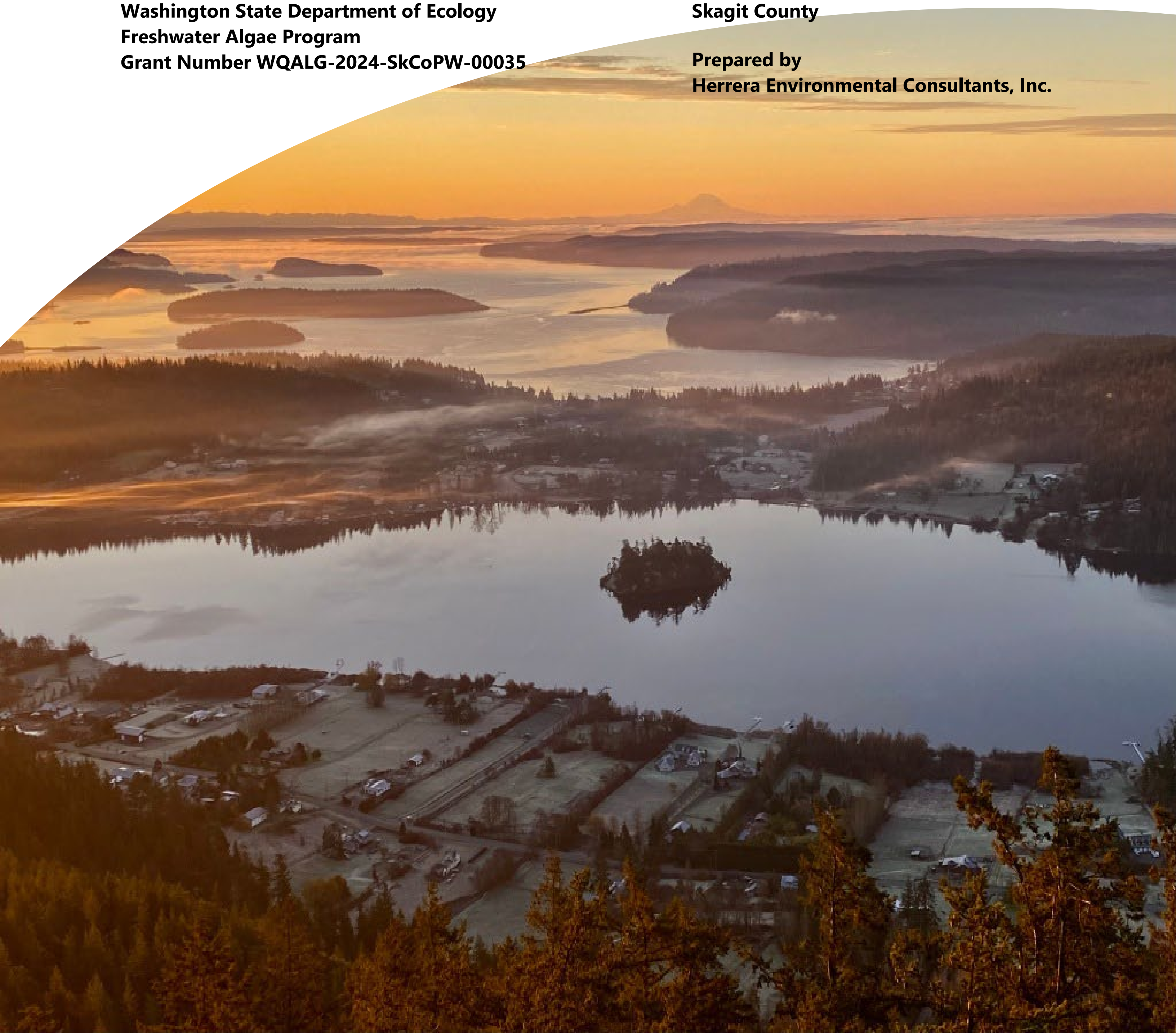
Lake Cyanobacteria Management Plan

Lake Campbell, Skagit County, Washington

Funded by
Washington State Department of Ecology
Freshwater Algae Program
Grant Number WQALG-2024-SkCoPW-00035

Prepared for
Skagit County

Prepared by
Herrera Environmental Consultants, Inc.



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Prepared for
Skagit County
1800 Continental Place
Mount Vernon, Washington 98273

Prepared by
Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
Telephone: 206-441-9080

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Executive Summary

Lake Campbell is a historically productive system with high plant and algae growth. In 1985 the lake was treated with aluminum sulfate ("alum") to reduce internal phosphorus sources fueling harmful algae (cyanobacteria) blooms (HABs). After an approximately 20-year reprieve due to the treatment, Lake Campbell once again suffers frequent toxic cyanobacteria blooms. These blooms impair beneficial uses of the lake by threatening human and animal health and by creating unsightly and odorous scums on the lake surface.

Skagit County Public Works was awarded a grant from the Washington State Department of Ecology Freshwater Algae Program (Grant Number WQALG-2024-SkCoPW-00035) to prepare a Lake Cyanobacteria Management Plan (LCMP). In 2023, Skagit County contracted with Herrera Environmental Consultants, Inc. (Herrera) to prepare the LCMP and develop a Quality Assurance Project Plan (QAPP) to collect additional data to inform LCMP development.

What Are Cyanobacteria and Why Are They a Problem?

A cyanobacteria bloom in Lake Campbell on August 23, 2023.

Cyanobacteria (also called "blue-green algae") are a diverse group of bacteria found in freshwater, saltwater, moist soils, and even within plants and lichen. Cyanobacteria are a normal part of the algae community in lakes but, under certain conditions, they can also form unsightly scums. Some cyanobacteria also produce toxins ("cyanotoxins"), like anatoxin-a or microcystin, that are harmful to humans and animals upon contact with skin or when consumed. Cyanobacteria may have several competitive advantages over other algae, including the ability to fix nitrogen and store phosphorus (two crucial nutrients for growth). In addition, they can regulate their buoyancy, moving up and down in the water column; they have low energy demands; and they are generally unpalatable to grazers that eat algae.

Why Does Lake Campbell Have Toxic Algae Blooms?

Cyanobacteria blooms occur in Lake Campbell because there is an abundance of nutrients to fuel their growth. The total algae productivity in Lake Campbell appears to be driven by the availability of both phosphorus and nitrogen, based on monitoring data collected from August to December 2023. Historical datasets from the Samish Indian Nation and the Washington State Department of Ecology (Ecology) indicate that the phosphorus tends to be the primary factor determining algae growth in the lake.

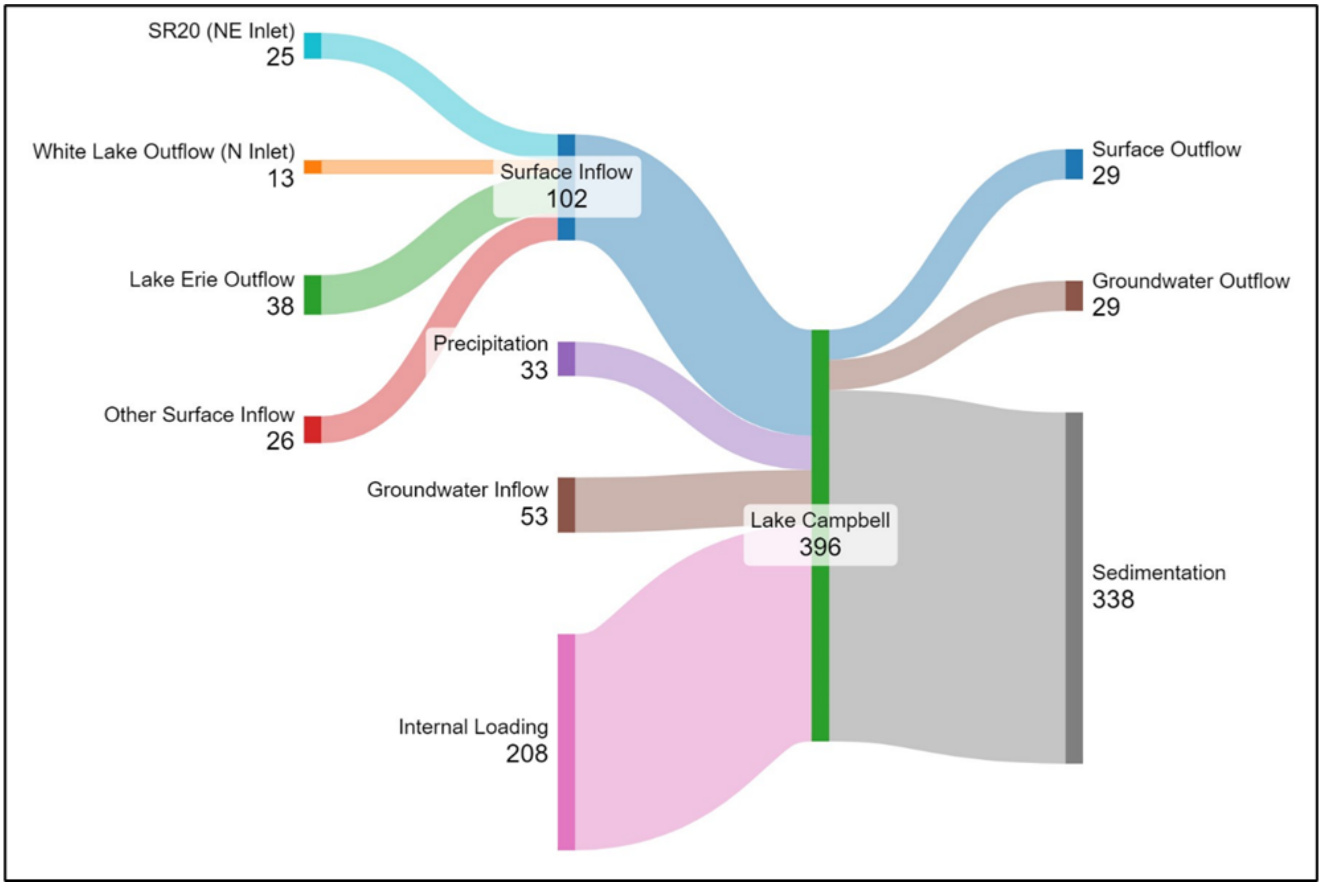
Cyanobacteria were by far the dominant algae species in samples collected in August, September, and October 2023, capitalizing on the abundance of phosphorus. When cyanobacteria populations reach high densities, they often produce cyanotoxins at levels that are harmful to human health. Toxic blooms have been seen in the summer and fall of 2021, 2022, and 2023, with high levels of microcystin, a liver toxin, exceeding the guidelines from the Washington State Department of Health.

Where is the Excess Phosphorus Coming From?

Relying on historical watershed monitoring data, we determined that the primary sources of phosphorus to Lake Campbell are (1) internal release from the lake sediments, (2) surface water inputs (especially outflow from Lake Erie and the SR 20 drainage), and (3) groundwater inputs (Figure ES-1). Waterfowl are estimated be a minor contributor. Onsite septic systems may have a significant impact on groundwater loads, but further investigation is needed to confirm their contribution. Because contemporary phosphorus concentrations are similar to those measured in the 1980s, we hypothesized that the surface and groundwater inputs into Lake Campbell are relatively unchanged, and that the return of poor water quality conditions are driven by the long-term accumulation of phosphorus within the lake following the 1985 alum treatment.

Sediments in Lake Campbell are rich in phosphorus bound to biologically available organic matter (such as dead algae and aquatic plants) and to a lesser degree, calcium and iron. When algae blooms occur, they elevate the pH of the lake because they are consuming dissolved carbon dioxide. Under elevated pH, there is expected to be enhanced release of phosphorus from some iron and aluminum complexes in oxygenated sediments. Mineralization of biogenic phosphorus also occurs from microbial decay of some organic matter in shallow oxygenated sediments. Additionally, due to the biological oxygen demand in the lake sediments caused by microbial decay, phosphorus bound to iron may also be released due to anoxic conditions in the sediments even if dissolved oxygen is present in the overlying waters. The high level of algae productivity throughout much of the year allows for accelerated phosphorus cycling within the lake. Because of these conditions, nearly all of the sediment area in Lake Campbell is expected to be contributing phosphorus.

Figure ES-1. Estimated Annual Phosphorus Import and Export (kilograms) to Lake Campbell.



Our theory for the eutrophication of Lake Campbell is summarized below:

- Nutrients enter the lake via surface water and groundwater inflows (at rates similar to that measured in the 1980s).
- Algae and aquatic plants use available nutrients to grow. When algae and aquatic plants die, they release some of the nutrients to the water column and fall as debris to the lake's bottom. Some amount of the suspended nutrients may be exported via the lake's outlet. Harvesting of aquatic plants may also remove nutrients from the lake.
- When algae blooms occur, they greatly increase the water's pH (by consuming carbon dioxide). Nutrient release from phosphorus bound to iron and aluminum is enhanced under elevated pH conditions, and nutrient release from decaying organic matter is enhanced by increased microbial activity.
- Furthermore, decaying organic matter in the lake's sediments uses up oxygen, which creates conditions where solid iron-phosphorus complexes dissolve, and additional phosphorus may be released. Nitrogen release as ammonia is also enhanced under these conditions.
- Due to the presence of the beaver dam at the lake's outlet, there is decreased export of nutrients from the lake, and more are retained within the lake's sediments, which may be recycled to fuel further algae blooms.

The 1985 alum treatment provided long-term relief from eutrophication in Lake Campbell, but over time the sediment reservoir of available nutrients has replenished.

What Are the Management Objectives for Lake Campbell?

Community feedback during a recent public meeting indicated the primary concerns for Lake Campbell are specific to safety and visual quality of the lake. Safety concerns include risks from contact with toxic algae blooms. Visual concerns include visible algae scums (not necessarily toxic). Additionally, some community members expressed concern of increased lake levels due to a beaver dam at the lake's outlet. The community highlighted a desire for near-term action to relieve the impact of cyanobacteria blooms.

Management of aquatic plants is covered in the Lakes Erie and Campbell Integrated Aquatic Vegetation Management Plan (2000), but it is not part of this Lake Cyanobacteria Management Plan.[1] However, it should be noted that by taking actions to reduce algae blooms in Lake Campbell, lake clarity will increase to the benefit of aquatic plants. Ongoing monitoring and management of aquatic plants will be critical to achieving the desired outcomes for Lake Campbell.

Based on public feedback, the cyanobacteria management objectives are:

- Reduction in the frequency of toxic algae blooms, to not exceed 2 years with toxic blooms in a 10-year period (which is the current state guideline for listing waters as impaired).[2]
- Reduction of the duration of toxic blooms, to not exceed 3 consecutive weeks with a toxic advisory.
- Reduction of the average amount of algae in the lake, to not exceed 12 parts per billion (ppb) chlorophyll-a as a summer average from May through October.[3]

What Do We Do Next?

We recommend an adaptive management approach that provides near-term relief from toxic algae blooms through in-lake treatment and long-term prevention through internal load reduction and watershed phosphorus control. Ongoing monitoring should be used to monitor achievement of water quality objectives and to inform adjustments to management techniques.

[1] <https://www.skagitcounty.net/PublicWorksSurfaceWaterManagement/Documents/LMD/Lakes%20Erie%20and%20Campbell%20Reports/Lakes%20Erie%20and%20Campbell%20IAVMP.pdf>.

[2] <https://apps.ecology.wa.gov/publications/SummaryPages/1810035.html>.

[3] 12 parts per billion (ppb) chlorophyll-a is the boundary between mesotrophic (moderate algae biomass) and eutrophic (high algae biomass) definitions for lake productivity.

In-Lake Management

Sediment Inactivation

For long-term management, we recommend conducting a sediment inactivation treatment using alum or lanthanum. The treatment will inactivate phosphorus in the sediments and provide a binding site for phosphorus released from organic and minerals. This treatment will interrupt the positive feedback loop where high nutrient availability fuels algae blooms that increase the lake's pH, which in turn causes release of nutrients from the lake sediments. The 1985 alum treatment showed decades-long effectiveness. To increase the long-term effectiveness of a sediment inactivation treatment, we recommend controlling watershed sources of nutrients from septic systems and surface drainage.

Alum, lanthanum, or proprietary chemicals may be applied in lakes to inactivate phosphorus in the water column and the sediments. The proprietary chemicals are not approved under the state Aquatic Plant and Algae Management permit and an exemption would need to be sought for their use. Therefore, in the interest of conducting treatment sooner, we recommend using alum or lanthanum, since both are approved under the permit. Between alum and lanthanum treatment, alum treatment is expected to provide the most immediate short-term relief from algae blooms. Alum forms flocculants that will pull algae and dissolved phosphorus from the water column, burying it in the sediments. This provides an immediate reduction in algae abundance and improvement in water clarity. Importantly, this increase in water clarity will benefit aquatic plants in the lake. Lanthanum does not form flocculants and will remove only dissolved phosphorus from the water column. Both alum and lanthanum will provide satisfactory sediment activation.

To inform the sediment inactivation dosage and to provide a better estimation of internal, we recommend completing a sediment incubation study. The study would evaluate the effectiveness of alum (or lanthanum) treatment at varying pH and oxygen conditions. This study can be used to confirm the internal load estimates described previously and to ensure the proper dosing of alum (or lanthanum) to reduce or altogether prevent sediment release. Skagit County has already received a grant from the Washington State Department of Ecology (WQALG-2025-SkCoPW-0004) to conduct the sediment study in the latter half of 2024.

Co-Existence with Beavers

Beaver dams play important ecological roles in shaping freshwater ecosystems. Beaver activity may conflict with human interests in some locations. Their presence at the outlet of a lake, such as Lake Campbell can have significant implications for water quality, particularly in terms of phosphorus accumulation and algae blooms. The presence of a beaver dam at the lake's outlet may have the following impacts:

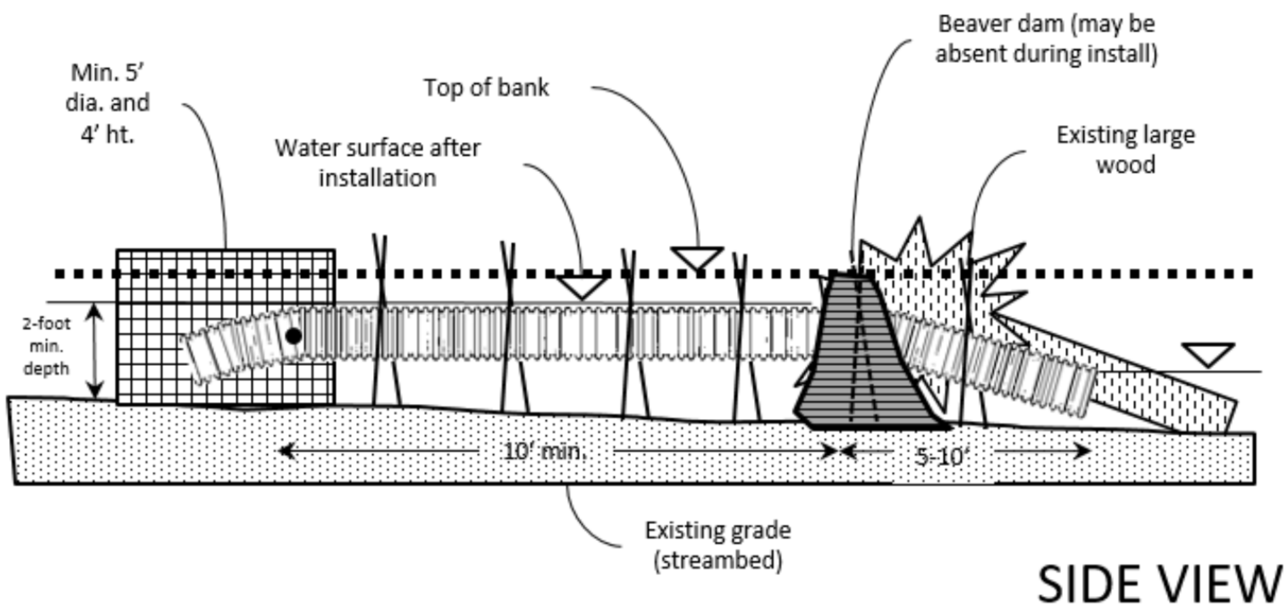
- Reduction of lake surface outflow and increase in lake level.
- Potential increase of subsurface water (groundwater) level around the lake increasing hydraulic connectivity from septic system drain fields (if present).
- Increase in lake nutrient retention due to decrease in lake outflow.

- Flooding of the nearshore of the lake.
- Downstream flooding impacts in the case of dam failure

Beavers provide ecological benefits by storing water and creating unique wetland habitats. Stored water may filter down into the water table and recharge groundwater. This stored water can also support summer stream flows, preventing streams from going dry. Beaver ponds are habitat for many insect, bird, amphibian, mammal, and fish species.

We recommend a beaver management approach that focuses on coexistence while minimizing flood risk and nutrient retention. We recommend installing a pond leveler at the lake's outlet. Pond levelers are used to control the height of water behind a beaver dam to prevent flooding (King County 2017). Levelers are designed to transport water through a dam in such a way that the beaver does not detect the flow of water through the dam and therefore does not instinctively do all it can to block the flow. Flows from storm events flow over the top of the dam, so the pipes do not need to be sized like road culverts, and after the storm, water levels return to normal via the pond leveler. Some pond levelers have been trademarked. Pond levelers are generally installed in ponded locations where water depth is sufficient to submerge the upstream end of the pipe along the pond bottom beyond the depth of most normal beaver activity (Figure ES-2).

Figure ES-2. Schematic of a Flexible Pond Leveler™.



If a pond leveler is not successful for managing beavers and level of the lake, beaver trapping and removal may be necessary on an as-needed basis. We recommend consulting with beaver management experts, such as Beavers Northwest, to develop a cohesive strategy that includes adaptive management options.

Watershed Source Control

A key long-term pathway to preventing cyanobacteria blooms is to decrease the loading of nutrients to the lake. This involves both source control and treatment. Source control is the removal or mitigation of a source, such as reducing phosphorus fertilizer use, installing livestock exclusion fencing along a stream, and fixing failing septic systems. Treatment is the reduction of a nutrient through built and natural infrastructure, such as infiltrating stormwater using low-impact design (LID) techniques, filtering stormwater with phosphorus-adsorbing media, or installing vegetative buffers along waterways.

Septic System Management

We recommend taking actions to identify existing septic systems that may be contributing disproportionate loads of phosphorus to Lake Campbell. These include failing systems that are no longer functioning per their initial design and systems that do not have adequate local conditions to remove phosphorus. Failing systems may be identified via operation and maintenance inspections by certified professionals. Systems that appear to be working can still be contributing phosphorus loading to the lake. Important factors for improperly sited systems and drain fields include distance to a nearby lake or stream, depth to the water table, and soil chemistry.

We recommend encouraging septic system owners throughout the watershed to complete routine inspections, as required by state law. Additionally, we recommend evaluating higher risk systems that are located around the lake or along streams to evaluate if adequate treatment is provided. In locations where the systems are not adequate, advanced treatment systems may be necessary.

Replacing septic systems can be very expensive (up to $20,000 to $40,000), depending on the location and installation constraints. However, there are numerous grants and low-interest loans available that may ease the upfront investment. This includes Craft3 Clean Water Loans, a low-interest loan program. The LCMP does not include budget for septic system management.

Stormwater Management

Stormwater runoff can also be an important pathway of nutrients to surface water and groundwater. Fertilized areas, domestic animals, wildlife, and erosion of soils and organic matter contribute phosphorus to stormwater runoff. Stormwater management seeks to treat or infiltrate runoff from impervious and pollutant-generating surfaces prior to discharging to a lake. External phosphorus reductions may be achieved through source control and stormwater treatment. Source control can include reduction in phosphorus-containing fertilizer use, identification and removal of illicit sewage connections, pet waste management, and erosion control. Stormwater treatment can include detention facilities, rain gardens, and regional treatment facilities. Stormwater management that reduces peak flows entering streams will also reduce streambank erosion. Lake management plans can be used to declare a lake as sensitive to phosphorus inputs and require new developments to install stormwater treatment systems that are designed to remove phosphorus not just suspended solids.

We recommend that a stormwater treatment and retrofit evaluation be completed in partnership with the County and Washington State Department of Transportation. The first step of such an effort would be to identify opportunity locations for stormwater treatment or retrofit based on existing infrastructure, land use/land cover, property ownership, and water quality data. This step includes identifying 5 to 10 opportunity locations and preparing high-level concepts and cost estimates. This first step is estimated to cost $20,000 to $30,000 but is variable with the number of opportunity locations and complexity of sites. Following this initial identification, the second step would be to conduct field verification and develop detailed conceptual designs for a shortlist of the locations. Assuming 5 to 6 sites are on this shortlist, this second step is estimated to cost $20,000 to $25,000, again scaling with the number of sites and their complexity. Overall, $50,000 should be budgeted for this initial planning effort over the next few years.

The cost of final design and installation for stormwater treatment and retrofit vary significantly based on the selected treatment approach and site conditions. Approximately $1M should be budgeted over 20 years in anticipation for design and installation of 5 to 10 small phosphorus treatment systems composed of bioretention systems or media filters with phosphorus retention media.

Shoreline and Waterfowl Management

Plants that grow in and along lake shorelines have an important role in protecting water quality and providing habitat aquatic organisms. Rooted plants can prevent shoreline erosion through their root systems, and in-water plants can reduce soil erosion and sediment suspension by dampening energy from waves. Shoreline plants can absorb and slow runoff from upslope, removing nutrients. They are also important for fostering native insects that are food for fish and birds. Over the years, people altered the lakeshore by removing trees and dead wood from the shorelines and by building bulkheads. Concrete or rock wall bulkheads negatively impact fish and wildlife habitat. They can accelerate erosion of shallow lake sediments by increasing wave energy, which can fuel cyanobacteria growth by suspending sediment nutrients. Developing a healthy shoreline program to promote and fund replacement of bulkheads and lawns with native plants is a recommended management action to reduce nutrient inputs and cyanobacteria growth in Lake Campbell.

While waterfowl were only a minor contributor of phosphorus to the lake, waterfowl management should be implemented to reduce phosphorus loading from the deposition of fecal matter in the lake and nearshore area. This will reduce both phosphorus loading and potential pathogens related to waterfowl feces. Management can include posting “do not feed” signs at public access points and educating lake community members. Shoreline planting can also be done to discourage waterfowl use, who prefer grassy nearshore areas with few shrubs.

Monitoring and Surveillance

No matter the management objectives or management strategy employed, ongoing monitoring is necessary to evaluate success and allow adaptive management. The adaptive management approach for Lake Campbell includes short-term and long-term monitoring. Short-term monitoring is focused on key data gaps and will provide the information needed to confirm and refine the selected measures and develop more accurate cost estimates. The sediment incubation study described previously is a short-term monitoring project identified. Long-term monitoring will provide the information needed to evaluate progress toward achieving management goals and to adjust or augment the lake management measures.

We recommend developing a monitoring plan. At bare minimum this should include summertime lake trophic state monitoring, which includes monthly sampling for chlorophyll-a, total phosphorus, and Secchi depth, estimated at approximately $12,000 per year (Option A). We also present Option B, which includes expanded monitoring to better inform ongoing adaptive management decisions and effectiveness of in-lake and watershed management actions. Option B includes additional lake sampling events and parameters, lake inlet sampling, and sediment sampling every 5 years, costing an estimated $40,600 per year. This estimated costs include field work, laboratory analysis, data management, and reporting.

Adaptive Management

To further the long-term water quality and lake use goals for Lake Campbell, this plan includes the following adaptive lake management framework to regularly reassess and amend LCMP strategies or goals as part of ongoing, adaptive lake management, pursuant to future lake needs, stakeholder values, and funding. This LCMP includes an Future Monitoring and Adaptive Management describing: (1) the decision-making process and adaptation framework by which the LCMP shall be modified, (2) current knowledge gaps and the recommended monitoring plan for continued effectiveness evaluation, and (3) potential future LCMP adaptations to begin considering.

We expect that the sediment inactivation treatment will substantially reduce internal phosphorus loading, but it alone will not be enough to meet the management objective for total phosphorus of less than 24 micrograms per liter (µg/L) as a summer average (Table ES-1). The 1985 alum treatment was estimated to reduce sediment release by 72 percent. If we assume that sediment inactivation will reduce internal loading by 75 percent, slightly more than a 25 percent reduction in watershed loading is needed to meet the objective.

Table ES-1. Observed and Predicted Total Phosphorus Concentrations in Lake Campbell Following Load Reduction Actions

Scenario	Total Phosphorus (annual average)
Current Conditions (average 2017–2023)	47.3
Predicted Total Phosphorus (TP) (current load)	50.5
75% Internal Load Reduction ONLY	29.2
75% Internal Load Reduction + 25% Watershed Load Reduction	24.8

Predicted TP using Brett and Benjamin (2008). $TP = TP\_In / (1 + 1.12 * T_w^{0.47})$.

The total phosphorus objective of 24 µg/L is the boundary between mesotrophic (moderate productivity) and eutrophic (high productivity) classifications that is also expected to meet the other established objectives for water clarity (Secchi depth), algae biomass (chlorophyll-a) and toxic cyanobacteria blooms (cyanotoxins) (see Lake Management Objectives).

If sediment inactivation alone does not meet the total phosphorus or other lake management objectives, then modification of the management strategies is needed. Modifications may include in order of priority:

1. Identify failing or underperforming septic systems, particularly those located with minimal set back to the lake.
2. Develop and implement a phosphorus/cyanobacteria management plan for Lake Erie. The Lake Erie drainage makes up about one-fifth of the surface water phosphorus load to Lake Campbell.
3. Prioritize stormwater retrofit at the SR 20 interchange with Campbell Lake Road. The SR 20 drainage makes up about one-fifth of the surface water phosphorus load to Lake Campbell.
4. Re-evaluate internal loading and re-apply alum or lanthanum to inactivate remaining available phosphorus.
5. Evaluate macrophyte harvesting techniques to remove aquatic plants (and their nutrients). Special concern must be given to Eurasian milfoil, which may spread via fragments cut during harvest.

Plan Cost and Funding

The recommended set of management strategies is estimated to cost approximately $647 to $936 thousand in the first 2 years and about $2.6 to $3.8 million over the following 20 years (Table ES-2). Additional funding sources will be necessary to implement the recommend elements of this plan. A combination of budget allocations, grants, and/or loans should be sought to fund and implement this management plan. We recommend considering the following sources:

- Lake Management District No. 3 Dues (would require restructuring to include additional scope and dues for algae management)
- Skagit County Surface Water Management Budget Allocations
- State Legislative Budget Allocations
- Freshwater Algae Control Grants
- Clean Water State Revolving Fund Loans
- Centennial Clean Water Grants
- Section 319(h) Clean Water Grants
- Onsite Sewage Financial Assistance Loans (Craft3)

Neither the Centennial and Section 319(h) Clean Water Grants may be used for in-lake treatment, according to current Department of Ecology policy.[4] However, those grants may be used for watershed source control, diagnostic and restoration planning, and lakeshore riparian restoration.

[4] <https://ecology.wa.gov/water-shorelines/water-quality/water-quality-grants-and-loans/wqc-funding-cycle>.

Table ES-2. Recommended Plan Implementation Cost Summary.				
	Near-Term Actions (first 2 years)		Long-Term Actions (following 20 years)	
Plan Element	**Description**	**Cost (2024$)**	**Description**	**Cost (2024$)**
Sediment Incubation Study	Conduct a short-term study to determine sediment release rates and effectiveness of alum or lanthanum treatment.	$50K	No work recommended	–
Lake Sediment Phosphorus Inactivation	A single long-term sediment inactivation dose or multiple doses	$436K to $667K	Treatment longevity is expected to be at least 10 years. (assume one additional treatment)	$0.7M to $1.3M
Outlet Beaver Dam Management	Design and install a pond leveling device to decrease lake flooding and increase nutrient export.	$7K	Ongoing inspection and maintenance of leveling device ($1.5K per year)	$42K
Watershed Source Control Education/Outreach (septic, shoreline, and land stewardship)	Leverage resources from LakeWise program from Snohomish County to encourage and install best management practices.	$0 (under lake management district and Skagit County staff)	Ongoing	$0 (under lake management district and Skagit County staff)
Stormwater Retrofit Evaluation	Evaluate potential stormwater retrofit locations.	$50K	Implement high-value, multi-benefit stormwater retrofits. Costs may be accrued by WSDOT.	$1.0M
Monitoring and Reporting	Option A: Routine monitoring and reporting of lake water quality. (base cost: $12K per year)	$24K	Option A ongoing (base cost: $12K per year)	$0.3M
	Option B: Routine monitoring and reporting of lake and stream water quality and hydrology. (base cost: $40.6K per year)	$82K	Option B ongoing (base cost: $40.6K per year)	$1.1M
Lake Management Administration	Finance and grant tracking. Adaptive management. Coordination with consultants and contractors. Implementation of management plan (base cost: $40K/year)	$80K	Finance and grant tracking. Adaptive management. Coordination with consultants and contractors. Implementation of management plan. (base cost: $20K/year)	$0.6M
	Total (first 2 years)	**$647K to $936K**	**Total (next 20 years)**	**$2.6M to $3.8M**

There is an assumed cost escalation of 3.5 percent each year in consideration of wage, utility, and material cost increases. If a loan is obtained to partially fund, additional loan management and interest costs should be considered.

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Introduction

Lake Campbell is a rural kettle lake located on Fidalgo Island in western Skagit County, Washington, that is primarily fed by the outflow of neighboring Lake Erie. Lake Campbell is historically a productive system with high algae and aquatic plant and growth and has a long history of effective algae and aquatic plant management. In 1985, the lake was treated with aluminum sulfate ("alum") to reduce internal phosphorus sources fueling harmful algae (cyanobacteria) blooms (HABs). In the years following the alum treatment, significant reductions in phosphorus concentrations and cyanobacteria were observed with substantial increases in water clarity. These water quality improvements and prevention of HABs persisted for more than a decade and greatly enhanced public use of Lake Campbell. To address aquatic weeds, Lake Erie and Campbell waterfront property owners voted in 2001 to establish Lake Management District No. 3 (LMD 3). LMD 3 currently manages aquatic weed growth in both lakes using the methods identified in the Integrated Aquatic Plant Management Plan (IAPMP) for Lakes Erie/Campbell (Skagit County 2000).

After an approximately 20-year reprieve from algae blooms, thanks to the alum treatment, Lake Campbell once again suffers frequent toxic cyanobacteria blooms. Recent data and observations show Lake Campbell continues to exhibit eutrophic conditions and that HABs have returned to the lake. Algae management is not currently financed under the LMD 3 program due to the typically high costs associated with management options, and because cyanobacteria blooms were historically short-lived. However, these toxic blooms impair beneficial uses of the lake by threatening the health of wildlife and recreators and impeding public uses. Based on observed trends in nutrients and their relationship to cyanobacteria, toxic blooms may continue to increase in Lake Campbell unless actions are taken to reduce nutrient sources and change lake conditions.

Skagit County Public Works was awarded a grant from the Washington State Department of Ecology Freshwater Algae Program (Grant Number WQALG-2024-SkCoPW-00035) to study the lake and prepare a Lake Cyanobacteria Management Plan (LCMP). This LCMP presents the study results and describes a strategy to reduce the frequency and duration of toxigenic algae blooms to restore recreational use. In 2023, Skagit County contracted with Herrera Environmental Consultants, Inc. (Herrera) to prepare the LCMP and develop a Quality Assurance Project Plan (QAPP) to guide all study design and methodology for collecting and analyzing additional data to inform LCMP development (Herrera 2023). Herrera developed the QAPP according to Freshwater Algae Grant Funding Guidelines (Ecology 2022) and Guidelines for Preparing Quality Assurance Project Plans (Ecology 2016; EPA 2002).

Using the scientific data collected in accordance with the QAPP, along with input from the County and the LMD, this LCMP identifies community concerns, defines priorities, outlines goals and objectives, characterizes the lake and watershed, and describes an adaptive lake management strategy. This LCMP 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.

Study Area Background

Lake and Watershed

Lake Campbell is a 384-acre lake located in a glacier-carved valley in the unincorporated, westernmost reach of Skagit County, Washington (Figure 1). Lake Campbell is shallow with a mean depth of 7.4 feet (2.2 meters), reaching up to 16 feet (4.8 meters) near the center of the lake just south of a small island (Figure 2; Table 1). More than half of the lake's volume (58 percent) is within the first 5 feet (1.5 meters) of depth (Table 2). The western shorelines deepen gradually to a shallow basin west of the small island, whereas the lake basin on the east side of the island is generally deeper (Figure 2).

Table 1. Morphometric Characteristics of Lake Campbell.

Characteristic	English	Metric
Surface Area	384 acres	155 hectares
Maximum Depth	16 feet	4.8 meters
Mean Depth	7.4 feet	2.2 meters
Volume	2,857 acre-feet	3,524,103 cubic meters
Osgood ratio (mean depth [m] / lake area $[km^2]^{(1/2)}$	1.8	
Lake Altitude (NAVD 88)	49 feet	14.9 meters
Watershed Drainage Area	3,808 acres	1,541 ha
Mean Annual Precipitation	25 inches	0.64 meters

m = meters

Table 2. Lake Campbell Depth-Area-Volume.

Depth		Area		Volume Below	
Meters	Feet	Hectares	Acres	Cubic Meters	Acre-feet
0	0	155	384	3,524,103	2,857
1.5	5	114	281	1,483,406	1,203
3.0	10	48	118	288,661	234
4.5	15	1	3	1,203	1
4.8	16	0	0	0	0

Data source: Ecology (2024) digitization from Ecology (1976).

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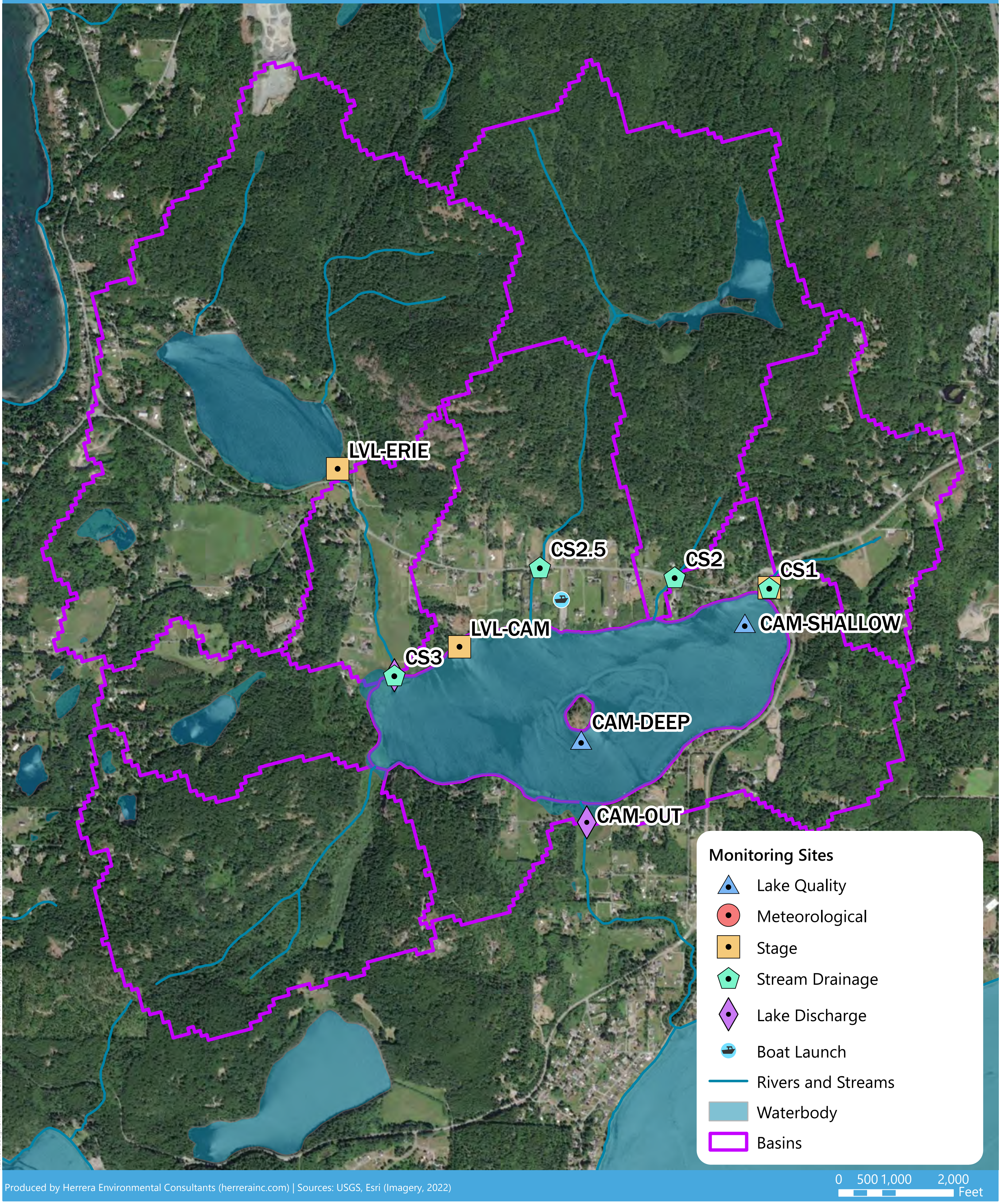
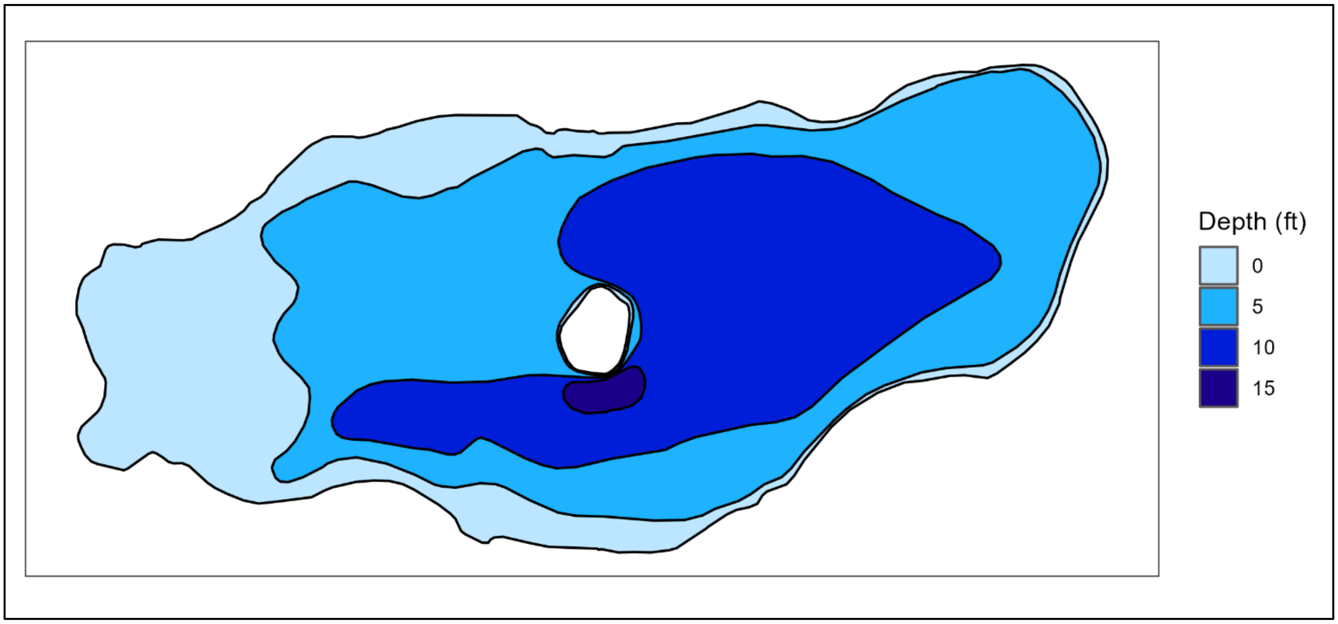
Science + Planning + Design

Figure 1.
Lake Campbell Watershed and Study Monitoring Stations.



Produced by Herrera Environmental Consultants (herrerainc.com) | Sources: USGS, Esri (Imagery, 2022)

Figure 2. Lake Campbell Bathymetry.



Data source: Ecology (2024) digitization from Ecology (1976).

Lake Campbell is located within the Olympic Mountain rain shadow on the peninsula of Fidalgo Island. Fidalgo Island is bordered by Fidalgo Bay to the east, by the Rosario Strait and San Juan Islands to the north and west, and Skagit Bay to the southeast. There are several intermittent streams that flow into the lake from the west and north sides of the lake, which contain intermittent overflow discharge from Lake Erie, Whistle Lake, and/or Trafton Lake. Direct runoff from State Route 20 (SR 20) and residential neighborhoods and shallow groundwater seepage also drain to the lakes.

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Water from Lake Campbell discharges into a stream (Campbell Creek) along the south shoreline, which is frequently occupied and disturbed by beaver activity. Removal of beavers and their dams occurred most recently in May 2023 by private residents (pers. comm., Leanne Ingman, Skagit County), but beaver activity returned to the site by late summer 2023. The outlet stream flows south for 1 mile before discharging into Similk Bay (of Skagit Bay) just east of Deception Pass and the Salish Sea.

The lake's drainage watershed (3,808 acres) is largely composed of a mix of developed area (12 percent; comprised largely of low-density residential area and developed open space), mixed and evergreen forests (71 percent), and some agriculture (8 percent) (Figure 3; Table 3). Impervious land cover in the watershed is minimal at only 3 percent of the watershed. The single major roadway is the SR 20 corridor that extends northeast-southwest, within 50 feet of the eastern edge of the lake. Runoff from this portion of SR 20 is collected and treated in a roadside stormwater facility before discharging to Lake Campbell (as measured for this study at monitoring station CS1) and may represent a source of additional contaminants not monitored in this study (e.g., metals).

The majority of shoreline land use is composed of forested (woody) wetlands and low-density residential (Figure 3; Table 3) with a few small businesses. Immediate shoreline around Lake Campbell is largely naturally vegetated, except near residences where, in many cases, lawns and/or bulkheads extend to the water's edge. Public access for boating, fishing, and swimming is available at a Washington Department of Fish and Wildlife (WDFW) public boat launch at the north central shoreline.

Table 3. Lake Campbell Watershed Land Cover, Skagit County, Washington.

NLCD 2019 Land Cover	Watershed		
	Area (acres)	Percent	Percent (excluding lake)
Open Water[a]	**530.1**	**12.6**	**3.5**
Total Developed	**445.0**	**10.6**	**12.1**
Developed, Open Space	205.3	4.9	5.6
Developed, Low Intensity	199.3	4.8	5.4
Developed, Medium Intensity	35.5	0.8	1.0
Developed High Intensity	4.9	0.1	0.1
Total Forest	**2,612.8**	**62.3**	**71.3**
Deciduous Forest	58.4	1.4	1.6
Evergreen Forest	2,198.2	52.4	60
Mixed Forest	356.2	8.5	9.7
Other	**604.5**	**14.3**	**16.6**
Barren Land (rock/sand/clay)	9.6	0.2	0.3
Shrub/Scrub	54.8	1.3	1.5
Grassland/Herbaceous	75.8	1.8	2.1
Pasture/Hay	285.9	6.8	7.8
Woody Wetlands	102.1	2.4	2.8
Emergent Herbaceous Wetlands	76.3	1.8	2.1
Entire Watershed[a]	**4,192.4**	**99.8**	**100**
Lake Drainage Area	**3,808.4**	**90.8**	**100**
Impervious Area	**105.7**	**2.5**	**2.8**

National Land Cover Database (NLCD) 2019 Land Cover Data used for land cover and imperviousness retrieved from MRLCC (2021).

[a] Open water and entire watershed areas include 384 acres of Lake Campbell.

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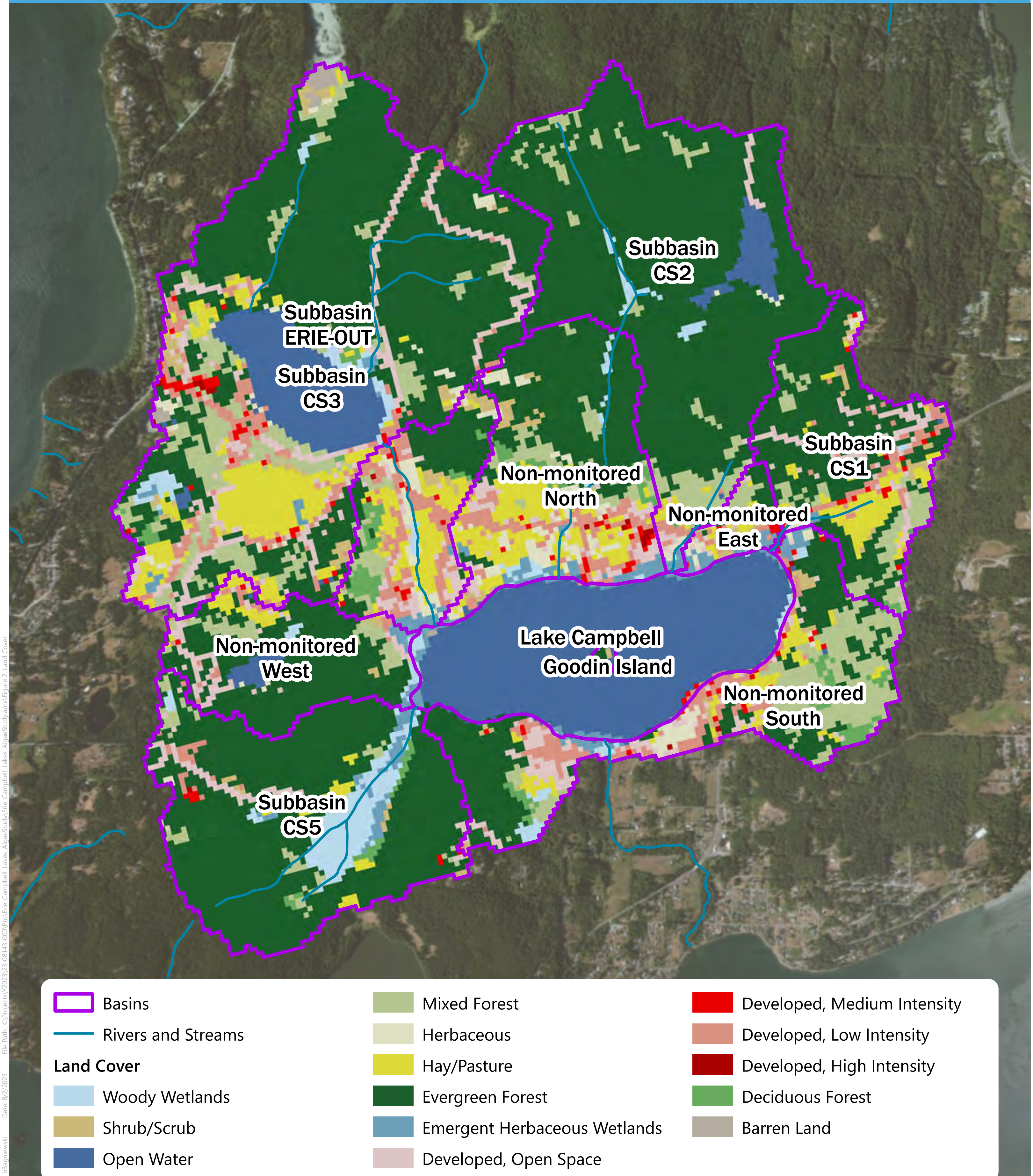
Figure 3.
Lake Campbell Watershed Drainage and Land Cover.



Produced by Herrera Environmental Consultants (herrerainc.com) | Sources: USGS, Esri (Imagery, 2022)

Beneficial Lake Uses

Lake Campbell provides visitors and residents with recreational opportunities such as birdwatching, boating, fishing, swimming, water skiing, canoeing, kayaking, sailing, and picnicking. The WDFW public boat launch at the north central shoreline offers year-round shoreline fishing access, a concrete boat ramp, a dock, parking, and restroom facilities. The remaining Lake Campbell shoreline is occupied open spaces, forest, and/or by year-round residential housing, with approximately 46 docks or other in-water structures.

Water Quality Standards for Surface Waters of the State of Washington provides use designations for freshwater bodies in Washington State (WAC 173-201A-600). Lake Campbell's designated uses are not specifically named in the regulation and by default include: salmonid habitat (spawning, rearing, and migration), primary contact recreation, water supply (domestic, industrial, agricultural, and stock), wildlife habitat, harvesting, commerce/navigation, boating, and aesthetic values.

Toxic algae blooms can impair each of Lake Campbell's designated uses. Applicable water quality criteria to support the designated aquatic life and recreational uses in lakes are specified in WAC 173-201A-200. Criteria are specified for conventional parameters (temperature, dissolved oxygen, and pH), *E. coli* bacteria, and toxic substances, but not for cyanobacteria or cyanotoxins at the present time. State surface water quality standards recommend conducting a lake-specific study to evaluate characteristic uses and impairments if the summer mean total phosphorus concentration exceeds the action value of 20 µg/L in the surface layer (epilimnion) of lakes in the Puget lowlands ecoregion (WAC 173-201A-230). Proposals to adopt appropriate total phosphorus criteria to protect characteristic uses of a lake must be developed by considering technical information and stakeholder input as part of a public involvement process.

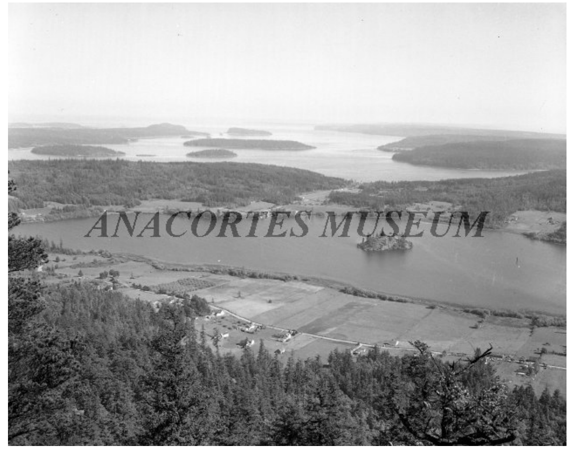
Current and Historical Land Uses

The study area is within the traditional territories of the Swinomish, Sauk Suiattle, Samish, Hul'qumi'num Treaty Group, and Skagit Native American tribes (<https://native-land.ca/>). The ancestral lands ceded to the United States government in the 1855 Treaty of Point Elliot (Cession 347) included millions of acres, which today include the cities of Seattle, Everett, Bellingham, Anacortes, Renton, Tukwila, and Bellevue. The Samish Indian Nation owns property within the Lake Campbell watershed, and tribal members still reside there.

Today, the watershed area is used for year-round residential housing, recreation, and commerce. Parks and historical landmarks in the watershed include:

- Deception Pass State Park, including Rodger Bluff/Hill and the John Tursi Trail and Old Cabin
- The Whistle Lake Area of the Anacortes Community Forest Lands (ACFL), which includes Mt Erie and the Mt Erie Summit Trail
- WDFW boat launch sites at Lake Campbell and Lake Erie
- Goodin Island in the middle of Lake Campbell

Jim Funk and Bill Rieger on Lake Campbell—circa 1934 (Anacortes Museum 2024).



Lake Campbell from Mt. Erie; 1950s (Anacortes Museum 2024).

Sanitary Wastewater and Stormwater

There are no point sources discharging into either Lake Campbell or Lake Erie. The potential non-point sources are onsite septic systems, agricultural run-off, residential use of fertilizers, stormwater runoff, and direct and indirect inputs related to fish stocking and aquatic plant control.

All sanitary wastewater in the Lake Campbell watershed is treated by onsite sewer systems (OSS). There are no sanitary sewer systems for wastewater treatment in the watershed. Skagit County data regarding septic systems for residences and businesses in the watershed are available that include information such as year installed, system type and size, and inspection and maintenance dates/details.

There are no stormwater conveyance infrastructure draining to Lake Campbell, apart from various roadside ditches and culverts and the roadside stormwater facility (swale), which treats SR 20 runoff before discharging to the lake. Discharge and water quality measurements were collected for this project at monitoring station CS1 to understand nutrient contributions from SR 20 runoff.

Water Withdrawals

There are no known significant water withdrawals from Lake Campbell for any water supply uses. According to Ecology's Water Rights Search application, there are approximately 95 water rights records in the Lake Campbell watershed (inclusive of Lake Erie). Records are largely compiled by drinking water wells and headworks (gravity flow) facilities, plus three surface water pumps around Trafton Lake, and three reservoir dams (at a small unnamed lake to the west of Lake Campbell, at Whistle Lake, and at the west end of South Lake Campbell Road).

Fisheries

Resident species present at Lake Campbell include largemouth bass, yellow perch, bluegill, black crappie, pumpkinseed sunfish, bullhead catfish, and sculpin. The most abundant species in the lake include largemouth bass and bluegill, followed by yellow perch (WDFW 2023a; Ecology 2001). WDFW historically stocked up to three species of fish at Lake Campbell annually from 1995 through 2023, including rainbow (or steelhead) trout, coastal cutthroat trout, and channel catfish (Table 4). Most pounds of stocked rainbow, cutthroat, and catfish were of legal size, but some were stocked as fingerlings or fry. On one occasion, WDFW stocked 2,015 pounds of fingerling steelhead trout (WDFW 2024a). Additionally, rainbow trout were stocked upstream in Lake Erie, a "trout only" lake, from 1995 through 2023 with between 4,960 and 9,174 pounds each year and with steelhead fry stocked in 2 years (1998 and 2007) (WDFW 2024a). Other reports indicate WDFW had also planted Chinook salmon circa 1995 (Skagit County 2000), and grass carp were planted in several years from 2002 through approximately 2017 (Skagit County 2000; pers. comm.).

