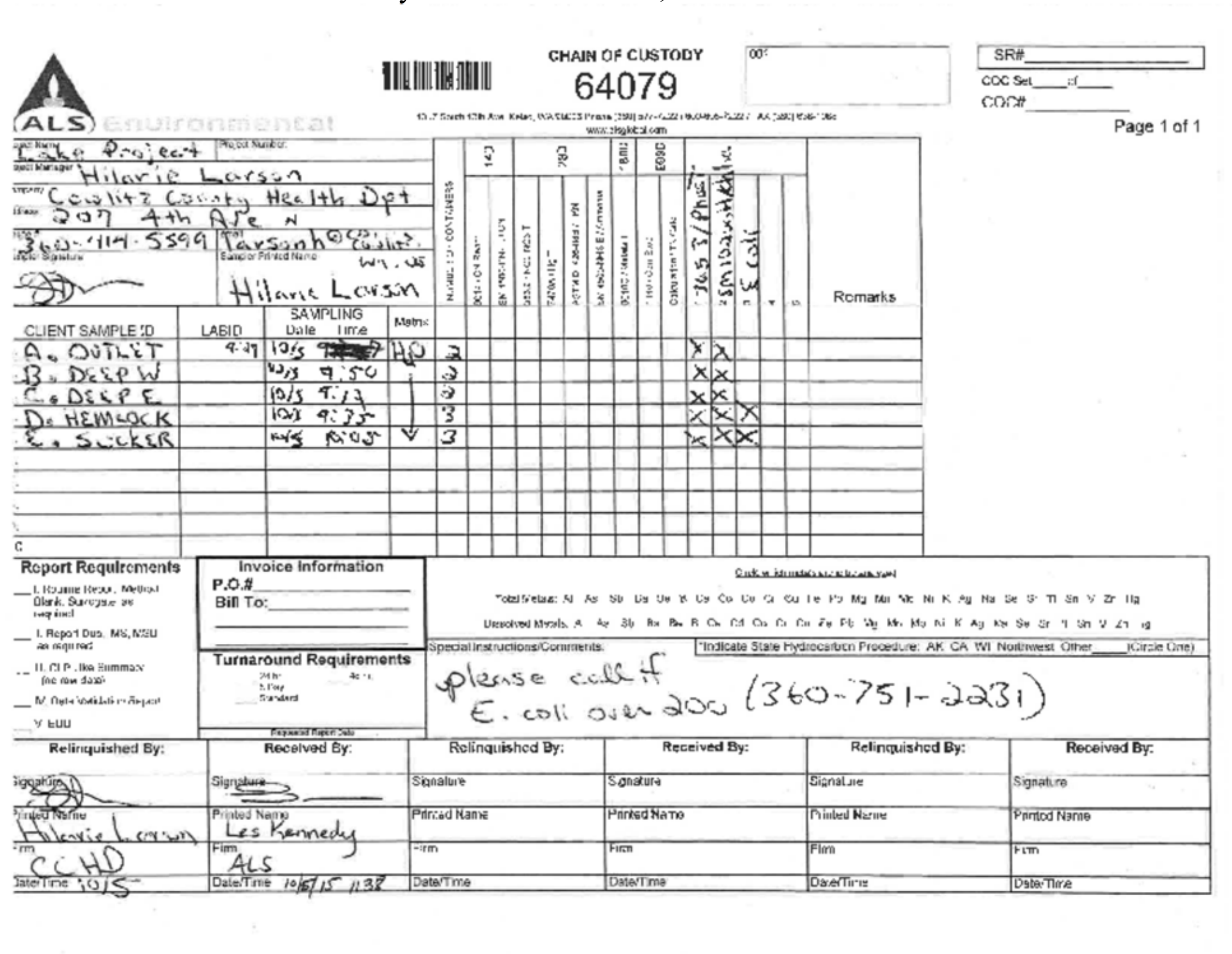
N/A (Explanation: per QAPP template, this is necessary where sampling substances contain high levels of contaminants, bacterial contamination, or contain organic materials that stick to the sampling devices.)

8.5 Sample ID

Standard sample ID protocol for ALS Global laboratory will be followed, according to chain of custody report.

