QUALITY ASSURANCE PROJECT PLAN

BLACKMANS LAKE
CYANOBACTERIA MANAGEMENT PLAN

Prepared for
City of Snohomish

Prepared by
Herrera Environmental Consultants, Inc.

HERRERA

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INTRODUCTION

Blackmans Lake, originally named Stillaguamish Lake (meaning "People of the River" in the Lushootseed language), is a monomictic lake located in the City of Snohomish, in Snohomish County, Washington, which was renamed for the Blackman family who had operated a logging camp along the shore from 1875 to 1884 (Heirman 1980). The lake features two public parks owned by the City of Snohomish (Hill Park and Ferguson Park), a public boat launch, and several private docks allowing abundant access for recreation. Blackmans Lake supports a range of wildlife such as ducks, migratory geese, and deer, and the lake is popular for fishing for stocked rainbow trout and a variety of other warmwater fish species.

In 1992, the City of Snohomish ("the City") contracted with KCM, Inc. to initiate a Phase I monitoring and restoration study in response to concerns over declining lake conditions, including algae blooms, low dissolved oxygen, high fecal coliform bacteria, and impaired fisheries and habitat quality. Funded by a grant from the Washington Department of Ecology ("Ecology") and an in-kind contribution from a Blackmans Lake community group, this study resulted in an abundance of water quality, hydrological, and limnological data, and an evaluation of lake management alternatives, including watershed controls and an alum treatment (KCM 1994). This study kickstarted the monitoring effort which has continued regularly over the past 30 years. Today, the City is contracted with Snohomish County ("the County") Surface Water Management staff and is assisted by volunteers from the Friends of Blackmans Lake nonprofit group to conduct bimonthly water quality monitoring as part of Snohomish County's Lake Management Program.

Blackmans Lake water quality assessments reveal lake conditions commonly associated with cyanobacteria blooms (KCM 1994; Snohomish County 2021, 2022a). Blooms of cyanobacteria are frequently seen on the lake, along with detectable levels of toxins produced by cyanobacteria (Ecology 2022b). Toxins produced by these blooms can both inhibit recreational use of the lake and impact the supported wildlife. Based on observed increasing trends in nutrients and their relationship to cyanobacteria, toxic blooms may continue to increase unless actions are taken to reduce nutrient sources and change lake conditions.

Working with the public, the City, and the County, the Blackmans Lake Cyanobacteria Management Plan (CMP) will identify community concerns, develop priorities, outline goals and objectives, and will describe a lake management strategy to reduce the frequency and duration of toxigenic algae blooms and restore recreational use. The CMP will be used as a guideline and tool for allocating resources to implement the recommended management activities, with a framework and decision steps for future management needs. This project will collect scientific data to identify sources of phosphorus, understand causes of cyanobacteria blooms, and build on past management actions of Blackmans Lake to meet this project goal.

The primary goal of this QAPP is to define procedures that assure the quality and integrity of the collected samples, the representativeness of the results, the precision and accuracy of the analyses, the completeness of the data, and to ultimately produce a scientifically defensible product to support management and policy decisions. This QAPP will thus guide all study design, sample collection, field and laboratory analyses, data analyses, quality assurance, and reporting activities.

To ensure the same quality as other CMP QAPPs in the state, Herrera developed this document according to Ecology's *Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies* (Lombard and Kirchmer 2004), guidelines for lake management plans, and the *Freshwater Algae Grant Funding Guidelines, State Fiscal Year 2022* (Ecology 2022a). A QAPP will be reviewed and approved by the City of Snohomish prior to initiating the investigative water quality monitoring study. The QAPP includes the following sections:

- Background
- Project Objectives
- Organization and Schedule
- Study Design
- Measurement Quality Objectives
- Field Procedures
- Laboratory Procedures
- Quality Control Procedures
- Data Management and Storage
- Audits and Reports
- Data Analysis Plan
- Funding Plan
- Stakeholder Involvement Plan
- Blackmans Lake Cyanobacteria Management Plan
- References

BACKGROUND

Thorough and concise documentation of lake and watershed characteristics will be critical to the framework for the CMP and adaptive management decisions. Herrera has compiled and summarized existing lake and watershed information for Blackmans Lake from the following key sources to be included in the QAPP and the CMP:

- Watershed GIS data (City of Snohomish and Snohomish County)
- Lake water quality and lake level monitoring data and reports (Snohomish County since 1990)
- Precipitation monitoring data (Snohomish County)
- Phase I restoration study (KCM 1994)
- Cyanobacteria scum and toxin monitoring data (Ecology Toxic Algae Program)
- Stormwater monitoring data (City of Snohomish and Snohomish County)
- Fish stocking data (WDFW)
- Aquatic plant data (Snohomish County and Ecology).

WATERSHED AND HYDROLOGY

Blackmans Lake is located within the City of Snohomish in southwest Snohomish County, about 35 miles north of downtown Seattle (Figure 1). Its watershed is small, draining approximately 500 acres of the Puget Sound glacial lowlands. In the early 1970's, about 70 percent of the watershed was agricultural with just 8 percent residential land (Snohomish County 2003), but today the watershed is approximately 50% developed, zoned mostly for single-family residential use with some business parks and little medium/high density residential or commercial uses (Snohomish County 2022b; COS 2022). Much of the watershed is within City limits, but a sizeable portion lies in unincorporated Snohomish County.

The watershed map is presented in Figure 2, which was delineated by Snohomish County Surface Water Management staff in June 2022. The watershed includes a wetland area to the north of the lake including a stormwater detention pond, which flows into Blackmans Lake Creek, the lake's sole inlet stream. The area contributing to this detention pond was estimated in 2013 to be about 20 percent single family land use, while 80 percent was assumed to be forest (COS 2013). Another small perennial inlet stream (called Grass Bottom Creek in KCM 1994) feeds into the northeast corner of the lake via Champagne Lane. The stream located here is fed by the area to the east and south of the lake and was estimated to be comprised of 80 percent single family land use and 20 percent park (COS 2013). Surface water runoff drains to the lake via approximately four stormwater outfalls located along the north and east lake shorelines (Figure 3).

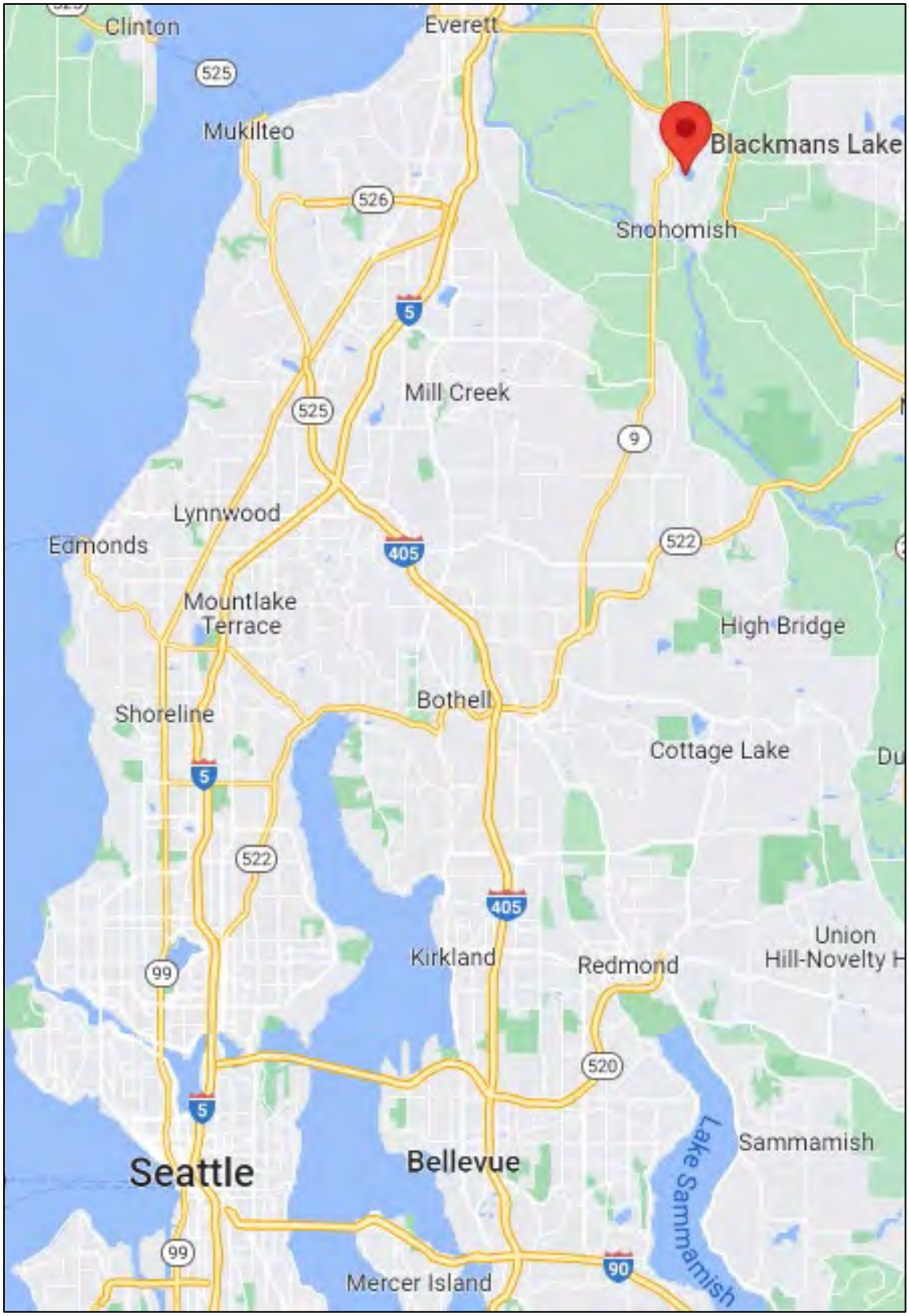


Figure 1. Blackmans Lake Vicinity Map

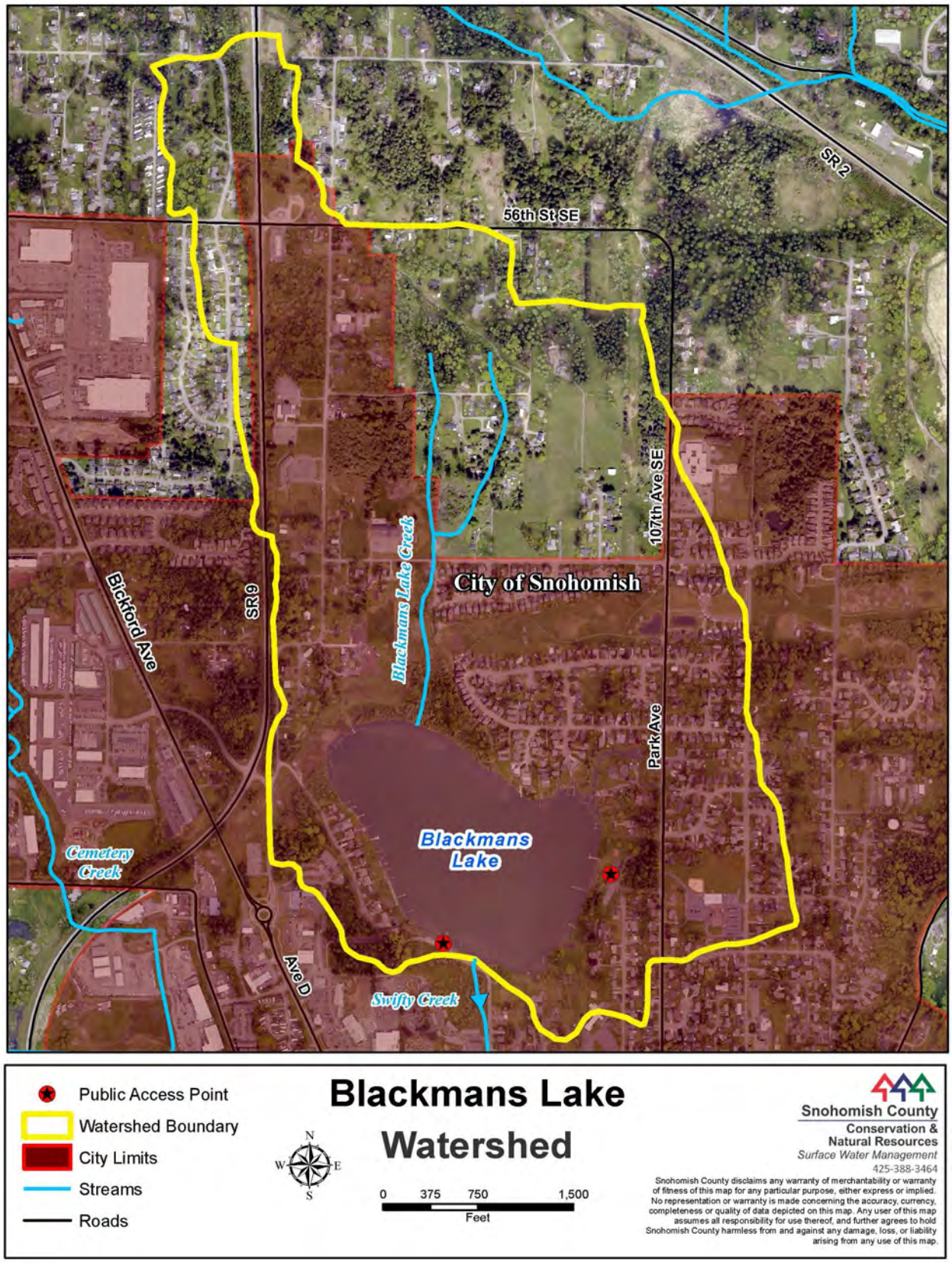


Figure 2. Blackmans Lake Watershed.

Underground springs feed the lake and adjacent wetlands via shallow perched aquifers, contained in the ground by impermeable glacial till units to the west of the lake and in the adjacent wetlands (KCM 1994). Seepage through these till units is likely slow and the lack of data prevents precise quantification of groundwater inflow through the bottom of the lake; however, a paired wellpoint analysis conducted in the winter and spring of water year 1994 from wells at the lake inlet, outlet, and the northwestern corner provided a rough estimation of groundwater inflow to and outflow from Blackmans Lake, ranging from 0.5 to 5 cubic meters per day (inflow and outflow rates were assumed equal), with little to no flow expected during the summer and fall months (KCM 1994). Additionally, the direction of water flow between the lake and wetlands changes seasonally but, generally, water flows from north to south through the lake to the outlet. The lake's outlet was historically a wetland and is today comprised of four 24-inch PVC culverts with fish screens. Water discharges from these culverts into Swifty Creek, which contains an earthen berm just downstream of the lake outlet to maintain lake levels and reduce winter flooding (Snohomish County 2021). Swifty Creek then flows south through the City of Snohomish to the Snohomish River and ultimately drains into the Puget Sound.

KCM (1994) estimated that the major inputs of water to Blackmans Lake were the two named creeks, followed by stormwater (Table 1). Water losses were greatest from the outlet into Swifty Creek (70 percent), followed by wetland recharging (21 percent) and evaporation (8 percent) (KCM 1994). Due to two major hydrologic changes (described below), it will be necessary to update this water budget.

Table 1. Blackman Lake Water Budget (May 1992 to April 1993) (KCM 1994).

Inflows	Volume (m^3)	Percent of Total	Outflows	Volume (m^3)	Percent of Total
Inlets (Grass Bottom and Blackmans creeks and unnamed intermittent western inlet)	594,200	37	Outlet (Swifty Creek)	1,120,700	70
Stormwater	451,100	28	Groundwater	900	0
Precipitation	219,300	14	Evaporation	125,300	8
Groundwater	900	0	Wetlands	336,800	21
Wetlands	335,100	21			
Total	**1,600,600**	**100**	**Total**	**1,583,700**	**100**
Change in Lake Storage	16,900	net gain			

Stormwater, water, and sewer drainage infrastructure data are shown in Figure 3.

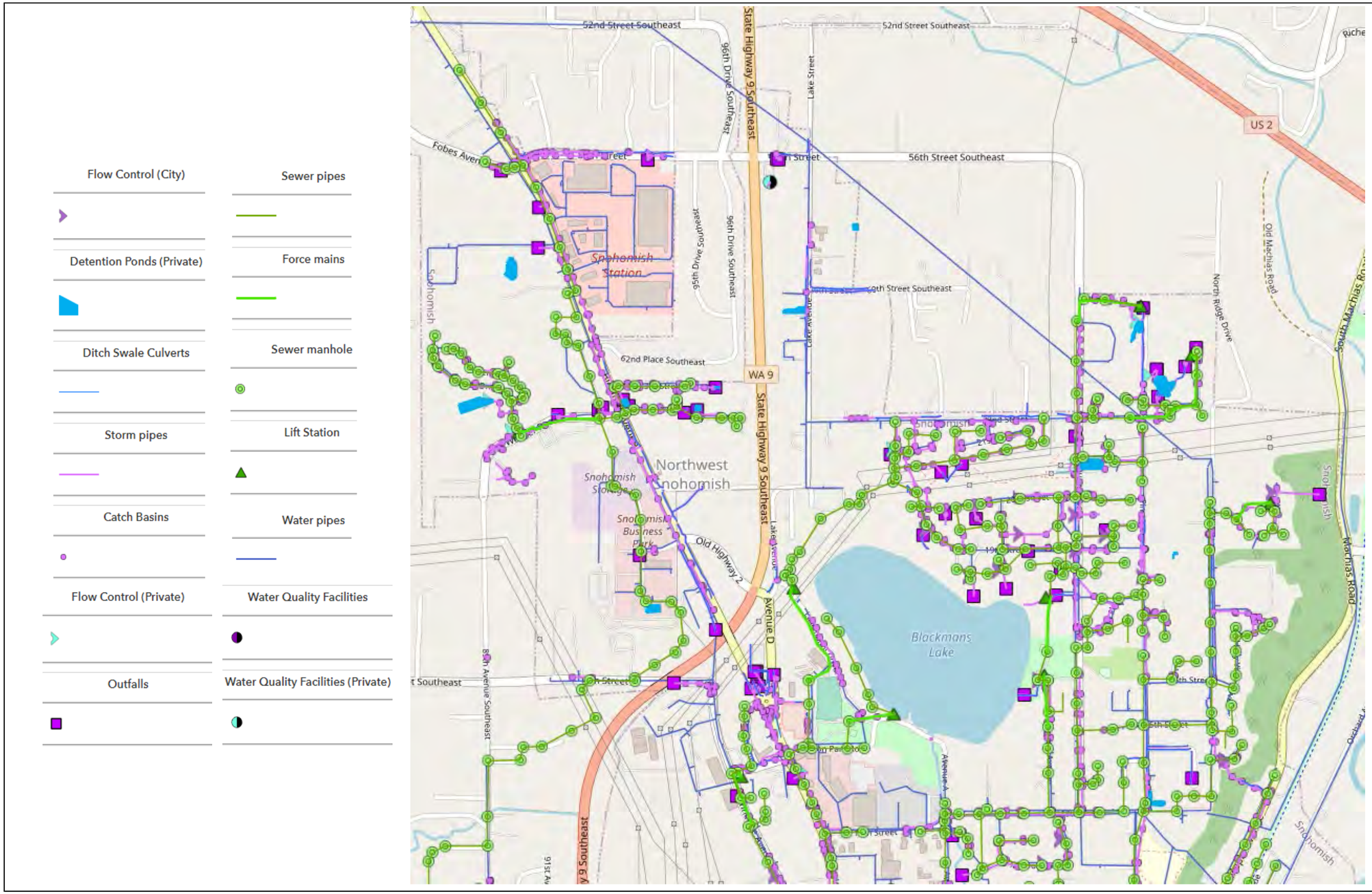


Figure 3. Blackmans Lake Watershed Sewer and Stormwater Infrastructure (COS 2022).

Since the water budget was completed in 1994, there have been two major changes to the hydrology of Blackmans Lake: (1) a retention pond was installed in the former flow path of Grass Bottom Creek in the powerline right-of-way; and (2) the lake outlet was modified to prevent flooding. Additionally, a 12-inch stormwater pipe in the Grass Bottom Creek flow path at the downstream of 19th Street and Park Ave was replaced with a 24-inch pipe to prevent backwatering through the surface catch basin (COS 2013). The lake outlet at Ferguson Park had experienced flooding due to silt accumulation and vegetation growth in the outlet channel, which resulted in high lake levels during storm events. Tetra Tech provided an analysis of the proposed improvements, including channel improvements, culvert replacement, sediment removal, and the installation of a weir north of the intersection at Avenue A and 13th Street (Snohomish County 2013); these improvements were implemented in 2016.

Sanitary wastewater in the watershed is in part delivered to and treated via City sewer connections, particularly from parcels along the east side of the lake, but many parcels use on-site sewage/ septic systems (OSS), along with parcels in unsewered areas north of the lake (KCM 1994).

LAKE CHARACTERISTICS AND USES

Blackmans Lake is 62.9 acres (0.25 km^2) in size with an average depth of 14 feet (4.3 m) and a maximum depth of 29 feet (8.8 m) at the central lake monitoring station (Figure 4) (Snohomish County 2021). Most of the shallow portion of the lake is on its north side.

Snohomish County Surface Water Management installed a continuous recording lake level gage at Hill Park at Blackmans Lake (station number "Bl") in June 2014 (Snohomish County 2021). Figure 5 presents daily average lake levels (surface elevation in NAVD88) from July 2014 to October 2022 along with daily total precipitation amounts recorded at the Snohomish County Native Plant Nursery (station number "Nu" located 6 miles north of Blackmans Lake). In recent years, lake levels reached a maximum of approximately 144.5 feet NAVD88 in the winter and spring and dropped during the summer to a low of 142.8 to 143.8 feet NAVD88 before the wet season begins in October (see Figure 5).

Much of the Blackmans Lake shoreline is occupied by year-round residential housing, with approximately 40 homes along the shoreline and approximately 30 with docks or other in-water structures. Waterfront vegetation on private property shoreline varies from a modified shoreline with bulkheads or fill, to a fully landscaped shoreline, and to a mix of native and weedy vegetation (COS 2017).

The City maintains two access points as public parks: (1) Ferguson Park features a boat ramp, a fishing dock, a basketball court, trails, disc golf course, a playground, and picnic facilities; and (2) Hill Park features picnic facilities and two American with Disability Act (ADA) accessible fishing docks. Boating is permissible on the lake for all vessels except those with gas-powered motors of any size and electric motors in excess of 1.75 horsepower , according to City of Snohomish Code Section 13.04.110.

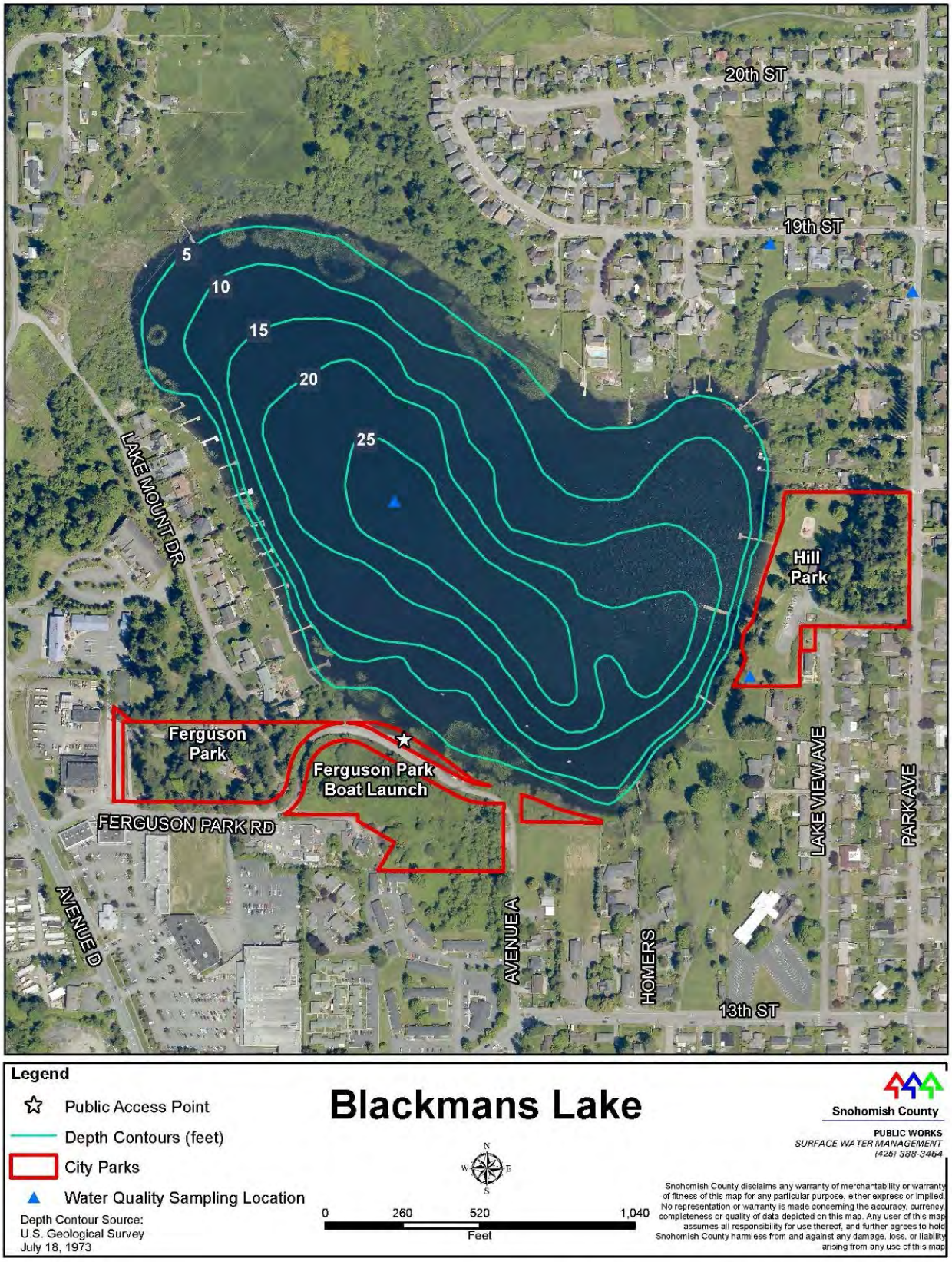


Figure 4. Blackmans Lake Bathymetric Map.

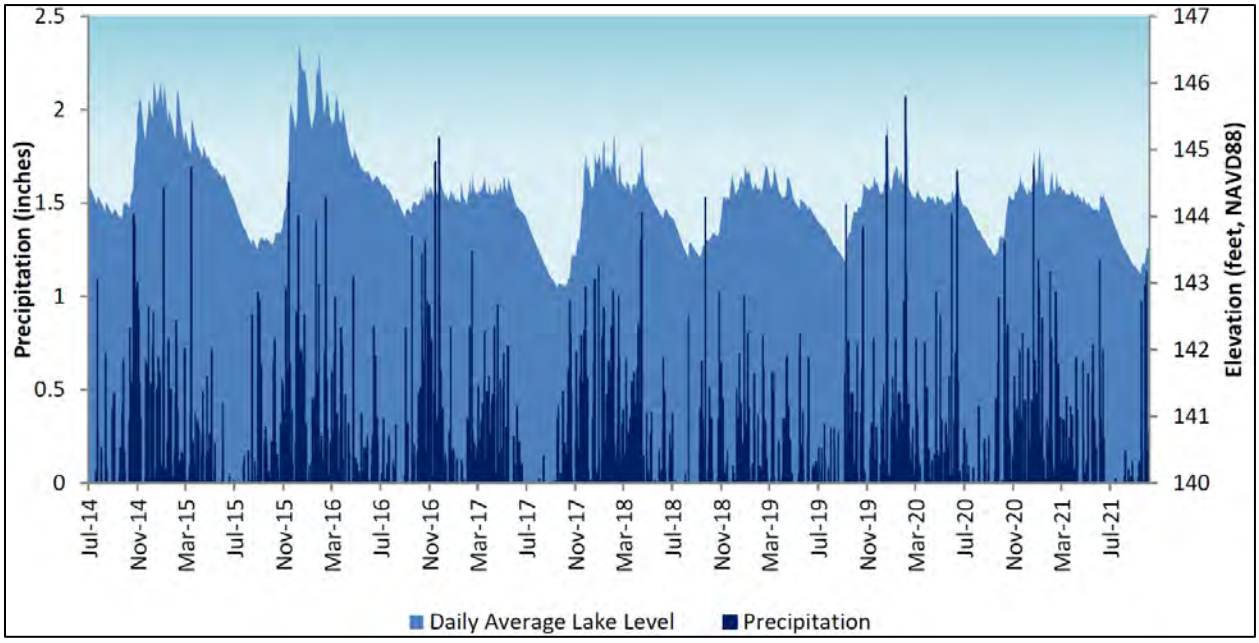


Figure 5. Daily Lake Level at Hill Park and Precipitation for Blackmans Lake.

LAKE WATER QUALITY

Water quality in Blackmans Lake has been monitored by volunteer data collectors and County Surface Water Management staff regularly since 1992 as part of the Snohomish County Lake Management Program to conduct monthly monitoring during the summers (May–October). The lake is listed as impaired (Category 5) due to fecal coliform bacteria pollution in Ecology's 2018 Water Quality Assessment due to elevated levels documented by KCM (1994). The lake was originally listed as Category 5 based on the 1998 assessment. Although these data are more than 10 years old, there are no recent data to justify removing the listing. Excess waterfowl continue to be a problem in the lake and may have been the primary source of high bacterial concentrations observed in 1994. The City recently monitored fecal coliform bacteria at six drainage sites from 2014 through 2020 for their National Pollutant Discharge Elimination System (NPDES) permit and the fecal coliform bacteria Total Maximum Daily Load (TMDL) for tributaries to the lower Snohomish River (Gray & Osborne 2021). Annual geometric mean concentrations of fecal coliform bacteria exceeded the criterion of 100 CFU/100 mL in the Washington State Surface Water Quality Standards (WAC 173-201A) each of the past 5 years at two of the six monitoring stations.

Temperature

Temperature of lake water varies by both season and depth. Lake surface water temperatures for the summers of 2001 through 2022 are presented in Figure 6. Summer water temperatures ranged from a low of 10 degrees Celsius (°C) in October to a maximum of 30°C in August. Thermal stratification occurs because warmer water is less dense than cool water and remains

on the surface. Due to the differences in temperature and density, distinct layers of water are created which do not easily mix. In Washington state, stratification typically occurs in deeper lakes where bottom waters can remain cool while high air temperatures during the summer warm the water surface. Stratification lasts until the surface waters cool in the fall and temperature differences decrease, allowing deep mixing of the water layers called lake turnover.

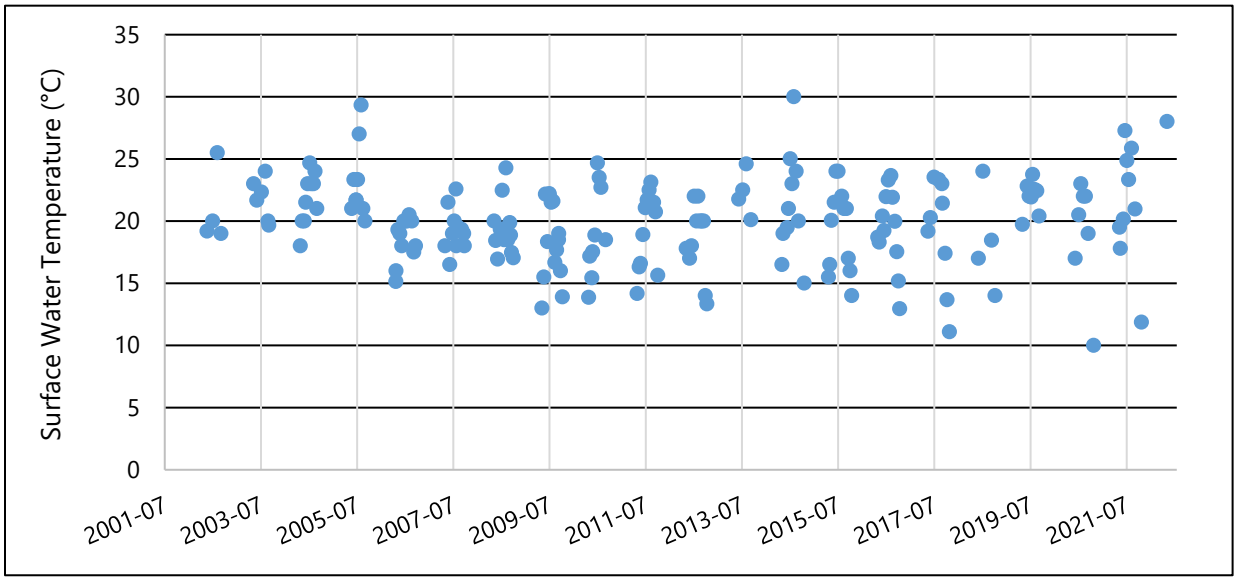


Figure 6. Blackmans Lake Summer Surface Water Temperatures (2001-2022).

Blackmans Lake forms a strong thermal stratification during the summers, beginning around April and lasting until September. By October, the lake turns over and remains vertically well-mixed through the winter until spring. This thermal stratification is presented for 2021 in Figure 7, where each vertical line represents a temperature profile of the water column during each monthly sampling event. At peak stratification in August, surface temperatures were approximately 24 degrees Fahrenheit (°F) (or 13°C) warmer than bottom waters.

Dissolved Oxygen

During stratification, dissolved oxygen in the bottom layer of water is very low (less than 2 milligrams per liter [mg/L]) (Figure 7). Surface levels range from 6 to 10 mg/L, likely in relationship to algal productivity (i.e., photosynthesis) and surface temperature. After lake turnover, seen in October for 2021 (Figure 7), oxygen levels are more consistent throughout the water column and higher at depth.

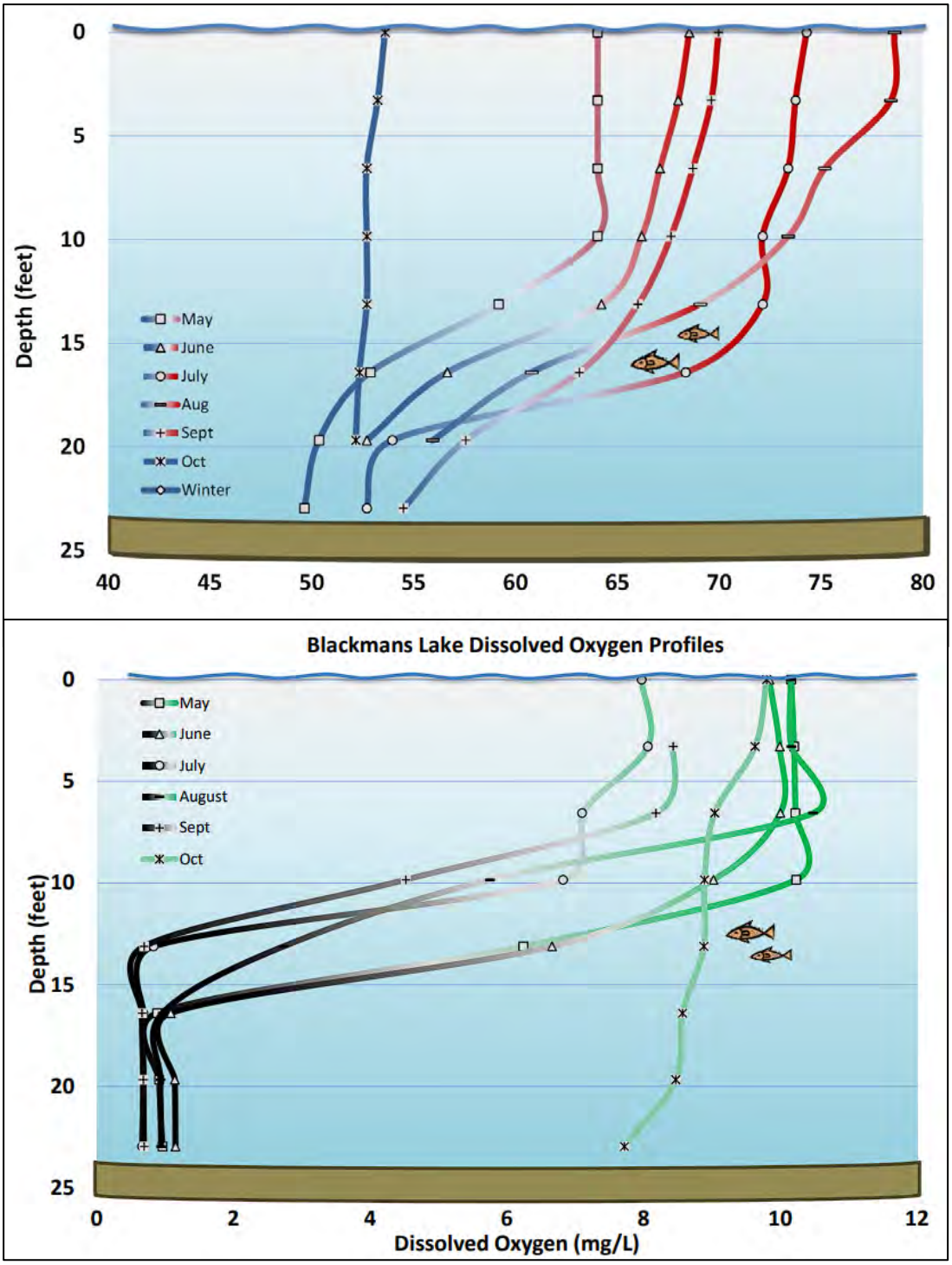


Figure 7. Blackmans Lake Temperature and Dissolved Oxygen (DO) Profiles (Snohomish County 2021).