Table 4. Pounds of Fish Stocked in Lake Campbell (WDFW 2024a).

Year	Channel Catfish	Cutthroat	Rainbow	Steelhead	Total
1995			123		123
1996			874		874
1998	330				330
1999	728			205	933
2000	879				879
2001	1,000				1,000
2002			43		43
2003	639		833		1,472
2004	327		758		1,085
2005	611	50	1,785		2,446
2006		87	1,566		1,653
2007		79	2,411		2,490
2008		133	755		888
2009		279	1,273		1,552
2010		286	1,321		1,607
2011	800	13	1,184		1,997
2012		153	1,179		1,332
2013		137	1,586		1,723
2014	1,364	107	1,583		3,054
2015		154	2,817		2,971
2016		132	8,990		9,122
2017		200	999		1,199
2018		104	1,137		1,241

Table 4 (continued). Pounds of Fish Stocked in Lake Campbell (WDFW 2024a).					
Year	**Channel Catfish**	**Cutthroat**	**Rainbow**	**Steelhead**	**Total**
2019		125	174		299
2020			3,996		3,996
2021		125	3,546		3,671
2022		168	2,462		2,630
2023			589		589
2024		133			133

Although the outflow stream for Lake Campbell provides spawning habitat for chum and coho salmon, winter-run steelhead, and coastal cutthroat trout (Skagit County 2000), these and other cold water species are largely absent due to warm temperatures, low oxygen levels at depth, and the extensive availability of warmwater fish habitat (large shallow, littoral areas) (Ecology 2001). Entranco (1983) reported that about 10,000 fish of the 40,000 stocked were harvested in a typical year, indicating high annual fish mortality. Acute fish mortalities have been observed at Lake Campbell and continue to occur with the most recent event observed in fall 2022. Entranco (1983) suggested causes of mortality include adverse water quality (i.e., anoxia at depth; high ammonia, temperature, and pH), excessive bird predation, and limited food supply in the winter months. No other estimates of current fishery conditions or population sizes are available.

Aquatic Plants

In 1983, Entranco presented the results of an aquatic plant survey in Lakes Erie and Campbell, which identified submersed and emergent plants around the shoreline and larger submersed plant beds within the western basin. Species identified included both yellow water lily (*Nuphar polysepala*) and fragrant water lily (*Nymphaea odorata* a Class C noxious weed), cattail (*Typha latifolia*), bullrush (*Scirpus* sp.), water shield (*Brasenia schreberi*), common water weed (*Elodea canadensis*), coontail (*Ceratophyllum demersum*), pondweeds (*Potamogeton* spp.; including *P. crispus* a Class C noxious weed), and water celery (also known as eelgrass; *Vallisneria americana*). In particular, a 34-acre bed of coontail in the western corner of the lake reportedly restricted fishing access and boating opportunities (Entranco 1987).

Mechanical harvesting in 1986 was performed to remove plants, as a phosphorus source, from the lake wherein 581 wet tons of plant biomass and an estimated 60 kilograms of phosphorus was removed (Entranco 1987). Harvesting was aimed at reducing coontail biomass by 75 percent to leave "vegetation islands" and was restricted to areas outside pre-determined "Conservancy Zones" to protect bass use and fish habitat. Follow-up surveys identified continued patches of coontail, lilies, and a native watermilfoil (*Myriophyllum exalbescens,* also known as *M. sibiricum*) (Entranco 1987).

By 1998, Eurasian watermilfoil ("milfoil"; *Myriophyllum spicatum* a Class B noxious weed) infested and became a dominant invasive weed in the lake (Table 5), forming surface mats by mid-summer each year (Ecology 2001). Due to this infestation, the Integrated Aquatic Plant Management Plan for Lakes Erie and Campbell (IAPMP) project was initiated. Using data from the 1998 Ecology survey and a new survey conducted by Resource Management, Inc. in July 2000, the IAPMP was published in October 2000 by

Skagit County Public Works Surface Water Management with assistance from a Citizen Advisory Committee, Terry McNabb (then of Resource Management, Inc.), and Ecology's Aquatic Weed Management Program (Skagit County 2000). The IAPMP provided short-term and long-term methods for the control of Eurasian watermilfoil and fragrant water lily. Short-term methods included application of herbicides (Navigate, Aquathol, and RODEO) in 2001 and 2002, while long-term methods included diver hand pulling, spot herbicide treatments, and stocking of grass carp beginning in 2002 (with installation of a carp screen at the Lake Campbell outlet). LMD 3 was formed in 2001 to employ the recommendations of the IAPMP to control invasive aquatic weeds and assess native plant populations (particularly around docks and swimming areas) in Lakes Erie and Campbell.

Table 5. Species List for Aquatic Plants in Lake Campbell (1998).

Scientific Name	Common Name	Distribution
Ceratophyllum demersum	Coontail; hornwort	3
Iris pseudacorus	Yellow flag	3
Juncus sp.	Rush	2
Lemna trisulca	Star duckweed	2
Myriophyllum spicatum	Eurasian watermilfoil	4
Nuphar polysepala	Spatter-dock, yellow water-lily	3
Nymphaea odorata	Fragrant water-lily	2
Potamogeton pectinatus	Sago pondweed	2
Potamogeton sp. (thin leaved)	Thin leaved pondweed	2
Scirpus sp.	Bulrush	2
Typha latifolia	Common cattail	2

Distribution Key:
1 = few plants in only one or a few locations
2 = few plants, but with a wide, patchy distribution
3 = plants in large patches, co-dominant with other plants
4 = plants in nearly monospecific patches, dominant
(Source: Washington State Department of Ecology, 2000)

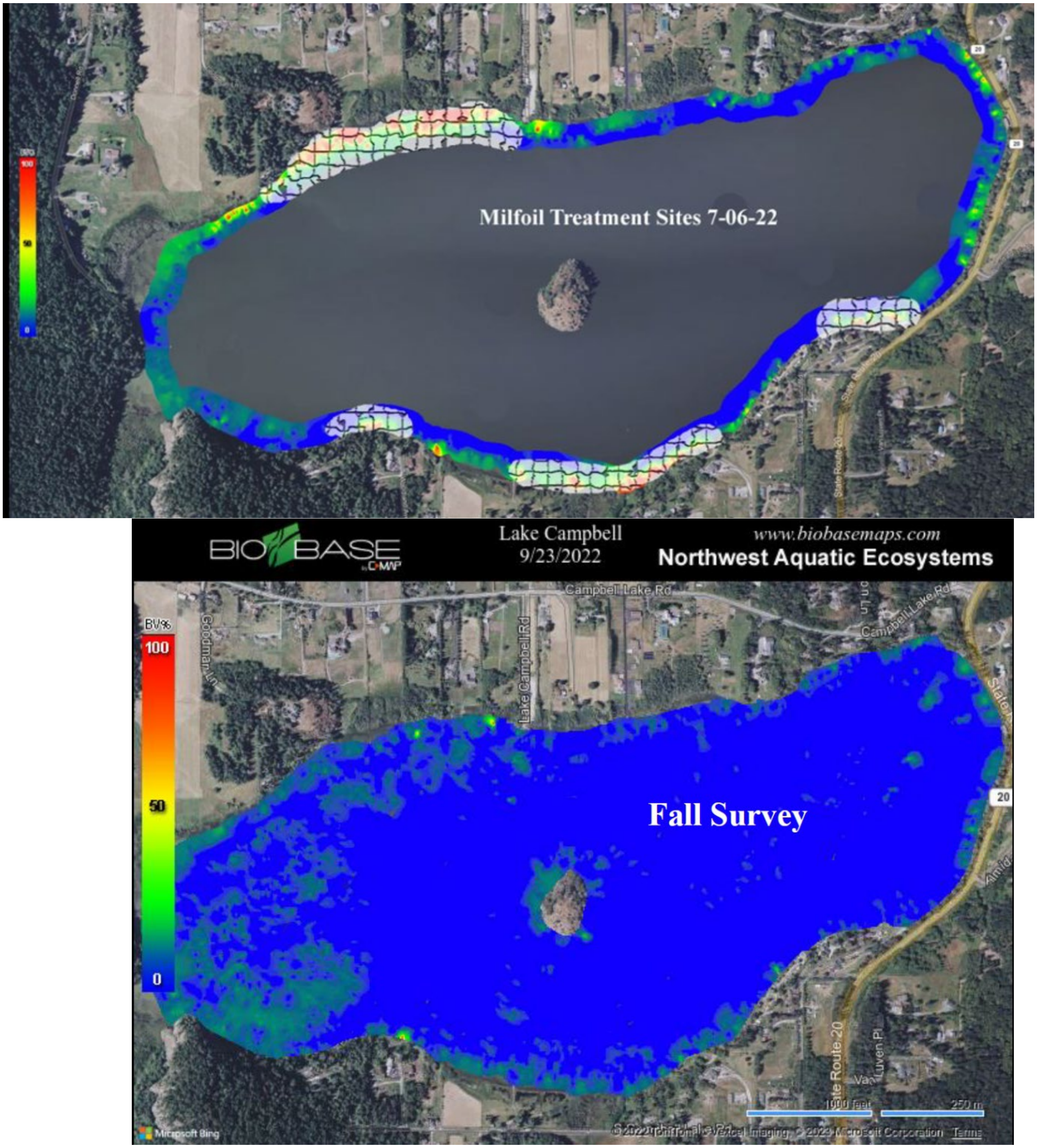
In the first year of the management program, an aquatic vegetation survey was conducted (July 2002); researchers identified species, qualitatively estimated the relative density of each plant, and collected representative specimens for a reference collection (Hilles et al. 2002). In addition to those species listed above, researchers also identified muskgrass (*Chara* spp.), rush (*Juncus* spp.), northern milfoil (*M. sibircum*), common water-nymph (*Najas guadalupensis*), ditch grass (*Ruppia* spp.), and common bladderwort (*Utricularia vulgaris*). Pondweeds observed included whitestem pondweed (*P. praelongus*), small pondweed (*P. pusillus*), Richardson's pondweed (*P. richardsonii*), and other thin-leaved pondweeds.

Annual herbicide treatments for water lily and milfoil along with pre- and post-treatment surveys and annual reporting continues today as part of the ongoing vegetation management program, performed by Northwest Aquatic Ecosystems since 2009. Shoreline noxious weed species treated include purple loosestrife (*Lythrum salicaria* a Class B noxious weed) and yellow flag iris (*Iris pseudacorus* a Class C noxious weed). The 2021 Aquatic Plant Control Program report described reduced milfoil populations and densities and increased native plant densities (e.g., thin-leaved pondweeds and *Najas* spp.) since the 2020 surveys (Northwest Aquatic 2022).

The 2022 report similarly noted an increase in native species and promising signs of expanding throughout the lake, but the report specified that native populations were not yet prevalent. With a reduction in milfoil from the 2021 treatments, Northwest Aquatic Ecosystems dedicated most of their resources in 2022 to the treatment of milfoil with Triclopyr in approximately 25 acres of Lake Campbell. Applicators noted a large pervasive algae bloom beginning in June and lasting through at least September 2022, which resulted in a lake closure for most of the summer. The algae bloom reportedly limited applicators' visibility of submersed weeds during both treatment and follow-up surveys and may have also led to the observed reduced growth of native aquatic plant populations. Northwest Aquatic Ecosystems supplementally treated shoreline areas, once in June and once in August 2022, for waterlily and purple loosestrife using a 1 percent triclopyr tank mix with adjuvant (Northwest Aquatic 2023). Post-treatment surveys in the fall did not detect any milfoil.

Figure 4 below shows the vegetation biomass heat maps from the milfoil treatment date on July 6, 2022, and the post-treatment survey on September 23, 2022, where red represents 100 percent biomass growth (growing to the water surface), and blue represents 0 percent biomass (no present). In the pre-treatment map, areas where elevated submersed plant biomass was detected overlapped with observed patches of milfoil infestations (Northwest Aquatic 2023).

Figure 4. Vegetation Biomass and Treatment Area Maps for Lake Campbell 2022.



Source: Northwest Aquatic Ecosystems (2023). Vegetation biomass heat maps where red shades indicate greater aquatic plant biomass and blue shades indicate little to no plant biomass.

Top: Biomass in Lake Campbell prior to treatment, with milfoil treatment areas overlain in white grids. Treatment occurred on July 7, 2022.
Bottom: Biomass in Lake Campbell on September 23, 2022, post-treatment.

Endangered/Rare Species Present

According to WDFW's Priority Habitats and Species (PHS) in Washington State tool (WDFW 2024b), natural habitats in the Lake Campbell watershed include lakes, [general] wetlands, freshwater emergent wetland, freshwater forested/shrub wetland, old growth/mature forests, and biodiversity areas and corridors. However, the PHS tool indicates that none of these habitats within the watershed are sensitive. Habitat notes by WDFW biologists indicate Deception Pass State Park nearby includes some of the old growth/mature forest and biodiversity corridors. Other biodiversity areas and corridors exist in Fidalgo Island's open spaces and Mt. Erie City Park.

The PHS tool additionally identified the following key species present in the watershed: resident coastal cutthroat (*Oncorhynchus clarki*), rainbow trout (*Oncorhynchus mykiss*), and coho salmon (*Oncorhynchus kisutch*). The only endangered, sensitive, or rare species identified for the Lake Campbell watershed are the little brown bat (*Myotis lucifugus*; sensitive status) and big brown bat (*Eptesicus fuscus*; sensitive status). Finally, the watershed represents an important waterfowl wintering area, where lakes provide loafing habitat and food resources for diving ducks and sometimes swans.

WDFW cautions PHS users that these data are not an exhaustive list of all fish and wildlife presence but is for informational purposes only. WDFW strongly recommends users to schedule field visit by a fish and wildlife biologist or habitat expert to make determinations about species presence, absence, or exact location before making any final decisions about a project.

Water Quality

Water quality in Lake Campbell has been monitored through a variety of studies since 1976. The current bathymetric map of the lake was measured by the United States Geological Survey (USGS) in 1973 (Ecology 1976). Key studies of the lake's water quality are provided below in Table 6. These studies were pivotal in early characterizations of Lake Campbell and upstream Lake Erie, and in tracking contemporary eutrophication and water level trends. Detailed summaries of these and other studies are described in the QAPP (Herrera 2023). The most comprehensive of these water quality datasets are the Entranco datasets (1981–1982 and 1985–1986) collected as part of the Erie and Campbell Lakes Restoration project, and the previously unpublished datasets collected by the Samish Indian Nation.

Table 6. Summary of Previous Studies at Lake Campbell.

Title	Author(s)	Data Year	Year Published	Description
Reconnaissance Data on Lakes in Washington, Volume 1	Ecology	1973	1976	Water quality study with physical chemical, biological, geographic, bathymetric, and drainage characterizations.
Water Quality Analysis and Restoration Plan for Erie and Campbell Lakes	Entranco Engineers	1981–1982	1983	Water quality study and evaluation of restoration alternatives
Erie and Campbell Lakes – Final Report: Restoration Implementation and Evaluation	Entranco Engineers	1985–1986	1987	Water quality study post-alum treatment; evaluation of restoration effectiveness
Water Quality Assessments of Selected Lakes Within Washington State	Ecology	1999	2001	Includes water quality assessment of Lake Campbell
Lake Campbell and Lake Erie 2002 Monitoring Projects	Hilles et al., Western Washington University	2002	2003	Water quality study and macrophyte survey
Lake Campbell and Lake Erie Total Phosphorus Total Maximum Daily Load: Water Quality Effectiveness Monitoring Report	Ecology	2004–2005	2007	Water quality study for total phosphorus and chlorophyll-a
Lake Campbell Outlet Investigation Summary of Findings	Butler and Johnson, Watershed Science and Engineering	2021	2021	Skagit County's Drainage Utility retained the Watershed Science and Engineering firm to investigate the Lake Campbell outlet.
Unpublished monitoring data	Samish Indian Nation	2017–2023	Unpublished	Lake water quality monitoring

Past Conditions

Since at least the early 1980s, Lake Campbell has suffered from conditions typical of shallow eutrophic lakes, including:

- High summertime algae growth, as indicated by high chlorophyll-a levels, which often exceed total maximum daily load (TMDL) goals.
- Annual toxic cyanobacteria blooms lasting several weeks to months.
- Infrequent and weak thermal stratification.
- Warm surface water temperatures.
- Low dissolved oxygen near deep sediments.
- Phosphorus loading from the lake sediments and watershed leading to high lake phosphorus concentrations (45 to 62 µg/L).
- Extensive aquatic vegetation.

Lake level over the years has also been substantially influenced by capacity of the outflow channel impacted in part by beaver activity/management, precipitation and streamflow, and obstructive vegetation. These challenges have led to drainage concerns during heavy rain events since most of the lake's water is received from streamflow.

Improvement Efforts

In 1985, aluminum sulfate ("alum") was applied to both Lake Erie and Lake Campbell to reduce internal phosphorus loading fueling cyanobacteria blooms. These alum treatments successfully and substantially reduced phosphorus release from sediments for at least 10 years. The result was reduced phosphorus export via Campbell Creek and reduced algae growth in both lakes, with increased lake water clarity and enhanced public use (Entranco 1987; Morency and Belnick 1987; Ecology 2007). Sporadic monitoring from 1999 to 2023 by Ecology, the Samish Indian Nation, Western Washington University, and this study, suggests that, as of at least the late 2010s, the lake trophic condition has appeared to return to pre-treatment conditions and its users once again suffer from HAB impacts.

To address aquatic weeds, Lake Erie and Lake Campbell waterfront property owners voted in 2001 to establish Lake Management District No. 3 (LMD 3) and to employ the recommendations of the IAPMP to monitor vegetation populations, and control invasive aquatic weeds and nuisance native plant populations (particularly around docks and swimming areas) in Lakes Erie and Campbell. LMD 3 continues to manage aquatic weed growth in both lakes, typically using annual mechanical harvesting and herbicide treatments. See additional details in the Aquatic Plants section above.

Current Conditions

Lake Campbell suffers from annual, persistent algae blooms, resulting in frequent and enduring public health advisories. Algae blooms are most often seen in Lake Campbell between August and October, and intermittently persist into the winter months (November through April). Cyanotoxins at levels above the state guideline have been reported multiple times in each year since 2021. These toxic algae blooms threaten swimmers and pets, are aesthetic nuisances, and destabilize the lake's ecosystem. When cyanotoxins are detected at levels at or above the state guideline, WDFW is prompted to close the public lake access facility and Skagit County advises against swimming, pet use of the lake, and boating. Cyanotoxin data collected since 2013 are presented and summarized Appendix A.

Based on historical data and the long-lasting effectiveness of alum treatments, phosphorus availability is a primary driver of these algal blooms. Anoxic conditions at the lake bottom during summer months increases phosphorus availability and may negatively impact aquatic life uses. Water quality and hydrological data collected from August 2023 through January 2024 for this LCMP are presented and discussed in Appendix A.

Contaminants of Concern

The contaminants of concern in Lake Campbell are the cyanotoxins microcystin and anatoxin-a, and total phosphorus. In accordance with the Clean Water Act, Ecology conducts a water quality assessment of Washington State waters approximately every 2 years. The result of these assessments is a database of categorical rankings for each applicable standard in each assessment unit. Those assessment units classified as Category 5 make up the 303(d) list of impaired water bodies of the state.

Lake Campbell and Lake Erie are listed under Section 303(d) of the Clean Water Act as a Category 4A for total phosphorus, which means their impairment by total phosphorus is being resolved by implementing a TMDL Plan (Ecology 2007). Lake Campbell is currently listed as a Category 5 (impaired) for dioxin in fish tissue and Category 4C (impaired but cannot be addressed by a TMDL plan) for nonnative plants under the 2018 water quality assessment approved by EPA.

Ecology recently revised Water Quality Program Policy 1-11 to develop Narrative Water Quality Standards for the basis of impairment for HABs (Ecology 2023). Ecology are using a combination of public health advisory information, cyanotoxin data from the Northwest Toxics Algae Database, public health assessment information, and the DOH recreational guidance as the basis for evaluating the health of contact recreation to prepare the next Water Quality Assessment (WQA). Based on available cyanotoxin data and closures in Lake Campbell, we anticipate the lake would be listed as impaired due to HABs in the next WQA and Integrated Report. The draft 303(d) list of impaired waters is anticipated to be released for public review and comment by summer 2024.

Project Description

Project Goals and Objectives

The overall goals of the Lake Campbell LCMP project are to identify the causes of the toxic algae blooms in Lake Campbell, develop water and nutrient budgets, evaluate lake and watershed management options for reducing the occurrence and duration of HABs in the lake, and ultimately support actions to enhance beneficial uses to humans and wildlife.

To support development of an LCMP for Lake Campbell, one project goal was to collect data of sufficient quality and quantity to evaluate the effects of environmental conditions and past lake management practices on algae growth and toxin production. Monitoring project objectives included:

- Collecting monthly surface water quality data from Lake Campbell
- Collecting six base flow water quality samples from the major contributing streams
- Collecting six wet-weather (storm flow) water quality samples from the major contributing streams
- Collecting continuous lake level data for Lakes Campbell and Erie
- Collecting 12 instantaneous discharge measurements at the outlet for Lake Campbell
- Characterizing the phosphorus fractions and iron content in sediment in Lake Campbell
- Determining the contribution of nutrients in surface runoff and groundwater inputs to Lake Campbell
- Obtaining a high-level characterization of lake macroecology through collection of phytoplankton and zooplankton community data

Monitoring was performed from August 2023 through January 2024 according to the Quality Assurance Project Plan (QAPP) (Herrera 2023), prepared following Ecology's LCMP template and guidance. Hydrologic monitoring of lake and stream levels extended into April 2024. Deviations from the QAPP are described in the *Data Quality Assurance* section of Appendix A. Validated data were used to:

- Track changes in the water quality characteristics Lake Campbell from August 2023 to January 2024.
- Identify the likely causes of cyanobacteria blooms in Lake Campbell.
- Quantify the nutrient loading of different sources and inputs of nutrients to Lake Campbell.
- Develop hydrologic and nutrient budgets for Lake Campbell.
- Provide recommendations for cyanobacteria management in Lake Campbell.

Lake Management Objectives

The goal for Lake Campbell management is to improve and protect lake uses by decreasing cyanobacteria blooms and the conditions that support them. The recommended water quality objectives for Lake Campbell are adapted from Ecology (2023) criteria for determining lake impairment due to harmful algae blooms:

- Within a 5-year period, there is no more than 1 year with two or more events with cyanotoxins exceeding state recommended guidelines.
- Within a 5-year period, there is no more than 1 year with a public health advisory lasting 3 weeks or longer.
- Levels of chlorophyll-a, total phosphorus, and Secchi depth are maintained at or below defined threshold values for the lowest end of the eutrophic scale (i.e., values occur in the mesotrophic range). Average summer (June through September) chlorophyll-a concentration does not exceed 7.2 micrograms per liter (μg/L) at 1 meter depth, total phosphorus does not exceed 24 μg/L at 1 meter depth, and Secchi depth is not less than 2.0 meters.

While not central to this plan, it is desirable that lake management strategies may additionally reduce or prevent flooding and provide co-benefits to fish and wildlife.

Schedule

Table 7 summarizes the schedule for the development of this plan.

Table 7. Consultant Tasks and Schedule.

Task	Schedule
Task 1 Literature Review and Database Development	July–August 2023
Task 2 QAPP Development	July–August 2023
Task 3 Monitoring and Data Management	August 2023–February 2024
Task 4 Lake Cyanobacteria Management Plan Preparation (includes water and phosphorus budget development)	February—June 2024
Task 5 Stakeholder Engagement	August 2023–June 2024

Data Used for Plan Development

This plan was developed using data collected as part of this LCMP project. A summary of the types of data gathered, methodology used, data quality assurance results, and sources of additional datasets are presented in Appendix A. Field data and laboratory data reports are compiled in Appendix B. Lake and watershed monitoring stations are shown in Figure 1.

Lake Campbell Hydrologic and Phosphorus Budgets

A limited water quality dataset was collected between August 2023 and January 2024 to characterize lake and inlet conditions. Hydrologic gaging datasets for the levels of Lake Erie and Lake Campbell span complete months between September 2023 and March 2024. These datasets, in addition to lake water quality data collected by the Samish Indian Nation, were summarized and compared to conditions observed in the 1980s as part of the initial lake restoration projects. Comparisons include:

- In-lake total phosphorus and chlorophyll-a concentrations
- Inlet total phosphorus concentrations and discharge during base and storm flow conditions
- Lake sediment phosphorus concentrations
- Estimated internal loading (via mass accumulation)

Long-Term Trend in Lake Trophic Conditions

Prior to the 1985 alum treatment in Lake Campbell, lake phosphorus concentrations were high (45 to 62 µg/L). Immediately following the 1985 treatment, lake phosphorus and chlorophyll-a concentrations dropped as measured in 1986. Sporadic monitoring from 1999 to 2023 by Ecology, Samish Indian Nation, Western Washington University, and under this study, suggests that as of at least the late 2010s that the lake trophic condition has appeared to return to pre-treatment levels. Summer mean values for the three trophic state parameters (total phosphorus, chlorophyll-a, and Secchi depth) in Lake Campbell are presented in Table 8.

The change in trophic conditions is likely caused by an increase in phosphorus loading. Pathways of phosphorus to the lake and relative estimated contributions are described below in Table 9.

Table 8. Summer Mean Water Quality at CAM-DEEP in Lake Campbell (1973–2023).					
			Summer (June to October) Average		
Year	Study	Sample Size	Total Phosphorus (µg/L)	Chlorophyll-a (µg/L)	Secchi Depth (meters)
1973	Ecology (1976)	2	48	–	1.2
1974–1980	No Data				
1981	Entranco (1983)	2	53	17	2.0
1982	Entranco (1983)	6	49	19	1.6
1985	Entranco (1987)	8	46	20	1.2
1986	Entranco (1987)	9	23	8.8	1.6
1987–1998	No Data				
1999	Ecology (2001)	4	40	42	1.8
2000–2001			No Data		
2002	Hilles et al. (2003)	3	29	7	1.6
2003	No Data				
2004	Ecology (2007)	3	18	18	1.8
2005	Ecology (2007)	3	19	14	1.7
2006–2016			No Data		
2017	Samish Nation	5	47	–	1.2
2018	Samish Nation	3	27	–	1.2
2019	Samish Nation	5	24	8 (n=1)	1.9
2020	No Data				
2021	Samish Nation	3	68	–	0.8
2022	No Data				
2023	This study	3	71	42	1.0

Values represent arithmetic means of discrete epilimnetic (lake surface) measurements for available data between June and October.

– = Not measured during defined period.

Double line border between cells indicates relative timing of alum treatment in Lake Campbell.

Table 9. Lake Campbell Phosphorus Loading Pathways.	
Pathway	**Description**
External Pathways	
Atmospheric Deposition/Precipitation	Phosphorus is carried in the atmosphere as dust particles and deposited onto the surface of lakes through precipitation (e.g., rain and snow). This can result from natural sources like dust storms, as well as human activities such as industrial emissions and agricultural practices.
Surface Runoff	Runoff from agricultural fields, urban areas, and other land surfaces carry phosphorus-containing fertilizers, animal waste, and soil particles into nearby water bodies, including lakes. This runoff can occur during rainfall or snowmelt events and is a significant pathway for phosphorus loading into lakes, especially in areas with intensive agricultural or urban land use.
Groundwater	Phosphorus can leach from soils and travel through groundwater to reach lakes. This pathway is particularly important in regions with porous soils or shallow groundwater tables, where phosphorus from fertilizers or septic systems can easily infiltrate into groundwater and eventually discharge into lakes.
Internal Pathways	
Sediment Release	Phosphorus can be released into lake water from sediments at the bottom of the lake. Over time, phosphorus accumulates in lake sediments through various inputs such as runoff, groundwater discharge, and decomposition of organic matter. Under certain conditions, such as low oxygen levels or changes in water chemistry, phosphorus bound to sediment particles can be released into the water column, contributing to nutrient enrichment and algal growth.
Aquatic Plant Decay	Aquatic plants, including algae and submerged vegetation, take up phosphorus from the water for growth. When these plants die and decompose, phosphorus is released back into the water. This process is a natural part of the lake's nutrient cycling but may be accelerated by excessive plant growth.
Fisheries/Fish Stocking	Introducing fish into lakes through stocking programs indirectly contribute to phosphorus loading. Fish excrete waste containing phosphorus into the water, which can add to the nutrient load.
Waterfowl	Waterfowl, such as ducks and geese, contribute to phosphorus loading in lakes through their feces. Waterfowl feed in and around lakes, and their waste contains nutrients, including phosphorus, which can be directly deposited into the water or onto the surrounding land and eventually wash into the lake through runoff.

Watershed Water and Phosphorus Loading

We estimated changed in watershed water and phosphorus budgets by comparing the measured discharge and phosphorus concentrations from this study to Entranco (1987).

In 1987, the watershed was characterized as 72 to 77 percent forested/unproductive, 12 to 16 percent agricultural, and 1 percent rural residential, with an estimated 130 residences with 415 people. Per the NLCD 2019 dataset (Table 3), the lake's watershed is currently 62.3 percent forested, 6.8 percent agriculture, 1.8 percent grasslands, 4.4 percent wetlands, and 10.6 percent developed. Development is about half open space (i.e., lawns) and half low-intensity (i.e., low-density, rural housing).

These watershed changes likely represent conversion of agricultural land to low-density development and potentially some densification. This is anticipated to have relatively minor impacts on the water and budget. Although there may be a slight increase in the surface runoff and decrease in groundwater due to an increase in impervious surfaces. However, the decrease in agricultural land use may be linked to decreased irrigation and crop evapotranspiration, which would increase and decrease the groundwater component, respectively. The impact on the water budget would depend on the initial source of irrigation water, whether from surface water, shallow groundwater, or deeper aquifers. Conversion from agricultural to rural residential development is hypothesized to decrease phosphorus loading due to a decrease in fertilizer use, soil loss (due to livestock erosion or tilling), and manure.

Precipitation

We compared monthly precipitation totals measured at the Washington State University AgWeatherNet (AWN) Anacortes station during the study period (April 2023 to March 2024) to the totals measured at the Anacortes COOP station in water year (WY) 1986 (Table 10). Entranco (1987) does not provide monthly precipitation totals, so only the annual totals were compared. On an annual basis, it appears that the Lake Campbell precipitation station received 7 inches less of rainfall than the COOP station located in Anacortes. We expect that the AWN station to receive approximately the same rainfall as the COOP station; the AWN is located at the Anacortes Regional Airport, 2.5 miles west-southwest of downtown Anacortes. Compared to the rainfall conditions observed during the Entranco (1987) study, the monthly precipitation values during the study period were fairly similar. During the wet months of the study (October 2023 to March 2024), 17.67 inches were measured at the AWN station, and during the same period of the Entranco (1987) study, 16.72 inches were measured at the COOP station.

Table 10. Comparison of Monthly and Annual Precipitation for WY1986 and This Study.

Month	Monthly Precipitation (inches)			
	WY1986 COOP Anacortes	WY1986 (Entranco 1987)	This Study (April 2023 to March 2024) AWN Anacortes	Monthly Averages COOP (1981–2010)
October	5.01	NP	2.85 (2023)	2.76
November	3.59	NP	2.63 (2023	4.67
December	0.59	NP	4.37 (2023)	3.44
January	2.94	NP	4.15 (2024)	3.58
February	2.58	NP	2.49 (2024)	2.34
March	2.01	NP	1.18 (2024)	2.31
April	2.20	NP	1.72 (2023)	1.93
May	3.01	NP	0.46 (2023)	1.88
June	1.42	NP	0.11 (2023)	1.50
July	1.99	NP	0.61 (2023)	0.86
August	0.00	NP	0.90 (2023	1.03
September	1.79	NP	0.94 (2023)	1.53
Total	**27.13**	**20.63**	**22.41**	**27.83**

NP: Not Provided

USC00450176 located downtown Anacortes 4.7 miles north of Lake Campbell.

AWN Anacortes station located at Anacortes Regional Airport; 3.9 mile north-northeast of Lake Campbell.

Lake Inlets

Table 11 compares watershed discharge and total phosphorus concentrations for WY1986 (Entranco 1987) to this study (August 2023 through January 2024). Discharge measurements in 2023 through 2024 were substantially reduced compared to those measured by Entranco in WY1986 at the four common inflow monitoring stations (see Figure 4), except at CS1 (also known as "SR 20") where discharge was low and unchanged. Mean discharge at CS2 (also known as "WHISTLE") and CS3 (also known as "EO") were 81 and 85 percent less, respectively, in 2023 through 2024 than in WY1986 (see Table 11). Conversely, concentrations of total phosphorus were greater at all stations in 2023 through 2024 compared to WY1986: 66 percent greater at CS1, 166 percent greater at CS2, and 25.5 percent greater at CS3.

The low stream flow observed in this study does not appear to be due to unusually dry weather during the study period (Table 10). Observed rainfall in WY1986 and during this study period were similar to the historical norms, however rainfall during the months preceding the study period (May to July) were lower than historical norms and observations in WY1986. This may have contributed to an overall lower shallow groundwater elevations and lower lake levels, which would affect baseflow in streams and lake outlets while these recharged. Additional inflow monitoring is recommended to confirm the observed differences in discharge and total phosphorus.

Table 11. Watershed Discharge and Total Phosphorus Comparison Between Entranco (1987) and This Study.

Flow	Parameter	CS1 ("SR 20")						CS2 ("WHISTLE")					
		Entranco (1987)			This Study			Entranco (1987)			This Study		
		Mean	Range	n	Mean	Range	n	Mean	Range	n	Mean	Range	n
Base	Discharge	0.04	0.02–0.11	n = 9	0.018	<0.001–0.046	n = 5	0.3	0.01–0.63	n = 4	0.028	0–0.134	n = 5
	TP	29	8–196		80.6	58–119		10.5	4–16		26.5	22–31	
Storm	Discharge	0.15	0.04–0.33	n = 7	0.101	0.003–0.322	n = 5	0.7	0.28–1.38	n = 6	0.15	0–0.512	n = 6
	TP	82	7–140		90.9	33–173		9.8	5–13		27	12–42	
Combined	Discharge	0.09	0.02–0.33	n = 16	0.059	<0.001–0.322	n = 10	0.51	0.01–1.38	n = 11	0.095	0–0.512	n = 11
	TP	52	7–140		86.3	33–173		9.7	4–16		25.8	12–42	
Flow	**Parameter**	**CS3 ("EO")**						**CAM-OUT ("CO")**					
Base	Discharge	0.5	0.03–1.28	n = 3	0.07	0–0.27	n = 4	1.6	<0.01–5.02	n = 5	0	0–0	n = 4
	TP	55.7	32–100		54.3	46–67		35.7	26–120		–	–	–
Storm	Discharge	1.2	0.03–2.46	n = 6	0.24	0–0.83	n = 5	4.3	<0.01–9.93	n = 6	0.166	0–0.471	n = 5
	TP	47.5	24–87		71.7	35–108		25.6	19–170		–	–	–
Combined	Discharge	0.9	0.03–2.46	n = 9	0.162	0–0.83	n = 9	3.1	<0.01–9.93	n = 11	0.092	0–0.471	n = 9
	TP	50.2	24–100		63	35–108		52	19–170		–	–	–
Flow	**Parameter**				**CS2.5 (this study only)**								
Base	Discharge				0.002	0–0.01	n = 5						
	TP				31	18–56							
Storm	Discharge				0.05	0–0.146	n = 5						
	TP				43	39–47							
Combined	Discharge				0.027	0–0.146	n = 10						
	TP				35.8	18–56							

Discharge in cubic feet per second (cfs). TP in ug/L.

Lake Outlet

The lake level and outflow discharge data collected between August 2023 and March 2024 (Table 12) were used to develop a hydrologic rating curve that relates lake level to outlet discharge. This relationship was used to estimate average discharge on a daily timestep, which was then summed to estimate monthly discharge volume. The estimated discharged volume was compared to that of the Entranco (1987) study. Importantly, lake outflow discharge volumes estimated for this study may be inaccurate because there were only three observations of measurable discharge from the lake that could be used to develop the rating curve (Table 12).

Table 12. Monthly Lake Outflow.

Month	Monthly Events (discrete cfs)		Estimated Lake Outflow (1,000 m^3)		Ratio of Monthly Volume
	Entranco 1987 (WY1986)	This Study	Entranco 1987 (WY1986)	This Study (August 2023–March 2024)	
October	0	0	0	0	NA
November	trace	R	133	0	NA
December	4.05	0.02	409	1.4	0.00
January	3.31	0.336 and 0.471	338	27.2	0.08
February	3.99	NM	302	34.6	0.11
March	9.93	NM	504	35.3	0.07
April	4.60	NM	260	NM	NA
May	5.02	NM	276	NM	NA
June	2.72	NM	119	NM	NA
July	0.46	NM	39	NM	NA
August	0	0	0	0	NA
September	0	0	0	0	NA
		Annual Total	**2,380**	**>98.5**	**0.065 (average)**

m^3 = cubic meters; NM = Not measured; NA = Not applicable.

Entranco (1987) did not provide monthly precipitation depths.

Estimated outflow from Lake Campbell from December 2023 to March 2024 was much less than the estimates in WY1986. While some of the lower outflow in this study may have been due to lower rainfall and inflow, it is believed to be primarily caused by the presence of a beaver dam. The average ratio of this study's monthly outflows to Entranco's (1987) estimates was 0.065. Assuming the beaver dam raised the water level by 2 feet (0.6 meter), the lake storage volume would increase by 939 thousand cubic meters, which is approximately 40 percent of the entire surface outflow estimated for WY1986. Water would still leave the lake by overtopping the beaver dam, trickling through it, and as shallow groundwater flow. For this planning level estimate, we assume that the presence of the beaver dam has decreased the surface outflows by 40 percent, and that that decrease resulted in an equivalent increase in groundwater outflow. This is a major uncertainty that affects the estimate of sedimentation of phosphorus in Lake Campbell. We hypothesize that the presence of the beaver dam has enhanced the deposition of suspended phosphorus (e.g., in algae) onto lake sediments, rather than allowing a fraction of it to be exported. The increased lake sedimentation rate combined with anoxic sediment conditions may be causing continual enrichment of phosphorus in the sediments and therefore the lake.

Watershed Water and Phosphorus Load Estimates

While the flow measurements were lower in this study compared to Entranco (1987), monitoring for this study did not extend into the spring, when we would expect greater discharge from CS2 and CS3 as lakes Erie and Whistle overtop outlet controls and more water is able to leave the lake (as with the Lake Campbell outlet). Table 13 presents the adjusted watershed phosphorus load and surface water export for Lake Campbell. For this planning level analysis, we assumed that the watershed water inputs remained the same and increased the phosphorus load using the ratio of the average total phosphorus in this study compared to WY1986 (Entranco 1987). There is insufficient evidence to alter the "other" watershed water and phosphorus loading from Entranco (1987).

Table 13. Watershed Phosphorus Loading Multiplication Factors for Entranco 1987 to Current Study.

Inlet	TP Ratio (current/1987)	Flow Ratio (current/1987)	Flow Ratio (assumed)	Load Factor (TP ratio x flow ratio)	P Load WY1986 (kg)	Estimated Current Load (kg)
CS1	1.7	0.66	1	1.7	14.9	25.3
CS2	2.7	0.19	1	2.7	4.8	13.0
CS3	1.25	0.18	1	1.25	30.0	37.5
Other Loads	NE	NE	1	1	26.3	26.3
Watershed Load Total	–	–	–	–	**76**	**102.1**
CAM_OUT	NA	0.065	0.6	0.6	48.4	29.0

kg = kilograms

Groundwater Loading

We estimated the change in groundwater loading by comparing the concentration of total phosphorus in the lake inlets to historical measurements of groundwater phosphorus concentrations. We assumed that the groundwater water volume inputs have not changed since the initial study completed in the 1980s given the approximately similar precipitation levels.

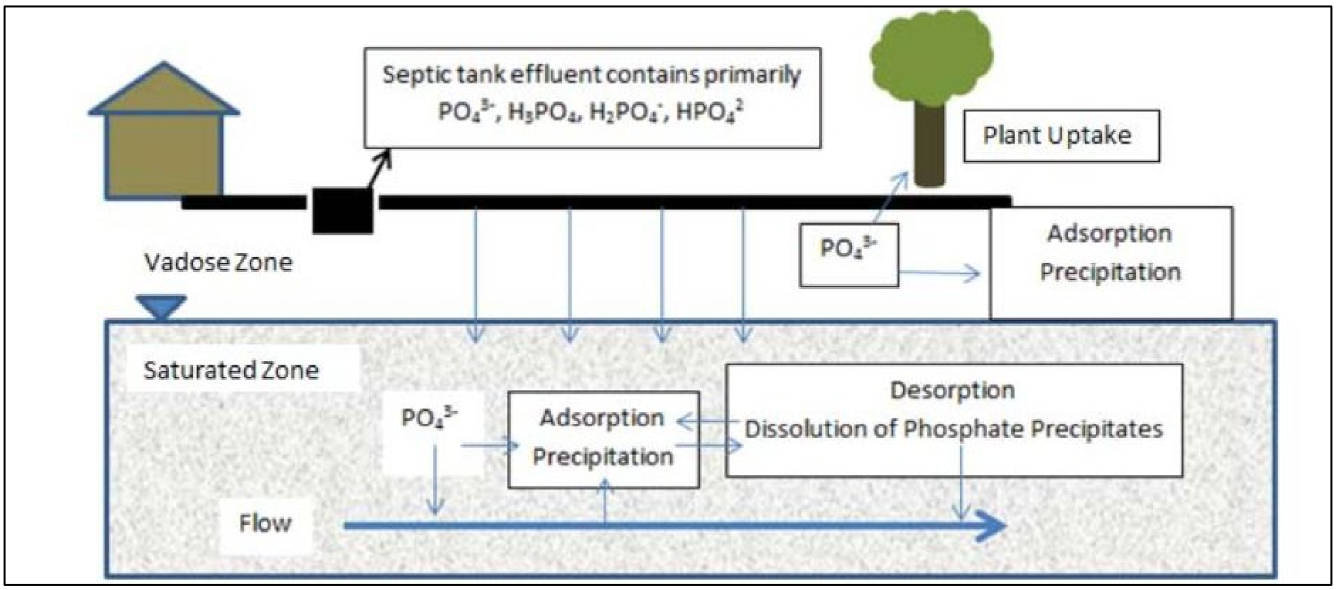
Average concentrations of total phosphorus in lake inlets during base flow conditions were lowest at CS2 in both WY2024 and WY1986 (26.5 and 10.5 µg/L) but increased at CS1 from 29 µg/L in WY1986 to 80.6 µg/L in WY2024. No significant changes in total phosphorus were observed at CS3 (54 µg/L versus 56 µg/L) from Lake Erie outflow (Table 11). Overall, the average base flow total phosphorus concentration was 52.6 µg/L. Entranco (1983) estimated groundwater inflow concentrations of total phosphorus at 60 µg/L based on monthly sampling at six fixed well points around the lake and a single sampling event using a well point sampler at 10 stations around the perimeter of the lake. Given the spatial similarity in average total phosphorus concentrations in base flow for this study and in groundwater by Entranco

(1983), we assume the current groundwater loading of phosphorus to the lake is approximately the same as estimated for WY1986.

Septic System Loading

Conventional septic systems offer little treatment or reduction of phosphorus, except the settling of solid-bound phosphorus to the bottom the septic tank. Total phosphorus concentrations in septic tank effluent range from 1 to 26 mg/L (1,000 to 26,000 µg/L) (McCray et al. 2005). Phosphorus is treated or removed in the drain field after leaving septic tank as effluent by precipitation, filtration, and adsorption to soils (Figure 5). Within a properly sized drain field, phosphorus will undergo mineralization, bind (adsorb) to soil particles, and be taken up by plants. A particular issue for lakes is septic systems located near the shoreline that may have critically undersized drain fields that offer limited opportunity for phosphorus removal. For this reason, septic systems are not allowed to be installed within 100 feet of a lake in Washington, and up to 300 feet in other states.

Figure 5. Fate and Transport of Phosphate (PO_4^{3-}) in a Septic System.



Most adsorption and precipitation reactions of phosphate are complete by the time the septic tank effluent reaches the water table. Thus, understanding how phosphate moves in the drain field is the key to determining the ultimate fate of phosphate from septic systems. Credit: Mary Lusk, UF/IFAS.

The effectiveness of soils and underlying aquifer materials in attenuating P movement to subsurface and surface water depends upon a number of factors including: the soil chemical and physical properties, the chemical properties and loading rate of the wastewater, site hydrology, proximity of the site to surface water, and the design and management of the onsite sewage disposal system (McCray et al. 2005). The soil type in Lake Campbell's immediate vicinity is largely gravely loam (Coveland and Swinomish soil groups). Generally, these soil groups have low capacity to attenuate phosphorus and are "very limited" for septic tank absorption fields due to high water table, filtering capacity, and/or slope (NRCS 2023).

We employed a simple model to estimate the potential loading of phosphorus from septic systems in Lake Campbell. This model is adapted from Ecology (2013). For this preliminary, screening analysis, we focused on making estimates using the following equation:

$$P_{OSS} = n * Occ * P_{Person} * (1 - a)$$

Where:

P_{OSS} = annual phosphorus load in kilograms (kg)
n = number of residences served by septic systems
Occ = occupancy rate (number of people per residence)
P_{Person} = per capita phosphorus contribution (kg-P/person-year)
a = phosphorus attenuation rate (i.e., the loss to/removal by soil)

We assumed an occupancy rate of 2.2 people per residence, and 1 kg-P/person/year for P_{Person}. For the attenuation rate, 90 percent may be used for fully functioning systems and 50 percent for failing systems (including systems with inadequate drainfield sizing). We modified the attenuation rate to generate a range of loading estimates. We assumed 25 households along Lake Campbell and 150 households in the watershed. Phosphorus contributions from septic systems ranged were estimated to range from 5.5 to 99 kg per year (Table 14). These estimates ranged from 10 percent of the groundwater (for the fully functioning shoreline-only scenario) to 187 percent for the scenario assuming all OSS in the watershed were contributing to Lake Campbell and half were failing. The latter is expected to be a substantial overestimate because additional phosphorus attenuation is expected due to seepage into deeper groundwater, uptake by plants, and capture in Lake Erie. The range of 5.5 to 33 kg is more reasonable. Entranco (1983) estimated that 38 kg of groundwater phosphorus loading were related to OSS and/or agricultural leachate.

Table 14. Septic System Phosphorus Loading Estimates.

Scenario	Phosphorus Load (kg/year)	Percent of Groundwater Loads (53 kg)
Shoreline OSS Only (n = 25) 100% Fully Functioning (a = 0.9)	5.5	10%
Shoreline OSS Only (n = 25) 50% Fully Functioning (a = 0.9) 50% Failing (a = 0.5)	16.5	31%
Watershed OSS (n = 150) 100% Fully Functioning (a = 0.9)	33	62%
Watershed OSS (n = 150) 50% Fully Functioning (a = 0.9) 50% Failing (a = 0.5)	99	187%

Internal Loading

Internal loading of phosphorus to a lake generally includes the release of phosphorus from lake sediments, release of phosphorus from decaying aquatic plants, sediment resuspension by wave action or bottom-feeding fish, and waterfowl fecal contributions. Accumulation of phosphorus in the entire lake volume over the summer months is often used to estimate internal phosphorus loading for shallow eutrophic lakes such as Lake Campbell because it is recognized that sediment oxygen concentrations are much lower than those measured in the water in both the surface and bottom layers (epilimnion and hypolimnion). Another reason to include mass accumulation in the surface layer is that sediment release in the surface layer also occurs from high pH conditions caused by rapid algae growth and carbon dioxide consumption during summer algae blooms. At high pH, the rate of sediment phosphorus release can increase due to desorption of phosphorus from ferric hydroxide by the replacement of phosphate with hydroxide.

To estimate the net internal load of phosphorus from the sediments, we relied on monthly lake monitoring data from the Samish Indian Nation collected between 2017 and 2021 (Table 15). To isolate internal loading, we looked at mass accumulation of phosphorus in the summer, defined as June to September. The summer period is assumed to have minimal watershed and groundwater inputs of phosphorus due to low rainfall and a lowered water table. The total mass gains during each of these study years are presented in Table 15.

Table 15. Annual and June Through September Lake Phosphorus Mass Accumulations.

Year	Months Monitored	June to September Period Mass Gain (kg)
2017	January through December	169
2018	January through August, October through December	99 (does not include September)
2019	January through December	309
2021	January through August, December	255 (does not include September)
	Average	**208**

Source: Samish Indian Nation, unpublished data.

Summer phosphorus mass gains ranged from 99 to 309 kg and averaged at 208 kg in 2017 through 2021 (see Table 15). Because this method only estimates internal loading during the summer and did not include September for 2 of the 4 years, it is believed to be a conservative estimate. Further, it is an estimate of net internal loading, rather than gross internal loading, because it does not consider the ongoing sedimentation of phosphorus in the water column.

Because monitoring did not begin until August 2023, we were not able to calculate summertime mass accumulation for estimating internal phosphorus loading for 2023. We attempted to use sediment phosphorus concentrations to estimate internal loading based on literature equations (e.g., Nurnberg 1988; Pilgrim et al. 2007). However, those literature equations are based on release of phosphorus from iron complexes due to anoxic conditions at the sediment-water interface. Because the release of phosphorus in Lake Campbell was considered to be primarily driven by high pH rather than low oxygen, those literature equations did not apply (Entranco 1983). We found in this study that in the biologically active zone (top 10 centimeters [cm]), the majority of phosphorus was in the biogenic fraction, i.e., in organic matter that may be readily broken down by microbes and released to overlying water. We also found relatively high pH of 8.0 to 9.0 throughout the water column in August and September 2023, and anoxic conditions (less than 1 mg/L) at and below 2 meters depth in August 2023 but not in September 2023. These observations suggest that sediment phosphorus release in Lake Campbell in 2023 may have been due to anoxia, high pH, and high biogenic phosphorus concentrations in the lake sediments.

Further confirmation of the internal loading rate for Lake Campbell is recommended. Summer mass accumulation (when external inputs are minor) suggest that internal loading is substantial (approximately 208 kg per year). However, iron-bound phosphorus concentrations in sediment are relatively low (10 percent of total phosphorus) and release equations in the literature based on iron-bound phosphorus would predict no internal loading. The lake's sediments in the biologically active zone (0 to 10 cm) are rich in phosphorus, especially biogenic phosphorus, which accounts for 37 percent of the total phosphorus and is generally composed of settled algae, bacteria, and aquatic plant detritus (Table 16). Biologically unavailable forms of sediment phosphorus included mostly aluminum-bound phosphorus (24 percent of total), followed by other organic phosphorus (16 percent of total) and calcium-bound phosphorus (14 percent of total).

Table 16. Sediment Phosphorus Concentrations.

Sediment Parameter	Entranco 1983 (top 30 cm) (Table D-6)	This Study (August 2023) Average of CAM-DEEP and CAM-SHALLOW Sites	
		(top 26 cm)	(top 10 cm)
Total Solids (percent)	5.1% (3.9% to 9.1%)	6.6% (4.6% to 8.6%)	6.4% (3.7% to 9.0%)
Iron (mg/kg-DW)	NM	14,290 (12,355 to 16,246)	15,093 (15,002 to 15,184)
Total Phosphorus (mg-kg-DW)	734 (318 to 1216)	831 (610 to 1052)	1,032 (798 to 1266)
Iron-Bound Phosphorus (mg/kg-DW)	NM	79 (20 to 139)	95 (20 to 170)
Organic Phosphorus (mg/kg-DW)	NM	461 (294 to 627)	605 (406 to 802)
Biogenic Phosphorus (mg/kg-DW)	NM	245 (140 to 350)	379 (238 to 519)
Calcium-Bound Phosphorus (mg/kg-DW)	NM	130 (125 to 134)	141 (122 to 160)
Aluminum-Bound Phosphorus (mg/kg-DW)	NM	209 (145 to 273)	246 (170 to 323)

NM: Not Measured; biogenic phosphorus is a portion of organic phosphorus.

We expect that biogenic phosphorus is readily released during microbial decay and that iron-bound phosphorus is released at high pH (>8) found during algae blooms. Total iron concentrations are relatively high in the surface sediments at 15 times the total phosphorus concentrations, and the observed ratio of 15:1 iron to phosphorus is equivalent to the minimum needed to bind iron to phosphorus and be the primary control of internal phosphorus loading (Cooke et al. 2005). While there is plenty of iron available in the lake's surface sediments, the high amount of biochemical oxygen demand is believed to cause low to negligible concentrations of dissolved oxygen, which causes reduction and dissolution of iron (preventing it from forming complexes with phosphorus and sequestering it). Sediment total phosphorus concentrations were similar to those reported by Entranco (1983) (Table 16).

Further study is already planned to collect sediment cores from Lake Campbell to conduct laboratory incubation studies under varying conditions of oxygen, pH, and alum dosage. These data may be used to calculate the sediment release rate and apply it to an updated lake phosphorus budget.

Waterfowl Contributions

Waterfowl were counted by lake monitoring volunteers during each monthly lake event from August to December 2023. Counts were recorded at either the mid-lake station or from the southwest shoreline where a full view of the lake surface is accessible, and were performed at various times (e.g., early morning, midday, late afternoon, and late evening). Birds are typically less active midday; for instance, ducks are most active at dawn and dusk (Korner et al. 2016).

During the monitoring period, geese were observed only during the August sampling event (with four individuals), and 47 ducks were counted only during October sampling event. No counts of geese or ducks were reported for other months. Additionally, herons were observed in September and November. Prior to the sampling event, lake residents explained that WDFW captured and removed 57 resident Canada geese (E. Goodman, pers. comms.). A higher resolution dataset would be necessary to understand the full extent of bird populations and potential phosphorus loading effects on Lake Campbell.

Estimation of phosphorus loading from waterfowl was performed following the methods of Boros (2021) using published waterfowl excrement rates and residential time factors (Manny et al. 1994; Marion et al. 1994; Boros 2021) (Table 17). Non-waterfowl bird species were not considered in this loading estimation.

Table 17. Literature Values for Bird Excrement Loading Rates and Residential Time Factors.

Bird Type	Residual Time Factor	Excrement Loading Rate (g P/day)	Source(s)
Geese	0.6	0.49	Boros 2021; Manny et al. 1994
Dabbling ducks	0.8	0.18	Manny et al. 1994
Herons	0.8	3.78	Marion et al. 1994; Boros 2021

To estimate waterfowl phosphorus contributions to Lake Campbell, we calculated loading in three ways to provide a range of potential values:

- Upper Estimate: Assumed that the maximum observed counts for each bird (57 geese, 47 ducks, 2 herons) were present every day.
- Lower Estimate: Average of the observed counts from the five monitoring events (1 goose, 9 ducks)
- Mid Estimate: Midpoint of lower and upper estimates

We then calculated daily load using the equation below, modified as noted from Boros (2021):

$$Load = A * E * RTF$$

Where:

A	=	daily abundance of a given species
E	=	daily net rate of excrement loading (e.g., mass phosphorus per individual per day)
RTF	=	residential time factor (proportion of a day that waterbird spends at lake)

Daily loads for each bird type were then summed together and across all days in the year to arrive at the rate of annual phosphorus loading by waterfowl in Lake Campbell (Table 18. Estimated annual waterfowl phosphorus loads ranged from 1.6 to 10.9 kilograms.

Table 18. Estimated Waterfowl Phosphorus Contributions.

Estimate	Assumptions (daily population)	Excrement P Load (g/day)	Annual Load (kg/year)
Lower	1 Goose 9 Ducks	4.5	1.6
Mid	29 Geese 29 Ducks 1 Heron	15.7	5.7
Upper	57 Geese 47 Ducks 2 Herons	29.9	10.9

Lake Campbell Water and Phosphorus Budgets

Table 19 presents the water and phosphorus budgets for WY1982, WY1987, and estimated contemporary conditions. The contemporary total phosphorus budget is presented graphically in Figure 6. The contemporary conditions were estimated based the modifications to the Entranco (1987) water and phosphorus budgets detailed in the previous sections. Notably, there is an estimated increase in surface water loading to the lake and from internal cycling. The 208 kg of contemporary internal loading is considered a low estimate because it only considers lake phosphorus mass accumulation in the summer (June to September), but sediment release is expected to occur to some degree in other parts of the year in Lake Campbell. The internal load estimate is assumed to be inclusive of waterfowl loading, which was estimated to range from 1.6 to 10.9 kg per year (1 to 5 percent of the internal load). The groundwater load is assumed to be inclusive of the loading from septic system leachate, which was estimated to range from 5.5 to 33 kg (10 to 62 percent of the groundwater load).