8.6 Chain-of-custody, if required

Standard ALS Chain of Custody forms will be used, such as shown below:



ALS Environmental

CHAIN OF CUSTODY 64079

SR#

COC Set ___ of ___

COC#

Page 1 of 1

Project Name: Lake Project

Project Manager: Hilarie Larson

Company: Cowlitz County Health Dept

Address: 207 4th Ave N

Phone: 360-414-5599 Email: larsonh@co.cowlitz.wa.us

Sampler Printed Name: Hilarie Larson

CLIENT SAMPLE ID	LAB ID	SAMPLING Date	SAMPLING Time	Matrix	NUMBER OF CONTAINERS
A. OUTLET		10/5		H2O	3
B. DEEP W		10/5	9:50		3
C. DEEP E		10/5	9:13		3
D. HEMLOCK		10/5	9:35		3
E. SUCKER		10/5	10:05		3

Remarks

Report Requirements

Invoice Information

P.O.#

Bill To:

Turnaround Requirements

Special Instructions/Comments:

please call if E. coli over 200 (360-751-2231)

Relinquished By:	Received By:	Relinquished By:	Received By:	Relinquished By:	Received By:
Signature	Signature	Signature	Signature	Signature	Signature
Printed Name: Hilarie Larson	Printed Name: Les Kennedy	Printed Name	Printed Name	Printed Name	Printed Name
Firm: CCHD	Firm: ALS	Firm	Firm	Firm	Firm
Date/Time: 10/5	Date/Time: 10/5/15 1138	Date/Time	Date/Time	Date/Time	Date/Time

8.7 Field log requirements

Field logs will be printed on waterproof paper, numbered, and bound in a notebook. Permanent, waterproof ink will be used for all entries. Corrections will be made with single line strikethroughs, initials and date of correction. White-out or correction fluid will not be used. Staff will utilize both a Log Sheet for Field – In Situ Testing, and a Check Off Sheet for Horseshoe Lake Lab Samples. See below.

Table 8.7 (A)

Log Sheet for Horseshoe Lake Field – In Situ Testing Names: Date:							
	Time	Secchi Depth	Air Temp	Surface Probe √	3' Probe √	3' Probe √	Notes
(1) Inlet							
(2) Swim Beach							
(3) Midpoint							
(4) South Arm							
(5) Alternative to (4) if necessary							Give GPS Coordinates if (5) Alternative sampling location is used due to inaccessibility of site (4). Also approximate boat lengths away. Latitude: Longitude:
Comments (weather, QA samples, QAPP deviations, etc):							

Table 8.7 (B)

Check Off Sheet for Horseshoe Lake Lab Samples

Date:

Start Time:

Staff:

#	Location	Time	Total Phos	Nitrate-Nitrite	Chlor a (fill to neck)	Turbidity Checks?	Field Duplicate / Blanks,		
1	Inlet								
2	Swim Beach								
3	Midpoint								
4	South Arm								

Note: Two Turbidity Lab Tests are to be performed every quarter.

Describe Field Duplicates or Field Blanks that are to be collected today, if any:

Comments (weather, QA samples, QAPP deviations, etc)

8.8 Other activities

HSLMC field volunteers and staff have been involved with sampling for several years now. Jody Bartkowski Herz is an engineering technician with the City of Woodland, and has been responsible for sampling. The CCHD project lead will hold an initial briefing to go over new QAPP approved sampling methods with all field personnel, emphasizing identifiable differences between past sampling techniques and QAPP approved techniques. The project lead will provide on-going supervision of sampling activities, as it is anticipated that the project lead will be present in order to administer the probe testing. Minimally, field staff will receive an informal audit on a quarterly basis by the project lead as they conduct their sampling activities.

Maintenance for field instrumentation will be conducted according to manufacturer's recommendations and specifications. The YSI representative conducted a hands on training for the County, and demonstrated proper calibration procedures. The ProDSS Quick Start Guide and Owner's Manual will be closely adhered to throughout the study.

9.0 Measurement Methods

9.1 Field procedures table/field analysis table

Table 9.1

Measurement Methods Table		
Field Analysis Table		
Analyte	**Matrix**	**Sample Number**
Secchi Depth	Water	128
Temperature	Air	128
Temperature 1'	water	128
Temperature 3'	Water	128
pH	Water	128
Dissolved Oxygen	Water	128
Turbidity	Water	128
Lab Procedures Table		
Analyte	**Matrix**	**Sample Number**
Total Phosphorus	Water	128
Total nitrate-nitrite	Water	96
Chlorophyll *a*	Water	128

9.2 Lab Procedures Table. This includes:

Field and Lab procedure tables are combined per template suggestion.
Please see Table 9.1 above.

9.2.1 Analyte

Please see Table 9.1 above.