Trophic State

The Trophic State Index (TSI) is a common index of a lake's biological productivity. TSI values are calculated from Secchi depth (a measure of water clarity), chlorophyll-a concentrations (a measure of algal biomass), and total phosphorus concentrations (the main nutrient that feeds algal growth). These three TSI estimates are all scaled between 0 and 100. Trophic state characteristics are shown in Table 2 for each of the three trophic state parameters.

Table 2. Lake Trophic State Classification System.

Trophic Class	Trophic State Index	Total Phosphorus (µg/L)	Chlorophyll *a* (µg/L)	Secchi Depth (meters)
Oligotrophic	< 40	< 12	< 2.6	> 4
Mesotrophic	40 to 50	12 to 24	2.6 to 7.2	2 to 4
Eutrophic	50 to 60	24 to 48	7.2 to 20.1	1 to 2
Hypereutrophic	> 70	> 96	> 56	< 0.5

Oligotrophic lakes (TSI <40) are very clear, with low nutrient concentrations and low algal growth. These are often mountain lakes or lakes in undisturbed forests. Eutrophic lakes (TSI >50) have cloudy water with high nutrient concentrations and high algal growth. These lakes can be naturally productive but are often highly altered lakes and may have frequent algal blooms. Mesotrophic lakes (TSI 40-50) are in the middle with fairly clear water and moderate nutrient concentrations and algal growth. Mesotrophic lakes are common in lowland western Washington, especially in areas with some development along the shoreline and in the watershed.

Blackmans Lake summer (May–October) TSI values are presented for total phosphorus (TP), chlorophyll-a (Chla), and Secchi depth in Figure 8 for 1973 to 2021, determined from the annual mean surface values reported in the 2021 Data Summary for Blackmans Lake (Snohomish County 2021). The Secchi and total phosphorus TSIs were typically in the mesotrophic range while the chlorophyll a TSI was often higher in the eutrophic range. Because chlorophyll-a is the primary parameter defining lake productivity, the trophic state of Blackmans Lake is classified as borderline mesotrophic/eutrophic. Despite some interannual variability, the 30-year trend in these water quality parameters indicates a slow decline in lake conditions and increase in trophic state.

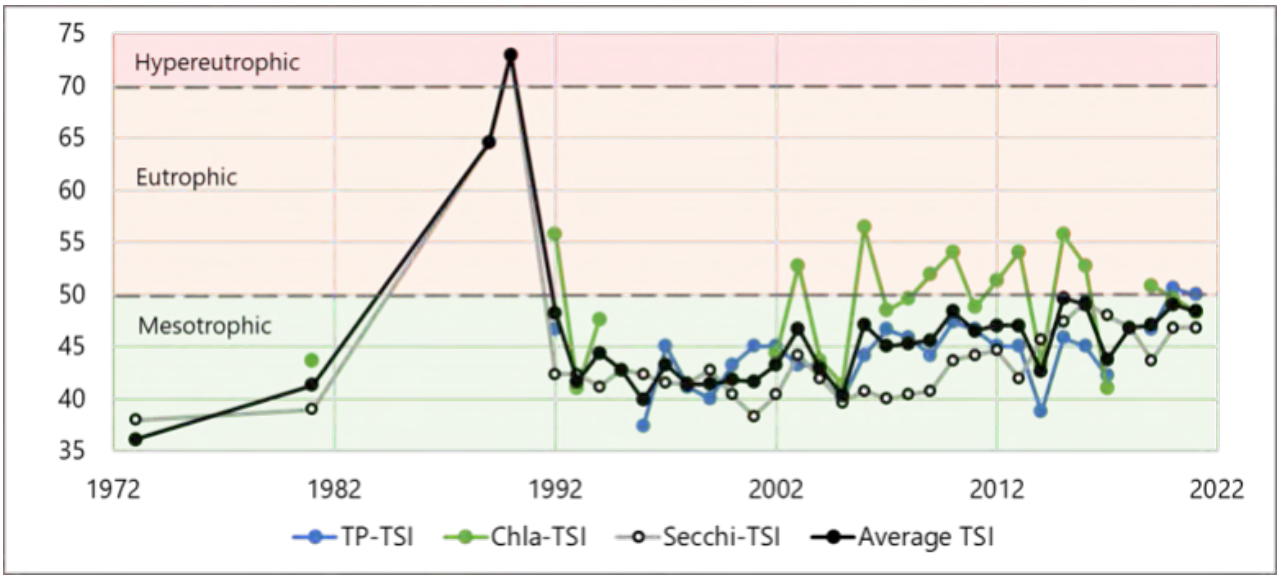


Figure 8. Blackmans Lake Trophic State Index (TSI).

Secchi Depth

Water clarity measured by Secchi depth, is presented for Blackmans Lake in Figure 9 for each monitoring date between June 2002 and July 2022. Secchi depths ranged from 1.2 to 6.2 meters in the summer, averaging about 3 meters; however, higher Secchi depths (increased water clarity) occurred less often in recent years according to an interannual trend in decreasing water clarity, as shown by the solid black line in Figure 9. Within each year, Secchi depth typically decreases during the summer from a spring maximum to a minimum in September or October.

Chlorophyll

Chlorophyll-a concentrations at 1 meter depth are presented in Figure 9 for each summertime monitoring date between July 1981 and June 2022. Chlorophyll-a concentrations ranged from 1 to 34 micrograms per liter (µg/L) with peaks greater than 10 µg/L in many monitored years. Chlorophyll-a measurements do not indicate any substantial interannual trends.

Nutrients

Total nitrogen (at surface, 1 meter depth) and total phosphorus (at surface and at bottom [6-7 m]) concentrations are presented in Figure 10 for each monitoring date from June 2002 through June 2022. Total nitrogen concentrations at the lake surface ranged from 58 to 671 µg/L and did not vary consistently with season. Total phosphorus at the lake surface ranged from 8 to 37 µg/L and was relatively stable year to year without seasonal variation.

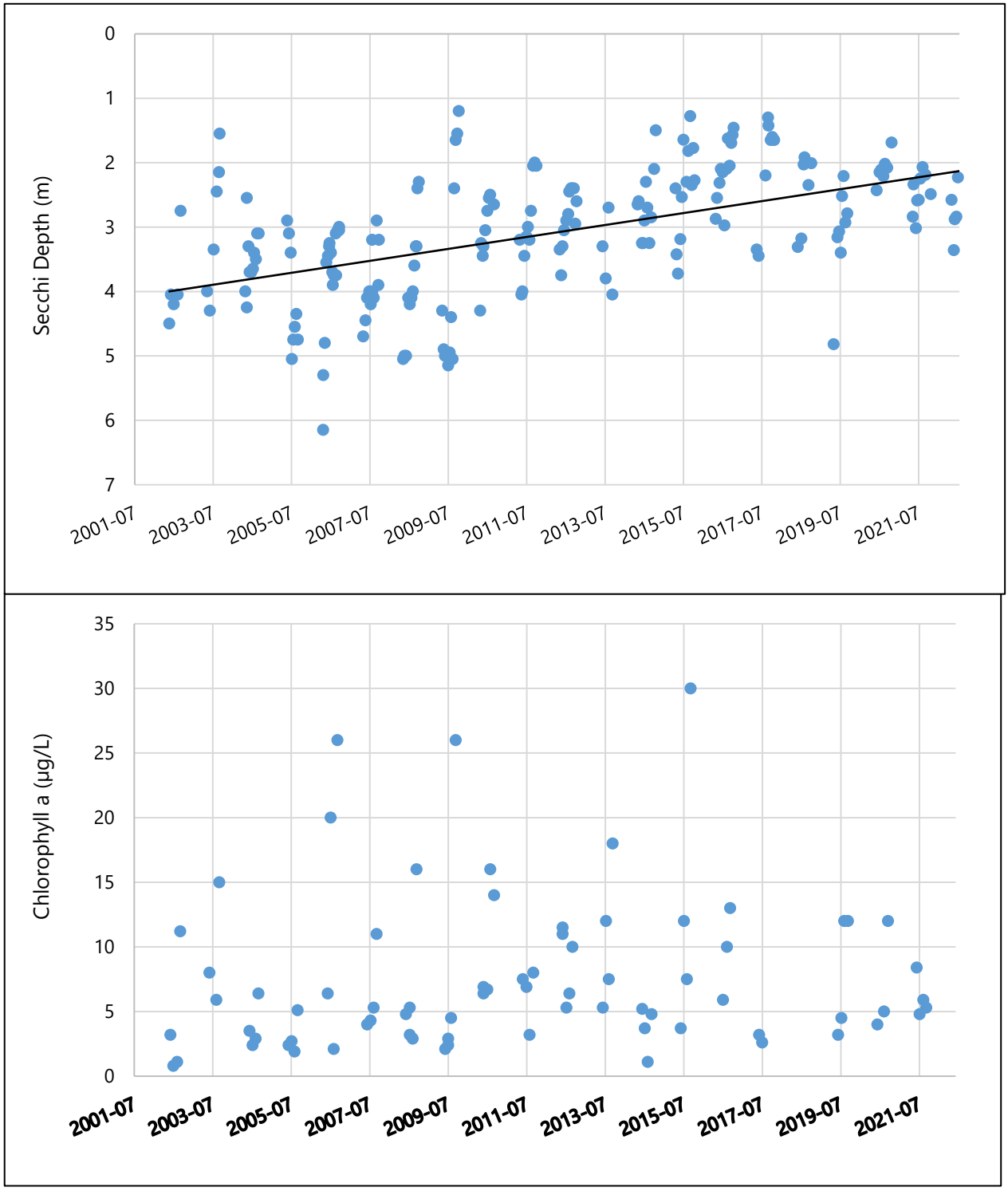


Figure 9. Blackmans Lake Summer Secchi Depth and Chlorophyll a Concentrations.

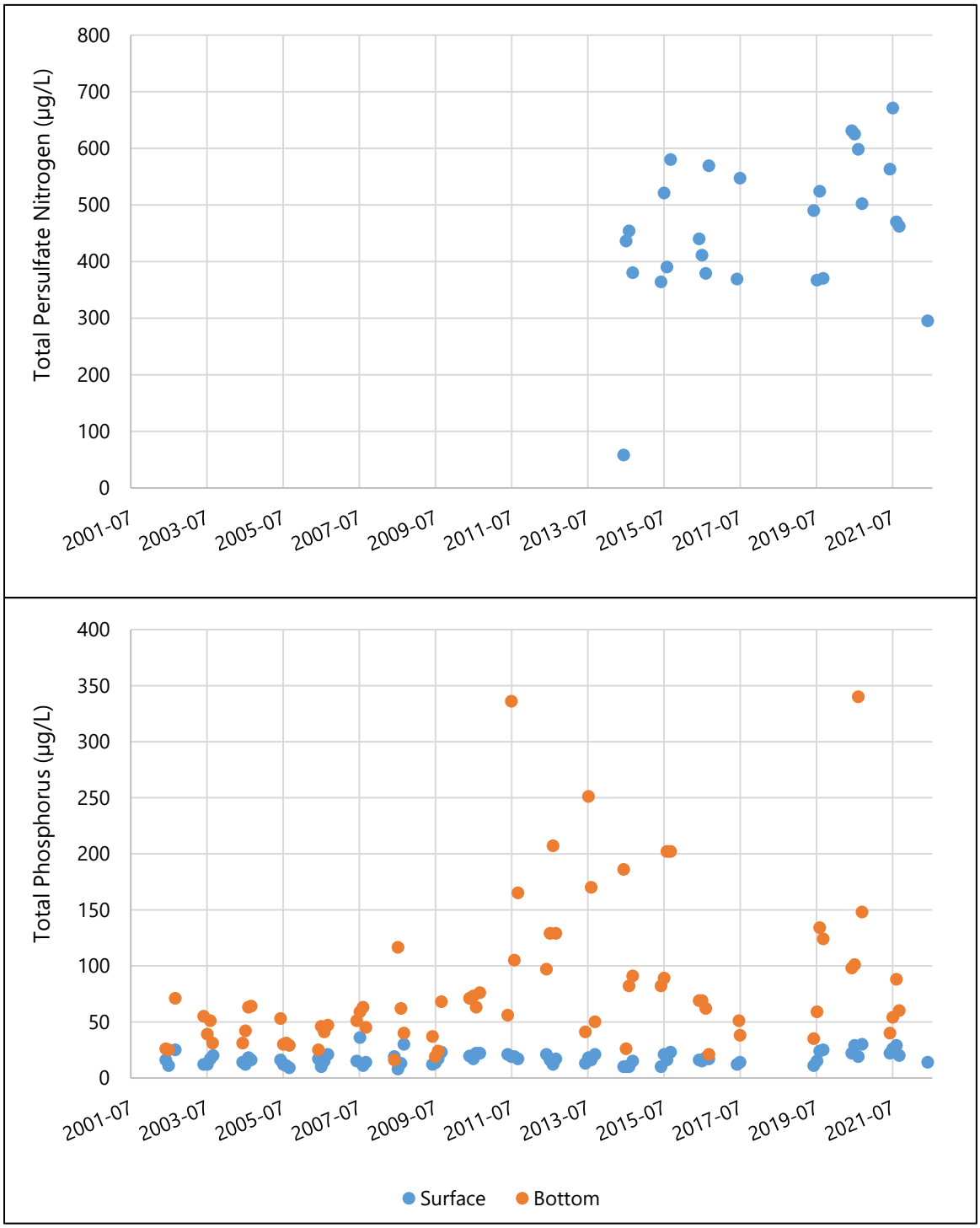


Figure 10. Blackmans Lake Summer Total Nitrogen and Phosphorus Concentrations.

Due to recent increases in surface phosphorus, Snohomish County staff measured total phosphorus in storm drains emptying into the lake (Table 3) from which greater concentrations were observed during storm events and supports the conclusion that surface water phosphorus originates from the watershed. This is further corroborated by KCM's 1994 report which calculated stormwater runoff as the greatest source of nutrients (at 55 percent), followed by nutrients from inlets (19 percent), internal loading during hypoxia (12 percent) (see below), wetland flow (7 percent), and precipitation (7 percent) (Table 4).

Table 3. Average Total Phosphorus (µg/L) from Blackmans Lake Stormwater Outfalls.

Winter Season	Park Avenue	19th Street	Hill Park
2011–2012	78	52	24
2012–2013	33	22	15
2013–2014	38	15	-
2014–2015	74	44	-
2015–2016	-	-	-
2016–2017	46.5	28	-
2017–2018		*Data rejected*	
2018–2019	25	20	-

Table 4. Blackmans Lake Phosphorus Budget (May 1992 to April 1993) (KCM 1994).

Inflows	Mass (kg)	Percent of Total	Outflows	Mass (kg)	Percent of Total
Inlets (Grass Bottom and Blackmans creeks and unnamed intermittent western inlet)	14	19	Outlet (Swifty Creek)	15	20
Stormwater	41	55	Groundwater	0	0
Precipitation	5	7	Sedimentation	48	62
Groundwater	0	0	Wetlands	3	17
Wetlands	5	7			
Internal Load	9	12			
Total	**76**		**Total**	**76**	
Change in Lake Storage	0	negligible	Change in wetland Storage	8	Net gain

Nutrient inflow and outflow between the lake and groundwater sources are presented in Table 5. Estimated from groundwater flow rates and groundwater quality sampling, results indicate a net (inflow minus outflow) phosphorus loading input of 35 to 350 mg/day and a net nitrogen loading output of 2,015 to 20,150 mg/day (KCM 1994).

Table 5. Groundwater Nutrient Flows to and from Blackmans Lake (KCM 1994).				
	Inflow to Lake		Outflow from Lake	
Nutrient	Average Concentration (mg/L)	Loading Rate (mg/day)[a]	Average Concentration (mg/L)	Loading Rate (mg/day)[a]
Total Phosphorus	0.15	75–750	0.08	40–400
Total Nitrogen	8.3	4,150–41,500	12.33	6,165–61,650

mg/L = milligrams per liter, mg/day = milligrams per day

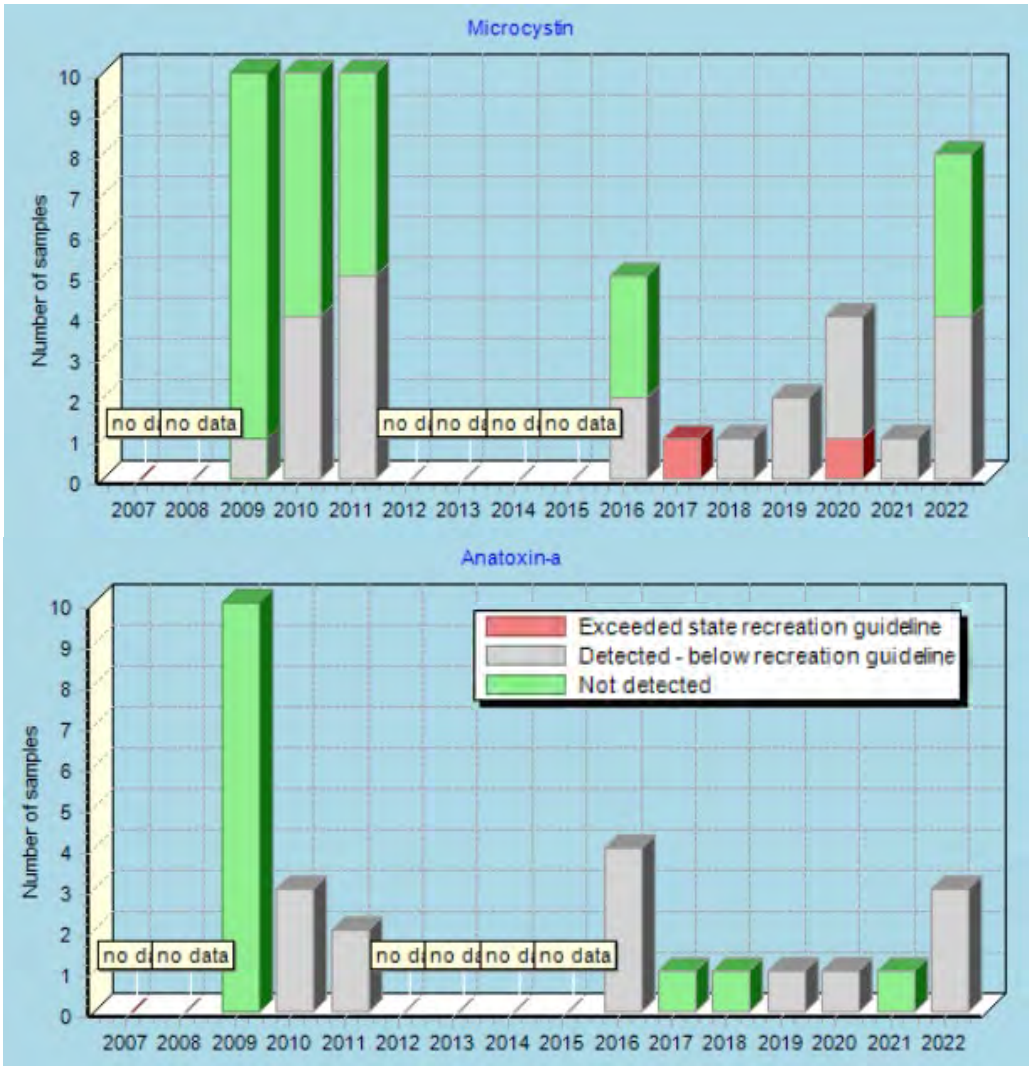
a = Assuming a groundwater flow rates of 0.5 to 5 cubic meters per day, estimated from the 1993 paired wellpoint analysis (KCM 1994).

Total phosphorus at the lake bottom (hypolimnion) was elevated compared to the lake surface and exhibited increased concentrations in recent years, ranging from 20 to 340 µg/L (see Figure 10). Total phosphorus measured from sediment cores collected from the lake in 1992 also exhibited high values ranging from 1,167 to 2,270 milligrams per kilogram dry weight (mg/kg) (KCM 1994). Deep lake water samples often exhibit much higher concentrations than surface samples due to an accumulation of nutrients in the lake sediments and internal recycling, as a consequence of long-term loading from the watershed. However, the KCM (1994) report further explains that the high phosphorus concentrations measured concurrently in the hypolimnion were likely due to the release of phosphorus from the iron minerals in the lake sediments from anoxic conditions during summer stratification. Conversely, the high iron content in the sediment also allows for a reduction in available phosphorus in the water column after the fall turnover (KCM 1994). As seen in Figure 9, the bottom layer of Blackmans Lake has anoxic/hypoxic conditions during stratification, and internal loading may continue to be a significant source of phosphorus to the lake.

Toxic Cyanobacteria

County staff and volunteers have monitored toxic cyanobacteria since 2005 as part of the lake monitoring program, with additional biweekly toxin monitoring from 2009-2011 conducted by the Washington State department of Health (DOH) for a separate larger project. Scums are reportedly observed often at Blackmans Lake through the winter (November–April) and persisting intermittently throughout the winter season, but sampling of these blooms has not been performed due to a lack of state funding and personnel resources (Snohomish County 2021).

Figure 11 presents the frequency of the samples exceeding Washington state recreational guidelines for anatoxin-a (1 µg/L) and microcystin (8 µg/L) (Ecology 2022b). Summer sampling did not detect any cylindrospermopsin or saxitoxin but has detected low to moderate levels of anatoxin-a and/or microcystin. Only two microcystin samples (from October 2017 and October 2020) exceeded guidelines. When detected, toxic algae warnings at Blackmans Lake are posted at public access points and on the City's website.



Year	Weeks Posted CAUTION	Weeks Posted WARNING	# Weeks Sampled	# Weeks Toxic*	Microcystin Range (µg/L)	Anatoxin Range (µg/L)
2008	-	-	1	1	greater than 6	-
2009	-	-	1	0	0.05	-
2010	-	-	6	0	0-2.77	-
2011	-	-	7	0	0-0.06	-
2015	-	-	1	0	less than 1	-
2016	10	-	5	0	0.2-0.4	0.01-0.04
2017	2	2	2	1	0-10.1	0
2018	4	-	1	0	0.31	0
2019	4	-	2	0	0-2.23	0-0.03
2020	-	18	4	1	0-21.6	0-0.01
2021	-	24	1	0	0-6.26	0

Figure 11. Blackmans Lake Cyanobacteria Toxin Exceedances (2007–2022) (Ecology 2022b, Snohomish County 2021).

AQUATIC PLANTS

The aquatic plant community of Blackmans Lake has been surveyed annually from 2009 to 2022 through the Snohomish County monitoring program. The aquatic plant community in the lake is robust and diverse, including large patches of native yellow waterlily (*Nuphar*) and the invasive fragrant water lily (*Nymphaea odorta)*. Additionally, there are moderately dense areas of the microalgae *Nitella* and *Chara*, as well as water nymph (*Najas flexilis*), common elodea (*Elodea canadensis*), and several species of native pondweed (*Potamogeton*).

In 2021 County staff identified the invasive plant curly leaf pondweed (*Potamogeton crispus*) near the boat launch. There were sparse plants in a small area. The City was notified and the pondweed was removed. The area will be inspected for regrowth in 2023. The City is considering methods to control the fragrant water lily population.

PROJECT OBJECTIVES

The overall goal of the project is the development of a cyanobacteria management plan that identifies sources of phosphorous fueling the toxic algae blooms that occasionally occur during the summer in Blackmans Lake. Monitoring of Blackmans Lake water quality and other parameters will be performed with the primary goal of evaluating the effects of environmental conditions and past lake management practices on algae growth and toxin production. Toxic algae blooms may have been stimulated by several factors, which may include but are not limited to:

- Stormwater runoff, washing nutrients into the lake
- Low oxygen in bottom waters or sediments from oxygen consumption by microbial respiration and decomposition, increasing the release of sediment phosphorus
- Warm weather, extending the period of low oxygen in bottom waters or sediments
- Wind mixing up nutrient-rich bottom waters
- Increased nutrients from the increased aquatic plant decay or waterfowl activity
- Trout stocking, reducing zooplankton grazing of algae
- A change in the dynamics of the northwest wetland to act as source, rather than a sink

The resulting cyanobacteria management plan will build on past management actions, provide recommendations for water quality improvements to enhance recreational and wildlife use of the lake, and primarily focus on developing a management strategy to reduce the frequency and duration of toxic algae blooms. To meet this goal, the following objectives have been defined for this project:

- Fill data gaps in water quality, watershed, and biological information for Blackmans Lake
- Evaluate effects of environmental conditions and past lake management practices on algae growth and toxin production
- Develop a phosphorous loading model and budget using data from the project and historical datasets
- Identify the sources of phosphorous which stimulate cyanobacteria blooms

- Determine predictors of chlorophyll-a concentration and algae production for modelling of treatment efficacies
- Develop recommendations for watershed phosphorus loading reduction treatments and in-lake restoration techniques
- Develop a cyanobacteria management plan which when implemented reduces the frequency and duration of cyanobacteria blooms
- Inform and guide future aquatic plant and waterfowl management actions, and ongoing monitoring strategies with respect to cyanobacteria blooms
- Provide high quality data for the City of Snohomish, Snohomish County, and other users

ORGANIZATION AND SCHEDULE

Key project participants are identified and listed below, followed by the schedule for project implementation.

ORGANIZATION AND KEY PERSONNEL

Water quality monitoring for Blackmans Lake will be performed by the Blackmans Lake monitoring volunteer(s), Snohomish County Surface Water Management staff, and Herrera following protocols outlined in this QAPP. Key personnel involved in this effort are identified below, and their respective roles are provided in Table 6.

Personnel	Organization	Role
Yoshihiro Monzaki	City of Snohomish	City of Snohomish Project Manager
Daniel Hotovitsky		Stormwater Monitoring Lead
Rob Zisette	Herrera Environmental Consultants	Herrera Project Manager and Principal Investigator
Timothy Clark		Herrera Technical Lead
Katie Sweeney		Herrera Data Manager and Technical Support
Katie Ruthenberg	Snohomish County	Snohomish County Coordinator
Anthony Bourke	Snohomish County Volunteer Lake Monitoring Program	Lead Volunteer
Kay Ditzenberger, PhD	Friends of Blackmans Lake (FOBL)	FOBL Volunteer Coordinator
Jim Sweet	Aquatic Analysts	Phytoplankton Analyst
Shanda McGraw	EcoAnalysts, Inc.	Zooplankton Analyst
Alex Hamilton	IEH Analytical Laboratories	Water Chemistry and Sediment Analyst

PROJECT SCHEDULE

For this project, the City of Snohomish, Snohomish County, Herrera, and the Blackmans Lake volunteers may share certain responsibilities and project actions. The lead entity and schedule for each project action are thus provided below in Table 7.

Table 7. Project Organization, Responsibilities, and Schedule.							
Task	Item	Responsible Entity				Begin Date	End Date
		HEC	COS	SCV	FOBL		
1	Project management	**X**	**X**			8/22/22	6/30/24
2	Draft QAPP	**X**	x			8/22/22	10/14/22
	Final QAPP	**X**	x	x	x	10/14/22	12/28/22
3	Stream/drainage monitoring	x	**X**			10/31/22	10/30/23
	Lake water quality monitoring (May-Oct)	x		**X**	x	10/30/22	10/30/23
	Lake water quality monitoring (Nov-April)	x		x	**X**	11/1/22	4/30/23
	Lake sediment P monitoring	**X**			x	8/1/23	8/30/23
4	Water/Phosphorus Budgets	**X**				11/1/23	12/30/23
5	Pre-draft CMP	**X**	x			11/1/23	3/3/24
	Draft CMP	**X**	x	x	x	3/3/24	4/14/24
	Final CMP	**X**	x	x	x	4/14/24	6/26/24
6	Stakeholder kickoff/QAPP meeting	x	**X**	x	x	11/14/22	12/12/22
	Pre-summer monitoring meeting	x	**X**	x	x	5/1/23	5/30/23
	Draft CMP meeting/presentation	**X**	x	x	x	4/1/24	4/30/24
	Final project meeting/presentation	**X**	x	x	x	6/1/24	6/30/24

X = lead entity; x = participating entity

HEC = Herrera Environmental Consultants; COS = City of Snohomish, SCV= Snohomish County Volunteer, BLV = Friends of Blackmans Lake Volunteer

STUDY DESIGN

This section describes the study design for the Blackmans Lake Cyanobacteria Management Plan project. In addition to reviewing the existing historical lake data, high-quality monitoring data of the lake water quality, lake sediment, and stormwater outfalls in the basin draining to the lake must be performed to inform the development of the Blackmans Lake CMP. These data will be collected throughout water year 2023 (October 2022 through October 2023) to thoroughly characterize lake conditions for the development of water and phosphorus budgets, which are both necessary to understand the dynamics driving cyanobacteria blooms in the lake and critical to developing a successful and sustainable strategy for both short-term and long-term toxic algae control.

Table 8 presents a summary of the study design including parameters, locations, and frequency of hydrological measurements, drainage sampling, lake water quality, lake sediment quality, and waterfowl surveys. Monitoring stations are described in Table 9. Monitoring stations and their associated basin areas are shown in Figure 12. The sanitary sewer system and onsite sewage systems in the watershed are shown in Figure 13.

Watershed monitoring will include a continuous rain gauge at the County's French Slough station ("Fr") and a continuous lake gauge at Hill Park ("Bl"). Water grab samples for total phosphorus will be collected and discharge will be measured by the City, or by Herrera staff as needed, at five stations located in the watershed. Lake outlet discharge also will be monitored during watershed monitoring. Watershed drainage sampling will occur for three base flow events and six storm events.

Lake water quality monitoring will be conducted at the mid-lake, deep station to correspond to routine monitoring by the volunteers as part of Snohomish County's Lake Monitoring Program. Routine monitoring at this station (see Volunteer Monitoring Calendars in Appendix A) will be slightly modified to include additional sampling:

1. Six sampling events for nitrate+nitrite as nitrogen and phytoplankton at the surface and dissolved orthophosphate at the bottom during the already planned six scheduled summer monthly events

2. Total phosphorus (surface and bottom) and chlorophyll-a (surface) analysis during every profiling visit (9 additional events)

3. Field measurements, total phosphorus, and chlorophyll-a at mid-depth in the Champagne Canal during six monthly summer events

4. One vertical tow of zooplankton for three summer monthly events

5. Additional monthly monitoring during the winter months (November 2022 through April 2023) for total phosphorus, chlorophyll a, and Secchi depth at the lake surface, temperature and dissolved oxygen profiles, and total phosphorus at the mouth of Blackmans Creek (BLK-MTH) (see Table 8)

To help identify and quantify nutrient contributions to the lake, the total number of waterfowl present on the lake will be recorded during each of the bimonthly lake sampling events as per the monitoring program, and will increase the frequency to daily or weekly basis throughout the year.

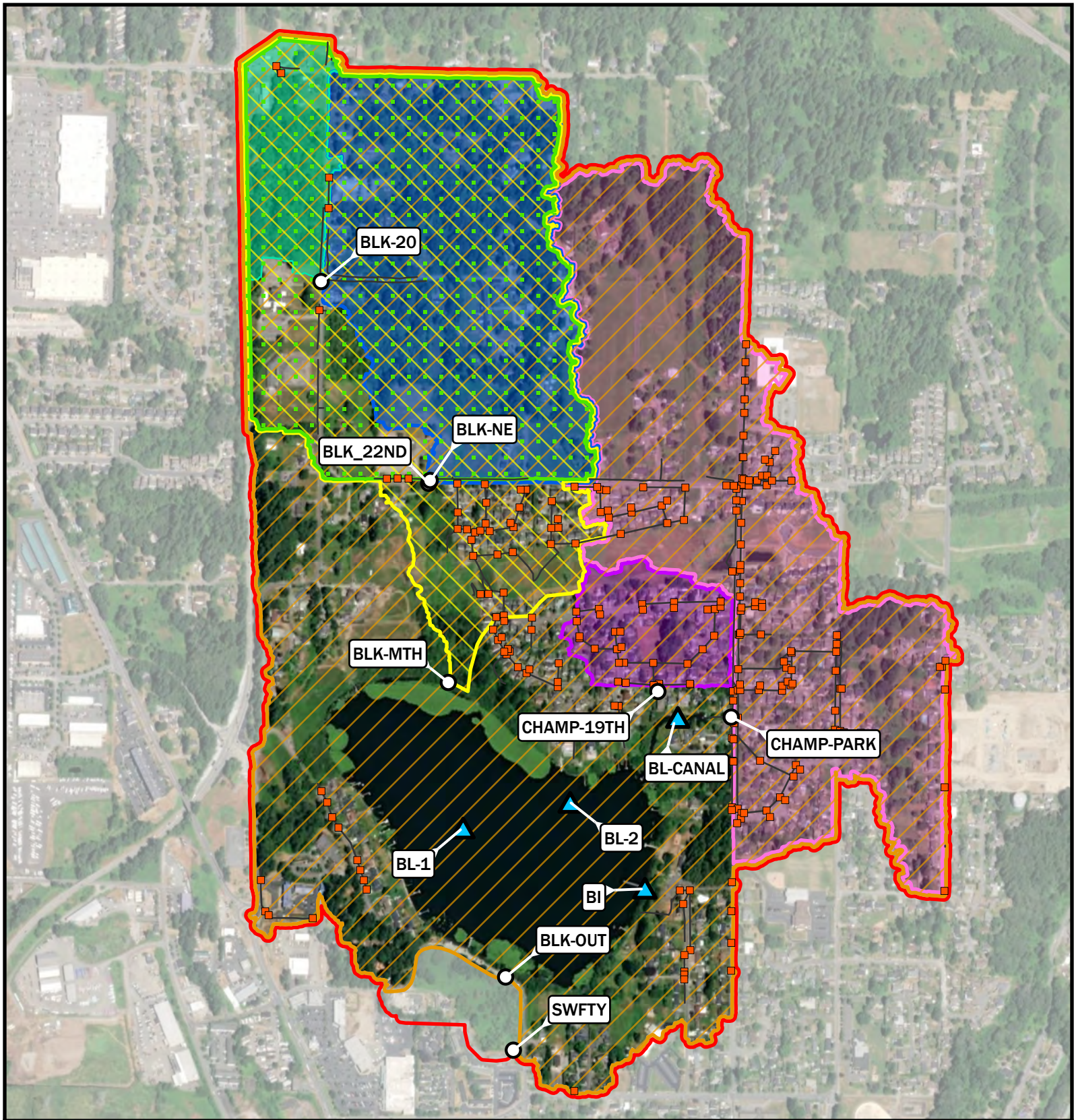
Sediment cores will be collected by Herrera staff, assisted by City staff and/or volunteers, on one occasion at each of two stations located at a shallow and deep location in the lake (Figure 12). Each core will be processed into five depth intervals for analysis of sediment phosphorus fractions, bulk density, and iron.