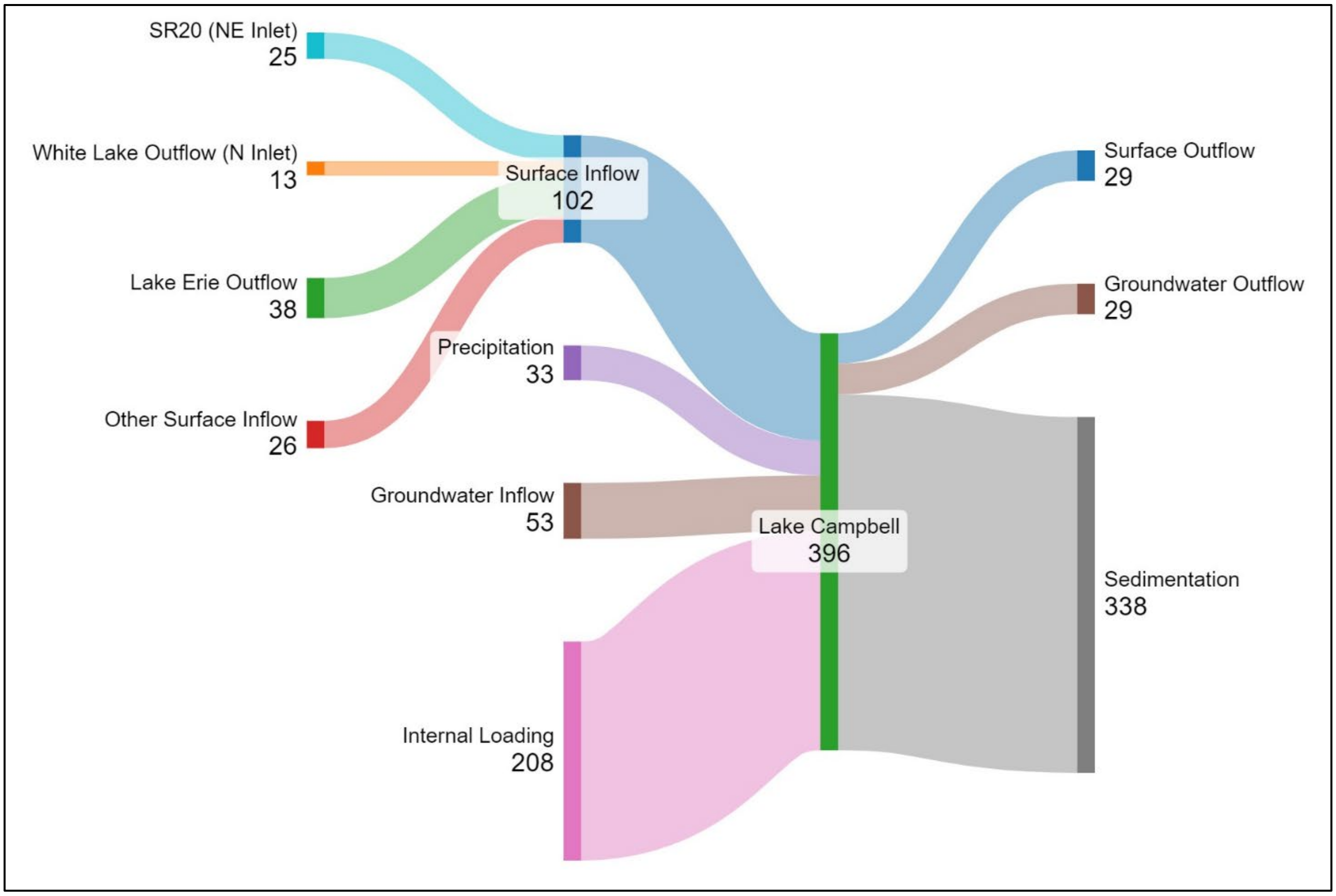
Table 19. Updated Lake Campbell Water and Phosphorus Budgets.

Component	Water Budget (1,000 m^3)			Phosphorus Budget (kg)		
	WY1982	WY1986	Contemporary[a]	WY1982	WY1986	Contemporary[a]
Inputs						
Precipitation	956	785	785	30	33	33
Surface Water	3,832	1,763	1,763	199	76	102
Groundwater	1,758	879	879	84	53	53
Internal				340	155	>208
Total	**6,546**	**3,427**	**3,427**	**653**	**317**	**>396**
Outputs						
Outflow	5,181	2,380	1,428	177	48	29
Evaporation	1,047	1,047	1,047	NA	NA	NA
Groundwater	318	0	952	2	0	29
Sedimentation				476	269	>338
Total	**6,546**	**3,427**	**3,427**	**653**	**317**	**>396**

[a] Contemporary groundwater outflows are expected to be higher due to the presence of a beaver dam at the lake outlet. For this planning level estimate, we assumed that decrease in surface water outflow was equivalent to the increase in groundwater outflow.

m^3 = cubic meters

Figure 6. Estimated Annual Phosphorus Import and Export (kg) to Lake Campbell.



Entranco (1987) noted that the water budget for WY1986 represented some significant differences from the WY1982 water budget. Entranco (1987) explained their lower estimates were due to improvements in localized precipitation estimates causing a decrease in the total rainfall (by 12 percent) and to improvements in flow measurements.

Additional monitoring may be conducted to confirm and update the water and phosphorus budgets, including:

- Monthly water quality and discharge monitoring at the inlets for an entire year
- Additional discharge monitoring at the Lake Campbell outlet to calibrate the discharge rating curve with lake level
- Additional discharge monitoring at CS3 to calibrate the discharge rating curve with Lake Erie level
- Higher resolution counts of waterfowl
- Sediment incubation study to determine phosphorus release rates
- Quarterly groundwater water quality sampling for an entire year

Summary of Findings

What Is Causing or Contributing to Cyanobacteria Blooms in Lake Campbell?

Cyanobacteria may have several competitive advantages over other algae, including the ability to fix nitrogen and store phosphorus (two crucial nutrients for growth). In addition, they can regulate their buoyancy, moving up and down in the water column; they have low energy demands; and they are generally unpalatable to grazers that eat algae.

Lake monitoring data from August to December indicate there is abundant phosphorus and nitrogen in Lake Campbell, and the algae blooms are likely limited by either both nutrients or just phosphorus. Monitoring in the 1980s and 2002 found phosphorus-limiting conditions. Cyanobacteria were by far the dominant algae species in samples collected in August, September, and October 2023. When cyanobacteria populations reach high densities, they often produce cyanotoxins at levels that are harmful to human health. Toxic blooms have been seen in the summer and fall of 2021, 2022, and 2023, with high levels of microcystin, a liver toxin.

Where Is the Excess Phosphorus Coming From?

Relying on historical watershed monitoring data, we determined that the primary source of phosphorus to Lake Campbell is internal release from the lake sediments representing 53 percent of the total inputs on an annual basis and a higher proportion during the summer/fall algae bloom period. Watershed inputs included surface water (especially outflow from Lake Erie and the SR 20 drainage) at 26 percent of the annual total and groundwater at 13 percent of the annual total. Waterfowl are estimated be a minor contributor. Onsite septic systems may have a significant impact on groundwater loads, but further investigation is needed to confirm their contribution. Because contemporary phosphorus concentrations are similar to those measured in the 1980s, the study results indicate that the surface and groundwater inputs to Lake Campbell are relatively unchanged, and that the return of poor water quality conditions are driven primarily by the long-term accumulation of phosphorus within the lake, following the 1985 alum treatment.

Sediments in Lake Campbell are rich in phosphorus bound to biologically available organic matter (such as dead algae and aquatic plants) and to a lesser degree, calcium and iron. When algae blooms occur, they elevate the pH of the lake because they are consuming dissolved carbon dioxide. Under elevated pH, there is expected to be enhanced release of phosphorus from some iron and aluminum complexes in oxygenated sediments (Jensen et al. 1992; Boers 1991; Drake and Haney 1987; Christophoridis and Fytianos 2006). Mineralization of biogenic phosphorus also occurs from microbial decay of some organic matter in shallow oxygenated sediments. Additionally, due to the biological oxygen demand in the lake sediments caused by microbial decay, phosphorus bound to iron may also be released due to anoxic conditions in the sediments when dissolved oxygen is present in the overlying waters. The high level of algae productivity throughout much of the year allows for accelerated phosphorus cycling within the lake.

Our theory for the eutrophication of Lake Campbell is summarized below:

- Nutrients enter the lake via surface water and groundwater inflows (at rates similar to that measured in the 1980s).
- Algae and aquatic plants use available nutrients to grow. When algae and aquatic plants die, they release some of the nutrients to the water column and fall as debris to the lake's bottom. Some amount of the suspended nutrients may be exported via the lake's outlet. Harvesting of aquatic plants may also remove nutrients from the lake.
- When algae blooms occur, they greatly increase the water's pH (by consuming carbon dioxide). Nutrient release from phosphorus bound to iron and aluminum is enhanced under elevated pH conditions, and nutrient release from decaying organic matter is enhanced by increased microbial activity.
- Furthermore, decaying organic matter in the lake's sediments uses up oxygen, which creates conditions where solid iron-phosphorus complexes dissolve, and additional phosphorus may be released. Nitrogen release as ammonia is also enhanced under these conditions.
- Due to the presence of the beaver dam at the lake's outlet, there is decreased export of nutrients from the lake, and more are retained within the lake's sediments, which may be recycled to fuel further algae blooms.

The 1985 alum treatment provided long-term relief from eutrophication in Lake Campbell, but over time the sediment reservoir of available nutrients has replenished.

Cyanobacteria Management Methods

This section provides a brief summary of watershed and in-lake management methods for cyanobacteria control, their advantages and disadvantages, and their suitability for implementation in Lake Campbell. Actions assessed as suitable for implementation in Lake Campbell are highlighted in green in Table 20 and further described in the sections below. These cyanobacteria management methods are further described in Appendix C. Actions determined not feasible for implementation in Lake Campbell and rationale are detailed in the *Methods Rejected* section of Appendix C.

Table 20. Cyanobacteria Management Feasibility Screening for Lake Campbell.

Method	Effectiveness	Cost	Non-Target Impact Risk	Feasibility	Suitability
WATERSHED (external nutrient loading control) METHODS					
Septic System Management	Low–Moderate	High	Low	Moderate	Yes
Stormwater Management	Low–Moderate	Moderate	Low	Moderate	Yes
Stream Phosphorus Inactivation	Low–Moderate	Moderate	Moderate	Low	No
Waterfowl Management	Low–Moderate	Moderate	Low	Moderate	Yes
Shoreline Management	Low–Moderate	Moderate	Low	Moderate	Yes
IN-LAKE PHYSICAL METHODS					
Lake Mixing – Surface Mixing by SolarBees	Low–Moderate	Low–Moderate	Low	Moderate–High	No; uncertain effectiveness
Lake Mixing – Whole-lake Mixing by Aeration	Low–Moderate	Moderate	Low	Moderate	No; uncertain effectiveness
Sonication	Low–Moderate	Moderate	Low–Moderate	Low	No; uncertain effectiveness
Lake Dilution	Moderate	High	Low	Low	No; high cost
Hypolimnetic Oxygenation/ Aeration	Low–Moderate	Moderate–High	Low-Fish Benefits	Moderate	No; lake too shallow
Ozone/Microbubbles/ Nanobubbles	Low	Moderate	Low	Low	No; not effective, experimental
Hypolimnetic Withdrawal	Low	Moderate	High	Low	No; insufficient inflow, downstream impacts
Beaver Dam/ Lake Level Management	Moderate	Low	Low–Moderate	Moderate	Yes
Dredging	Low–Moderate	Very High	Moderate	Low	No; high cost/benefit
Shading (Dyes)	Moderate	Low–Moderate	High	Low	No; not feasible

Table 20 (continued). Cyanobacteria Management Feasibility Screening for Lake Campbell.					
Method	**Effectiveness**	**Cost**	**Impact Risk**	**Feasibility**	**Suitability**
LAKE CHEMICAL METHODS					
Algaecide Treatment	Moderate	Low–Moderate	Low–Moderate	Moderate	No; not a long-term solution
Sediment Phosphorus Inactivation with Alum or Lanthanum	High	Moderate	Low–Moderate	Moderate	Yes
Calcium Treatment	Low	Low–Moderate	Low	Low	No; not effective with low hardness
Iron Treatment	Low	Low	Low	Low–Moderate	No; not effective with sediment layer anoxia
LAKE BIOLOGICAL METHODS					
Grass Carp Removal	Low	Moderate–High	Low–Moderate	Low	No; high cost/benefit
Biomanipulation (zooplankton planting; piscivore stocking)	Low	Low–Moderate	Low–Moderate	Low	No; not feasible, low effectiveness
Aquatic Weed Harvesting	Low–Moderate	Moderate	Low	Moderate	No; high cost/benefit
Macrophyte Plantings	Low	Moderate	Low	Low	No; high cost/benefit
Barley Straw	Low	Low	Low–Moderate	Low	No; uncertain benefit

Recommended Management Plan

We recommend an adaptive management approach that provides near-term relief from toxic algae blooms through in-lake treatment and long-term prevention through internal load reduction and watershed phosphorus control. Ongoing monitoring should be used to monitor achievement of water quality objectives and to inform adjustments to management techniques. Table 21 at the end of this section provides a summary of the implementation costs.

For long-term management, we recommend conducting a sediment inactivation treatment using alum or lanthanum. The treatment will inactivate phosphorus in the sediments and provide a binding site for phosphorus released from organic and minerals. This treatment will interrupt the positive feedback loop where high nutrient availability fuels algae blooms that increase the lake's pH, which in turn causes release of nutrients from the lake sediments. The 1985 alum treatment proved to be very effective, lasting more than the average of 10 years reported for alum treatments in other lakes (Cooke et al. 2005). To increase the long-term effectiveness of a sediment inactivation treatment, we recommend evaluating and implementing low-cost controls for watershed sources of nutrients, i.e., septic systems and stormwater runoff.

Beaver activity at the lake's outlet has been observed to decrease lake outflow and to increase winter lake levels. Flooding may cause property damage and inundate septic drain fields, increasing hydraulic connectivity of a contamination source. Decreases in lake outflow may be increasing the accumulation of nutrients within the lake year after year as the lake acts as a net sink. We recommend designing and installing a beaver pond leveling device to minimize flooding and nutrient retention with a focus on co-existence.

Table 21. Recommended Plan Implementation Cost Summary.				
	Near-Term Actions (first 2 years)		Long-Term Actions (following 20 years)	
Plan Element	**Description**	**Cost (2024$)**	**Description**	**Cost (2024$)**
Sediment Incubation Study	Conduct a short-term study to determine sediment release rates and effectiveness of alum or lanthanum treatment.	$50K	No work recommended.	–
Lake Sediment Phosphorus Inactivation	A single long-term sediment inactivation dose or multiple doses.	$436K to $667K	Treatment longevity is expected to be at least 10 years. (assume one additional treatment).	$0.7M to $1.3M
Outlet Beaver Dam Management	Design and install a pond leveling device to decrease lake flooding and increase nutrient export.	$7K	Ongoing inspection and maintenance of leveling device ($1.5K per year).	$42K
Watershed Source Control Education/ Outreach (septic, shoreline, and land stewardship)	Leverage resources from LakeWise program from Snohomish County to encourage and install best management practices.	$0 (under lake management district and Skagit County staff)	Ongoing.	$0 (under lake management district and Skagit County staff)
Stormwater Retrofit Evaluation	Evaluate potential stormwater retrofit locations.	$50K	Implement high-value, multi-benefit stormwater retrofits. Costs may be accrued by WSDOT.	$1.0M
Monitoring and Reporting	Option A: Routine monitoring and reporting of lake water quality (base cost: $12K per year).	$24K	Option A.	$0.3M
	Option B: Routine monitoring and reporting of lake and stream water quality and hydrology. (base cost: $40.6K per year)	$82K	Option B.	$1.1M
Lake Management Administration	Finance and grant tracking. Adaptive management. Coordination with consultants and contractors. Implementation of management plan (base cost: $40K/year)	$80K	Finance and grant tracking. Adaptive management. Coordination with consultants and contractors. Implementation of management plan. (base cost: $20K/year).	$0.6M
	Total (first 3 years)	**$647K to $936K**	**Total (next 20 years)**	**$2.6M to $3.8M**

There is an assumed cost escalation of 3.5 percent each year in consideration of wage, utility, and material cost increases. If a loan is obtained to partially fund, additional loan management and interest costs should be considered.

Long-Term Management

Phosphorus Inactivation Treatment

Alum, lanthanum, or proprietary chemicals may be applied in lakes to inactivate phosphorus in the water column and the sediments. Appendix C provides detailed description of inactivation approaches and the development of cost estimates. Table 22 describes three types of phosphorus inactivation chemicals that are suitable for use in Lake Campbell.

Table 22. Comparison of Phosphorus Inactivation Chemicals.

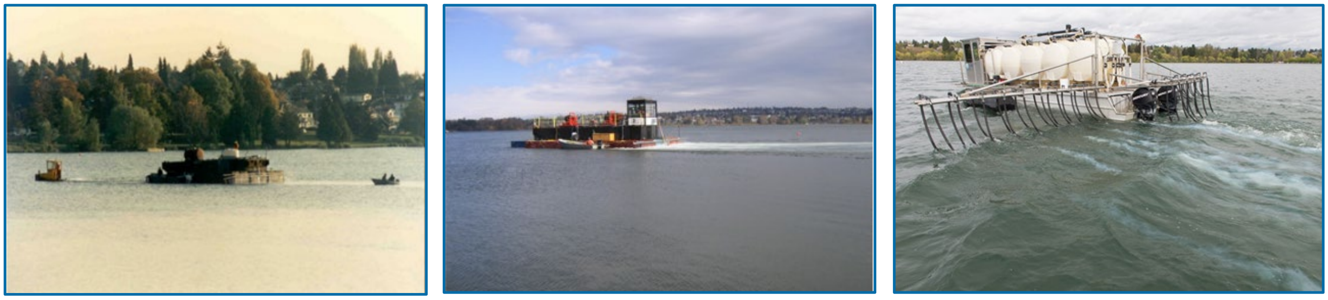
Water Column Inactivation Method	Alum	Lanthanum	Proprietary Blend
Commercial Products	Available from general chemical suppliers.	Phoslock EutroSORB G	MetaFloc EutroSORB WC
Mode of Inactivation	Forms stable complexes with dissolved phosphorus. Forms floccules that pull particulate phosphorus (i.e., algae and sediment from the water column. Stable at pH 6 to 9.	Forms stable complexes with dissolved phosphorus. Binding efficiency is highest between pH 5 and 7. Dissolution may occur at elevated pH levels (>9).	Form complexes with dissolved phosphorus. Most blends include a floccule agent that, like alum, will pull particulate phosphorus (i.e., algae and sediment) from the water column.
Application Approach	Applied at water surface and settled to the sediment. Alum is expected to sink and incorporate into the lake sediments.	Applied as lanthanum modified bentonite or as lanthanum salt across the waters surface. Expected to incorporate into the lake's sediments.	Applied at water surface and settled to the sediment.
Potential Negative Consequences	Aluminum toxicity to aquatic life may occur if inadequate buffer is applied and the pH is outside permitted range of 6 to 8.5. This can be prevented through rigorous planning and monitoring as required by the permit.	Lanthanum concentration immediately following application may exceed estimated toxicity thresholds, particularly for zooplankton, and little study has been done for impacts on benthic organisms. Generally, because lanthanum is applied in phosphorus-rich waters, the amount of free lanthanum ions is low as they bind to phosphate. Jar tests prior to application can be used to ensure proper dosage.	The specific make-up of the blends is proprietary. If alum and lanthanum blend, then the same potential impacts and toxicity prevention approaches.

Table 22 (continued). Comparison of Phosphorus Inactivation Chemicals.			
Water Column Inactivation Method	**Alum**	**Lanthanum**	**Proprietary Blend**
Permitting	Alum is an approved phosphorus inactivation chemical in the APAM permit.	Lanthanum is an approved phosphorus inactivation chemical in the APAM permit.	Ecology must be allowed to confirm that the chemicals in the product are already approved or an experimental application permit must be obtained.
Water Stripping Estimated Cost for 2025	$151,000 (unbuffered alum).	$143,000 (EutroSORB G) $245,000 (Phoslock) (note these will only strip *dissolved* phosphorus)	$156,000 (MetaFloc) $226,000 (EutroSORB WC)
Long-Term 20-Year Water Stripping Cost	$3.9 million.	$3.7 million (EutroSORB G) $5.8 million (PhosLock)	$4.0 million (MetaFloc) $5.4 million (EutroSORB WC)
Sediment Inactivation Estimated Cost for 2025	$436,000 (buffered alum).	$667,000 (EutroSORB G) $2,550,000 (Phoslock)	$906,000 (MetaFloc) $2,194,000 (EutroSORB WC)
Long-Term 20-Year Sediment Inactivation Cost (one to two treatments)	$0.4 to $1.1 million.	$0.7 to $1.6 million (EutroSORB G) $2.6 to $6.2 million (PhosLock)	$0.9 to $2.2 million (MetaFloc) $2.2 to $5.3 million (EutroSORB WC)
Recent Past Applications	Black Lake, Tumwater, Washington (2021) Waughop Lake, Lakewood, Washington (2020) Heart Lake, Anacortes, Washington (2018) Wapato Lake, Tacoma, Washington (2017) Green Lake, Seattle, Washington (2016).	Kitsap Lake, Bremerton, Washington (2020; [annually]) Lake Lorene, Federal Way, Washington (2012)	No published case studies or management plans.

Phosphorus inactivation can be conducted annually to strip phosphorus from the water column and settle it to the sediments, or larger treatments may be conducted to both remove phosphorus from the water column and inactivate sediment in the phosphorus (“sediment reset”). Figure 7 presents pictures of buffered alum treatments in Green Lake (Seattle) for sediment inactivation in 1991, 2004, and 2016.

Water column stripping with alum often does not need a buffer because of the low dose and acidity. Sediment inactivation with alum needs to use sodium aluminate as a buffer to the acidic alum (aluminum sulfate) in the soft waters of Lake Campbell, and unit product costs are higher than just alum for a stripping treatment because sodium aluminate is much more expensive than alum. Lanthanum products (EutroSORB G or Phoslock) are neutral and do not require a buffer for either water column stripping or higher doses for sediment inactivation.

Figure 7. Buffered Alum Treatments in 1991, 2004, and 2016 (left to right) for Sediment Phosphorus Inactivation in Green Lake, Seattle.



Between alum and lanthanum treatment, alum treatment is expected to provide the most immediate short-term relief from algae blooms. Alum forms flocculants that will pull algae and dissolved phosphorus from the water column, burying it in the sediments. This provides an immediate reduction in algae abundance and improvement in water clarity. Importantly, this increase in water clarity will benefit aquatic plants in the lake. Lanthanum does not form flocculants and will remove only dissolved phosphorus from the water column. Both alum and lanthanum will provide satisfactory sediment activation.

Over the long term, annual applications generally are expected to cost more than their respective sediment reset applications due to mobilization costs (Table 23). The longevity of sediment inactivation treatments is dependent on the control of external loading and stability of the bonds between the inactivation chemical and sediment phosphorus. Given the relatively low watershed phosphorus loading to Lake Campbell and the longevity of the past treatment, a long-term sediment inactivation treatment is likely to last approximately 10 to 20 years at a cost of approximately $0.4 to $1.6 million for one to two treatments in a 20-year period, assuming using buffered alum or EutroSORB G.

To inform the treatment, we recommend conducting a sediment incubation study to evaluate the effectiveness of alum (or lanthanum) treatment at varying pH and oxygen conditions. This study can be used to confirm the internal load estimates described previously and to ensure the proper dosing of alum (or lanthanum) to reduce or altogether prevent sediment release.

Table 23. Estimated Long-Term Cost of Phosphorus Inactivation Through Water Stripping or Sediment Inactivation.

Phosphorus Inactivation Chemical	Annual Water Stripping (20 years)	Single Sediment Inactivation Treatment (20-year longevity)	Two Sediment Inactivation Treatments (10-year longevity)
Buffered Alum	–	$436,000	$1,050,000
Unbuffered Alum	$3,890,000	–	–
PhosLock	$5,840,000	$2,550,000	$6,150,000
EutroSORB G	$3,720,000	$670,000	$1,610,000
MetaFloc	$3,980,000	$910,000	$2,180,000
EutroSORB WC	$5,430,000	$2,190,000	$5,290,000

Beaver Management at the Lake Outlet

Beaver dams play important ecological roles in shaping freshwater ecosystems. Beaver activity may conflict with human interests in some locations. Their presence at the outlet of a lake, such as Lake Campbell, can have significant implications for water quality, particularly in terms of phosphorus accumulation and algae blooms. The presence of a beaver dam at the lake's outlet may have the following impacts:

- Reduction of lake surface outflow and increase in lake level.
- Potential increase of subsurface water (groundwater) level around the lake increasing hydraulic connectivity from septic system drain fields (if present).
- Increase in lake nutrient retention due to decrease in lake outflow.
- Flooding of the nearshore of the lake.
- Downstream flooding impacts in the case of dam failure

Beavers provide ecological benefits by storing water and creating unique wetland habitats. Stored water may filter down into the water table and recharge groundwater. This stored water can also support summer stream flows, preventing streams from going dry. Beaver ponds are habitat for many insect, bird, amphibian, mammal, and fish species.

We recommend a beaver management approach that focuses on coexistence while minimizing flood risk and nutrient retention. We recommend installing a pond leveler at the lake's outlet. Pond levelers are used to control the height of water behind a beaver dam to prevent flooding (King County 2017). Levelers are designed to transport water through a dam in such a way that the beaver does not detect the flow of water through the dam and therefore does not instinctively do all it can to block the flow. Flows from storm events flow over the top of the dam, so the pipes do not need to be sized like road culverts, and after the storm, water levels return to normal via the pond leveler. Some pond levelers have been trademarked. Pond levelers are generally installed in ponded locations where water depth is sufficient to submerge the upstream end of the pipe along the pond bottom beyond the depth of most normal beaver activity (Figure 8). High-level cost estimates associated with installing a beaver pond leveler are presented below in Table 24.

Figure 8. Schematic of a Flexible Pond Leveler™.

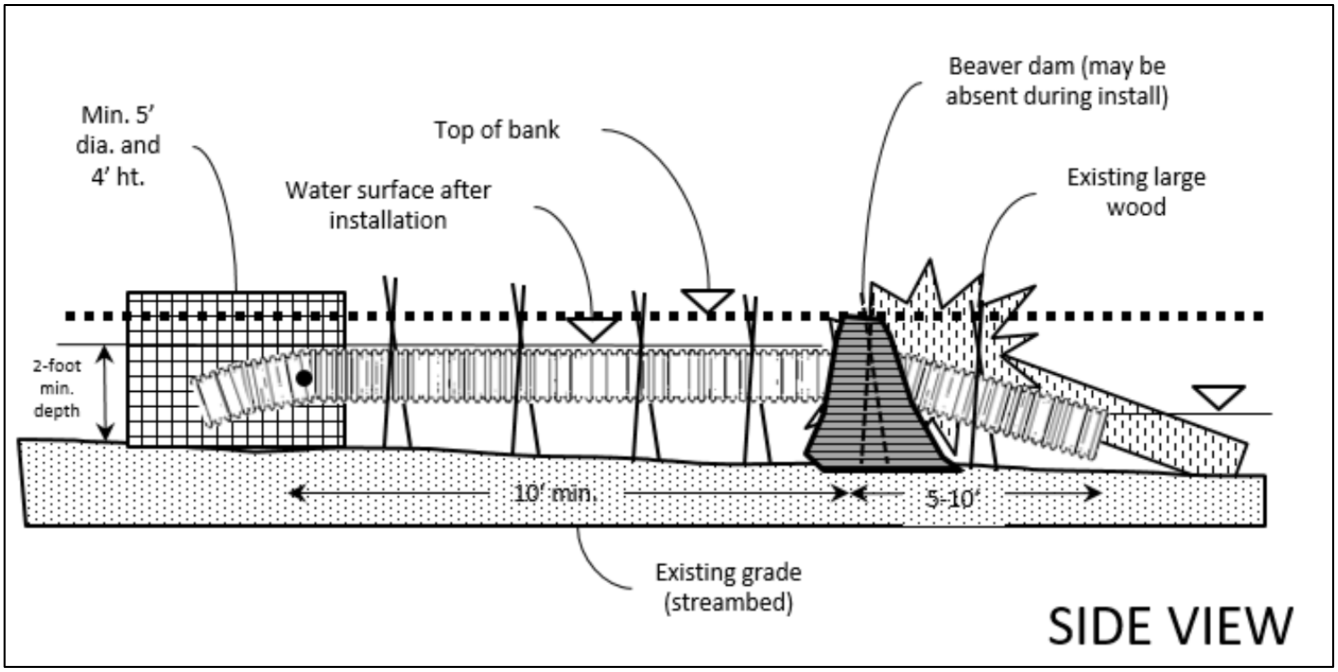


Table 24. Beaver Pond Leveler Cost Estimates.		
Action	**Level of Effort**	**Estimated Cost**
Determine desired lake level that will be acceptable for both lake management and beaver use. Consult with beaver management experts (e.g., Beavers NW)	Consultation fee of $2,000 and 5 hours of County Engineer time.	$2,750
Attain necessary permits (e.g., Hydraulic Project Approval)	5 hours of County Engineer time (assume at $150/hour, burdened).	$750
Installation of Pond Leveler	Material plus installation and three follow-up visits (King County 2022).	$1,600 to $2,400
Fencing of Trees and Shrubs	$10 to $20 per tree for material. Assume 50 trees and 16 hours of junior staff time ($75/hour, burdened).	$1,700 to $2,200
	Initial Cost	**$6,800 to $8,100**
Ongoing Maintenance	Assume fencing 10 trees per year and 16 hours of junior staff time.	**$1,300 to $1,400**

County engineer staff hourly rate assumed at $150 per hour, fully burdened. Junior county staff hourly rate assumed at $75 per hour, fully burdened.

Watershed Source Control

A key long-term pathway to preventing cyanobacteria blooms is to decrease the loading of nutrients to the lake from the watershed. This involves both source control and treatment. Source control is the removal or mitigation of a source, such as reducing phosphorus fertilizer use, installing livestock exclusion fencing along a stream, and fixing failing septic systems. Treatment is the reduction of a nutrient through built and natural infrastructure, such as infiltrating stormwater using low-impact design (LID), filtering stormwater with phosphorus-adsorbing media, or installing vegetative buffers along waterways.

Onsite Septic System Stewardship and Management

We recommend taking actions to identify existing septic systems that may be contributing disproportionate loads of phosphorus to Lake Campbell. These include failing systems that are no longer functioning per their initial design and systems that do not have adequate local conditions to remove phosphorus. Systems that appear to be working can still be contributing phosphorus loading to the lake. Failing systems may be identified via operation and maintenance inspections by certified professionals. Important factors for improperly sited systems and drain fields include distance to a nearby lake or stream, depth to the water table, and soil chemistry.

We recommend encouraging septic system owners throughout the watershed to complete routine inspections, as required by state law. Additionally, we recommend evaluating higher risk systems that are located around the lake or along streams to evaluate if adequate treatment is provided. In locations where the systems are not adequate, advanced treatment systems may be necessary. For instance, membrane bioreactor systems treat wastewater before discharge to the drain field and therefore do not necessitate the full drain field treatment area. The installation of such technology must be permitted by Skagit County Health Department, per WAC 246-272A. We recommend coordination with Skagit County Health Department and the Washington State Department of Health, to develop a pathway for upgrading septic systems that do not have adequate drain field areas or soil treatment.

Replacing septic systems can be very expensive (up to $20,000 to $40,000), depending on the location and installation constraints. However, there are numerous grants and low-interest loans available that may ease the upfront investment. This includes Craft3 Clean Water Loans, a low-interest loan program.

Stormwater Management

Stormwater runoff can also be an important pathway of nutrients to surface water and groundwater. Fertilized areas, domestic animals, wildlife, and erosion of soils and organic matter contribute phosphorus to stormwater runoff. Stormwater management seeks to treat or infiltrate runoff from impervious and pollutant-generating surfaces prior to discharge to lake. External phosphorus reductions may be achieved through source control and stormwater treatment. Source control can include reduction in phosphorus-containing fertilizer use, identification and removal of illicit sewage connections, pet waste management, and erosion control. Stormwater treatment can include detention facilities, rain gardens, and regional treatment facilities. Stormwater management that reduces peak flows entering streams will also reduce streambank erosion. Lake management plans can be used to declare a lake as sensitive to phosphorus inputs and require new developments to install stormwater treatment systems that are designed to remove phosphorus not just suspended solids.

We recommend that a stormwater treatment and retrofit evaluation be completed in partnership with the County and Washington State Department of Transportation. The first step of such an effort would be to identify opportunity locations for stormwater treatment or retrofit based on existing infrastructure, land use/land cover, property ownership, and water quality data. This step includes identifying 5 to 10 opportunity locations and preparing high-level concepts and cost estimates. This first step is estimated to cost $20,000 to $30,000 but is variable with the number of opportunity locations and complexity of sites. Following this initial identification, the second step would be to conduct field verification and develop detailed conceptual designs for a shortlist of the locations. Assuming five to six sites are on this shortlist, this second step is estimated to cost $20,000 to $25,000, again scaling with the number of sites and their complexity. Overall, $50,000 should be budgeted for this initial planning effort over the next few years.

The cost of final design and installation for stormwater treatment and retrofit vary significantly based on the selected treatment approach and site conditions. Approximately $1M should be budgeted over 20 years in anticipation for design and installation of 5 to 10 small phosphorus treatment systems composed of bioretention systems or media filters with phosphorus retention media.

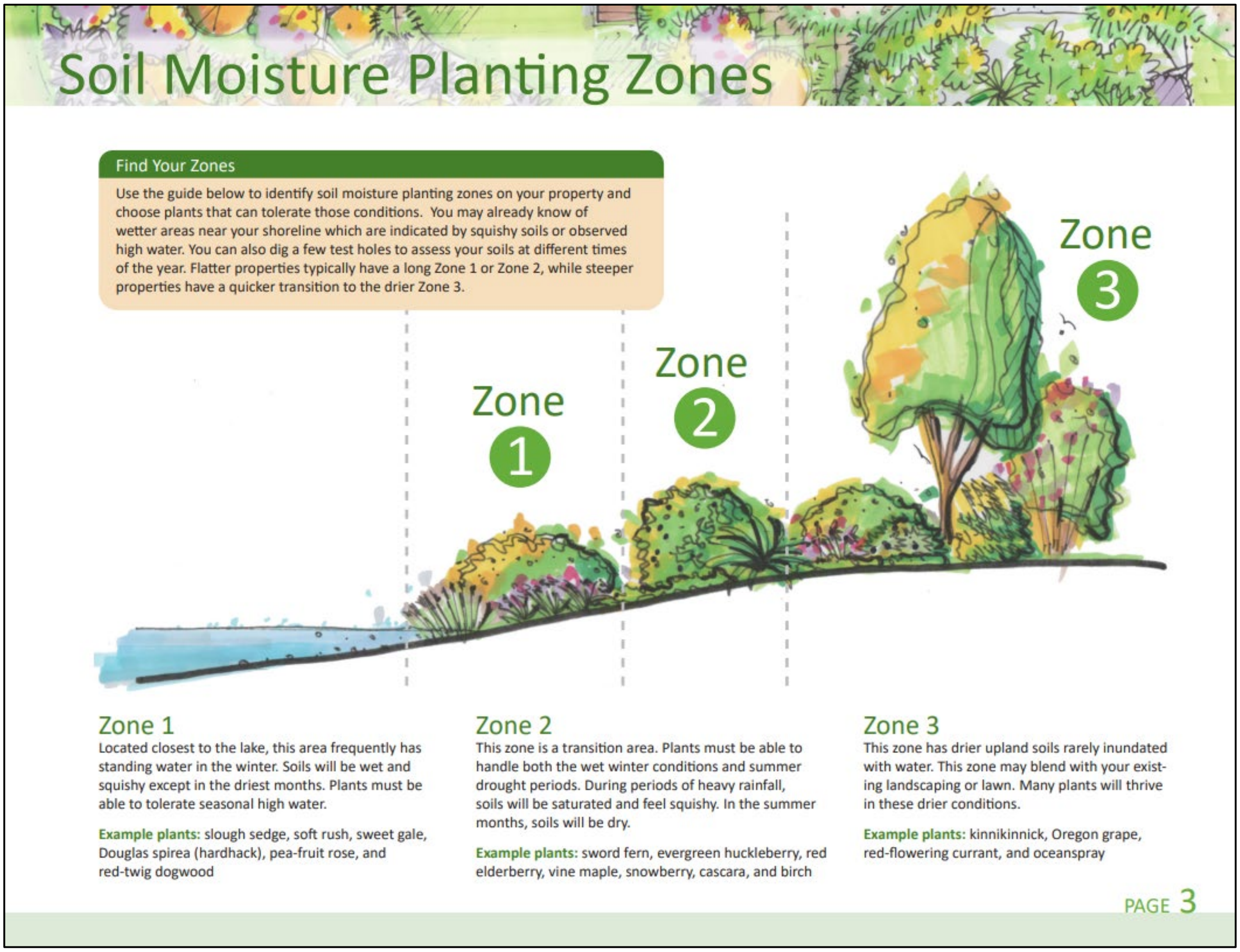
Shoreline and Waterfowl Management

Plants that grow in and along lake shorelines have an important role in protecting water quality and providing habitat aquatic organisms. Rooted plants can prevent shoreline erosion through their root systems, and in-water plants can reduce soil erosion and sediment suspension by dampening energy from waves. Shoreline plants can absorb and slow runoff from upslope, removing nutrients. They are also important for fostering native insects that are food for fish and birds. Over the years, people altered the lakeshore by removing trees and dead wood from the shorelines and by building bulkheads. Concrete or rock wall bulkheads negatively impact fish and wildlife habitat. They can accelerate erosion of shallow lake sediments by increasing wave energy, which can fuel cyanobacteria growth by suspending sediment nutrients.

Developing a healthy shoreline program to promote and fund replacement of bulkheads and lawns with native plants is a recommended management action to reduce nutrient inputs and cyanobacteria growth in Lake Campbell. A healthy shoreline program should be developed for Lake Campbell to encourage and provide resources to lake residents. This program should be modelled after Snohomish County’s LakeWise program (Snohomish County 2023) and can share many of those resources. Figure 9 presents an example of a healthy shoreline program resource.

While waterfowl were only a minor contributor of phosphorus to the lake, waterfowl management should be implemented to reduce phosphorus loading from the deposition of fecal matter in the lake and nearshore area. This will reduce both phosphorus loading and potential pathogens related to waterfowl feces. Management can include posting “do not feed” signs at public access points and educating lake community members. Shoreline planting can also be done to discourage waterfowl use, who prefer grassy nearshore areas with few shrubs.

Figure 9. Snohomish County LakeWise Shoreline Planting Guide Excerpt.



Future Monitoring and Adaptive Management

To further the long-term water quality and lake use goals for Lake Campbell, this plan includes the following adaptive lake management framework to regularly reassess and amend LCMP strategies or goals as part of ongoing, adaptive lake management, pursuant to future lake needs, stakeholder values, and funding. This section describes (1) the decision-making process and adaptation framework by which the LCMP shall be modified, (2) current knowledge gaps and the recommended monitoring plan for continued effectiveness evaluation, and (3) potential future LCMP adaptations to begin considering.

Framework and Procedures

Adaptive management is a structured process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. This form of management can improve clarity about key plan elements and focus decision-makers' attention on the *what, why*, and *how* of action implementation, and emphasizes accountability and explicitness in decision making (Williams et al. 2009). This is particularly important for resource management, which often entails multiple management objectives, constrained authorities and abilities, dynamic resource systems, and uncertainty in the responses to management actions. According to the Technical Guide for Adaptive Management Plans by the U.S. Department of the Interior (Williams et al. 2009), activities comprising this structural decision-making approach should include:

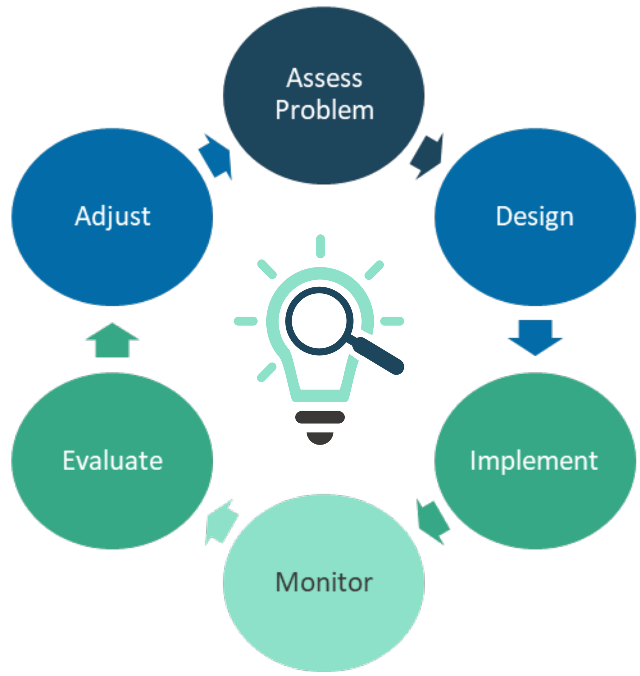
- Engaging stakeholders in the decision-making process
- Identifying the problem(s) to be addressed
- Specifying the objectives and tradeoffs that capture stakeholder values
- Characterizing assumptions about resource structures and functions
- Predicting the consequences of alternative actions
- Identifying key uncertainties
- Measuring risk tolerance for potential consequences of decisions
- Anticipating future impacts of present decisions
- Accounting for legal guidelines and constraints

Under the framework of the existing Lake Management District, this LCMP recommends Skagit County, with consultation from the LMD Advisory Committee, to continue management of a formal, science-based adaptive management program. This adaptive management program shall provide science-based recommendations and technical information to assist in the determination of *if* and *when* it is necessary or advisable to adjust the goals, objectives, management actions, and/or measures of evaluation set forth in previous versions of the LCMP. Additional LCMP adaptive management participants may include those staff members defined by the County or Board, independent reviewers, and policy makers.

The following generalized procedure may be used for LCMP adaptive management and decision making (see inset graphic):

Assessing the Problem

The County, Advisory Committee, and other stakeholders shall provide observations of the system function and identify issues.



Adaptive Management Cycle. Adapted from Williams et al. (2009)

Designing a Solution

The County manager, with consultation from the Advisory Committee, should establish key questions, and define and prioritize resource objectives. Lake resource objectives may consist of functional objectives, which are broad statements regarding potentially affected major functions, and performance targets, which are measurable criteria defining specific and attainable conditions and processes.

Implementation

Adaptive management proposals should be submitted to the County manager by the Advisory Committee and/or other relevant participants, or by the general public at public/board meetings. Proposals should demonstrate how future impacts will address key questions and lake resource objectives/issues. Proposal approval and prioritization will be determined by the County. Approved projects are then implemented and/or delegated at the County's discretion.

Monitoring

Monitoring is a key component of adaptive management. A basic monitoring program at Lake Campbell should be conducted by trained staff and/or volunteers and should consist of the minimum elements described in the following section. Independent scientific review may be conducted at identified points of implementation, pursuant to study goals, County/Board direction, and/or funding resources.

Effectiveness Evaluation

Using monitoring data and observations, project performance and management effectiveness will be evaluated. An evaluation report should outline recommended actions, data gaps, and next steps for County and Advisory Committee review. Relevant reports or petitions for rulemaking shall be shared with the public.

Adjust

Based on the recommendations established in the evaluation report and those provided by technical advisors, and the values of the community and general public, the County is responsible for all final decisions regarding LCMP adaptations/adjustments.

Measurable Management Objectives

We acknowledge there is inherent uncertainty to the success of the recommended management actions. Therefore, it is critical to set measurable objectives, maintain monitoring of those objectives, and adjust the management plan if those objectives are not being met.

For each recommended management activity, we recommend the following measurable objectives and adaptive management actions for when objectives are not met (Table 25).

Table 25. Measurable Management Objectives.

Activity	Objective	Potential Adaptive Management Action
Sediment Phosphorus Inactivation	Reduce summertime phosphorus available for algae to average concentrations less than 24 µg/L in the water column.	Continue lake monitoring to track effectiveness of inactivation. Adjust dosage or chemical used.
Beaver Management at Lake Outlet	Maintain desirable lake level (to be defined).	Adjust the elevation of the leveler inlet. Consider relocation and dam removal if coexistence is not possible.
Beach Cyanotoxin Monitoring	Cyanotoxin samples are collected when a bloom is present and additional samples are collected following state protocol. Warning signs should be posted when there is an exceedance of state recreational and removed after 2 weeks without an exceedance. Beach closures should occur no more than twice in a 5-year period, lasting no longer than 3 weeks.	If weekly samples are not collected or immediate public notification of exceedances is not completed, audit program to understand challenges. If beach closure objective is not achieved, re-evaluate cause(s) of cyanobacteria blooms in consideration of changes in internal and external loads resulting from management actions.
OSS Management	To be determined by Skagit County Health Department.	Survey OSS owners to understand barriers to inspection, repair, and upgrade. Secure additional funding, if needed. Evaluate enforcement-based approach.
Shoreline and Waterfowl Management	Adoption of shoreline and landscaping management practices by at least 50% of private residences along the lake perimeter. Appropriate signage at boat lunch discouraging waterfowl feeding.	Survey property owners to understand barriers to adopting management practices. Secure additional funding, if needed.
Stormwater Management	Maintain or reduce stormwater phosphorus loading to Lake Campbell.	Evaluate effectiveness of retrofit projects. Secure additional funding for future retrofits if needed.

Data Gaps

Data gaps identified for the characterization of water quality in Lake Campbell (see Appendix A), which can be considered to inform cyanobacteria and adaptive lake management, include:

- Comprehensive and consistent lake water quality data (including chemistry, biology, and physical data). Specifically:
  - Temperature, DO, conductivity, and pH measurements throughout the water column on a monthly basis from April through October.
  - Chlorophyll-a and total phosphorus from the lake surface and bottom on a monthly basis during summer months.
  - Orthophosphate, total nitrogen, ammonia nitrogen, and nitrate + nitrite nitrogen from the lake surface every second month during the summer months.
  - Regular phytoplankton and zooplankton taxonomic composition and biovolume, at least every second month.
  - Continuous lake level.
- Comprehensive and consistent inlet and outlet water quality data (including chemistry and physical data). Specifically:
  - pH, conductivity, temperature, DO, and total phosphorus on at least 6 occasions per year at three inlets and one outlet location.
  - Analysis of orthophosphate, total phosphorus, nitrate + nitrite nitrogen, and total nitrogen fractions in the inlet samples
  - Year-round monthly discharge and/or continuous flow measurements
  - Continuous lake outlet stream level and elevation measurements (including beaver dam location and elevational data, as necessary).
- Enhanced cyanotoxin monitoring and analysis. Specifically:
  - Cyanotoxin analysis regularly throughout the year, unrestricted to reported scum or bloom samples.
  - Occasional observation and sampling for benthic cyanobacteria species.
  - Long-term comparative analysis of cyanotoxin concentrations and cyanobacteria compositions.
- Regular sediment phosphorus and iron characterizations.
- Groundwater flow and nutrient characterizations.
- Assessment of septic contributions to nutrient inputs.
- Annual reporting of aquatic plant surveys and management effectiveness.
- Long-term and/or year-round waterfowl, lake usage, and fish harvest data.

Additional discussion and water quality data details are presented in Appendix A.

Recommended Monitoring

No matter the management objectives or management strategy employed, ongoing monitoring is necessary to evaluate success and allow adaptive management. The adaptive management approach for Lake Campbell includes short-term and long-term monitoring. Short-term monitoring is focused on key data gaps and will provide the information needed to confirm and refine the selected measures and develop more accurate cost estimates. Long-term monitoring will provide the information needed to evaluate progress toward achieving management goals and to adjust or augment the lake management measures.

The sediment incubation study (see the Phosphorus Inactivation Treatment section above) is identified as a short-term monitoring project to confirm the internal load estimates described previously and to ensure the proper dosing of alum (or lanthanum) to reduce or altogether prevent sediment release. Long-term monitoring will provide the information needed to evaluate progress toward achieving management goals and to adjust or augment the lake management measures. As outlined in Table 27 in the Funding Strategy section that follows, we recommend developing a monitoring plan that builds on current water quality data to include:

- A sediment incubation study
- Continued, routine lake monitoring for both Lake Erie and Lake Campbell
- Enhanced cyanobacteria bloom and fecal bacteria surveillance
- Regular lake inlet (CS1 and CS3) and outlet monitoring
- Regular sediment nutrient monitoring

We recommend developing a monitoring plan and identified two options (Table 26). At bare minimum this should include summertime lake trophic state monitoring, which includes monthly sampling for chlorophyll-a, total phosphorus, and Secchi depth, estimated at approximately $12,000 per year (Option A). We also present Option B, which includes expanded monitoring to better inform ongoing adaptive management decisions and effectiveness of in-lake and watershed management actions. Option B includes additional lake sampling events and parameters, lake inlet sampling, and sediment sampling every 5 years, costing an estimated $40,600 per year. The estimated costs include field work, laboratory analysis, data management, and reporting.

Table 26. Future Monitoring and Adaptive Management.			
OPTION A: ROUTINE LAKE MONITORING			
Monitoring Component	**Description**	**Reporting/Activity**	**Estimated Additional Cost**
Lake Water Quality	Establish a monthly summertime monitoring program: Surface (1 meter) and deep (1 meter above bottom) water quality grab samples analyzed monthly for pH, chlorophyll-a, and total and phosphorus.	Annual reporting on monitoring activities, water quality, evaluating trends, emerging issues, and recommendations.	$6,000 per year for routine Volunteer Lake Monitoring Program Assumes lake monitoring is performed by volunteers. Assumes three phytoplankton samples per year.
Lake Level	Re-install Skagit County lake level gauge and continue monitoring.	Include lake level summary and trend evaluation in annual report.	$0
Data QA and Management	Input laboratory and field data into database, perform data QA/QC.	Qualify data and modify procedures as necessary. Include QA results in annual report.	$375 per year Assumes 5 hours staff time at $75/year.
Annual Reporting	Summary of Monitoring Data, Management Effectiveness (if applicable), and Adaptive Management Recommendations.	–	$3,000 per year Assumes 40 extra hours staff time per year at $75/year.
Project Management	Coordination	–	$900 per year Assumes 12 hours staff time per year at $75/year.
		Subtotal Cost	$10,275
		Contingency at 20%	$2,055
		OPTION A AVERAGE ANNUAL COST	**$12,330**
OPTION B: COMPREHENSIVE LAKE AND WATERSHED MONITORING			
Monitoring Component	**Description**	**Reporting/Activity**	**Estimated Additional Cost**
Lake Water Quality	Establish a twice monthly summertime monitoring program: Surface (1 meter) and deep (1 meter above bottom) water quality grab samples analyzed monthly for pH, chlorophyll-a, and total and dissolved phosphorus and nitrogen. At least three samples per year analyzed for phytoplankton species biovolume.	Annual reporting on monitoring activities, water quality, evaluating trends, emerging issues, and recommendations.	$12,000 per year for routine Volunteer Lake Monitoring Program Assumes lake monitoring is performed by volunteers. Assumes three phytoplankton samples per year.
Lake Level	Re-install Skagit County lake level gauge and continue monitoring.	Include lake level summary and trend evaluation in annual report.	$0
Recreational Safety	Weekly monitoring (Memorial Day to Labor Day) at the WDFW boat launch for algae bloom observation and *E. coli* fecal bacteria testing.	Compare results to state recreation criteria to issue lake advisories. Include data summary and trend evaluation in annual report.	$2,800 per year Assumes 14 *E. coli* samples at $50 each by lab and 2 hours staff time per event at $75/hour for 14 events.
Surveillance for Cyanobacteria Blooms	Expand existing surveillance program for identifying and sampling cyanobacteria blooms to year-round to encompass potential late season and wintertime algae blooms.	If a bloom is observed, contact Skagit County Public Health and collect a sample to analyze through the Northwest Toxic Algae Program or King County Laboratory if outside program period. Compare results to state recreation criteria to issue lake advisories. Include activities, advisory decisions, and results (including non-detects) in annual report.	$2,000 per year Assumes 5 cyanotoxin sample analyses/year by King County at $175/sample Assumes 16 hours staff time/year at $75/hour.
Sediment Monitoring	Collect 2 sediment cores every 5 years for phosphorus fractionation, iron, and bulk density analysis in 5 sediment layers each. Collect additional cores pre-/post- phosphorus inactivation treatments as necessary.	Evaluate trends in concentrations and annual loads, assess for efficacy and/or dosage of phosphorus inactivation treatments, if applicable, and provide recommendations in reports.	$2,100 per year (20-year average) Assumes lab cost = $3,000 per event, every 5 years Assumes 50 hours consultant staff time per event at $150/hour.
Inlet/Outlet Monitoring	Monitor two inlets (CS1 and CS3) and lake outlet (CAM-OUT) for 6 events/year, including total phosphorus and total nitrogen analysis and discharge measurements.	Evaluate annual nutrient input and export, and long-term trends.	$7,290 per year (20-year average) Assumes 18 TP samples/year at $35/sample lab cost and 18 TN samples/year at $70 lab cost. Assumes 6 hours/event and 36 hours/year staff time at $75/hour.

Table 26 (continued). Future Monitoring and Adaptive Management.			
OPTION B: COMPREHENSIVE LAKE AND WATERSHED MONITORING (continued)			
Data QA and Management	Input laboratory and field data into database, perform data QA/QC.	Qualify data and modify procedures as necessary. Include QA results in annual report.	$750 per year Assumes 10 hours staff time at $75/year.
Annual Reporting	Summary of Monitoring Data, Management Effectiveness (if applicable), and Adaptive Management Recommendations	–	$6,000 per year Assumes 80 extra hours staff time per year at $75/year
Project Management	Coordination	–	$900 per year Assumes 12 hours staff time per year at $75/year.
		Subtotal Cost	$33,840
		Contingency at 20%	$6,768
		OPTION B AVERAGE ANNUAL COST	**$40,608**

Funding Strategy

The recommended set of management strategies is estimated to cost approximately $647 to $936 thousand in the first 2 years and about $2.6 to $3.8 million over the following 20 years.

Algae management is not currently financed under the LMD No. 3 annual assessments, nor can the funds raised under such assessments be re-allocated to algae management. Therefore, we further recommend LMD No. 3 acquire supplemental funds for the additional purposes of algae control, water quality improvement, and further monitoring through, for example, (1) an amended special assessment roll to property owners (pursuant to Revised Code of Washington [RCW] 36.61 and district resolutions) which raises rates, and/or (2) expand the district boundaries to include additional upland properties within the watershed(s).

Rate amendments (i.e., to increase or otherwise modify the amount to be financed) and district boundary updates are made using the same procedure in which a lake or beach management district is created. The process may include but is not limited to (1) an amendment to the resolution of intention on how assessment funds will be used, (2) a public hearing hosted by the County, and (3) landowner approvals consistent with the procedures established in RCW 36.61. Therefore, community engagement is a crucial consideration to garner sufficient landowner support for passing any proposed amendments.

Additional funding sources will be necessary to implement the recommend elements of this plan. A combination of budget allocations, grants, and/or loans should be sought to fund and implement this management plan. We recommend considering the sources provided in Table 27. Additional supplementary grants and programs that may provide limited or specialized benefit are summarized in Appendix E.

Table 27. Funding Sources for Lake Management Actions.

Funding Source	Description	Applicable Activities
Lake Management District No. 3 Dues	Lake Management District funds may be used to partially fund implementation of this LCMP, if a proposed amendment to intention of fund uses is approved. Renewal of the LMD with inflation-adjusted fee structure is recommended when required to provide ongoing funding as well as continue to serve as a lead decision-making entity (see the Roles and Responsibilities section).	Outreach and Education
Establish a Water-Quality-Focused LMD District	Establish a second LMD that focuses on water quality. This LMD can include additional members in the lake's watershed, including WDFW and WSDOT, City of Anacortes	Water Quality Monitoring Watershed Management Onsite Septic Repair and Replacement In-Lake Management Outreach and Education

Table 27 (continued). Funding Sources for Lake Management Actions.		
Funding Source	**Description**	**Applicable Activities**
Skagit County Public Works Funds	The Surface Water Management Division (SWM) works to address local and regional drainage concerns, provides stormwater management, flood awareness resources, and landslide awareness resources. SWM is funded in part through a per parcel utility program special assessment for unincorporated Skagit County properties. Presently, SWM covers the administrative costs of the LMD, including staff time for project management and community coordination. SWM has supported development of the Lake Cyanobacteria Management Plan and conducted the hydrologic and water quality monitoring of lake inlets and the lake outlet. Additional funding may be allocated through or other capital facilities planning, as approved by the Skagit County Council.	Water Quality Monitoring Watershed Management Onsite Septic Repair and Replacement In-Lake Management Outreach and Education
Legislative Budget Allocations	The Washington State Legislature has previously allocated funding for management of various lakes in Washington, through approved state budgets (e.g., Spanaway Lake, Vancouver Lake). Pursuant to appropriation purpose, these funds could be used for managing nuisance aquatic vegetation, conducting water quality monitoring, refining nutrient loading estimates, developing this management plan, securing permits, and implementing management strategies.	Water Quality Monitoring Watershed Management Onsite Septic Repair and Replacement In-Lake Management Outreach and Education
Freshwater Algae Control Grants	The Washington State Freshwater Algae Program has an annual funding cycle for projects to manage toxic algae (cyanobacteria) blooms. The grant funds up to $50,000 and requires a 25% in-kind match. In-lake treatments, such as alum or lanthanum, *are* eligible for this grant, provided the waterbody has an approved Lake Cyanobacteria Management Plan.	Water Quality Monitoring Watershed Management Onsite Septic Repair and Replacement In-Lake Management Outreach and Education
Clean Water State Revolving Fund Loans	The Clean Water State Revolving Fund Loans (CWSRF) program is funded via an annual U.S. Environmental Protection Agency (EPA) capitalization grant, state matching funds, and principal and interest repayments on past CWSRF loans. This program provides low-interest and forgivable principal loan funding for wastewater treatment construction projects, eligible nonpoint source pollution control projects, and eligible green projects. In-lake treatments, such as phosphorus inactivation and oxygenation, *are* eligible for these loans.	Water Quality Monitoring Watershed Management Onsite Septic Repair and Replacement In-Lake Treatments (if lake is publicly accessible) Outreach and Education
Centennial Clean Water Grants	The Centennial Clean Water Fund is a Washington State-funded grant program administered by Ecology. Local governments, special purpose districts, conservation districts, and federally recognized Tribes are eligible for these funds applicable to water quality infrastructure (e.g., wastewater treatment facilities) and nonpoint source pollution projects to improve and protect water quality. In-lake treatments, including phosphorus inactivation and oxygenation are not eligible for these grants.	Water Quality Monitoring Watershed Management Onsite Septic Repair and Replacement Outreach and Education

Table 27 (continued). Funding Sources for Lake Management Actions.		
Funding Source	**Description**	**Applicable Activities**
Section 319(h) Clean Water	EPA provides "Section 319(h)" grant funds to Washington State where the State is required to provide a 40% match in funding. The Section 319(h) program provides grants to eligible nonpoint source pollution control projects, similar to the state Centennial Clean Water Fund. Eligible projects include lake water quality planning, riparian and wetlands habitat restoration and enhancement, and other water quality improvement efforts. Non-profit organizations are also eligible for these funds. A 25% match is required, and grants may be limited to $250,000 or $500,000, depending on the match type. In-lake treatments, including phosphorus inactivation and oxygenation are not eligible for these grants.	Water Quality Monitoring Watershed Management Onsite Septic Repair and replacement Outreach and Education
Onsite Sewage Financial Assistance Loans (Craft3)	Ecology funding for a regional loan program to support the origination and servicing of loans to property owners for the repair and replacement of failing onsite sewage systems (OSS) throughout the marine (Puget Sound and coastal) counties. Ecology also contracted with local lender Craft3, a non-profit Community Development Financial Institution (CDFI), to originate and service loans for the Regional Onsite Sewage System Program. The program may provide lending measures to repair/replace failing OSS.	Onsite Septic Repair and Replacement

Roles and Responsibilities

Projects and partnerships succeed when participants share a common understanding of roles and responsibilities. It is important to establish clarity regarding those roles, responsibilities, and expectations for each participating entity at the outset, to ensure the best chance at achieving the project's vision, mission, goals, and objectives. When roles and responsibilities are clearly defined, productivity, respect, communication, value for individual contributions, and shared ownership for success is enhanced throughout the team.