9.2.2 Matrix

Please see Table 9.1 above.

9.2.3 Number of samples

Please see Table 9.1 above.

9.2.4 Expected range of results

Based on the most recent testing conducted by HSLMC, total phosphorus is expected to range from ND to 220 µg/L (Bartowski 2015).

When Entranco conducted testing in 1998, average results of chlorophyll *a* may were 14 to 15 µg/L (Entranco Inc and Gibbs & Olson Inc 1999).

Secchi depth was tested by both Entranco and HSLMC; expected range per recent HSLMC is 4 feet to 11 feet, or 1.2 to 3.4 meters (Bartowski, 2015), and Entranco's averages were 1.2 meters (3.9 feet) before alum treatment and 2.1 meters (6.9 feet) after treatment (Entranco Inc and Gibbs & Olson Inc 1998).

9.2.5 Analytical method

See Chart Below at 9.2.6.

9.2.6 Sensitivity/Method Detection Limit (MDL)

Table 9.2.6

ALS Lab Measurement Methods							
Analyte	Method	MDL	MRL	Units	Accuracy LCS %Rec	Matrix Spike %Rec	Precision % RPD
Phosphorus, Total	EPA 365.3	0.004	0.01	mg/L	85-115	70-130	20
Total nitrite-nitrate	EPA 353.2	0.02	0.05	mg/L	90-110	90-110	20
Chlorophyll-*a*	SM10200 H	0.3	0.8	mg/m3	88-113	NA	20

9.3 Sample preparation method(s)

All preparation and methods used are standard, as listed.

9.4 Special method requirements

N/A

9.5 Lab(s) accredited for method(s)

CCHD has inspected and has on file the paper work for ALS Global Laboratory, and has confirmed that the labs are Ecology accredited for each specific method.

10.0 Quality Control (QC) Procedures

10.1 Table of field and lab QC required

Table 10.1

Field and Lab QC						
Parameter	Field		Laboratory			
	Blanks	Field Replicates	Check Standards	Method Blanks	Analytical Duplicates	Matrix Spikes
Temp	Quarterly	Each event	NA	NA	NA	NA
pH	Quarterly	Each event	NA	NA	NA	NA
Dissolved O2	Quarterly	Each event	NA	NA	NA	NA
Turbidity	Quarterly	Each event	NA	NA	NA	NA
Total Phosphorus	Annually	Quarterly	1 per Batch or 1 per 20 samples	1 per Batch or 1 per 20 samples	1 per Batch or 1 per 20 samples	1 per Batch or 1 per 20 samples
Total nitrite-nitrate	Annually	Quarterly	1 per Batch or 1 per 20 samples	1 per Batch or 1 per 20 samples	1 per Batch or 1 per 20 samples	1 per Batch or 1 per 20 samples
Chlorophyll *a*	Annually	Quarterly	1 per Batch or 1 per 20 samples	1 per Batch or 1 per 20 samples	Per client request	NA

For tests conducted with ALS Laboratories including total phosphorus, nitrite-nitrate, chlorophyll *a*, a co-located sample will be collected once every three months (at the same time as field audits) to estimate overall variability due to sampling and analysis. The site chosen for the co-located (duplicate) sample will be chosen at random and documented by the project lead. The duplicate sample will be taken sequentially (taken at the same location and depth as the original sample) and will include all parameters scheduled for collection at that point**.**

The results from an original sample and its duplicate (sequentially collected) sample are used to calculate the expected variance that is due to short-term environmental factors, field collection and processing, and laboratory analysis.

Contamination will be assessed by the submission of field blanks. Once a year, fresh distilled water will be submitted rather than the co-located (duplicate) sample. These will be "transport" blanks for constituents where there is no field processing of the sample (e.g. nutrients), and "rinsate blanks" for filtered constituents. Blank results are expected to be below reporting limits.

Laboratory QC will follow each lab's internal procedures.

Profile data will be collected using Ysi ProDSS datasonde, calibrated and used according to manufacturer's instructions (https://www.ysi.com/ProDSS). To verify accurate calibration, lab samples for turbidity will be taken at two in situ locations during the first sampling event and thereafter on a quarterly basis. Field duplicates will be taken upon every sampling event.

10.2 Corrective action processes

If analytical results fall outside of the quality control acceptance criteria, and the analytical method does not state the consequence, then the results will be flagged as such and the project lead will assess the best course of action. Each situation will be appropriately documented.