Table 8. Monitoring Plan for the Blackmans Lake Cyanobacteria Management Plan.

Activity	Parameter	Station/Location	2022 (Month/Week)			2023 (Month/Week)															
			10	11	12	1	2	3	4	5	5	6	6	7	7	8	8	9	9	10	10
			Wk4	Wk2	Wk2	Wk2	Wk2	Wk2	Wk2	Wk1	Wk3	Wk1	Wk3	Wk1	Wk3	Wk1	Wk3	Wk1	Wk3	Wk1	Wk3
Watershed Monitoring	Precipitation	Fr	Continuous at Snohomish County's French Slough Rain Gauge																		
	Lake Level	BI	Continuous at Snohomish County's Hill Park Dock Staff Gauge																		
	Inflow/Outflow Discharge, Total P	Lake outlet and 5 inflows		Ba1	St1	St2*	Ba2	St3*	St4	St5		Ba3*								St6	
Lake Water Quality Monitoring	Blackmans Creek Inflow, Total P	BLK-MTH	G	G	G	G	G	G	G	G	G	G								G	G
	Secchi Depth	BL-1, CANAL	S	S	S	S	S	S	S	SC	S	SC	S	SC	S	SC	S	SC	S	SC	S
	Temperature/DO	BL-1, CANAL							P	PC	P	PC	P	PC	P	PC	P	PC	P	PC	P
	pH	BL-1, CANAL								SC		SC		SC		SC		SC		SC	
	Total Phosphorus	BL-1, CANAL	SB	S	S	S	S	S	S	S*BC	SB	SBC	SB	S*BC	SB	SBC	SB	S*BC	SB	SBC	SB
	Chlorophyll a[a]	BL-1, CANAL	S	S	S	S	S	S	S	S*C	S	SC	S	S*C	S	SC	SB	S*C	S	SC	S
	Dissolved Ortho P	BL-1								B		B		B*		B		B		B	
	Total Nitrogen	BL-1								S		S		S*		S		S		S	
	Nitrate+Nitrite-N	BL-1								S		S		S*		S		S		S	
	Phytoplankton	BL-1								S		S		S		S		S		S	
	Zooplankton	BL-1										T				T				T	
Lake Sediment	Phosphorus, Iron, Dry Wt., Density	BL-1, BL-2														5 in 2 cores					
Lake Observations	Algae, Waterfowl, Boat, Fisher, Swimmer	Lake	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O

Red colored letters are conducted as part of the Snohomish County's Volunteer Lake Monitoring Program or other existing monitoring programs.
Watershed monitoring schedule is suggested and is subject to change based on staff availability and storm events. Ultimately, three baseflow events and six storm events should be sampled.
St = storm flow monitoring, Ba = base flow monitoring, G = Grab Total P sample if flow is present during lake sampling; S = surface sample (1 m below lake surface), B = bottom sample (0.5 meter above sediment), P = profile at 1-meter intervals. C = Canal (mid-depth),
T = vertical net tow, O = Observations during each lake event plus daily counts of waterfowl,
* Indicates a field duplicate

Table 9. Monitoring Stations for the Blackmans Lake Cyanobacteria Management Plan			
Site ID	**Description**	**Latitude, Longitude**	**Parameters Measured**
Lake Stations			
BL-1	Lake deep station near the deepest point of the lake	47.93233, -122.09493	Water and Sediment Quality (see Table 8)
BL-2	Lake shallow sediment station, , at about 8 feet depth in the shallow area just south of the northeast shore docks	47.932815, -122.092128	Sediment Quality (see Table 8)
BL-CANAL	Champagne Canal near center	47.934325, -122.089308	Water Quality (see Table 8)
Bl	Lake level gauge "Bl" located near Hill Park. Operated by Snohomish County	47.9313, -122.09012	Lake surface elevation (continuous)
Stream/Drainage Stations			
BLK-OUT	Outlet from Blackmans Lake at downstream side of road at 4 pipe outfalls	47.929675°, -122.093788°	Discharge
SWFTY	Swifty Creek downstream of lake outlet.	47.928395, -122.093375	Discharge (alternate)
BLK-MTH	Blackmans Creek Mouth at lake shore. Access by boat during winter lake sampling.	47.934883, -122.095728	Total Phosphorus
BLK-22	Lower Blackmans Creek at 22nd St in outfall of 24-inch concrete culvert.	47.938379°, -122.096006°	Total Phosphorus Discharge
BLK-26	Upstream Blackmans Creek at south side of 26th St in outfall of 24-inch metal culvert under Lake Ave (99th Ave SE).	47.941960, -122.098787	Total Phosphorus Discharge
BLK-NE	Blackmans Creek Northeast Fork at inflow to 22nd St culvert from east ditch, and adjacent to inflow from NW Fork in west ditch.	47.938448, -122.095931	Total Phosphorus Discharge (estimate proportions of both forks)
CHAMP-PARK	Outflow from catch basin on west side of Park Ave before discharging to Champagne Canal of Blackmans Lake that was formerly Grass Bottom Creek.	47.934348 -122.087889	Total Phosphorus Discharge
CHAMP-19	Ditch on south side of 19th St across from 704 19th St in residential neighborhood.	47.934789 -122.089861	Total Phosphorus Discharge
Rain Gauge			
Fr	Snohomish County French Slough "Fr" gauge	47.88857 -122.08796	Precipitation (continuous)



Legend

- Lake Station
- Watershed Station
- Catch basin
- Storm Drain

Basin

- BLK-22
- BLK-MTH
- BLK-NE
- BLK-OUT
- CHAMP-19TH
- CHAMP-PARK
- BLK-20
- SWFTY

Figure 12.
Monitoring Stations and Basins for the Blackmans Lake Cyanobacteria Management Plan.

N

0 375 750 1,500 Feet

HERRERA

ESRI (Aerial, 2021)

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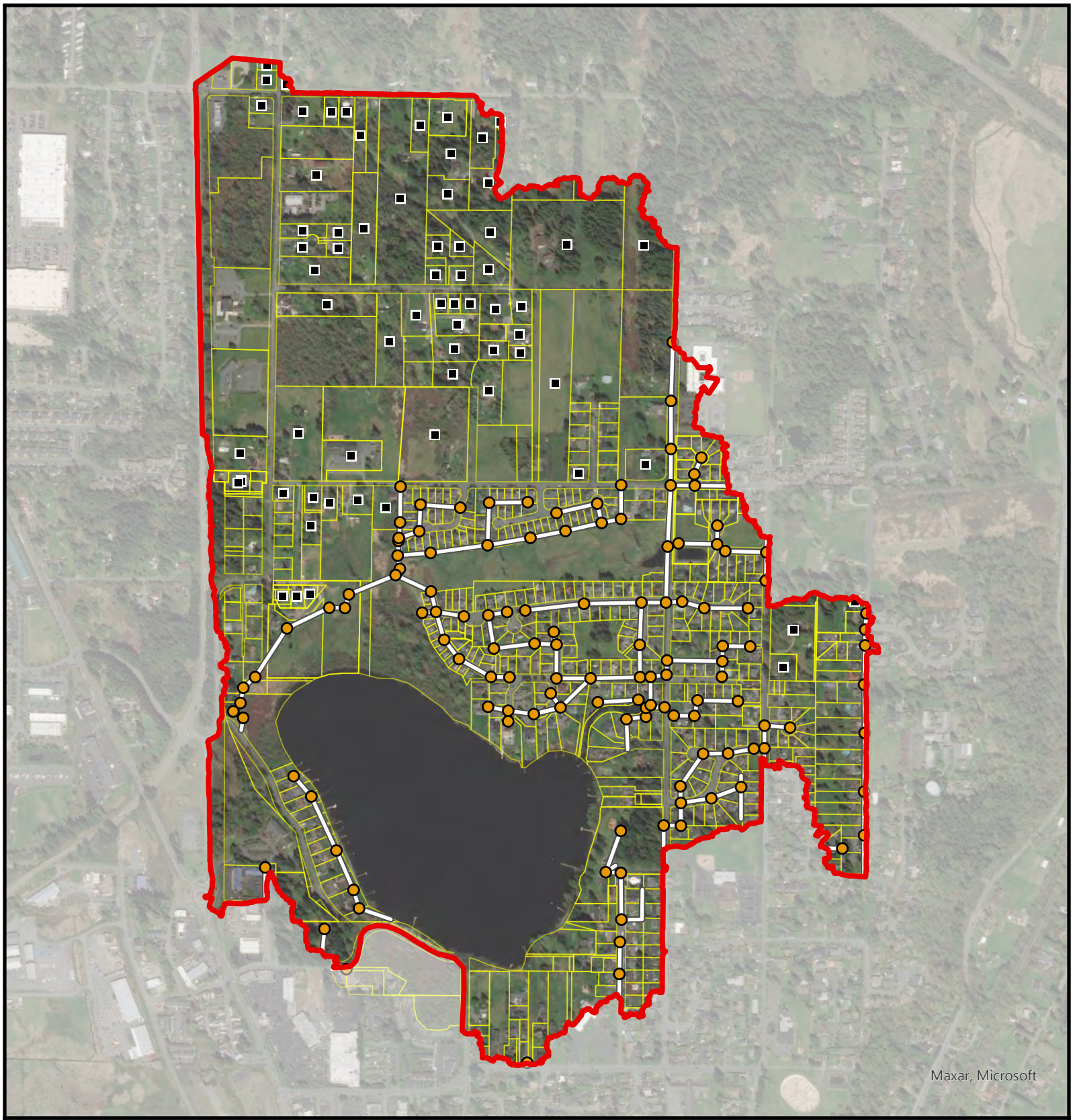

Legend

- Blackmans Lake stormwater basin
- Sanitary sewer
- Manhole
- Parcel boundary
- Onsite septic system

Figure 13.
Sanitary Sewer and Onsite Sewage Systems in the Blackmans Lake Watershed.

N

0 250 500 1,000
Feet

HERRERA

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MEASUREMENT QUALITY OBJECTIVES

The overall measurement quality objective is to ensure that data of a known and acceptable quality are obtained. All measurements will be performed to yield consistent results that are representative of the media and conditions measured. Measurement quality objectives (MQOs) are defined by precision, bias, representativeness, completeness, and comparability. Project-specific MQOs are provided below in Table 10.

PRECISION

Precision will be assessed based on the analyses of laboratory and field duplicates. One laboratory duplicate will be analyzed with each batch of samples, and one field duplicate will be analyzed at the frequency described below in Field Procedures.

Two levels of precision for duplicate analyses will be evaluated using reported values for parameters of concern. The relative percent difference (RPD) of laboratory duplicates will be less than or equal to 20 percent (35 percent for bacteria and organics) for values that are greater than 5 times the detection limit, and ± 2 times the detection limit for values less than or equal to 5 times the detection limit.

Precision in these samples will be quantified based on their relative percent difference (RPD):

$$RPD = \frac{(C_1 - C_2) \times 100\%}{(C_1 + C_2)/2}$$

Where:

RPD	=	relative percent difference
C_1	=	larger of two values
C_2	=	smaller of two values

Specific MQOs for laboratory and field duplicates are defined by analysis method in Table 10.

Table 10. Measurement Quality Objectives for Water Quality Data.								
Parameter	**Analytical Method**	**Method Number[a]**	**Maximum Holding Time**	**Method Detection Limit**	**Method Blank[b]**	**Control Standard Recovery[b]**	**Matrix Spike Recovery[b]**	**Duplicate RPD[b]**
Field Analyses								
Secchi depth	20-cm disc	NALMS 1995	*in situ*	0.1 meter	NA	NA	NA	≤10%
Temperature	Electrode	Field meter	*in situ*	0.5°C	NA	± 0.5°C	NA	≤5%
Dissolved oxygen	Electrode	Field meter	*in situ*	0.5 mg/L	NA	± 1.0 mg/L	NA	≤10%
pH	Electrode	Field meter	*in situ*	NA	NA	± 0.2°units	NA	≤5%
IEH Water Sample Analyses								
Total phosphorus	Persulfate, ascorbic acid	SM4500-P-B, F	28 days	0.002 mg/L	≤ MDL	90 to 110%	80-120%	≤20%
Dissolved orthophosphate phosphorus	Ascorbic acid	SM4500-P-B, F	48 hours	0.001 mg/L	≤ MDL	90 to 110%	80-120%	≤20%
Nitrate+nitrite nitrogen	Cadmium Reduction	SM 4500-NO3 F	28 days	0.01 mg/L	≤ MDL	90 to 110%	80-120%	≤20%
Total persulfate nitrogen	Persulfate, cadmium reduction	SM 4500-N-C	28 days	0.05 mg/L	≤ MDL	90 to 110%	80-120%	≤20%
Chlorophyll *a*	Spectrophotometric	SM10200-H	28 days	0.1 µg/L	≤ MDL	80 to 120%	NA	≤20%
IEH Sediment Sample Analyses								
Loosely bound phosphorus	Ammonium chloride, ascorbic acid	Rydin and Welch 1998; SM-4500PF	28 days	2 mg/kg	≤ MDL	85 – 115%	75-125%	≤25%
Iron bound phosphorus	Bicarbonate/dithionate, ascorbic acid	Rydin and Welch 1998; SM-4500PF	28 days	2 mg/kg	≤ MDL	85 – 115%	75-125%	≤25%
Aluminum bound phosphorus	Sodium hydroxide, ascorbic acid	Rydin and Welch 1998; SM-4500PF	28 days	2 mg/kg	≤ MDL	85 – 115%	75-125%	≤25%
Calcium bound phosphorus	Hydrochloric acid, ascorbic acid	Rydin and Welch 1998; SM-4500PF	28 days	2 mg/kg	≤ MDL	85 – 115%	75-125%	≤25%
Organic phosphorus	Residue digestion, ascorbic acid	Rydin and Welch 1998; EPA 365.1	28 days	2 mg/kg	≤ MDL	85 – 115%	75-125%	≤25%

Table 10(continued). Measurement Quality Objectives for Water Quality Data.								
Parameter	**Analytical Method**	**Method Number[a]**	**Maximum Holding Time**	**Method Detection and Unit**	**Method Blank[b]**	**Control Standard Recovery[b]**	**Matrix Spike Recovery[b]**	**Duplicate RPD[b]**
Biogenic phosphorus	Residue residual, ascorbic acid	Rydin and Welch 1998; EPA 365.1	28 days	2 mg/kg	≤ MDL	85 – 115%	75-125%	≤25%
Total phosphorus	Sum of all P fractions minus Biogenic P		28 days	5 mg/kg	≤ MDL	85 – 115%	75-125%	≤25%
Total iron	ICP/MS	EPA 6020	28 days	2 mg/kg	≤ MDL	90 to 110%	80-120%	≤20%
Percent solids	Gravimetric	SM 2540 B	28 days	1 percent	≤ MDL	NA	80-120%	≤20%
Bulk density	Gravimetric	SM 2540	28 days	0.1 gram/mL	≤ MDL	NA	80-120%	≤20%
Aquatic Analysts and EcoAnalysts Plankton Analyses								
Phytoplankton	Species cell and biovolume density	Laboratory	6 months	Cells/mL and μ^3/mL	NA	NA	NA	NA
Zooplankton	Species individual density	Laboratory	6 months	No./L	NA	NA	NA	NA

[a] Method numbers from Standard Methods (APHA 2012), EPA (2012), and NALMS (1995), except where not applicable.

[b] Method blank, control standard, matrix spike, and laboratory duplicate will be analyzed at least once per sampling event for each applicable parameter.

[c] whichever is greater

[d] Samples must be filtered within 48 hours.

°C = degrees Celsius; cm = centimeter; mL = milliliter, L = liter, μ^3 = cubic micron

mg/L = milligrams per liter; µg/L = micrograms per liter; µS/cm = micro Siemens per centimeter, mg/kg = milligrams per kilogram, No./L = number per liter

NA = not applicable

MDL = method detection limit

RPD = relative percent difference

Bias

Bias will be assessed based on analyses of method blanks, matrix spikes (MS), and laboratory control samples (LCS). Bias in MS and LCS will be quantified based on percent recovery or the average (arithmetic mean) of the percent recovery. Percent recovery for MS will be calculated using the following equation:

$$\%R = \frac{(S - U) \times 100\%}{C_{sa}}$$

Where: %R = percent recovery

S = measured concentration in spike sample

U = measured concentration in unspiked sample

C_{sa} = actual concentration of spike added

Percent recovery for LCS will be calculated using the following equation:

$$\%R = \frac{M}{T} \times 100\%$$

Where: %R = percent recovery

M = measured value

T = true value

Specific MQOs for MS and LCS are defined in Table 10 by analysis method.

Representativeness

Sample representativeness will be ensured by employing consistent and standard sampling procedures identified in this QAPP.

Completeness

Completeness will be assessed based on the percentage of specified samples (listed in this QAPP) collected. The completeness goal shall be 95 percent. Completeness for acceptable data is defined as the percentage of acceptable data out of the total amount of data generated. Acceptable data is either data that passes all QC criteria, or data that may not pass all QC criteria but has appropriate corrective actions taken.

Completeness will be assessed by comparing valid sample data with this quality assurance project plan and the chain-of-custody records. Completeness will be calculated by dividing the number of valid values by the total number of values. If completeness is less than 95 percent, then samples will be reanalyzed or recollected if possible.

COMPARABILITY

Standard sampling procedures, analytical methods, units of measurement, and reporting limits will be applied in this study to meet the goal of data comparability. The results will be tabulated in standard spreadsheets to facilitate comparison with other study results and water quality threshold limits (e.g., WAC 173 201A).

FIELD PROCEDURES

STREAM/DRAINAGE MONITORING

Stream/drainage monitoring will be conducted by City of Snohomish or Herrera at each of the five inflow stations and one outflow station during one day for each of nine events in water year 2023, including three baseflow events and six storm events, as outlined in Table 8. Storm event monitoring will occur on days when the following criteria for storm event conditions are met:

- At least 0.25 inches of rain is predicted to occur on the sampling date and at least 0.10 inches of rain occurs before sampling begins.

Baseflow sampling will occur according to the schedule with the following criterion for baseflow conditions: less than 0.04 inches of rain in the previous 24 hours.

Precipitation will be measured at a nearby rain gauge operated by Snohomish County (station # Fr). Forecasted rainfall amounts will be checked at various online sources before monitoring to ensure criteria are met.

Field staff should take photographs of each sampling site during each sampling visit.

Discharge Measurements

Discharge will be measured using a Swoffer current meter after at the lake outlet and five drainage sites after sampling for total phosphorus. If it is not possible to measure velocity, the discharge will be estimated based on the Manning's formula:

$$Q = \frac{1.49}{n} * A * R^{\frac{2}{3}} * S^{0.5}$$

Where
Q = discharge (cfs)
A = flow area (ft^2)
n = Manning's roughness coefficient (0.024 for concrete)
R = hydraulic radius (ft)
S = channel slope (ft/ft) = 0.209 ft/ft

Field staff will measure the depth of water at the outlet of the culvert using a ruler. The depth will be used to calculate A and R according to the following equation:

$$A = r^2 * \arccos\left(1 - \frac{h}{r}\right) - (r - h) * \sqrt{r^2 - (r - h)^2}$$

$$R = r * \frac{2 * A}{r^2}$$

Where
A = flow area (ft^2)
h = water depth (ft)
r = pipe radius (ft) = 0.75 ft
R = hydraulic radius (ft)

Discharge at the lake outlet (BLK-OUT) will be measured using the current meter to measure the velocity and depth of water in each the four 18-inch PVC pipes. If these pipes are not accessible, stream discharge will be measured downstream in Swifty Creek (SWFTY) using open-channel cross-section method according to Ecology's Standard Operating Procedures (Ecology 2017, 2018a, 2018b).

Discharge monitoring equipment will include one current meter, a ruler, and data sheets. Watershed monitoring at each site will generally consist of the following procedures:

- Collect grab samples by directly filling each pre-labeled sample bottle at mid-depth from the center of the stream, ditch, or pipe
- Store sample bottles in a cooler with ice
- Measure and record instantaneous discharge rate.

Sample Collection

Grab samples for total phosphorus analysis will be collected at each of five drainage stations during each of the nine events. Water samples will be collected by hand from each monitoring station using pre-cleaned bottles supplied the laboratory. At each stream site, water samples will be collected by submerging each sample bottle to mid depth in the center (or thalweg) of the drainage pipe or channel and orienting the bottle opening upstream (against flow) while filling. If the distance to the sampling point is too far to reach by hand, a pole will be used to position the sample bottle in the center of the channel for sample collection purposes. The sample bottle will be removed when the bottle is 90 percent full and sealed with the cap.

The collected water samples will be immediately stored in a cooler with ice at a temperature less than 6°C (Celsius). All samples will be delivered or shipped overnight to the laboratory (IEH) on the day of collection for analysis of total phosphorus (see Table 10).

Lake Water Quality Monitoring

The Lake Monitoring Program at Blackmans Lake has used trained volunteers (see Table 8) to collect a set of water quality measurements at one station near the center of Blackmans Lake, at the deepest point, routinely since 1992. The current project will monitor a modified set of parameters at modified frequencies (see Table 9) utilizing trained volunteers to lead sampling events, with assistance from Herrera, City of Snohomish, and Snohomish County staff during the first routine event in October 2022 to provide additional training on modifications to routine lake monitoring procedures for this project.

Lake water quality monitoring conducted from the deep station (BL-1) near the center of Blackmans Lake will include 13 monitoring events occurring monthly from October 2022 through April 2023 and twice monthly from May through October 2023 as follows:

- For every event, a surface water sample will be collected from 1 meter depth for analysis of total phosphorus and chlorophyll-a. During each summer event, 1-meter profiles temperature and dissolved oxygen will be measured.
- For every winter lake sampling event (October to June), a total phosphorus sample will be collected at the mouth of Blackmans Creek it if flowing to the lake, accessed via boat.
- For every event except the six events from November 2022 through April 2023, a surface water sample will be collected for analysis of chlorophyll-a, and a bottom water sample will be collected from 0.5 meters from the lake bottom for analysis of total phosphorus.
- Nitrate + nitrite nitrogen, total nitrogen, and phytoplankton samples will be collected from a 1-meter depth and a dissolved orthophosphate sample will be collected from 1 meter above the lake bottom monthly in May through October 2023.
- For one sampling event in early June, August, and October 2023, a vertical net tow sample will be collected for zooplankton species analysis.

Field Measurements

Lake water quality monitoring procedures will generally consist of the following procedures:

- Equilibrate the temperature/dissolved oxygen meter probe and record data at 1.0 meter intervals as the probe is lowered to the lake bottom and again as it is raised to the lake surface, and record the maximum lake depth.
- Collect grab samples with a Van Dorn sampler and directly filling each pre-labeled sampling bottles for the surface (S) (1 meter from surface) or bottom (B) (0.5 meter from bottom) grab sample.

- Store the sample bottles in a cooler with ice

Field measurement procedures will be based on the volunteer lake monitoring procedures outlined in the Snohomish County Lake Monitoring Program Guide (Appendix A). Field monitoring equipment will include one YSI meter with a 30-foot cable, Secchi disk, Van Dorn sampler with thermometer, one plankton net, sample bottles, cooler, and data sheets. Monitoring equipment will meet the measurement quality objectives and required reporting limits (see Table 10).

The water quality multimeter will be used to make *in situ* measurements temperature and dissolved oxygen at the lake monitoring location. The meter will be calibrated in accordance with the user manual prior to making measurements at the first monitoring location. The meter accuracy will be checked against calibration standards upon completion of each monitoring event. All calibration information will be documented on standardized field forms (see example in Appendix B).

To make *in situ* temperature and dissolved oxygen measurements, the Field Sampler will directly submerge the meter's probe in the water at lake monitoring station, recording each parameter at 1.0-meter intervals. Because oxygen is consumed by the sensor during measurement, the Field Sampler will gently shake the cable to move the probe and avoid false low readings. When the meter's readings have stabilized, the Field Sampler teams will record the measurements on standardized field forms (see example in Appendix B).

Secchi depth, as a measure of water clarity, will be estimated using a Secchi disk. The disk will be lowered into the water on the shaded side of the boat to reduce glare. The Field Sampler team will lower the disk into the water until it just barely disappears from view. The point on the line that meets the water surface will be noted, and the distance in meters (in 0.25-meter increments) between this point and the Secchi disk will be taken as the Secchi depth.

Sample Collection

Water quality samples will be collected by hand from the lake monitoring locations using pre-cleaned bottles supplied the laboratories. The Field Sampler will use aseptic techniques for collecting water samples. A Van Dorn sampler will be used to collect the water with which to gently fill bottles. In each case, the sample bottle will be removed when the bottle is 90 percent full and sealed with the cap.

The collected water samples will be immediately stored in a cooler with ice at a temperature less than 6°C (Celsius). In June to September, County staff will pick up samples on the day-of or the following morning and deliver the sample to IEH. For all remaining samples, the City will coordinate delivery of sample to IEH.

Phytoplankton samples will be collected at 1 meter depth by filling bottles pre-filled with 1 percent Lugol's solution with at least 125 mL of water from the Van Dorn sampler. The

samples will be packed and mailed by the samplers to Aquatic Analysts (Friday Harbor, WA) for analysis.

Zooplankton samples will be collected by lowering Herrera's 50-µm plankton net to 1 meter from the lake bottom and pulling upwards through the water column. While holding the net vertically above the lake surface, lake water is splashed through the outside of the net to wash all contents down the net and into the bucket at the cod end of the net. The bucket is swirled to drain water out of its screening material, and then removed from the net to pour its contents into a 250-mL wide mouth sample jar. The bucket is rinsed with distilled water and ethanol is added to the sample jar for preservation. Zooplankton samples will be preserved in 70 percent ethanol immediately after collection (refrigeration is not necessary), and then packed and mailed by the samplers to EcoAnalysts (Moscow, ID) for analysis.

Lake Sediment Monitoring

One 2-foot sediment core will be collected at each the shallow and deep sediment monitoring stations in Blackmans Lake by Herrera staff during one day in August 2023. Each sediment core will be collected using an Aquatic Research Instruments universal percussion corer fitted with 2-foot-long and 2 5/8ths-inch diameter polycarbonate tube (and plastic core catcher, and then lowered slowly into the lake sediment until refusal. The corer will be lowered by hand to the lake bottom and a second line will be used to raise and lower a hammer to drive the core 2 feet. Upon retrieval, the tube will be immediately capped at the bottom before raising it above the lake surface, and then the tube will be removed core head and capped at the top. All core tubes will be stored upright in a bucket with ice and covered with black plastic to block light.

The cores will be processed at Herrera's lab on the day of collection into the following five depth intervals: 0-2, 4-6, 8-10, 16-18, and 24-26 centimeters. The cores will be processed as follows:

- Attach the core tube vertically to a stand, remove the bottom cap, and inset the plunger in the core tube bottom.
- Remove the top cap and slowly push the plunger up the core spilling water until the sediment surface reaches the top.
- Push the core tube up 2 centimeters and remove the upper 2 centimeters of sediment with a spoon and place in labeled sample container.
- Repeat steps until all samples are collected and stored in a cooler with ice.

The collected sediment samples will be immediately stored in a cooler with ice at a temperature less than 6°C (Celsius). Upon completion of sample processing, the 10 sediment samples will be delivered to Institute for Environmental Health (IEH) Analytical Laboratories for analysis of loosely-bound phosphorus, iron-bound phosphorus, aluminum-bound phosphorus, calcium-bound phosphorus, organic phosphorus, biogenic phosphorus, total phosphorus, percent solids,

and bulk density (see Table 10). In addition, total iron will be measured in the upper three depth intervals of each core to determine if there is sufficient amount of iron in the upper 10 centimeters of sediment to bind with all of available phosphorus.

LAKE OBSERVATIONS

In keeping with previous lake monitoring through the Snohomish County Lake Monitoring Program, samplers will record additional observations as shown on the Volunteer Monitoring Data Sheet in Appendix B, including

- Weather (air temperature, cloud cover, wind)
- Number of waterfowl (e.g., geese, ducks) and other birds
- Number boats, anglers, and swimmers/waders
- Qualitative algae observations
- Water color

Waterfowl counts will also be made by FOBL members on a daily basis when possible, and the data will be entered in a spreadsheet with the date, time, observer initials, and counts for each waterfowl type (geese, ducks, coots, gulls, cormorants, and others).

Trout stocking data will be obtained from WDFW and used together with any previously collected creel survey data to evaluate potential effects of stocked trout and resident fish on the cyanobacteria blooms in the lake.

FIELD DUPLICATES

Temperature and dissolved oxygen will be measured in duplicate on the way down and again on the way up through the water column during each lake sampling event.

For watershed monitoring of total phosphorus, one field duplicate sample will be collected for during 3 of 9 events (see Table 8). The field duplicate sample will be collected from a different station during each sampling event by filling a second set of sample bottles at the same time of collection of the regular sample and labeling the field duplicate sample bottles with a blind sample identification number (see below).

For lake monitoring quality control, three field duplicate samples will be collected for the lake surface sample and analyzed for the primary water quality parameters (total phosphorus and chlorophyll-a) and one field duplicate sample will be collected for the secondary water quality parameters (orthophosphate phosphorus, total nitrogen, and nitrate+nitrite nitrogen). The field duplicate samples will be collected in May, July, and September 2023 for primary parameters,

and in July 2023 for the secondary parameters. Each field duplicate sample will be collected by filling a second sample bottle for each analyte immediately after collection of the regular sample and labeling the field duplicate sample bottles with a blind sample identification number.

Thus, field duplicates will constitute a minimum of 5 percent of the total number of project water quality samples. All field duplicate samples will be submitted to the laboratory and labeled as separate (blind) samples identified as "DUPE." The resultant data from these samples and the laboratory duplicates will be used to assess the observed variation in the analytical results that is attributable to environmental (natural), sampling, and analytical variability.

Field duplicate samples will not be collected for sediment quality, phytoplankton, or zooplankton. Laboratory duplicate results will be used to evaluate precision of the sediment analyses.

LABORATORY PROCEDURES

This section identifies the analytical methods to be used by the laboratories for the Blackmans Lake Cyanobacteria Management Plan project. This section includes information regarding the procedures for analyzing water samples for parameters of concern and laboratory reporting procedures.

The required reporting limits of laboratory data should be attainable through the analytical methods listed in Table 10. Laboratory staff will consult with the project manager if any changes in procedures are recommended or if matrix difficulties are encountered.

Samples are to be analyzed at four separate laboratories; Table 10 indicates which analytes will be measured at each laboratory. Laboratories include:

- IEH Analytical Laboratories in Seattle, WA for water quality analysis and sediment analysis.
- Aquatic Analysts in Friday Harbor, WA for phytoplankton analysis
- EcoAnalysts in Moscow, ID for zooplankton analysis

IEH Analytical Laboratory is accredited by Ecology to perform the required analyses. Laboratory analytical procedures will be analyzed in accordance with standard methods listed in Table 10 (APHA 2012; EPA 2012). These methods provide detection limits that are below the state and federal regulatory criteria or guidelines, and they will enable direct comparison of analytical results with these criteria. Sample preservation, maximum holding times, and analytical methods meet federal requirements for the Clean Water Act (Federal Register 40 CFR Part 136; EPA 2012) and recommendations by Standard Methods (APHA 2012). IEH participates in audits and inter-laboratory studies by Ecology and EPA. These performance and system audits have verified the adequacy of the laboratory standard operating procedures, which include preventative maintenance and data reduction procedures.

IEH Analytical Laboratory will report the analytical water quality and sediment results within 30 days of receipt of the samples. If necessary, the laboratory will provide draft results within hours of receipt of the samples. Sample and quality control data will be reported in a standard format. The reports will also include a case narrative summarizing any problems encountered in the analyses.

Samples analyzed for phytoplankton species and biovolume data will follow procedures included in the Aquatic Analysts SOP in Appendix A. EcoAnalysts will count 200 to 400 zooplankton individuals, identifying to lowest practical taxonomic unit (i.e., genus, and species

when possible) following procedures outlined in their laboratory analysis SOP in Appendix A. Taxa reports and QC reports will be delivered within 90 days of sample receipt.

Data Reports

Data reports from the laboratory will present the test results clearly and accurately. Each lab report will include the information necessary for interpretation and validation of the data. Data reports will be submitted as PDFs. The laboratories will also provide electronic data deliverables (EDD). Lab reports will include the following:

- Report title
- Name and address of laboratory
- Name and address of client and project name
- Description and name of tested sample
- Date and time of sample collection, date of sample receipt, and date of analysis
- Identification of test method
- QC results for laboratory spikes and percent recovery of spiked samples, if applicable
- QC results for laboratory duplicates and relative percent difference of laboratory duplicates
- An explanation of failed QC and any non-standard conditions that may have affected the data quality
- Completed chain-of-custody record

Email updates will be submitted to the Herrera and City of Snohomish Project Managers after each sampling event providing notification of any issues or problems for which corrective actions have been taken. The results of all corrective actions or data quality assessments will be reported to the Project Managers upon completion.

Electronic Data

Field and laboratory data for this monitoring study will be entered into an Excel spreadsheet for all subsequent data management and archiving tasks. The Data Manager will perform an independent review to ensure that all the data were entered without error (see the Audits and Reports section).

QUALITY CONTROL PROCEDURES

To ensure the data quality objectives for this study are met, the project team will implement the procedures specified in the following subsections for field and laboratory quality control (QC).

FORMS AND CHECKLISTS

Standardized forms will be used on this project to ensure that all data are collected with maximum efficiency and to prevent gaps and inaccuracy in the data record. Data forms to be used for this project are located in Appendix B and include:

- A Snohomish County Lake Monitor data sheet, for volunteers to report: environmental data, waterfowl counts, sample collection information, and YSI calibration information before and after site visits.
- A Watershed Monitoring Field Form, for reporting discharge measurements and sample collection information gathered at stream/drainage stations
- Chain-of-custody forms, for submittal of samples to the analytical laboratories.

Field Operation Records

The sampler will document sampling event observations on standardized field forms. Documentation will be sufficient to enable participants to accurately and objectively reconstruct events that occurred during the project at a later time. Entries will be made in waterproof ink, dated, and signed. Project-specific field data forms/sheets will be used to capture field operations and observations (Appendix B). If corrections are necessary, these corrections will be made by drawing a single line through the original entry (so that the original entry is legible) and writing the corrected entry alongside. The correction will be initialed and dated. Corrected errors may require a footnote explaining the correction.

For all events, station ID, location, sampling time, sampling date, weather, and the sample collector's name are recorded. Detailed observational data from each station are recorded including water appearance, biological activity, stream uses, unusual odors, specific sample information, and missing parameters or changes in procedures. Field forms will be filed and included with the final report for this project.

Samples will be identified by station identification letters/numbers followed by the date the sample was collected in year-month-day format (i.e., BL1-20230621), except duplicate samples which will be labeled with a blind sample identification number (i.e., DUPE-20230621). Containers will be marked with indelible ink and labeled with the following information:

- Sample identification number

- Date of collection
- Time of collection, except for duplicates
- Analytical parameters
- Initials of field personnel and client

Laboratory Records

Laboratory reports will be retained as PDF files and electronic data deliverable files. Data quality review findings will be recorded on Laboratory Data Quality Assurance Worksheets (Appendix B).

Laboratory Quality Control Procedures

Laboratory QC samples are summarized in Table 10. The laboratory will analyze all the samples collected during each event in a single batch. By doing this, a single set of QC parameters will be applicable to all samples collected during each sampling event.

A method blank will be analyzed with each batch to assess potential contamination from sample handling in the laboratory.

The laboratory control sample (LCS) is sometimes referred to as a blank spike. The LCS is used to measure the accuracy of the laboratory by determining the ability of the lab to recover known amounts of target analytes in the absence of matrix effects.

The matrix spikes (MS) are samples that have known amounts of target analytes added to them in the laboratory. The laboratory measures the percent recovery of these compounds to estimate accuracy. Analytical precision is estimated by laboratory duplicates. The matrix spikes allow the laboratory to assess matrix interferences. Precision is also impacted by field variability since separate samples are being collected as field duplicates.

LCS and MS tests are not required for some of the parameters. Laboratory blanks and laboratory duplicate analyses provide sufficient QC data to meet the data quality objectives for this project.