Lake Management District No. 3 was formed in 2001 to control nuisance and invasive aquatic vegetation in both Lake Erie and Lake Campbell, working with Skagit County Public Works Surface Water Management. As the current lead entity for representing concerns of lake residents and users with the goal of advocating for the health of Lake Campbell, the LMD provides community leadership and initiative. Authorized through 2030, we recommend the continued renewal of the LMD to act as a lead entity for decision making and fund raising in partnership with Skagit County, in the implementation of this plan and development of an ongoing, adaptive management plan. This may require amending the LMD resolution of intention(s), boundaries, and/or assessment rate structure to allow for expanded lake management goals (i.e., in addition to current aquatic plant management goal).

Example Updated Lake Management District No. 3 Goal:

"Work with the users of Lakes Erie and Campbell to monitor and improve water quality, control nuisance and invasive aquatic plants, reduce toxic algae blooms, and restore habitat to promote a healthy ecosystem and safe recreation for all."

The relevant entities to fulfill the required roles and responsibilities of organizing, governing, and executing the decisions of this LMD, as the lake management structure and primary mechanism for decision making, funding acquisition, and implementation of management activities for Lake Campbell, have been defined below in Table 28.

Table 28. Potential Role and Responsibilities.

Agency/Group	Role	Responsibilities
Lake Management District No. 3	Lead Entity	Raise funds annually through the LMD assessment on properties with shoreline access Identify and apply for grants and funding partnerships
Skagit County Department of Public Works,Surface Water Management	LMD Administration Stormwater Management and Retrofit Evaluation Watershed Monitoring Data Management	Operates, manages and administers the Lake Management District Lake Campbell monitoring program leadership, coordination, reporting; including toxic algae monitoring program Stormwater and lake inlet monitoring Weekly beach monitoring in the summer Lead for loan application through CWSRF Procure and manage contracts for lake improvement services Lead permitting processes and NPDES APAM permit administration Provide supplemental funding through utility fees Maintenance of existing stormwater infrastructure Revise stormwater code to require phosphorus treatment Retrofit of existing stormwater infrastructure
Washington Department of Transportation	Stormwater Retrofit Evaluation	Maintenance of existing stormwater infrastructure Retrofit of existing stormwater infrastructure
Skagit County Health Department	Management and Monitoring Support	Implementation of OSS O&M Program Toxic algae testing and communication of public health advisories.
Lake Management District No. 3 Community Advisory Board	Aid in Operation and Management of the District	Annually identify lake maintenance issues and recommend management measures Recommend annual appropriation of LMD assessment funds Review and comment on the proposed annual workplan Assist in outreach and engagement to LMD landowners
Community Members and Lake Residents	Monitoring Support and Community Engagement	Assists Skagit County in lake monitoring and surveillance for toxic algae bloom Outreach to elected officials to seek budget allocations through Skagit County Council and Washington State Legislature Outreach and engagement to advertise lake and septic system stewardship

Community Involvement and Public Support

Public stakeholders include lakeshore homeowners and other Lake Campbell community members who recreate on the lake. This community is engaged in lake activities, which are orchestrated through LMD 3 as the primary organization for lake management and community engagement.

Government stakeholders include:

- Skagit County, which directs and funds the development and implementation of this LCMP, and provides regulatory oversight, guidance, and monitoring leadership and coordination.
- City of Anacortes, which owns and operates land within the Lake Campbell watershed.
- Washington State Parks and Recreation Commission, which owns and operates land within the Lake Campbell watershed.
- Washington Department of Fish and Wildlife, which maintains the public boat launch.
- Washington State Department of Ecology, which provided a grant to prepare this LCMP and supports toxic cyanobacteria monitoring of the lake through the Washington State Toxic Algae Program

For this LCMP, four community meetings were held on the following occasions:

- Stakeholder kickoff and QAPP meeting on August 8, 2023.
- Monitoring training and site visit meeting on August 22, 2023
- Draft LCMP meeting and presentation to the Skagit County and the LMD on June 3, 2024.
- Final project meeting and presentation on June 24, 2024.

Summary of Public Comments

Comments on the draft LCMP were solicited from stakeholders and the public, including but not limited to in-text suggestions and questions or comments vocalized during the June 3 and June 24, 2024, public meetings. These questions, comments, and project team responses are summarized below and were considered in this final Plan.

- Phosphorus Budget
    - Several meeting attendees were interested in specific estimation of loading from waterfowl and septic systems, which were not included in a previous draft of this LCMP. These estimates have now been added to the phosphorus budget section. The calculations indicate that waterfowl

were a minor contributor based on available count data and that septic systems may be a significant source of phosphorus to groundwater loadings.

- Bioturbators in the lake (i.e., primarily catfish and common carp) will not be specifically addressed in this plan. We do not expect the longevity of a potential alum treatment to be impacted by bioturbators as binding of sediment phosphorus occurs regardless of whether the sediment is disturbed. Some common carp may disturb the sediment deeper than where alum penetrates (<10 cm), but if a sediment inactivation dose is applied such to inactivate mobile phosphorus, then the disturbance may not result in the release of bioavailable phosphorus (Huser et al. 2016).

- Watershed Phosphorus Management
  - There was significant discussion around methods to identify watershed sources of phosphorus.
    - Herrera staff explained that future microbial source tracking studies may be performed to better understand the biological sources of phosphorus in the watershed and target management actions, but those studies are not needed at this time to control the reservoir of phosphorus already within Lake Campbell. It was noted that a similar source tracking study was performed in the 1980s, and that there are less livestock in the watershed now compared to when that study was performed.
  - Noting how similar this Plan is to the Entranco 1983 and 1987 reports, a lake resident raised a philosophical discussion about what steps or strategies we can employ now to reduce the chance of repeating this effort again in another few decades: "How do we get to where we want to be" … in terms of alum treatments, shoreline impacts, and external controls? Alum addresses the symptoms of a long history of [both natural and anthropogenic] phosphorus loading from the watershed and does not address those causes, but it is necessary in this lake to reduce those symptoms for near-term lake use and safety.
    - Herrera response: Controlling watershed sources is important to reducing phosphorus loads to Lake Campbell, but it will take decades to see that impact especially in terms of septic contributions. Taking those actions now will benefit those later generations. We did not find a single point source to address in the watershed; it can be challenging to address many sources. Better long-term investments in infrastructure systems will also prevent other types of contamination, as co-benefits to managing the lake. There are more resources and funding for watershed management activities (e.g., septic and stormwater improvements) than for in-lake treatments and can be used piecemeal to address these external sources.

- Plan Implementation
  - Several questions were raised related to the estimated cost of an alum treatment and logistics relative to the treatment performed in the 1980s. The recommended treatment is a sediment inactivation treatment, which is a more expensive option than a water column treatment because it requires a higher dosage and use of a buffer to keep pH neutral and ensure safety. In 1985, a buffer was not used. This method is recommended because it is expected to be more effective long term and more cost effective than annual water column stripping treatments. The cost of the alum itself is similar to that from the 1985 treatment, but there are increased costs related to

the other associated tasks (e.g., development of a strategy, mobilization, monitoring, and dosage/incubation studies). These cost estimates were developed based on unit costs for the materials and costs for mobilization, permitting, etc. These numbers come from past experience (e.g., Heart Lake, Green Lake) and quotes from applicators (AquaTechnex). Please see Appendix C for further detail on the management strategies and cost estimates.

- One attendee sought more information related to using EutroSORB for reducing nutrient loading to the lake within inlets. Please see Appendix C for more information or visit EutroSORB's website.
- Relatedly, funding sources were called into question. In deciding on management strategies, it is important to consider how funding is acquired and what the timeframe is for using those dollars. Annual water column stripping treatments may be a viable strategy if the main funding source is ongoing and reliable (e.g., from LMD assessments). However, if relying on larger grants or budget allocations, those sources provide a higher dollar amount to invest in the lake at a single time and must be used within a shorter timeframe, so a larger, one-time strategy may be more feasible.
- A WDFW fish biologist commented "I think that the proposed measures seem logical and well thought out. I look forward to working with the team moving forward and seeing how the fish community responds to the cascading effects of nutrient management in Campbell" and offered information about the fish community over time. He also suggested to clarify details related to carp plants in the lake, which has now been done.
- From questions regarding implementation, prioritization, and responsibility, Skagit County clarified that much of the management role will eventually become the LMD's responsibility but for at least the next year, Skagit County will continue to act as management lead.

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Appendix A

Lake Campbell Existing Water Quality Conditions

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Water Quality Report for the Lake Cyanobacteria Management Plan

Lake Campbell, Skagit County, Washington

Prepared for
Skagit County

Prepared by
Herrera Environmental Consultants, Inc.

Funded by
Washington State Department of Ecology
Freshwater Algae Program
Grant Number WQALG-2024-SkCoPW-00035

Water Quality Report for the Lake Cyanobacteria Management Plan

Lake Campbell, Skagit County, Washington

Prepared for
Skagit County
1800 Continental Place
Mount Vernon, Washington 98273

Prepared by
Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
Telephone: 206-441-9080

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Washington State Department of Ecology Freshwater Algae Program
Grant Number WQALG-2024-SkCoPW-00035

June 28, 2024

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Introduction

Herrera Environmental Consultants (Herrera) contracted with Skagit County to prepare a Lake Cyanobacteria Management Plan (LCMP) for Lake Campbell, which is a eutrophic lake in western Skagit County that experiences frequent cyanobacteria blooms impairing recreational use of the lake. To inform the LCMP, Herrera developed a Quality Assurance Project Plan (QAPP) (Herrera 2023) to collect a comprehensive set of scientific data from August 2023 through January 2024, including hydrological, chemical, biological information from the lake and watershed. This water quality report summarizes the methods and results of water quality monitoring conducted for the LCMP and is included as an appendix to the LCMP.

Monitoring Methods

Campbell Lake has undergone several detailed of water quality and hydrology in the lake and its watershed. Key studies are provided below in Table 1. These studies were pivotal in early characterizations of Campbell Lake and upstream Lake Erie, and in tracking contemporary eutrophication and water level trends. Detailed summaries of these and other studies are described in the QAPP (Herrera 2023).

Table 1. Summary of Previous Studies at Lake Campbell.

Title	Author(s)	Data Year	Year Published	Description
Reconnaissance Data on Lakes in Washington, Volume 1	Ecology	1973	1976	Water quality study with physical chemical, biological, geographic, bathymetric, and drainage characterizations.
Water Quality Analysis and Restoration Plan for Erie and Campbell Lakes	Entranco Engineers	1981–1982	1983	Water quality study and evaluation of restoration alternatives
Erie and Campbell Lakes – Final Report: Restoration Implementation and Evaluation	Entranco Engineers	1985–1986	1987	Water quality study post-alum treatment; evaluation of restoration effectiveness
Water Quality Assessments of Selected Lakes Within Washington State	Ecology	1999	2001	Includes water quality assessment of Campbell Lake
Lake Campbell and Lake Erie Total Phosphorus Total Maximum Daily Load: Water Quality Effectiveness Monitoring Report	Ecology	2004–2005	2007	Water quality study for total phosphorus and chlorophyll-a
Lake Campbell and Lake Erie 2002 Monitoring Projects	Hilles et al., Western Washington University	2002	2003	Water quality study and macrophyte survey
Lake Campbell Outlet Investigation Summary of Findings	Butler and Johnson, Watershed Science and Engineering	2021	2021	Skagit County's Drainage Utility retained the WSE engineering firm to investigate the Lake Campbell outlet.
Unpublished monitoring data	Samish Indian Nation	2017–2023	Unpublished	Lake water quality monitoring

Thorough characterization of lake and watershed conditions is necessary to develop water and phosphorus budgets, to understand the dynamics driving cyanobacteria blooms in the lake, and to construct a successful strategy for both short-term and long-term control of toxic cyanobacteria blooms.

To supplement historical and contemporary datasets, high-quality monitoring data of the lake water quality, lake sediment, and watershed drainage were collected from August 2023 through January 2024 (also referred to as the "monitoring period"). Table 2 summarizes the types of data gathered, methodology used, and the locations at which those data were collected. Table 3 presents the lake monitoring schedule and Table 4 presents the watershed monitoring schedule. Figure 1 below shows the station locations in Lake Campbell and its watershed which were monitored for the LCMP.

Monitoring objectives and measurement quality objectives are specified in the QAPP. Monitoring procedures were according to procedures specified in the QAPP (Herrera 2023) for field procedures, laboratory procedures, quality control procedures, and data management, analysis, and reporting. Deviations from the QAPP are described in the following section.

Table 2. Lake Campbell Monitoring Program for LCMP.

Component	Element/Parameters	Summary	Station/Source
Hydrological	Bathymetry	Hydro-acoustic mapping.	Ecology 1976
	Precipitation	WSU rain gauges	AWN Tier 2 Anacortes
	Lake level	Skagit County continuous level gauge	LVL-CAM
	Stream and lake outlet discharge	Discrete depth and velocity measurements using a Swoffer current meter during sampling.	CS1, CS2, CS2.5, CS3, CAM-OUT
Stream Water Quality	Discrete sampling for total phosphorus	Grab samples at stream/inflow locations.	CS1, CS2, CS2.5, CS3
Lake Water Quality	Counts of waterfowl, boats, anglers, and swimmers	Additional observations about lake use and appearance during lake monitoring events.	Lake Campbell field data
	Discrete sampling for total phosphorus, orthophosphate, total kjeldahl nitrogen, nitrate+nitrite, ammonia, chlorophyll-a, phytoplankton, zooplankton	Grab samples with a Van Dorn sampler at 0.5-1.5 meters from surface, and from 1 meter from the lake bottom. Zooplankton samples by vertical tow through the water column.	CAM-DEEP
	Cyanotoxin sampling for microcystin and anatoxin-a	Grab samples during [often lake-wide] algae blooms, analyzed through Ecology's Freshwater Algae Control program.	East side of lake
	Trout stocking data	Number and pounds of each species stocked in the lake.	WDFW 2024
Sediment Quality	Core sampling for phosphorus fractions (loosely bound, iron bound, aluminum bound, calcium bound, organic, biogenic, and total), total iron, percent solids, bulk density	One 2-foot core collected at each location using a universal percussion corer, processed into 5 discrete depth intervals.	CAM-DEEP, CAM-SHALLOW

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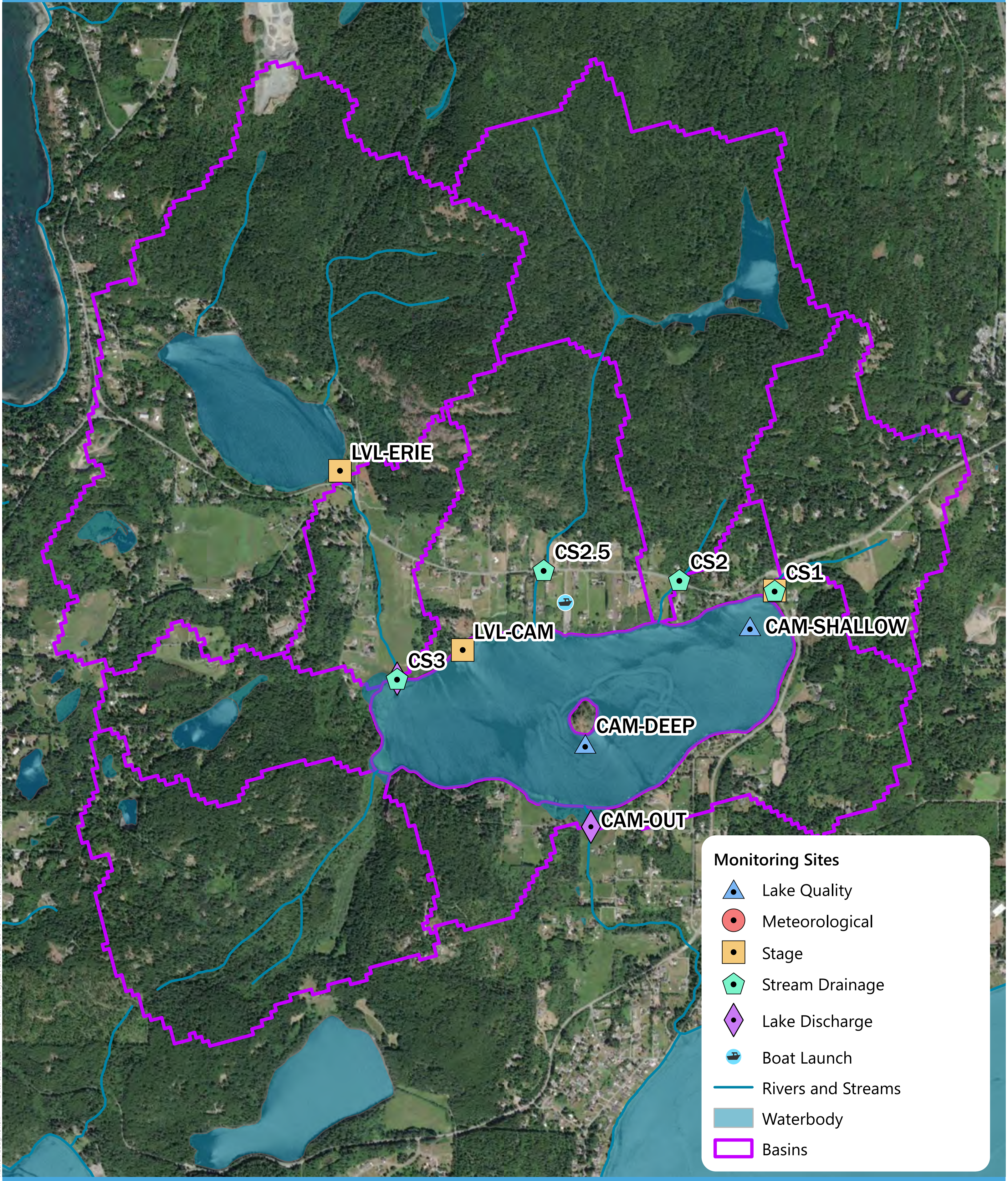
Figure 1.
Lake Campbell Watershed and Study Monitoring Stations.



Produced by Herrera Environmental Consultants (herrerainc.com) | Sources: USGS, Esri (Imagery, 2022)

Table 3. Lake Monitoring for the Lake Cyanobacteria Management Plan for Lake Campbell.

Parameter	Sample Depth Layers by Date					
	8/22/23	9/18/23	10/6/23	10/24/23	11/15/23	12/13/23
Secchi Depth	S	S	–	S	S	S
Temperature/DO/pH/Conductivity	P	P	–	P	P	P
Chlorophyll-a	S,B	S,B	–	S,B	S,B	S,B
Total Phosphorus	S,B	S,B	–	S,B	S,B	S,B
Orthophosphate	S,B	S,B	–	S,B	S,B	S,B
Total Kjeldahl Nitrogen	S,B	S,B	–	S,B	S,B	S,B
Nitrate+Nitrite-N	S,B	S,B	–	S,B	S,B	S,B
Ammonia	S,B	S,B	–	S,B	S,B	S,B
Phytoplankton	T	T	–	T	–	–
Zooplankton	T	–	T	T	–	–

S = surface, B = bottom, P = profile, T = water column tow, – = no sample

Table 4. Watershed Monitoring Events for the Lake Cyanobacteria Management Plan for Lake Campbell.

Station	Base Flow						Storm Flow				
	2023-08-25	2023-09-18	2023-10-26	2023-11-15	2023-12-13	2024-01-22	2023-09-28	2023-10-24	2023-12-01	2023-12-22	2024-09-19
CS1	–	D,G	D,G	D,G	D,G	D,G	D,G	D,G	D,G	D,G	D,G
CS2	–	–	–	D	D,G	D,G	–	–	–	D,G	D,G
CS2.5	–	–	–	D,G	D,G	D,G	–	–	–	D,G	D,G
CS3	–	–	–	D,G	D,G	D,G	–	–	D,G	D,G	D,G
CAM-OUT	–	–	D,G	–	–	D	–	–	–	D	D

D = Discharge measurement, G = Grab sample for ammonia, nitrate+ nitrite, orthophosphate, total kjeldahl nitrogen, and total phosphorus

Red text (– or D) = no measurable discharge and/or no grab sample because no discharge

Data Quality Assurance

An independent review of the laboratory quality control (QC) data from each sampling event was performed using the measurement quality objectives (MQOs) identified in the QAPP (Herrera 2023). The quality of these data was evaluated by Herrera data managers for precision and completeness. The data quality for all parameters was generally considered acceptable, based on holding time, reporting limit, method blank, spike recoveries, control standard, and laboratory duplicate criteria specified in the QAPP. 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. Deviations from the QAPP and results from the data QC review are described below.

Lake Campbell monitoring was executed as planned, with lake monitoring events once per month August 2023 through December 2023, except the January 2024 was not completed due to no available volunteers. Watershed monitoring was executed nearly as planned, with all six base flow events and five out of six storm flow events performed between August 2023 and January 2024 at each of four watershed stream stations and one lake outlet station.

Exceptions to planned lake and watershed monitoring include:

- The January 2024 lake monitoring event was cancelled
- Zooplankton were not collected during the 9/18/2023 event and were instead collected on 10/6/2023 when the Herrera-provided zooplankton net (50 µm mesh size) was available.
- One storm flow event was not sampled.

Field and laboratory data were validated according to the QAPP. Quality control procedures and criteria defined in the QAPP were generally met, resulting in no data qualification or corrective action, with the following exceptions identified below.

The following results were qualified as estimated (J) or rejected (R) due to field procedures which deviated from the QAPP:

- A zooplankton net was not available for the 8/22/2023 event, instead a student's phytoplankton net, with unknown mesh size, was sunk using additional weights and towed to the surface for a zooplankton sample. The mesh size is suspected to be 20 or 50 µm. Results are estimated (J).
- Secchi depth for 10/24/2023 is estimated (J) due to the use of the zooplankton net to estimate clarity instead of the Secchi disk, which was not available during the event.
- Total phosphorus and total Kjeldahl nitrogen results at CS1 on 9/18/2023 are rejected (R) due to field filtration upon collection.
- All nitrate+nitrite results (n=92) from all lake and watershed events (except from CAM-DEEP on 8/22/2023) are estimated (J) due to lack of sample filtration before laboratory analysis (i.e., no filtration in field or upon laboratory receipt).
- All orthophosphate results (n=92) from all lake and watershed events (except from CAM-DEEP on 8/22/2023) are rejected (R) due to lack of sample filtration before laboratory analysis (i.e., no filtration in field or upon laboratory receipt).

The following results were qualified as estimated (J) due to laboratory qualification of sample as 'non-homogenous' during analysis:

- Ammonia results at CS1 collected on 9/18/2023, and at CAM-DEEP collected on 10/24/2023.
- Total Kjeldahl Nitrogen at CS2 collected on 12/22/2023.

The following results were qualified as estimated (J) due to low matrix spike percent recovery during laboratory analysis:

- Total phosphorus and total Kjeldahl nitrogen at CAM-OUT collected on 10/26/2023

The following results were qualified as estimated (J) due to results detected below the reporting detection limit (RDL):

- Ammonia results at CS2.5 on 11/15/2023 and 1/22/2024
- Ammonia results at CS3 on 12/1/2023, and on 12/22/2023
- Chlorophyll-a results at CAM-DEEP on 9/18/2023, 10/24/2023, 11/15/2023, and 12/13/2023, in both surface and bottom samples
- Orthophosphate results at CS3 on 12/22/2023
- Nitrate+nitrate results at CS3 on 12/1/2023, and at CAM-DEEP on 12/13/2023 in both surface and bottom samples

The following stream discharge results were qualified as estimated (J):

- Three results at CAM-OUT (on 12/22/2023, 1/19/2024, and 1/22/2024) due to estimated velocities at individual point measurements in the stream cross-sections. On 1/22/2024, water additionally saturated vegetation beyond bank.
- Four results at CS2 (on 12/13/2023, 12/22/2023, 1/19/2024, and 1/22/2024) due to estimated velocities at individual point measurements in the stream cross-sections.
- Three results at CS2.5 (on 12/22/2023, 1/19/2024, and 1/22/2024) due to estimated velocities at individual point measurements in the stream cross-sections.
- Five results at CS3 (on 11/15/2023, 12/13/2023, 12/22/2023, 1/19/2024, and 1/22/2024) due to estimated velocities at individual point measurements in the stream cross-sections and/or disturbance by debris.

The results below are qualified as non-detects (U) due to concentrations not detected at or above the MDL:

- Nitrate+nitrite results for samples collected at the lake surface and bottom at CAM-DEEP on 8/22/2023, 9/18/2023, 10/24/2023, and 11/15/2023

- Nitrate+nitrite results for samples collected at CS1 on 10/24/2023 and at CS3 on 11/15/2023
- Total kjeldahl nitrogen for samples collected at CS1 on 10/24/2023
- All results for loosely bound phosphorus in lake sediments at both CAM-DEEP and CAM-SHALLOW.
- Seven results at the lake outlet CAM-OUT (8/25/2023, 9/18/2023, 9/28/2023, 10/24/2023, 10/26/2023, 12/13/2023, and 1/22/2024) due to no flow, backward flow, and/or disconnected flow.
- Six results at CS2 (8/25/2023, 9/18/2023, 9/28/2023, 10/24/2023, 10/26/2023, and 12/1/2023) due to dry conditions and/or no flow.
- Six results at CS2.5 (8/25/2023, 9/18/2023, 9/28/2023, 10/24/2023, 10/26/2023, and 11/15/2023) due to dry conditions and/or no flow.
- Five results at CS3 (8/25/2023, 9/18/2023, 9/28/2023, 10/24/2023, and 11/15/2023) due to dry conditions and/or no flow.

Field data sheets for each lake and watershed monitoring event are presented in Appendix B of the LCMP. Laboratory data reports from each monitoring event are provided in Appendix C of the LCMP.

Lake Monitoring Results

Lake Observations

Lake observations were recorded on field sheets during each visit and included: weather, counts of recreators and waterfowl observed, and notes related to water color and algae (Table 5).

Water color varied through various shades of green, with algae scums observed during the August event and heavy algae clumps observed during the November event. Boats and swimmers were recorded only during the November lake monitoring event, and no anglers were recorded during the monitoring period (Table 5).

Bird counts were recorded on three days during the monitoring period (Table 5), for which only the numbers of geese and ducks were recorded. Lake residents explained that WDFW captured 57 geese in July 2023. Additionally, herons were observed in September and November. A higher resolution dataset would be necessary to understand the full extent of bird populations and potential phosphorus loading effects on Lake Campbell.

Table 5. 2023 Lake Use Observations.

Date	Vessels	Swimmers	Anglers	Geese	Ducks	Water Color
August 22, 2023	0	0	0	4	0	Green/ brown
September 18, 2023	0	0	0	0	<1	Green/ yellow
October 24, 2023	0	0	0	0	47	Tea green
November 15, 2023	2	1	0	0	0	Pea green
December 13, 2023	0	0	0	0	0	NA

Blank spaces in field sheets assumed to represent 0 birds, when bird counts were performed.

Lake Water Quality

Lake water quality data collected at CAM-DEEP for the LCMP for Lake Campbell are summarized for the entire monitoring period (August through December 2023) in Table 6 and on a summer basis (August through October) in Table 7. Results are presented separately for each parameter in the sections below, with comparison to contemporary data (2017-2022) collected and provided by the Samish Indian Nation, and historical (1981–1982, 1985–1986) data presented by Entranco (1987).

Table 6. Lake Campbell August-December 2023 Monitoring Period Water Quality Summary Statistics.

Parameter	MDL and Unit	Depth	N	Percent non-detect	Min.	Median	Mean	Max.
Secchi depth	0.1 meter	S	5	–	0.9	1.15	1.15	1.5
Temperature	0.3°C	S	23	–	6.2	13.4	13.42	22.7
		B	18	–	6.1	13.35	12.89	21.7
Dissolved oxygen	0.2 mg/L	S	23	–	0.8	8.77	7.89	10.3
		B	18	–	0.06	6.975	6.82	9.45
pH	0.1 units	S	14	–	7.26	7.765	7.94	8.98
		B	9	–	7.44	7.78	7.78	8.34
Conductivity	1 µS/cm	S	23	–	253	262	262	273
		B	18	–	253	262	261	269
Total phosphorus	1.9-2.1 µg/L	S	7	0	30	40	61.3	122
		B	7	0	21	37	83.1	164
Orthophosphate[a]	10 µg/L	S	1	0	40	40	40	40
		B	1	0	60	60	60	60
Total Kjeldahl nitrogen	26.7-84.8 µg/L	S	7	0	900	1,140	1,267	1,940
		B	7	0	900	1,000	1,606	2,900
Nitrate+nitrite	4.2-4.7 µg/L	S	2	50	<MDL	6.55	6.55	8.9
		B	3	33.3	<MDL	7.1	6.13	7.1
Ammonia	4.5-8.8 µg/L	S	7	0	11	28	88.1	470
		B	7	0	11	24	147	880
Chlorophyll-a	0 µg/L	S	6	0	25.6	34.6	39.1	56.1
		B	5	0	10.4	39.4	33.3	56.6

MDL = method detection limit; N= sample size; °C = degrees Celsius; mg/L = milligrams per liter; µg/L = micrograms per liter; S = Surface (epilimnion); B= Bottom (hypolimnion)

a=Rejected all but one sample (collected in August 2023) as samples were not filtered prior to analysis.

Table 7. Lake Campbell 2023 Summer (August-October) Water Quality Summary Statistics.

Parameter	MDL and Unit	Depth	N.	Percent non-detects	Summer Min.	Summer Median	Summer Mean	Summer Max.
Secchi depth	0.1 meter	S	3	–	0.9	1.0	1.03	1.2
Temperature	0.3°C	S	13	–	13.4	19.7	18.0	22.7
		B	10	–	13.3	19.0	17.3	21.7
Dissolved oxygen	0.2 mg/L	S	13	–	0.8	7.16	6.6	10.3
		B	10	–	0.06	5.39	4.85	6.98
pH	0.1 units	S	8	–	7.26	8.42	8.15	8.98
			5	–	7.44	8.03	7.87	8.34
Conductivity	1 µS/cm	S	13	–	262	264	264	269
		B	10	–	262	267	266	273
Total phosphorus	1.9-2.1 µg/L	S	5	0	30	81	70.6	122
		B	3	0	130	163	152	164
Orthophosphate	10 µg/L	S	1	0	40	40	40	40
		B	1	0	60	60	60	60
Total kjeldahl nitrogen	58.5-84.8 µg/L	S	3	0	2,070	2,500	2,490	2,900
		B	5	0	1,000	1,340	1,366	1,940
Nitrate+nitrite	4.2 µg/L	S	1	100	<MDL	<MDL	<MDL	<MDL
		B	1	100	<MDL	<MDL	<MDL	<MDL
Ammonia	4.5-8.8 µg/L	S	5	0	15	28	114	470
		B	3	0	28	53	320	880
Chlorophyll-a	0 µg/L	S	4	0	25.6	42.85	41.9	56.1
		B	3	0	10.4	39.4	35.5	56.6

MDL = method detection limit; N= sample size; °C = degrees Celsius; mg/L = milligrams per liter; µg/L = micrograms per liter; S = Surface (epilimnion); B= Bottom (hypolimnion)

Table 8. Historical Lake Campbell Summer Water Quality Summary Statistics (Entranco 1987).

Summer Period	Total Phosphorus (µg/L)[a]		Chlorophyll-a (µg/L)[a]		Secchi Depth (meters)	
	Mean	Maximum	Mean	Maximum	Mean	Minimum
May-August 1982	45	68	18	45	1.8	1.0
May-Sept 1985	53	84	18	36	1.3	0.6
May-Sept 1986[b]	28	32	10	15	1.8	1.3

µg/L = micrograms per liter; S = Surface (epilimnion)

a = means are depth-averaged

b = the only summer sampled after the September 1985 alum treatment.

Water Temperature

Figure 2 shows lake water temperature profiles collected from the deepest part of Lake Campbell from August through December 2023. Temperatures ranged from about 6 to 23 degrees Celsius (°C) (Table 3), with marginally cooler temperatures near the lake bottom and warmer temperatures near the lake surface in only August and September. These profiles illustrate that Lake Campbell was never thermally stratified during the 2023 monitoring period and able to be fully mixed from surface to bottom. This 2023 profile agrees with previously observed ranges (Figure 3). Water temperatures in 2017–2022 exhibited similarly mixed water columns throughout the year (January through December) (e.g., in 2021 [Figure 4]), with brief periods of observed thermal stratification. Wind-driven mixing is expected to quickly overcome the weak thermal stratification in Lake Campbell due its large area and shallow depth (Osgood 1988).

Surface temperatures in 2023 were not observed to exceed the U.S. Environmental Protection Agency (EPA 2021) recommended maximum temperature for survival of juvenile trout (24°C) or for largemouth bass (34°C).

Figure 2. Water Temperature Profile in Lake Campbell (August–December 2023).

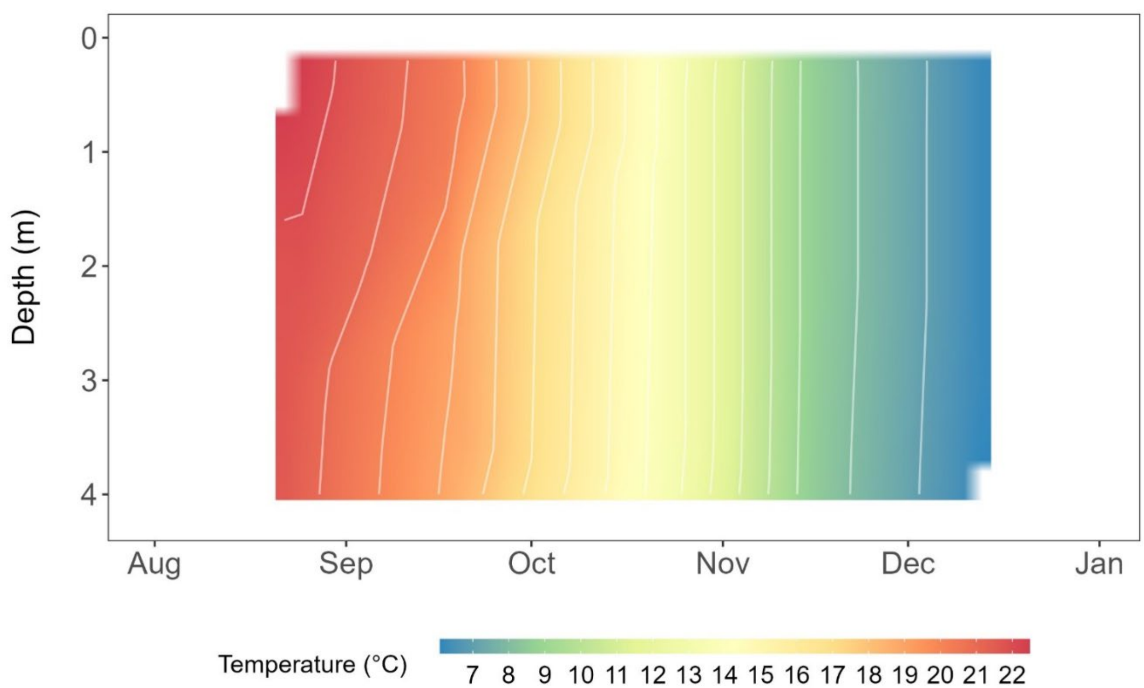


Figure 3. Water Temperature Annual Range Comparison in Lake Campbell (2017–2023).

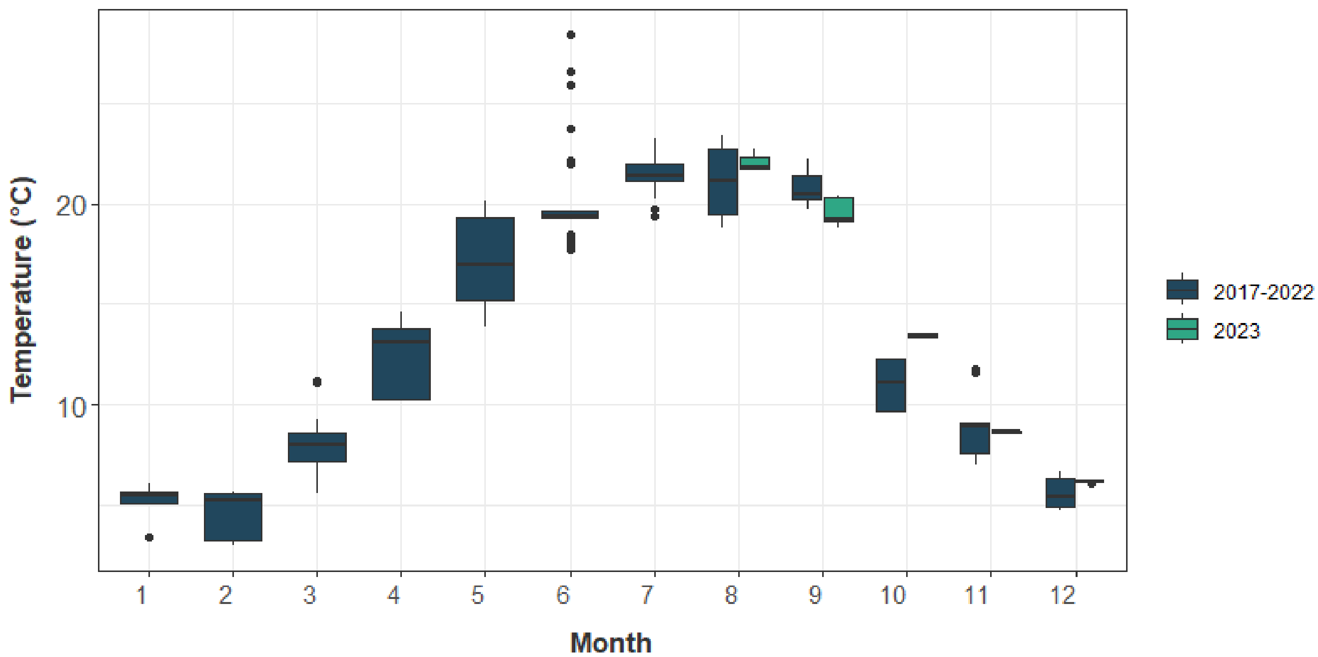
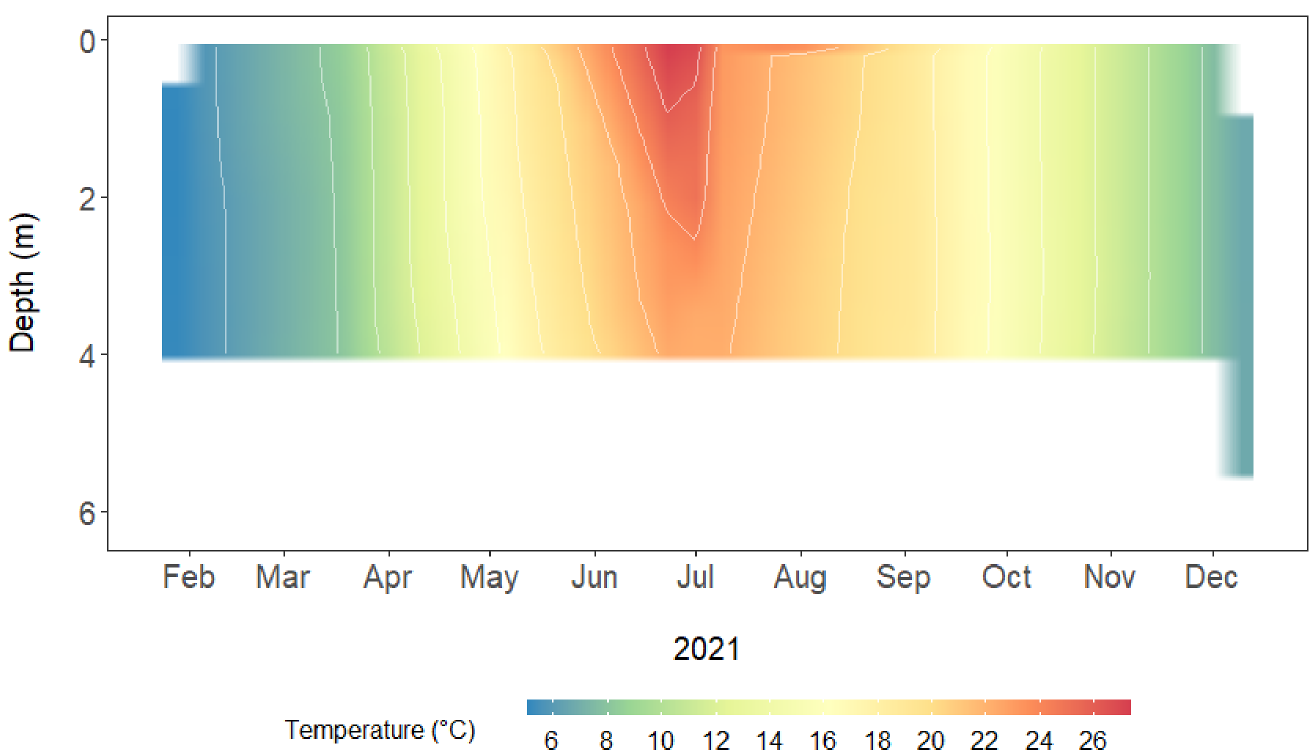


Figure 4. Water Temperature Profile in Lake Campbell (January–December 2021).



Dissolved Oxygen

Dissolved oxygen (DO) is an important water quality parameter for salmonids and other aquatic organisms. Low DO levels can be harmful to larval life stages and respiration of juvenile and adult fish. Therefore, it directly affects the survival of aquatic organisms. Depletion of oxygen in water bodies can also lead to a shift in the composition of the aquatic community. The EPA recommends a 1-day minimum DO concentration of 4.0 mg/L for adult trout and 3.0 mg/L for adult warm-water fish (EPA 2021).

Figure 5 shows DO profiles for Lake Campbell during the 2023 monitoring period. Initially in August, there was depressed DO in the lake's bottom waters, likely due the establishment of weak thermal stratification and lack of recent wind-induced mixing events (Table 6, Figure 5). In subsequent monitoring events, profiles indicated whole-lake mixing and surface algae blooms. DO concentrations can be progressively depleted in the because of decomposing organic material (e.g., dead algae cells, detritus) in the sediment.

This 2023 profile largely agrees with previously observed trends (Figure 6). DO in 2017–2022 was similarly mixed throughout the water column for most of the year, except during the summer when anoxia developed in the hypolimnion for somewhat varying depths and durations (Figure 7).

Figure 5. Dissolved Oxygen Profile in Lake Campbell (August–December 2023).

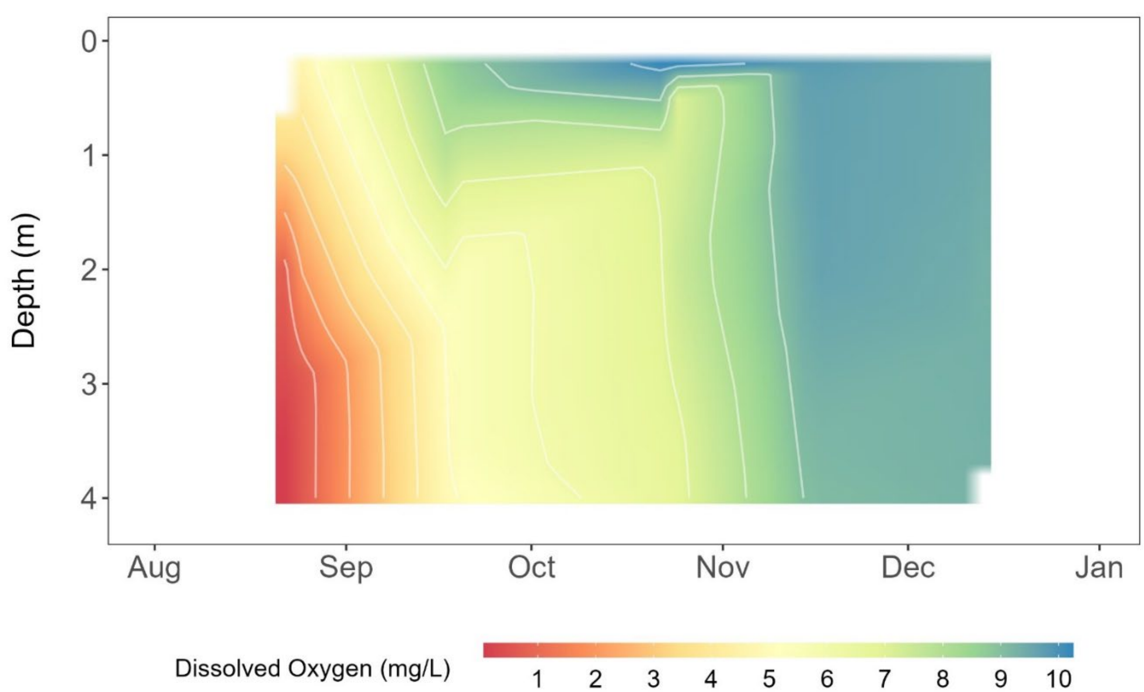


Figure 6. Dissolved Oxygen Annual Range Comparison in Lake Campbell (2017–2023).

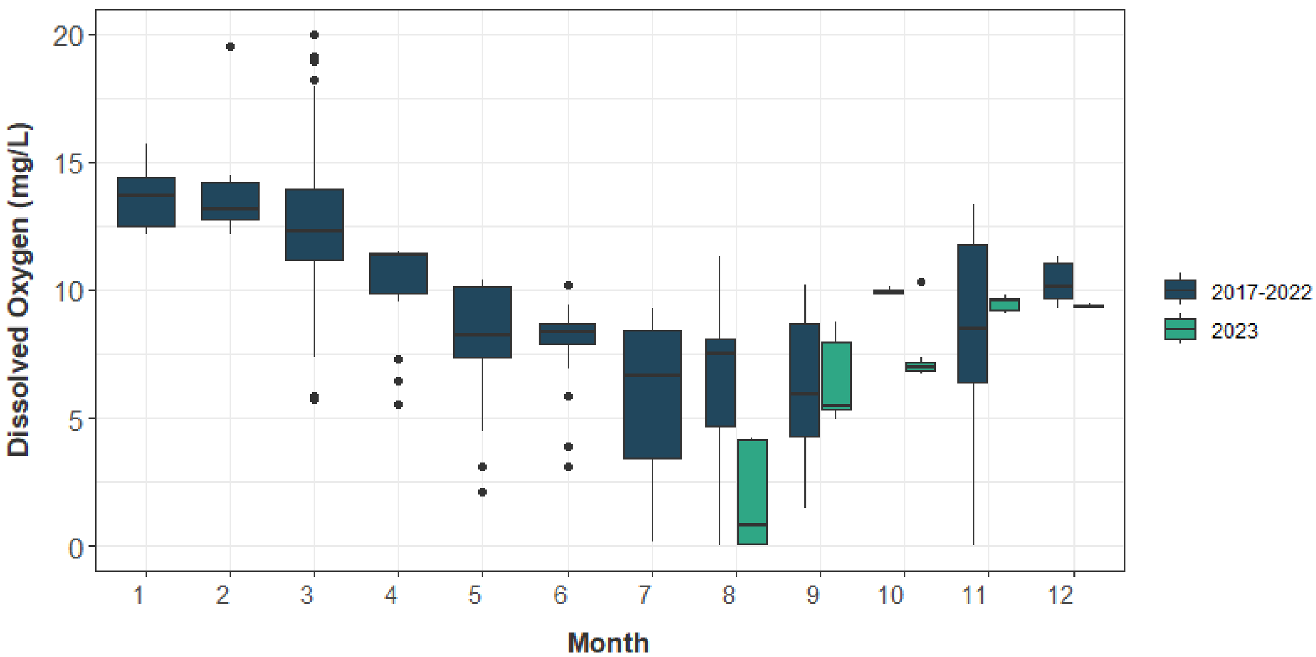
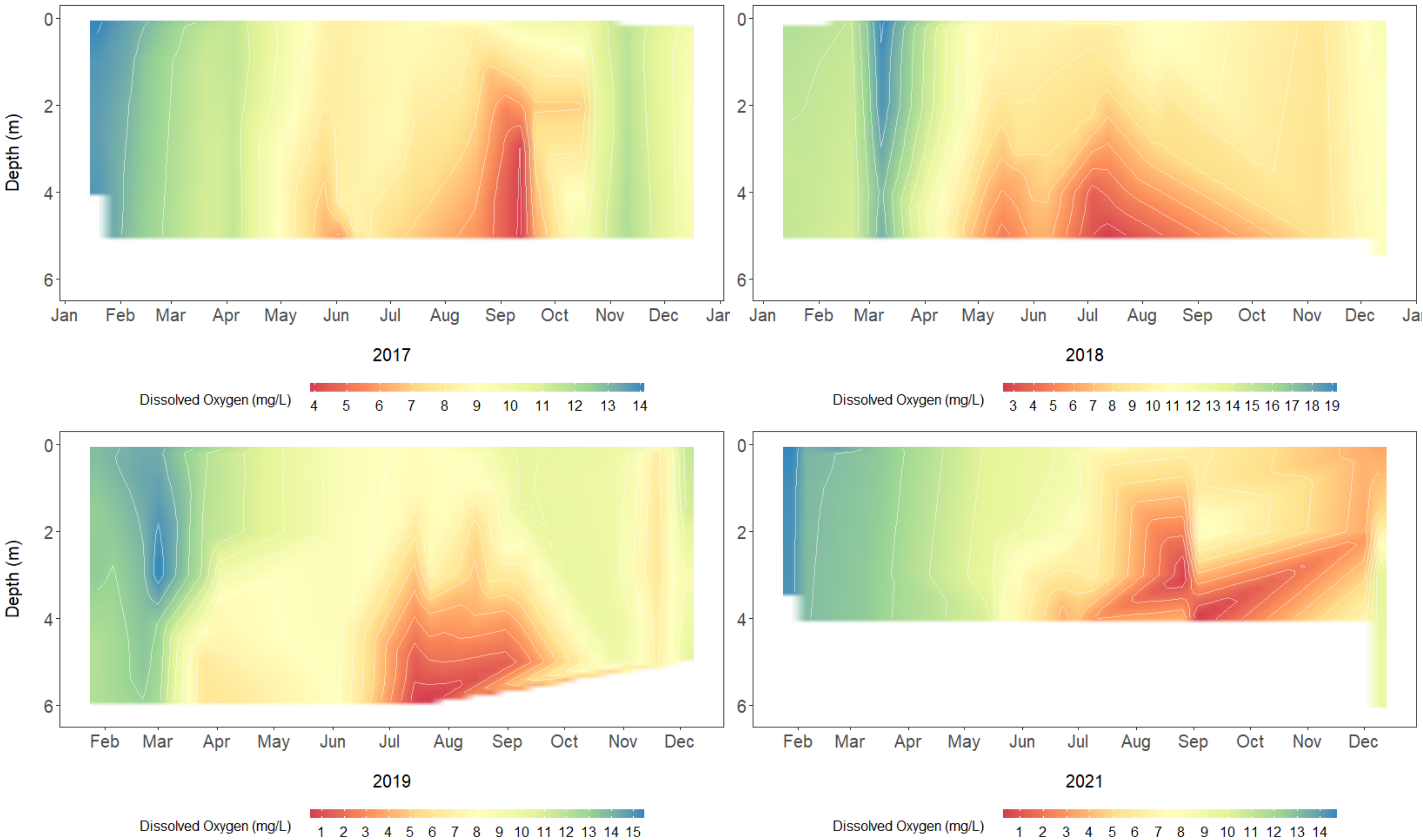


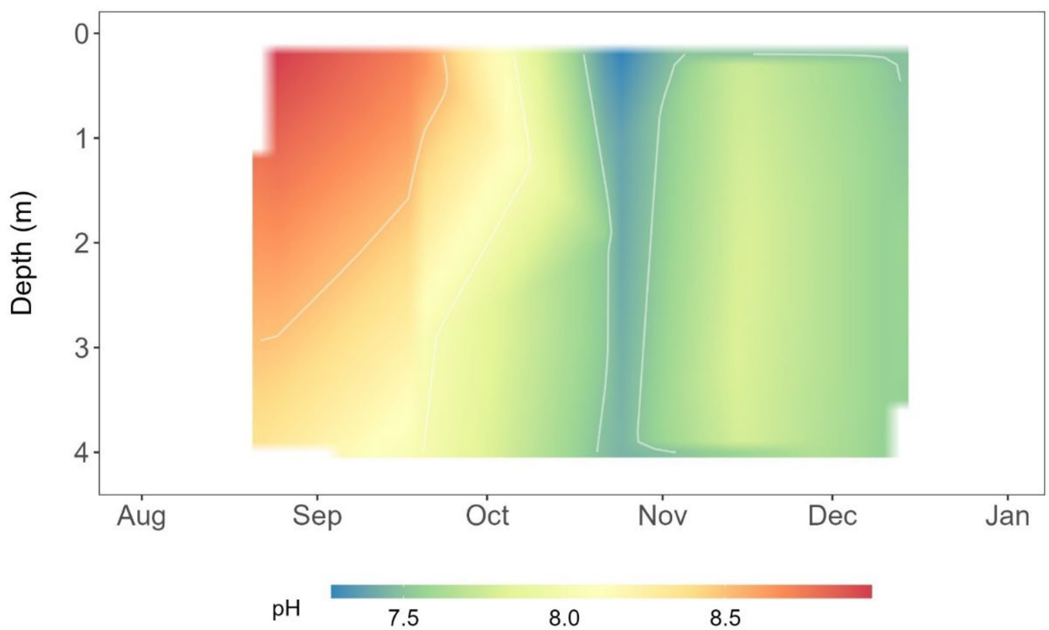
Figure 7. Dissolved Profiles in Lake Campbell (January–December, 2017, 2018, 2019, and 2021).



pH

pH is a measure of the hydrogen ion activity in water and can have a direct effect on aquatic organisms or an indirect effect via altering the toxicity of various common pollutants. Figure 8 presents pH profiles for August through December 2023. Similar to temperature and dissolved oxygen, pH was well-mixed throughout the water column with exception of the August sampling, where surface pH samples were elevated. These high pH values were likely due to the observed algae bloom. In the fall, near-neutral results are well within the state aquatic life criteria for pH (between 6.5 and 8.5) but pH during the summer appears to exceed criteria, especially at the lake surface where pH reached a maximum of 8.98. Elevated pH at the lake surface can occur due to consumption of carbon dioxide (a weak acid) by algal productivity. Conversely, low pH can occur due to the production of acids such as carbon dioxide and hydrogen sulfide during the decomposition of algae and organic matter in the hypolimnion.

Figure 8. pH Profile in Lake Campbell (August–December 2023).



Results from 2023 are similar to the ranges of pH observed in previous years (Figure 9), between approximately 6.5 and 9.0. Figure 10 presents pH profiles from select previous years wherein summertime periods of higher pH (basic conditions) developed in the epilimnion. The October 2023 samples were lower the historic values and lower than the surrounding values in 2023. It is suspected that this may be due to measurement or calibration error.

Figure 9. pH Monthly Range Comparison in Lake Campbell (2017–2023).