11.0 Data Management Procedures

11.1 Data recording/reporting requirements

The laboratory verifies its measurement results. In addition, the following procedures will be followed and are the responsibility of the project lead:

- Standard lab and field QC procedures will be adhered to.
- The data will be checked for data entry errors and completeness.
- Results will be checked for reasonableness.
- Lab and Field QC results will be evaluated to ensure that the measurement quality objectives (MQOs) were met. Data failing to meet MQOs will be either coded or discarded.

11.2 Lab data package requirements

Standard with Excel and text formats.

11.3 Electronic transfer requirements

Data will be imported onto the project's comprehensive excel spreadsheet to limit reentry issues and facilitate the analysis of the data**.**

11.4 Acceptance criteria for existing data

N/A

11.5 EIM/STORET data upload procedures

Annually, at the end of each full year of sampling, all data will be input into Ecology's EIM.

12.0 Audits and Reports

12.1 Number, frequency, type, and schedule of audits

The project lead will perform a technical systems audit (a qualitative audit of conformance to the QA Project Plan) within the first three months of the commencement of work. A brief report will be generated discussing the relevant sections of the QAPP, any necessary corrective actions, and included in the progress and final report.

12.2 Responsible personnel

All reports will be the responsibility of the project lead.

12.3 Frequency and distribution of report

CCHD will submit progress reports to Ecology quarterly as described in the grant's scope of work. In addition, the project lead will email Ecology with a brief description of the technical systems audit results.

12.4 Responsibility for reports

The CCHD project lead will write the final report.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

The following procedures will be followed and are the responsibility of the project lead:

- Standard field QC procedures will be adhered to.
- The data will be checked for data entry errors and completeness by the project lead.
- Results will be checked for reasonableness by the project lead.
- Field QC results will be evaluated to ensure that the measurement quality objectives (MQOs) were met. Data failing to meet MQOs will be either coded as estimates or discarded.
- In this study, data is generated by the lab, the volunteers, and in the case of probe generated data, the project lead. The project lead will perform the data verification.

13.2 Lab data verification

Lab data verification will be according to internal QC procedures.

13.3 Validation requirements, if necessary

N/A

14.0 Data Quality (Usability) Assessment

14.1 Process for determining whether project objectives have been met

QA assessments for precision will be made by comparing calculated standard deviation of split sample pairs to the larger of the percent relative standard deviation times the mean of the sample pair or the maximum standard deviation tabulated in the MQOs (Tables 6.2.A and 6.2 B).

Data will be compiled, and computation of the results' mean, variance and standard deviation will occur. Results will be presented graphically and in such a way that significant trends are easily identified. Carlson's Trophic State Index (Carlson 1977) will also be calculated using Secchi depth, phosphorus, and chlorophyll *a*, independently.

14.2 Data analysis and presentation methods

Results of this study will be compared to those of the HSLMC sampling.

All results will be graphed, and further statistical analysis will include mean, variance, and standard deviation.

QA assessments for precision will be made by comparing calcualted standard deviations of split sample pairs to the larger of the percent relative standard deviation multiplied by the mean of the sample pair or the maximum standard deviation tabulated in the MQOs (Table 3). Standard deviation for paired samples may be calculated according to Equation 1:

$$s = \sqrt{(r_1 - r_2)^2 / 2}$$

where “s” is the standard deviation and “r_1” and “r_2” are paired results.

Where results are to be combined then QC pairs may be pooled using Equation 2:

$$s_p = \sqrt{\sum (r_1 - r_2)^2 / 2m}$$

where “s_p” is the pooled standard deviation and m is the number of pairs. The value “s_p” may then be compared to the MQOs in Table X.

14.3 Treatment of non-detects

As referred to in EPA web archive:
http://archive.epa.gov/region02/water/dredge/web/html/nondetect.html
Region 2 Water Non-Detect Policy of elutriate data, non-detects will be treated in accordance with the below described method:

i) If a concentration of a specific contaminant in an elutriate sample is reported as "non-detect" and the method detection limit *was not* achieved, then the reported detection limit should be used as an estimate of the (maximum possible) concentration of the contaminant in the sample.

ii) If a concentration of a specific contaminant in an elutriate sample is reported as "non-detect" and the detection limit achieved *was at or below* the method detection limit, then half the achieved detection limit should be used as an estimate of the concentration of the contaminant in the sample.

14.4 Sampling design evaluation

Evaluation of the south sampling site will be appropriate, including quality of data due to depth, and absence of data due to inaccessibility.