Verification and Validation Methods

For the purposes of this document, data verification is a systematic process for evaluating performance and compliance of a set of data to ascertain its completeness, correctness, and consistency using the methods and criteria defined in the QAPP. Validation means those processes taken independently of the data-generation processes to evaluate the technical usability of the verified data with respect to the planned objectives or intention of the project.

Additionally, validation can provide a level of overall confidence in the reporting of the data based on the methods used.

All data obtained from field and laboratory measurements will be reviewed and verified for conformance to project requirements, and then validated against the data quality objectives which are listed in the Measurement Quality Objectives section. Only those data which are supported by appropriate quality control data and meet the measurement performance specification defined for this project will be considered acceptable and used in the project.

Roles and responsibilities are as follows:

- The **Field Sampler** is responsible for ensuring that field data are properly reviewed and verified for integrity.
- The **Laboratory Manager** is responsible for ensuring that laboratory data are scientifically valid, defensible, of acceptable precision and accuracy, and reviewed for integrity.
- The **Herrera Data Manager** is responsible for entering the data in the project database.
- The **Herrera Project Manager** is responsible for ensuring that all data are properly reviewed, verified, and submitted in the required format to the project database. The Herrera Project Manager is responsible for validating the data, and with the concurrence of the City of Snohomish Project Manager, is responsible for ensuring that all data to be reported meet the objectives of the project and are suitable for reporting.

All data will be verified to ensure they are representative of the sample batch (i.e., the samples collected during one sampling event) and locations where measurements were made, and that the data and associated quality control data conform to project specifications. The staff and management of the respective field, laboratory, and data management tasks are responsible for the integrity, validation and verification of the data each task generates or handles throughout each process. The field and laboratory tasks ensure the verification of raw data, electronically generated data, and data on chain-of-custody forms and hard copy output from instruments.

Laboratory data will be verified and validated within 7 business days of receiving the results from the laboratory (see *Audits and Reports* section). This review will be performed to ensure that all data are consistent, correct, and complete, and that all required quality control information has been provided. Quality control reviews, and any problems and corrective actions, will be summarized in a Quality Assurance Worksheet (Appendix B). Values associated with minor quality control problems will be considered estimates and assigned J qualifiers. Values associated with major quality control problems will be rejected and qualified R. Estimated values may be used for evaluation purposes, whereas rejected values will not be used. The following sections describe the data validation procedures for these quality control elements:

- **Completeness**– assessed by comparing valid sample data with this quality assurance project plan and the chain-of-custody records. Completeness will be calculated by dividing the number of valid values by the total number of values. If completeness is less than 95 percent, then samples will be reanalyzed or recollected if possible.

- **Methodology**– assessed by examination of the field notebook and laboratory reports for any deviations from this sampling and analysis plan. Unacceptable deviations will result in rejected values (R) and will be corrected for future analyses.

- **Holding times**– Holding times for each analytical parameter are outlined in Table 10. Analysis dates and times will be reported by the laboratory. Holding time compliance will be assessed by comparing analytical dates and times to sample collection dates and times. Values that exceed the maximum holding time by less than 2 times the holding time will be considered estimates (J), whereas severe exceedances (more than 2 times the holding time) will result in rejected values (R).

- **Method Blanks**– One preparation blank consisting of clean laboratory water will be analyzed with each sample batch, and the results will be reported in each laboratory report. Method blank values will be compared to the MQOs that have been identified for this project (see Table 10). If an analyte is detected in a method blank at or below the reporting limit, no action will be taken. If blank concentrations are greater than the reporting limit, the associated method blank data will be labeled with a U (in essence increasing the reporting limit for the affected samples), and sample values that are less than 5 times a detected blank value will be considered estimates (J).

- **Reporting Limits**– Reporting limits will be presented in each laboratory report. If the proposed reporting limits are not met by the laboratory, the laboratory will be requested to reanalyze the samples or revise the method, if time permits. Proposed reporting limits for this project are summarized in Table 10.

- **Duplicates**– Precision of laboratory duplicate results will be presented in each laboratory report. One laboratory duplicate will be analyzed with each batch of samples, and field duplicates will be analyzed as applicable (see Field Procedures section above). Duplicate results exceeding the MQOs for this project (see Table 10) will be noted in the quality assurance worksheets, and associated values may be flagged as estimates (J). If the objectives are severely exceeded (e.g., more than twice the objective), then associated values may be rejected (R).

- **Matrix Spikes**– Matrix spike samples are analyzed with each batch of samples. Percent recovery values that exceed the MQOs (see Table 10) will be noted in the quality assurance worksheets, and associated values may be flagged as estimates (J). If the objectives are severely exceeded (e.g., less than 10 percent recovery), then the associated values may be rejected (R). Data other than the original sample will not be flagged for only matrix spike exceedances.

- **Control Standards**– Control standards are analyzed with each batch of samples. Percent recovery values that exceed the MQOs (see Table 10) will be noted in the quality assurance worksheets, and associated values will be flagged as estimates (J). If the objectives are severely exceeded (e.g., more than twice the objective), then the associated values will be rejected (R).

- **Sample Representativeness**– The data collected for this study will be labeled with unique quality assurance flags for both laboratory and field data quality issues. Table 11 presents the flagging scheme that will be used in the reports produced for this project.

Table 11. Data Qualifier Definitions and Usage Criteria.

Data Qualifier	Definition	Criteria for Use
J	Value is an estimate based on analytical results.	MQOs for field duplicates, laboratory duplicates, matrix spikes, laboratory control samples, holding times, or blanks have not been met.
R	Value is rejected based on analytical results.	Major quality control problems with the analytical results.
U	Value is below the reporting limit.	Based on laboratory method reporting limit.
UJ	Value is below the reporting limit and is an estimate based on analytical results.	Based on laboratory method reporting limit; MQOs for analytical results have not been met.

CUSTODY PROCEDURES

The primary objective of chain-of-custody procedures is to provide an accurate written or computerized record that can be used to trace the possession and handling of a sample from collection to completion of all required analyses. A sample is in custody when any of the following conditions are true:

- The sample is in someone's physical possession
- The sample is in someone's view
- The sample is locked up
- The sample is kept in a secured area that is restricted to authorized personnel

A chain-of-custody form will accompany each set of samples. The chain-of-custody form (see Appendix B) indicates the name of the collector of the samples, date and time of collection, number of containers, tests to be performed, shipper, receiver, and date and time of shipping and receiving. Samples are to be placed on ice and delivered to the lab according to procedures pre-arranged with the lab (i.e., courier pickup).

Field Custody Procedures

The sampler will use the following guidance to ensure proper control of samples while in the field:

- As few people as possible will handle the samples.
- The Field Sampler will be responsible for the care and custody of collected samples until they are transferred to another person or dispatched properly under chain-of-custody rules.
- The Field Sampler will record sample data on standardized field data forms (see example in Appendix B).
- The Field Sampler will determine whether proper custody procedures were followed during the fieldwork and will decide if additional samples are required.
- The Field Sampler will be responsible for packaging samples, mailing or delivering samples to appropriate laboratories, and coordinating pick up with couriers. When transferring custody (i.e., releasing samples to a courier or mailing to a laboratory), the following rules will apply:
    - The container in which samples are packed will be sealed and accompanied by one copy of the chain-of-custody record. When transferring samples, the individuals relinquishing and receiving them must sign, date, and note the time on the chain-of-custody record. This record will document sample custody transfer.
    - Samples will be dispatched to the laboratory for analysis with separate chain-of-custody records accompanying each shipment. Shipping containers will be sealed with custody seals for shipment to the laboratory. The chain-of-custody records will be signed by the relinquishing individual, and the method of shipment, name of courier, and other pertinent information will be entered on the chain-of-custody record before placement in the shipping container.
    - All shipments will be accompanied by the original chain-of-custody record identifying their contents.

Laboratory Custody Procedures

A designated sample custodian at the laboratory will accept custody of the shipped samples from the carrier and enter preliminary information about the package into a package or sample receipt log, including the initials of the person delivering the package and the status of the custody seals on the coolers (i.e., broken versus unbroken). The custodian responsible for sample log-in will follow the laboratory's SOP for opening the package, checking the contents, and verifying that the information on the chain-of-custody agrees with samples received. The laboratory will follow its internal chain-of-custody procedures as stated in the laboratory QA Manual.

DATA MANAGEMENT AND STORAGE

The following procedures will be used to ensure that all data generated for the Blackmans Lake Cyanobacteria Management Plan project are accurately entered into the project database, are securely stored in a manner that facilitates data analysis and are properly archived.

Samples will be collected and transferred to the laboratory for analysis as described above. Data will be sent by the laboratories to Herrera (via the City of Snohomish in some cases) in PDF and electronic format within 30 days of receiving the water quality and sediment samples for analysis, and within 90 days of receiving plankton samples. Herrera staff will then review the data and complete a Quality Assurance Worksheet (Appendix B). The worksheet and the approved data will be submitted as part of project report.

All validated field and laboratory monitoring data will be entered into a Microsoft® Excel spreadsheet for subsequent data management and archiving tasks. Laboratory data for each analytical batch will be combined into one spreadsheet with one row for each sample, which allows for sorting and statistical analyses. Field data will also be combined into spreadsheets with one row for each observation or measurement. Continuous data will be combined into one excel file with a separate tab for each monitoring station and with one row for each value. Herrera's Data Manager will perform an independent review of all data entry to ensure individual sample values and data flags were entered without error. The project database will be submitted separate from the final project report.

Original field notebooks, field datasheets, and laboratory data sheets will be stored in the Herrera office for a 5-year period after completion of the project. The project database will be located on a network server in the Herrera office and backed up on a regular basis.

AUDITS AND REPORTS

The following section describes the procedures used to ensure that this QAPP is implemented correctly, that the data generated is of sufficient quality to meet the project objectives, and that corrective actions, if necessary, are implemented in a timely manner. The procedures include revisions, audits and response actions, corrective actions, and data quality assurance reporting.

REVISIONS TO THE MONITORING PLAN

In the event that significant changes to this monitoring plan are required prior to the completion of the study, a revised version of the document (with changes tracked) shall be

prepared and submitted to the City of Snohomish and Herrera project managers for review. The approved version of the monitoring plan shall remain in effect until the revised version has been approved. Justifications, summaries, and details of expedited changes to the monitoring plan will be documented in the monitoring report.

Audits and Response Actions

Audits will be conducted for field, laboratory, and data management activities, following the schedule outlined below in Table 12.

Table 12. Quality Assurance Audit Schedule and Response Actions.

Assessment Activity	Approximate Schedule	Responsible Party	Scope	Response Requirements
Field Measurement Audit	Within 7 days of completion of sampling event	Herrera Project Manager	Review of field notes and data	Annotate field notes and notify field staff within 3 days
Laboratory Measurement Audit	Within 7 days of receiving laboratory data reports	Herrera Project Manager	Review analytical and quality control procedures employed at laboratory	Laboratory to respond in writing within 3 days to address corrective actions
Data Entry Audit	Within 7 days of data entry	Herrera Data Manager	Review all data entry values	Correct errors and repeat audit until no errors found

Corrective Actions

The Herrera Project Manager is responsible for implementing and tracking corrective action procedures as a result of audit findings. Records of audit findings and corrective actions are maintained by the Data QA Officer in the project file. Documentation of quality assurance issues will be made by the Data QA Officer in the project file and in quality assurance worksheets, if applicable.

Upon completion of an audit, the results will be reviewed to determine if a deficiency has occurred, and whether the deficiency is classified as a nonconformance. Deficiencies are defined as unauthorized deviations from procedures documented in the QAPP. Nonconformances are deficiencies which affect data quality and render the data unacceptable or indeterminate. Deficiencies related to field and laboratory measurement systems include but are not limited to instrument malfunctions and quality control sample failures.

The Herrera Project Manager, in consultation with other affected individuals/organizations, will determine if the deficiency constitutes a nonconformance. If it is determined a nonconformance does exist corrective actions will be evaluated and implemented. Corrective actions may include the qualification of the data as estimates or rejected (R). If the data is qualified as rejected (R),

additional corrective actions may include collection of additional samples or reanalysis of the existing samples as authorized by the Herrera Project Manager.

Data Quality Assurance Report

The Herrera Project Manager will provide an independent review of the laboratory QC data from each sampling event using the MQOs that have been identified in this monitoring plan. A data quality assurance report will be prepared that summarize the following information:

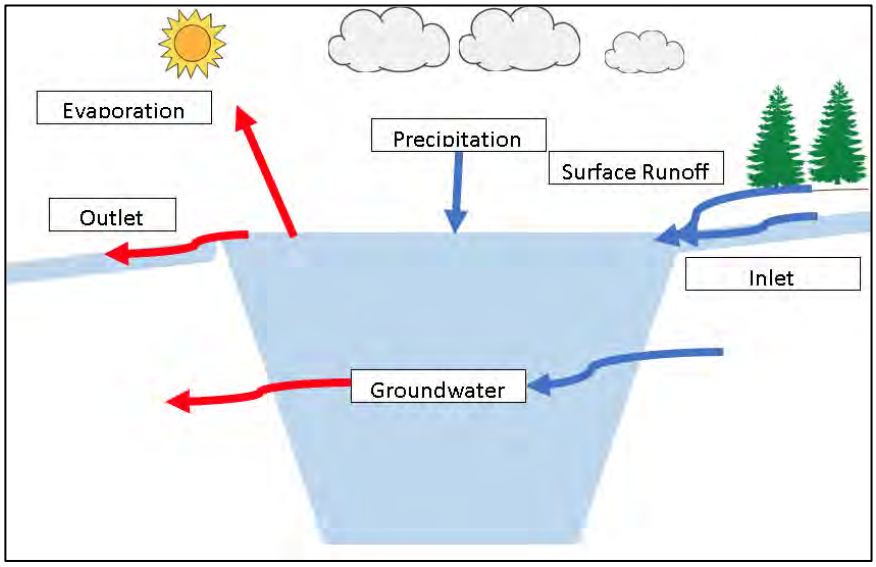
- Changes in the monitoring plan
- Significant quality assurance problems and corrective actions
- Data quality assessment in terms of precision, accuracy, representativeness, completeness, comparability, and detection limits
- Discussion of whether the quality assurance objectives were met, and the resulting impact on decision-making
- Limitations on use of the measurement data.

DATA ANALYSIS PLAN

Herrera will develop monthly water and phosphorus budgets for the 1-year monitoring period from October 2022 through October 2023. These water volume and nutrient mass balance budgets will consist of spreadsheet models accounting for all inputs/gains, outputs/losses, and change in lake storage amounts at monthly time steps.

WATER BUDGET

The water budget will account for all inputs and outputs of water as depicted in the following conceptual schematic.



Data sources will include:

- Input volumes of direct precipitation (DP) on the lake using data from the nearby rain gauge multiplied by the lake area.
- Stormwater runoff input volumes for each drainage basin will be estimated by the Simple Method (Shaver et al. 2007) multiplying the total monthly precipitation depth by the basin area and applying a runoff coefficient calculated from a formula based on the fraction of impervious area.
- Base flow input volumes for each drainage basin will be estimated using instantaneous measurements and observations of discharge at monitoring stations and extrapolating over the study year.

- Output volumes for the lake outlet (BLK_OUT) by converting daily lake stage to outlet discharge based on calculations for a sharp-crested weir using the lake level and the elevation of the four vertical overflow standpipes at the outlet culverts (discussed in Field Procedures).

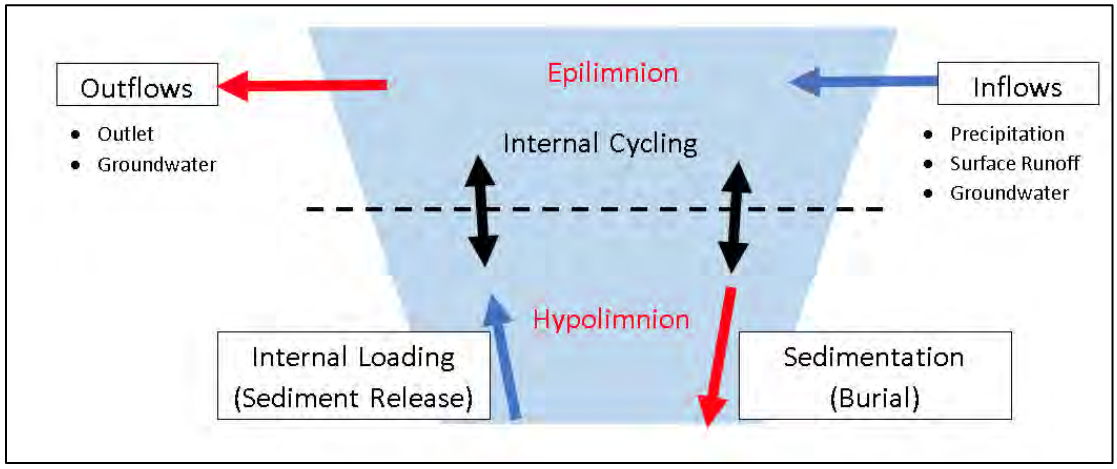
- Output volumes for lake evaporation (EV) using the Penman formula for the evaporation rate from a lake that is simplified to the following: EV (mm/day) = 700 Tm/(100 – A) + 15 (T – Td) (80 – T) where Tm = T + 0.006h, h is the elevation (meters), T is the daily mean temperature (°C), A is the latitude (degrees), and Td is the daily mean dew-point (°C).

- Change in lake storage volume (LS) based on lake level and bathymetric data.

- Net groundwater (GW) input and output volumes, including wetland exchange, based on residual gains and losses from all other estimated sources of water in the lake. These will be compared to the estimates from the 1994 KCM study.

PHOSPHORUS BUDGET

The phosphorus budget will account for all inputs and outputs of total phosphorus (TP) as depicted in the following conceptual schematic. Historical data indicate that Blackmans Lake has a strong annual thermocline and often hypoxic hypolimnion during the summer months as indicated in the conceptual schematic. Internal cycling occurs in a lake regardless of thermal stratification.



Data sources will include:

- Inputs of direct precipitation phosphorus (PP) based on TP concentrations in rainfall samples collected by others in the region using an average value of 24 µg/L based on measured values ranging from 8 to 33 µg/L for five lakes in western Washington and

accounting for all atmospheric deposition (Ecology 2013) and multiplied by the direct precipitation volume (PL).

- Inputs of surface drainage based on surface inflow volumes and TP concentrations measured in storm and base flow samples and using either annual or seasonal arithmetic average or flow-weighted average TP concentrations depending on observed patterns in the TP data. TP concentrations for unmonitored basins will be based on those for monitored basins with similar land cover/use. These TP concentrations and loadings will be compared to the estimates from the 1994 KCM study.

- Inputs of groundwater from net groundwater inflow volumes and TP concentrations in base flow drainage samples. These will be compared to the estimates from the 1994 KCM study. Inputs of groundwater from wetlands will be considered by comparing changes in TP concentrations passing through wetlands from BLK-22 to BLK-MTH.

- Inputs from waterfowl feces and aquatic macrophyte decay based on lake observations and literature values for phosphorus content.

- Outputs from the lake outlet stream based on the lake outlet flow volumes and TP concentrations in BLK-OUT and lake surface water samples.

- Outputs of groundwater from net groundwater outflow volumes and TP concentrations in BLK-OUT and lake surface water samples. These will be compared to the estimates from the 1994 KCM study.

- Change in lake phosphorus storage from lake volume change and TP concentrations in the lake.

Net outputs from lake sedimentation and net inputs from internal sediment phosphorus release are based on the mass balance residual of all phosphorus inputs and outputs. Phosphorus sedimentation rates will be estimated from the net residual output in the winter months assuming no internal loading input and those rates will be applied to summer months based on lake phosphorus concentrations. Net inputs during the summer months will be attributed to internal sediment phosphorus release. Summer inputs of internal sediment phosphorus release will also be estimated by comparing results of multiple methods, including sediment release equations from the literature based on total and available phosphorus concentrations in lake sediments (Pilgrim et al. 2007 and Nurnberg 1988, 2009) and by calculating the accumulation of phosphorus mass in the hypolimnion during the summer (Nurnberg 2009). For comparison, annual phosphorus loss from the lake (sigma) will be estimated from the mean lake hydraulic residence time (lake volume divided by total lake inflow volume) based on the equation developed by Brett and Benjamin (2008).

Herrera will identify potential algae management methods to reduce the frequency and duration of toxigenic algae blooms based on the lake monitoring results and water and nutrient budgets. Potential management methods may include, but not be limited to, watershed methods such as:

- Stormwater management to include phosphorus treatment of runoff from new and existing development
- Agricultural and hobby farm best management practices
- Septic system maintenance and upgrades
- Sanitary sewer connection or wastewater management
- Stream and wetland restoration.

Potential management methods may include, but not be limited to in-lake methods such as:

- Phosphorus inactivation using alum or Phoslock
- Lake circulation by aeration or mechanical devices (e.g., SolarBee)
- Lake oxygenation using nanobubbles or hypolimnetic aeration
- Ultrasonic control of algae (e.g., LG Sonic).

Herrera will estimate the reduction in phosphorus inputs, algae biomass (as chlorophyll a), and the frequency of toxic algae blooms for each potential management method. Phosphorus reductions will be estimated from the phosphorus budget using literature values for other lakes based on specific attributes of Blackmans Lake. Algae biomass reductions will be estimated from ratios of phosphorus and algae concentrations observed in Blackmans Lake. Toxic algae bloom reductions will be based on reductions in algae biomass, trophic state, and other factors favoring a shift in dominance types of algae that do not produce toxins (i.e., those other than cyanobacteria). The relative certainty in the reduction estimates will be identified in addition to indirect benefits/impacts and advantages/disadvantages of the methods.

Herrera will evaluate sediment phosphorus fraction data and water column phosphorus data to calculate the amount of either aluminum from a buffered aluminum sulfate (alum) treatment, or Phoslock (bentonite with lanthanum) that would be needed for sediment phosphorus inactivation. The amount of aluminum needed for sediment phosphorus inactivation by alum treatment will be calculated using methods developed by Herrera and other researchers.

Among the potential management methods, Herrera will identify the most feasible management methods, with preference for long-term solutions, that are predicted to substantially reduce algae biomass and toxic algae blooms in Blackmans Lake. Planning-level costs will be estimated for the feasible management methods. Up to three algae management scenarios will be developed using one or a combination of feasible methods that represent a range of costs and benefits. Stakeholder input (i.e., from the City of Snohomish, various Snohomish County departments, public, and Ecology) on the management scenarios will be obtained and used to develop one preferred management scenario. Potential funding options for implementation of the management plan will be identified.

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APPENDIX A

Standard Operating Procedures (SOPs)

Blackmans Lake Drainage Sampling Instruction Sheet

Equipment

- Bottles, cooler, and ice
- Swoffer current meter for discharge measurement
- Ruler in tenths of feet
- Measuring tape and two stakes for cross section discharge
- Waders/boots
- High Viz vest
- Manhole puller
- Bottle grabber tool or cup on a stick

Visit Order	Locator	Where to Park	What to Sample/Measure	Equipment
1	BLK-26	South shoulder of 26th St (aka 60th St SE) just E of Lake Ave (aka 99th Ave SE)	Total Phosphorus Discharge in culver outlet	Hand grab sample Swoffer/ruler
2	BLK-22	Faith Church lot at 1220 22nd St.	Total Phosphorus Discharge in culvert outfall	Hand grab sample Swoffer/ruler
3	BLK-NE	Faith Church lot at 1220 22nd St.	Total Phosphorus Discharge in E channel to culvert inlet; estimate W channel flow proportion	Hand grab sample Swoffer/ruler
4	CHAMP-19	Electric box across from 704 19th St	Total Phosphorus Discharge in channel	Hand grab sample Swoffer/ruler
5	CHAMP-PARK	Across street from 1802 Park Ave	Total Phosphorus Discharge in catch basin E inlet pipe	Manhole puller Bottle grabber Swoffer
6	BL-GAUGE	Hill Park at 1610 Parke Ave	Lake stage at gauge on nearshore, left side of Fishing Pier	None
7	BLK-OUT	Ferguson Park near lake outlet	Discharge in 4 outlet pipes	Swoffer/ruler
8	SWIFTY	West shoulder of Ave A	Discharge in channel or culvert outfall if can't measure in outlet pipes	Swoffer/Measuring Tape

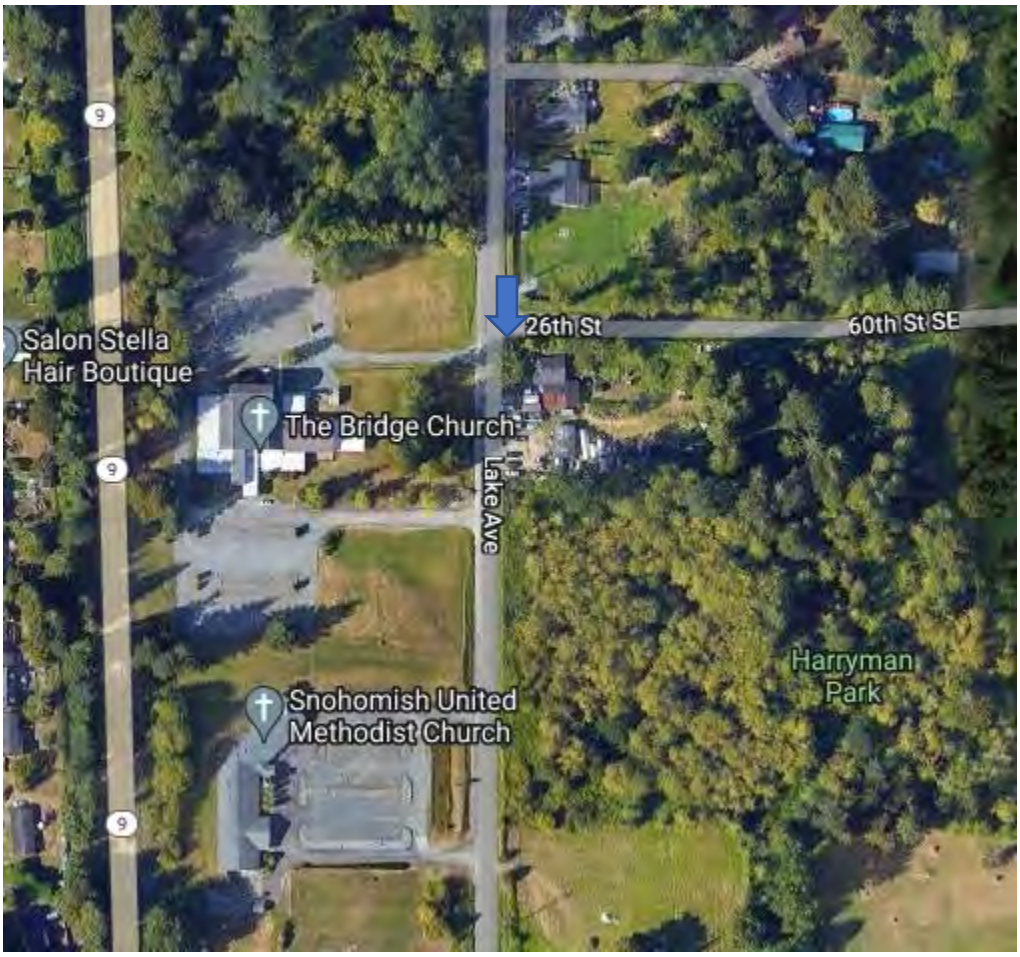
1. BLK-26

Parameters

- Total Phosphorus
- Water discharge in culvert outfall

Where to park

- On south shoulder of 26th St just east of Lake Ave



1. Walk to outfall of culvert crossing Lake Ave on south side of 26th St that conveys water south in a ditch on the west side of Lake Ave and enters the culvert just north of the north driveway of The Bridge Church
2. Grab TP sample bottle with a grabbing tool, remove cap, rinse and then fill bottle with outflow from culvert, and replace cap.
3. Measure the average depth and velocity of water (or multiple cross section measurements) with a Swoffer/ruler in partially filled culvert.

2. BLK-22

Parameters

- Total Phosphorus
- Water discharge in 24-inch culvert outfall from velocity and depth in center of pipe

Where to park

- Park in Faith Church eastern driveway off of 22nd St / 64 St SE at 1220 22nd St, Snohomish, WA 98290
- This is the same parking spot for BLK-NE
- BLK-22ND is just across the street, just east of the driveway. Water flows to culvert inlet on north side of 22nd from a 12-inch metal culvert to the west and from a ditch to the east.

1. Walk down short steep road embankment on north side of 22nd to the 24-inch concrete culvert outfall pipe and carefully sit on bank with feet resting on top of pipe.
2. Grab TP sample bottle with a grabbing tool, remove cap, rinse and then fill bottle with outflow from culvert, and replace cap.
3. Measure depth and velocity of water at center of culvert with Swoffer current meter.

3. BLK-NE

Parameters

- Total Phosphorus
- Discharge

Where to park

- Same as BLK-22

1. Walk to inlet of 24-inc concrete culvert on north side of 22nd
2. Sample inflow to the culvert from the east ditch
3. Measure discharge in the east ditch.
4. Estimate discharge in the west ditch that originates from 12-inch metal culvert under Church driveway

4. CHAMP-19TH

Parameters

- Total Phosphorus
- Discharge

Where to park

- Park on south side of 19th Street next to electric panel and mailbox across from 704 19th St. Snohomish, WA 98290
- On south side of street, follow fence on right of drainage channel and step over channel to sample and measure discharge in open channel free of vegetation

1. Collect sample from short straight section of narrow channel that has been cleared of vegetation.
2. Waders/boots should not be necessary
3. Measure average depth and velocity and total width in channel

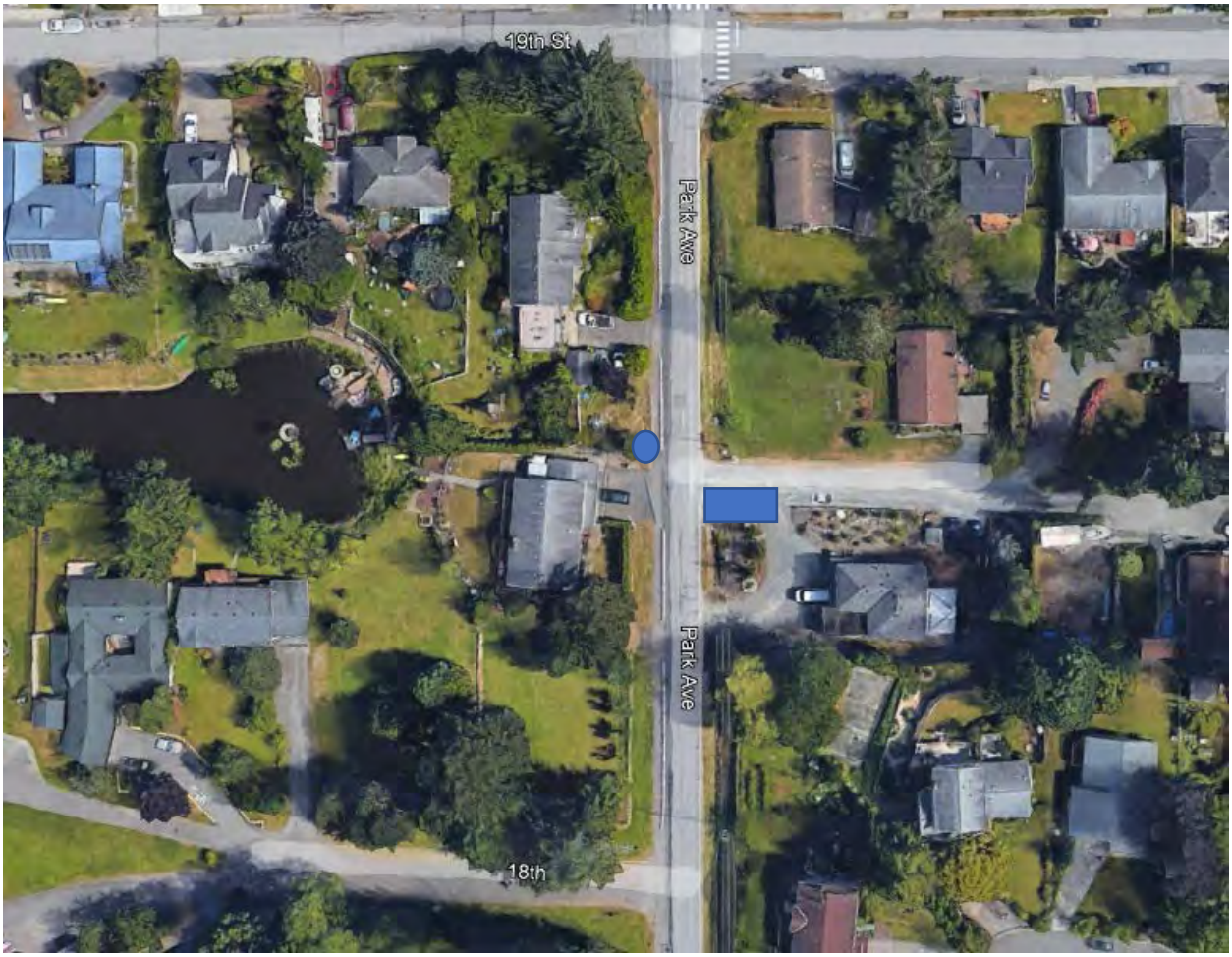
5. CHAMP-PARK

Parameters

- Total Phosphorus
- Discharge

Where to park

- Park on south side of gravel road across street from 1802 Park Ave (see blue rectangle).
- Catch basin is a low point on north side of the residence driveway of 1802 Park Ave (see blue circle). The inflow “bird cage” structure is across the street, just north of parking area.



1. Use manhole puller to remove catch basin grate, or just turn it over by hand
2. There is a filter sock here, which may be filled with gravel. Carefully remove sock and set aside.
3. Collect water sample from catch basin outlet (away from street) using bottle grabbing tool or pole sampler
4. Measure depth and velocity of in center of 24-inch PVC east inlet pipe and in 24-inch HDPE west outlet pipe with Swoffer.

Figure 1. Catch basin, will need to remove sock. may be filled with gravel.

6. Lake Staff Gauge BI

Where to park

- HIll Park at 1610 Park Ave, follow park entrance to parking lot and walk to Fishing pier on the left

Parameters

- Lake surface elevation to 1/100 ft on County's lake staff gauge near shore on left side of pier.