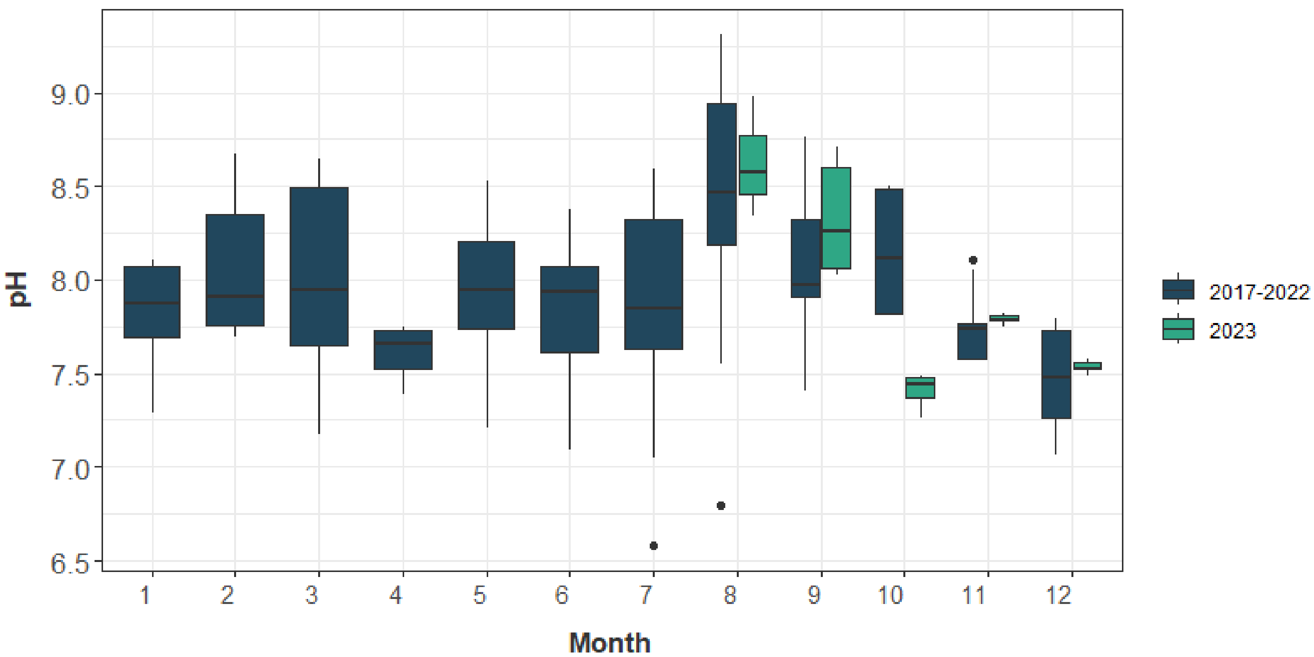
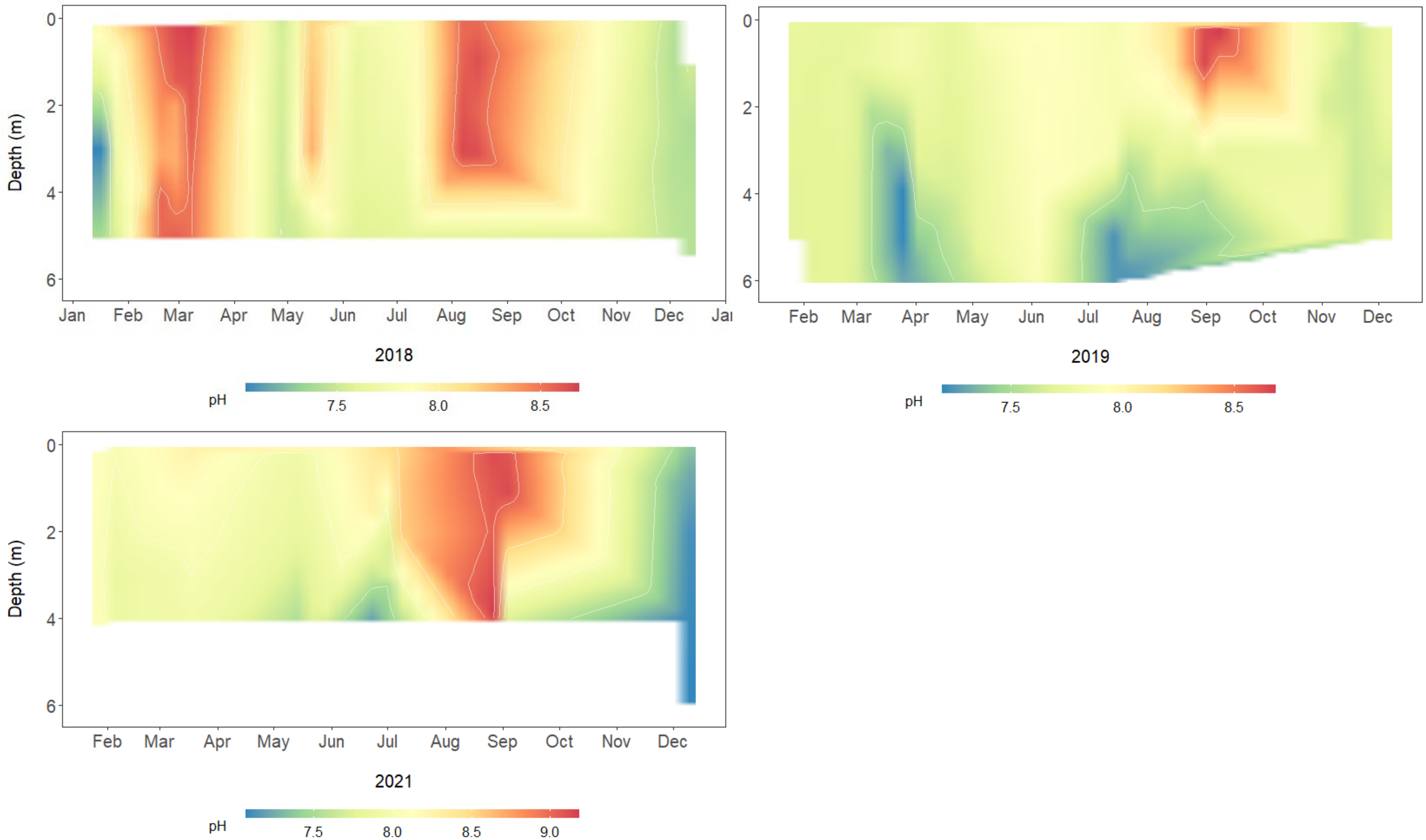


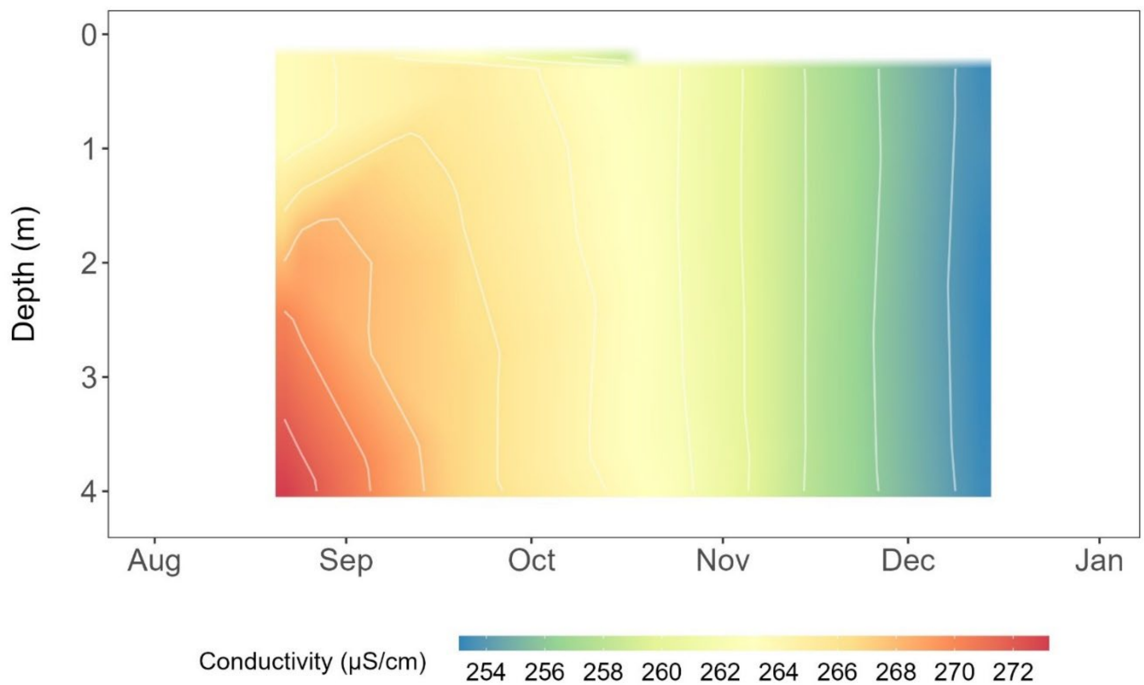
Figure 10. pH Profiles in Lake Campbell (January–December, 2018, 2019, and 2021).



Conductivity

Specific conductance (conductivity) is a measure of the capacity of water to conduct an electric current standardized at 25°C, allowing comparison of waters of different temperatures. Temperature and the concentration of major dissolved ions in water determine its conductivity. Figure 11 shows conductivity in the water column at Lake Campbell was highly homogenous in late 2023, with higher conductivity developing in the hypolimnion during the summer. This elevated conductivity is likely due to the dissolution of chemical bonds in the lake's sediments caused by anoxia and the decomposition of organic matter.

Figure 11. Conductivity Profile in Lake Campbell (August–December 2023).



Conductivity in 2023 was within range of the past conductivity of Lake Campbell (Figure 12), where each year conductivity is typically greatest July through September, and lowest January through May. Figure 13 presents conductivity profiles from select previous years wherein the timing and magnitude of high hypolimnetic conductivity varies from acute events in the summer and/or fall to sustained higher conductivity throughout the summer, fall, and into the winter.

Figure 12. Conductivity Monthly Range Comparison in Lake Campbell (2017–2023).

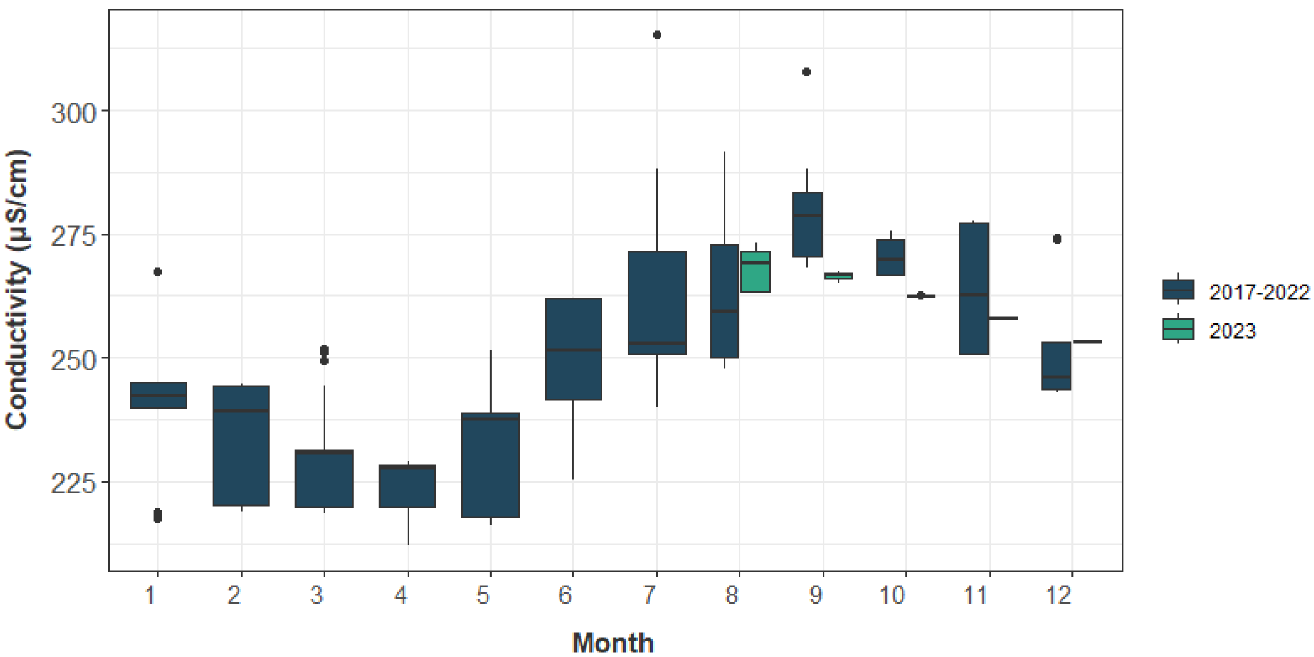
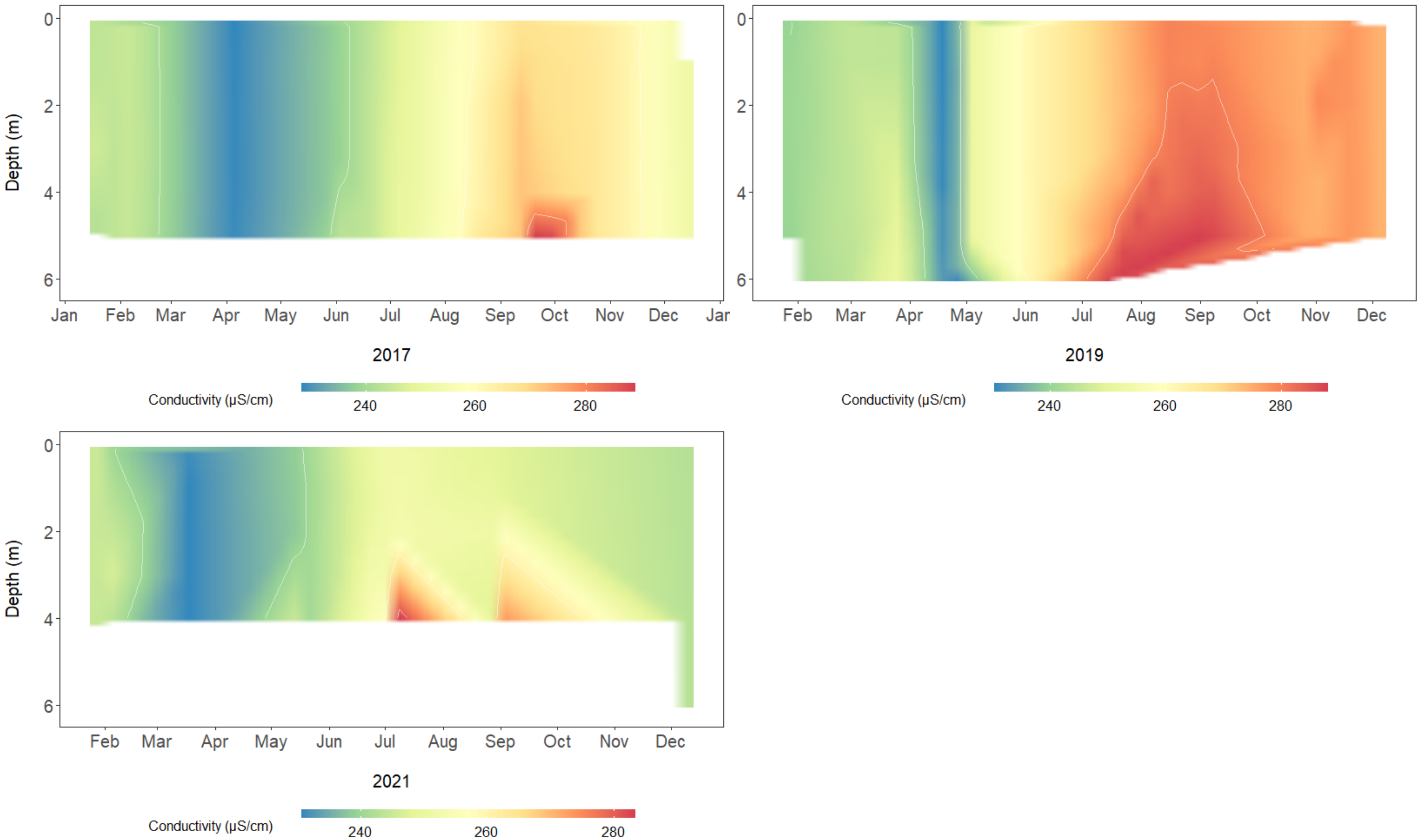


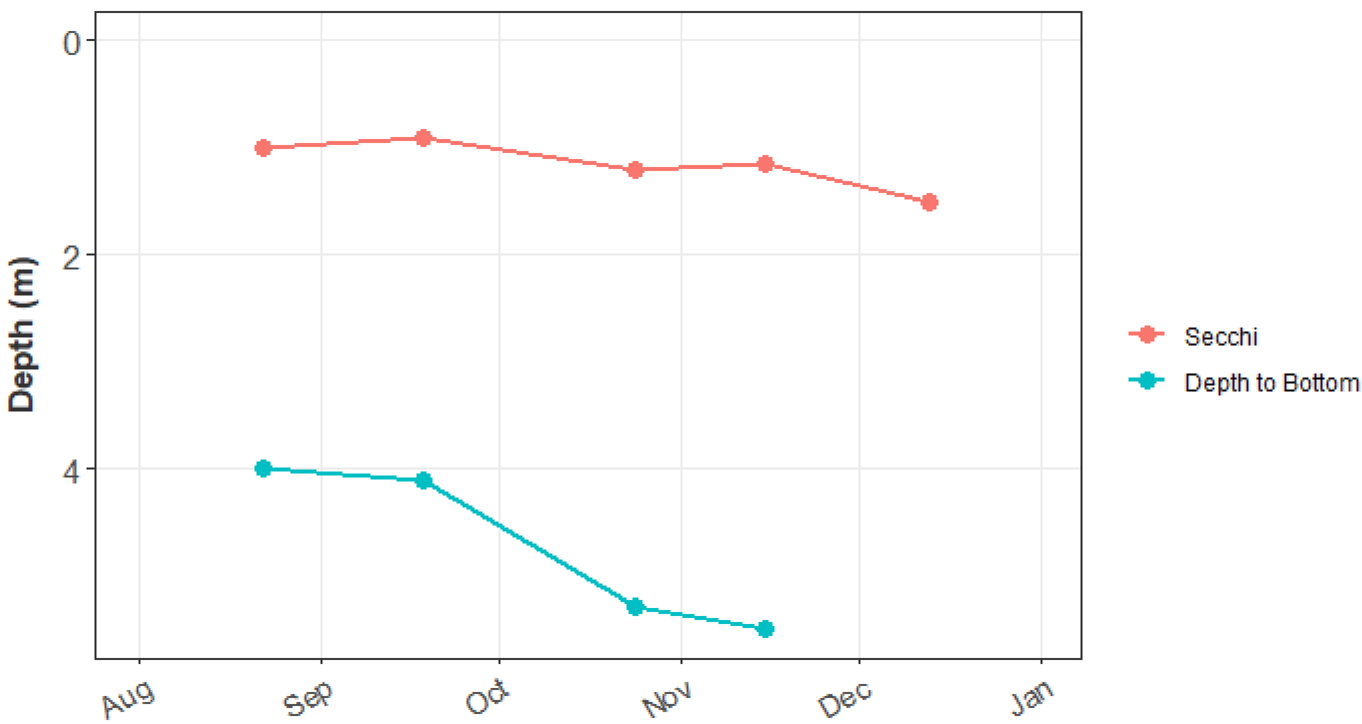
Figure 13. Conductivity Profiles in Lake Campbell (January–December 2017, 2019, and 2021).



Secchi Depth

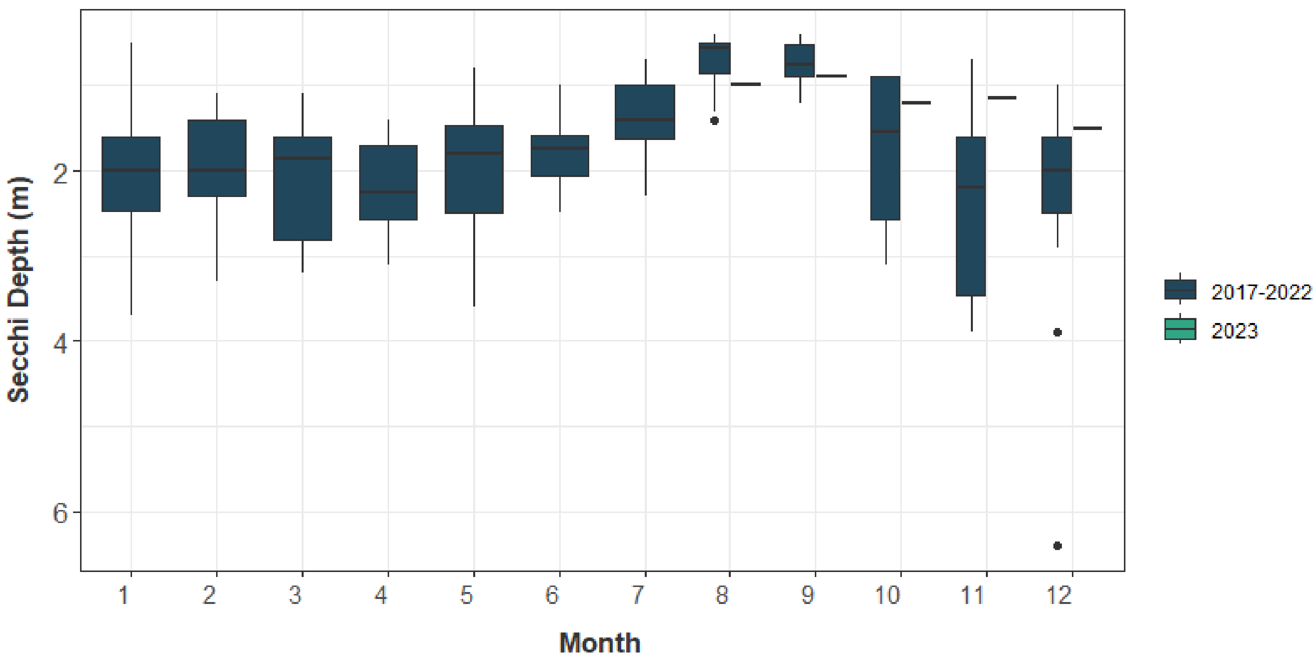
Secchi depth is a measure of water clarity, which is primarily affected by the amount and size of algae and other suspended particles in the water. Secchi depth can also be affected by color in tannic waters and waves. In temperate lakes, Secchi depths often decrease (indicating reduced clarity) during spring algae blooms (frequently diatoms), increase to a summer clear water maximum, and then decrease to a minimum in September or October as increased algae growth causes a more turbid state. Due to the limited monitoring period, no seasonal trends were observed in Lake Campbell in 2023 (Figure 14). In 2023, transparency ranged only 0.9 to 1.5 meters. However, historical measurements from the 1980s indicate that reduced water clarity aligns well with periods of elevated algae growth (Entranco 1987).

Figure 14. Secchi Depth in Lake Campbell (August–December 2023).



Additionally, data collected by the Samish Indian Nation show that water clarity may vary substantially from year to year but is usually consistent through the first half of the year at about 2 meters, then decreases June through September to as shallow as 0.25 meters before returning to higher clarity in October through December. Comparing 2023 values to those in 2017 through 2022 indicates that Lake Campbell was somewhat clearer than usual in late summer 2023, but from October through December 2023 the lake surface was much more turbid than we typically observe during those months (Figure 15), likely due in part to the *Microcystis* cyanobacteria bloom recorded in October.

Figure 15. Secchi Depth Monthly Range Comparison in Lake Campbell (2017–2023).



Chlorophyll-a

Chlorophyll-a is the primary photosynthetic pigment used by phytoplankton (algae). It is both a common measure of phytoplankton biomass and the most important factor used in determining a lake's trophic state (see *Trophic State Index* section below). However, chlorophyll-a is present in highly varied amounts among phytoplankton species and growth stages. As a result, it often does not relate well to other measures of phytoplankton biomass like cell biovolume. It typically negatively correlates well with Secchi depth (water clarity) unless there are large amounts of suspended inorganic particles causing turbidity in a lake.

Chlorophyll-a in Lake Campbell has been measured infrequently: twice monthly for the pre- and post-restoration studies (September 1981 to August 1982; April 1985 to October 1986), once in July 2019, and in August to December 2023 for this study.

On July 16, 2019, chlorophyll-a at the lake surface was 8.0 μg/L. In August through December 2023, chlorophyll-a ranged from 26 to 56 μg/L at the lake surface and from 10 to 57 μg/L at the lake bottom (Figure 16), with a mean summertime surface value of 42 μg/L (Table 7). These 2023 concentrations align with previous trends, which indicate chlorophyll-a is typically low early to mid-summer (<10 μg/L), followed by a late summer bloom shown by elevated chlorophyll-a (Figure 17). With a maximum of 56 μg/L, the 2023 summer bloom more closely resembled summer blooms in 1982 and 1985 before alum treatment (at maxima of 45 and 36 μg/L, respectively) than the 1986 bloom post-treatment (at a maximum of 15 μg/L) (Table 8).

Mesotrophic systems are defined by average surface chlorophyll-a concentrations in the epilimnion between 2.6 and 7.2 µg/L while eutrophic systems exhibit chlorophyll-a concentrations between 7.2 and 56 µg/L (see *Trophic State* section below). Chlorophyll-a results from the surface of the deepest point in Lake Campbell indicate the lake is currently in a eutrophic state.

Figure 16. Chlorophyll-a in Lake Campbell (August–December 2023).

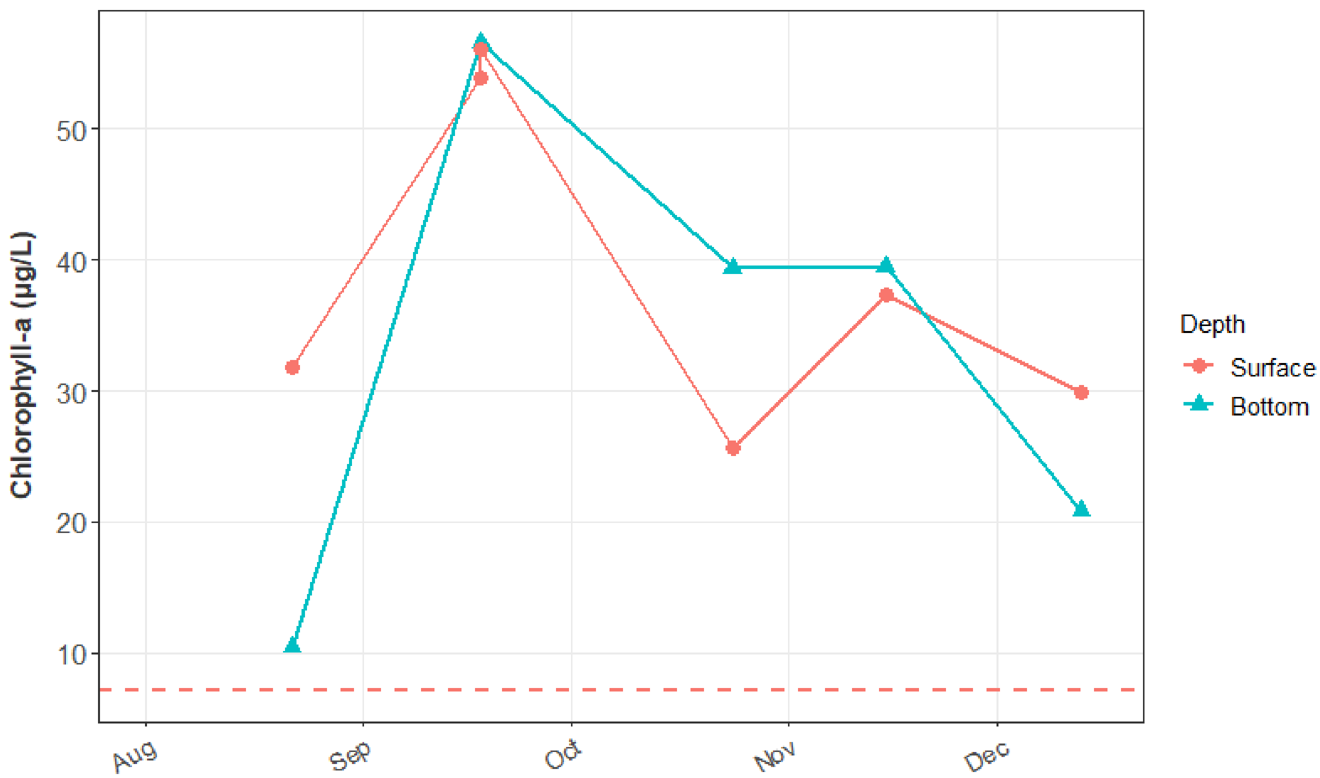
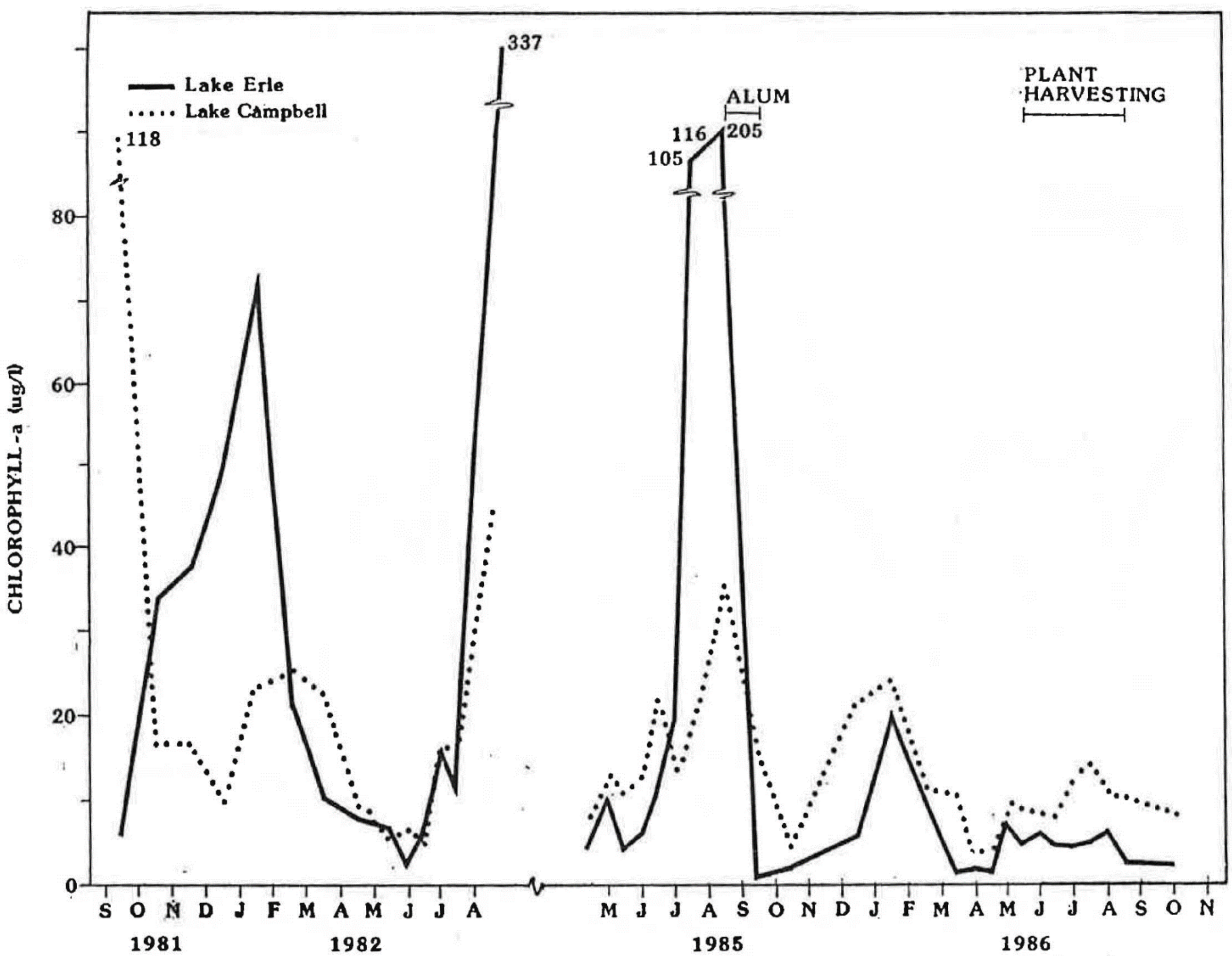


Figure 17. 1981-1982 and 1986-1986 Chlorophyll-a in Lake Campbell (Entranco 1987)).



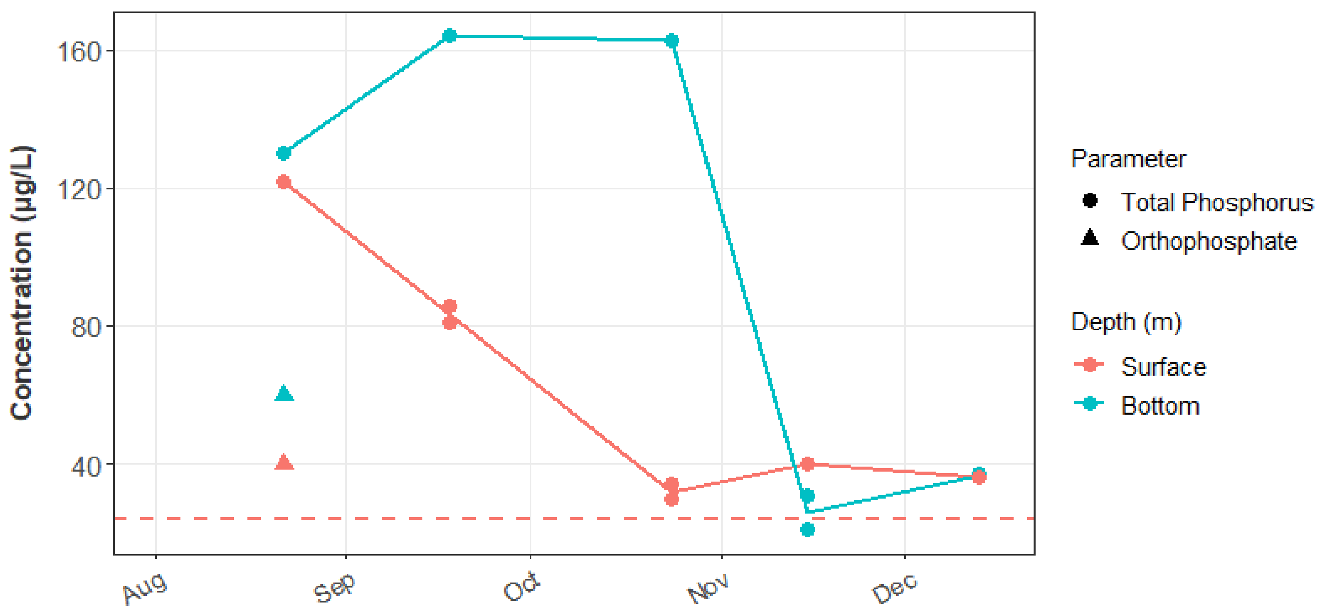
Phosphorus

Key nutrients affecting algae growth in freshwater environments are phosphorus and nitrogen. Other nutrients like silica are also important for some groups such as diatoms, but do not typically limit algae growth in lakes. Phosphorus is typically the most limiting nutrient in Pacific Northwest freshwater lakes. Total phosphorus (TP) is a combination of inorganic and organic forms of phosphorus, which can come from natural sources (e.g., wild animal waste, decaying vegetation, and resuspension or release from lake sediments) and anthropogenic sources (e.g., wastewater treatment plants, septic system failures, animal manure storage, and fertilizer runoff). Phosphorus is a concern in freshwaters because high levels can lead to accelerated plant growth and algal blooms, which, in turn, can result in low dissolved oxygen, decreases in aquatic diversity, and eutrophication.

TP was measured for the Lake Campbell treatment studies in the 1980s (Entranco 1987) and more routinely measured by the Samish Indian Nation since 2017. From this study, TP concentrations at the lake surface in 2023 ranged from 30 to 122 µg/L between August and December (Figure 18). Generally, TP were higher the deep-water samples, reaching maximum concentrations of 164 µg/L in October

(Figure 18) before declining to a minimum of 11 µg/L in November 2023. Elevated phosphorus in the hypolimnion is believed to be primarily due to the release of phosphorus from iron in lake bottom sediment. Even under well-mixed conditions, it expected that a layer of anoxia develops at the sediment-water interface in the summer given the high amount of organic matter in the lake sediments. Furthermore, elevated pH associated with algae bloom can also result in enhanced release of phosphorus from chemical bonds.

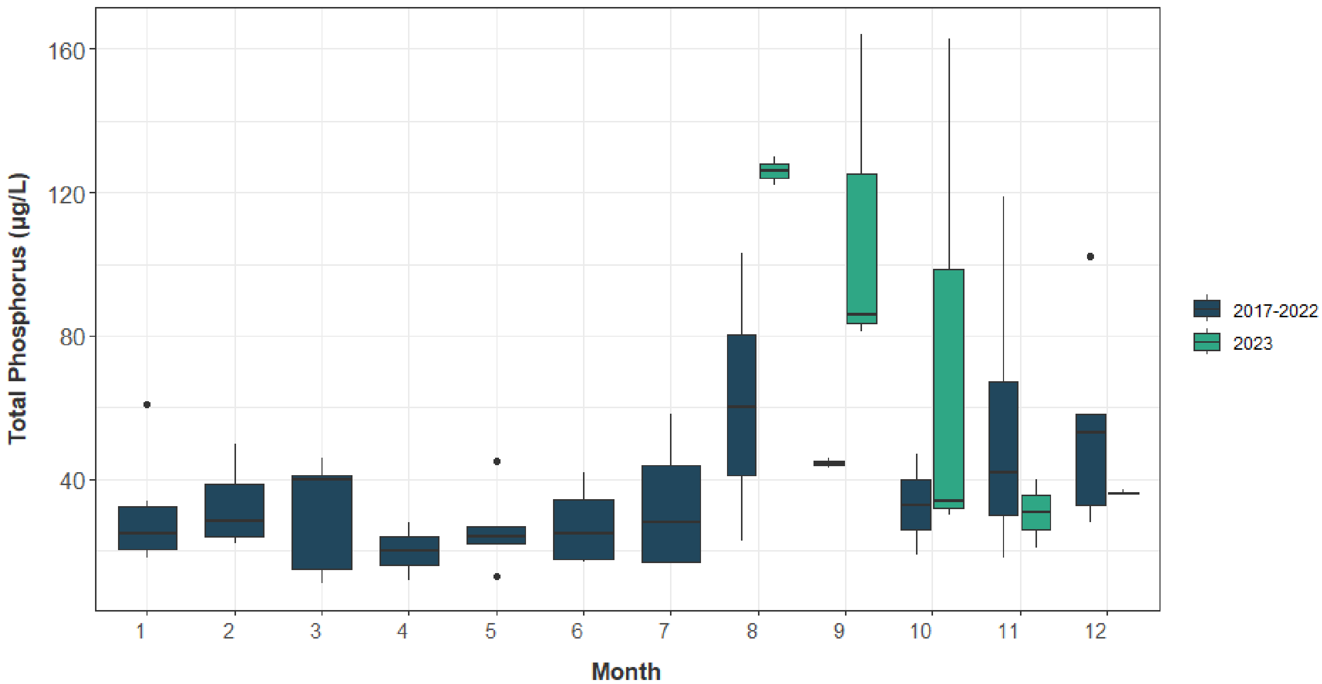
Figure 18. Total Phosphorus and Orthophosphate in Lake Campbell (August–December 2023).



Dashed line represents the lower total phosphorus threshold for classification as eutrophic for surface (1 m) waters (24 µg/L for summer average total phosphorus). All results were detected above the method detection limit.

Surface TP concentrations were similar to surface concentrations observed since 2017, which ranged from 11 to 119 µg/L (Figure 19). Historically, TP was greatest between July and September, reaching concentrations up to 84 µg/L (Table 8; Entranco 1987). These contemporary values (2017-2023) represent greater summertime peaks in TP than observed even prior to the first alum treatment.

Figure 19. Total Phosphorus Monthly Range Comparison in Lake Campbell (2017–2023).



Mesotrophic systems are defined by summer average surface TP concentrations between 12 and 24 µg/L while eutrophic systems exhibit average TP concentrations between 24 and 96 µg/L (see Table 9). Washington State Surface Water Quality Standards (WAC 173-201A) established an action level of 20 µg/L for summer average surface TP in Puget Sound lowland lakes (Ecology 2000). Summer mean concentrations greater than 30 µg/L generally result in undesirable algae growth that interferes with recreational uses of lakes in the Puget Sound region (Gilliom 1983). The summer mean total phosphorus concentration at the surface of Lake Campbell was 70.6 µg/L (see Table 7), exceeding the state action level of 20 µg/L, within the defining TP range for eutrophic systems, and surpassing the minimum suggested TP level for facilitating excessive algae growth.

Dissolved orthophosphate a form of phosphorus readily available for uptake by algae. In 2023, orthophosphate in Lake Campbell was sampled and filtered only once on August 22 (Figure 18); the remaining monthly samples were not filtered and the data therefore rejected. Like TP, orthophosphate in the hypolimnion was greater than at the surface. The relative amount of orthophosphate respective to TP indicates how much phosphorus is available for additional algae growth, while the remaining phosphorus is comprised by the standing crop of algae biomass.

Nitrogen

Nitrogen is another important nutrient for algae. Total nitrogen (TN) includes organic nitrogen (bound to organic matter) and dissolved inorganic nitrogen (comprised of nitrate, nitrite, and ammonia). Nitrogen is typically in plentiful supply in lakes, in part because nitrogen gas readily dissolves in the water from the atmosphere and nitrogen-fixing bacteria and some cyanobacteria species use it. Total Kjeldahl nitrogen

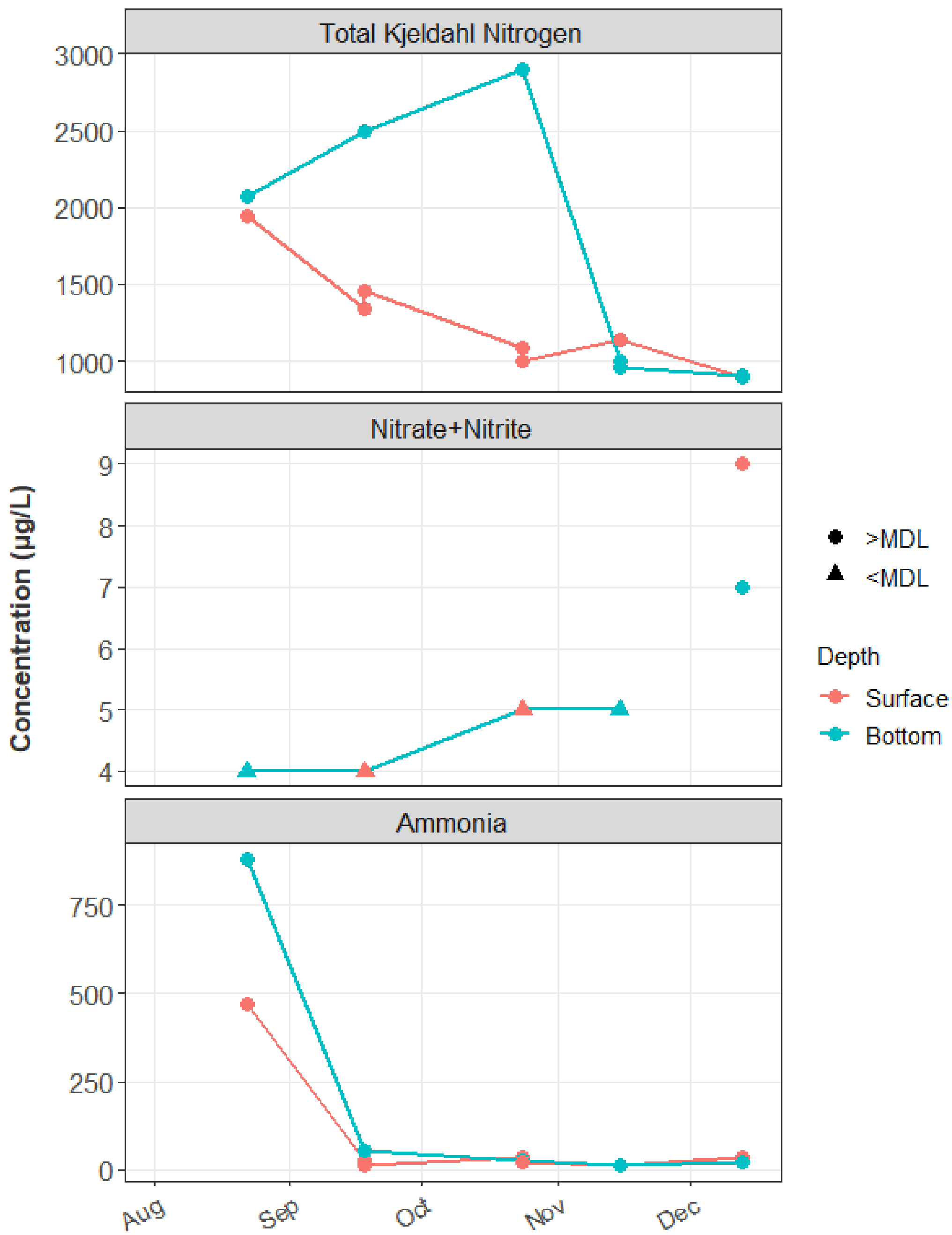
(TKN) is measure of nitrogen that includes total organic nitrogen and dissolved ammonia. TKN and nitrate+nitrite concentrations may be summed to calculate TN.

Total Kjeldahl nitrogen (TKN), nitrate+nitrite nitrogen, and ammonia nitrogen were measured from Lake Campbell on five occasions during the 2023 monitoring period. At the lake surface, TKN ranged from 900 to 1,940 µg/L, nitrate+nitrite nitrogen ranged from undetectable levels to 8.9 µg/L, and ammonia nitrogen was ranged from 11 to 470 µg/L. At the bottom of Lake Campbell, nitrogen fractions were typically greater than those measured at the lake surface, with maxima of 2,900, 7.1, and 880 µg/L, for TKN, nitrate+nitrite nitrogen, and ammonia nitrogen respectively (Table 6). Overall, TN in Lake Campbell was primarily organic nitrogen. Ammonia is typically present in bottom waters because it is readily produced by bacteria under anoxic conditions and is not typically detected in surface waters because it is a preferred source of nitrogen for algae growth. The detections of ammonia at the lake surface is likely due to mixing with the nutrient-rich hypolimnion.

Figure 20 below shows TKN increasing at the lake surface from August through October 2023, after which TKN concentrations substantially decline and nitrate+nitrite nitrogen increases. Ammonia, however, was greatest in August when DO was low and TP was elevated throughout the water column. This availability of both nutrients likely contributed to the algae blooms observed in August and September.

TKN and ammonia were not measured by the Samish Indian Tribe but were measured for the pre- and post- restoration studies in the 1980s. TKN historically peaked at up to 2,400 and 2,300 µg/L at the lake surface and bottom, respectively, in late summer prior to the alum treatment. TKN appeared to be well-associated with the amount of algae in the lake. TKN then decreased in the winter months as algae productivity decreased (Entranco 1987). Similarly, TKN in 2023 was elevated throughout the growing season, reaching a maximum of 1,940 µg/L at the surface and 2,900 µg/L in the hypolimnion (Table 6). Ammonia in 2023 (up to 880 µg/L) also resembled levels from before the alum treatment in 1985, which ranged from undetectable to approximately 725 µg/L compared to post-treatment concentrations which ranged up to 320 µg/L (Entranco 1987).

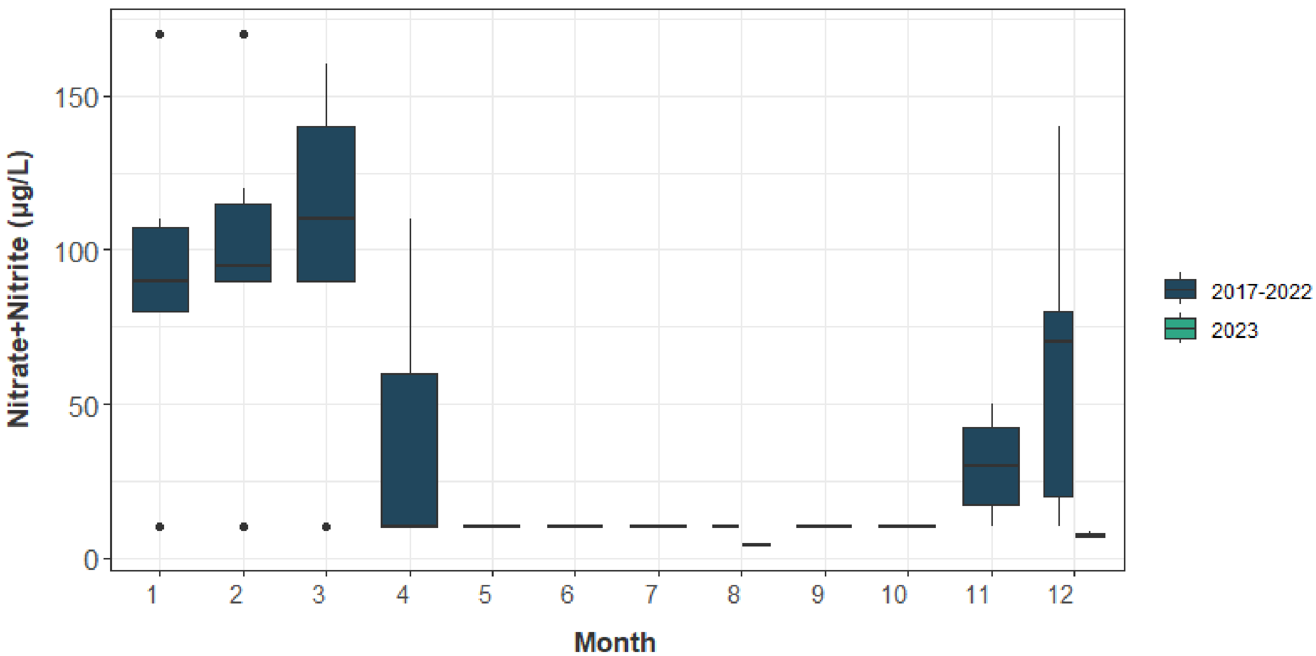
Figure 20. Nitrogen Fractions in Lake Campbell (August–December 2023).



MDL=method detection limit.

Nitrate+nitrite nitrogen historically exhibited a “strong seasonal trend”, wherein concentrations were greatest in the winter (up to approximately 475 µg/L) due to elevated surface and groundwater flows. Nitrate+nitrite nitrogen was historically lowest during the summer and fall (up to approximately 125 µg/L) as available nutrients were taken up by algae and weeds (Entranco 1987). In agreement with historical trends, nitrate+nitrite nitrogen in 2017–2022 was greatest at the lake surface during the winter months and undetectable during the summer (Figure 21), but recent maxima (up to 170 μg/L) were substantially less than historical maxima. Nitrate+nitrite nitrogen was low during the 2023 monitoring period (Figure 20), aligning with historical lows in late summer through fall.

Figure 21. Nitrate+Nitrite Monthly Range Comparison in Lake Campbell (2017–2023).



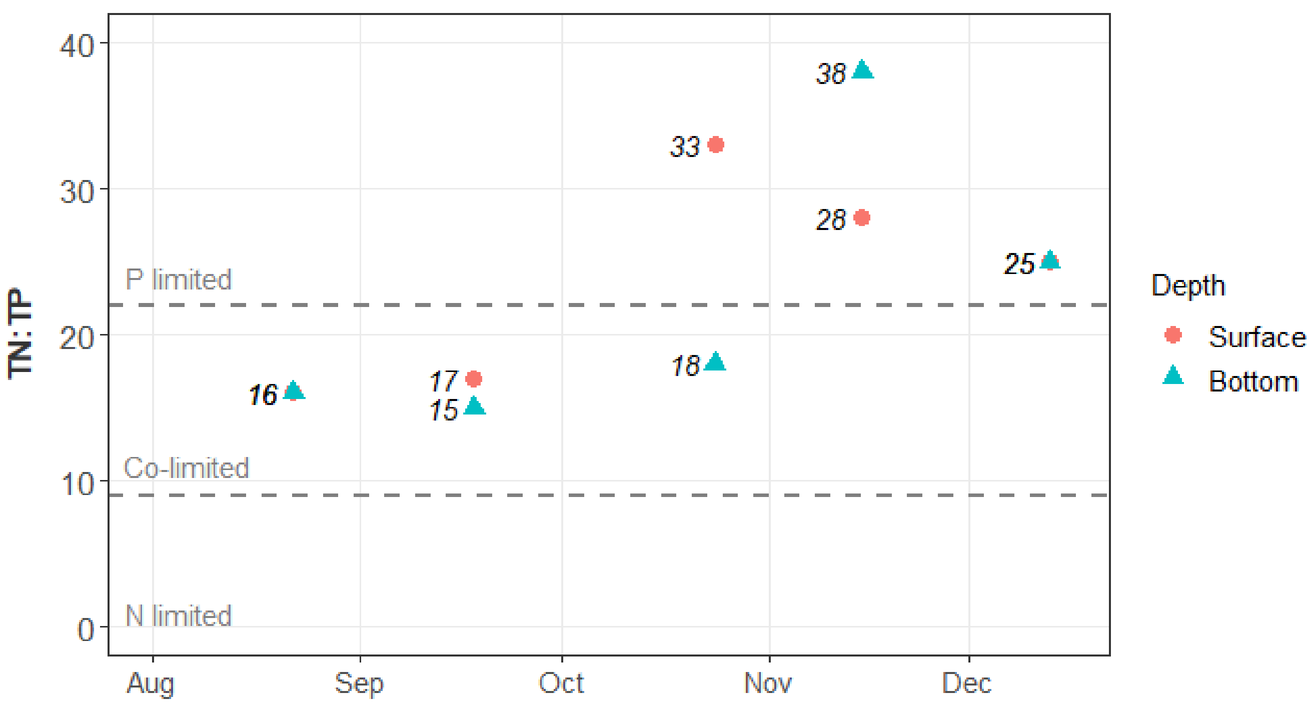
Total Nitrogen: Total Phosphorus

Although phosphorus is generally the primary limiting nutrient in most lakes and nitrogen is generally the primary limiting nutrient in most marine waters, a review of nutrient limitation literature concluded that most lakes appear to be limited over the short term (months) by both phosphorus and nitrogen (co-limitation), and possibly by other resources such as iron (Sterner 2008). Ratios of total nitrogen to total phosphorus (TN:TP) can be used to indicate which nutrient is most limiting to algae growth in the long term (Guildford and Hecky 2000). Based on nutrient relationships from 221 lakes, Guildford and Hecky (2000) found that ratios greater than 22 indicate phosphorus limitation, ratios less than 9 indicate nitrogen limitation, and ratios between 9 and 22 indicate co-limitation of algae growth by both phosphorus and nitrogen.

Figure 22 shows the TN to TP ratios for the five monthly monitoring dates in August through December when both TN and TP samples were collected. Italicized numbers adjacent to each point reflect the TN:TP values for each sample. TN:TP ratios ranged from 16 to 33 at the lake surface and 15 to 38 at the lake bottom, indicating that algae growth throughout the water column of Lake Campbell is largely limited by phosphorus, but is also co-limited by nitrogen in late summer and early fall. These ratios align with historical summer TN:TP means (27 prior to the alum treatment, and 35 post-treatment) indicating historical phosphorus limitation (Entranco 1987). Undetectable concentrations of dissolved inorganic nutrients (nitrate+nitrite) at the lake surface additionally suggests high nutrient uptake and limitation.

In Lake Campbell, TN:TP ratios indicate algae growth is controlled by phosphorus with nitrogen co-limitation. The parallel importance of nitrogen and phosphorus as co-limiters and the over-abundance of bioavailable nutrients (orthophosphate and ammonia) in Lake Campbell suggest that algae growth in 2023 was actually more likely limited by light or other nutrients, like iron. Regardless, controlling the amount of available nitrogen and phosphorus, particularly during the summer months, is key to reducing algae and cyanobacteria blooms.

Figure 22. TN:TP in Lake Campbell (August–December 2023).



Note: surface and bottom TN:TP values for August and December are equivalent and appear overlapping.

Trophic State

The Trophic State Index (TSI) is a common index of a lake's biological productivity, used to classify lakes into four trophic states based on their amount of nutrients and algae. Specifically, TSI is based on chemical and physical conditions measured in the lake surface layer and averaged over the summer months. Lake productivity is scaled between 0 and 100, as a continuum ranging from oligotrophic (e.g., low algae biomass and nutrients), to mesotrophic (e.g., moderate algae biomass and nutrients), to eutrophic (e.g., high algae biomass and nutrients), and to hypereutrophic (very high algae biomass and nutrients (Table 9). Oligotrophic lakes (TSI <40) are very clear, with low nutrient concentrations and low algal growth. These lakes are often located in mountains or undisturbed forests. Eutrophic lakes (TSI 50-70) have cloudy water with high nutrient concentrations and high algal growth. These lakes can be naturally productive but are often highly altered 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.

Table 9. Lake Trophic State Classification System.

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

Arithmetic mean values for summer months (typically June through September) in the surface layer of the lake.