14.5 Documentation of assessment

All documentation of assessment will be presented in the final report

15.0 References

Bartowski Herz J. 2015 Aug. Testing results. Horseshoe Lake Management Committee. Woodland WA.

Carlson RE. 1977. A trophic state index for lakes. Limnology and Oceanography. 22:361-369.

Carlson RE, Simpson J. 1996. A coordinator's guide to volunteer lake monitoring methods. North American Lake Management Society. 96pp.

Entranco Inc, Gibbs & Olson Inc. 1998. Horseshoe Lake phase II restoration project. Report on the application of aluminum sulfate/sodium aluminate for internal phosphorus control.

Entranco Inc, Gibbs & Olson Inc. 1999. Final report Horseshoe Lake restoration project.

EPA. 1997. Non-Detect Policy. web archive: http://archive.epa.gov/region02/water/dredge/web/html/nondetect.html

Horseshoe Lake Management Committee. 2000. Information and proposals regarding issues of safety, levels of lake and erosion.

North American Lake Management Society. ©2015. A trophic state index. http://www.secchidipin.org/index.php/monitoring-methods/trophic-state-equations/

Somers SG. 1989. Horseshoe Lake water quality report 1988-1989. Cowlitz Conservation District

Washington Administrative Code (WAC) 173-201A-230 Establishing lake nutrient criteria.

Welch EB, Whiley AJ, Spyridakis DE. 1992. Horseshoe Lake quality, nutrient loading and management. University of Washington Department of Civil Engineering, Environmental Engineering and Science.

16.0 Figures

Figure 1: Map Horseshoe Lake by Entranco (1999):