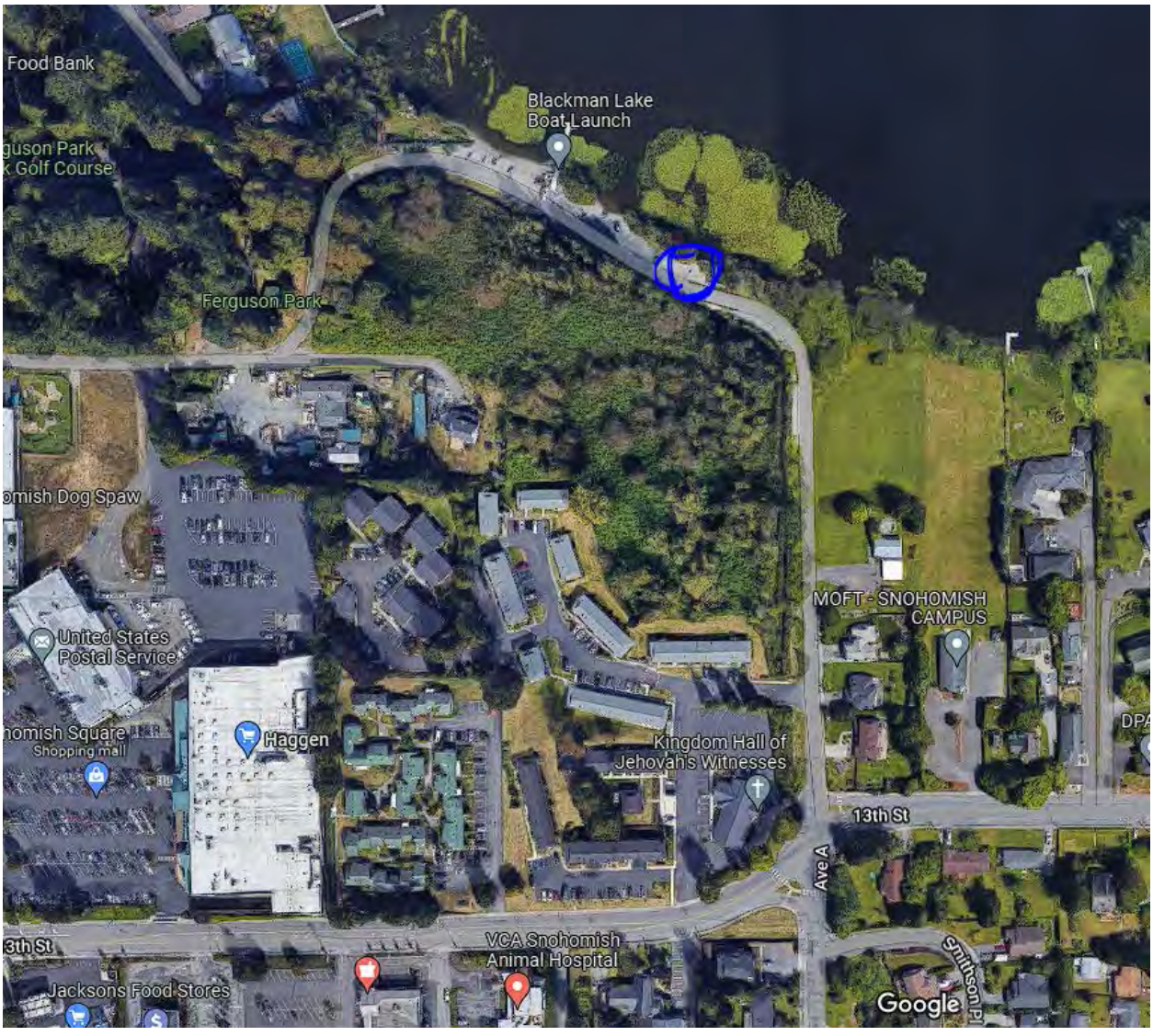
7. BLK-OUT

Where to park

- Ferguson Park, west side of bridge in gravel area or on south shoulder of Ave A east of pipe outlets

Parameters

- Average water depth and velocity in center of each of 4 outlet pipes



1. Walk onto platform and photograph the inlets to the 4 lake outlet pipes and note inflow or debris clogging
2. Walk across Ave A to shore of pond where four 18-inch green PVC pipes outfall into pond. Wade into pond and measure the average depth and velocity of water with a Swoffer/ruler at center of each outlet pipe .

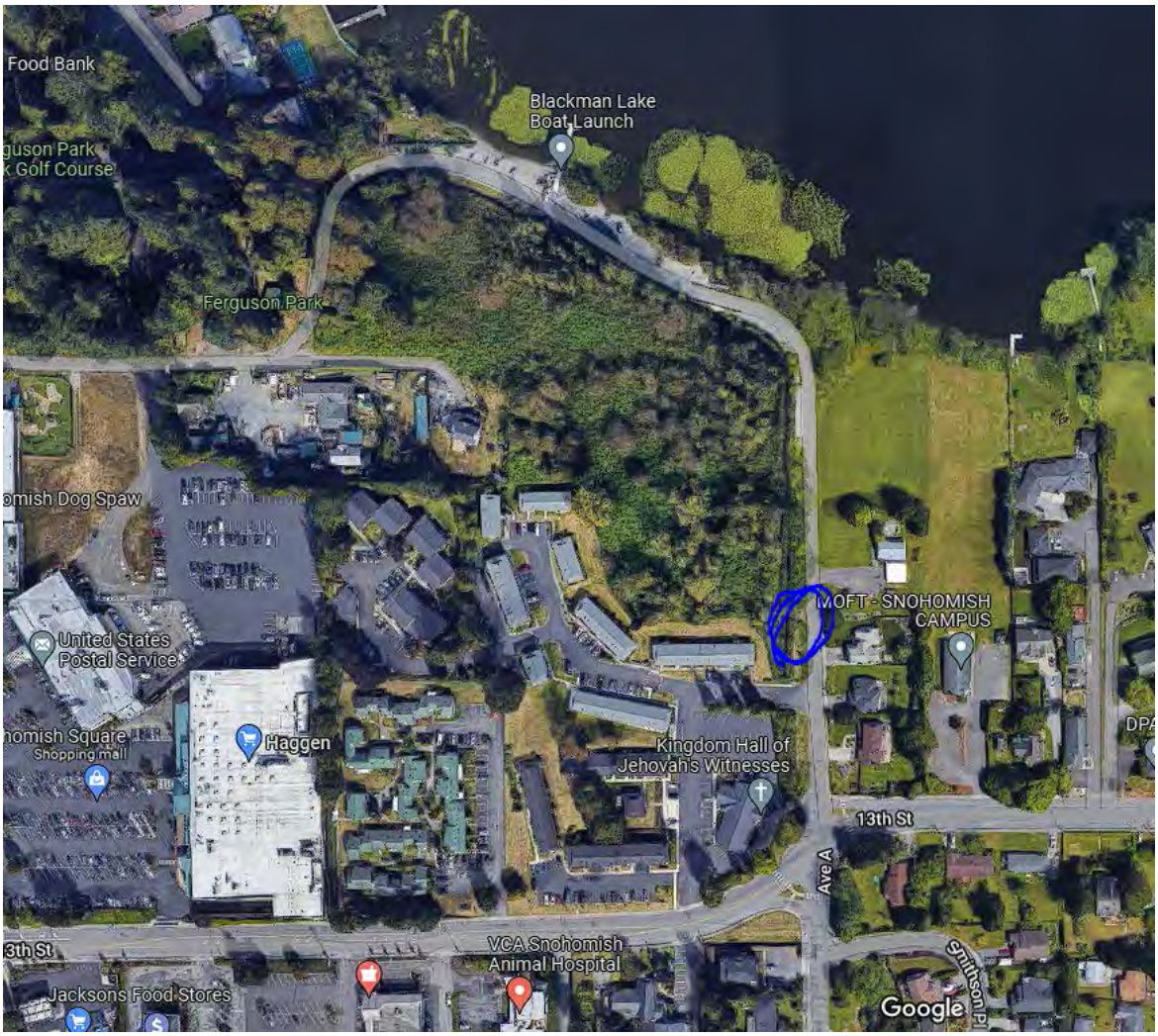
8. SWIFTY

Parameters

- Discharge if can't measure discharge in four outlet pipes

Where to park

- On west side of Avenue A in gravel shoulder, just north of driveway/bridge to Kingdom hall



1. There is an access point to the stream near the gravel pullout. Look for an area without shrub.
2. There's a good amount of willow in the stream channel, and the channel is very wide, shallow, and has gradual slope. Hopfully when there is lake overflow, the discharge is substantial enough that channel modification is needed to measure discharge.

Swifty Creek channeling, looking north

Swifty creek bank at access point.

APPENDIX A:

SNOHOMISH COUNTY LAKES VOLUNTEER MONITORING MANUAL

February 2003

Revised January 2011

Revised March 2015

Revised December 2018

Surface Water Management Division

Public Works Department

Snohomish County

Acknowledgements

Volunteers

To our past, present, and future volunteers, this program would not be possible without your dedication.

Department of Ecology Centennial Clean Water Fund

The Snohomish County Volunteer Lake Monitoring Project was initiated in 1992 with funds from the State of Washington through a Centennial Clean Water Fund Grant.

Washington State Department of Ecology

Washington Department of Ecology. A Citizen's Guide to Understanding and Monitoring Lakes and Streams. November 1999.

The monitoring methods presented in this manual are also patterned after those used in the Department of Ecology's volunteer lake monitoring program during the 1990s.

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Overview of Snohomish County Lake Monitoring Program

Thank you for participating in Snohomish County's Lake Monitoring Program. Your efforts are essential in helping all of us protect the lakes in Snohomish County. Regular monitoring provides the basic information about the condition of lakes in our county. This information helps the County and the public better manage our lakes.

The goal of the Snohomish County Lake Monitoring Program is to collect data that will support short and long-term management decisions that protect lakes, promote public health and safety, and build a foundation for understanding the nature and character of the county's lakes. Specific objectives of the monitoring program are:

- Assess current water quality status of the county's lakes.
- Identify long-term changes in water quality.
- Identify specific water quality problems at individual lakes.
- Identify lakes that need additional study or specific actions to solve water quality problems.
- Identify toxic algae blooms and notify the public of health risks.
- Involve Snohomish County residents in monitoring their lake's health.

This volunteer manual will cover basic information about lakes and the information volunteers will collect. This manual will also cover detailed instructions on how to collect data.

What is a Volunteer's Role in this Program?

From May to October, volunteers will regularly perform simple scientific measurements at their lakes. Snohomish County staff will provide field equipment and training annually. Measurements include water clarity, temperature, total phosphorus, total nitrogen, chlorophyll a, and lake level. Observations include water color, weather conditions, and other conditions in the lake and watershed. Some volunteers may also measure dissolved oxygen and temperature profiles.

At the end of the year, County staff will prepare a brief report on the status of county lakes based on the results of volunteer monitoring. This report will summarize the general condition of each lake and compare lakes within Snohomish County.

General Lake Information

This section provides basic information about lakes.

Lakes and Watersheds

Lakes are standing bodies of water an acre or more in size. Lakes are closely linked to their surrounding watersheds. A watershed is simply the land area that drains into a lake. Everything that happens in the watershed affects the lake in some way.

The watershed supplies the water that sustains the lake. Water enters the lake from precipitation that falls on the lake surface itself and from precipitation in the watershed that runs off into the lake. Precipitation also percolates through the soil to the groundwater and may ultimately seep into the lake.

Watersheds affect the chemical and biological conditions of the lake water. Water from the watershed carries with it many chemicals and other materials. Runoff washes over plants, dirt, roads, and driveways, picking up

materials, dissolved substances, and organic matter. All of these substances are deposited in the lake. Groundwater also transports dissolved chemicals into the lake. The substances transported into the lake by runoff and groundwater affect the clarity of the water, the amount and types of algae and rooted aquatic plants in the lake, and even the abundance of fish in lake. In addition, if pollutants are present in the watershed, the lake is likely to receive some of them and to suffer because of it.

Temperature, oxygen, and other chemical properties of the water also affect the lake condition. During spring and summer, the upper water in a lake is warmed by the sun. Because warmer water is less dense, it tends to float above the cooler and denser water below, forming two distinct layers. During this period of solar warming, the lake may be stratified into two layers that do not mix. Fresh oxygen from the atmosphere is no longer supplied to the bottom waters because of the thermal separation or stratification. If there is an abundance of decaying matter on the lake bottom, the decaying process consumes oxygen, potentially reducing the oxygen content of the lower waters. This can stress fish and introduce nutrients from the lake bottom that stimulates algae production.

In the fall, as the upper waters cool, the temperature difference between the lake layers decreases. Eventually, the wind and waves are able to overcome the density forces separating the two layers and the entire lake mixes again. This phenomenon is called fall turnover. During turnover, dissolved nutrients from the lake bottom are distributed throughout the lake. This can fertilize the growth of algae and cause algae blooms.

Lake Eutrophication

Lakes, like all geologic formations, are not permanent features of the landscape. All lakes move through a cycle, from creation to dry land. This process, similar to aging, happens because of eutrophication. Eutrophication, which literally means “well nourished,” occurs as lakes are enriched by excess nutrients and sediment, primarily from the surrounding watershed. The nutrients and sediment nourish plant and algae life in a lake. Given enough nourishment, plants will eventually take over the entire lake. Under natural conditions, this cycle takes tens or hundreds of thousands of years because undisturbed watersheds are relatively stable. However, human activity often dramatically accelerates this process by disturbing the soil and vegetation within the watershed, as well as directly contributing nutrients to the lake.

Most of the lakes in Snohomish County were formed by glaciers. When the lakes were newly formed, they were crystal clear, with little plant or animal life because the level of nutrients was low. Nutrients, such as phosphorus and nitrogen, are the basic food of algae and other plants. A few of the Snohomish County lakes are still at this early stage of life, with very clear water and limited plants. The trophic status of these lakes is called “oligotrophic.”

Over time, sediment and nutrients wash into a lake from the surrounding watershed. Algae, which are microscopic plant-like organisms suspended in the water, are the basis of the food pyramid in a lake. Microscopic animals called zooplankton feed on the algae, and the zooplankton in turn are eaten by fish and other animals. As a lake becomes richer in nutrients, more algae and more floating-leaved plants, such as lily pads, begin to grow in the water. The plants provide food and habitat for fish and other animals.

When the algae and plants die and sink to the bottom, they decompose, adding sediment to the lake. The lake gradually becomes shallower. With more nutrients and plant growth in the lake, the water is no longer as clear. The lake is now in the middle, or “mesotrophic”, stage of eutrophication. Some of our lakes in Snohomish County are at this stage.

When there is an excessive amount of nutrients available for plants, algae blooms may occur. Algae blooms are dramatic explosions of algae that can form scums and cloud the water. This usually happens during summer months when light and temperature are optimal for plant growth. But, blooms can also occur after the lake turns over in the fall or winter and nutrients become mixed throughout the water.

An excessive amount of nutrients in the water may also cause the algae species in a lake to change. Algae species that are eaten by zooplankton and fish are often replaced by blue-green algae species, which are not easily eaten by animals. Large populations of blue-green algae are usually indicators of polluted or threatened lakes.

When lakes reach the stage where they contain excess nutrients, especially phosphorus, and support vigorous growths of algae and plants, the lakes are considered to be "eutrophic." Eutrophic lakes often exhibit low levels of oxygen. Decomposition of dead plant matter collected on the bottom uses up oxygen. When a lake is stratified, divided into layers by temperature, this lack of oxygen may allow the release of nutrients from the lake bottom back into the water to be used again and again by plants and algae. Some Snohomish County lakes are at this advanced stage of eutrophication.

Human Activities That Cause Water Quality Problems

The natural life cycle of a lake takes thousands of years. However, human activities within a lake's watershed may introduce excess nutrients and sediment that greatly speed up the process of eutrophication. Activities that can affect lake water quality include:

- use of fertilizers and pesticides, especially in large quantities near the water.
- use of detergents and household products containing phosphates and toxic chemicals.
- excess waterfowl and pet wastes.
- runoff from roads, driveways, rooftops, and other hard or paved surfaces.
- land clearing and development that causes erosion into streams or the lake.
- septic systems that are poorly maintained or improperly designed.
- agricultural practices, inducing animal access to streams or the lake.

All of these activities add nutrients and/or sediment to the lake and hasten the process of eutrophication. These activities are difficult to control, however, because they involve almost every property in a watershed to some degree or another. This is why public stewardship of lake water quality is so important. Unless we all take steps to protect water quality, our lakes will suffer.

Significance of Volunteer Monitoring Data

Volunteers collect a wide variety of data to assist in understanding the condition of Snohomish County lakes. The results of lake monitoring can be used to identify problems and solutions that residents and others can use to protect and improve lakes.

Water Clarity

Volunteers will use a Secchi disk to measure the clarity of the water. A Secchi disk is about 8 inches in diameter and is painted black and white in alternating quadrants. A rope is attached to the disk and marked in tenths of a meter. Volunteers lower the disk into the water and record the depth at which it can no longer be seen. This depth is called the Secchi disk depth or transparency of the lake. An online Secchi reading simulator can be found at http://www.mainevolunteerlakemonitors.org/recertify/disk.php?.

The Secchi disk is a convenient method for determining water quality. It measures how far light can penetrate through the water. Secchi depth readings will vary with the clarity of the water. The more suspended material, such as algae and sediment, in the water, the shallower the Secchi depth reading. The clearer the water, the deeper the Secchi disk can be seen.

The amount of suspended material in the lake may fluctuate during the monitoring season. During periods of heavy rain and runoff, silt and other soil particles may be washed into the lake, clouding the water. During summer, populations of algae may grow in response to the increased light and warmth. Secchi depth readings will be shallower during such periods because of the amount of algae suspended in the water. In some lakes, the water is colored because surrounding wetland and peat soils release natural tannins into the water. This will also reduce the Secchi depth readings.

Poor water clarity affects fish and aquatic life in several ways. Sunlight may be blocked from reaching submersed aquatic plants. These plants need light for photosynthesis. If photosynthesis is restricted, the plants will produce less oxygen for fish and aquatic life. Suspended matter in the water can clog the gills of fish and shellfish and can also interfere with animals that are dependent on visibility to find food.

Water clarity is one of the indicators of the water quality of a lake. Shallow Secchi depth readings may indicate that there is an excess of algae and/or sediment in the water. Progressive declines in Secchi depth may tip us off to problems at a stage when the problems can still be solved. We can also use Secchi depth measurements to scientifically classify the condition of a lake in regard to the eutrophication process. Lakes with poor water clarity are often eutrophic and suffer from nutrient enrichment.

Temperature

Temperature is a simple measurement and one of the most important parameters to monitor in a lake. Temperature dramatically affects the rates of chemical reactions and biological activity in the water, which in turn affect water quality. Warmer water generally increases the rates of plant and algae growth, as well as that of many animals. On the other hand, warm water is able to hold less oxygen than cold water. Cold-water fish, such as trout and salmon, cannot survive in very warm water. Warm water also accelerates the decay of organic matter in a lake, using up more oxygen in the water.

Volunteers will measure the surface temperature of their lakes. This will give an indication of how warm or cool the lake becomes and how quickly the water temperature changes through the seasons.

Some volunteers will have equipment allowing them to measure the temperature at different depths within the lake. This is especially important information for lakes. It provides information about conditions in the lake that may affect oxygen levels and algae growth, as well as how the lakes mix.

During the spring and summer months, the surface waters of a lake will be warmer than deeper waters because of heating by the sun. During this period, the two layers of water will not mix because colder water is more dense than warmer water. The greater the temperature

Table 1 Comparison of Celsius to Fahrenheit

Celsius (°C)	Fahrenheit (°F)
0	32
1	34
2	36
3	37
4	39
5	41
6	43
7	45
8	46
9	48
10	50
11	52
12	54
13	55
14	57
15	59
16	61
17	63
18	64
19	66
20	68
21	70
22	72
23	73
24	75

difference, the stronger the separation of water layers. While a lake is stratified, or divided into layers, oxygen from the atmosphere cannot reach the lower waters. If there is sufficient decaying matter in the lake, the oxygen content of the lower waters will soon be depleted. This can threaten fish and animal life. Lack of oxygen can also release nutrients from the bottom sediments that fuel the growth of undesirable algae.

In the fall, the upper waters cool until the entire lake is close to the same temperature. Then, wind and waves will mix and "turn over" the lake from top to bottom. Oxygen will be restored to the bottom waters, but nutrients accumulated during the period of stratification are available for rapid algae growth. Temperature measurements by volunteers will provide information about the timing and strength of lake stratification and turnover.

Volunteers will be measuring temperature with thermometers marked in degrees Celsius or with electronic temperature probes. Using the Celsius scale will make the volunteer-collected data comparable to data from other monitoring programs and more useful for scientists. For reference, Table 1 compares degrees Celsius and Fahrenheit.

Dissolved Oxygen

Dissolved Oxygen is another important measurement for lake water quality. Oxygen dissolved in the water is essential for all plants and animals in the lake. When oxygen levels in the water fall below 3-5 mg/L (milligrams per liter or parts per thousand), many fish and other animals cannot survive. When oxygen levels fall below 2 mg/L, a chemical reaction can occur that releases nutrients from the bottom sediments.

Oxygen enters the water at the surface of a lake from the atmosphere. The mixing action of wind and waves assists oxygen transfer from the atmosphere to the water. Oxygen is introduced into lake water also by aquatic plants and algae as a by-product of photosynthesis.

Dissolved oxygen levels in a lake will vary over time and with depth. For example, in a productive lake, oxygen levels increase during the daytime as aquatic plants and algae release oxygen during photosynthesis. During the night, the plants and algae take up oxygen as they respire, lowering oxygen levels in the water. Oxygen levels increase after storm events, strong winds and waves, and during the winter when the entire lake is well-mixed.

In the spring and summer, oxygen levels will decrease in bottom waters because stratification prevents oxygen from being re-supplied from the atmosphere. Oxygen is also consumed by the bacteria that decompose organic matter on the lake bottom. This low oxygen condition persists throughout the summer until fall turnover provides fresh oxygen from the atmosphere. However, in some lakes, oxygen levels may actually decrease after fall turnover because of the huge oxygen deficit that has been created through the rapid decomposition of organic matter in the lake bottom during the summer.

Another fact to know is that warm water holds less oxygen than cold water. **Table 2** shows the maximum amount of oxygen that water can hold at different water temperatures, also known as 100% saturation.

Table 2 Solubility of Dissolved Oxygen in Water

Temperature (°C)	Dissolved Oxygen (mg/L)
0	14.6
4	13.1
8	11.9
12	10.9
16	10.0
20	9.2
24	8.6
28	7.9

Snohomish County staff will visit each lake at least once during the year to measure dissolved oxygen and temperature levels. Some volunteers will also be given instruments to measure the amount of oxygen at different depths in the lake. Together with temperature information, data on dissolved oxygen will provide an indication of the biological and chemical conditions in each lake.

Phosphorus

Phosphorus is an essential nutrient for the growth of both plants and animals. Phosphorus occurs naturally in the soil and rocks and can be found in all plant and animal tissue, as well as attached to particles in the atmosphere.

Phosphorus may enter a lake in multiple ways. Phosphorus can be deposited from the atmosphere as dust directly onto the surface of the lake. It can be released from the watershed by the weathering of rocks and soils, and transported by surface runoff and streams to the lake. Human impacts in the watershed can increase the amount of phosphorus in runoff. Sources of phosphorus include lawn fertilizers, agricultural fertilizers, wastes from pets and farm animals, runoff from roads, roofs, and paved areas, land clearing and soil erosion, and poorly maintained or failing septic systems.

Phosphorus is important to algae growth and is usually the limiting factor in biological productivity in a lake. Phosphorus is usually measured in two components—soluble phosphorus and total phosphorus. Soluble or dissolved phosphorus is that portion of the phosphorus that is immediately available for use by algae. Total phosphorus includes both soluble phosphorus and other forms of phosphorus that may be attached to soil particles or contained within the cells of algae and zooplankton.

Too much phosphorus in a lake can lead to nuisance algae blooms, and lake eutrophication. A eutrophic lake can have multiple water quality issues associated with the excess amount of algae growth caused by too much phosphorus. These could include toxic algae blooms, interference with recreational activities and boating, decline in fish and wildlife habitat, and aesthetic problems.

It is important to know the concentration of phosphorus in a lake to assess the degree of eutrophication. Snohomish County staff or volunteers will collect monthly samples at different depths in each lake to measure the phosphorus concentrations.

Nitrogen

Nitrogen is also an essential nutrient for the growth of plants and algae. Various forms of nitrogen can be found in water, including organic and inorganic forms. Organic forms of nitrogen are derived from living organisms and include amino acids and proteins. Inorganic forms are composed of materials other than plants or animals and include nitrate, nitrite, ammonia, and nitrogen gas. Total nitrogen is a measure of all the various forms of nitrogen found in a water sample, except for nitrogen gas. In general, algae and aquatic plants directly utilize inorganic forms of nitrogen.

Like phosphorus, nitrogen can enter the lake in multiple ways. Some algae can "fix" or pull gaseous nitrogen from the atmosphere and convert it to a usable form. It can be transported by surface runoff and streams to the lake. Human impacts in the watershed can increase the amount of nitrogen in runoff. Sources of nitrogen include lawn fertilizers, agricultural fertilizers, wastes from pets and farm animals, runoff from roads, roofs, and paved areas, and poorly maintained or failing septic systems.

It is useful to know total nitrogen concentrations in a lake to assess the ratio between phosphorus and nitrogen. This ratio is a useful tool to understand the relative importance of these nutrients and algae abundance in a lake. Snohomish County staff or volunteers will collect monthly samples at different depths in most lakes to measure the total nitrogen concentrations.

Chlorophyll-a

Chlorophyll-*a* is a photosynthetic pigment present in all algae and aquatic plants. In the process of photosynthesis, chlorophyll captures light energy, using it to combine carbon dioxide and water into sugar, and storing the energy as chemical energy. Because chlorophyll-*a* is present in all algae and is such an important component of algae growth, it is used as a measure of algae biomass in lakes.

Knowing the concentration of chlorophyll-*a* in a lake provides a good estimation of the amount of algae in the water column. Chlorophyll-*a* concentrations are usually high in the spring and summer months when there is a lot of light and nutrients are available for growth. Chlorophyll-*a*, like phosphorus, is an indicator of the condition of the lake and is used to determine the trophic status. Snohomish County staff or volunteers will collect monthly samples near the surface in most lakes to measure chlorophyll-*a* concentrations.

Phycocyanin

Unlike chlorophyll-*a,* which is a pigment present in all algae and aquatic plants, phycocyanin is a pigment only present in cyanobacteria. Phycocyanin readings provide a good estimation of the amount of blue-green algae in the water column. In addition, when phycocyanin and chlorophyll-*a* readings are both taken, the proportion of blue-green algae to other types of algae can be estimated.

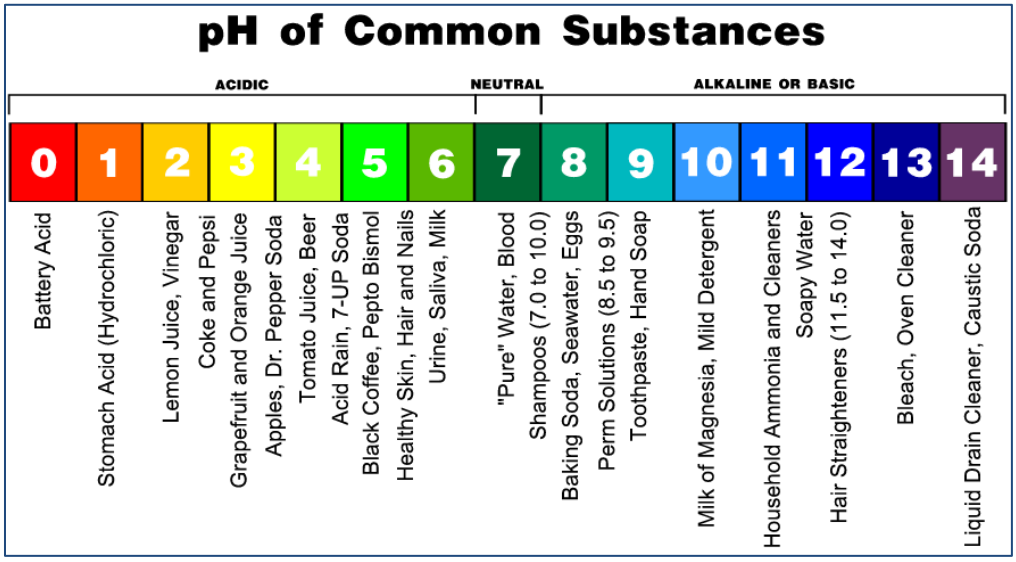
Phycocyanin concentrations are usually high in the spring and summer months when there is a lot of light and nutrients are available for cyanobacteria growth. Phycocyanin will be highest when there is a blue-green algae bloom. Snohomish County staff will collect surface and 1 meter readings when monitoring for special projects.

pH

Hydrogen ion activity, or pH, is a measure of the relative acidity of a liquid. The pH of water is measured on a scale of 0 to 14. A pH of 0 is extremely acidic and a pH of 14 is extremely alkaline or basic. A pH of 7 is considered neutral. Distilled water has a pH of about 7 and rainwater is closer to 6.

The pH scale is exponential. That is, a change of one whole number on the scale is a ten-fold change in acidity. So a pH change of one whole number would mean significant change in the chemical composition of the lake water. Figure 1 shows the relative pH of common substances.

Figure 1 pH Scale



Measurement of pH is important because pH affects biological and chemical activity in a lake. Extremes of acidic or basic conditions may threaten living organisms. Most animals cannot survive if pH is less than 5 or greater than 9. Measurement of pH is also important because pH can be an indicator of water quality. Lake pH can be affected by activities within the lake and the watershed. Photosynthesis by aquatic plants and algae increases pH. Sediment from soil erosion can change pH depending on the types of soils and rocks found in the watershed. Agricultural practices, fertilizers, pesticides, septic system effluent, and runoff from developed areas can affect the pH of the water.

Another property of lake water quality that is related to pH is alkalinity. Alkalinity is a measure of a lake's ability to resist changes in pH. This is known as the buffering capacity of the lake. Low alkalinity reduces a lake's resistance to changes. A lake with low buffering capacity (soft water) is more susceptible to pollution than one with a high buffering capacity (hard water) because only small changes in chemistry are needed to affect the lake water quality. Volunteers are not asked to measure pH, but County staff will measure pH in most lakes whenever they perform the monitoring, usually every other year.

Conductivity

Conductivity is a measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water, and for this reason is often used as an indirect measure of the salt concentration in waterbodies. Drought conditions, heat and low humidity, increased sediment load, and animal and human waste contamination can cause elevated salt levels.

In general, conductivity concentrations in lakes in this region are quite low. Volunteers are not asked to measure conductivity, but County staff will measure conductivity in most lakes whenever they perform the monitoring, usually every other year.

Lake Level

Volunteers will also measure the water level of their lakes. This indicates both the amount of water in the lake and the balance between water flowing in from precipitation or groundwater and water leaving by evaporation or outflow. Lake levels in our region will be highest in early spring and lowest in late summer and fall. The importance of lake level is to indicate the seasonal effects of the water balance in the lake. Several factors may contribute to changes in lake level, including; rainfall, sedimentation, surrounding topography, beaver activity, and plugged outlets.

Water Color Observations

Volunteers will observe and describe the apparent water color of their lakes each time they take a Secchi disk measurement. Apparent color is the color of the water as seen by the human eye. Because observation of water color is a subjective judgment, volunteers will choose from a list the color that best matches their perception of the lake water color.

Water color is generally not a water quality concern. However, color can be a factor influencing the interpretation of other data collected on a lake. For example, the water in some lakes may be brown, or amber because of the lake's proximity to natural wetlands that release tannins into the water. The color does not indicate pollution, but does reduce the ability of light to penetrate the water.

Natural water color affects the Secchi readings and may complicate the interpretation of the relationship between Secchi depth and lake water quality. In other cases, water color may indicate the presence of suspended algae (which come in various colors) or fine silt in the water. Accordingly, the color of the water may change based on the amount of algae production and the recent history of rainfall and erosion.

Water Color Measurements (True Color)

True color is the color of water after all suspended substances that could influence the color, like algae and suspended sediment, have been removed. True color is determined by first filtering a water sample to remove all suspended substances. After the samples have been filtered, they are compared to a specific color scale. This comparison is generally done in a laboratory with a spectrophotometer.

The most commonly used color scale is the platinum-cobalt color scale. This system is comprised of 1,000 color units or platinum-cobalt units (PCU or Pt-Co units). If one were to use the platinum-cobalt color scale to measure lake water that is especially clear (colorless), the color readings would probably be less than 10 PCU, whereas lakes that have a little color will have a true color measurement ranging from 20 to 50 PCU. On the far end of the spectrum, lake water that is extremely dark in color will have a color reading of 500 PCU or higher.

Snohomish County staff or volunteers will collect true color samples every five to ten years.

Weather and Lake and Watershed Observations

Weather conditions will affect measurements of Secchi depth, temperature, dissolved oxygen, lake level, and other aspects of lake condition. Therefore, volunteers will record recent weather conditions when they collect monitoring data.

Since Secchi measurements rely on light and the eyesight of the volunteer, the amount of cloud cover, smoothness of the water surface, and time of day will affect the readings. In addition, recent storms may have washed sediment into the lake, creating temporary turbidity (cloudiness) in the water.

Water temperature and dissolved oxygen are also affected by weather. Windy, rainy conditions will add oxygen to the water and may mix the lake unless the lake is strongly stratified. In contrast, a succession of warm, sunny, calm days provides conditions that are ideal for algae and plant growth.

Volunteers are asked to record other observations about the lake and the watershed. This includes floating algae, odors, muddy water, waterfowl, oil on the water surface, land clearing, rapid increases in the abundance of aquatic plants, or any other conditions that the volunteers consider significant.

These observations, though sometimes subjective, provide clues about possible water quality problems and may indicate potential causes of the problems. Observant and concerned residents serve a valuable role in protecting lakes and alerting the community to water quality problems. If agencies and residents learn about problems in time, there are greater opportunities to address the problems before they permanently damage the lake.

Recreational Suitability Observations

Lakes are used for a wide variety of recreational opportunities. Therefore, another perspective on lake condition is the quality of a lake in terms of its suitability for recreational use. Some microbial organisms, algae toxins, and other contaminants may be present in lakes and can even make people sick.

Volunteers are asked to record other observations about the extent of recreation that occurs at their lakes. This includes the number of boats, number of fishermen on the lake, the number of people swimming or wading, as well as a subjective ranking of their lake's recreational suitability.

This suitability ranking is focused on nuisance algae and its effect on recreational activities. The ranking is from one to five, one being the best, and five being the worst. Current weather conditions and temperature should not factor into the ranking. The descriptions of the recreational suitability are;

1. beautiful could not be nicer.
2. minor aesthetic concerns - still good for swimming and boating.
3. swimming, boating and aesthetic enjoyment slightly impaired.
4. swimming, boating and aesthetic enjoyment substantially impaired (would not swim, but boating is ok).
5. swimming, boating and aesthetic enjoyment are severely limited (would not swim or boat in lake).

Monitoring Procedures

The following sections describe lake monitoring procedures in detail. Please read these pages over before you begin monitoring, and please carry out the monitoring in the order described. The instructions are broken down into major activities that you are to complete and procedures necessary to measure each parameter. The major activities include;

- Monitoring Schedule
- Check of Weather Conditions
- Equipment and Monitoring Preparation
- Location of Monitoring Site
- Basic Monitoring Activities
- Water Sampling
- Temperature and Dissolved Oxygen Profiles
- Chain of Custody Form
- Sample Pick-up
- Equipment Storage
- Data Submittal

County staff will also provide a two-page waterproof "monitoring cheat sheet" specific to your lake. An example of this monitoring cheat sheet is available at the end of this appendix. Please refer to the annual monitoring schedule for your lake and instructions from Snohomish County staff to confirm the monitoring you will perform.

Monitoring Schedule

County staff will prepare a monitoring schedule at the beginning of each monitoring season. This schedule will include basic monitoring activities, water sampling dates, and sample pick-up dates. All monitoring must be done between 9:00AM and 4:00PM.

- Basic monitoring activities are scheduled twice a month between May and October. This monitoring can be performed any time during that week or weekend.
- Water sampling is scheduled once a month between June and September. Water sampling must be performed on a Saturday or Sunday, and should be done along with the basic monitoring activities.
- Sample pick-up times are scheduled for Monday mornings following a water sampling weekend. County staff will begin to pick up water samples at 8:00AM.

Because of weather conditions or other time commitments, it may not always be possible for you to monitor on the day you have planned. Try to complete the monitoring within two days of your scheduled date. Even if you miss the date by more than two days, you should still perform the monitoring. Late or early data are better than no data.

The only exception is for phosphorus and chlorophyll *a* sampling. If you cannot collect these samples on the designated weekend, please contact County staff. Please remember that regular monitoring is needed to accurately document any changes in lake condition. Please call County staff if you have questions about scheduling.

Check of Weather Conditions

Check the current and forecasted weather conditions and decide if conditions allow for safe monitoring. Check the lake for waves and rough water. Do not go out in stormy or dangerous conditions. No data are worth your safety.

Equipment and Monitoring Preparation

Ensure that you have all equipment for the monitoring to be performed that day. Table 3 lists all of the equipment necessary to perform basic monitoring, water sampling, and dissolved oxygen and temperature profiles.