Lakes often transition between trophic states over time, depending on several factors such as human disturbance or geological origin. Eutrophication is the process of a waterbody becoming more productive due to associated increases in nutrients. This can lead to decreased water clarity, increased occurrence and/or magnitude of harmful algal blooms, and high variation in pH and/or DO, which can further impact public uses and fish and wildlife. Trophic state classifications are commonly used as a general evaluation of lake health.

TSI values for Lake Campbell based on Secchi depth, chlorophyll-a, and total phosphorus are presented in Table 10. Of these metrics, chlorophyll-a TSI is the most directly relevant to lake productivity, whereas Secchi depth and total phosphorus are good predictors of productivity. The summer 2023 TSI values for all three indicator parameters indicate Lake Campbell is eutrophic.

Historical TSI values for Lake Campbell are also presented for total phosphorus, chlorophyll-a, and Secchi depth in Table 10. The TSI values for 2023 were generally similar to those observed previously except, notably, total phosphorus for which the mean summer concentration and consequently TSI value were both greater in 2023 than in any previously monitored year.

Table 10. Trophic State Index at Lake Campbell.

Summer[a]	Secchi depth		Chlorophyll-a		Total Phosphorus		Classification
	Mean (meters)	TSI	Mean (µg/L)	TSI	Mean (µg/L)	TSI	
1982	1.8	51.5	18	58.9	45	59.1	Eutrophic
1985	1.3	56.2	18	58.9	53	61.4	Eutrophic
1986	1.8	51.5	10	53.1	28	52.2	Eutrophic
2017	1.26	56.7	29.5	63.8	46.1	59.4	Eutrophic
2018	1.26	56.6	7.61	50.3	32.1	54.2	Eutrophic
2019	1.94	50.5	11.2	54.3	33.5	54.8	Eutrophic
2021	1.42	55.0	47.8	68.5	65.1	64.4	Eutrophic
2022	0.80	63.2	13.5	56.1	49.0	60.3	Eutrophic
2023	1.03	59.5	41.9	67.2	70.6	65.5	Eutrophic

a = summer is defined as May through October, except for 1982 (May–August), and 1985 and 1986 (May–September).

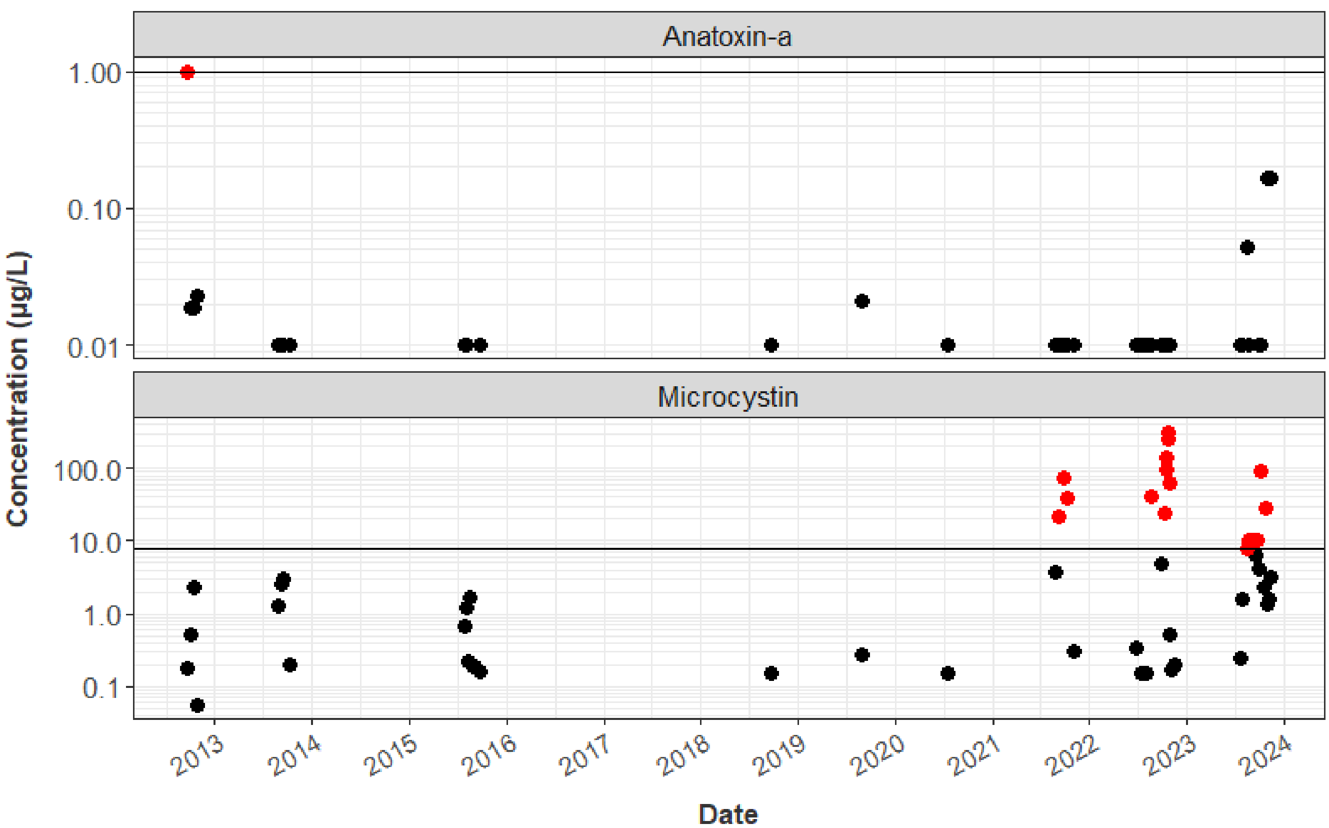
Data sourced from Entranco (1987) for 1982–1986, and from Samish Indian Tribe (unpublished) for years 2017–2022.

Cyanotoxins

In recent years, toxic and odorous algae scums have been observed throughout Lake Campbell and aggregating along the shorelines in late summer and persisting into the fall, often resulting in lake closures.

Algae and cyanotoxin samples are collected from Lake Campbell by Skagit County Environmental Health Division staff when surface scums are present and sent for analysis as part of the statewide Northwest Toxic Algae program managed by Ecology. Between 1 and 15 samples have been analyzed for cyanobacteria toxins each monitored year since 2012, for a total of 9 years of toxin monitoring since the inception of the program. Figure 23 presents cyanotoxin concentrations from samples collected between 2012 and 2023, where red points represent samples exceeding state recreational guidelines. Anatoxin-a is frequently not detected and has only been detected at or above the state criterion (1 µg/L) once, in 2012. Microcystin has exceeded the state criterion (revised from 6 to 8 µg/L in 2019) several times, all since 2021 (Figure 23).

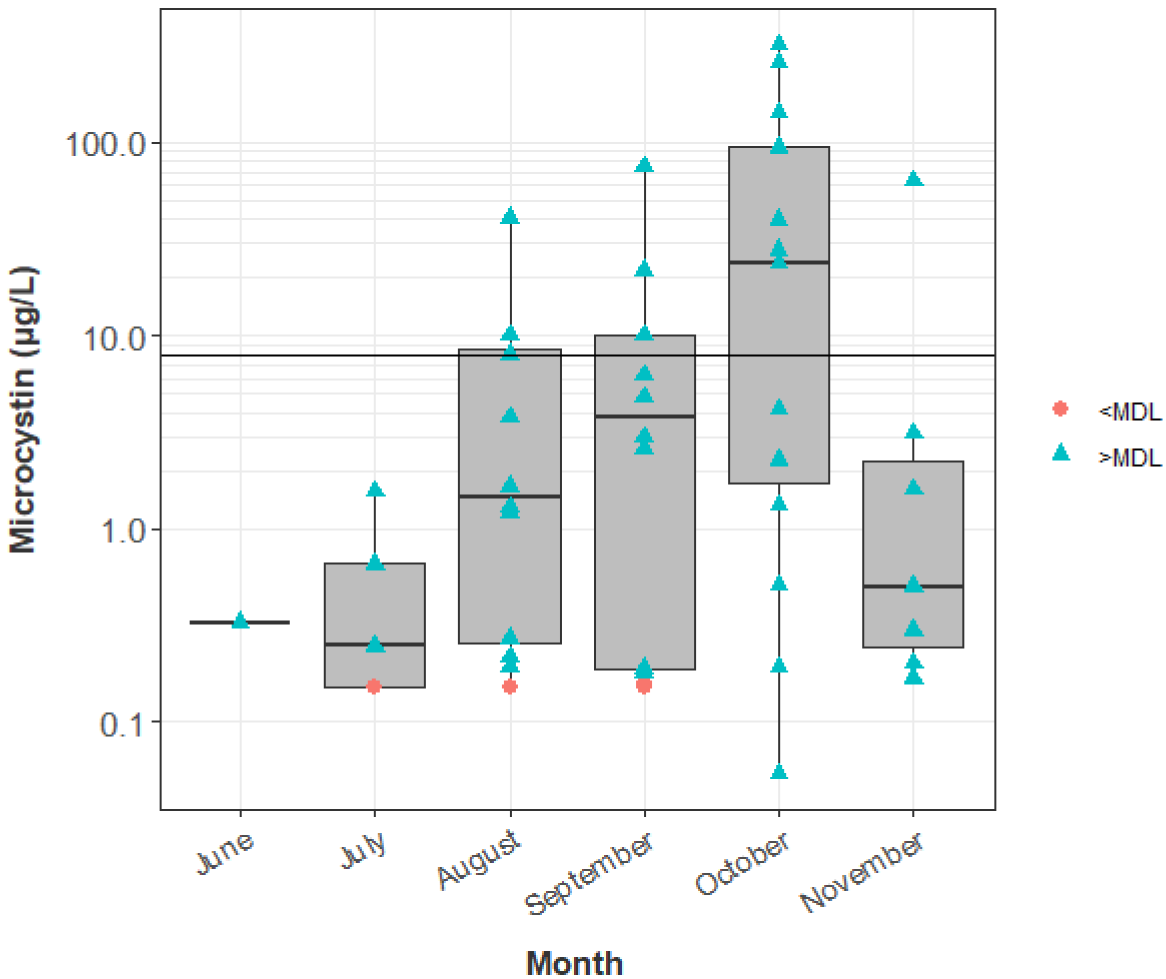
Figure 23. Cyanotoxins in Lake Campbell (2023–2023).



Data source: NW Toxic Algae (Ecology 2024). Note the log scale on the y-axes. Horizontal lines represent current state recreational guidelines (1 µg/L anatoxin-a, 8 µg/L microcystin). Guideline for microcystin prior to 2019 was 6 µg/L. Saxitoxin and cylindrospermopsin were tested but never detected.

Figure 24 shows the concentration of microcystin in Lake Campbell during all sampled months (June through November) between 2012 and 2023. The most frequently sampled months were August (n=12), September (n=12), and October (n=13). Concentrations in October are typically substantially higher than in other months, but exceedances of state criterion have occurred in all months from August through November.

Figure 24. Microcystin in Lake Campbell (2012–2023).



In 2023, samples were collected weekly from a persistent algae bloom beginning in late July and lasting through mid-November. Anatoxin-a was detected in only one sample (on August 16, 2023, at 0.052 µg/L) while microcystin was detected in all samples and met or exceeded the state criterion on seven occasions, nearly every week from mid-August through late October with concentrations ranging from 8 to 93.9 µg/L. The maximum microcystin concentration was measured on October 9, 2023.

Phytoplankton

As part of the LCMP project, phytoplankton (suspended algae) species were identified and enumerated in three monthly surface samples (August, September, and October 2023). Figure 25 shows the phytoplankton community composition on each of these sample dates, grouped by the following major algae classes: blue-green algae/cyanobacteria, cryptophytes, diatoms, dinoflagellates, euglenoids, and green algae. Composition is shown for both unit density and biovolume concentration.

Cyanobacteria were dominant by cell density in every month, at both the surface and bottom of the lake (Figure 25). Cyanobacteria commonly occur in filamentous or globular colonies such that the actual cell density is typically substantially higher than natural unit density (i.e., individual multi-cellular colonies). In contrast, most diatoms are unicellular, so the cell density is roughly equal to natural unit density. For these reasons, algae biovolume is a better unit for comparing phytoplankton species or class amounts, abundance, and dominance. By biovolume, cyanobacteria dominated the lake surface each monitored month (73.6–86.1 percent), with minor additional contributions of green algae, cryptophytes, and diatoms. At the lake bottom, however, cyanobacterial dominance (89 percent in August) declined over time (to 39.3 percent) giving way to dominance by diatoms in October. Specifically, diatoms grew from 4 percent in August, to subdominant (at 33.4 percent) in September to the dominant taxon (at 54.4 percent) in October (Figure 25).

From the six samples collected, five species of cyanobacteria were identified: *Aphanizomenon flos-aquae, Anabaena flos-aquae, Anabaena planctonica*, *Anabaena circinalus*, and *Microcystis aeruginosa* (Figure 26*)*. By cell density, *Microcystis* dominated the cyanobacteria community on all dates and at both depths. By biovolume, *Anabaena spp.* (now known as *Dolichospermum spp.*) together dominated the August and September communities, followed by a dominance by *Microcystis* in October at both the surface and bottom.

Additionally, the July 24, 2023, boat launch sample analyzed through the Northwest Toxic Algae program identified at least six cyanobacteria species: *Aphanizomenon* sp., *Dolichospermum* sp. (formerly *Anabaena* sp.), *Gloeotrichia* sp., *Microcystis* sp., *Phormidium* sp., and *Woronichinia* sp.

In all, the toxin-producing cyanobacteria genera most frequently observed in Lake Campbell in 2023 were *Dolichospermum* (previously known as *Anabaena*) and *Microcystis,* followed by *Aphanizomenon. Dolichospermum* is a filamentous cyanobacteria shown to produce microcystin and anatoxin-a. *Aphanizomenon* is a filamentous cyanobacteria shown to produce anatoxin-a. *Microcystis* is a small-celled colonial cyanobacteria that produces only microcystin, which is the most widespread cyanotoxin (Ecology 2024). *Microcystis* is the most common bloom-forming genus and is almost always toxic. Importantly, *Microcystis* seems to produce much higher amounts of microcystin toxin in Lake Campbell than its reduced biovolume would suggest. Other cyanobacteria*,* like *Gloeotrichia, Phormidium,* and *Woronichinia*, are also present in Lake Campbell but are not known to produce toxins in Washington state.

Entranco (1987) reports that the surface of Lake Campbell was dominated by cyanobacteria each month from May through October 1985 and May through September 1986 (comprising approximately 45 to 90 percent of phytoplankton). Cyanobacteria species included *Dolichospermum* sp., *Aphanocapsa* sp., *Microcystis aeruginosa*. The researchers also noted that mean summer algal biomass was reduced by 90 percent after the alum treatment, but no compositional shift was observed with a continuation of cyanobacterial dominance (Entranco 1987).

Figure 25. Phytoplankton in Lake Campbell (August-October 2023).

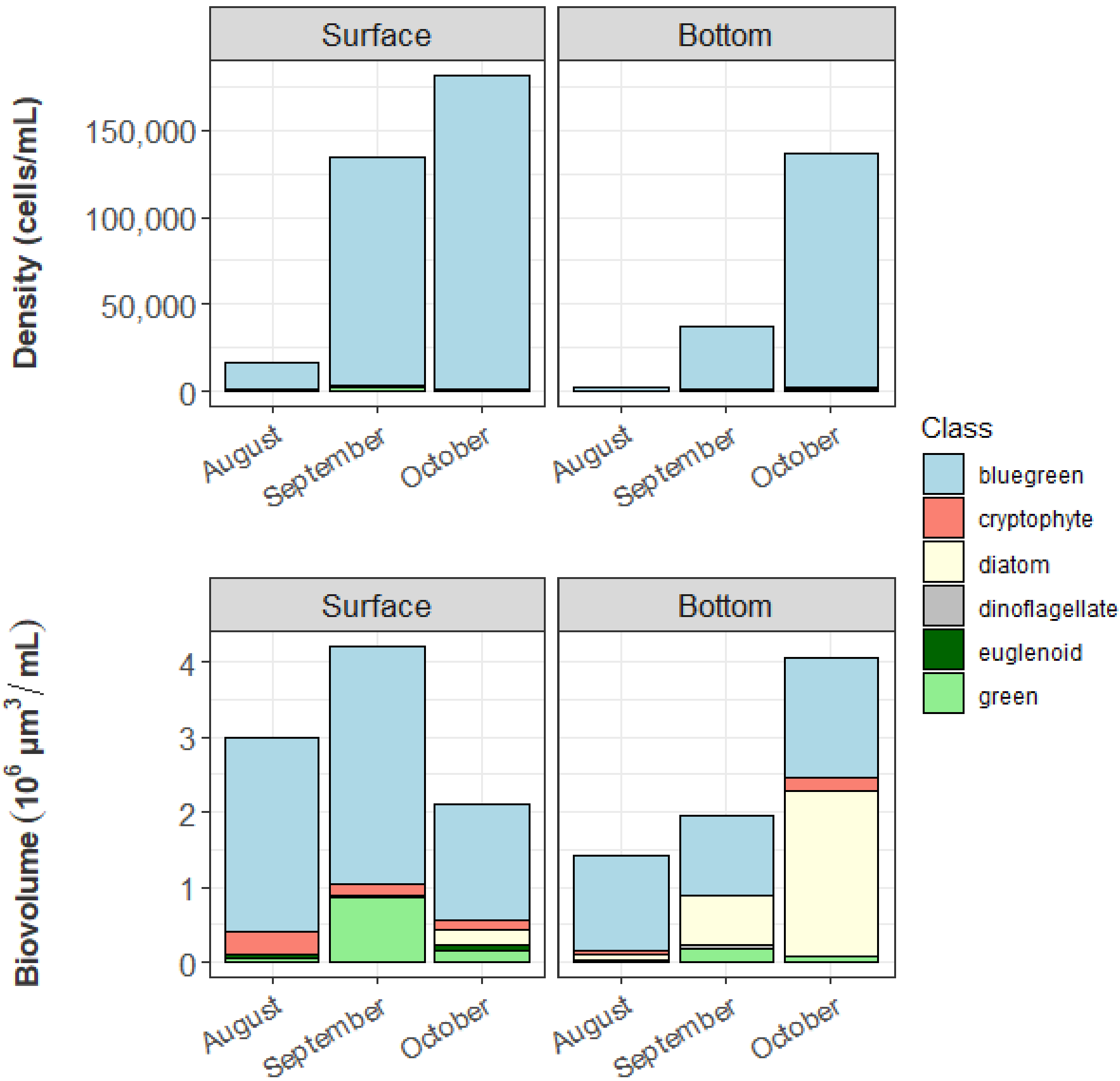
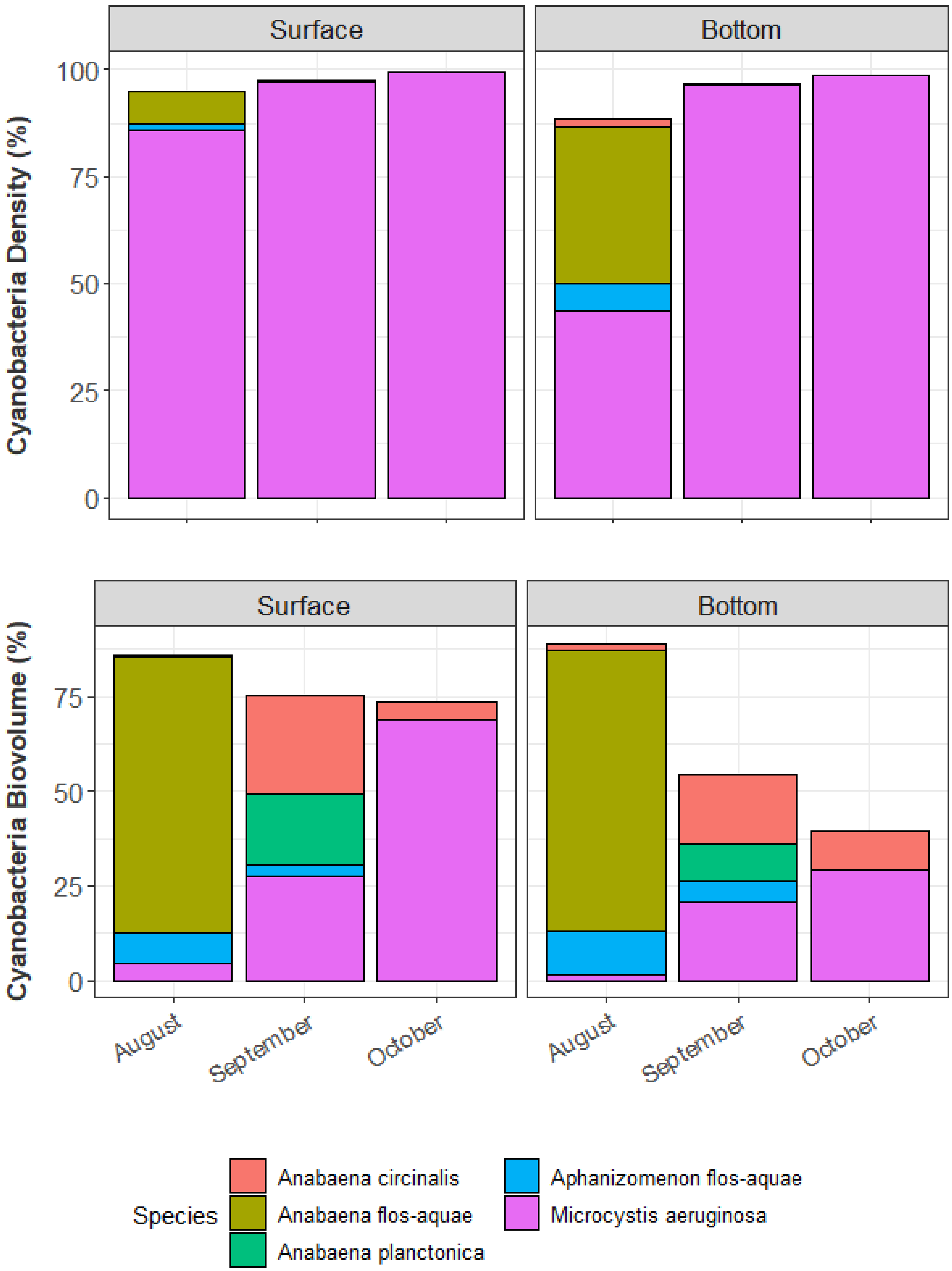


Figure 26. Cyanobacteria Composition in Lake Campbell (August-October 2023).



Zooplankton

Zooplankton, microscopic animals between 20 microns and 2 mm in size, are the primary consumers of phytoplankton and are an important food source for many forms of aquatic life, such as juvenile salmonids and other small fish. The types of zooplankton present in a water body and their feeding habits can influence and provide insight to algae dynamics.

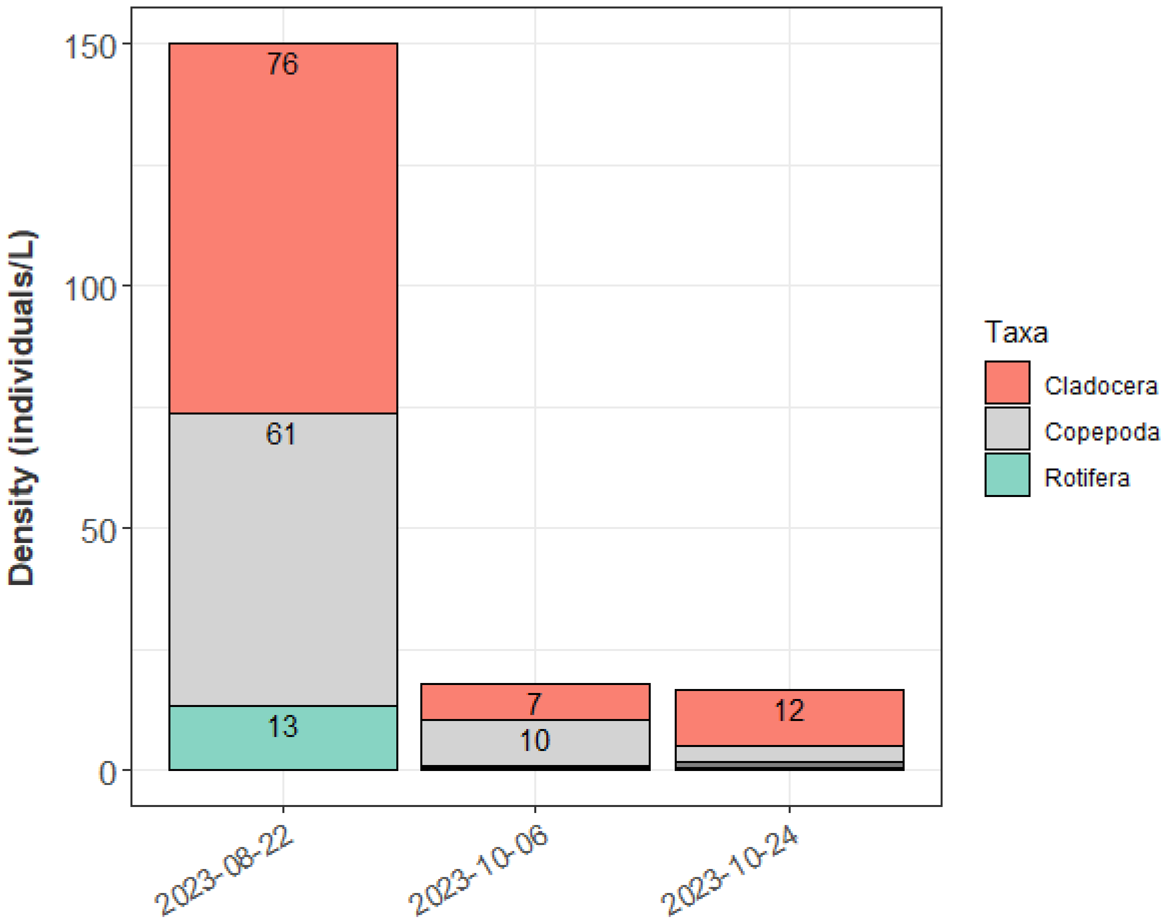
Zooplankton tows of the entire water column were performed from the deep lake site (CAM-DEEP) at Lake Campbell three times during 2023. Table 11 and Figure 27 show the 2023 zooplankton sampling results. Zooplankton tows resulted in a maximum in August of 150 individuals/liter, which substantially declined to low densities in early and late October (17.8 and 16.8 individuals/liter, respectively). In terms of composition by the average concentration of individuals in the water column, the zooplankton community in each sample was consistently dominated by cladocerans (41 to 51 percent), followed by copepods (19.6 to 54 percent), and rotifers (0.02 to 8 percent).

Table 11. Lake Campbell 2023 Zooplankton Composition.

Taxa/ Species	Density (No./liter)		
	8/22/2023	**10/6/2023**	**10/24/2023**
Bosmina longirostris	11.84	5.71	8.43
Ceriodaphnia reticulata	40.13	0.26	0.64
Chydorus sphaericus	3.29	–	–
Daphnia mendotae	17.11	–	2.49
Daphnae dubia	–	1.3	–
Diaphanosoma brachyurum	3.95	–	–
Copepods – Adult	36.32	9.61	3.21
Copepods – Nauplii	24.34	–	0.08
Ostracoda	–	0.52	1.61
Keratella sp.	13.16	–	–
Unidentified	–	0.35	0.32
Total	**150.14**	**17.75**	**16.78**

This dominance by larger crustacean zooplankton like cladocerans and copepods in Lake Campbell is potentially partially an artifact of the net used to collect zooplankton. A 50-micron mesh size would be too large for adequately collecting smaller zooplankton like rotifers. It is common for rotifers and other small zooplankton to dominate eutrophic systems, as also noted by Entranco (1987). However, cladocerans and copepods were also noted to dominate Lake Campbell both before and after alum treatments in 1985 and 1986, representing 65 and 23 percent of the means summer density, respectively. Crustaceans can dominate freshwater systems by biomass and can exert substantial trophic impacts which may cascade through the food web as important grazers of phytoplankton and critical food sources for juvenile fish. The abundance of large, predatory zooplankton and inedible phytoplankton may explain why there are so few rotifers in Lake Campbell. It is likely that multi-level trophic dynamics are controlling this unique community composition.

Figure 27. Zooplankton Composition in Lake Campbell (August and October 2023).



Lake Sediment Quality

To inform the LCMP, sediment cores were collected from the lake bottom at one deep (CAM-DEEP) and one shallow (CAM-SHALLOW) station in Lake Campbell. Each core was processed into five depth intervals and analyzed separately for phosphorus fractions, total iron, and percent solids (Table 12). This information was used to estimate internal phosphorus loading from sediment release into the deep waters under anoxic conditions and to estimate the amount of aluminum and lanthanum needed to inactivate the forms of phosphorus available for algae uptake.

The total solids content was low near the surface (<5 percent) and increased with depth in both cores. Iron concentrations ranged from 6,852 to 18,865 mg/kg, and was generally greater in the deep core. Iron-bound phosphorus concentrations were generally moderate (<31 mg/kg) except in the top six centimeters of the shallow station core where iron-bound phosphorus reached 177 mg/kg at the sediment surface and rapidly declined to nearly 2 mg/kg in the next few centimeters of sediment. The iron to phosphorus (Fe:P) ratios were high in both cores, ranging from 10.1 to 24.5 in the deep core and from 11.1 to 31.2 in the shallow sediment core. A total Fe:P ratio of 10 is believed to be the minimum for iron to regulate sediment phosphorus release (Caraco et al. 1993). If the sediment surface has oxygen and the Fe:P ratio is 15 or greater, then it is believed that internal loading may be altogether prevented (Jensen et al. 1992). A Fe:P ratio greater than 10 and moderate to high iron-bound phosphorus in the upper 10 cm of both cores indicate that iron is regulating phosphorus release into the anoxic hypolimnion of the lake to some degree.

Other sediment phosphorus release mechanisms can include resuspension from wave action, bioturbation by benthic invertebrates and fish, decay of aquatic plants, decay of organic matter in sediments by bacteria, acceleration of organic phosphorus release by elevated temperatures, and acceleration of iron phosphorus release by high pH during algae blooms (Sondergaard et al. 2003). The complex mechanisms of internal phosphorus loading and how they vary with sediment and other lake characteristics is not well understood.

Phosphorus levels varied between the cores with the deep core exhibiting higher concentrations of total phosphorus and aluminum-bound phosphorus, and similar concentrations of iron-bound phosphorus and organic phosphorus. Calcium-bound phosphorus was generally greater in the shallow core. Biologically unavailable aluminum-bound phosphorus typically made up about a quarter to a third of total phosphorus. Organic phosphorus was the most substantial component, comprising 36 to 70 percent of total phosphorus, and was shown to be mostly biogenic (52 percent on average), which generally represents dead algae and other organic matter grown in the lake that decays more rapidly than the remaining organic phosphorus typically originating from the watershed. Loosely bound phosphorus (orthophosphate) was below detection in all samples, which is not uncommon in lake sediments because it readily diffuses into the water, but it also may have been due to binding of orthophosphate to iron when samples became oxidized during sample transportation and holding prior to analysis.

Concentrations of sediment phosphorus fractions available for release are summarized in Table 13. Results are summarized for the top 10 cm depth intervals because this is the zone where the most biologic activity and chemical diffusion into the water is occurring and is used as the appropriate target for phosphorus inactivation. Active phosphorus consists of chemically mobile phosphorus (sum of loosely- and iron-bound phosphorus) and biogenic phosphorus (readily degradable organic phosphorus). Active phosphorus represented approximately 27 to 51 percent of the total phosphorus in the biologically active sediment zone.

Both the Phase 1 Study (Entranco 1983) and Phase 2 Study (Entranco 1987) collected sediment samples by Eckman dredge grabs from eight locations, which were combined and homogenized for use in incubation experiments to quantify sediment phosphorus release. Water samples throughout the incubation were analyzed for orthophosphate, TP, ammonia nitrogen, nitrate+nitrite nitrogen, and TKN. Sediment samples were not analyzed.

Table 12. Lake Campbell Sediment Chemistry (8/22/2023).

Core Sample Site	Depth Interval (cm)	Loosely Bound P (mg/kg-DW)	Iron Bound P (mg/kg-DW)	Aluminum Bound P (mg/kg-DW)	Calcium Bound P (mg/kg-DW)	Biogenic [a] P (mg/kg-DW)	Organic P (mg/kg-DW)	Total P (mg/kg-DW)	Total Fe (mg/kg-DW)	% Solids	Percent Organic	Fe:TP Ratio
CAM-DEEP	0-2	<2	14.4	379	99.7	684	995	1,487	15,057	2.64%	67%	10.1
	4-6	<2	30.5	276	107	486	750	1,164	14,837	4.00%	64%	12.7
	8-10	<2	14.5	313	159	389	662	1,148	15,658	4.53%	58%	13.6
	12-16	<2	10.4	208	151	201	407	777	18,865	5.20%	52%	24.3
	20-26	<2	27.5	187	151	162	320	686	16,812	6.54%	47%	24.5
CAM-SHALLOW	0-2	<2	177	292	132	508	790	1,391	15,363	4.19%	57%	11.1
	4-6	<2	2.16	128	173	143	273	577	16,321	10.4%	47%	28.3
	8-10	<2	9.24	89.0	175	64.3	154	427	13,322	12.5%	36%	31.2
	12-16	<2	28.4	108	68.8	31.6	109	315	6,852	7.66%	35%	21.8
	20-26	<2	10.3	109	79.1	53.9	144	342	9,817	8.45%	42%	28.7

[a] Biogenic P is a fraction of the organic P not included in the calculation of total P.

P = phosphorus; Fe = iron

mg/kg-DW = milligrams per kilogram of dry weight; cm = centimeters

Table 13. Depth Interval Summarized Sediment Phosphorus Fractions.

Core	Depth Interval (cm)	Mobile P (mg/kg)		Biogenic P (mg/kg)		Active P (mg/kg)		Total P (mg/kg)		% Active P
		DW	WW	DW	WW	DW	WW	DW	WW	
CAM-DEEP	0-10	20	0.8	519	18.4	539	19.1	1266	45.9	43%
	12-26	19	1.2	181	10.5	200	11.7	731	42.6	27%
CAM-SHALLOW	0-10	170	12.2	238	14.7	408	26.9	798	57.2	51%
	12-26	108	8.7	43	3.5	151	12.2	502	56.7	30%
Average	**0-10**	**95**	**6.5**	**379**	**16.5**	**474**	**23.0**	**1032**	**51.6**	**46%**

Mobile P = Labile P + Iron P

Active P = Mobile P + Biogenic P

DW = dry weight

WW = wet weight

Watershed Monitoring Results

Nutrients were sampled and stream velocities and depth were measured by County staff at four inlets to Lake Campbell between August 2023 and January 2024. Eleven events were sampled, six of which were base flow events and the remaining five were storm flow events. Many of the inflow streams were often dry or not flowing during the monitoring event. Nutrient summary statistics are presented in Table 14, calculated discharge is presented in Table 15, and results are discussed in the following sections.

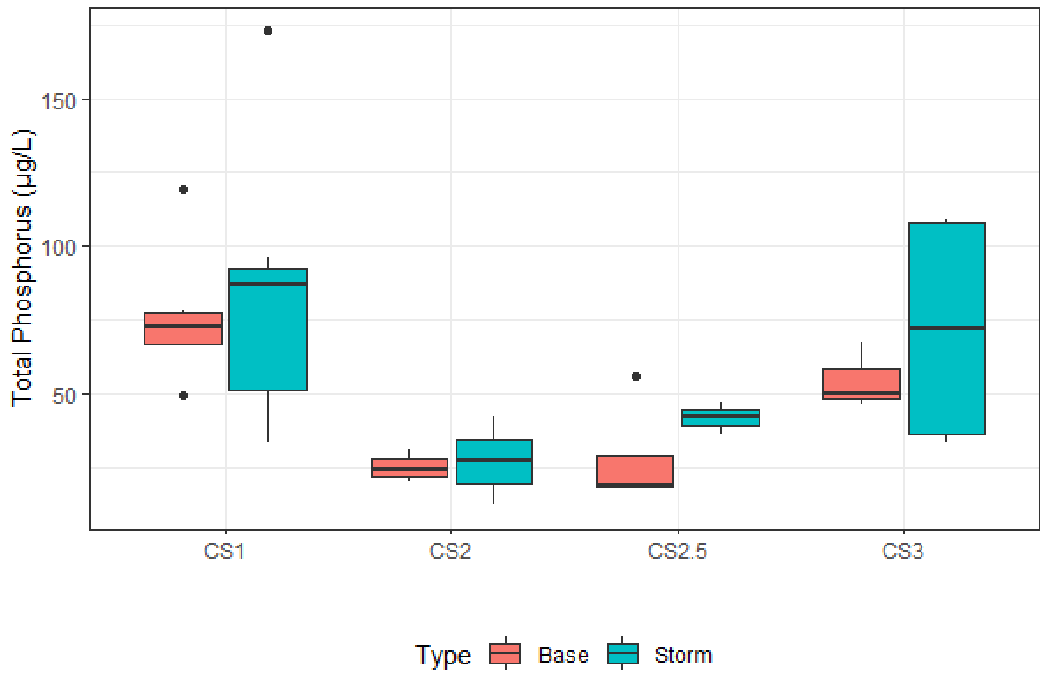
Inflow and Outflow Nutrients

Total phosphorus in these inflows, when positive flow was observed, ranged from 12 to 49 µg/L. Of all inflows, the concentrations observed at CS1 (33-173 µg/L), which drains runoff from SR-20, were most similar to concentrations observed in Lake Campbell (21-164 µg/L). Mean total phosphorus and overall variation were typically greater during storm flow events than during base flow events at each station (Table 14; Figure 28), except concentrations measured from the January 22, 2024 event. Comparing differences between stations, mean concentrations during both storm and base flow were highest at CS1 and CS3 (Figure 28).

Table 14. Lake Campbell Watershed August 2023 – January 2024 Water Quality Summary Statistics.

Parameter	MDL and Unit	Station	Event Type	N	Percent non-detects	Min.	Mean	Max.
Total Phosphorus	1.9 µg/L	CAM-OUT	Base	1	0	317	317	317
		CS1	Base	6	0	49	76	119
			Storm	7	0	33	83	173
		CS2	Base	3	0	20	25	31
			Storm	2	0	12	27	42
		CS2.5	Base	4	0	18	28	56
			Storm	3	0	36	42	47
		CS3	Base	3	0	46	54	67
			Storm	5	0	33	72	109
Orthophosphate	3.2 µg/L	CS1	Base	2	0	60	60	60
Total Kjeldahl Nitrogen	84.8 µg/L	CAM-OUT	Base	1	0	4180	4180	4180
	26.7-84.8 µg/L	CS1	Base	6	0	560	810	1050
			Storm	7	29	85	837	2150
	26.7 µg/L	CS2	Base	3	0	370	427	510
	26.7-84.8 µg/L		Storm	2	0	490	625	760
		CS2.5	Base	4	0	370	483	620
			Storm	3	0	460	510	600
		CS3	Base	3	0	680	910	1240
			Storm	5	0	600	828	1110
Ammonia	4.5 µg/L	CAM-OUT	Base	1	0	620	620	620
	4.5-8.8 µg/L	CS1	Base	8	0	13	26	40
			Storm	7	0	12	60	130
	4.5-6.6 µg/L	CS2	Base	3	0	12	69	180
			Storm	2	0	11	16	21
		CS2.5	Base	4	0	7	11	17
			Storm	3	33	7	15	19
		CS3	Base	3	0	10	25	43
			Storm	5	20	7	14	42
Nitrate+Nitrite	4.2 µg/L	CAM-OUT	Base	1	0	700	700	700
	4.2-4.7 µg/L	CS1	Base	8	0	50	416	800
			Storm	6	0	60	268	630
	4.7 µg/L	CS2	Base	3	0	170	203	270
			Storm	2	0	90	150	210
	4.7 µg/L	CS2.5	Base	4	0	290	505	1090
			Storm	3	0	100	300	400
Nitrate+Nitrite	4.7 µg/L	CS3	Base	2	0	140	205	270
			Storm	5	0	6	104	310

Figure 28. Total Phosphorus in Inflows to Lake Campbell (August 2023–January 2024).



Similar to TP, CS1 and CS3 had the highest levels of TKN to Lake Campbell with concentrations ranging 85 to 2,150 µg/L (Figure 29). Nitrate+nitrite was greatest at inflows CS1 and CS2.5 (Figure 30), and the greatest observations of ammonia were recorded at CS1 and CS2 (Figure 31). Unlike TP, concentrations of these nitrogen fractions did not vary consistently with event type; rather, some base flow events exhibited greater concentrations of nitrogen than during storm events.

Outflow from Lake Campbell was incidentally sampled during a single sampling event at the lake's outlet. During this event, the outlet exhibited nutrient concentrations far greater than any inflow concentrations (Table 14).

Figure 29. Total Kjeldahl Nitrogen in Inflows to Lake Campbell (August 2023–January 2024).

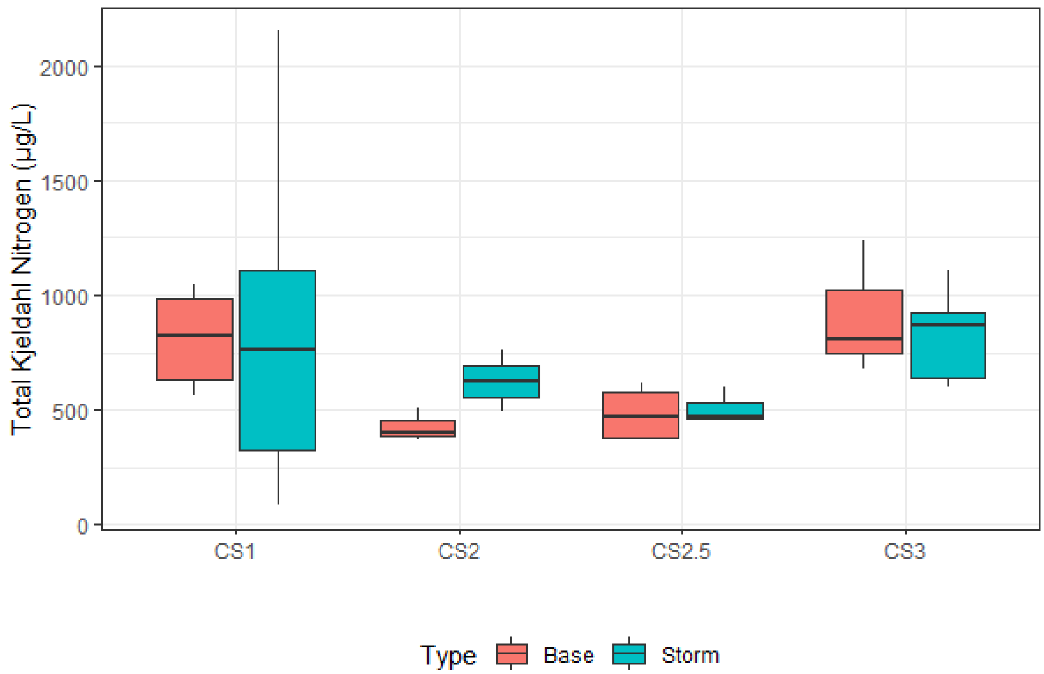


Figure 30. Nitrate+Nitrite in Inflows to Lake Campbell (August 2023–January 2024).

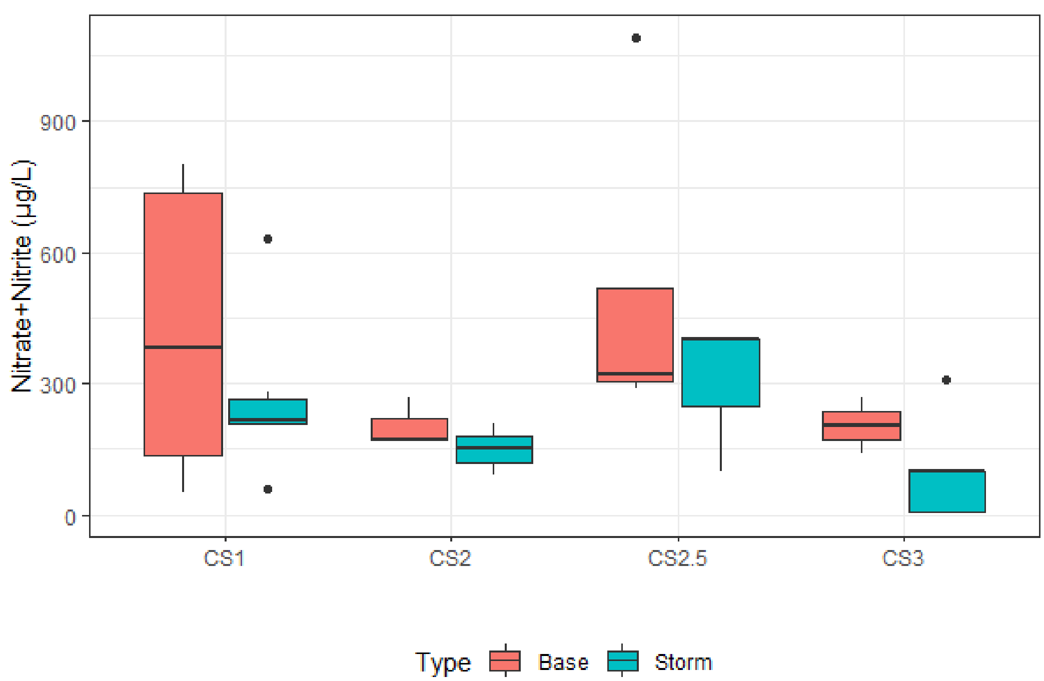
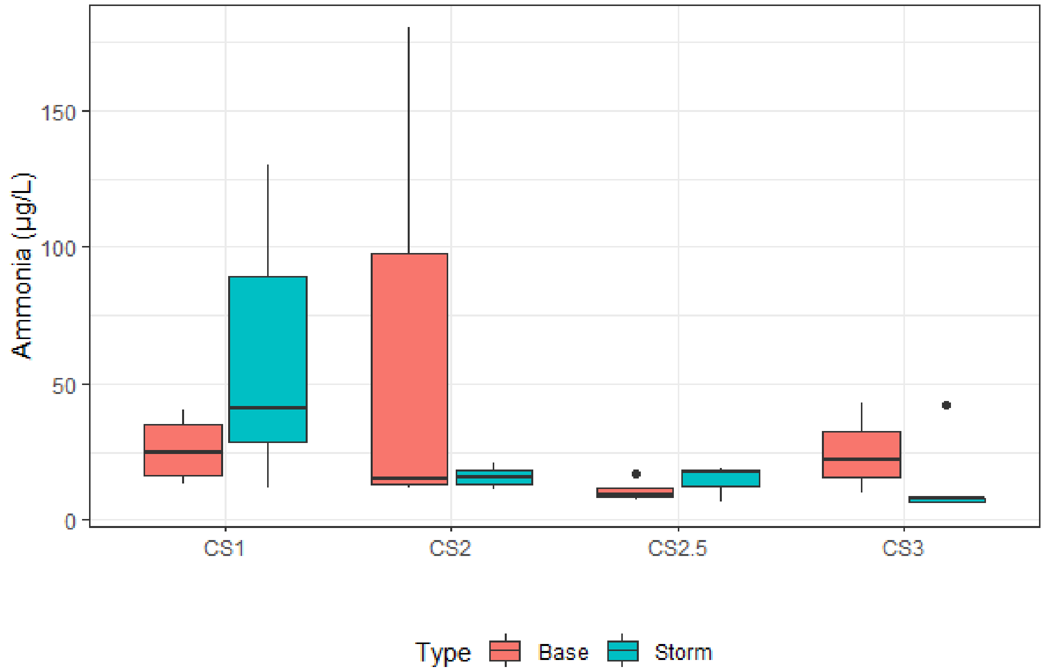


Figure 31. Ammonia in Inflows to Lake Campbell (August 2023–January 2024).



Inflow and Outflow Discharge

Figure 32 below shows the range of discharge measurements for validated data at each station for each storm flow and base flow monitoring events, calculated from measurements of stream velocity and depth. See the *Data Quality Assurance* section above for a description of data rejected and rationale. As expected, the mean inflow discharge was much higher during storm events than base flow events, with discharge from one event (January 22, 2024) skewing base flow maxima closer to those observed during storm flow events. Overall, surface inflows to Lake Campbell were very low throughout the monitoring period, with frequent lack of observable flow. Inflow may instead be infiltrating, following a groundwater flow path to the lake.

Table 15. Lake Campbell Watershed 2023 Stream Discharge Summary Statistics.

Parameter	MDL and Unit	Station	Event Type	N	Percent non-detects	Min.	Mean	Max.
Discharge	0.01 cfs	CAM-OUT	Base	5	100	0	0.094	0.471
			Storm	4	50	0	0.090	0.336
		CS2	Base	5	60	0	0.129	0.512
			Storm	5	60	0	0.078	0.278
		CS2.5	Base	5	80	0	0.029	0.146
			Storm	4	50	0	0.029	0.110
		CS3	Base	5	60	0	0.171	0.583
			Storm	4	50	0	0.150	0.493

Figure 32. Inflow Discharge to Lake Campbell (August 2023–January 2024).

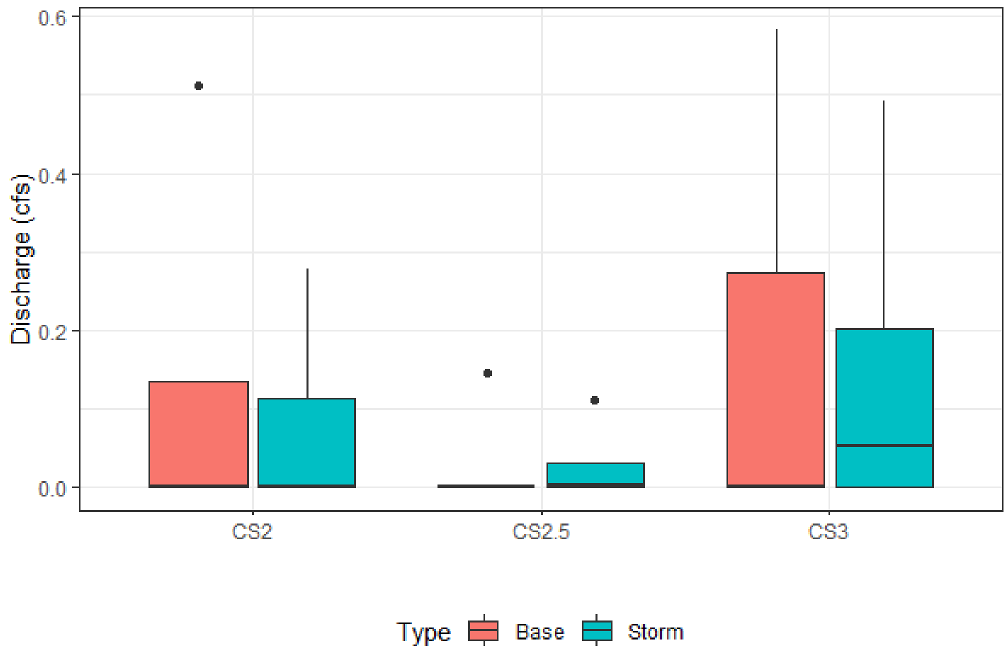
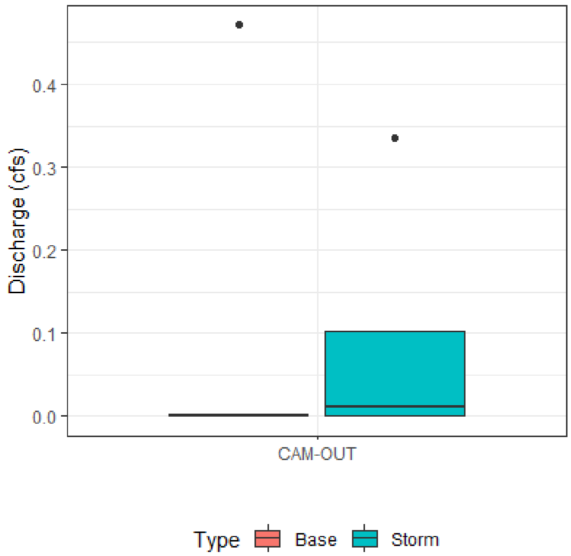


Figure 33 shows discharge measurements collected from the lake outlet (CAM-OUT). No measurable lake outflow was observed during the base flow sampling events, apart from one event on January 22, 2024 which was more akin to a storm flow event than a typical base flow event. Beaver activity largely restricted lake outflow in 2023–2024, where only high lake levels resulting from multiple fall and winter storms resulted in measurable flow at the lake outlet.

Figure 33. Outflow Discharge from Lake Campbell (August 2023–January 2024).



Lake Campbell Partial Hydrologic Budget

A partial year hydrologic budget was developed for September 2023 to March 2024. This water budget was used to support the comparison to the WY1986 hydrologic budget to current conditions and to develop appropriate estimates for a contemporary lake hydrologic budget.

A lake's hydrologic budget refers to the quantification and analysis of the various inflows, outflows, and storage changes that contribute to the overall water balance of the lake over a defined period, typically annually. This concept is vital for understanding the hydrological dynamics and sustainability of a lake ecosystem. A comprehensive description of a lake's water budget involves the following components:

- Precipitation (P): Precipitation represents the input of water to the lake in the form of rain and snowfall.
- Evaporation (E): Evaporation refers to the loss of water from the lake surface due to the conversion of liquid water to water vapor driven by solar radiation and atmospheric conditions. Evaporation rates vary based on factors such as air temperature, humidity, wind speed, and lake surface area.
- Runoff (R): Runoff includes all surface water inflows to the lake from its watershed. Runoff can result from rainwater and snowmelt, and it carries nutrients, sediments, and pollutants into the lake. In Lake Campbell, Runoff consists of inputs from several intermittent inlets (Q_{Inlets}). and direct stormwater discharges from areas around the lake (Q_{Storm}).
- Groundwater Inflow (GW_{In}): Groundwater inflow represents the subsurface flow of water from aquifers into the lake. This contribution can significantly influence the lake's water budget, particularly in regions with permeable soils and high groundwater recharge.
- Groundwater Outflow (GW_{Out}): Groundwater outflow represents the subsurface flow of water from lake into aquifers.

- Outflow (O): Outflow consists of water leaving the lake via surface water. In Lake Campbell, the outflow is Campbell Creek.
- Change in Storage (ΔS): This component accounts for the change in the lake's water volume stored over the defined time period. Positive values indicate an increase in storage (lake level rise), while negative values signify a decrease (lake level decline).

The water budget equation can be expressed as the difference between inflows and outflows:

$$\Delta S = P + Q_{Inlets} + Q_{Storm} + GW_{IN} - (O + E + GW_{Out})$$

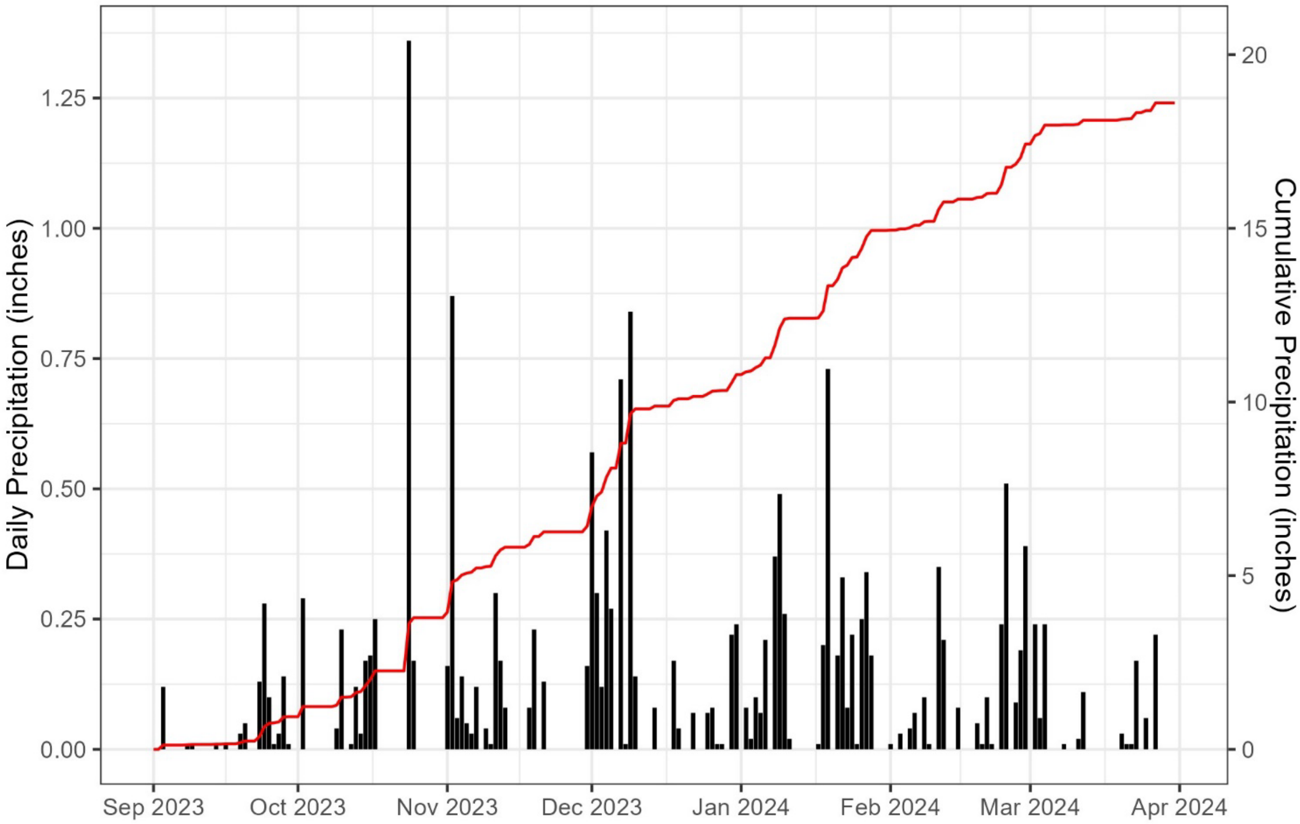
Because of the difficultly in measuring groundwater flows, the groundwater component is often expressed as the net (GW_Net), calculated as the difference between inflows and outflows plus the change in storage:

$$GW_{Net} = GW_{In} - GW_{OUt} = (Ouflows + \Delta S) - Inflow$$

Precipitation

Daily rainfall data (Figure 34) from the Anacortes AgWeatherNet Station operated by Washington State University in partnership with the Skagit Conservation District was used and were multiplied by the daily lake surface area to calculate the volume of direct precipitation.