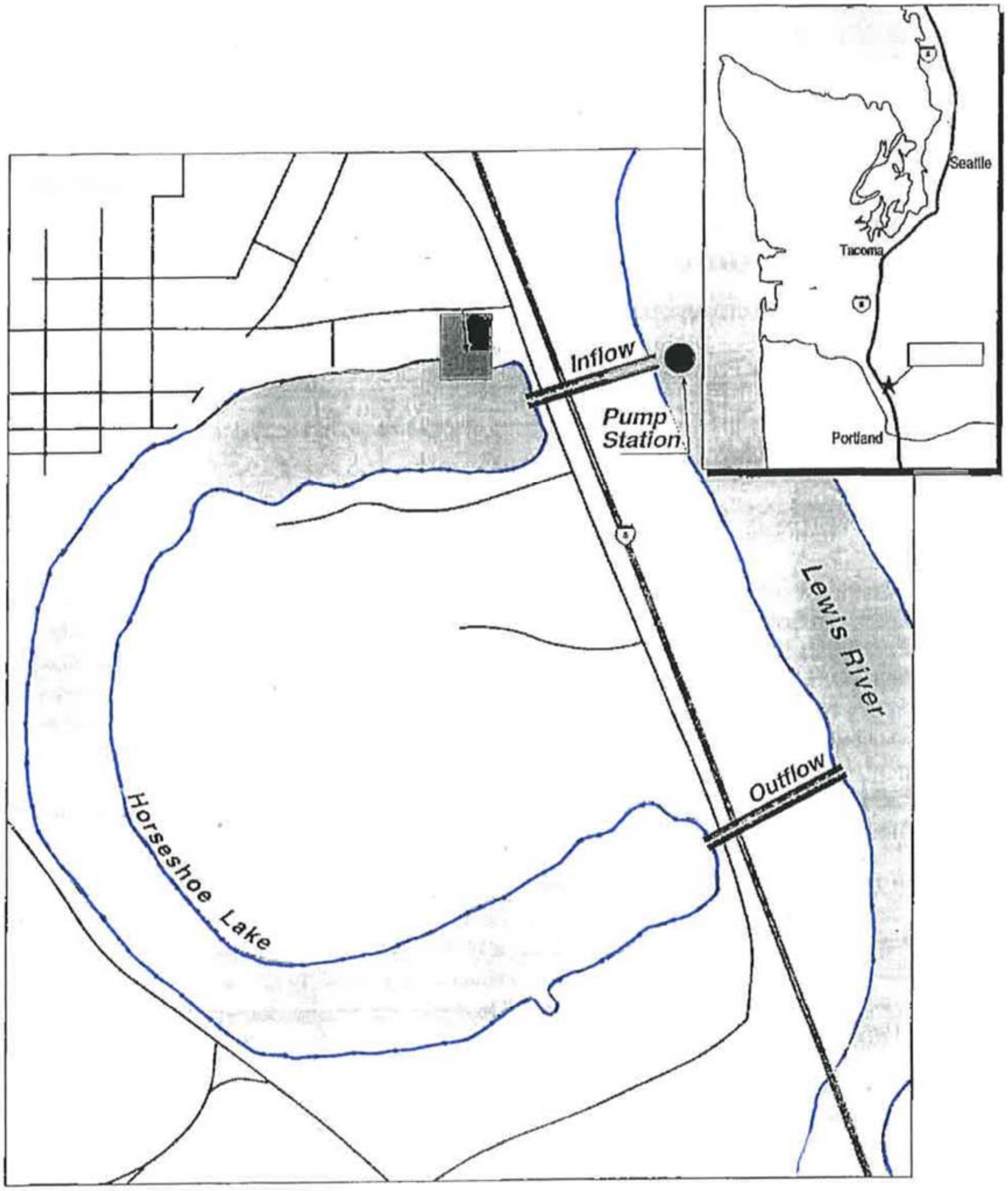
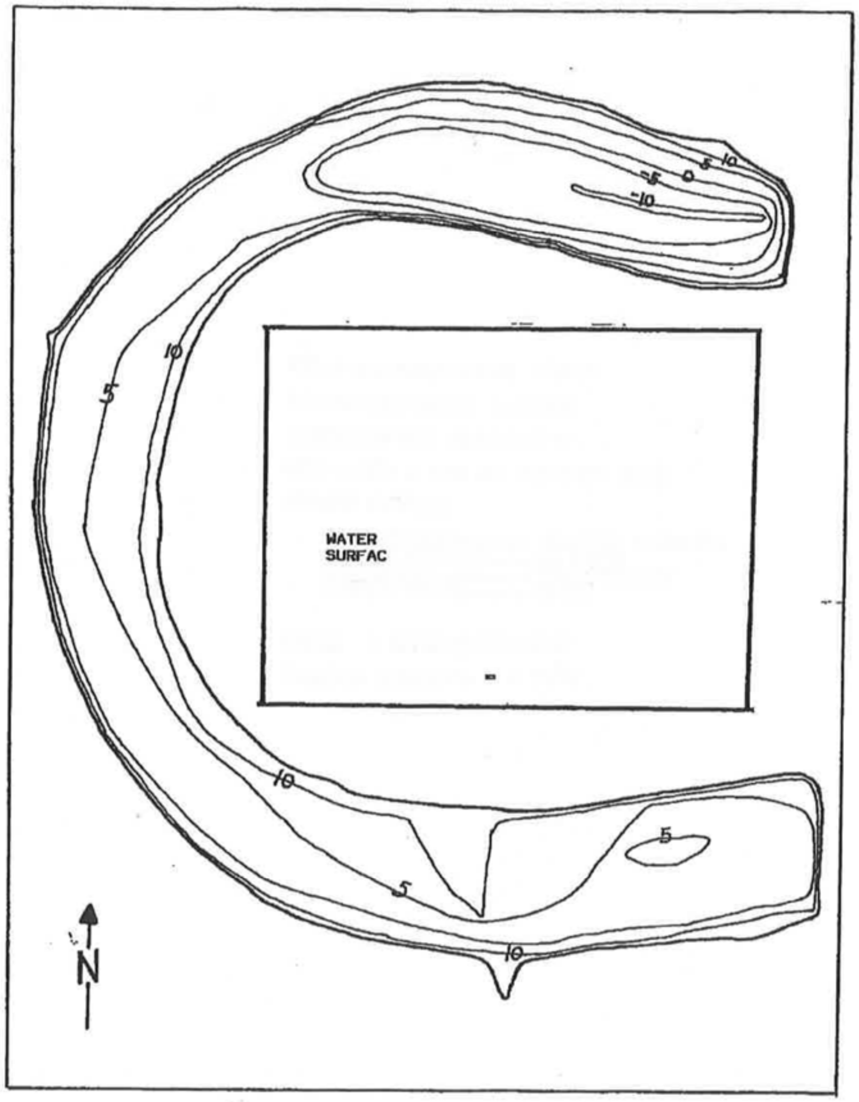

Inflow
Pump Station
Outflow
Lewis River
Horseshoe Lake
Seattle
Tacoma
Portland

Figure 2: Horseshoe Lake Depth (Horseshoe Lake Water Quality Study 1988-1989 by Cowlitz Conservation District):



17.0 Tables

Tables are located in the relevant sections above.