Table 3 Equipment Checklist

Basic Monitoring		Water Sampling	Dissolved Oxygen
☐ Instruction Sheet	☐ Life jacket	☐ Water sampler	☐ YSI meter
☐ Data Sheet	☐ Anchor	☐ 1 TP/TPN bottle	☐ DO Instructions
☐ Clipboard	☐ Hat (optional)	☐ 1 TP bottle	☐ Algae Screening bottle
☐ Pencil & Sharpie	☐ Towel (optional)	☐ 1 Chl-*a* bottle (public)	☐ gloves
☐ Thermometer	☐ Boat (not optional)	☐ Cooler with ice	☐ Camera (optional)
☐ Secchi Disk		☐ Extra Bottle Set	

Before going out on the lake;

1. Please label your sample bottles with Sharpie or other permanent marker, to include the following information:
    a. Lake name and depth.
    b. Date and approximate time the sample will be collected (use the same time for all bottles).
2. If you are assigned a dissolved oxygen meter, calibrate the instrument (see specific instructions).

Location of Monitoring Site

Monitoring locations for all Snohomish County lakes are found in Appendix B of the *Quality Assurance Plan: Snohomish County Lake Management Program*.

Use the following steps to locate the monitoring location for your lake:

3. Monitoring should be performed at the deepest point in the lake. This location provides the best indication of the overall condition of the lake. Be sure to conduct your monitoring at the same spot in the lake every time. This will provide consistency in the data and make the results more scientifically valid.
4. Your map indicates the approximate location of the deepest spot in the lake. County staff will also help you locate this point before you begin the monitoring and will mark your map with shoreline landmarks. These landmarks will consist of two sets of features that line up together and form an imaginary "X" when you are at the correct location in the lake. (An alternative method is to anchor a buoy at the appropriate location. A buoy works best in small, shallow lakes with little boat traffic.
5. Once you have located the correct spot, anchor your boat. Anchoring will keep the boat from drifting into shallow water while you monitor.
6. If your lake is shallow, avoid re-positioning the anchor once it is dropped. Moving the anchor may stir up sediment and affect your monitoring results.

Basic Monitoring Activities

Basic monitoring is done twice a month from May through October. Begin filling in the monitoring datasheet with lake name, volunteer name(s), and monitoring date and time. The specific monitoring procedures for each parameter are located in the following sections. Only follow those procedures for parameters that have been assigned to you, in the order in which they appear in the following pages. Some volunteers in the program may monitor and collect samples for more or less parameters than you will be doing for your lake.

Temperature and Weather Conditions

Complete the temperature and weather conditions section of the field form. Use the thermometer provided to you by County staff for measuring temperature. (Be sure to take the thermometer out of its case.) The weather conditions should be the conditions that are present when you are doing your Secchi disk measurement.

Air Temperature

1. Measure the air temperature. First, dry the thermometer and place it in your boat out of the direct sun (or you can hang it under a shady tree or bush away before you go out in the boat). Keep the thermometer away from any large objects that can radiate heat.
2. Wait two to three minutes to allow the thermometer to stabilize at the correct temperature.
3. Read the thermometer and record the value on the data sheet to the nearest ½ degree C, which is the smallest division on the thermometer. The next longer marks are for each degree. The longest marks are for every five degrees. Please note that the "5" between 10 and 20 is for 15 degrees and the "5" between 20 and 30 is for 25 degrees.

Surface Water Temperature

1. Measure the water temperature. Be sure the string is attached securely to the cork float.
2. Hold the thermometer about 6 to 12 inches below the surface of the lake. Wait two minutes for the thermometer to stabilize.
3. Pull the thermometer out of the water and read the temperature quickly but accurately. It is important to read the temperature quickly because the thermometer will start changing immediately in response to air temperature and wind.
4. Record the surface temperature to the nearest ½ degree C. That is the smallest division on the thermometer. The next longer marks are for each degree. The longest marks are for every five degrees. Please note that the "5" between 10 and 20 is for 15 degrees and the "5" between 20 and 30 is for 25 degrees.

Weather Conditions

1. Record the percentage of cloud cover. "0%" means the sky is completely sunny. "100%" means the sky is completely overcast. Choose the cloud cover percentage that best describes conditions at the time of the Secchi reading.
2. Describe the extent of rain within the last two days. If there has been rain, use your judgment to determine how much rain there was. You may also write in observations about recent weather, such as describing a brief but heavy downpour that produced lots of runoff.
3. Describe the current wind conditions. Windy conditions will disturb the lake surface and affect the monitoring results. Choose the wind conditions that best describe conditions at the time of the Secchi reading.

Water Clarity

1. Remove your sunglasses and lean over the shaded side of the boat. This is important to reduce sun glare and provide optimum conditions for looking into the water.
2. Lower the Secchi disk into the water slowly until the disk just disappears from view. Then, slowly raise the disk until you can barely see it again. Move the disk carefully up and down a few inches until the exact vanishing/re-appearing point is found. Make sure the rope is vertical when you take the reading. Take your time because your view of the disk will be very faint.
3. Without moving the disk again, record the depth where the rope touches the water surface as the "1st Secchi Reading."
    a. Please record the Secchi reading to the nearest tenth (0.1) of a meter. If it is exactly on the meter mark, record "0" tenths, such as "4.0" meters.
    b. If the disk hits the lake bottom before disappearing from view, write down the depth and check the appropriate box on the form.
    c. If the disk disappears into the weeds, move a short distance away from the weeds. If you have to move more than a few feet because of weeds, take the Secchi reading at the new location, note the problem, and call County staff.
4. Repeat the Secchi disk depth measurement by following steps 2-3. If the second reading is more than one tenth (0.1) meter different from the first, please do a third reading.
5. Record the second reading on the data sheet as the "2nd Secchi Reading".
6. If you had to do three or more readings to get two within 0.1 meters, please enter the two readings that were within one tenth of a meter.

Algae Observations

1. Lower the Secchi disk 6 inches below the water on the sunny side of the boat and observe the small particles (the algae) over the disk. If there are too many particles to count in an area the size of a half dollar, select "Yes" for Heavy Algae.
2. Look for mats of stringy filamentous algae throughout your monitoring trip and note if observed. Filamentous algae will not break apart when disturbed with a stick and look like long strands or dense mats of "hair".
3. Look for algae scums throughout your monitoring trip and note if they are present and the scum type. Algae scum is an accumulation of algae cells that often looks like spilled paint.
    a. Figure 2 shows the difference between small clumps, thin film, and thick scum types.
4. Indicate if an algae sample was taken during the monitoring event. Write down the location on the lake where the sample was taken.

Algae Sampling

Algae Sample kits will provided by County staff to sample scums.

1. Put on nitrile gloves provided before sampling algae scums.
2. Fill out the sample bottle label with lake name, sampling date, and sampling location.
3. Collect the algae scum using a skimming motion across the lake surface. The skimming motion will ensure that scum will enter the bottle.
4. Place sample in cooler.

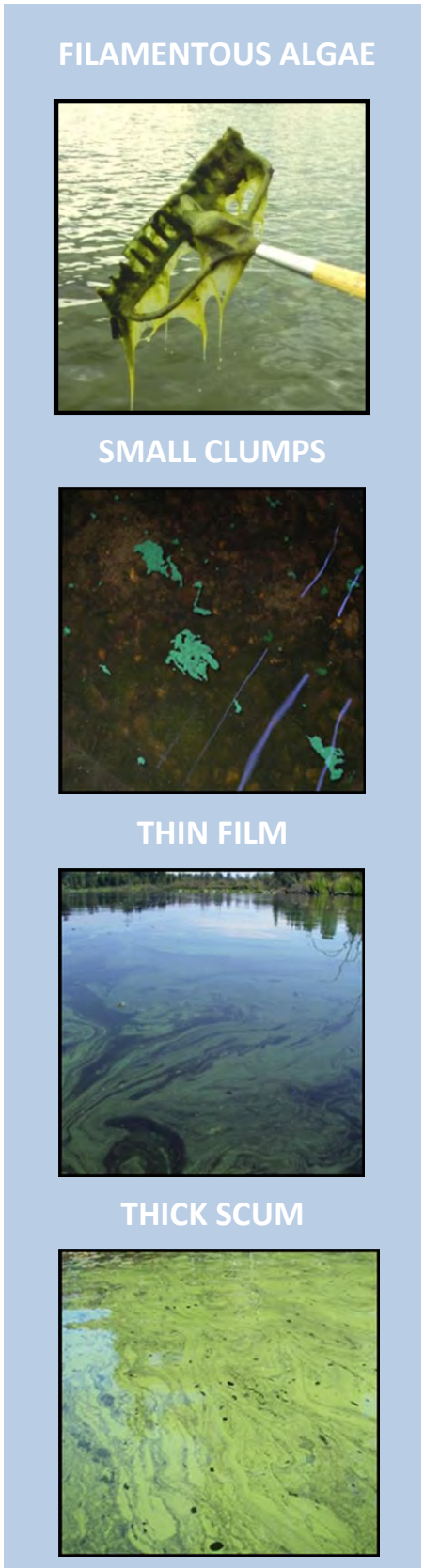
Water Color

1. Lower the Secchi disk to ½ the Secchi depth reading for that day and look at the white part of the disk to determine the water color.
2. Select the color on the datasheet that best matches the color you observe. If none of the colors on the datasheet is close, write in your own description.
3. Choose the intensity that best matches the water color you observe. The options are light, moderate and dark.
    a. Light intensity is a faint wash of color.
    b. Moderate intensity is vivid color.
    c. Dark intensity is when the color appears murky.

Other Observations

1. Record the lake level at the lake staff plate or a pre-determined location and circle inches or feet. If you don't have a location set up to record lake level, please contact County staff.
2. Record numbers of ducks, geese, and other waterfowl seen throughout monitoring trip. Write in names of other waterfowl seen on the lake.
3. Record numbers of the following seen throughout the monitoring trip;
    a. boats.
    b. people fishing.
    c. swimmers or people wading in the water.
4. Select the option that best describes your perception of the lake recreational suitability from one to five (1=best, 5=worst). Please disregard poor weather conditions (such as cold weather) when selecting one of the following options;
    - 1- beautiful could not be nicer

Figure 2 Algae Types



- 2 - minor aesthetic concerns - still good for swimming/boating
- 3 - swimming, boating & aesthetic enjoyment slightly impaired
- 4 - swimming, boating & aesthetic enjoyment substantially impaired (would not swim, but boating ok)
- 5 - swimming, boating & aesthetic enjoyment are severely limited (would not swim or boat in lake)

5. Note other observations from your monitoring trip, or that have taken place on or around your lake, e.g. aquatic plants, odors, wildlife, pollution, land clearing, or equipment issues. There is additional space for notes and comments on the back side of the field sheet.

Water Sampling

Water sampling is done once a month from June through September.

- Check the provided monitoring schedule to verify that it is a water sampling weekend.
- Label sample bottles and prepare a cooler with ice before going out on the lake.
- Please conduct your regular monitoring and temperature/dissolved oxygen profiles on the same day that you collect samples.

1 Meter Samples: Total Phosphorus (TP), Total Nitrogen (TPN), Chlorophyll-a (chl-a)

Prior to collecting the 1-meter samples, review the following guidelines:

- If collecting field duplicates, please follow the procedures "Sample Procedures for Collecting Field Duplicates" located immediately following these procedures.
- Conduct all other monitoring (except chlorophyll *a*) before you collect the TP and TPN samples.

Collect TP/TPN sample at 1 meter

1. Open the sampler and rinse three times with lake water.
2. Obtain a water sample from 1 meter deep.
3. Collect the TP/TPN Sample:
    a. Rinse the 1 meter TP/TPN bottle and cap three times with water from the sampler, being careful not to touch the inside of the cap or bottle with your hands.
    b. Fill the 1 meter TP/TPN bottle to the shoulder, being careful not to touch the bottle with the sampler tube.
4. Immediately place the sample in the cooler.
5. Refrigerate all samples immediately after returning to your home.

Collect Chlorophyll-a sample (public lakes only) at 1 meter

1. Obtain a water sample from 1 meter deep.
    a. **DO NOT RINSE** the Chl-a sample bottle. This bottle has a small amount of preservative inside.
    b. **DO NOT POUR OUT**. If by accident you rinse it, use your extra Chl-a bottle instead and return the empty rinsed bottle with your samples.

2. Fill the bottle to the shoulder.
3. Immediately place the sample in the cooler. It is important to keep the Chl-a sample cold and dark to prevent the sample from degrading.
4. Refrigerate all samples immediately after returning to your home.

Deep Sample (1 meter from lake bottom): Total Phosphorus (TP)

Prior to collecting deep sample, review the following guidelines:

- If collecting field duplicates, please follow the procedures "Sample Procedures for Collecting Field Duplicates" located immediately following these procedures.
- Refer to Table 4 for the assigned lake depth for each lake. This is important because the hypolimnion sample should be taken about 1 to 1.5 meters above the bottom of the lake.
- Do not measure the lake depth when you collect samples. The bottom sediments could be stirred up and are likely to contaminate the sample.

Collect TP Sample at X meters

Specific sample depths for each lake are located in Table 4 and are also provided on the "cheat sheet" for your lake.

1. Obtain a water sample from X meters.
    a. If the water sample is cloudy with sediments, dump it out and sample again on other side of the boat.
    b. Rinse the X meter TP bottle and cap **three times** with water from the sampler, being careful not to touch the inside of the cap or bottle with your hands.
    c. Fill the X meter TP bottle to the shoulder, being careful not to touch the bottle with the sampler tube.
2. Record if there is a rotten egg odor in the remaining sample water within the sampler.
3. Immediately place the sample in the cooler.
4. Refrigerate all samples immediately after returning to your home.

Table 4 Hypolimnion Sample Depths in meters

Lake Name	Max Depth	SAMPLE DEPTH
ARMSTRONG	8.7	7.0
BEECHER	3.0	2.0
BLACKMANS	8.8	6.0
BOSWORTH	24.1	20.0
BRYANT	7.0	6.0
CASSIDY	7.5	6.0
CHAIN	6.0	5.0
COCHRAN	16.0	15.0
CRABAPPLE	14.9	12.0
CRYSTAL	9.8	9.0
ECHO	15.2	13.0
FLOWING	21.0	18.0
GOODWIN	15.2	13.0
HOWARD	15.2	14.0
KAYAK	6.0	4.0
KETCHUM	6.4	5.0
KI	21.3	18.0
LITTLE MARTHA	6.1	5.0
LOMA	8.5	7.0
LOST	13.7	11.0
MARTHA N.	21.3	19.0
MARTHA S.	14.6	10.0
MEADOW	6.4	5.0
NINA	12.5	10.0
PANTHER	11.0	10.0
RILEY	13.7	9.0
ROESIGER N.	33.5	30.0
ROESIGER S.	21.0	20.0
ROWLAND	7.6	6.0
RUGGS	4.7	3.0
SERENE	6.7	5.0
SHOECRAFT	10.7	9.0
STEVENS	47.0	40.0
STICKNEY	10.0	9.0
STORM	14.0	12.0
SUNDAY	6.0	4.5
WAGNER	6.7	5.0

Temperature and Dissolved Oxygen Profiles

Some volunteers will be assigned a YSI dissolved oxygen (DO) and temperature instrument during the monitoring season. Dissolved oxygen and temperature profiles should be measured during each monitoring trip after the basic monitoring activities are completed. The directions for instrument calibration and use will vary by the instrument model number. Specific instructions for all in-use instrument models are given at the end of this document and additional training will be provided to volunteers prior to the monitoring season. If you are interested in taking dissolved oxygen and temperature profiles for your lake, please contact County staff.

1. Calibrate the DO instrument according to specific instructions provided to you by County staff. This step should be completed before you go out on the lake.
2. Record the temperature, DO in mg/L, and %DO on the back side of the data sheet at the surface and each meter down to the lake bottom.
    a. Keep the probe at the desired depth for at least a minute to allow for the meter to stabilize.
    b. For some instruments, you will need to "jiggle" the probe up and down to ensure that water is flowing past the membrane so that you can get an accurate DO reading. Jiggle the probe by holding the cord and lifting it up and down about 1 to 2 inches at a rate of approximately 100 times per minute.
3. Record the lake depth in meters by lowering the instrument probe to the lake bottom.
4. Record the instrument name.
5. Note any comments specific to the DO instrument.

pH and Conductivity Profiles

Volunteer assigned instruments do not have the capability to record pH and conductivity profiles, so SWM staff will take pH and conductivity profiles during volunteer training site visits. The directions for instrument calibration and use will vary by the instrument model number. Specific instructions for all in-use instrument models are given at the end of this document.

1. Calibrate the pH and conductivity instrument according to specific instrument instructions. This step will be completed by SWM staff before leaving the office.
2. Record the pH and specific conductance on the back side of the data sheet at the surface and each meter down to the lake bottom.
    a. Keep the probe at the desired depth for at least a minute to allow for the meter to stabilize.
3. Record the lake depth in meters by lowering the instrument probe to the lake bottom.
4. Record the instrument name.
5. Note any comments specific to the readings and instrument.

Chain of Custody Form

Fill out the Chain of Custody (COC) form with the following information:

1. Date and time of the sampling, just as written on the sample bottles.
2. "Sample ID," write the lake name and depth just as it appears on each bottle.
3. Mark the parameter for each sample:
    a. 1 meter samples will have TP, TPN, and Chl-a marked.

   b. Bottom samples will have TP marked.

4. Sign your name in the space labeled “Sampled by” near the bottom of the sheet
5. Write the date and time that you will set out the samples for pick-up.

Sample Pick-Up

County staff will schedule sample pick-ups for the Monday following the water sampling weekend.

1. Place samples in a cooler with ice at your designated pick-up location by 8:00AM.
2. Include the COC and monitoring datasheets with your sample.
3. Make sure your forms are in a Ziploc bag.

Equipment Storage

Once you have completed your lake monitoring activities for the day, you will need to rinse and dry the monitoring equipment and store it in a dry spot.

- Make sure that fragile equipment, such as the thermometer, will not be crushed in the storage location.
- Please store thermometers in an upright position. This will prevent the liquid inside the thermometers from separating.
- Do not leave the vertical samplers in an open position. This will stretch the internal tubing and make the sampler leak and become difficult to close in the future.
- If you are assigned a dissolved oxygen meter, make sure that the sponge in the probe sleeve is moistened. This will prevent the membrane from drying out.

Data Submittal

County staff will provide pre-addressed and stamped envelopes to mail in your completed monitoring datasheets.

Generic Lake Monitoring Cheat Sheet

Please find a generic lake monitoring cheat sheet that summarizes all the monitoring methods and procedures at the end of Appendix A. You will also be given a monitoring cheat sheet tailored to your specific lake. Please take that cheat sheet with you every time you do the monitoring.

Glossary of Terms

The following terms are used throughout this monitoring manual and in other lake reports.

Acre-Foot – The volume of water that would cover an area of one acre to a depth of one foot; equivalent to 43,560 cubic feet, or 325,850 gallons of water.

Algae – Small plant-like organisms occurring as single cells, multi-celled colonies, or filaments. Algae contain chlorophyll and form the base of the food web in lakes.

Algae (or Algal) Bloom – A heavy growth of algae in a lake resulting from high nutrient concentrations and favorable weather conditions.

Alkalinity – The capacity of water to neutralize acids; the buffering capacity of water to resist a change in pH.

Anoxia – A condition where no dissolved oxygen remains in the water, usually occurring near the bottom in stratified lakes which have large amounts of decomposing organic matter in the lake sediments.

Bathymetric Map – A map showing the depth contours of the bottom of a lake.

Benthic – Referring to the bottom of a lake, which supports a community of small organisms that live on or in the sediment and are important in decomposing organic matter.

Blue-green Algae – One of the main groups of algae that are responsible for many of the unpleasant algae blooms in lakes. More properly known as Cyanobacteria, blue-green algae are physically like bacteria, but function more like plants.

Chlorophyll *a* – A type of green pigment found in all algae. It plays an essential role in photosynthesis.

Conductivity –A measure of the capacity of water to conduct an electrical current; an indicator of the amount of dissolved ions in the water.

Dissolved Oxygen – The oxygen gas that is dissolved in water and available for use by microorganisms and fish.

Emergent – Aquatic plants that have their roots and lower stems in the water while the upper portions of the plants stand above the water surface.

Epilimnion – The uppermost, warm, well-mixed layer of water in a lake during stratification.

Eutrophic – Description of a lake that is rich in nutrients and highly productive of plants and algae.

Eutrophication – The natural process of lake enrichment caused by accumulating nutrients and sediment that results in increased growth of plants and algae, reduced water clarity, and lake filling. Human activities that add nutrients and sediment to a lake can greatly accelerate this process.

Filamentous Algae – types of green algae that grow as long, thin filaments in a lake. Filamentous algae usually grow in shallow water attached to aquatic plants or the lake bottom.

Food Web – The system of feeding interactions occurring among the organisms in a lake.

Hypolimnion – The deep, cooler layer of water in a lake isolated from surface influences during stratification.

Limnology – The study of fresh waters, especially lakes.

Loading (External and Internal) – The total amount of nutrients added to the water of a lake. External loading comes from sources outside the lake, such as streams, direct runoff, pipes, ground water, and the air; internal loading comes from sources within the lake itself, such as recycling from the bottom sediments and release from decaying plants and animals.

Macrophytes – Another term for aquatic plants, either rooted or floating, that grow in lakes.

Mesotrophic – Description of a lake that contains moderate levels of nutrients and produces moderate amounts of plants and algae.

Metalimnion – The layer of lake water between the epilimnion and hypolimnion during stratification, where water temperature and density change rapidly with depth.

Nitrogen – One of the nutrients essential for plant and algae growth. Nitrogen is present in several forms, and some algae can take it directly out of the atmosphere. The relative abundance of nitrogen and phosphorus is a key indicator of lake conditions.

Nutrient – Any chemical element, ion, or compound that is essential for life and growth, such as nitrogen, phosphorus, carbon, and oxygen.

Oligotrophic – Description of a lake that contains few nutrients and produces little algae and aquatic plants.

Periphyton – Algae that grow attached to underwater surfaces, such as rocks, pilings, and aquatic plants. Periphyton do not float freely in a lake as phytoplankton do.

pH – A measure of the concentration of hydrogen ions in a substance such as water. Values go from 0 to 14; a pH of 7 is neutral; values below 7 are increasingly more acidic, while values greater than 7 are increasingly more basic (alkaline). Each increment represents a ten-fold change in acidity.

Phosphorus – One of the nutrients essential for plant and algae growth. Phosphorus availability often limits algae growth in a lake because it is the nutrient in shortest supply.

Photosynthesis – The process by which chlorophyll-containing cells in plants and algae produce organic matter from carbon dioxide and water using light energy.

Phytoplankton – Microscopic algae that float freely in open water.

Productivity – The rate at which aquatic plants and algae create organic matter through photosynthesis.

Secchi Disk – A black and white disk (usually 8 inches in diameter) used to measure light transparency (water clarity) in a lake.

Stratification – The layering of lake water caused by differences in temperature and density. Layers are called the epilimnion, the metalimnion, and the hypolimnion. Stratification is typical of deeper lakes during the warm summer months.

Submersed – Rooted aquatic plants that grow entirely, or almost entirely, under the water.

Trophic State – The degree of eutrophication of a lake. Lakes may be classified as oligotrophic, mesotrophic, or eutrophic.

Turnover – The mixing of lake water from top to bottom that usually occurs in the fall and is caused by the cooling of surface waters and wind energy.

Watershed – The land area that drains to or contributes water to a lake or other waterbody.

Zooplankton – Microscopic animals that float in open water and feed on bacteria, algae, and organic matter and may be consumed by fish.

ATTACHMENT 1 - GENERIC LAKE MONITORING INSTRUCTIONS

1. PREPARE FOR MONITORING

- Check monitoring calendar to confirm monitoring activities and dates
- Check weather and lake conditions; DO NOT monitor in bad weather
- Monitor between 9:00 am and 4:00 pm (Secchi readings after 5:00 pm cannot be accepted)
- Ensure that you have all equipment for the monitoring to be performed that day

Basic Monitoring		Water Sampling	Dissolved Oxygen
☐ Instruction Sheet	☐ Life jacket	☐ Water sampler	☐ YSI meter
☐ Data Sheet	☐ Anchor	☐ 1 TP/TPN bottle	☐ DO Instructions
☐ Clipboard	☐ Hat (optional)	☐ 1 TP bottle	**Algae Screening**
☐ Pencil & Sharpie	☐ Towel (optional)	☐ 1 Chl-*a* bottle	☐ Algae Screen bottle
☐ Thermometer	☐ Boat (not optional)	☐ Cooler with ice	☐ Gloves
☐ Secchi Disk		☐ Extra Bottle Set	☐ Camera (optional)

2. LABEL SAMPLE BOTTLES (IF MONITORING ON A WATER SAMPLING DATE)

- Before heading out label the water sample bottles with date, collection time, and sample ID as follows

Sample Type	Sample ID	Bottle Description
Chlorophyll *a*	Lake Name - 1 meter	Large Brown bottle
TP/TPN	Lake Name - 1 meter	Clear 125 mL bottle
TP	Lake Name - X meters (varies by lake)	Clear 125 mL bottle

3. LOCATE YOUR MONITORING SITE

- Find the monitoring location at the deepest part of the lake using your bathymetric map
- Always anchor your boat and monitor in the same location

4. RECORD WEATHER CONDITIONS

- Record air temperature to nearest ½ ˚C by holding the thermometer in the shade for 2 minutes
- Record water temperature to nearest ½˚C by holding the thermometer or a DO probe 6-12 inches under the water surface for 2 minutes (read thermometer quickly)
- Select method used to take water temperature – thermometer or DO probe
- Choose the cloud cover percentage that best describes conditions at the time of the Secchi reading
- Choose the wind conditions that best describe conditions at the time of the Secchi reading
- Choose the amount of rain that best describes the recent rainfall in the area

5. MEASURE WATER CLARITY

- Remove sunglasses and use shady side of boat
- Lower the Secchi disk until it just disappears, raise disk until it re-appears, move disk slowly up and down until you find the exact vanishing point
- Measure and record depth of the Secchi disk to the nearest 0.1 meter at the vanishing point
- Repeat until you get two readings within 0.1 meters (data cannot be accepted if more than 0.1 m apart)
- If the Secchi disk hits the lake bottom or enters weeds, check the appropriate box

6. EVALUATE ALGAE CONDITIONS

- Lower the Secchi disk 6 inches below the water on the sunny side of the boat and observe the small particles (the algae) over the disk. If there are too many particles to count in an area the size of a half dollar, select "Yes" for Heavy Algae
- Look for mats of stringy filamentous algae throughout your monitoring trip and note if observed
- Look for algae scums throughout your monitoring trip especially along the shoreline. If a scum is present
    - Choose the term that best describes the algal scum type
    - Label your algae screening sample bottle and collect a sample of the scum while wearing gloves

- Take a photo of the scum if possible
- If you take a sample, please call 425-388-3464 to arrange a pick-up if not a scheduled pick-up date

7. RECORD LAKE LEVEL

- Record the lake level at your established fixed point at shoreline or dock and include unit used (inches or feet)
- Record lake level at County staff plate after your fixed point reading 2-3 times per season (if applicable)

8. IDENTIFY WATER COLOR AND ODOR

- Lower the Secchi Disk to ½ the Secchi depth taken that day (e.g. if Secchi was 4 meters, lower disk to 2 meters)
- Choose the Intensity and Tint that best describes the color of the water over the white portion of the disk

9. RECORD OTHER OBSERVATION

- Record the lake level at the lake staff gage or a pre-determined location and circle inches or feet
- Record the numbers of ducks, geese, and other waterfowl seen throughout monitoring trip
- Record the number of boats, people fishing, and swimmers/waders seen throughout monitoring trip
- Select the option that best describes your perception of the lake recreational suitability (1 = best; 5 = worst)
- Note other observations: aquatic plants, odors, wildlife, pollution, land clearing, equipment issues, etc

10. COLLECT WATER SAMPLES (IF WATER SAMPLING DATE)

COLLECT 1 METER SAMPLE(S)

- Open the sampler and rinse three times with lake water
- Obtain a water sample from 1 meter depth
- Collect the TP/TPN Sample:
  - Rinse the 1 meter TP/TPN bottle and cap three times with water from the sampler, being careful not to touch the inside of the cap or bottle with your hands or the sampler tube
  - Fill the 1 meter TP/TPN bottle to the shoulder, being careful not to touch the inside of the cap or bottle with your hands or the sampler tube
- Collect the Chlorophyll a sample:
  - DO NOT RINSE the Chl-a sample bottle - it has a small amount of preservative - DO NOT POUR OUT
  - If by accident you rinse it, use your extra Chl-a bottle instead and return rinsed bottle with samples
  - Fill the bottle to the shoulder (obtain more water if needed)
- Immediately place the samples in the cooler – keep cold and dark

COLLECT BOTTOM SAMPLE

- Obtain a water sample from «X» meters (1 meter from the bottom)
- If the water sample is cloudy with sediments, dump it out and sample again on other side of the boat.
- Collect the TP Sample
  - Rinse the bottom TP sample bottle and cap three times with water from the sampler, being careful not to touch the inside of the cap or bottle with your hands or the sampler tube
  - Fill the bottom TP sample bottle to the shoulder, being careful not to touch the inside of the cap or bottle with your hands or the sampler tube
- Record if there is a rotten egg odor in the remaining sample water (means no oxygen at bottom)
- Immediately place the sample in the cooler – keep cold and dark

11. CONDUCT DISSOLVED OXYGEN PROFILE MONITORING

- If you have volunteered to take dissolved oxygen profiles, refer to Dissolved Oxygen Profile Instructions.

12. SUBMIT DATA SHEET AND SAMPLES

- Store water samples in fridge
- Sign and date the Chain of Custody section on the data sheet and submit with samples
- Place samples in cooler with ice and set on porch or at end of driveway by 8:30 am Monday.
- Submit the original data sheet with water samples, email to lakes@snoco.org or mail with the provided envelope

Calibration & Use Instructions

1. Remove the probe from the clear plastic cap. Pour enough water into the sleeve to get the sponge wet. Then turn the sleeve over and pour out all the excess water. (You want to sponge to be wet, but you don't want the probe to be immersed in water).
2. Put about 1 inch of lake water in a tall cup and place the probe in the cup with the small cap still on – this can be done at the shore or in the boat. Don't let water run over into the plastic cap.
3. Connect the probe cable to the meter and turn on the instrument by setting the function switch to the "°C" position. An audible tone will sound and the display will appear. A second tone will sound in the about 7 seconds and the display will blink briefly. *If there is a problem the display will "freeze" or will not appear – if this happens please contact us as it will need repairs.*
4. The temperature will be displayed after the second tone. Observe the reading for stability. Temperature equilibration may take up to 5 minutes.
5. Once the temperature is stable, set the function switch to the "mg/L" position and allow 15 more minutes for the system to stabilize. If calibration is attempted prematurely, calibration values will drift and may be out of specification.
6. After 15 minutes set the function switch to "mg/L CAL".
7. Press the "CAL" key once. The mg/L reading will automatically correspond to the percentage of oxygen in the air sample (which should be fully saturated).
8. Turn the function switch to "mg/L". This display will show "CAL". In a few seconds one or two audible tones will sound.
9. Next the appropriate calibration value in mg/L will be displayed. Observe the reading for two to three minutes to make sure it is stable (small fluctuations are ok).
10. If the calibration is successful – remove the plastic cap and you are now ready to take measurements. LEAVE THE INSTRUMENT ON until you finish taking measurements – otherwise you will need to repeat the calibration.
11. BE SURE TO BOUNCE THE PROBE UP AND DOWN VIGOROUSLY AS YOU TAKE MEASUREMENTS to obtain accurate dissolved oxygen readings.
12. Take readings at 0.5 meters and at every meter interval until you reach the bottom of the lake. If the lake is deeper than 10 meters – you can start taking readings every other meter after 10 meters. Please note on your data sheet when the probe hits the bottom.
13. Select one depth near the surface (0.5, 1, or 2 meters) or near the lake bottom and take a duplicate temperature and dissolved oxygen reading and write that on the form.
14. Turn off the instrument when you are finished.

BE SURE THAT THE SPONGE INSIDE THE CALIBRATION SLEEVE IS WET BEFORE STORAGE

Calibration & Use Instructions

1. Remove the probe from the calibration storage chamber. Pour enough water into the chamber to get the sponge wet. Then turn the sleeve over and pour out all the excess water. (You want to sponge to be wet, but you don't want the probe to be immersed in water).

2. Re-insert the probe in the calibration chamber and stand the probe up (keep the cord on top and the sensor on the bottom).

3. Turn the instrument by pressing the **ON/OFF** button. Press the **MODE** button until dissolved oxygen is displayed as mg/L. Wait for the dissolved oxygen and temperature readings to stabilize (usually 15 minutes is required).

4. Press and release both the **UP ARROW** and **DOWN ARROW** buttons at the same time.

5. You will be prompted to enter the local altitude in hundreds of feet. Use the arrow keys to increase or decrease the altitude. When the proper altititude appears on the screen, press the **ENTER** button once. (Example 3 = 300 feet)

6. The screen should now display **CAL** in the lower left of the display, the calibration value should be displayed in the lower right of the display and the current % reading (before calibration) should be on the main display. Make sure that the current % reading (large display) is stable, then press the **ENTER** button. The display should read **SAVE** then should return to the Normal Operation Mode.

7. If the calibration is unsuccessful, an error message will display on the screen. If the sensor will not calibrate correctly or does not provide stable readings contact Marisa 425-338-3464 X 4639.

8. If the calibration is successful – you are now ready to take measurements. BE SURE TO BOUNCE THE PROBE UP AND DOWN VIGOROUSLY AS YOU TAKE MEASUREMENTS to obtain accurate dissolved oxygen measurements.

9. Take temperature and oxygen readings at 0.5 meters and at every meter until you reach the bottom of the lake. If the lake is deeper than 10 meters – you can start taking readings every other meter after 10 meters. Please note on your data sheet when the probe hits the bottom in the "Lake Depth" field.

10. Select one depth near the surface (0.5, 1, or 2 meters) or near the lake bottom and take a duplicate temperature and dissolved oxygen reading and write that on the form. It may take a few minutes for the DO to re-stabilize. The duplicate dissolved oxygen should be within 1 mg/L of the original.

BE SURE THAT THE SPONGE INSIDE THE CALIBRATION CHAMBER IS WET BEFORE STORAGE

**Note – takes six AA-size alkaline batteries*

Calibration & Use Instructions

1. Remove the probe from the calibration storage chamber. Pour enough water into the chamber to get the sponge wet. Then turn the chamber over and pour out all the excess water. (You want to sponge to be wet, but you don't want the probe to be immersed in water).

2. Re-insert the probe in the chamber. Turn the instrument on and wait for the dissolved oxygen and temperature readings to stabilize (five to fifteen minutes is usually required).

3. Press and release both the **UP ARROW** and **DOWN ARROW** buttons at the same time.

4. Press the **MODE** key until % is displayed on the right side of the screen for oxygen units & press **ENTER.**

5. You will be prompted to enter the local altitude in hundreds of feet. Use the arrow keys to increase or decrease the altitude. When the proper altitude appears on the screen, press the **ENTER** key. (Example: Crystal enter 2 for 200 feet).

6. **CAL** will now be displayed in the lower left of the display, the calibration value in the lower right corner and the current % reading (before calibration) should be on the main display. Once DO readings stabilize, press the **ENTER** button.

7. You will be prompted to enter the salinity. Enter "0" and press the **ENTER** key.

8. If the calibration is successful – you are now ready to take measurements. If the calibration is unsuccessful, an error message will display on the screen. If sensor will not calibrate correctly or does not provide stable readings contact Jen at 425-388-3464 x4352.

9. Press the **MODE** key once in order to read the dissolved oxygen results in "mg/L".

10. BE SURE TO BOUNCE THE PROBE UP AND DOWN VIGOROUSLY AS YOU TAKE MEASUREMENTS to obtain accurate dissolved oxygen measurements.

11. Take temperature and oxygen readings at 0.5 meters in mg/l and at every meter until you reach the bottom of the lake. If the lake is deeper than 10 meters – you can start taking readings every other meter after 10 meters. Please note on your data sheet when the probe hits the bottom in the "Lake Depth" field.

12. Select one depth near the surface (0.5, 1, or 2 meters) or near the lake bottom and take a duplicate temperature and dissolved oxygen reading and write that on the form. It may take a few minutes for the DO to re-stabilize. The duplicate dissolved oxygen should be within 1 mg/L of the original.