Figure 34. Daily and cumulative rainfall measured at Anacortes AgWeatherNet Station (September 1, 2023 to March 31, 2024).

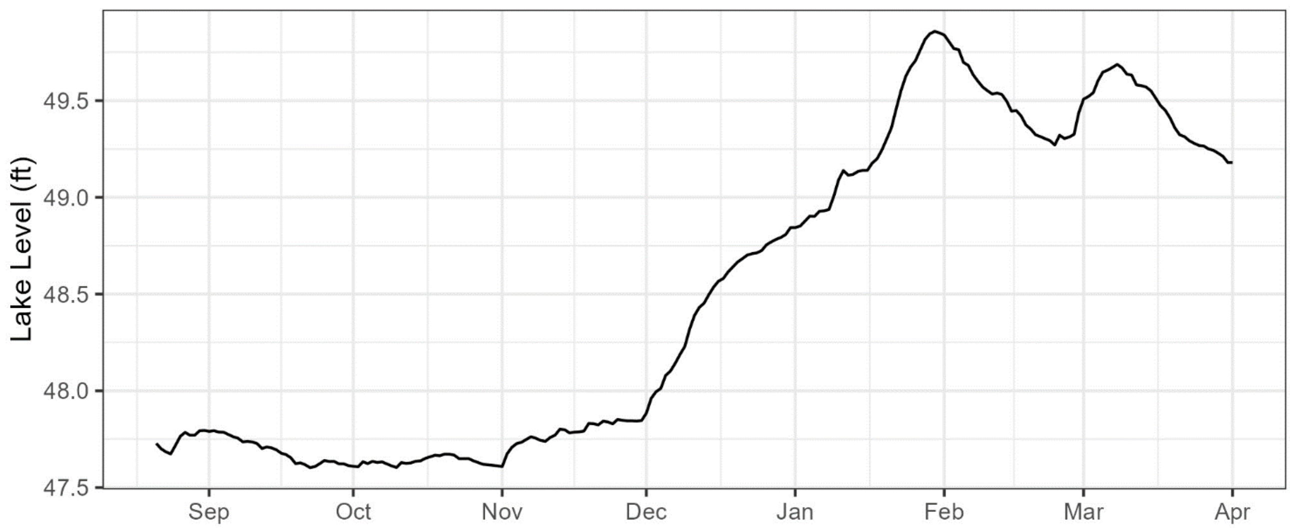


Change in Lake Storage

Continuous lake level measurements were recorded by Skagit County using a level logger mounted on a dock at station LVL-CAM (Figure 35). The volume of water in the lake for each day was estimated based on the lake level and lake bathymetry, and the daily changes in volume were calculated. Volumes were summed monthly.

The level of the lake began increasing substantially in December 2023, reaching 49.9 feet above sea level at the end of January 2024, then the level slowly declined to approximately 49.25 feet during the month of February. Then, rains in late February and early March brought lake level up to by approximately 1 foot.

Figure 35. Lake Campbell Level for August 21, 2023, to March 31, 2024.



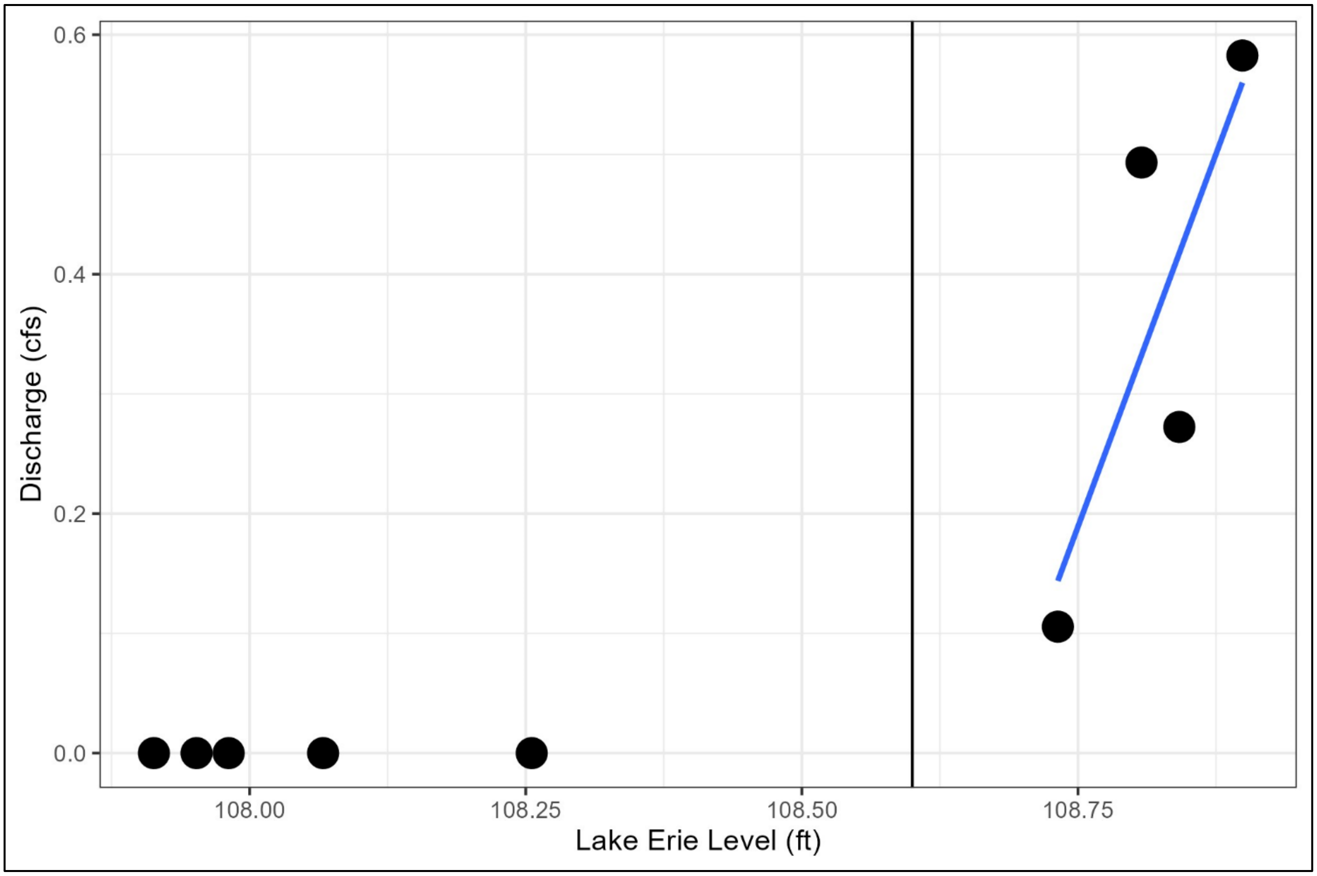
Lake Inlets

Gaged Stations

Under the QAPP, two stations were planned to have continuous water level loggers installed to support development of a rating curve, CS1 and ERIE-LVL. The measurements of the CS1 logger were impacted by lake backwatering and could not be used to develop a rating curve, and therefore the water inputs from CS1 were developing using the method for non-gaged stations discussed below.

The ERIE-LVL was used to develop a rating curve with the CS3 monitoring site. Discharge at CS3 was measured using a current meter to measure the velocity and depth of water. The instantaneous discharge measurements and the Lake Erie level were used to develop a rating curve (Figure 36). Four watershed monitoring events were used to develop the rating curve. There were five additional monitoring events where no flow was observed. This rating curve was used to calculate daily discharge across the monitoring period, including the period with interpolated lake level values (Figure 37).

Figure 36. Lake Erie Outlet (CS3) Discharge-Level Relationship.

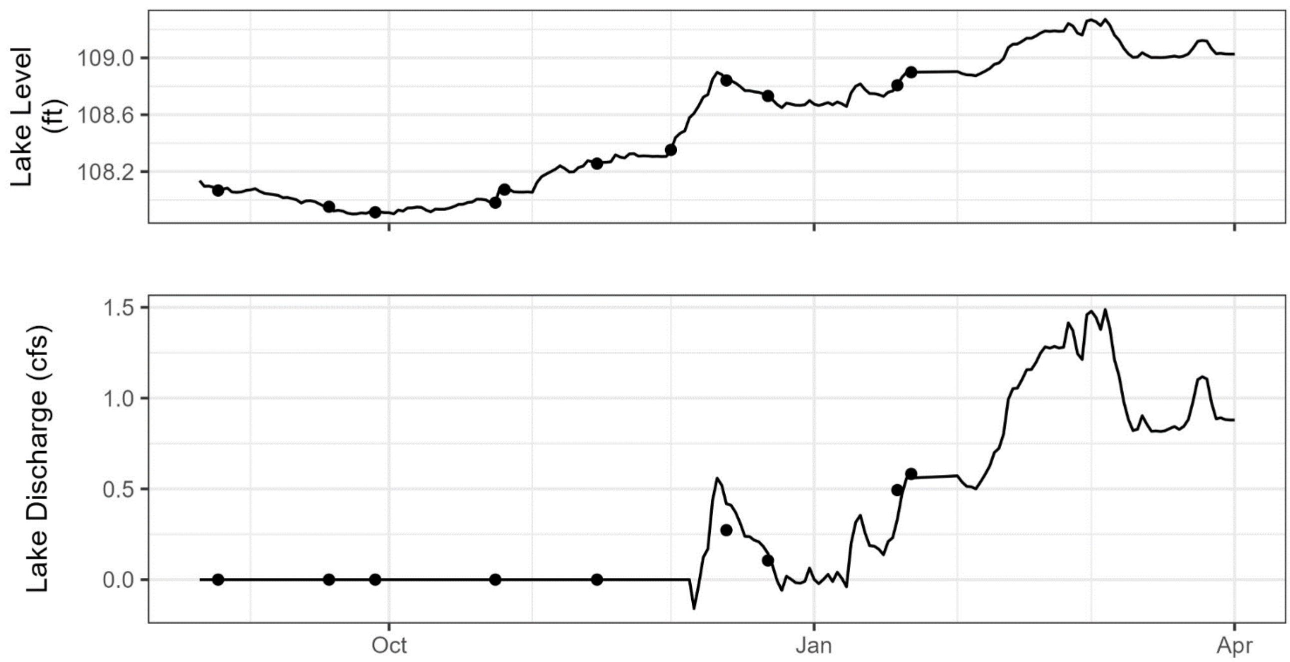


Vertical line is estimated elevation where no discharge from Lake Erie will occur (108.6 ft).

Best fit line equation: Discharge = -270.64 +2.49*Lake_Level (R^2 = 0.65).

Importantly, the rating curve only capture lake level up to about 108.9 feet, but the observed lake level reached 109.3. feet. Therefore, some extrapolation was necessary, because a linear rating curve was developed (as opposed to a logarithmic curve), the effect of the extrapolation is minimized. The extrapolated values should be sufficient for high-level water budget estimation for Lake Campbell, but additional data are recommended to develop an expanded rating curve.

Figure 37. Lake Erie (CS3) outlet estimated discharge.



Non-gaged Stations

We estimated surface inflows separated by base flow and storm flow. We used monitored base flow discharge measurements collected by Skagit County staff for each of the stream stations split between wet- (October to June) and dry-season (July to September) (Table 16). We assumed there is no surface base flow for the non-monitored basins and that all those loads would be captured in groundwater load.

Table 16. Average Measured Discharge at Monitoring Stations.

Station	Dry Season Base Flow (cfs)	Wet Season Base Flow (cfs)	Storm Flow (cfs)
CS1	0.0008 (n=2)	0.0295 (n=3)	0.101 (n=5)
CS2	0.0 (n=2)	0.0458 (n=3)	0.150 (n=6)
CS2.5	0.0 (n=2)	0.0035 (n=3)	0.052 (n=5)
CS3	0.0 (n=2)	0.136 (n=2)	0.236 (n=5)

For storm flow, we implemented the Simple method (Schueler, 1987). The technique requires a modest amount of information, including the watershed drainage area and impervious cover, and annual precipitation.

$$V_{S,i} = R_{v,i} * P * A_i$$

Where

- V is the runoff volume for watershed i
- Rv is the runoff coefficient for watershed i
- P is the precipitation depth (m)
- A is the total watershed area for watershed i (m2)

The runoff coefficient Rv is calculated using the following equation:

$$R_{v,i} = 0.05 + 0.9 * I_{a,i}$$

Where I_a is the impervious fraction for watershed i.

Drainage basin land cover and runoff coefficients are provided in Table 17.

Table 17. Impervious Land Cover and Runoff Coefficient for Lake Drainage Areas.

Subbasin	Impervious Area (acres)	Total Area (acres)	Percent Impervious	Rv
CS5	4.3	509.5	0.8%	0.06
CS2	1.8	687.9	0.3%	0.05
ERIE-OUT	31.6	1126.2	2.8%	0.08
CS3	46.4	1320.6	3.4%	0.08
CS2.5	17.4	363.6	4.7%	0.09
CS1	10.6	288.7	3.7%	0.08
Goodin Island	0.0	4.9	0.0%	0.05
Non-monitored South	18.6	366.1	5.1%	0.10
Non-monitored East	3.1	46.5	6.7%	0.11
Non-monitored West	3.5	217.3	1.6%	0.06
TOTAL	**105.7**	**3803.0**	**2.8%**	**-**

Note that subbasin CS3 is inclusive of ERIE-OUT, and flow for CS3 are estimated using a rating curve described in the previous section.

The estimated lake inflows from September 2023 to March 2024 are presented in Table 18. Note that because CS3 (Lake Erie outflow) was estimated using a rating curve, the entirety of its flows are captured under base flow volume.

Table 18. Monthly Lake Inlet Flow Volumes.

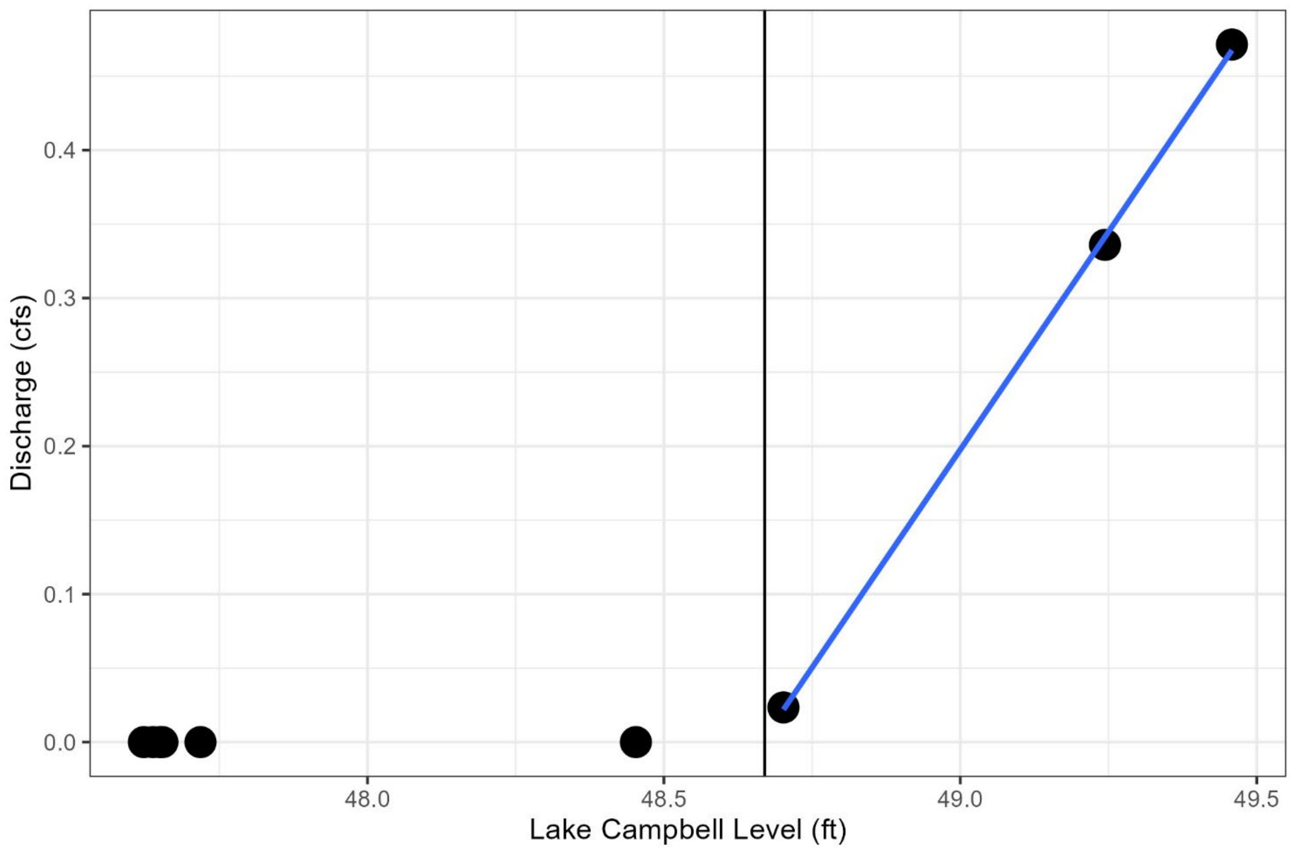
Base Flow Volume (1000 m³)								
Year	**Month**	**CS1**	**CS2**	**CS2.5**	**CS3**	**CS5**	**Other**	**TOTAL**
2023	9	0.1	0.0	0.0	0.0	0.0	0.0	**0.1**
2023	10	2.2	3.5	0.3	0.0	0.0	0.0	**6.0**
2023	11	2.2	3.4	0.3	0.0	0.0	0.0	**5.8**
2023	12	2.2	3.5	0.3	11.5	0.0	0.0	**17.5**
2024	1	2.2	3.5	0.3	10.4	0.0	0.0	**16.4**
2024	2	2.0	3.1	0.2	69.5	0.0	0.0	**74.9**
2024	3	2.2	3.5	0.3	74.4	0.0	0.0	**80.4**
Base Total		**13.1**	**20.5**	**1.7**	**165.8**	**0.0**	**0.0**	**201.1**
Storm Flow Volume (1000 m³)								
Year	**Month**	**CS1**	**CS2**	**CS2.5**	**CS3**	**CS5**	**Other**	**TOTAL**
2023	9	2.3	3.5	3.3	NA	2.8	5.3	**17.2**
2023	10	7.0	10.5	9.9	NA	8.6	15.9	**52.0**
2023	11	6.5	9.7	9.1	NA	7.9	14.7	**48.0**
2023	12	10.8	16.2	15.2	NA	13.2	24.4	**79.8**
2024	1	10.2	15.4	14.4	NA	12.5	23.2	**75.7**
2024	2	6.1	9.2	8.7	NA	7.5	13.9	**45.4**
2024	3	2.9	4.4	4.1	NA	3.6	6.6	**21.6**
Storm Total		**45.9**	**68.9**	**64.7**	NA	**56.2**	**104.0**	**339.7**
Total (Base + Storm flow) Volume (1000 m³)								
Base + Storm		**59.0**	**89.4**	**66.4**	**165.8**	**56.2**	**104.0**	**540.8**

Lake Campbell Outflow

Under the QAPP, lake level and measured outlet discharge volumes were to be used to develop a hydrologic rating curve. During the monitoring period, measurable flow from Lake Campbell was found during 5 of 11 events. Unfortunately, measurement error resulted in only 3 of these 5 events having reputable measurements of lake outflow. A rating curve was developed using these three events, but it highly recommended that additional sampling be done to develop a suitable rating curve. Outflow from the lake is greatly impacted by beaver activity near the Lake Campbell Road bridge and accumulation of debris at the nearby fish screens.

The CAM-LVL was used to develop a rating curve with the CAM-OUT monitoring site. Discharge at CAM-OUT was measured using a current meter to measure the velocity and depth of water. The instantaneous discharge measurements and the Lake Campbell level were used to develop a rating curve (Figure 38). Three watershed monitoring events were used to develop the rating curve. This rating curve was used to calculate daily discharge across the monitoring period, including the period with interpolated lake level values (Figure 39).

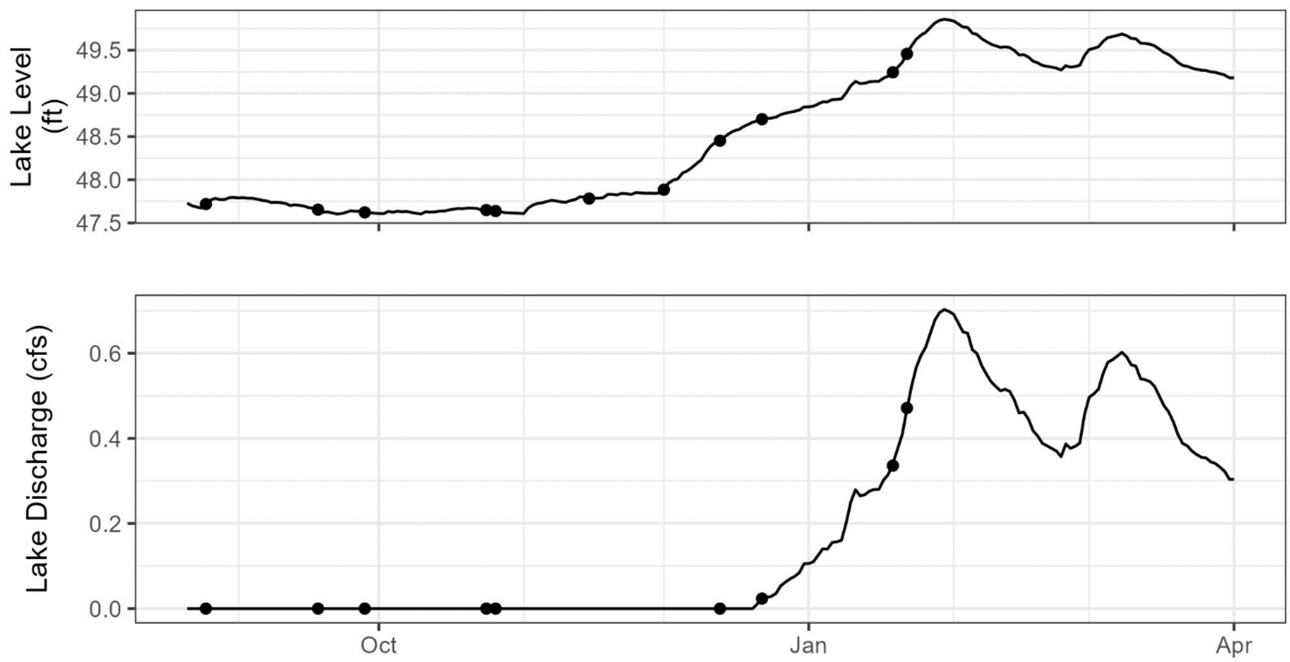
Figure 38. Lake Campbell Outlet (CAM-OUT) Discharge-Level Relationship.



Vertical line is estimated elevation where no discharge from Lake Erie will occur (48.67 ft).
Best fit line equation: Discharge = -28.66 +0.589*Lake_Level (R^2 = 0.99).

Importantly, the rating curve only capture lake level up to about 49.5 feet, but the observed lake level reached just over 49.9 feet. Therefore, some extrapolation was necessary, because a linear rating curve was developed (as opposed to a logarithmic curve), the effect of the extrapolation is minimized. The extrapolated values should be sufficient for high-level water budget estimation for Lake Campbell, but additional data are recommended to develop an expanded rating curve.

Figure 39. Lake Campbell (CAM-OUT) outlet estimated discharge.



Evaporation

Evaporation depth was calculated using daily average air temperature and dew point from the Anacortes AgWeatherNet station. The daily evaporation depth was multiplied by the daily surface area of the lake to calculate total monthly evaporation volume.

To estimate evaporation, we used the simplified Penman equation (Linacre 1977):

$$E = (700 * (T + 0.006 * h)/(100 - A) + 15 * (T - T_d)) / (80 - T)$$

Where:

- E = evaporation (mm/day)
- T = mean daily air temperature (deg C)
- h = elevation (m)
- A = Latitude (deg)
- T_d =dew point

Summary of Partial Hydrologic Budget

The monthly hydrologic budget for Lake Campbell from September 2023 to March 2024 is presented on a monthly basis in Table 19. The budget had moderate residuals during each month, which are assumed to be Groundwater Inflow when positive and Groundwater Outflow when negative.

The annual net groundwater inflow was 534 thousand cubic meters, which is approximately one-third of the total inflow to the lake. During the monitoring period, the lake was slightly more of a net groundwater importer, with 445 thousand cubic meters exported primarily in February and March. We expect there is substantial groundwater export in the spring. The beaver dam at the lake outlet prevents surface export when the lake level is low and export during this time is likely to be predominantly via subsurface flow. The residuals may also be due to over- or under-estimates in the inflows and outflows of the lake. We believe the hydrologic budget provides adequate planning level estimates of the volume of water moving through Lake Campbell and to compare with the estimates from Entranco (1987) for WY1986. The budget would benefit from further calibration of the flow rating curve and the monitoring or modeling of groundwater levels and flow velocity and direction.

Table 19. Lake Campbell September 2023 to March 2024 Hydrologic Budget (1000s m3)

Year	Month	Precip-itation	Base Flow	Storm Flow	Total Surface Inflow	Evaporation	Lake Outflow	Total Surface Outflow	Change in Lake Volume	Residual
2023	9	34.3	0.1	17.2	**51.6**	147	0	**147**	-62.2	33.2
2023	10	104	6	52	**162**	122.5	0	**122.5**	9.8	-29.7
2023	11	96.6	5.8	48	**150.4**	76.4	0	**76.4**	98.9	24.9
2023	12	165.2	17.5	79.8	**262.5**	83.1	1.4	**84.5**	406.6	228.6
2024	1	166.1	16.4	75.7	**258.2**	67.1	27.2	**94.3**	411.1	247.2
2024	2	100.4	74.9	45.4	**220.7**	77.2	34.5	**111.7**	-168.3	-277.3
2024	3	47.6	80.4	21.6	**149.6**	86.3	35.1	**121.4**	-109.5	-137.7
	TOTALS	**714.2**	**201.1**	**339.7**	**1255.0**	**659.6**	**98.2**	**757.8**	**586.5**	**89.3**

Note that Base Flow includes all of CS3 Flows

Data Gaps

This section summarizes the data gaps identified in the characterization of water quality in Lake Campbell. Collecting data to fill these gaps should be considered to inform continuing adaptive lake cyanobacteria management. Key data gaps include:

- Comprehensive and consistent lake water quality data (including chemistry, biology, and physical data). Specifically:
  - Temperature, DO, conductivity, and pH measurements throughout the water column on a monthly basis.
  - Chlorophyll-a and total phosphorus from the lake surface and bottom on a monthly basis.
  - Orthophosphate, total nitrogen, ammonia nitrogen, and nitrate + nitrite nitrogen from the lake surface every month during the summer months.
  - Regular phytoplankton and zooplankton taxonomic composition and biovolume
  - Continuous lake level.
- Comprehensive and consistent inlet and outlet water quality data (including chemistry and physical data). Specifically:
  - pH, conductivity, temperature, DO, and total phosphorus on at least 6 occasions per year at three inlets and one outlet location.
  - Analysis of orthophosphate, total phosphorus, nitrate + nitrite nitrogen, and total nitrogen fractions in the inlet samples
  - Year-round monthly discharge and/or continuous flow measurements
  - Continuous lake outlet stream level and elevation measurements (including beaver dam location and elevational data, as necessary).
- Enhanced cyanotoxin monitoring and analysis. Specifically:
  - Cyanotoxin analysis regularly throughout the year, unrestricted to reported scum or bloom samples.
  - Occasional observation and sampling for benthic cyanobacteria species.
  - Long-term comparative analysis of cyanotoxin concentrations and cyanobacteria compositions.
- Regular sediment phosphorus and iron characterizations.
- Groundwater flow and nutrient characterizations.
- Assessment of septic contributions and other non-point sources (e.g., agriculture) to nutrient inputs.
- Contemporary and comprehensive fecal bacteria monitoring and/or microbial source tracking in the lake and watershed

- Long-term and/or year-round waterfowl, lake usage, and fish harvest data.
- Quantification of annual phosphorus contributions from waterfowl and decaying aquatic plants.
- A shoreline modification survey for extents modified with bulkheads, fill, or other changes to the natural shoreline.
- Assessment of other potential and emerging contaminants in the lake and watershed (e.g., metals, PCBs, phthalates, pesticides).

It is also important to continue frequent cyanotoxin and algae bloom monitoring, not limited to scum/bloom only samples, to understand patterns between and leading up to potential blooms.

Trophic cascade effects of stocked, native, and invasive fish on plankton communities are not well understood for Lake Campbell or other Washington lakes. These impacts are difficult to monitor or to model. Conceptually, planktivorous fish that eat cyanobacteria-eating zooplankton may stimulate cyanobacteria blooms. Generally, cyanobacteria are not the preferred food source for most zooplankton. Population studies of fish, zooplankton, and phytoplankton in Lake Campbell could help elucidate potential trophic cascade effects of stocked trout and other planktivorous fish in the lake. This study would be particularly interesting since Lake Campbell's zooplankton composition (in the 1980s and 2023) is opposite of what is typically observed in eutrophic lakes, like in Lake Erie, despite the two lakes historically having similar phytoplankton compositions.

Summary and Interpretation

Lake Campbell is a eutrophic lake with high algal productivity in late summer through fall, each year. Nutrient and chlorophyll-a conditions in Lake Campbell closely resembled those from prior to the fall 1985 alum treatment than those from the summer of 1986 after the alum treatment, indicating heightened eutrophication in recent years continuation of a eutrophic state.

Eutrophic conditions in Lake Campbell are characterized by increasingly high phosphorus concentrations, persistently high algae growth, and low water clarity. Algae blooms in Lake Campbell occur June through November, and are frequently toxic at levels which may risk the health of humans or wildlife. Existing blooms are driven by an abundance of bioavailable nutrients and algae growth is typically limited by the amount of bioavailable phosphorus and occasionally co-limited by bioavailable nitrogen. Key evidence for these conditions, summarized from the monitoring data discussed above, include:

- Anoxia near the lake sediments in the summer. This anoxia allowed the release of nutrients like ammonia and phosphorus from the lake sediments, causing high hypolimnetic nutrient concentrations relative to surface waters in the summer and early fall, which are readily mixed upwards during frequent wind-induced mixing events.
- Brief, weak summertime thermal stratification in July when surface temperatures were elevated, but otherwise Lake Campbell appeared to be thermally well-mixed throughout water column from September to December.

- Well-mixed waters allowed hypolimnetic nutrients to algae blooms throughout the water column, as supported by elevated chlorophyll-a concentrations throughout the water column and low water clarity for most of the monitoring period, and by observed toxic algae blooms from August through October 2023.
- Mean surface TP was greater in 2023 than in any previously monitored year.
- TN:TP ratios indicative of co-limitation by both phosphorus and nitrogen in the summer and early fall, with phosphorus limitation through the winter. However, the parallel importance of nitrogen and phosphorus as co-limiters and the over-abundance of bioavailable nutrients suggest that algae growth in 2023 was actually more likely limited by light or other bioavailable micronutrients, like iron. Regardless, controlling nutrients, primarily phosphorus, is key to reducing algae blooms.
- A persistent algae bloom from July through November 2023 which exceeded state recreational guideline for microcystin nearly every week tested. Microcystin was present in each sample in 2023 and was greatest (at 93.9 µg/L) in October. Anatoxin-a was detected only once in August.
- Cyanobacteria were the dominant taxa in both August and September, and at the lake surface in October. Together, three species of *Dolichospermum* (formerly *Anabaena*) comprised most of the cyanobacteria in August and September and are likely responsible for the anatoxin-a detected. Despite relatively low biomass for most of the monitoring period, *Microcystis aeruginosa* was responsible for consistent microcystin exceedances, and its dominance in October was matched by a substantial elevation in toxin concentrations. These relative compositions and toxic species present are consistent with phytoplankton records from Entranco (1987).
- Zooplankton community composition is not what we would expect from a eutrophic system but is consistent with Entranco (1987) results and interpretation.
- Lake sediments are rich in phosphorus, more so in the deep (> 4 meters) pelagic (central) region than in the shallow littoral (nearshore) region of the lake. The amount of iron relative to phosphorus is moderate in both the deep and shallow sediments. This indicates iron may be sufficient to regulate phosphorus release throughout Lake Campbell, when oxygenated.
- The amount of free reactive (mobile) phosphorus is relatively high, at an average of 46 percent of the total phosphorus in surface (0-10 cm) sediments, indicating abundant phosphorus available for sediment release and uptake by algae.
- Total phosphorus concentrations at the CS1 watershed inflow monitoring location, draining runoff from SR-20, were similar to concentrations in Lake Campbell. CS1 is one of three main surface water inputs to Lake Campbell, though many inflows were either frequently dry or not flowing. Mean total phosphorus concentrations were greater during storm flow than during base flow conditions. Lake and outlet phosphorus concentrations were much higher than the inlets' concentrations. These lines of evidence suggest stormwater runoff contributes to the lake's phosphorus load but may not be substantial compared to sources of internal of phosphorus loading to the lake.
- Lake outlet discharge was highly restricted by beaver activity such that outflow occurred only during some storm events when precipitation led to water levels in the lake high enough to overtop the

beaver dam. Due to this, a longer retention time for water and nutrients in the lake may be contributing to internal nutrient cycling and sediment release.

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Appendix B

Field Sheets and Laboratory Data Reports

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add cal instructions

2023 LAKE CAMPBELL CMP MONITORING DATA SHEET

Field Equipment Checklist

- ☐ Secchi disk
- ☐ YSI multimeter
- ☐ Cooler with ice
- ☐ Anchor
- ☐ Van Dorn / Kemmerer
- ☐ Hanna pH meter
- ☐ Sample bottles
- ☐ ~~Ethanol~~
- ☐ Filters & syringes
- ☐ Plankton net

Project: Lake Campbell Cyanobacteria Management Plan Project No.: 23-08143-000

Client: Skagit County Field Personnel: TC, KS, LF + Volunteer

Weather:

Wind (still, windy, choppy): still @ first and later choppy

Number of vessels on lake:

Number of shoreline swimmers:

Number of shoreline anglers:

Number of geese: 4 ducks:

other waterfowl

CAM-DEEP

Collection Date and Time: August 22, 2023 1400

Secchi Depth (m): 1.0 m Depth to Bottom (m): 4 m

Water color: Green-brown

Notes Captured 57 geese one month ago (WDFW)

Profile Readings (every monthly event):

add half meter

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	pH
0.2	22.7	4.14	263.5	8.98
~~1.0~~ 0.5	22.3	4.21	~~263.5~~ 263.5	
2.0	21.8	0.80	269.2	8.57
3.0	21.7	0.09	271.5	
4.0	21.6	0.06	~~273.2~~ 273.2	8.34

-S: 0.5 m

-B 3.5 m

li b2_campbell_lakemonitoring_field form_blank

Water Quality Samples Collected* (every monthly event):

Sample Type/ Bottle*	Surface (1 m below surface) Sample ID	Bottom (1 m above bottom) Sample ID
Total Nutrients (500 mL HDPE with H_2SO_4)	CAM-DEEP-2023______-S	CAM-DEEP-2023______-B
Dissolved Nitrogen (500 mL HDPE with H_2SO_4)**	CAM-DEEP-2023______-S	CAM-DEEP-2023______-B
Orthophosphate (250 mL HDPE)**	CAM-DEEP-2023______-S	CAM-DEEP-2023______-B
Chlorophyll-a (125-mL dark HDPE)	CAM-DEEP-2023______-S	CAM-DEEP-2023______-B

*Water quality samples must be kept on ice or refrigerated until delivered to lab

**Dissolved nitrogen and orthophosphate samples must be field filtered into bottles

Plankton Samples

Phytoplankton and Zooplankton to be collected monthly during August, September, and October only.

Sample Type/ Bottle	Details	Sample ID
Phytoplankton (125-mL dark HDPE, with Lugol's)	Surface (1 m below surface)	CAM-DEEP-2023______-S
	Bottom (1 m above bottom)	CAM-DEEP-2023______-B
Zooplankton (250-mL HDPE, with ethanol)	Vertical Tow from 1 m above lake bottom to surface	CAM-DEEP-2023______

Note: Change sample IDs to CAM-DEEP-2024___-__ for January event

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2023 LAKE SEDIMENT SAMPLING DATA SHEET

Field Equipment Checklist

- ☐ Secchi disk
- ☐ YSI multimeter
- ☐ Cooler with ice
- ☐ Van Dorn / Kemmerer
- ☐ Sediment corer
- ☐ Sample bottles
- ☐ Plankton net
- ☐ Sediment core tubes
- ☐ Boat

Project: Lake Campbell CMP
Project No.: 23-08143-000
Client: Skagit County
Field Personnel: KS, TC
Weather: sunny, partly cloudy 65°F
Wind (still, windy, choppy): slight breeze / still
Number of vessels on lake: 1
Number of shoreline swimmers: 0
Number of shoreline anglers: 0
Number of geese:
ducks:
other waterfowl: 2 herons on island

Deep Station ~~CR~~ CAM-DEEP

Collection Date and Time: 8/22/23 1100
Secchi Depth (m): NS
Depth to Bottom (m): 5.5
Water color: anabaena flocs → bloom, boat ramp closed
Sample ID:
Notes: put in boat @ Bob's house next to boat ramp.

Profile Readings: *see lake sampling sheet, separate same day

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	pH
0.2				
1.0				
2.0				
3.0				
4.0				

Shallow Station CAM-SHALLOW

Collection Date and Time: 8/22/23 1115

Secchi Depth (m): NS Depth to Bottom (m): 3.0

Water color: turbid, anabaena flocs

Sample ID: CAM-SHALLOW-20230822

Notes lots of large active copepods w/ egg sacs at surface of core

Profile Readings:

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	pH
0.2				
1.0				
2.0				
3.0				
4.0				

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SEDIMENT CORE RECORD

Sample Station Number CAM-DEEP
Sheet 1 of 1

Project Name: Campbell Lake CMP
Project Number:
Client: Skagit Co
HEC Samplers: Clark and Katie
Processors: Rob and Katie

Date Sampled 8/22/23 @ 1100
Location: CAM-DEEP
~~Photo~~ Date 8/23/23 Time 0950
~~Number~~: Processed

Photo ~~Wood Chips (Y or N)~~	Soil Description/Comments	Wt (g) ~~Time Sampled~~	Vol (mL) ~~Depth (feet)~~	Sample Interval	Sample ID ~~Sediment Core Log~~
Photo	Total core length = 43.5 cm				
~~Photo~~	Watery dark brown silt, No debris or odor, org film on top of water	66.9 g	68 mL	0-2	CAM-D-0-2
Photo	Med brown w/ black ~~[illegible]~~ Watery - gelatenous No debris or odor	—	—	2-4	—
Photo	same less water	75.9 g	75 mL	4-6	CAM-D-4-6
—	Med brown silt, less black gelatenous	—	—	6-8	—
Photo	med brown silt gelatinous, chironomid buried down, No debris or odor	74.9 g	75 mL	8-10	CAM-D-8-10
~~[illegible]~~ Photo	Same ~~No~~ chironomid - blood worm	—	—	10-12	—
Photo	Med brown gelatenous silt - pudding No debris or odor	137.3	130 mL	12-16	CAM-D-12-16
Photo	Stiff column of med Brown silt pudding w/ blood worm dead	—	—	16-20	—
Photo	Stiff sludge med brown silt some "root"-like debris	215.5	220 mL est.	20-26	CAM-D-20-26
Photo	Same w/ sulfide odor	—		26-33	—
Photo	same w/ reddish hue very firm	—		33-43	

L of fallen column into cup

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Wood Chips (Y or N)	Soil Description/Comments	Time Sampled	Depth (feet)	Sample Interval	Sediment Core Log
			3		
			4		

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SEDIMENT CORE RECORD

Sample Station Number CAM-SHALLOW
Sheet 1 of 1

Project Name: Campbell Lake CMP
Project Number:
Client: Skagit Co.
HEC Samplers: Clark and Katie
Processors: Rob and Katie

Date Sampled: 8/22/23 @ 1115
Location: Campbell Lake East
~~Photo Number~~ Date/Time processed: 8/23/23 @ 1100

Photo (~~Wood Chips (Y or N)~~)	Soil Description/Comments	Wt (g) (~~Time Sampled~~)	Vol (mL) (~~Depth (feet)~~)	Sample Interval	Sample ID (~~Sediment Core Log~~)
Photo	0-34 cm core length				
Photo	Dark brown surface on med brown silt watery. Snail, clam, blood worm ↑ copepods ~~No odor~~ minor plant debris, No odor (org)	84.8 g	85 mL	0-2	CAM-S-0-2
-	Dark/med brown blood worm, plant debris (grass-like)	-	-	2-4	-
Photo	Med brown gel. silt watey blood worm, plant debris, 1 small rock ~~3 mm~~	77.7 g	78 mL	4-6	CAM-S-4-6
-	firm med brown gel. silt plant debris, No odor	-	-	6-8	-
Photo	Same with 2 mm seeds brown	74.7 g	75 mL	8-10	CAM-S-8-10
-	Same fine root hairs but also larger stems 3 mm and leaves brown	-	-	10-12	-
Photo + photo	Same, more stems of ~~[illegible]~~ / stem tan	141.3	145 mL	12-16	CAM-S-12-16
photo	of column, same	-	-	16-20	-
Photo of seed closeup (saved in ziplock for ID)					-
Photo	Same, stems but No seeds, No critters ~~[illegible]~~	216.8 g	230 mL No odor	20-26	CAM-S-20-26
Photo + Photo of stems	Dark brown firm silt w/ stems	-	-	26-34	-

* Stems are likely pondweed rhizomes w/ root hairs

HERRERA

Wood Chips (Y or N)	Soil Description/Comments	Time Sampled	Depth (feet)	Sample Interval	Sediment Core Log
			3		
			4		

Chain of Custody / Analysis Request (Please complete all applicable shaded sections)

Report to: SKA02 Skagit Co. Public WKS	**For Lab Use Only**
Address: 1800 Continental Place	Ref#
City: Mount Vernon State: WA Zip: 98273	**Check Regulatory Program**
Attn: Leanne Ingman	☐ Safe Drinking Water Act
Phone: (360) 416-1450 Fax:	☐ Clean Water Act
Email: .leannei@co.skagit.wa.us, MeghanM@co.skagit.wa.us	☐ RCRA / CERCLA
Project Name: Lake Campbell CMP	☐ Other

EDGE ANALYTICAL

Main Lab (800-755-9295)
1620 South Walnut St. Burlington, WA 98233
Microbiology (888-725-1212)
805 W. Orchard Dr. Suite 4 Bellingham, WA 98225
Wilsonville Lab (503-682-7802)
9150 SW Pioneer Ct. Suite W Wilsonville, OR 97070
Corvallis Lab (541-753-4946)
540 SW 3rd St. Corvallis, OR 97333

	Sample ID	Location	Sample Matrix *	Date	Time	Ortho phos	Ammonia, TKN, T. Phos, NO2/NO3	Chlorophyll	Special Instructions/ Conditions on Receipt
1	CAM-DEEP-S		SW	8/22/23	1530	☐	☐	☒	
2	CAM-DEEP-20230822-B		SW	8/22/23	1500	☐	☐	☒	
3	CAMDEEP-S	0.5m	SW	8/22/23	1513		☒	☐	
4	CAM DEEP-S	0.5M	SW	8/22/23	1514	☒	☐	☐	
5	CAM DEEP-20230822-B	3.5M	SW	8/22/23	1800	☐	☒	☐	
6	CAM DEEP-20230822-B		SW	8/22/23	1508	☒	☐	☐	
7			SW			☐	☐	☐	
8			SW			☐	☐	☐	
9			SW			☐	☐	☐	
10			SW			☐	☐	☐	
11			SW			☐	☐	☐	
12			SW			☐	☐	☐	
13			SW			☐	☐	☐	
14			SW			☐	☐	☐	
15			SW			☐	☐	☐	
16			SW			☐	☐	☐	
17			SW			☐	☐	☐	
18			SW			☐	☐	☐	
19			SW			☐	☐	☐	
20			SW			☐	☐	☐	
21			SW			☐	☐	☐	
22			SW			☐	☐	☐	
23			SW			☐	☐	☐	
24			SW			☐	☐	☐	
25			SW			☐	☐	☐	
26			SW			☐	☐	☐	
27			SW			☐	☐	☐	

Sampled by:	Phone:	Email:
KS, TC		

Relinquished by	Date	Time	Received by	Date	Time
Leanne Ingman	8/23/23	0801	MS (WI) RECS	8-23-23	0802

Burlington, WA *Corporate Laboratory (a)*
1620 S Walnut St - Burlington, WA 98233 - **800.755.9295** • 360.757.1400
Bellingham, WA *Microbiology (b)*
805 Orchard Dr Ste 4 - Bellingham, WA 98225 - 360.715.1212
Portland, OR *Microbiology/Chemistry (c)*
9725 SW Commerce Cr Ste A2 - Wilsonville, OR 97070 - 503.682.7802
Corvallis, OR *Microbiology/Chemistry (d)*
1100 NE Circle Blvd, Ste 130 - Corvallis, OR 97330 - 541.753.4946
Bend, OR *Microbiology (e)*
20332 Empire Blvd Ste 4 - Bend, OR 97701 - 541.639.8425

Data Report

Client Name: Skagit County Public Works
1800 Continental Place
Mount Vernon, WA 98273

Reference Number: **23-25668**
Project: Lake Campbell CMP

Report Date: 9/20/23

Date Received: 8/23/23
Approved by: mcs,tjb
Authorized by:

Lawrence J Henderson, PhD
Director of Laboratories, Vice President

Sample Description: Cam-Deep S — Matrix SW — Sample Date: 8/22/23 3:30 pm
Lab Number: 50697 — Sample Comment: — Collected By: KS,TC

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
NA	**CHLOROPHYLL A**	31.8	0.0001	0	mg	1.0	SM10200-H		8/24/23	RL	WML_230824	Analyzed by WML
NA	**PHEOPHYTIN A**	15.9	0.0001	0	mg	1.0	SM10200-H		8/24/23	RL	WML_230824	Analyzed by WML

Sample Description: Cam-Deep 2023 0822-B — Matrix SW — Sample Date: 8/22/23 3:00 pm
Lab Number: 50698 — Sample Comment: — Collected By: KS,TC

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
NA	**CHLOROPHYLL A**	10.4	0.0001	0	mg	1.0	SM10200-H		8/24/23	RL	WML_230824	Analyzed by WML
NA	**PHEOPHYTIN A**	18.6	0.0001	0	mg	1.0	SM10200-H		8/24/23	RL	WML_230824	Analyzed by WML

Sample Description: Cam Deep-S 0.5M — Matrix SW — Sample Date: 8/22/23 3:13 pm
Lab Number: 50699 — Sample Comment: — Collected By: KS,TC

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.47	0.010	0.0088	mg/L	1.0	350.1	a	9/6/23	MSO	350.1_230906	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	1.94	0.20	0.0585	mg/L	1.0	351.2	a	9/14/23	DIC	351.2_230914	
E-10128	**TOTAL NITRATE+NITRITE as N**	ND	0.01	0.0042	mg/L	1.0	SM4500-NO3 F	a	9/11/23	CJET	NO3NO2_230911	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.122	0.010	0.0021	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	9/13/23	CJET	TPHOS_230913	

Sample Description: Cam Deep-S 0.5M — Matrix SW — Sample Date: 8/22/23 3:14 pm
Lab Number: 50700 — Sample Comment: — Collected By: KS,TC

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
14265-44-2	**ORTHO-PHOSPHATE**	0.04	0.01	0.0032	mg/L	1.0	SM4500-P F	a	8/23/23	CJET	OPHOS_230823	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

If you have any questions concerning this report contact us at the above phone number.

EDGE ANALYTICAL

Reference Number: **23-25668**
Report Date: 9/20/23

Data Report

Sample Description: Cam Deep-2023 0822-B 3.5M | Matrix SW | Sample Date: 8/22/23 3:00 pm
Lab Number: 50701 | Sample Comment: | Collected By: KS,TC

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.88	0.010	0.0088	mg/L	1.0	350.1	a	9/6/23	MSO	350.1_230906	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	2.07	0.20	0.0585	mg/L	1.0	351.2	a	9/7/23	DIC	351.2_230907	
E-10128	**TOTAL NITRATE+NITRITE as N**	ND	0.01	0.0042	mg/L	1.0	SM4500-NO3 F	a	9/11/23	CJET	NO3NO2_230911	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.130	0.010	0.0021	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	9/13/23	CJET	TPHOS_230913	

Sample Description: Cam Deep-2023 0822-B | Matrix SW | Sample Date: 8/22/23 3:08 pm
Lab Number: 50702 | Sample Comment: | Collected By: KS,TC

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
14265-44-2	**ORTHO-PHOSPHATE**	0.06	0.01	0.0032	mg/L	1.0	SM4500-P F	a	8/23/23	CJET	OPHOS_230823	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

EDGE ANALYTICAL

SAMPLE INDEPENDENT QUALITY CONTROL REPORT

Reference Number: **23-25668**
Report Date: 09/20/23

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
Calibration Check											
350.1_230906	0	AMMONIA-N	2.53	2.50	mg/L	350.1	101	90-110		CAL	
351.2_230907	0	TOTAL KJELDAHL NITROGEN as N	2.48	2.50	mg/L	351.2	99	90-110		CAL	
351.2_230914	0	TOTAL KJELDAHL NITROGEN as N	2.59	2.50	mg/L	351.2	104	90-110		CAL	
NO3NO2_230911	0	TOTAL NITRATE+NITRITE as N	1.06	1.00	mg/L	SM4500-NO3 F	106	90-110		CAL	
OPHOS_230823	0	ORTHO-PHOSPHATE	0.98	1.00	mg/L	SM4500-P F	98	85-115		CAL	
TPHOS_230913	0	TOTAL PHOSPHORUS-P	0.100	0.100	mg/L	SM4500-P F	100	85-115		CAL	
Laboratory Fortified Blank											
351.2_230907	0	TOTAL KJELDAHL NITROGEN as N	1.96	2.00	mg/L	351.2	98	90-110		LFB	
351.2_230914	0	TOTAL KJELDAHL NITROGEN as N	1.90	2.00	mg/L	351.2	95	90-110		LFB	
Laboratory Reagent Blank											
351.2_230907	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		LRB	
351.2_230914	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		LRB	
NO3NO2_230911	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		LRB	
OPHOS_230823	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		LRB	
TPHOS_230913	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		LRB	
Method Blank											
350.1_230906	0	AMMONIA-N	ND		mg/L	350.1		0-0		MB	
351.2_230907	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		MB	
351.2_230914	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		MB	
NO3NO2_230911	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		MB	
OPHOS_230823	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		MB	
TPHOS_230913	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		MB	
Quality Control Sample											
350.1_230906	0	AMMONIA-N	3.71	3.72	mg/L	350.1	100	85-115		QCS	
351.2_230907	0	TOTAL KJELDAHL NITROGEN as N	3.27	3.26	mg/L	351.2	100	85-115		QCS	
351.2_230914	0	TOTAL KJELDAHL NITROGEN as N	3.42	3.26	mg/L	351.2	105	85-115		QCS	
NO3NO2_230911	0	TOTAL NITRATE+NITRITE as N	1.93	2.00	mg/L	SM4500-NO3 F	97	90-110		QCS	
OPHOS_230823	0	ORTHO-PHOSPHATE	0.92	1.00	mg/L	SM4500-P F	92	90-110		QCS	
TPHOS_230913	0	TOTAL PHOSPHORUS-P	0.190	0.195	mg/L	SM4500-P F	97	90-110		QCS	

*Notation:
% Recovery = (Result of Analysis)/(True Value) * 100
NA = Indicates % Recovery could not be calculated.
Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.
FORM: QCIndependent4.rpt

SAMPLE DEPENDENT
QUALITY CONTROL REPORT
Duplicate, Matrix Spike/Matrix Spike Duplicate and Confirmation Result Report

Duplicate

Batch	Sample	Analyte	Result	Duplicate Result	Units	%RPD	Limits	QC Qualifier	Type	Comments
350.1_230906										
7664-41-7	50486	AMMONIA-N	0.038	0.033	mg/L	**14.1**	0-20		DUP	
7664-41-7	50699	AMMONIA-N	0.47	0.46	mg/L	**2.2**	0-20		DUP	
7664-41-7	50726	AMMONIA-N	ND	ND	mg/L	**NA**	0-20		DUP	
7664-41-7	50898	AMMONIA-N	0.012	0.018	mg/L	**40.0**	0-20	INH	DUP	
7664-41-7	51040	AMMONIA-N	ND	ND	mg/L	**NA**	0-20		DUP	
351.2_230907										
E-10264	50701	TOTAL KJELDAHL NITROGEN as N	2.07	2.10	mg/L	**1.4**	0-20		DUP	
E-10264	51355	TOTAL KJELDAHL NITROGEN as N	25.5	26.6	mg/L	**4.2**	0-20		DUP	
351.2_230914										
E-10264	53414	TOTAL KJELDAHL NITROGEN as N	12.6	7.74	mg/L	**47.8**	0-20	IM	DUP	
E-10264	53816	TOTAL KJELDAHL NITROGEN as N	0.96	1.18	mg/L	**20.6**	0-20	IM	DUP	
NO3NO2_230911										
E-10128	50699	TOTAL NITRATE+NITRITE as N	ND	ND	mg/L	**NA**	0-20		DUP	
E-10128	52652	TOTAL NITRATE+NITRITE as N	0.27	0.27	mg/L	**0.0**	0-20		DUP	
E-10128	52835	TOTAL NITRATE+NITRITE as N	ND	ND	mg/L	**NA**	0-20		DUP	
E-10128	52917	TOTAL NITRATE+NITRITE as N	ND	ND	mg/L	**NA**	0-20		DUP	
E-10128	53294	TOTAL NITRATE+NITRITE as N	0.87	0.86	mg/L	**1.2**	0-20		DUP	
OPHOS_230823										
14265-44-2	50762	ORTHO-PHOSPHATE	0.12	0.13	mg/L	**8.0**	0-20		DUP	
TPHOS_230913										
7723-14-0	53071	TOTAL PHOSPHORUS-P	0.019	0.019	mg/L	**0.0**	0-20		DUP	
7723-14-0	53081	TOTAL PHOSPHORUS-P	3.26	3.37	mg/L	**3.3**	0-20		DUP	
7723-14-0	54561	TOTAL PHOSPHORUS-P	0.038	0.038	mg/L	**0.0**	0-20		DUP	

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

Reference Number: 23-25668
Report Date: 9/20/2023

Laboratory Fortified Matrix (MS)

Batch/CAS	Sample	Analyte	Result	Spike Result	Duplicate Spike Result	Conc	Units	Percent Recovery MS	Percent Recovery MSD	Limits*	%RPD	Limits*	QC Qualifier	Type	Comments
350.1_230906															
7664-41-7	50486	AMMONIA-N	0.038	0.89	0.99	1.00	mg/L	**85**	**95**	70-130	**11.1**	0-20		LFM	
7664-41-7	50699	AMMONIA-N	0.47	1.47	1.39	1.00	mg/L	**100**	**92**	70-130	**8.3**	0-20		LFM	
7664-41-7	50726	AMMONIA-N	ND	0.94	0.94	1.00	mg/L	**94**	**94**	70-130	**0.0**	0-20		LFM	
7664-41-7	50898	AMMONIA-N	0.012	0.96	0.94	1.00	mg/L	**95**	**93**	70-130	**2.1**	0-20		LFM	
7664-41-7	51040	AMMONIA-N	ND	0.94	0.95	1.00	mg/L	**94**	**95**	70-130	**1.1**	0-20		LFM	
351.2_230907															
E-10264	50701	TOTAL KJELDAHL NITROGEN as N	2.07	4.07		2.00	mg/L	**100**		70-130	**NA**	0-20		LFM	
E-10264	51355	TOTAL KJELDAHL NITROGEN as N	25.5	28.0		2.00	mg/L	**125**		70-130	**NA**	0-20		LFM	
351.2_230914															
E-10264	53414	TOTAL KJELDAHL NITROGEN as N	12.6	13.5		2.00	mg/L	**45**		70-130	**NA**	0-20	IS	LFM	
E-10264	53816	TOTAL KJELDAHL NITROGEN as N	0.96	2.84		2.00	mg/L	**94**		70-130	**NA**	0-20		LFM	
NO3NO2_230911															
E-10128	50699	TOTAL NITRATE+NITRITE as N	ND	0.96	0.94	1.00	mg/L	**96**	**94**	80-120	**2.1**	0-20		LFM	
E-10128	52652	TOTAL NITRATE+NITRITE as N	0.27	1.27	1.28	1.00	mg/L	**100**	**101**	80-120	**1.0**	0-20		LFM	
E-10128	52835	TOTAL NITRATE+NITRITE as N	ND	0.99	0.99	1.00	mg/L	**99**	**99**	80-120	**0.0**	0-20		LFM	
E-10128	52917	TOTAL NITRATE+NITRITE as N	ND	0.99	0.99	1.00	mg/L	**99**	**99**	80-120	**0.0**	0-20		LFM	
E-10128	53294	TOTAL NITRATE+NITRITE as N	0.87	1.83	1.84	1.00	mg/L	**96**	**97**	80-120	**1.0**	0-20		LFM	
OPHOS_230823															
14265-44-2	50762	ORTHO-PHOSPHATE	0.12	0.58	0.58	0.50	mg/L	**92**	**92**	70-130	**0.0**	0-20		LFM	
TPHOS_230913															
7723-14-0	53071	TOTAL PHOSPHORUS-P	0.019	0.070	0.072	0.050	mg/L	**102**	**106**	70-130	**3.8**	0-20		LFM	
7723-14-0	53081	TOTAL PHOSPHORUS-P	3.26	3.63	3.46	0.050	mg/L	**740**	**400**	70-130	**59.6**	0-20	IS	LFM	
7723-14-0	54561	TOTAL PHOSPHORUS-P	0.038	0.089	0.093	0.050	mg/L	**102**	**110**	70-130	**7.5**	0-20		LFM	

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

EDGE ANALYTICAL

Qualifier Definitions

Reference Number: 23-25668
Report Date: 09/20/23

Qualifier	Definition
IM	Matrix induced bias assumed
INH	The sample was non-homogeneous
IS	The ratio of the spike concentration to sample background was too low to meet performance criteria

Note: Some qualifier definitions found on this page may pertain to results or QC data which are not printed with this report.