3.1.4 (A)	Horseshoe Lake Water Quality Treatment Results
3.1.4 (B)	HSLMC Phosphorus Test Results (µg/L)
5.1	Key Individuals
5.4	Project Schedule
5.6 (A)	Total Project Budget for Both Lakes
5.6 (B)	Project Budget for Task 1 Specific Activities for Both Lakes
5.6 (C)	Project Budget for Task 2 Specific Activities for Both Lakes
5.6 (D)	Laboratory Budget for Horseshoe Lake
6.2 (A)	MQOs – Precision & Bias in Field Constituents
6.2 (B)	MQOs – ALS Global Lab Constituents
6.2.1.3	MQOs – Sensitivity
7.1.1	Horseshoe Lake Sample and Test Schedule (per Calendar Year) by Site #
7.1.3	Horseshoe Lake Sampling Plan
8.2	Sample Volume, Container, Preservation, Storage, & Holding Time Requirements
8.7	Horseshoe Lake Field Log
9.1	Measurement Methods Table
9.2.6	ALS Lab Measurement Methods
10.1	Field and Lab QC

Measurement Quality Objectives are included in Tables 6.2 (A) and 6.2 (B)
Sample Containers, Preservation and Holding Times are found in Table 8.2.
Measurement Methods (Laboratory) are included in 9.2.6 ALS Lab Measurement Methods.
QC Samples, Types, and Frequency are included in Table 10.1. Field and Lab QC.

18.0 Appendices

Appendix A. Pictures of Horseshoe Lake

Please see separate attachment

Appendix B. Horseshoe Lake SOP

Please see separate attachment.

Appendix C. Glossary, Acronyms, and Abbreviations

Quality Assurance Glossary

Accreditation - A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

Accuracy - the degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms precision and bias be used to convey the information associated with the term accuracy. (USGS, 1998)

Analyte - An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e. g. fecal coliform, Klebsiella, etc. (Kammin, 2010)

Bias - The difference between the population mean and the true value. Bias usually describes a systematic difference reproducible over time, and is characteristic of both the measurement system, and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI). (Kammin, 2010; Ecology, 2004)

Blank - A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process. (USGS, 1998)

Calibration - The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured. (Ecology, 2004)

Check standard - A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards, but should be referred to by their actual designator. (i. e. CRM, LCS, etc.) (Kammin, 2010; Ecology, 2004))

Comparability - The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator. (USEPA, 1997)

Completeness - The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator. (USEPA, 1997)
Continuing Calibration Verification Standard (CCV) - A QC sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run. (Kammin, 2010)

Data Integrity- A qualitative DQI that evaluates the extent to which a dataset contains data that is misrepresented, falsified, or deliberately misleading. (Kammin, 2010)

Data Quality Indicators (DQI) - Data Quality Indicators (DQIs) are commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity. (USEPA, 2006)

Data Quality Objectives (DQO) - Data Quality Objectives are qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. (USEPA, 2006)

Dataset - A grouping of samples organized by date, time, analyte, etc (Kammin, 2010)

Data validation - An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment, and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability and integrity, as these criteria relate to the usability of the dataset. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation
- Use of third-party assessors
- Dataset is complex
- Use of EPA Functional Guidelines or equivalent for review

Examples of data types commonly validated would be:

- Gas Chromatography (GC)
- Gas Chromatography-Mass Spectrometry (GC-MS)
- Inductively Coupled Plasma (ICP)

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier, data is usable for intended purposes
- J (or a J variant), data is estimated, may be usable, may be biased high or low
- REJ, data is rejected, cannot be used for intended purposes (Kammin, 2010; Ecology, 2004)

Data verification - Examination of a dataset for errors or omissions, and assessment of the Data Quality Indicators related to that dataset for compliance with acceptance criteria (MQO's). Verification is a detailed quality review of a dataset. (Ecology, 2004)

Detection limit (limit of detection) - The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero. (Ecology, 2004)

Duplicate samples - two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis. (USEPA, 1997)

Field blank - A blank used to obtain information on contamination introduced during sample collection, storage, and transport. (Ecology, 2004)

Laboratory Control Sample (LCS) - A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. (USEPA, 1997)

Matrix spike - A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects. (Ecology, 2004)

Measurement Quality Objectives (MQOs) - Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness. (USEPA, 2006)