BE SURE THAT THE SPONGE INSIDE THE CALIBRATION CHAMBER IS WET BEFORE STORAGE

**Note –this instrument takes 4 "C" sized alkaline batteries*

Calibration & Use Instructions

1. Remove the probe from the gray plastic sensor sleeve. Pour enough water into the sleeve to get the sponge wet. Then turn the sleeve over and pour out all the excess water. (You want to sponge to be wet, but you don't want the probe to be immersed in water).

2. Re-insert the probe in the calibration sleeve and stand the probe up (keep the cord on top and the sensor on the bottom).

3. Turn the instrument on and wait 10-15 minutes for the DO sensor to stabilize.

4. Press and hold the "Cal" key for three seconds. At the end of the 3 seconds "Calibration Successful" will display for a few seconds to indicate a successful calibration and then the instrument will return to the run screen.

5. If the calibration is unsuccessful, an error message will display on the screen. Press the "Cal" key to exit the error message and return to the run screen. If sensor will not calibrate correctly ("Calibration Over" or "Unstable Reading" Error) or does not provide stable readings contact Katie at 425-422-5708.

6. If the calibration is successful – you are now ready to take measurements.

7. Remove the sleeve and screw the probe weight onto the bottom of the sensor.

8. BE SURE TO BOUNCE THE PROBE UP AND DOWN VIGOROUSLY AS YOU TAKE MEASUREMENTS to obtain accurate dissolved oxygen measurements.

9. Take temperature and oxygen readings at 0.5 meters and at every meter until you reach the bottom of the lake. If the lake is deeper than 10 meters – you can start taking readings every other meter after 10 meters. Please note on your data sheet when the probe hits the bottom in the "Lake Depth" field.

10. Take a duplicate measurement. Select one depth near the surface (0.5, 1, or 2 meters) or near the lake bottom and take a duplicate temperature and dissolved oxygen reading and write that on the form. It may take a few minutes for the DO to re-stabilize. The duplicate dissolved oxygen should be within 1 mg/L of the original.

11. When finished, remove weight and store sensor in sleeve.

BE SURE THAT THE SPONGE INSIDE THE SENSOR SLEEVE IS WET BEFORE STORAGE

**Note – this meter takes 2 "C" batteries*

Calibration Verification & Use Instructions

1. Remove the probe from the gray plastic sensor sleeve. Pour enough water into the sleeve to get the sponge moistened. Then turn the sleeve over and pour out all the excess water. (You want to sponge to be wet, but you don't want the probe to be immersed in water).
2. Re-insert the probe in the calibration sleeve and stand the probe up (keep the cord on top and the sensor on the bottom).
3. Turn the instrument on and wait 5-10 minutes for the DO sensor to stabilize.
4. Press the "Cal" key. Highlight "DO" and press enter. Highlight "DO%" and press enter to confirm.
5. Wait for Temperature and DO % values under "Actual Readings" to stabilize, then highlight "Accept Calibration" and press enter to calibrate.
6. "Calibration Successful" will display for a few seconds to indicate a successful calibration and then the instrument will return to the run screen.
7. If the calibration is unsuccessful, an error message will display on the screen. Press the "Cal" key to exit the error message and return to the run screen. If sensor will not calibrate correctly ("Calibration Over" or "Unstable Reading" Error) or does not provide stable readings contact Jen at 425-531-1933.
8. If the calibration is successful – you are now ready to take measurements.
9. Remove the sleeve and screw the probe weight onto the bottom of the sensor.
10. Take temperature and oxygen readings at 0.5 meters and at every meter until you reach the bottom of the lake. If the lake is deeper than 10 meters – you can start taking readings every other meter after 10 meters. Please note on your data sheet when the probe hits the bottom in the "Lake Depth" field.
11. Take a duplicate measurement. Select one depth near the surface (0.5, 1, or 2 meters) or near the lake bottom and take a duplicate temperature and dissolved oxygen reading and write that on the form. It may take a few minutes for the DO to re-stabilize. The duplicate dissolved oxygen should be within 1 mg/L of the original.
12. When finished, remove weight and store sensor in sleeve.

BE SURE THAT THE SPONGE INSIDE THE SENSOR SLEEVE IS WET BEFORE STORAGE

**Note – this meter takes 2 "C" batteries*

CALIBRATION PREPARATION

- Make sure the calibration cup, sensor guard, and all sensors are clean
- Allow calibration standards to come to room temperature prior to calibration
- Fill out calibration record with calibration standard lot and expiration date information

BAROMETRIC PRESSURE

1. Determine your local barometric pressure (BP) in mmHg from a mercury barometer, an independent laboratory, or from a local weather service. If the BP reading has been corrected to sea level, use the following equation to determine the true BP in mmHg for your altitude:

   True BP = (Corrected BP in mmHg) – {2.5 * (Local Altitude in feet/100)}

2. Check the barometer, if the instrument displays the correct reading, no further action is required. If incorrect, please continue with calibration.
3. Record pre-calibration value
4. Press the **CAL** key, highlight **Barometer** and press the Enter key
5. Highlight **Calibration Value** and press the Enter key to adjust.
6. Use the Alpha/Numeric screen to enter True BP, highlight ENTER and press the Enter key
7. Highlight **Accept Calibration** and press the Enter key to finish the calibration
8. Record post-calibration value

DEPTH

1. Make sure that the depth sensor is clean and in <u>air</u> during calibration
2. Keep the bulkhead still while calibrating
3. Press the **CAL** key, highlight **Depth** and press the Enter key
4. Allow the readings to stabilize by observing the graph on the measurement screen
5. Wait for white line on graph shows no significant change for at least 40 seconds
6. Once stable, highlight **Accept Calibration** and press the Enter key to calibrate
7. "Calibration successful!" will be displayed in the message area at the bottom of the screen

OPTICAL DISSOLVED OXYGEN

1. Place a small amount of water (1/8 inch) in the calibration cup
2. Slide the calibration cup over the sensor guard
3. Tighten the calibration cup retaining nut, but disengage a thread or two to ensure atmospheric venting
4. Make sure the ODO and temperature sensors are not immersed in the water and there are no water droplets on the sensors
5. Wait approximately 5 to 10 minutes for the calibration cup to become saturated
6. Record pre-calibration values
7. Push the **CAL** key, highlight **ODO** and press the Enter key

8. Highlight **DO%** and press the Enter key
9. Verify the barometric pressure displayed is accurate
10. Allow the readings to stabilize by observing the graph on the measurement screen
11. Wait for white line on graph shows no significant change for at least 40 seconds
12. Once DO % and temperature are stable, highlight **Accept Calibration** and press the Enter key
13. "Calibration successful!" will be displayed in the message area at the bottom of the screen
14. Record post-calibration values

CONDUCTIVITY

1. Rinse calibration cup and sensors with clean water, then discard rinse
2. Rinse calibration cup and sensors with rinse 84 µS/cm calibration standard, then discard rinse
3. Fill the calibration cup with fresh 84 µS/cm calibration standard to a to the top line and tighten the cup
4. Make sure the solution is above the vent holes on the side of the conductivity sensor
5. Gently rotate and/or move the sensor up and down to remove any bubbles from the conductivity cell
6. Allow at least one minute for temperature equilibration before proceeding
7. Record pre-calibration value
8. Push the **CAL** key, highlight **Conductivity** and press the Enter key
9. Highlight **Specific Conductance** and press the Enter key
8. Select **Calibration value** then enter the calibration value (as it is listed for 25°C) of the standard used
9. Allow the readings to stabilize by observing the graph on the measurement screen
10. Wait for white line on graph shows no significant change for at least 40 seconds
11. Once stable, highlight **Accept Calibration** and press the Enter key to calibrate
12. "Calibration successful!" will be displayed in the message area at the bottom of the screen
13. Record post-calibration value
14. Save the calibration standard in rinse container for the next calibration

pH (2-POINT OR 3-POINT CALIBRATION)

NOTE: When performing a 2- or 3-point calibration, one point should be in buffer 7; however, the calibration points can be in any order.

1. Rinse calibration cup and sensors with clean water, then discard rinse
2. Rinse calibration cup and sensors with rinse pH 7 calibration standard, then discard rinse
3. Fill the calibration cup with fresh pH 7 calibration standard to a to the bottom line and tighten cup
4. Allow at least one minute for temperature equilibration before proceeding
5. Record pre-calibration value
6. Push the **CAL** key, highlight **pH/ORP** and press the Enter key
7. Highlight **pH** and press the Enter key
8. "Ready for cal point 1" will be displayed in the message area at the bottom of the screen
9. The **Calibration value** will automatically recognize these buffers and will compensate the calibration value for temperature- do not enter a calibration value
10. Allow the readings to stabilize by observing the graph on the measurement screen
11. Wait for white line on graph shows no significant change for at least 40 seconds
12. Record the **pH millivolts** for this calibration point. The acceptable mV outputs for each buffer are shown below:
    - pH 7 mV value = 0 mV +/- 50 mV
    - pH 4 mV value = +165 to +180 from pH 7 buffer mV value
    - pH 10 mV value = -165 to -180 from pH 7 buffer mV value

13. Once stable, highlight **Accept Calibration** and press the Enter key to calibrate
14. Record post-calibration value
15. "Ready for cal point 2" will be displayed in the message area at the bottom of the screen
16. Save the pH 7 calibration standard in rinse container for the next calibration
17. Rinse calibration cup and sensors with clean water, then discard rinse
18. Rinse calibration cup and sensors with rinse pH 4 calibration standard, then discard rinse
19. Fill the calibration cup with fresh pH 4 calibration standard to a to the bottom line and tighten the cup
20. Allow at least one minute for temperature equilibration before proceeding
21. The **Calibration value** will automatically recognize these buffers and will temperature compensate
22. Allow the readings to stabilize by observing the graph on the measurement screen
23. Wait for white line on graph shows no significant change for at least 40 seconds
24. Record the **pH millivolts** for this calibration point, ensuring that it is within acceptable mV outputs
25. Once stable, highlight **Accept Calibration** and press the Enter key to calibrate
26. Record post-calibration value
27. "Ready for cal point 3" will be displayed in the message area at the bottom of the screen
28. Highlight **Finish Calibration** and press Enter to complete a 2-point calibration, or continue for a 3-point calibration
29. Save the pH 4 calibration standard in rinse container for the next calibration
30. Rinse calibration cup and sensors with clean water, then discard rinse
31. Rinse calibration cup and sensors with rinse pH 10 calibration standard, then discard rinse
32. Fill the calibration cup with fresh pH 10 calibration standard to a to the bottom line and tighten the cup
33. Allow at least one minute for temperature equilibration before proceeding
34. The **Calibration value** will automatically recognize these buffers and will temperature compensate
35. Allow the readings to stabilize by observing the graph on the measurement screen
36. Wait for white line on graph shows no significant change for at least 40 seconds
37. Record the **pH millivolts** for this calibration point, ensuring that it is within acceptable mV outputs
38. Once stable, highlight **Accept Calibration** and press the Enter key to calibrate
39. Record post-calibration value
40. Highlight **Finish Calibration** and press Enter, or the procedure will automatically finish after calibrating using a third buffer
41. Save the pH 10 calibration standard in rinse container for the next calibration

TURBIDITY (1-POINT OR 2-POINT CALIBRATION)

NOTE: When performing a turbidity calibration, the first point must be zero (0.00). Clear deionized or distilled water is suitable for the 0 NTU calibration.

1. Rinse calibration cup and sensors with clean water two times, then discard rinse
2. Fill the calibration cup with clean dionized or distilled water to a to the bottom line and tighten the calibration cup
3. Record pre-calibration value
4. Allow at least one minute for temperature equilibration before proceeding
5. Push the **CAL** key, highlight **Turbidity** and press the Enter key
6. "Ready for cal point 1" will be displayed in the message area at the bottom of the screen
7. Select **Calibration value** then enter 0.00
8. Allow the readings to stabilize by observing the graph on the measurement screen
9. Wait for white line on graph shows no significant change for at least 40 seconds
10. Once stable, highlight **Accept Calibration** and press the Enter key to calibrate

11. Record post-calibration value
12. "Ready for cal point 2" will be displayed in the message area at the bottom of the screen
13. Highlight **Finish Calibration** and press Enter to complete a 1-point calibration, or continue for a 2-point calibration
14. Rinse calibration cup and sensors with clean water, then discard rinse
15. Rinse calibration cup and sensors with rinse 12.4 NTU calibration standard, then discard rinse
16. Fill the calibration cup with fresh 12.4 NTU calibration standard to the bottom line. Pour standard slowly down the side of the calibration container so you do not aerate the sample
17. Slowly place the turbidity sensor into the calibration cup when the cup is tilted at a 45 degree angle and tighten the calibration cup
18. Allow at least one minute for temperature equilibration before proceeding
19. Select **Calibration value** then enter the value of the second standard
20. Allow the readings to stabilize by observing the graph on the measurement screen
21. Wait for white line on graph shows no significant change for at least 40 seconds
22. Once stable, highlight **Accept Calibration** and press the Enter key to calibrate
23. Record post-calibration value
24. Highlight **Finish Calibration** and press Enter
25. Save the 12.4 NTU calibration standard in rinse container for the next calibration

PRODSS USAGE

1. If the calibration is successful – you are now ready to take measurements.
2. Remove instrument from the cup and screw the probe weight onto the bottom of the sensor.
3. Take temperature and oxygen readings at the surface and at every meter until you reach the bottom of the lake. If the lake is deeper than 10 meters – you can start taking readings every other meter after 10 meters. Please note on your data sheet when the probe hits the bottom in the "Lake Depth" field.
4. Take a duplicate measurement. Select one depth near the surface (1 or 2 meters) or near the lake bottom and take a duplicate temperature and dissolved oxygen reading and write that on the form. It may take a few minutes for the DO to re-stabilize. The duplicate dissolved oxygen should be within 1 mg/L of the original.
5. When finished, remove weight and store sensor in cup with ~1 inch of water in the cup. Probes should NOT be submersed in water during storage.

Calibration Verification & Use Instructions

1. Turn the instrument on and wait 5 seconds for the instrument to warm up.
2. Make sure sample cuvette is clean and does not have any scratches. Rinse cuvette three times and then fill with distilled water. Wipe outside of cuvette dry with Kim-wipes.
3. Insert blank sample of distilled water with the black dot closest to the back, and press <READ>. While measuring, the instrument will blink "READING" then the top left corner will display "WAIT".
4. Once "WAIT" disappears, record the reading result that appears on the Home screen in the pre-calibration column on data sheet.
5. Insert the 50.81 standard sample with the plastic handle closest to the back, and press <READ>.
6. Once "WAIT" disappears, record the reading result that appears on the Home screen in the pre-calibration column on data sheet.
7. Press the <CAL> button to begin calibration. Press <ENT>.
8. Insert blank sample of distilled water, and press <ENT>. Wait until message says "Insert cal soln then press <ENT>".
9. Insert standard sample, and press <ENT>. Wait until instrument says "Calibration complete".
10. Press <ENT> to finish calibration.
11. Insert blank sample of distilled water, and press <READ>.
12. Once "WAIT" disappears, record reading in the post-calibration column on data sheet.
13. Insert the 50.81 standard sample, and press <READ>.
14. Once "WAIT" disappears, record reading in the post-calibration column on data sheet.
15. Rinse cuvette three times with water from the lake's surface, fill and wipe dry with Kim-wipe. Press <READ> and record value on data sheet.
16. Rinse cuvette three times with water from the 1 meter sample, fill and wipe dry with Kim-wipe. Press <READ> and record value on data sheet.
17. When finished, rinse cuvette with distilled water, turn instrument off, and store in dry place.

**Note – this instrument takes 4 "AAA" batteries*

- AquaFluor is designed with "ambient light rejection." The black sample compartment cover does NOT need to be closed when reading samples.

BLACKMANS MONITORING INSTRUCTIONS

1. PREPARE FOR MONITORING

- Check monitoring calendar to confirm monitoring activities and dates
- Check weather and lake conditions; DO NOT monitor in bad weather
- Monitor between 9:00 am and 4:00 pm (Secchi readings after 5:00 pm cannot be accepted)
- Ensure that you have all equipment for the monitoring to be performed that day

Basic Monitoring		Water Sampling	Dissolved Oxygen
☐ Instruction Sheet	☐ Life jacket	☐ Water sampler	☐ YSI meter
☐ Data Sheet	☐ Anchor	☐ 1 TP/TPN bottle	☐ DO Instructions
☐ Clipboard	☐ Hat (optional)	☐ 1 TP bottle	**Algae Screening**
☐ Pencil & Sharpie	☐ Towel (optional)	☐ 1 Chl-*a* bottle	☐ Algae Screen bottle
☐ Thermometer	☐ Boat (not optional)	☐ Cooler with ice	☐ Gloves
☐ Secchi Disk		☐ Extra Bottle Set	☐ Camera (optional)

2. LABEL SAMPLE BOTTLES (IF MONITORING ON A WATER SAMPLING DATE)

- Before heading out label the water sample bottles with date, collection time, and sample ID as follows

Sample Type	Sample ID	Bottle Description
Chlorophyll *a*	BLACKMANS - 1 meter	Large Brown bottle
TP/TPN	BLACKMANS - 1 meter	Clear 125 mL bottle
TP	BLACKMANS - 6 meters	Clear 125 mL bottle

3. LOCATE YOUR MONITORING SITE

- Find the monitoring location at the deepest part of the lake using your bathymetric map
- Always anchor your boat and monitor in the same location

4. RECORD WEATHER CONDITIONS

- Record air temperature to nearest ½ ˚C by holding the thermometer in the shade for 2 minutes
- Record water temperature to nearest ½˚C by holding the thermometer or a DO probe 6-12 inches under the water surface for 2 minutes (read thermometer quickly)
- Select method used to take water temperature – thermometer or DO probe
- Choose the cloud cover percentage that best describes conditions at the time of the Secchi reading
- Choose the wind conditions that best describe conditions at the time of the Secchi reading
- Choose the amount of rain that best describes the recent rainfall in the area

5. MEASURE WATER CLARITY

- Remove sunglasses and use shady side of boat
- Lower the Secchi disk until it just disappears, raise disk until it re-appears, move disk slowly up and down
  until you find the exact vanishing point
- Measure and record depth of the Secchi disk to the nearest 0.1 meter at the vanishing point
- Repeat until you get two readings within 0.1 meters (data cannot be accepted if more than 0.1 m apart)
- If the Secchi disk hits the lake bottom or enters weeds, check the appropriate box

6. EVALUATE ALGAE CONDITIONS

- Lower the Secchi disk 6 inches below the water on the sunny side of the boat and observe the small particles (the algae) over the disk. If there are too many particles to count in an area the size of a half dollar, select "Yes" for Heavy Algae
- Look for mats of stringy filamentous algae throughout your monitoring trip and note if observed
- Look for algae scums throughout your monitoring trip especially along the shoreline. If a scum is present
    - Choose the term that best describes the algal scum type
    - Label your algae screening sample bottle and collect a sample of the scum while wearing gloves
    - Take a photo of the scum if possible
    - If you take a sample, please call 425-388-3464 to arrange a pick-up if not a scheduled pick-up date

7. RECORD LAKE LEVEL

- Record the lake level at your established fixed point at shoreline or dock and include unit used (inches or feet)
- Record lake level at County staff plate after your fixed point reading 2-3 times per season (if applicable)

8. IDENTIFY WATER COLOR AND ODOR

- Lower the Secchi Disk to ½ the Secchi depth taken that day (e.g. if Secchi was 4 meters, lower disk to 2 meters)
- Choose the Intensity and Tint that best describes the color of the water over the white portion of the disk

9. RECORD OTHER OBSERVATION

- Record the lake level at the lake staff gage or a pre-determined location and circle inches or feet
- Record the numbers of ducks, geese, and other waterfowl seen throughout monitoring trip
- Record the number of boats, people fishing, and swimmers/waders seen throughout monitoring trip
- Select the option that best describes your perception of the lake recreational suitability (1 = best; 5 = worst)
- Note other observations: aquatic plants, odors, wildlife, pollution, land clearing, equipment issues, etc

10. COLLECT WATER SAMPLES (IF WATER SAMPLING DATE)

COLLECT 1 METER SAMPLE(S)

- Open the sampler and rinse three times with lake water
- Obtain a water sample from 1 meter depth
- Collect the TP/TPN Sample:
    - Rinse the 1 meter TP/TPN bottle and cap three times with water from the sampler, being careful not to touch the inside of the cap or bottle with your hands or the sampler tube
    - Fill the 1 meter TP/TPN bottle to the shoulder, being careful not to touch the inside of the cap or bottle with your hands or the sampler tube
- Collect the Chlorophyll a sample:

- DO NOT RINSE the Chl-a sample bottle - it has a small amount of preservative - DO NOT POUR OUT
- If by accident you rinse it, use your extra Chl-a bottle instead and return rinsed bottle with samples
- Fill the bottle to the shoulder (obtain more water if needed)

- Immediately place the samples in the cooler – keep cold and dark

COLLECT BOTTOM SAMPLE

- Obtain a water sample from 6 meters (1 meter from the bottom)
- If the water sample is cloudy with sediments, dump it out and sample again on other side of the boat.
- Collect the TP Sample
  - Rinse the bottom TP sample bottle and cap three times with water from the sampler, being careful not to touch the inside of the cap or bottle with your hands or the sampler tube
  - Fill the bottom TP sample bottle to the shoulder, being careful not to touch the inside of the cap or bottle with your hands or the sampler tube
- Record if there is a rotten egg odor in the remaining sample water (means no oxygen at bottom)
- Immediately place the sample in the cooler – keep cold and dark

11. CONDUCT DISSOLVED OXYGEN PROFILE MONITORING

- If you have volunteered to take dissolved oxygen profiles, refer to Dissolved Oxygen Profile Instructions.

12. SUBMIT DATA SHEET AND SAMPLES

- Store water samples in fridge
- Sign and date the Chain of Custody section on the data sheet and submit with samples
- Place samples in cooler with ice and set on porch or at end of driveway by 8:30 am Monday.
- Submit the original data sheet with water samples, email to lakes@snoco.org or mail with the provided envelope

BLACKMANS LAKE WINTER 2022/23 MONITORING INSTRUCTIONS

1. PREPARE FOR MONITORING

- Schedule monitoring on a day near the middle of each month from November through April, preferably on a Sunday and not on Thursday through Saturday (see schedule below).
- Notify Kay Ditzenberger and Yoshihiro Monzaki of actual sample date
- Check weather and DO NOT monitor during moderate to high winds for safety reasons
- Monitor between 9:00 am and 4:00 pm (Secchi readings after 4:00 pm cannot be accepted)
- Ensure that you have all equipment for the monitoring to be performed that day
- Bring a plastic bag of ice with you to get equipment from Kay's Boathouse

Basic Monitoring Equipment		Water Sampling	Dissolved Oxygen*
☐ Instruction Sheet	☐ Life jacket	☐ Water sampler	☐ YSI meter
☐ Data Sheet	☐ Anchor	☐ Small cooler with:	☐ DO Instructions
☐ Clipboard	☐ Boat, E motor, battery, oars	☐ 2 TP bottles	*Get from Anthony Bourke for April sampling only
☐ Pencil & Sharpie		☐ 1 spare TP bottle	
☐ Thermometer	☐ Towel (optional)	☐ 1 Chl-*a* bottle	
☐ Secchi Disk	☐ Hat (optional)	☐ Bag of ice or blue ice	

2. LABEL SAMPLE BOTTLES

- Before heading out label the water sample bottles with date, collection time, and sample ID

Sample Type	Sample ID	Sample Description	Bottle Description
Chlorophyll *a*	BL-1-1	Van Dorn sample from 1 meter depth at deep lake station BL-1	Large Brown bottle
TP	BL-1-1		Clear 125 mL bottle
TP	BLK-MTH	Creek inflow from north on right of fence in lake	Clear 125 mL bottle

3. LOCATE YOUR MONITORING SITE

- Find the lake monitoring location at the deepest part of the lake using the Google pin https://goo.gl/maps/aGAxhVj4RojNLDQZ6 (see image below)
- Always anchor your boat and monitor in the same location

4. RECORD WEATHER CONDITIONS

- Record air temperature to nearest ½ ˚C by holding the thermometer in the shade for 2 minutes
- Record water temperature to nearest ½˚C by holding the thermometer or a DO probe 6-12 inches under the water surface for 2 minutes (read thermometer quickly)
- Select method used to take water temperature – thermometer or DO probe
- Choose the cloud cover and wind conditions percentage that best describes conditions at the time of the Secchi reading
- Choose the amount of rain that best describes the recent rainfall in the area

5. MEASURE WATER CLARITY

- Remove sunglasses and use shady side of boat
- Lower the Secchi disk until it just disappears, raise disk until it re-appears, move disk slowly up and down until you find the exact vanishing point
- Measure and record depth of the Secchi disk to the nearest 0.1 meter at the vanishing point
- Repeat until you get two readings within 0.1 meters (data cannot be accepted if more than 0.1 m apart)

6. EVALUATE ALGAE CONDITIONS

- Lower the Secchi disk 6 inches below the water on the sunny side of the boat and observe the small particles (the algae) over the disk. If there are too many particles to count in an area the size of a half dollar, select "Yes" for Heavy Algae
- Look for mats of stringy filamentous algae throughout your monitoring trip and note if observed
- Look for algae scums throughout your monitoring trip especially along the shoreline. If a scum is present
    - Choose the term that best describes the algal scum type and take a photo of it if possible
    - Do not collect an algae scum sample in the winter but call Snohomish County at call 425-388-3464 if one is present

7. IDENTIFY WATER COLOR AND ODOR

- Lower the Secchi Disk to ½ the Secchi depth taken that day (e.g. if Secchi was 4 meters, lower disk to 2 meters)
- Choose the Intensity and Tint that best describes the color of the water over the white portion of the disk

8. RECORD OTHER OBSERVATION

- Record the numbers of ducks, geese, and other waterfowl seen throughout monitoring trip
- Record the number of boats, people fishing, and swimmers/waders seen throughout monitoring trip
- Select the option that best describes your perception of the lake recreational suitability (1 = best; 5 = worst)
- Note other observations: aquatic plants, odors, wildlife, pollution, land clearing, equipment issues, etc

9. COLLECT LAKE WATER SAMPLE

- Open the sampler and rinse three times with lake water
- Obtain a water sample from 1 meter depth
- Collect the TP Sample:
    - Rinse the 1 meter TP bottle and cap three times with water from the sampler, being careful not to touch the inside of the cap or bottle with your hands or the sampler tube
    - Fill the 1 meter TP bottle to the shoulder, being careful not to touch the inside of the cap or bottle with your hands or the sampler tube
- Collect the Chlorophyll a sample:
    - DO NOT RINSE the Chl-a sample bottle
    - Fill the bottle to the shoulder (obtain more water if needed)
- Immediately place the samples in the cooler – keep cold and dark

10. CONDUCT DISSOLVED OXYGEN PROFILE MONITORING

- Take dissolved oxygen profile in April only, refer to Dissolved Oxygen Profile Instructions.

11. COLLECT CREEK SAMPLE

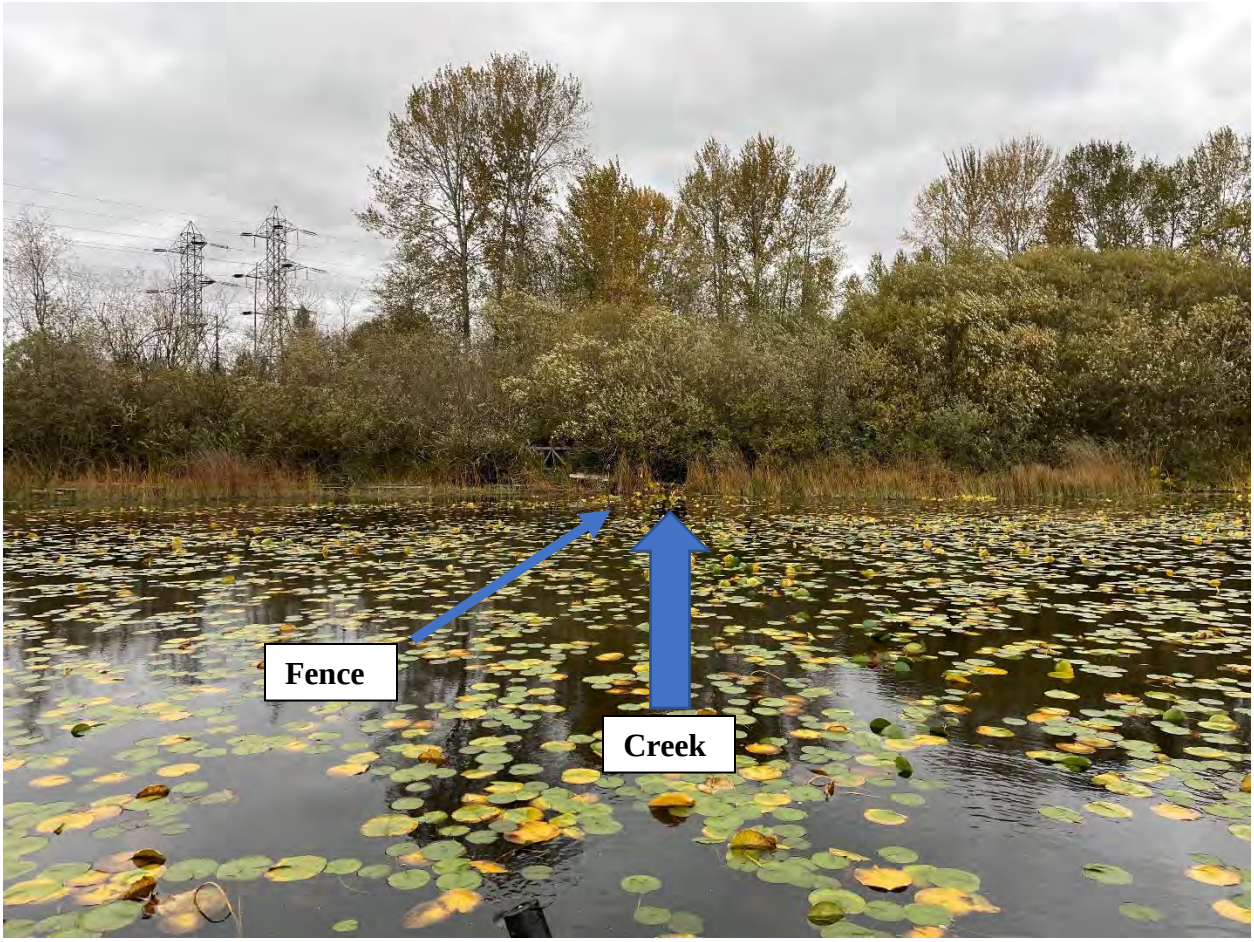
Boat to the north shore towards the first tree east of the power line tower and beach boat on the east side of metal fence in the lake (see image and photograph below or use google pin https://goo.gl/maps/zSpXP7Ys8qi2peWr7)

- Step out of boat with rubber boots and TP bottle where creek flow is highest

- Collect the TP Sample by rinsing bottle and cap first and then filling from mid-depth at deepest point in creek
- Immediately place the sample in the cooler – keep cold and dark

12. <u>SUBMIT DATA SHEET AND SAMPLES</u>

- Store water samples in cooler with either blue ice or regular ice in a plastic bag so labels stay dry
- Sign and date the Chain of Custody section on the data sheet
- Scan or photograph data sheet and email it to Yoshihiro Monzaki at monzaki@snohomishwa.gov and Katie Sweeney at ksweeney@herrerainc.com
- Place data sheet in cooler on top of samples and ice
- Place cooler on Kay's porch for pick up by the City of Snohomish



SAMPLING SCHEDULE AND CONTACTS

• November 13-16 – Kay Ditzenberger, 1605 Lake Mt Dr, Snohomish, WA 98290, 206-914-2656, kay.ditzenberger@gmail.com

• December 11-14 - Marci Gionet and Doug Campbell, 1635 Lake Mount Drive, Snohomish, WA. 98290, 425-971-6018, 425-508-6456, cgionet@earthlink.net, campbell.jdoug@gmail.com

• January 15-18 - Brad and Melissa Steiner, 1647 Lake Mount Drive, Snohomish, WA. 98290, 206-819-9577, 206-755-0014, melissa.steiner1019@gmail.com, wishniwzfishn@gmail.com

• February 12-15 - Doug Goodman, 1653 Lake Mount Drive, Snohomish, WA. 98290, 425-405-0197, goodman.douglas@gmail.com

• March 12-15 - Kim and Kevin Eno, 1625 Lake Mount Drive, Snohomish, WA. 98290, 425-478-9829. 425-478-2465, kimeno43@yahoo.com

• April 16-19 – Anthony Bourke 425-232-2289, anthony.m.bourke@gmail.com
or backup Kay Ditzenberger, kay.ditzenberger@gmail.com

DUPLICATE WATER SAMPLING INSTRUCTIONS

We are asking you to take field duplicates of your water samples this month as part of our quality control and quality assurance efforts. This quality control exercise will help assure the public and outside agencies that our lake monitoring data are reliable and high quality. In addition to reading these instructions, please view the instructional videos on taking duplicates at www.lake.surfacewater.info.

1. LABEL SAMPLE BOTTLES BEFORE HEADING OUT – YOU SHOULD HAVE TWO SETS OF BOTTLES

Sample Type	Sample ID	Duplicate Sample ID	Bottle Description
Chlorophyll *a*	Lake Name - 1 meter	Lake Name - 1 meter DUP	Large Brown bottle
TP/TPN	Lake Name - 1 meter	Lake Name - 1 meter DUP	Clear 125 mL bottle, yellow highlight on label
TP	Lake Name - X meter (X= bottom depth for your lake)	Lake Name - X meter DUP (X= bottom depth for your lake)	Clear 125 mL bottle

2. COLLECT DUPLICATE WATER SAMPLES

COLLECT 1 METER SAMPLE(S)

- Open the sampler and rinse three times with lake water.
- Obtain a water sample from 1 meter deep.
- Collect the Duplicate TP/TPN Samples:
  - Rinse the 1 meter TP/TPN bottles and caps three times with water from the sampler, being careful not to touch the inside of the cap or bottle with your hands.
  - Fill both bottles simultaneously as follows
    - Put the bottles side by side
    - Let a small amount flow into the first bottle
    - Switch to the second bottle and let a small amount in
    - Alternate at least **9-10 times** before the bottles are full
    - Be careful to not let the tube touch the inside of the bottles
    - If you run out of water take another sample and continue filling where you left off
    - It is ok to dump out and repeat if needed
- Collect the Duplicate Chlorphyll *a* samples
    - DO NOT RINSE the Chl-a sample bottles
    - Fill the bottles simultaneously as above, but alternate **15-20 times** before they are full
    - If you run out of water take another sample and continue filling where you left off
    - If you make a mistake – **do not dump out** – just make a note on your data sheet
- Immediately place the samples in the cooler – keep cold and dark.

COLLECT BOTTOM SAMPLE

- Obtain a water sample 1 meter from the bottom (see specific depth for your lake).
- If the water sample is cloudy with sediments, dump it out and sample again on other side of the boat.
- Collect the TP Duplicate Sample
  - Repeat the procedures the TP/TPN sample above **alternating 9-10 times** before filing the bottles.
- Record if there is a rotten egg odor in the remaining sample water (means no oxygen at bottom).
- Immediately place the samples in the cooler – keep cold and dark.

Thank you for helping out!

APRIL 2018

2023

Lake Volunteer Monitoring Schedule

MAY

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	**13**
14	15	16	17	18	19	20
21	22	23	24	25	26	**27**
28	29	30	31			

JUNE

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	**10**
11	**12**	13	14	15	16	17
18	19	20	21	22	23	**24**
25	26	27	28	29	30	

JULY

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	**8**
9	10	11	12	13	14	**15**
16	**17**	18	19	20	21	22
23	24	25	26	27	28	**29**
30	31					

AUGUST

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	**12**
13	**14**	15	16	17	18	19
20	21	22	23	24	25	**26**
27	28	29	30	31		

SEPTEMBER

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	**9**
10	**11**	12	13	14	15	16
17	18	19	20	21	22	**23**
24	25	26	27	28	29	30

OCTOBER

S	M	T	W	T	F	S
1	2	3	4	5	6	**7**
8	9	10	11	12	13	14
15	16	17	18	19	20	**21**
22	23	24	25	26	27	28
29	30	31				

Lake Monitoring - Can also be done during the week if not available on weekend

Lake Monitoring & Water Sampling - Must be done on Saturday or Sunday

Sample Pickup Day - Have samples out in cooler by 8:00 AM

Aquatic Analysts

Algae Analytical and Quality Assurance Procedures

September 3, 2018

Sample Handling

Sample Collection and Preservation

Phytoplankton are collected by filling bottles with natural water samples. Samples are collected at either discrete depths, or integrated through the photic zone of lakes. A volume of 125 mL is sufficient for most samples.