Measurement result - A value obtained by performing the procedure described in a method. (Ecology, 2004)

Method - A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed. (EPA, 1997)

Method blank - A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples. (Ecology, 2004; Kammin, 2010)

Method Detection Limit (MDL) - This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984)

Percent Relative Standard Deviation (%RSD) - A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$\%RSD = (100 * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010)

Parameter - A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all "parameters" (Kammin, 2010; Ecology, 2004)

Population - The hypothetical set of all possible observations of the type being investigated. (Ecology, 2004)

Precision - The extent of random variability among replicate measurements of the same property; a data quality indicator. (USGS, 1998)

Quality Assurance (QA) - A set of activities designed to establish and document the reliability and usability of measurement data. (Kammin, 2010)

Quality Assurance Project Plan (QAPP) - A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives. (Kammin, 2010; Ecology, 2004)

Quality Control (QC) - The routine application of measurement and statistical procedures to assess the accuracy of measurement data. (Ecology, 2004)

Relative Percent Difference (RPD) - RPD is commonly used to evaluate precision. The following formula is used:

$$[Abs(a-b)/((a + b)/2)] * 100$$

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples - two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled. (USGS, 1998)

Representativeness - The degree to which a sample reflects the population from which it is taken; a data quality indicator. (USGS, 1998)

Sample (field) – A portion of a population (environmental entity) that is measured and assumed to represent the entire population. (USGS, 1998)

Sample (statistical) – A finite part or subset of a statistical population. (USEPA, 1997)

Sensitivity - In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit. (Ecology, 2004)

Spiked blank - A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method. (USEPA, 1997)

Spiked sample - A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency. (USEPA 1997)

Split Sample – The term split sample denotes when a discrete sample is further subdivided into portions, usually duplicates. (Kammin 2010)

Standard Operating Procedure (SOP) – A document which describes in detail a reproducible and repeatable organized activity. (Kammin, 2010)

Surrogate – For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis. (Kammin 2010)

Systematic planning - A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning. (USEPA 2006)

Quality Assurance Glossary References (from Ecology QAPP template)

Ecology. 2004. Guidance for the preparation of quality assurance project plans for environmental studies. https://fortress.wa.gov/ecy/publications/summarypages/0403030.html

USEPA. 1997. Glossary of quality assurance terms and related acronyms. www.ecy.wa.gov/programs/eap/qa/docs/epa_quality_glossary.pdf

USEPA. 2006. Guidance on systematic planning using the data quality objectives process EPA QA/G-4. http://www.epa.gov/quality/qs-docs/g4-final.pdf

Kammin. 2010. Definition developed or extensively edited by William Kammin, 2010.

USGS. 1998. Principles and practices for quality assurance and quality control. Open-File Report 98-636. http://ma.water.usgs.gov/fhwa/products/ofr98-636.pdf

Glossary – General Terms

Ambient: Background or away from point sources of contamination.

Baseflow: The component of total streamflow that originates from direct groundwater discharges to a stream.

Char: Char (genus *Salvelinus*) are distinguished from trout and salmon by the absence of teeth in the roof of the mouth, presence of light colored spots on a dark background, absence of spots on the dorsal fin, small scales, and differences in the structure of their skeleton. (Trout and salmon have dark spots on a lighter background.)

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Eutrophic: Nutrient rich and high in productivity resulting from human activities such as fertilizer runoff and leaky septic systems.

Fecal coliform: That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10 to 10,000 fold over a given period. The calculation is performed by either: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities. This includes, but is not limited to, atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination is considered a nonpoint source. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act is a nonpoint source.

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

Parameter: A physical chemical or biological property whose values determine environmental characteristics or behavior.

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or is likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Riparian: Relating to the banks along a natural course of water.

Salmonid: Any fish that belong to the family *Salmonidae*. Any species of salmon, trout, or char is considered a salmonid. www.fws.gov/le/ImpExp/FactSheetSalmonids.htm

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standard, and are not expected to improve within the next two years.

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency

et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
QA	Quality assurance
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife

Units of Measurement

°C	degrees centigrade
cms	cubic meters per second, a unit of flow.
ft	feet
g	gram, a unit of mass
km	kilometer, a unit of length equal to 1,000 meters.
m	meter
mg	milligram
mg/L	milligrams per liter (parts per million)
mL	milliliters
mm	millimeter
NTU	nephelometric turbidity units
ug/L	micrograms per liter (parts per billion)
um	micrometer