These samples are preserved with 1% Lugol's solution immediately after collection. Refrigeration is not necessary, and holding times are a year or more.

Sample Tracking

All samples received in the laboratory are immediately logged into a Sample Receipt Log. All samples are stored in a dedicated area until they are processed. After samples are processed and analyzed and data reports have been submitted to clients, samples are placed in storage for at least one year.

Sample Preparation

Permanent microscope slides are prepared from each sample by filtering an appropriate aliquot of the sample through a 0.45 micrometer membrane filter (APHA Standard Methods, 1992, 10200.D.2; McNabb, 1960). A section is cut out and placed on a glass slide with immersion oil added to make the filter transparent, followed by placing a cover slip on top, with nail polish applied to the periphery for permanency. A benefit to this method is that samples can be archived indefinitely; we have nearly 35,000 slides archived.

Microscopic Analyses

Algae Identifications

Aquatic Analysts has an extensive library of algae literature, including journal reprints, standard reference books, and internet reference sites. We also maintain files, notes, and photographs of algae we've encountered during the past 35 years of identifying algae. Most algae are identified by cross-referencing several taxonomic sources.

Enumeration

Algal units (defined as discrete particles - either cells, colonies, or filaments) are counted along a measured transect of the microscope slide with a Zeiss standard microscope (1000X, phase contrast). Only those algae that were believed to be alive at the time of collection (intact chloroplast) are counted. A minimum of 100 algal units are counted. (Standard Methods, 1992, 10200.F.2.c.).

Biovolume Estimates

Average biovolume estimates of each species are obtained from calculations of microscopic measurements of each alga. The number of cells per colony is recorded during sample analysis to arrive at biovolume per unit-alga. Average biovolumes for algae are stored in a computer, and measurements are verified for each sample analyzed.

Data Analyses and Reports

Sample Reports

Results of sample and data analyses are provided to the client in electronic format. Deliverables include individual sample reports, data summaries, database file, and combined species lists.

Individual sample reports include sample identification, a trophic state index, total sample density, total sample biovolume, and a list of algae species with their absolute and relative densities and biovolumes. All data are reported in Excel format.

Data summaries include sample identification, total density, total biovolume, the trophic state index, and the top 5 most common algae species (codes) and their relative densities. The summary format allows for easy calculations and graphs of algae sample data.

Database files include information for each species from each sample within a sample set. Information includes sample ID, species names and codes, densities and biovolumes, taxonomic group, and any notes on each sample.

Combined species lists of all species within related groups of samples allow greater sensitivity in comparing different lakes, sites, dates, or depth. Algae species are compiled according to their relative densities.

Trophic State Index

A Trophic State Index based upon phytoplankton biovolume has been developed from a data set of several hundred lakes located throughout the Pacific Northwest (Sweet, 1986, Report to EPA). The index was derived in a similar fashion as Carlson (1977) derived indices for Secchi depth, chlorophyll concentration, and total phosphorus concentration. The biovolume index ranges from 1 for ultraoligotrophic lakes to 100 for hypereutrophic lakes. Values agree well with Carlson's indices.

The index is defined as:

TSI (biovolume) = (Log-base 2 (B+1)) * 5

Where B is the phytoplankton biovolume in cubic micrometers per milliliter divided by 1000.

TSI values below 20 are generally considered to be ultraoligotrophic, values from 20-35 are oligotrophic, 35-50 mesotrophic, 50-65 eutrophic, and above 65 is hypereutrophic.

Quality Assurance

Microscope Calibration

Aquatic Analysts use a Zeiss Standard phase-contrast microscope primarily with a 1000X magnification for identification and enumeration of algal samples. The diameter of the field of view at 1000X magnification is 0.182 mm. The effective area of a filter is 201 millimeters square.

Algae are enumerated along a measured transect, measured accurately to 0.1 mm with a stage micrometer. The algal densities are calculated from the area observed (transect length times diameter of field of view), the effective filter area, and the volume of sample filtered.

The microscope was calibrated using a standard concentration of latex spheres provided by EPA (Cincinnati, OH). The concentration of these spheres was 12,075 per milliliter. Duplicate preparations of the standard spheres were analyzed; the average result was

11,700 spheres per milliliter (96.9 percent). The computer program used to calculate algae densities compensates for this 3.1% error.

Replicates

Replicate algae samples are analyzed at the client's request. We encourage blind replicates for approximately 10% of all samples collected. Replicates are assessed for algae abundance (relative mean difference of densities) and species composition (similarity indices, species lists).

Independent Analyses

Aquatic Analysts has participated in the analyses of split algae samples on several occasions, with general agreement between samples in terms of algae density and algae species compositions. On occasion, we also contract independent algae analysts for second opinions on some difficult to identify algae species.

Internal Data Verification

A custom computer program handles all calculations and data analyses. Final sample reports are compared with laboratory bench sheets before releasing data.

Data summaries, tables of similarity indices, abundance graphs, and combined species lists are searched for inconsistencies, outliers, and interrupted patterns that may indicate possible errors.

Archives

Aquatic Analysts maintains an herbarium of all microscope slides analyzed (over 35,000 to date). These may be reviewed if questions arise after data are reported. In addition, all computer data (sample tracking data, raw count data, final reported data, data analyses, narrative reports) are archived on CD's in permanent storage.

STANDARD OPERATING PROCEDURES

for

Laboratory Analysis: Zooplankton Indicator

Prepared by

EcoAnalysts, Inc.
LIFE IN WATER

1420 South Blaine Street, Suite 14
Moscow, Idaho 83843

July 2017

A1. TITLE AND APPROVAL SHEET

Document Title:
Quality Assurance Project Plan for Laboratory Analysis: Zooplankton Indicator

Preparer:
EcoAnalysts, Inc., Moscow, Idaho

Address and Telephone Number:
1420 South Blaine Street, Suite 14, Moscow, Idaho 8343/ (208) 882-2588

Day/Month/Year
15/July/2017

EcoAnalysts, Inc. President/CEO, Project Manager: _____
Gary T. Lester. / 15 July 2017

EcoAnalysts, Inc. Quality Assurance Manager: _____
Robert Bobier / 15 July 2017

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Table 1. Acronyms and Abbreviations

CEO	Chief Executive Officer
EPA	United States Environmental Protection Agency
DQO	Data Quality Objective
EcoAnalysts	EcoAnalysts, Inc.
QA	Quality Assurance
QAM	Quality Assurance Manager
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
QC	Quality Control
SOP	Standard Operating Procedure
US EPA	United States Environmental Protection Agency

DOCUMENT CONTROL

This document has been prepared according to the United States Environmental Protection Agency publication, *EPA Requirements for Quality Assurance Project Plans* (EPA QA/R5, March 2001). This QAPP will be reviewed annually and updated as needed. Updated versions of this QAPP will bear a new (x + 1) revision number.

GROUP A: PROJECT MANAGEMENT

A3. DISTRIBUTION LIST

Each person listed on the Approval Signature Page and each person listed in Table 2 or his/her successor will receive a copy of the final approved version of this Quality Assurance Project Plan. A copy will also be made available to other persons taking part in the project and to other interested parties.

Table 2. QAPP for Laboratory Analysis: BMI Distribution List

Name	Title/Affiliation	Address	Phone/email
Gary Lester	CEO, Project Manager EcoAnalysts, Inc.	1420 South Blaine Street, Suite 14 Moscow, ID 83843	208-882-2588 ext 21 glester@ecoanalysts.com
Robert Bobier	QA Manager EcoAnalysts, Inc.	1420 South Blaine Street, Suite 14 Moscow, ID 83843	208-882-2588 ext 34 rbobier@ecoanalysts.com
William LaVoie	Taxonomy Coordinator EcoAnalysts, Inc.	1420 South Blaine Street, Suite 14 Moscow, ID 83843	208-882-2588 ext 80 blavoie@ecoanalysts.com
Megan Payne	Sorting Lab Manager EcoAnalysts, Inc.	1420 South Blaine Street, Suite 14 Moscow, ID 83843	208-882-2588 ext 59 mpayne@ecoanalysts.com

A4. PROJECT/TASK ORGANIZATION

The primary responsibilities of the principals are as follows:

<u>EcoAnalysts Project Manager – Gary Lester, CEO</u>

- Provides overall coordination of the project and makes decisions regarding the proper functioning of all aspects of the project; and
- Makes assignments and delegates authority as needed, to other parts of the project organization.

<u>EcoAnalysts QA Manager – Robert Bobier</u>

- Oversees transfer of samples and related records for the zooplankton indicator;
- Ensures the validity of data for the zooplankton indicator;
- Interacts with EcoAnalysts Project Manager on issues related to sample processing and schedules for conduct of activities;
- Collects copies of all official forms, evaluation checklists and reports;
- Oversees and maintains records of laboratory operations, but is not part of laboratory operations; and
- Directs laboratory audits.

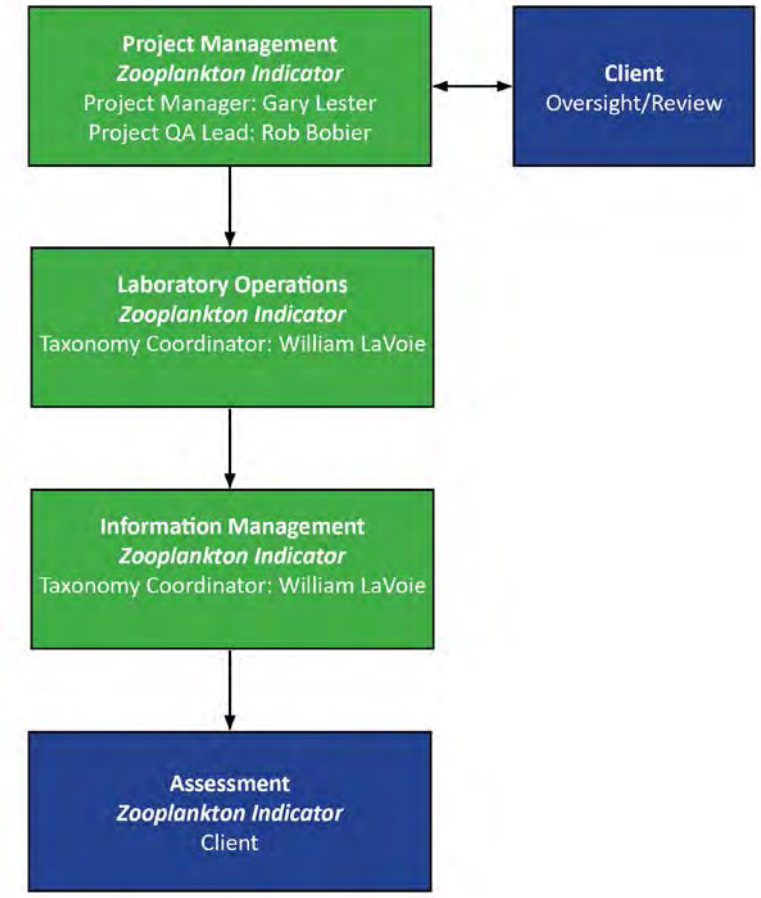
<u>EcoAnalysts Taxonomy Coordinator – William LaVoie</u>

- Oversees analysis of zooplankton samples; and
- Ensures the validity of data for the zooplankton indicator.

Table 3. Principal Contact List

Gary Lester CEO, Project Manager EcoAnalysts, Inc. 1420 South Blaine Street Suite 14 Moscow, ID 83843 208-882-2588 ext. 21 208-883-4288 glester@ecoanalysts.com	Robert Bobier QA Manager EcoAnalysts, Inc. 1420 South Blaine Street Suite 14 Moscow, ID 83843 208-882-2588 ext. 34 208-883-4288 rbobier@ecoanalysts.com	William LaVoie Taxonomy Coordinator EcoAnalysts, Inc. 1420 South Blaine Street Suite 14 Moscow, ID 83843 Phone: 208-882-2588 ext. 80 Fax: 208-883-4288 blavoie@ecoanalysts.com

Figure 1. Project Organization



The QA Manager is independent from project staff that generates data. The QA Manager, Robert Bobier, is responsible for managing this QAPP and is available to address project QA/QC problems and concerns.

A5. PROBLEM DEFINITION/BACKGROUND

This QAPP addresses the laboratory analysis of zooplankton indicator samples. This Laboratory Operations Quality Assurance Project Plan is a tool to guide EcoAnalysts' laboratory operations for processing zooplankton samples. This plan contains elements of project management, data quality objectives, measurement and data acquisition, and information management for processing zooplankton samples.

This QAPP covers in scope the processing of zooplankton samples collected from all water body types (coasts and estuaries, wetlands, lakes, and rivers).

A6. PROJECT/TASK DESCRIPTION

Ecoanalysts is adequately equipped and staffed to conduct highly specialized analyses related to the zooplankton indicator. EcoAnalysts complies with all methods, procedures, and QA/QC requirements as described in required laboratory methods manuals. Prior to initiation of task orders, EcoAnalysts' laboratory operations may be evaluated by EcoAnalysts' QAM.

Zooplankton samples collected and preserved at each site will be processed and identified at Ecoanalysts' laboratory to the lowest practicable level or level required. The taxonomy coordinator will oversee and periodically review the work performed by taxonomists.

A7. QUALITY OBJECTIVES AND CRITERIA

For analyzing zooplankton indicator samples, performance objectives (associated primarily with measurement error) are established (following USEPA Guidance for Quality Assurance Plans EPA240/R-02/009). The following sections describe approaches for evaluating zooplankton indicator sample analyses.

A7.1 Taxonomic Precision and Accuracy

Taxonomic precision will be quantified by comparing whole-sample identifications. To calculate taxonomic precision for zooplankton, 10 percent of the samples will be randomly-selected for re-identification and percent similarity will be calculated. Percent similarity is a measure of similarity between two communities or two samples (Washington 1984). Values range from 0% for samples with no species in common, to 100% for samples which are identical. It is calculated as follows:

Equation 1. Percent Similarity

$$PSC = 1 - 0.5\sum_{i=1}^{K}|a-b|$$

where:
a and b = for a given species, the relative proportions of the total samples A and B, respectively, which that species represents.

A MQO of ≥85% is recommended for percent similarity of taxonomic identification. If the MQO is not met, the reasons for the discrepancies between analysts should be discussed. If a major discrepancy is found in how the two analysts have been identifying organisms, the last batch of samples that have been counted by the analyst under review may have to be recounted.

Additionally, percent similarity should be calculated for re-processed subsamples. This provides a quantifiable measure of the precision of subsampling procedures. A MQO of ≥70% is recommended for percent similarity of subsamples. If a sample does not meet this threshold, additional subsamples should be processed from that sample until the MQO is achieved.

Corrective actions for samples exceeding these MQOs can include defining the taxa for which re-identification may be necessary (potentially even by a third party), for which samples (even outside of the

10% lot of QC samples) it is necessary, and where there may be issues of nomenclatural or enumeration problems.

Accuracy of taxonomy will be qualitatively evaluated through specification of target hierarchical levels (e.g., family, genus, or species); and the specification of appropriate technical taxonomic literature or other references (e.g., identification keys, voucher specimens). Samples will be identified using the most appropriate technical literature that is accepted by the taxonomic discipline and reflects the accepted nomenclature. Where necessary, the Integrated Taxonomic Information System (ITIS, http://www.itis.usda.gov/) will be used to verify nomenclatural validity and spelling.

A8. SPECIAL TRAINING/CERTIFICATION

Training of EcoAnalysts' project staff, when needed, is done internally through assistance from senior project staff. All identifications are completed by taxonomists certified in the appropriate area.

A9. DOCUMENTATION AND RECORDS

All versions of the QAPP are retained by EcoAnalysts. EcoAnalysts retains sorting bench sheets indefinitely. Taxonomic data are entered into EcoAnalysts' custom LIMS program by taxonomists during the identification process. Sample data are retained by ecoanalysts indefinitely following completion of the project.

GROUP B: DATA GENERATION AND ACQUISITION

B1. SAMPLING DESIGN

The specific details for the collection of samples associated with different indicators are described in the zooplankton indicator-specific sections of the field QAPP or client field manual.

B2. SAMPLING METHODS

The specific details for the collection of samples associated with different indicators are described in the zooplankton indicator-specific sections of the field QAPP or client field manual.

B3. SAMPLE HANDLING AND CUSTODY

Immediately upon receipt of zooplankton samples, all containers are inspected for damage or leakage. Sample labels are checked against chain of custody forms and/or packing slips and any discrepancies are noted. Receipt records are reported to the client within one business day of sample receipt. Chain of custody logs are reported throughout the project according to timelines and methods requested by the client.

Samples are logged into the EcoAnalysts, Inc. custom Laboratory Information Management System, LIMS, database and assigned a unique sample tracking number.

B4. ANALYTICAL METHODS

B4.1 Preparing Zooplankton Samples

Samples are checked out via LIMS. A sheet is printed out containing all of the sample information and sorting protocols designated for it. Samples are rinsed with 70% ethanol into a 500 ml jar, and the sample is weighed.

B4.1 Taxonomic Identification and Enumeration of Zooplanktons

After weighing the sample, a 1 mL Hensen-Stempel pipette is inserted into the sample and is used to homogenize the sample, mixing it in a random fashion (not swirling). The sub-sample is captured during the mixing process to avoid bias due to sinking of heavier planktonic organisms.

The subsample taken from the homogenized sample is rinsed into a watch glass with 70% ethanol. Based on the organism density of the first 1 mL of the subsample, more 1-mL aliquots are added until the target count of 200-400 non-rotifer zooplankters is present in the watch glass. If the target count is exceeded in one mL of sample, a secondary dilution is made by transferring aliquots from the sample into a second beaker and diluting this subsample. After weighing the secondary dilution, aliquots are then taken from this secondary dilution for analysis. Identifications are taken to the lowest practical level (Genus and species for Cladocera, Cyclopoida, Calanoida, and Anostraca, family level for Diptera, Hydracarina, and order level for Harpacticoida). The length measurements of 15 individuals of the top five dominant taxa are taken.

The entire contents of the watch glass are counted to allow proper abundance calculations. After identification, enumeration, and measurements, the sample (and the secondary dilution, if used) is weighed to calculate the total volume analyzed.

After initial analyses are complete, 10% of the samples will be randomly selected for re-identification. See Section A7.1 for taxonomic precision and accuracy measurement quality objectives. The final data will be adjusted according to the recommendations of both taxonomists.

B5. QUALITY CONTROL

Zooplankton samples are checked for quality control. See Section A7.1 of this QAPP for quality objectives and methods.

B6. INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

All microscopes and laboratory equipment are inspected regularly according to manufacturer recommendations.

B7. INSTURMENT/EQUIPMENT CALIBRATION AND FREQUENCY

All microscopes and laboratory equipment, including digital imaging equipment, are calibrated regularly according to manufacturer recommendations. Calibration will be checked throughout the project and equipment will be recalibrated if necessary.

B8. INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

Supplies and consumables include alcohol and sample jars. Supplies and consumables are purchased only from reputable and reliable suppliers and are inspected for usability upon receipt.

B9. NON-DIRECT MEASUREMENTS

EcoAnalysts maintains a library of current taxonomic references. These are used for taxonomic identification purposes when such need arises. Taxonomists are responsible for using current references and publications.

B10. DATA MANAGEMENT

As the zooplankton sample is being identified, the taxonomist enters data directly into the computer using a custom built LIMS database and user interface. The data entry program has several features built into it, including steps for taxonomic identification of a specimen, the number of specimens in each taxon, life stage information, taxonomic notes, etc. There is a visual confirmation at each step which prompts for a user confirmation. A running tally of invertebrates as well as the number and type of taxa in the sample are displayed on the screen; therefore, a taxonomist can quickly look for low or high counts as a flag for major discrepancies. Note: With this process, we have successfully eliminated the need for handwritten bench sheets, thereby doing away with a secondary step of data entry and the errors associated with it.

Throughout the project and sample analysis, data entry is double checked for accuracy. Using our networked computer systems, the appropriate data are combined for each sample to obtain the sorting statistics and comprehensive taxa lists and counts.

Data are delivered in an electronic format specified by the client and emailed to the technical contact(s). Hard copies and/or copies on compact disc can be mailed to the client upon request. The delivery schedule will be agreed upon by the client and EcoAnalysts in advance, specifying the sample lots, dates, and components. EcoAnalysts, Inc. retains all raw data files used and derived in our projects.

Quality assurance data sheet checks include scanning for apparent entry errors, measurement errors, omissions, and anomalies. Suspect data are flagged and/or excluded from use. Data may be presented in table, graph, and chart format. Unusual data are rechecked to verify their accuracy.

GROUP C: ASSESSMENT AND OVERSIGHT

C1. ASSESSMENT AND RESPONSE ACTIONS

The project manager, Gary Lester, is responsible for all reporting, tracking, and overall project management including field activities, reviewing the data, reporting, and forwarding all data to the client for inspection. Megan Payne and Pat Barrett are responsible for laboratory operations involving processing zooplankton indicator samples for projects. Robert Bobier, EcoAnalysts QAM, is authorized to oversee all activities as required for quality assurance.

C2. REPORTS TO MANAGEMENT

Draft reports of project findings will be prepared for the client on a regular basis, as requested. Problems that arise during the project are corrected and reported to client and EcoAnalysts staff via this report. The project manager will submit a final report prior to the conclusion of the task order. All data are tracked through use of EcoAnalysts' LIMS. The data compiled during this project are incorporated into spreadsheets and sent to the client and if requested, will be uploaded to the client's database.

GROUP D: DATA VALIDATION AND USABILITY

D1. DATA REVIEW, VERIFICATION, AND VALIDATION

All raw data are transcribed into EcoAnalysts' LIMS. Hard copies of raw data are organized and filed. Statistical analyses on replicate samples are recorded so that the degree of certainty can be estimated. All laboratory analytical results are cross checked to ensure data are complete and error free. Data are archived using EcoAnalysts' LIMS on EcoAnalysts' servers.

D2. VERIFICATION AND VALIDATION METHODS

Project staff follows the EPA *Guidance on Environmental Verification and Validation* (EPA QA/G-8) whereby the data are reviewed and accepted or qualified by project staff.

D3. RECONCILIATION WITH USER REQUIREMENTS

Upon receipt of results of each sample group, calculations and determinations of precision and accuracy are made and corrective action implement, if needed. If data quality does not meet project specifications, the deficient data are flagged and the cause of failure evaluated. Any limitations on data use are detailed in the project reports and other documentation. For the data to be considered valid, data collection procedures, the handling of samples, and data analysis must be monitored for compliance with all the requirements described in this QAPP. Data are flagged and qualified if there is evidence of habitual violations of the procedures described in this QAPP. Any limitations placed on the data are reported to the data end user in narrative form.

APPENDIX B

Forms and Checklists

lake monitor
SNOHOMISH COUNTY

Lake: _____ **Date:** _____ **Time:** _____

Name(s): _____

Staff Use Only
Entered ☐
Verified ☐

WEATHER CONDITIONS

Air Temperature _____ºC

Water Temperature *(~6 inches deep)* _____ºC
Collected with: ☐ thermometer ☐ DO probe

Percent Cloud Cover
☐ 0% ☐ 10% ☐ 25% ☐ 50% ☐ 75% ☐ 90% ☐100%

Current Wind Conditions
☐ calm ☐ light *(ripples)* ☐ breezy *(small waves)* ☐ strong *(white caps)*

Rain within last 2 days
☐ none ☐ slight ☐ moderate ☐ heavy

WATER CLARITY

Secchi Disk
Repeat until readings are within 0.1 meter

1st Secchi Reading _____ meters

2nd Secchi Reading _____ meters

*Did Secchi disk: ☐ hit bottom? ☐ enter weeds?
(leave blank if neither)

ALGAE

Heavy Algae in Water? ☐ Yes ☐ No
(*Use Secchi disk to assess 6-12 inches below surface)*

Filamentous Algae Observed? ☐ Yes ☐ No
(*Mats of <u>stringy</u> algae - does not dissipate if disturbed)*

Algae Scum Observed? ☐ Yes ☐ No
(*Looks like paint floating on surface - dissipates if disturbed)*

Scum Type: ☐ small clumps ☐ light film ☐ thick scum

Sample Taken: ☐ Yes ☐ No Location:_____

LAKE LEVEL

Lake Level: _____ **Unit**:_____ (*inches or feet)*
(taken from established fixed point at shoreline or dock)

County Staff Plate:_____ feet

WATER COLOR

Water Color
(Lower disk to half of today's Secchi depth to identify color)

Intensity: ☐ light ☐ moderate ☐ dark

Tint: ☐ green ☐ brown ☐ red ☐ orange
☐ yellow ☐ green yellow ☐ green brown
☐ yellow brown ☐ other _____

WATER SAMPLES

Water Samples Collected: ☐ Yes ☐ No

Samples Collected & Labeled:

☐ TP/TPN/Color - 1 meter
☐ Chlorophyll *a* - 1 meter
☐ TP—____ meters
(1 meter from bottom)

Chain of Custody
Relinquished by
Sign:_____
Date:_____

Odor in Bottom Sample? *(rotten egg)* ☐ Yes ☐ No

OTHER OBSERVATIONS

# of Waterfowl:
ducks: ____ geese: ____ swans: _____
other : _____ type(s):_____

Recreational Lake Usage:
# of boats: _____ # of people fishing: _____
# of swimmers/waders:_____

Recreational Suitability *(disregard poor weather)*:
☐ 1 - beautiful could not be nicer
☐ 2 - minor aesthetic concerns
☐ 3 - swimming & boating slightly impaired
☐ 4 - swimming, boating & aesthetic enjoyment substantially impaired *(would not swim, but boating ok)*
☐ 5 - swimming, boating & aesthetic enjoyment are severely limited *(would not swim or boat in lake)*

COMMENTS

(Provide additional comments for aquatic plants, odors, wildlife, pollution, equipment issues, etc. - continued on back)

_____

_____

lake monitor
SNOHOMISH COUNTY

Staff Use Only
Entered ☐
Verified ☐

DISSOLVED OXYGEN MONITORING - LAKE PROFILES

Depth (m)	Temp (°C)	DO (mg/L)	DO%
Surface			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
12			
14			
16			
18			
20			
Duplicate* _____(m)			
Duplicate Criteria**	± 0.5 °C	± 1.0 mg/L	

** Repeat measurement at one depth to verify instrument precision. Select a duplicate depth near the lake surface or lake bottom.*

*** Duplicate reading should be within the listed criteria. If the instrument does not meet the criteria, notify the Lakes group.*

Advanced Monitoring Information:

Lake Depth: _____ meters
(depth at which probe hits lake bottom)

Instrument Name:

_____

Instrument Calibration Successful?

☐ Yes ☐ No

Instrument Comments:
(describe any problems experienced etc.)

_____

_____

_____

_____

Other Comments *(continued from page 1):*

_____

_____

_____

_____

_____

_____

_____

_____

_____

BLACKMANS LAKE WATERSHED MONITORING FORM

PROJECT: **Blackmans Lake Cyanobacteria Management Plan** PROJECT NO.: **22-07905-000**

CLIENT: **City of Snohomish** FIELD PERSONNEL: _____

DATE AND EVENT TYPE/NUMBER: **Storm** **Base**

WEATHER/RAIN AMOUNTS: _____

SAMPLING DATA

SITE ID	PHOSPHORUS SAMPLE ID	SAMPLE TIME	DUPLI-CATE?	PHOTO(S) TAKEN?	WATER DESCRIPTION (TURBIDITY; UNUSUAL COLOR, ODOR, SHEEN)
BLK-26	BLK-26				
BLK-22	BLK-22				
BLK-NE	BLK-NE				
CHAMP-19	CHAMP-19				
CHAMP-PARK	CHAMP-PARK				

DISCHARGE DATA

SITE ID	MEASURE LOCATION	WATER DEPTH (FT)*	VELO-CITY (FT/SEC)*	CALC. FLOW (CFS)	OBSERVATIONS
BLK-26	24" pipe outfall to narrow channel	1: 2: 3:	1: 2: 3		Total width (ft)=
BLK-22	24" pipe outfall				
BLK-NE	East ditch				% of BLK-22 flow=
CHAMP-19	Narrow ditch				Total width (ft)=
CHAMP-PARK	24" E inlet pipe				% of total from S pipe=
BL-GAUGE	Hill Park Dock		NA	NA	
BL-OUT	4-24" pipes				

*mean depth and velocity unless otherwise noted

BL-OUT DISCHARGE IN FOUR PIPES **SWIFTY CREEK DISCHARGE CHANNEL WIDTH = ____ FEET**

Pipe	Depth (ft) from top of pipe	Velocity (f/s) at center	Point	Feet to bank	Depth* (ft)	Velocity (f/s)	Point	Feet to bank	Depth* (ft)	Velocity (f/s)
1 W			1				5			
2			2				6			
3			3				7			
4 E			4				8			

CALC FLOW (CFS)= _____ **CALC FLOW (CFS)= _____**

NOTES:_____

_____

_____

_____

_____

_____

_____

METER CALIBRATION LOG

Project: _____

Personnel Performing Calibration: _____

Meter (s): _____

Date/Time: _____

PRE-Event Calibration	Meter Reading	Buffer / Cal Std	Comments
pH		7	
		10	
		4	
Conductivity (µS/cm)		0	
Conductivity (µS/cm)		1,000	
DO % Saturation		100	

POST-Event Calibration Check	Meter Reading	Buffer / Cal Std	Comments
pH		7	
		10	
		4	
Conductivity (µS/cm)		1,000	
DO % Saturation		100	

Notes:

Calibration Procedures:

Rinse Multimeter Sonde Between Each Operation

Rinse with deionized water, then with the solution to be used for calibrating or testing.

pH Calibration Notes:

1. Perform 3-point calibration, starting with pH 7 buffer, followed by 10 and 4 buffers.
2. Fill calibration cup to bottom line with each pH buffer, ensure all sensors are submerged, wait until meter indicates that it has stabilized, hit "Calibrate/OK".

Conductivity Calibration Notes:

1. Dry the conductivity probe with a lab tissue (e.g., KimWipes®) and calibrate @ 0 µS.
2. Fill the calibration cup to bottom line with 1,000 µS standard and ensure that the temperature/conductivity probes are completely submerged.
3. Make sure there are no bubbles in the conductivity sensor.
4. Enter the appropriate standard value (1,000 µS/cm or 1.0 mS/cm) for Sp Cond. and calibrate once meter indicates that it has stabilized.

Dissolved Oxygen Calibration Notes:

1. Fill calibration cup with ~1/2 inch of water; it should be below the DO sensor cap.
2. Use KimWipes® to carefully dab/dry water from the sensor cap.
3. Invert sonde and gently rest it on the storage cup **without** screwing shut the cup.
4. Wait for the meter to stabilize; when it indicates it has stabilized, hit "Calibrate/OK".
5. To retain calibration accuracy between measurements, keep a small amount of water in the storage cup between sample sites.

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

REPORT TO:

Client: City of Snohomish
Address: P.O. Box 1589
116 Union Ave., Snohomish, WA, 98291
Contact: Yoshihiro Monzaki
Email: monzaki@snohomishwa.gov
Phone: 360-282-3161 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)

Client:
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION

Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format

☐ Fax ☒ Email ☐ Mail

QC Data Reported

☐ Yes ☐ No

Sample Disposal

☐ Hold ☒ Dispos ☐ Return

Turn Around Time (TAT)*

☐ Next Day ☐ 2 Business Days
☐ 3 Business Days ☒ Standard

Specific Date:

*Advanced notice required for Rush Ar

SAMPLING			SAMPLE DESCRIPTION	Number of Containers	Analysis Requested														LAB USE ONLY		
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)		TP	Chlorophyll a	–									Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Case File Number: Temp	Case File Number: Lab ID
		SW																			

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:
Report Copy to: Rob Zisette, Herrera, rzisette@herrerainc.com

Sampled By	Date	Time
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By	Shipping Reference	
Received at Aquatic By	Date	Time

IEH - Aquatic Research
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REPORT TO:

Client: City of Snohomish
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Phone: 360-282-3161 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)

Client:
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION

Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format

☐ Fax ☒ Email ☐ Mail

QC Data Reported

☐ Yes ☐ No

Sample Disposal

☐ Hold ☒ Dispos ☐ Return

Turn Around Time (TAT)*

☐ Next Day ☐ 2 Business Days
☐ 3 Business Days ☒ Standard

Specific Date:

*Advanced notice required for Rush Ar

SAMPLING			SAMPLE DESCRIPTION	Number of Containers	Analysis Requested														LAB USE ONLY		
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)		TP												Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Case File Number: Temp	Case File Number: Lab ID
		SW																			

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:
Report Copy to: Rob Zisette, Herrera, rzisette@herrerainc.com

Sampled By	Date	Time
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By	Shipping Reference	
Received at Aquatic By	Date	Time

IEH Analytical Laboratories
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

REPORT TO:
Client: _____
Address: _____
_____
Contact: _____
Email: _____
Phone: _____

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: _____
Addres _____
_____
Contac _____
Email: _____
Phone: _____ Fax: _____

PROJECT INFORMATION
Quote No.: _____
Client PO: _____
Client Project: _____

Reporting/Invoicing Format
☐ Fax ☐ Email ☐ Mail

QC Data Reported
☐ Yes ☐ No

Sample Disposal
☐ Hold ☐ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☐ Standard

Specific Date: _____

SAMPLING			SAMPLE DESCRIPTION	Number of Containers	Analysis Requested				LAB USE ONLY	
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)		Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID

Case File Number

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments.

	Date	Time
Sampled By		
Received By		
Relinquished to IAL By (Signature)		

Shipped By	Shipping Reference	
Received at IAL By	Date	Time

HERRERA
2200 Sixth Avenue | Suite 1100
Seattle, Washington | 98121
p 206 441 9080 | f 206 441 9108

Chain of Custody Record

Project Name:	Project Number:	Client:
Report To:		Copy To:
Sampled By:		Delivery Method:
Laboratory:	Requested Completion Date:	Total No. of Containers:
Lab Use:		

Sample ID	Date	Time	Sample Type (see codes)	Preser-vative? (Y/N)	Matrix (see codes)	Number of Containers	Analyses Requested										Lab ID No.

Comments/Special Instructions:

Relinquished by (Name/CO/	Signature	Date/Time	Received By (Name/CO)	Signature	Date/Time
Relinquished by (Name/CO/	Signature	Date/Time	Received By (Name/CO)	Signature	Date/Time

Sample Type: G=Grab C=Composite **Matrix Codes:** A=Air GW=Groundwater SE=Sediment SO=Soil SW=Surface Water W=Water (blanks) M=Material O=Other (specify)

Data Quality Assurance Worksheet

By _____

Project Name/No./Client: _____ Date _____ Page ____ of ____

Laboratory/Parameters: _____ Checked: initials _____

Sample Date/Sample ID: _____ date _____

Parameter	Completeness/ Methodology	Pre-preservation Holding Times (days)		Total Holding Times (days)		Method Blanks Reporting Limit	Matrix Spikes/ Surrogate Recovery (%)		Lab Control Samples Recovery (%)		Lab Duplicates RPD (%)		Field Duplicates RPD (%)		Instrument Calibration/ Performance	ACTION
		Reported	Goal	Reported	Goal		Reported	Goal	Reported	Goal	Reported	Goal[1]	Reported	Goal[1]		
						1.0										

[1] If the sample or duplicate value is less than five times the reporting limit, the difference is calculated rather than the relative percent difference (RPD). The QA goal is a difference <2 times the detection limit instead of the number indicated in the goal column.
NA – not applicable or not available; NC – not calculable due to one or more values below the detection limit; NS – field duplicate not sampled.