IEH ANALYTICAL LABORATORIES
LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER:	**1742336**	**PAGE**	**1**
REPORT DATE:	**10/17/23**		
DATE SAMPLED:	**08/22/23**	**DATE RECEIVED:**	**08/25/23**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON SEDIMENT SAMPLES FROM HERRERA ENVIRONMENTAL

CASE NARRATIVE

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

SAMPLE DATA - SEDIMENTS (DRY WT. BASIS)

SAMPLE ID	% SOLIDS	% WATER	IRON (mg/kg)	TOTAL-P (mg/kg)	LOOSELY BOUND P (NH4CL) (mg/kg)	FE BOUND P (DITHIONATE) (mg/kg)	AL BOUND P (NAOH) (mg/kg)	BIOGENIC P (mg/kg)	CA BOUND P (HCL) (mg/kg)	ORGANIC P (mg/kg)
CAM-D-0-2	2.64%	97.4%	15057	1487	<2.00	14.4	379	684	99.7	995
CAM-D-4-6	4.00%	96.0%	14837	1164	<2.00	30.5	276	486	107	750
CAM-D-8-10	4.53%	95.5%	15658	1148	<2.00	14.5	313	389	159	662
CAM-D-12-16	5.20%	94.8%	18865	777	<2.00	10.4	208	201	151	407
CAM-D-20-26	6.54%	93.5%	16812	686	<2.00	27.5	187	162	151	320
CAM-S-0-2	4.19%	95.8%	15363	1391	<2.00	177	292	508	132	790
CAM-S-4-6	10.4%	89.6%	16321	577	<2.00	2.16	128	143	173	273
CAM-S-8-10	12.5%	87.5%	13322	427	<2.00	9.24	89.0	64.3	175	154
CAM-S-12-16	7.66%	92.3%	6852	315	<2.00	28.4	108	31.6	68.8	109
CAM-S-20-26	8.45%	91.5%	9817	342	<2.00	10.3	109	53.9	79.1	144

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER:	**1742336**	**PAGE**	**2**
REPORT DATE:	**10/17/23**		
DATE SAMPLED:	**08/22/23**	**DATE RECEIVED:**	**08/25/23**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON SEDIMENT SAMPLES FROM HERRERA ENVIRONMENTAL

QA/QC DATA- SEDIMENTS

QC PARAMETER	% SOLIDS	IRON (mg/kg)	TOTAL-P (mg/kg)	LOOSELY BOUND P (NH4CL) (mg/kg)	FE BOUND P (DITHIONATE) (mg/kg)	AL BOUND P (NAOH) (mg/kg)	BIOGENIC P (mg/kg)	CA BOUND P (HCL) (mg/kg)	ORGANIC P (mg/kg)
METHOD	SM18 2540B	EPA 6010	CALCULATED	SM18 4500PF	SM18 4500PF	SM18 4500PF	EPA 365.1	SM18 4500PF	EPA 365.1
DATE PREPARED	10/09/23	09/02/23	09/27/23	09/26/23	09/26/23	09/27/23	09/27/23	09/27/23	09/27/23
DATE ANALYZED	1.00%	2.00	5.00	2.00	2.00	2.00	2.00	2.00	2.00
DETECTION LIMIT									
DUPLICATE									
	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH	BATCH
SAMPLE ID	24.8%	264	1038	<2.00	144	309	55	426	159
ORIGINAL	24.8%	277	1022	<2.00	145	314	60	405	158
DUPLICATE	0.21%	4.81%	1.62%	NC	0.85%	1.85%	8.03%	5.28%	1.11%
RPD									
SPIKE SAMPLE									
SAMPLE ID									
ORIGINAL									
SPIKED SAMPLE									
SPIKE ADDED	NA	NA	NA	NA	NA	NA	NA	NA	NA
% RECOVERY									
QC CHECK									
(mg/l)									
FOUND		5.20		0.040	0.040	0.039	0.095	0.039	0.095
TRUE		5.00		0.039	0.039	0.039	0.094	0.039	0.094
% RECOVERY	NA	104.00%	NA	101.96%	101.96%	100.00%	101.06%	100.00%	101.06%
BLANK	NA	<2.00	NA	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00

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

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

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

Chain of Custody Record

1742336

Project Name:	Project Number:	Client:
Campbell Lake CMP	23-08143-000	Skagit County

Report To:	Copy To:
Tim Clark, tclark@herrerainc.com	ksweeney@herrerainc.com

Sampled By:	Delivery Method:
Clark and Sweeney	

Laboratory:	Requested Completion Date:	Total No. of Containers:
IEH Analytical Laboratories, C/O Sergio Sanchez, 3927 Aurora Avenue North, Seattle, WA 98103 (phone 206-632-2715)	Standard	10

Lab Use:

Sample ID	Date	Time	Sample Type (see codes)	Preser-vative? (Y/N)	Matrix (see codes)	Number of Containers	Loosely bound phosphorus (SM 4500PF)	Iron bound phosphorus (SM 4500PF)	Aluminum bound phosphorus (SM 4500PF)	Calcium bound phosphorus (SM 4500PF)	Organic phosphorus (EPA365.1)	Biogenic phosphorus (EPA365.1)	Total phosphorus (calculated)	Total iron (EPA 6020)	Percent solids (SM 2540 B)		Lab ID No.
CAM-D-0-2	8/22/23	1100	G	N	SE	1	X	X	X	X	X	X	X	X	X	1339	10
CAM-D-4-6	8/22/23	1100	G	N	SE	1	X	X	X	X	X	X	X	X	X	1339	11
CAM-D-8-10	8/22/23	1100	G	N	SE	1	X	X	X	X	X	X	X	X	X	1339	12
CAM-D-12-16	8/22/23	1100	G	N	SE	1	X	X	X	X	X	X	X	X	X	1339	13
CAM-D-20-26	8/22/23	1100	G	N	SE	1	X	X	X	X	X	X	X	X	X	1339	14
CAM-S-0-2	8/22/23	1115	G	N	SE	1	X	X	X	X	X	X	X	X	X	1339	15
CAM-S-4-6	8/22/23	1115	G	N	SE	1	X	X	X	X	X	X	X	X	X	1339	16
CAM-S-8-10	8/22/23	1115	G	N	SE	1	X	X	X	X	X	X	X	X	X	1339	17
CAM-S-12-16	8/22/23	1115	G	N	SE	1	X	X	X	X	X	X	X	X	X	1339	18
CAM-S-20-26	8/22/23	1115	G	N	SE	1	X	X	X	X	X	X	X	X	X	1339	19

Comments/Special Instructions:

Run all Herrera project samples in a single batch

Relinquished by (Name/CO/	Signature	Date/Time	Received By (Name/CO)	Signature	Date/Time
Timothy Clark	[signature]	8/25 1350	Matthew Good	Matthew Good	1350 8/25/23
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)

LIMNOpro
Aquatic Science

Zooplankton Taxonomic Services
Chain of Custody

Ship To: Limnopro Aquatic Science, *Inc.*
C/O Dan McEwen
5 11th St SW
St. Stephen, MN 56375

General Information

Client Name: Skagit County

Project Contact: Tim Clark, Herrera Environmental Consultants, Inc.

Email: tclark@herrerainc.com

Phone: 971.361.2238

Reporting/Billing Address: Herrera Environmental Consultants, 107 SE Washington Street, Suite 140, Portland, OR 97214

Sampling Details

Sampled By: Katie Sweeney

Collection Date(s): 8/22/23

Waterbody Name/County/State: Lake Campbell/Skagit/WA

Additional Notes:

Type: ☐ Grab
☑ Plankton Tow: Mesh Opening: 80 µm Net Opening: 12.7 cm Tow Length: 38.1 cm (Please Specify Units)
☐ Other (Please Specify) ____________

Preservative: ☑ Ethanol (95 %) ☐ Isopropanol (_____ %) ☐ Formalin ☐ Live on ice ☐ Other (Please Specify) 150 mL of 95% EtOH

Taxonomic Resolution: ☑ Standard: (*Ostracods/rotifers to phylum, copepods to family, cladocerans to species, and all other to lowest practicable level).*
☐ Maximum: *(All to genus or species where possible - **Additional charges may apply**)*

Data Required: ☑ Counts and ID only ☐ Counts, ID, and Biomass

Chain of Custody

Relinquished by (signature in ink): Leanne Ingman Number of Samples 1 Date/Time (AM/PM) 8/24/23 02:00pm

Received by lab (signature in ink): [signature] Number of Samples 1 Date/Time (AM/PM) 8/29/23

Please label each bottle with the appropriate information including organization, waterbody name, and date.

LIMNOPRO AQUATIC SCIENCE, INC. CHAIN OF CUSTODY ZOOPLANKTON TAXONOMY

12.7x300 cm
=38003.66
=38 L

CLIENT: Skagit County
PRESERVATIVE: Ethanol

PROJECT: Lake Campbell Cyanobacteria Management Plan (23-08143-000)
NET (MESH/OPENING): 80-µm mesh; ___ diameter opening

Client Provided Information							*Laboratory Use Only*			
Sample Number/ID	Date Collected	Time Collected	Site Location	Number of Containers	Length of tow (m)	Collector Initials	Lab Code	Date Logged	Initials	Remarks
CAM-Deep	8/22/23	1510	CAM-DEEP	1	3M	KS				

At a minimum label each container as it corresponds to the "Sample Number/ID" in the table above. Use additional sheets as needed.

LIMNOpro
Aquatic Science

Zooplankton Report

Samples: 1
Preservative: 95% ethanol
Client: Herrera
Reference Method: : EPA LG403, Revision 07, July 2016
Site: Lake Campbell, Skagit County (CAM-DEEP)
Collection Dates: 8/22/2023
Processing Dates: 10/26/2023
Report Date: 10/30/2023, 1/16/2024 revised

This report is a revision of an original report distributed to the client on 10/30/2023, which contained an inaccuracy based on an error interpreting the original COC. Original report had a sampled volume of 4.83 L based on the COC which reported a 38.1 cm tow length using a net with a diameter of 12.7 cm and 80-micron mesh. The attached sample sheet indicated, however, the tow was actually 3 L or 300 cm. The total sampled volume based on these data was 38 L rather than 4.83 L. The table below is updated with this correction. Sample was concentrated into 0.250 L sampling jar. A subsample of 10 ml was required to count >200 organisms. After subsampling, the entire sample was poured onto a gridded Petri dish where it scanned for large and/or rare taxa not accounted for in the subsample. All counts and identifications were done by Daniel McEwen.

Results

			Raw	Multiplier	N/Tow	**N/ L**	**%/L**
Cladocera	Bosminidae	*Bosmina longirostris*	18	25	450	**12**	**7.9%**
Cladocera	Chydoridae	*Chydorus sphaericus*	5	25	125	**3**	**2.2%**
Cladocera	Daphniidae	*Ceriodaphnia reticulata*	61	25	1525	**40**	**26.8%**
Cladocera	Daphniidae	*Daphnia mendotae*	26	25	650	**17**	**11.4%**
Cladocera	Sididae	*Diaphanosoma brachyurum*	6	25	150	**4**	**2.6%**
Copepoda	Diaptomidae	Adult	5	1	5	**0**	**0.1%**
Copepoda	Cyclopidae	Adult	55	25	1375	**36**	**24.1%**
Copepoda	Cyclopidae	Nauplii	37	25	925	**24**	**16.2%**
Rotifera	Brachionidae	*Kerotella* sp.	20	25	500	**13**	**8.8%**

Raw = actual counts in 10 ml subsample (or full scan for calanoids = Diaptomidae)
Multiplier = 250 ml concentrated sample / 10 ml subsample
N / Tow = estimated animals per 38 L tow (12.7 cm diameter net x 300 cm length tow)
N / L = estimated animals per L
%/L = percent animal taxon per L

Taxonomic Keys: Haney, J.F. et al. "An-Image-based Key to the Zooplankton of North America" version 5.0 released 2013. University of New Hampshire Center for Freshwater Biology <cfb.unh.edu> 24 Jan 2018; Edmondson, W.T. ed. 1959. Ward & Whipple's Fresh-Water Biology. 2nd Edition. New York: John Wiley & Sons.; Needham, J.G. and Needham, P.R., 1962. Guide to the Study of Freshwater Biology. San Francisco: Holden-Day, Inc.; Pennak, R.W. 1978. Fresh-water Invertebrates of the United States. 2nd Edition. New York: John Wiley & Sons.; Thorp, J.H. and Covich, A.P. eds., 2009. Ecology and Classification of North American Freshwater Invertebrates. 2nd Edition. San Diego: Academic Press.

dan@limnopro.com ● www.limnopro.com ● (320) 342 - 2210 ● 1848 3rd St., N, PO Box 721, St. Cloud, MN 56303

HERRERA
Science + Planning + Design

2023 LAKE CAMPBELL CMP WATERSHED MONITORING DATA SHEET

Field Equipment Checklist

☐ Flow meter
☐ YSI multimeter
☐ Cooler with ice
☐ Tape Measure
☐ Hanna pH meter
☐ Chain-of-Custody
☐ Filters & syringes
☐ Sample bottles
☐

Project: Lake Campbell Cyanobacteria Management Plan Project No.: 23-08143-000
Client: Skagit County Field Personnel: LEANNE INGMAN
Event Type and Number Storm ( ) Routine/Base (√)
Weather and predicted rainfall (in): 61°F cloudy & rain

Routine sampling to occur every month (August 2023-January 2024) on the day of or day before lake sampling. Three additional wet weather sampling events to occur during fall and winter storms.

Sampling Data

All samples analyzed for total and dissolved nutrients.

disconnected did not take sample

Site ID	Sample ID	Sample Time	Duplicate Collected?	Photos Taken?	Water Description (Turbidity; Unusual color, odor, sheen)
CS1	CS1-20230825	~~0800~~		✓	clear disconnected flow
CS2	CS2-2023_____				
CS2.5	CS2.5-2023_____				
CS3	CS3-2023_____			✓	
CAM-OUT				✓	

no sample needed

Notes & observations:

Discharge Data

CS1

Monitoring Location: SR-20 inflow

Discharge measurement method: Culvert measurements + Manning's equation

Collection Date and Time: 08/25/23 @ 0846

Notes & Observations 250 mL in 30 seconds

disconnected before lake

Culvert diameter = 36 inches

Water depth = 0.1 inches feet

Water velocity (flow) = ______ f/s

Calculated Flow (cfs) = ______

CS2

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: Culvert measurements + Manning's equation

Collection Date and Time: ______

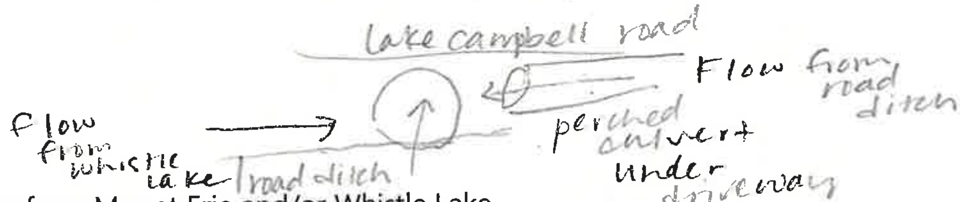
Notes & Observations No water

Culvert diameter = 36 inches

Water depth = ______ feet

Water velocity (flow) = ______ f/s

Calculated Flow (cfs) = ______



CS2.5

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: Culvert measurements + Manning's equation

Collection Date and Time: ______

Notes & Observations: Wet / no flow. landowner noted water mostly accummulates from the South West.

Culvert diameter = 36 inches

Water depth = ______ feet

Water velocity (flow) = ______ f/s

Calculated Flow (cfs) = ______

- Bucket method does not work for culvert going under roadway could work for perched culvert
- Standard flow measurement for whistle/ditch flow... 2 measurements @ site - one from either direction?

CS3

Monitoring Location: Lake Erie outlet

Discharge measurement method: Culvert measurements + Manning's equation

Collection Date and Time: ______

Notes & Observations: no water. bridge - wide spot - Flow slows ~3 ft deep. landowner clears grass

Culvert diameter = ______ inches

Water depth = ______ feet

Water velocity (flow) = ______ f/s

Calculated Flow (cfs) = ______

Standard flow meter measurement

CAM-OUT

Monitoring Location: Outlet for Lake Campbell

Discharge measurement method: Stream cross-section

Collection Date and Time: 8/25/23 @ 0828

Notes & Observations: Beaver dam disconnecting lake & outlet → No Flow

Total channel section width = _______ feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		–	–
1			
2			
3			
4			
5			
6			
7			
8			
Edge of Bank		–	–

Calculated Flow (cfs) = ___________

Other Observations

2023 LAKE CAMPBELL CMP
MONITORING DATA SHEET

Field Equipment Checklist

- ☐ Secchi disk
- ☐ YSI multimeter
- ☐ Cooler with ice
- ☐ Van Dorn / Kemmerer
- ☐ Hanna pH meter
- ☐ Sample bottles
- ☐ Plankton net
- ☐ Anchor
- ☐ Filters & syringes

Project: Lake Campbell Cyanobacteria Management Plan Project No.: 23-08143-000

Client: Skagit County Field Personnel: Toni Bob Ben Gab Jim

Weather: Clear sunny, windy to mild wind

Wind (still, windy, choppy): ~~Very~~ windy to collect

Number of vessels on lake: 0 1 sample

Number of shoreline swimmers: -0-

Number of shoreline anglers: -0-

Number of geese: ducks:

other waterfowl Heron cormier ducks

CAM-DEEP (at deepest point south of island)

Collection Date and Time: 9/18/23 1:00 P.M.

Secchi Depth (m): 90 cm Depth to Bottom (m): 13 1/2 Ft

Water color: green/yellow

Notes

67°

13.5' depth

13 1/2' Ft.

1

Profile Readings (every monthly event):

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Specific Conductivity (µS/cm)	pH*
0.2	~~21.1~~ 20.4	~~5.75~~ 8.77	~~64.5~~ 97.1	~~268.2~~ 265.2	8.71
0.5	~~20.9~~ 20.4	~~6.10~~ 8.53	~~63.3~~ 94.1	~~261.3~~ 265.1	X
1.0	~~20.7~~ 20.3	~~5.90~~ 7.95	~~64.1~~ 86.3	~~262.5~~ 267.2	8.60
1.5	~~20.4~~ 19.7	~~5.82~~ 7.27	~~64.0~~ 81.0	~~261.1~~ 266.1	X
2.0	~~19.9~~ 19.2	~~5.65~~ 5.73	~~61.5~~ 61.4	~~263.5~~ 266.9	8.26
2.5	~~19.6~~ 19.1	~~6.18~~ 5.18	~~66.9~~ 55.3	267.3 ~~264.6~~	X
3.0	~~19.5~~ 19.1	~~5.72~~ 5.33	~~66.1~~ 57.1	267.0 ~~265.3~~	8.06
3.5	~~19.4~~ 19.1	~~5.75~~ 5.45	~~61.8~~ 58.1	266.8	X
4.0	~~19.5~~ 18.8	~~5.85~~ 4.97	~~63.0~~ 53.1	267.0 ~~265.2~~	8.03

*pH sampling done in 1-meter increments

Notes ~~TAKE~~ cover off Probe

Campbell Lake 9/18

Water Quality Samples Collected* (every monthly event):

Fill in the Sample IDs and depths below. Check the box (X) for each sample bottle filled. Duplicates should be collected during each monthly event; record the same time and depth here as the depth the duplicate was collected. Do not label sample bottles with the sample time or depth.

Sample ID	Sample Time	Sample Depth (m)	Total Nutrients (500 mL HDPE with H_2SO_4)	Dissolved Nitrogen ** (500 mL HDPE with H_2SO_4)	Orthophosphate ** (250 mL HDPE)	Chlorophyll-a (125-mL dark HDPE)
CAM-DEEP-2023__________-S Dup.	9/18 2:15 9/18 2:35	0.5				
CAM-DEEP-2023__________-B	9/18 2:52	3.5				
CAM-DUPE-2023__________ Surface						

*All water quality samples must be kept on ice or refrigerated until delivered to lab.

**Dissolved nitrogen and orthophosphate samples must be field filtered into bottles using syringes.

Notes No algae bottle for duplicate

Plankton Samples (monthly during August, September, and October only)

Fill in the Sample IDs and depths below. Check the box (X) for each sample bottle filled.

Sample ID	Sample Time	Sample Depth (m)	Phytoplankton Samples (125-mL dark HDPE, with Lugol's)	Zooplankton Vertical Tow (250-mL HDPE, with ethanol)
CAM-DEEP-2023______________-S	9/18/23 2:30 * 9/18/2 2:40	Duplicate 0.5	Surface only	1 sample NA
CAM-DEEP-2023 3 1/2 M -B	9/18 2:52	3.5 M		NA
CAM-DEEP-2023______________		From ______ m to surface	NA	

Note: Change sample IDs to "CAM-DEEP-2024______-__" for any 2024 events.

*Note: 9/18 No algae Bottle on duplicate

HERRERA
Science + Planning + Design

2023 LAKE CAMPBELL CMP WATERSHED MONITORING DATA SHEET

Project: Lake Campbell Cyanobacteria Management Plan Project No.: 23-08143-000
Client: Skagit County Field Personnel: Ingman, Elliston
Event Type and Number Storm ( ) Base (✓)
Weather and predicted rainfall (in): sunny, breezy, 61

Base flow sampling to occur every month (August 2023 through January 2024) on the day of or day before lake sampling. Six additional wet weather (storm flow) sampling events to occur during fall and winter storms September 2023 through January 2024.

Field Equipment Checklist

- ☑ Flow meter
- ☑ YSI multimeter
- ☑ Cooler with ice
- ☑ Tape Measure
- ☑ Hanna pH meter
- ☑ Chain-of-Custody
- ☑ Sample bottles

Sampling Data

All samples analyzed for total nutrients. Duplicates are to be collected monthly from September 2023 through January 2024 at a random site during a random event. If applicable, record duplicate sample information below. Do not include duplicate sample times on COCs.

Site ID	Sample ID	Sample Time	Photos Taken?	Water Description (Turbidity; Unusual color, odor, sheen)
CS1	CS1-20230918	1340		clear, low flow,
~~CS2~~	~~CS2-2023~~			
~~CS2.5~~	~~CS2.5-2023~~			
~~CS3~~	~~CS3-2023~~			
DUPE	DUPE-20230918	1316 1330		

Notes & observations:

mf b2_campbell_watershedmonitoring_field form_blank.docx

Discharge Data

CS1

Monitoring Location: SR-20 inflow

Discharge measurement method: ☑ Timed bucket fill ☐ Stream cross-section with flow probe ☐ Other (describe):

Collection Date and Time:

Notes & Observations

702 uS/s SpC 82.3% DO 8.42 mg/L pH 7.62

Salinity 0.4 temp 15.3 °C

Culvert diameter = 36 in inches

Water depth = 0.5 inches ~~feet~~ 0.04 ft

Water velocity (flow) = ________ f/s

Calculated Flow (cfs) = ________

1800 mL / 50 seconds
1.8 L
0.036 L / sec
2.16 L / 60 sec
1 min

36 mL / sec

CS2

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐ Stream cross-section with flow probe ☐ Other (describe):

Collection Date and Time:

Notes & Observations dry

Culvert diameter = ________ inches

Water depth = ________ feet

Water velocity (flow) = ________ f/s

Calculated Flow (cfs) = ________

mf b2_campbell_watershedmonitoring_field form_blank.docx

CS2.5

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe): ____

Collection Date and Time: ____

Notes & Observations stagnant, no flow

Culvert diameter = ____ inches

Water depth = ____ feet

Water velocity (flow) = ____ f/s

Calculated Flow (cfs) = ____

CS3

Monitoring Location: Lake Erie outlet

Discharge measurement method: Stream cross-section

Collection Date and Time: ____

Notes & Observations dry

Total channel section width = ____ feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		–	–
1			
2			
3			
4			
5			
6			
7			
8			
Edge of Bank		–	–

Calculated Flow (cfs) = ____

mf b2_campbell_watershedmonitoring_field form_blank.docx

CAM-OUT

Monitoring Location: Outlet for Lake Campbell

Discharge measurement method: Stream cross-section

Collection Date and Time: 9/18/23 1226

Notes & Observations

disconnected / no flow

Total channel section width = _______ feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		–	–
1			
2			
3			
4			
5			
6			
7			
8			
Edge of Bank		–	–

Calculated Flow (cfs) = ________________

Other Observations

photos taken

CHAIN OF CUSTODY / ANALYSIS REQUEST (PLEASE COMPLETE ALL APPLICABLE SHADED SECTIONS)

REPORT TO: SKA02 SKAGIT CO. PUBLIC WKS
ADDRESS: 1800 CONTINENTAL PLACE
CITY: MOUNT VERNON STATE: WA ZIP: 98273
ATTN: Leanne Freyman
PHONE: (360) 899-6758 FAX:
EMAIL: leanne@co.skagit.wa.us meghanm@co.skagit.wa.us
PROJECT NAME: lake Campbell-09/18/2023

FOR LAB USE ONLY
REF#

CHECK REGULATORY PROGRAM
- ☐ SAFE DRINKING WATER ACT
- ☐ CLEAN WATER ACT
- ☐ RCRA / CERCLA
- ☐ OTHER

EDGE ANALYTICAL
Main Lab (800-755-9295)
1620 South Walnut St. Burlington, WA 98233
Microbiology (888-725-1212)
805 W. Orchard Dr. Suite 4 Bellingham, WA 98225
Wilsonville Lab (503-682-7802)
9150 SW Pioneer Ct. Suite W Wilsonville, OR 97070
Corvallis Lab (541-753-4946)
540 SW 3rd St. Corvallis, OR 97333

#	SAMPLE ID	LOCATION	SAMPLE MATRIX *	DATE	TIME	Ortho phos	Ammonia, tkn, t. phos, NO2/NO3	Chlorophyll	SPECIAL INSTRUCTIONS/ CONDITIONS ON RECEIPT
1	CS1-20230918	CS1	SW	09/18/23	1340	☑	☑	☐	
2	Dupe-20230918	CS1	SW	09/18/23		☑	☑	☐	
3	Camdeep - B	Bottom	SW	09/18/23	1450	☐	☐	☑	
4	Camdeep-Dupe	surface	SW	09/18/23		☐	☐	☑	
5	Camdeep-S	surface	SW	09/18/23	1430	☐	☐	☑	
6	Dupe-20230918		SW	09/18/23	1440	☑	☑	☐	unfiltered
7	Cam-deep-20230918-B		SW	09/18/23	1450	☑	☑	☐	unfiltered
8	Cam-deep-20230918-S		SW	09/18/23	1435	☑	☑	☐	unfiltered
9			SW			☐	☐	☐	
10			SW			☐	☐	☐	
11			SW			☐	☐	☐	
12			SW			☐	☐	☐	
13			SW			☐	☐	☐	
14			SW			☐	☐	☐	
15			SW			☐	☐	☐	
16			SW			☐	☐	☐	
17			SW			☐	☐	☐	
18			SW			☐	☐	☐	
19			SW			☐	☐	☐	
20			SW			☐	☐	☐	
21			SW			☐	☐	☐	
22			SW			☐	☐	☐	
23			SW			☐	☐	☐	
24			SW			☐	☐	☐	
25			SW			☐	☐	☐	
26			SW			☐	☐	☐	
27			SW			☐	☐	☐	

SAMPLED BY: LF, TM PHONE: EMAIL:

RELINQUISHED BY	DATE	TIME	RECEIVED BY	DATE	TIME
Leanne Freyman	09/18/23	1552	WBM/WJKE18	9/18/23	1552

Burlington, WA *Corporate Laboratory (a)*
1620 S Walnut St - Burlington, WA 98233 - **800.755.9295** • 360.757.1400
Bellingham, WA *Microbiology (b)*
805 Orchard Dr Ste 4 - Bellingham, WA 98225 - 360.715.1212
Portland, OR *Microbiology/Chemistry (c)*
9725 SW Commerce Cr Ste A2 - Wilsonville, OR 97070 - 503.682.7802
Corvallis, OR *Microbiology/Chemistry (d)*
1100 NE Circle Blvd, Ste 130 - Corvallis, OR 97330 - 541.753.4946
Bend, OR *Microbiology (e)*
20332 Empire Blvd Ste 4 - Bend, OR 97701 - 541.639.8425

Data Report

Client Name: Skagit County Public Works
1800 Continental Place
Mount Vernon, WA 98273

Reference Number: **23-28651**
Project: Lake Campbell - 09/18/2023

Report Date: 11/13/23

Date Received: 9/18/23
Approved by: bj,mcs,tjb
Authorized by:

Lawrence J Henderson, PhD
Director of Laboratories, Vice President

Sample Description: CSI-20230918 CSI — Matrix SW — Sample Date: 9/18/23 1:40 pm
Lab Number: 56575 — Sample Comment: — Collected By: LI, TH

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.036	0.010	0.0088	mg/L	1.0	350.1	a	9/28/23	MSO	350.1_230928	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.23	0.20	0.0585	mg/L	1.0	351.2	a	10/4/23	MSO	351.2_231004	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.05	0.01	0.0042	mg/L	1.0	SM4500-NO3 F	a	9/19/23	TJB	NO3NO2_230919	
14265-44-2	**ORTHO-PHOSPHATE**	0.06	0.01	0.0032	mg/L	1.0	SM4500-P F	a	9/19/23	TJB	OPHOS_230919	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.028	0.010	0.0021	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	10/10/23	TJB	TPHOS_231010	

Sample Description: Dupe-20230918 CSI — Matrix SW — Sample Date: 9/18/23 1:40 pm
Lab Number: 56576 — Sample Comment: — Collected By: LI, TH

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.029	0.010	0.0088	mg/L	1.0	350.1	a	10/3/23	TJB	350.1_231003	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.23	0.20	0.0585	mg/L	1.0	351.2	a	10/4/23	MSO	351.2_231004	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.06	0.01	0.0042	mg/L	1.0	SM4500-NO3 F	a	9/19/23	TJB	NO3NO2_230919	
14265-44-2	**ORTHO-PHOSPHATE**	0.06	0.01	0.0032	mg/L	1.0	SM4500-P F	a	9/19/23	TJB	OPHOS_230919	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.031	0.010	0.0021	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	10/10/23	TJB	TPHOS_231010	

Sample Description: Camdeep-B Bottom — Matrix SW — Sample Date: 9/18/23 2:50 pm
Lab Number: 56577 — Sample Comment: — Collected By: LI, TH

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
NA	**CHLOROPHYLL A**	56.6	0.1	0	mg/m3	1.0	SM10200-H		9/19/23	CP	WML_230919	Analyzed by WML
NA	**PHEOPHYTIN A**	18.5	0.1	0	mg/m3	1.0	SM10200-H		9/19/23	CP	WML_230919	Analyzed by WML

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

If you have any questions concerning this report contact us at the above phone number.

Reference Number: **23-28651**
Report Date: 11/13/23

Data Report

Sample Description: Camdeep-Dupe Surface | Matrix SW | Sample Date: 9/18/23 2:50 pm
Lab Number: 56578 | Sample Comment: | Collected By: LI, TH

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
NA	**CHLOROPHYLL A**	53.9	0.1	0	mg/m3	1.0	SM10200-H		9/19/23	CP	WML_230919	Analyzed by WML
NA	**PHEOPHYTIN A**	ND	0.1	0	mg/m3	1.0	SM10200-H		9/19/23	CP	WML_230919	Analyzed by WML

Sample Description: Camdeep-S Surface | Matrix SW | Sample Date: 9/18/23 2:30 pm
Lab Number: 56579 | Sample Comment: | Collected By: LI, TH

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
NA	**CHLOROPHYLL A**	56.1	0.1	0	mg/m3	1.0	SM10200-H		9/19/23	CP	WML_230919	Analyzed by WML
NA	**PHEOPHYTIN A**	ND	0.1	0	mg/m3	1.0	SM10200-H		9/19/23	CP	WML_230919	Analyzed by WML

Sample Description: Dupe-20230918 | Matrix SW | Sample Date: 9/18/23 2:40 pm
Lab Number: 56580 | Sample Comment: unfiltered | Collected By: LI, TH

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.028	0.010	0.0088	mg/L	1.0	350.1	a	10/5/23	MSO	350.1_231005	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	1.34	0.20	0.0585	mg/L	1.0	351.2	a	10/4/23	MSO	351.2_231004	
E-10128	**TOTAL NITRATE+NITRITE as N**	ND	0.01	0.0042	mg/L	1.0	SM4500-NO3 F	a	9/19/23	TJB	NO3NO2_230919	
14265-44-2	**ORTHO-PHOSPHATE**	0.03	0.01	0.0032	mg/L	1.0	SM4500-P F	a	9/19/23	TJB	OPHOS_230919	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.081	0.010	0.0021	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	10/10/23	TJB	TPHOS_231010	

Sample Description: Cam-Deep-20230918-B | Matrix SW | Sample Date: 9/18/23 2:50 pm
Lab Number: 56581 | Sample Comment: unfiltered | Collected By: LI, TH

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.053	0.010	0.0088	mg/L	1.0	350.1	a	10/5/23	MSO	350.1_231005	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	2.50	0.20	0.0585	mg/L	1.0	351.2	a	10/4/23	MSO	351.2_231004	
E-10128	**TOTAL NITRATE+NITRITE as N**	ND	0.01	0.0042	mg/L	1.0	SM4500-NO3 F	a	9/19/23	TJB	NO3NO2_230919	
14265-44-2	**ORTHO-PHOSPHATE**	0.03	0.01	0.0032	mg/L	1.0	SM4500-P F	a	9/19/23	TJB	OPHOS_230919	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.164	0.010	0.0021	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	10/10/23	TJB	TPHOS_231010	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

EDGE ANALYTICAL

Reference Number: **23-28651**
Report Date: 11/13/23

Data Report

Sample Description: Cam-Deep-20230918-S | Matrix SW | Sample Date: 9/18/23 2:35 pm
Lab Number: 56582 | Sample Comment: unfiltered | Collected By: LI, TH

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.015	0.010	0.0088	mg/L	1.0	350.1	a	10/5/23	MSO	350.1_231005	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	1.46	0.20	0.0585	mg/L	1.0	351.2	a	10/4/23	MSO	351.2_231004	
E-10128	**TOTAL NITRATE+NITRITE as N**	ND	0.01	0.0042	mg/L	1.0	SM4500-NO3 F	a	9/19/23	TJB	NO3NO2_230919	
14265-44-2	**ORTHO-PHOSPHATE**	0.03	0.01	0.0032	mg/L	1.0	SM4500-P F	a	9/19/23	TJB	OPHOS_230919	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.086	0.010	0.0021	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	10/10/23	TJB	TPHOS_231010	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

SAMPLE INDEPENDENT QUALITY CONTROL REPORT

Reference Number: **23-28651**
Report Date: 11/13/23

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
Calibration Check											
350.1_230928	0	AMMONIA-N	2.51	2.50	mg/L	350.1	100	90-110		CAL	
350.1_231003	0	AMMONIA-N	2.62	2.50	mg/L	350.1	105	90-110		CAL	
350.1_231005	0	AMMONIA-N	2.53	2.50	mg/L	350.1	101	90-110		CAL	
351.2_231004	0	TOTAL KJELDAHL NITROGEN as N	2.56	2.50	mg/L	351.2	102	90-110		CAL	
NO3NO2_23091§	0	TOTAL NITRATE+NITRITE as N	1.05	1.00	mg/L	SM4500-NO3 F	105	90-110		CAL	
ophos_230919	0	ORTHO-PHOSPHATE	1.02	1.00	mg/L	SM4500-P F	102	85-115		CAL	
tphos_231010	0	TOTAL PHOSPHORUS-P	0.100	0.100	mg/L	SM4500-P F	100	85-115		CAL	
Laboratory Fortified Blank											
351.2_231004	0	TOTAL KJELDAHL NITROGEN as N	1.91	2.00	mg/L	351.2	96	90-110		LFB	
Laboratory Reagent Blank											
350.1_231003	0	AMMONIA-N	ND		mg/L	350.1		0-0		LRB	
351.2_231004	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		LRB	
NO3NO2_23091§	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		LRB	
ophos_230919	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		LRB	
tphos_231010	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		LRB	
Method Blank											
350.1_230928	0	AMMONIA-N	ND		mg/L	350.1		0-0		MB	
350.1_231005	0	AMMONIA-N	ND		mg/L	350.1		0-0		MB	
351.2_231004	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		MB	
NO3NO2_23091§	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		MB	
ophos_230919	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		MB	
tphos_231010	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		MB	
Quality Control Sample											
350.1_230928	0	AMMONIA-N	3.62	3.72	mg/L	350.1	97	85-115		QCS	
350.1_231003	0	AMMONIA-N	3.86	3.72	mg/L	350.1	104	85-115		QCS	
350.1_231005	0	AMMONIA-N	3.79	3.72	mg/L	350.1	102	85-115		QCS	
351.2_231004	0	TOTAL KJELDAHL NITROGEN as N	3.28	3.26	mg/L	351.2	101	85-115		QCS	
NO3NO2_23091§	0	TOTAL NITRATE+NITRITE as N	1.95	2.00	mg/L	SM4500-NO3 F	98	90-110		QCS	
ophos_230919	0	ORTHO-PHOSPHATE	0.91	1.00	mg/L	SM4500-P F	91	90-110		QCS	
tphos_231010	0	TOTAL PHOSPHORUS-P	0.189	0.195	mg/L	SM4500-P F	97	90-110		QCS	

*Notation:

% Recovery = (Result of Analysis)/(True Value) * 100

NA = Indicates % Recovery could not be calculated.

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QCIndependent4.rpt

Reference Number: **23-28651**
Report Date: 11/13/2023

SAMPLE DEPENDENT
QUALITY CONTROL REPORT
Duplicate, Matrix Spike/Matrix Spike Duplicate and Confirmation Result Report

Duplicate

Batch	Sample	Analyte	Result	Duplicate Result	Units	%RPD	Limits	QC Qualifier	Type	Comments
350.1_230928										
7664-41-7	56033	AMMONIA-N	14.5	13.9	mg/L	**4.2**	0-20		DUP	
7664-41-7	56089	AMMONIA-N	ND	ND	mg/L	**NA**	0-20		DUP	
7664-41-7	56178	AMMONIA-N	ND	ND	mg/L	**NA**	0-20		DUP	
7664-41-7	56243	AMMONIA-N	0.46	0.45	mg/L	**2.2**	0-20		DUP	
7664-41-7	56575	AMMONIA-N	0.036	0.024	mg/L	**40.0**	0-20	INH	DUP	
350.1_231003										
7664-41-7	56576	AMMONIA-N	0.029	0.026	mg/L	**10.9**	0-20		DUP	
7664-41-7	57008	AMMONIA-N	ND	ND	mg/L	**NA**	0-20		DUP	
7664-41-7	57075	AMMONIA-N	ND	ND	mg/L	**NA**	0-20		DUP	
7664-41-7	57292	AMMONIA-N	2.78	2.79	mg/L	**0.4**	0-20		DUP	
7664-41-7	57413	AMMONIA-N	0.10	0.097	mg/L	**3.0**	0-20		DUP	
350.1_231005										
7664-41-7	56580	AMMONIA-N	0.028	0.023	mg/L	**19.6**	0-20	INH	DUP	
7664-41-7	57657	AMMONIA-N	0.77	0.77	mg/L	**0.0**	0-20		DUP	
7664-41-7	57927	AMMONIA-N	ND	ND	mg/L	**NA**	0-20		DUP	
7664-41-7	58020	AMMONIA-N	90.6	82.6	mg/L	**9.2**	0-20		DUP	
351.2_231004										
E-10264	56575	TOTAL KJELDAHL NITROGEN as N	0.23	ND	mg/L	**NA**	0-20	INH	DUP	
E-10264	57297	TOTAL KJELDAHL NITROGEN as N	ND	ND	mg/L	**NA**	0-20		DUP	
NO3NO2_230919										
E-10128	56575	TOTAL NITRATE+NITRITE as N	0.05	0.06	mg/L	**18.2**	0-20		DUP	
E-10128	57079	TOTAL NITRATE+NITRITE as N	0.08	0.08	mg/L	**0.0**	0-20		DUP	
OPHOS_230919										
14265-44-2	56575	ORTHO-PHOSPHATE	0.06	0.06	mg/L	**0.0**	0-20		DUP	
14265-44-2	57079	ORTHO-PHOSPHATE	0.0091	0.0091	mg/L	**0.0**	0-20		DUP	
TPHOS_231010										

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

Reference Number: 23-28651
Report Date: 11/13/2023

Duplicate

Batch	Sample	Analyte	Result	Duplicate Result	Units	%RPD	Limits	QC Qualifier	Type	Comments
7723-14-0	56575	TOTAL PHOSPHORUS-P	0.028	0.029	mg/L	**3.5**	0-20		DUP	
7723-14-0	58906	TOTAL PHOSPHORUS-P	0.135	0.103	mg/L	**26.9**	0-20	IM	DUP	
7723-14-0	59228	TOTAL PHOSPHORUS-P	0.096	0.090	mg/L	**6.5**	0-20		DUP	

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QC Dependent2.rpt

Reference Number: 23-28651
Report Date: 11/13/2023

EDGE ANALYTICAL QA

Laboratory Fortified Matrix (MS)

Batch/CAS	Sample	Analyte	Result	Spike Result	Duplicate Spike Result	Conc	Units	Percent Recovery MS	Percent Recovery MSD	Limits*	%RPD	Limits*	QC Qualifier	Type	Comments
350.1_230928															
7664-41-7	56033	AMMONIA-N	14.5	23.7	23.9	10.0	mg/L	**92**	**94**	70-130	**2.2**	0-20		LFM	
7664-41-7	56089	AMMONIA-N	ND	0.98	0.97	1.00	mg/L	**98**	**97**	70-130	**1.0**	0-20		LFM	
7664-41-7	56178	AMMONIA-N	ND	0.99	1.00	1.00	mg/L	**99**	**100**	70-130	**1.0**	0-20		LFM	
7664-41-7	56243	AMMONIA-N	0.46	1.45	1.42	1.00	mg/L	**99**	**96**	70-130	**3.1**	0-20		LFM	
7664-41-7	56575	AMMONIA-N	0.036	1.03	1.02	1.00	mg/L	**99**	**98**	70-130	**1.0**	0-20		LFM	
350.1_231003															
7664-41-7	56576	AMMONIA-N	0.029	1.08	1.08	1.00	mg/L	**105**	**105**	70-130	**0.0**	0-20		LFM	
7664-41-7	57008	AMMONIA-N	ND	1.07	1.06	1.00	mg/L	**107**	**106**	70-130	**0.9**	0-20		LFM	
7664-41-7	57075	AMMONIA-N	ND	1.11	1.07	1.00	mg/L	**111**	**107**	70-130	**3.7**	0-20		LFM	
7664-41-7	57292	AMMONIA-N	2.78	3.75	3.75	1.00	mg/L	**97**	**97**	70-130	**0.0**	0-20		LFM	
7664-41-7	57413	AMMONIA-N	0.10	1.15	1.17	1.00	mg/L	**105**	**107**	70-130	**1.9**	0-20		LFM	
350.1_231005															
7664-41-7	56580	AMMONIA-N	0.028	1.00	0.98	1.00	mg/L	**97**	**95**	70-130	**2.1**	0-20		LFM	
7664-41-7	57657	AMMONIA-N	0.77	1.72	1.75	1.00	mg/L	**95**	**98**	70-130	**3.1**	0-20		LFM	
7664-41-7	57927	AMMONIA-N	ND	1.01	1.00	1.00	mg/L	**101**	**100**	70-130	**1.0**	0-20		LFM	
7664-41-7	58020	AMMONIA-N	90.6	125	133	50	mg/L	**69**	**85**	70-130	**20.8**	0-20		LFM	
351.2_231004															
E-10264	56575	TOTAL KJELDAHL NITROGEN as N	0.23	2.08		2.00	mg/L	**93**		70-130	**NA**	0-20		LFM	
E-10264	57297	TOTAL KJELDAHL NITROGEN as N	ND	1.82		2.00	mg/L	**91**		70-130	**NA**	0-20		LFM	
NO3NO2_230919															
E-10128	56575	TOTAL NITRATE+NITRITE as N	0.05	1.02	1.02	1.00	mg/L	**97**	**97**	80-120	**0.0**	0-20		LFM	
E-10128	57079	TOTAL NITRATE+NITRITE as N	0.08	1.09	1.09	1.00	mg/L	**101**	**101**	80-120	**0.0**	0-20		LFM	
OPHOS_230919															
14265-44-2	56575	ORTHO-PHOSPHATE	0.06	0.51	0.51	0.50	mg/L	**90**	**90**	70-130	**0.0**	0-20		LFM	
14265-44-2	57079	ORTHO-PHOSPHATE	0.0091	0.48	0.48	0.50	mg/L	**94**	**94**	70-130	**0.0**	0-20		LFM	
TPHOS_231010															
7723-14-0	56575	TOTAL PHOSPHORUS-P	0.028	0.080	0.085	0.050	mg/L	**104**	**114**	70-130	**9.2**	0-20		LFM	
7723-14-0	58906	TOTAL PHOSPHORUS-P	0.135	0.180	0.180	0.050	mg/L	**90**	**90**	70-130	**0.0**	0-20		LFM	
7723-14-0	59228	TOTAL PHOSPHORUS-P	0.096	0.148	0.149	0.050	mg/L	**104**	**106**	70-130	**1.9**	0-20		LFM	

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

Qualifier Definitions

Reference Number: 23-28651
Report Date: 11/13/23

Qualifier	Definition
IM	Matrix induced bias assumed
INH	The sample was non-homogeneous

Note: Some qualifier definitions found on this page may pertain to results or QC data which are not printed with this report.

Zooplankton Report

Samples: 1
Preservative: 95% ethanol
Client: Herrera
Reference Method: EPA LG403, Revision 07, July 2016
Site: Lake Campbell, Skagit County (Lake Campbell)
Collection Dates: 10/06/2023
Processing Dates: 11/20/2023
Report Date: 1/16/2024

The calculated sampling volume was 283 L based on client-reported plankton net with an opening of 30 cm and tow length of 400 cm. Mesh opening for the net was reported as 50-microns. The sample was concentrated into 0.250 L sampling jar with a total of 0.196 L sample. A subsample of 8 ml was required to count >200 organisms. After subsampling, the entire sample was poured onto a gridded Petri dish where it scanned for large and/or rare taxa not accounted for in the subsample. All counts and identifications were done by Ethan Hosey and verified by Daniel McEwen.

Results

			Raw	Multiplier	N/Tow	**N/ L**	**%/L**
Cladocera	Bosminidae	*Bosmina longirostris*	66	24.5	1617	**6**	**31.7%**
Cladocera	Daphniidae	*Ceriodaphnia reticulata*	3	24.5	73.5	**0**	**1.4%**
Cladocera	Daphniidae	*Daphnia dubia*	15	24.5	367.5	**1**	**7.2%**
Copepoda	Diaptomidae	Adult	1	24.5	24.5	**0**	**0.5%**
Copepoda	Cyclopidae	Adult	110	24.5	2695	**10**	**52.9%**
Rotifer			4	24.5	98	**0**	**1.9%**
Ostracoda			6	24.5	147	**1**	**2.9%**

Raw = actual counts in 8 ml subsample
Multiplier = 196 ml concentrated sample / 8 ml subsample
N / Tow = estimated animals per 283 L tow (30 cm diameter net x 400 cm tow)
N / L = estimated animals per L
%/L = percent animal taxon per L

Taxonomic Keys: Haney, J.F. et al. "An-Image-based Key to the Zooplankton of North America" version 5.0 released 2013. University of New Hampshire Center for Freshwater Biology <cfb.unh.edu> 24 Jan 2018; Edmondson, W.T. ed. 1959. Ward & Whipple's Fresh-Water Biology. 2nd Edition. New York: John Wiley & Sons.; Needham, J.G. and Needham, P.R., 1962. Guide to the Study of Freshwater Biology. San Francisco: Holden-Day, Inc.; Pennak, R.W. 1978. Fresh-water Invertebrates of the United States. 2nd Edition. New York: John Wiley & Sons.; Thorp, J.H. and Covich, A.P. eds., 2009. Ecology and Classification of North American Freshwater Invertebrates. 2nd Edition. San Diego: Academic Press.

HERRERA
Science + Planning + Design

2023 LAKE CAMPBELL CMP WATERSHED MONITORING DATA SHEET

Project: Lake Campbell Cyanobacteria Management Plan Project No.: 23-08143-000

Client: Skagit County Field Personnel: Leanne Ingman, Cindy Elston

Event Type and Number Storm (√) Base ( )

Weather and predicted rainfall (in): 53°F 0.14" precip

Base flow sampling to occur every month (August 2023 through January 2024) on the day of or day before lake sampling. Six additional wet weather (storm flow) sampling events to occur during fall and winter storms September 2023 through January 2024.

Field Equipment Checklist

- ☐ Flow meter
- ☐ YSI multimeter
- ☐ Cooler with ice
- ☐ Tape Measure
- ☐ Hanna pH meter
- ☐ Chain-of-Custody
- ☐ Sample bottles

Sampling Data

All samples analyzed for total nutrients. Duplicates are to be collected monthly from September 2023 through January 2024 at a random site during a random event. If applicable, record duplicate sample information below. Do not include duplicate sample times on COCs.

	Site ID	Sample ID	Sample Time	Photos Taken?	Water Description (Turbidity; Unusual color, odor, sheen)
unfiltered	CS1	CS1-2023_0928	9:39		bubbles
	CS2	CS2-2023_______			
	CS2.5	CS2.5-2023_______			
	CS3	CS3-2023_______			
unfiltered	DUPE	DUPE-2023_0928	9:39		bubbles

Notes & observations: ______________________________

Discharge Data

CS1

Monitoring Location: SR-20 inflow

Discharge measurement method: ☑ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe):

Collection Date and Time: 9:39am 9/28/23

Notes & Observations unfiltered samples

bubbles below culvert

Culvert diameter = ______ inches

Water depth = 0.0417 feet ← 0.5 inches

Water velocity (flow) = ______ f/s ← 10 sec 2750mL

Calculated Flow (cfs) = ______

wetted width: 10 inches

YSI

DO	7.31 mg/L
	71.0 %
Cond	402.3
Sal	0.2
temp	14.2

pH: 7.28

CS2

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe):

Collection Date and Time: 9:30 am 9/28/23

Notes & Observations

dry

Culvert diameter = ______ inches

Water depth = ______ feet

Water velocity (flow) = ______ f/s

Calculated Flow (cfs) = ______

mf b2_campbell_watershedmonitoring_field form_blank.docx

CS2.5

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe):

Collection Date and Time: 9:24 am 9/28/23

Notes & Observations

dry

Culvert diameter = ________ inches

Water depth = ___________ feet

Water velocity (flow) = ___________ f/s

Calculated Flow (cfs) = __________________

CS3

Monitoring Location: Lake Erie outlet

Discharge measurement method: Stream cross-section

Collection Date and Time:

Notes & Observations

Total channel section width = _______ feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		–	–
1			
2			
3			
4			
5			
6			
7			
8			
Edge of Bank		–	–

Calculated Flow (cfs) = __________________

CAM-OUT

Monitoring Location: Outlet for Lake Campbell
Discharge measurement method: Stream cross-section
Collection Date and Time: 10:03 am 9/28/23
Notes & Observations
no flow

Total channel section width = _______ feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		–	–
1			
2			
3			
4			
5			
6			
7			
8			
Edge of Bank		–	–

Calculated Flow (cfs) = _______________

Other Observations

mf b2_campbell_watershedmonitoring_field form_blank.docx

CHAIN OF CUSTODY / ANALYSIS REQUEST (PLEASE COMPLETE ALL APPLICABLE SHADED SECTIONS)

REPORT TO: SKA02 SKAGIT CO. PUBLIC WKS	**FOR LAB USE ONLY**
ADDRESS: 1800 CONTINENTAL PLACE	REF#
CITY: MOUNT VERNON STATE: WA ZIP: 98273	**CHECK REGULATORY PROGRAM**
ATTN: LEANNE INGMAN	☐ SAFE DRINKING WATER ACT
PHONE: (360) 416-1450 FAX:	☐ CLEAN WATER ACT
EMAIL: LEANNEI@CO.SKAGIT.WA.US, MEGHANM@CO.SKAGIT.WA.US	☐ RCRA / CERCLA
PROJECT NAME: LAKE CAMPBELL CMP	☐ OTHER

EDGE ANALYTICAL

Main Lab (800-755-9295)
1620 South Walnut St. Burlington, WA 98233
Microbiology (888-725-1212)
805 W. Orchard Dr. Suite 4 Bellingham, WA 98225

Wilsonville Lab (503-682-7802)
9150 SW Pioneer Ct. Suite W Wilsonville, OR 97070
Corvallis Lab (541-753-4946)
540 SW 3rd St. Corvallis, OR 97333

	SAMPLE ID	LOCATION	SAMPLE MATRIX *	DATE	TIME	Ortho phos	AMMONIA, TKN, T. PHOS, NO2/NO3	CHLOROPHYLL	SPECIAL INSTRUCTIONS/ CONDITIONS ON RECEIPT
1	CS1-20230928	CS1	SW	9/28/23	9:39	☑	☑	☐	unfiltered
2	DUPE-20230928	~~[illegible]~~ CS1	SW	9/28/23	9:39	☑	☑	☐	unfiltered
3			SW			☐	☐	☐	
4			SW			☐	☐	☐	
5			SW			☐	☐	☐	
6			SW			☐	☐	☐	
7			SW			☐	☐	☐	
8			SW			☐	☐	☐	
9			SW			☐	☐	☐	
10			SW			☐	☐	☐	
11			SW			☐	☐	☐	
12			SW			☐	☐	☐	
13			SW			☐	☐	☐	
14			SW			☐	☐	☐	
15			SW			☐	☐	☐	
16			SW			☐	☐	☐	
17			SW			☐	☐	☐	
18			SW			☐	☐	☐	
19			SW			☐	☐	☐	
20			SW			☐	☐	☐	
21			SW			☐	☐	☐	
22			SW			☐	☐	☐	
23			SW			☐	☐	☐	
24			SW			☐	☐	☐	
25			SW			☐	☐	☐	
26			SW			☐	☐	☐	
27			SW			☐	☐	☐	

SAMPLED BY: Leanne PHONE: 360 416 1450 EMAIL: leannei@co.skagit.wa.us

RELINQUISHED BY	DATE	TIME	RECEIVED BY	DATE	TIME
Leanne Ingman	9/28/23	1057	[illegible signature]	9-28-23	1057
				10.8	

EDGE ANALYTICAL

Burlington, WA *Corporate Laboratory (a)*
1620 S Walnut St - Burlington, WA 98233 - **800.755.9295** • 360.757.1400
Bellingham, WA *Microbiology (b)*
805 Orchard Dr Ste 4 - Bellingham, WA 98225 - 360.715.1212
Portland, OR *Microbiology/Chemistry (c)*
9725 SW Commerce Cr Ste A2 - Wilsonville, OR 97070 - 503.682.7802
Corvallis, OR *Microbiology/Chemistry (d)*
1100 NE Circle Blvd, Ste 130 - Corvallis, OR 97330 - 541.753.4946
Bend, OR *Microbiology (e)*
20332 Empire Blvd Ste 4 - Bend, OR 97701 - 541.639.8425

Data Report

Client Name: Skagit County Public Works
1800 Continental Place
Mount Vernon, WA 98273

Reference Number: **23-29847**
Project: Lake Campbell CMP

Report Date: 10/25/23

Date Received: 9/28/23
Approved by: bj,tjb
Authorized by:

Lawrence J Henderson, PhD
Director of Laboratories, Vice President

Sample Description: CSI-20230928 CS1 Matrix SW Sample Date: 9/28/23 9:39 am
Lab Number: 59227 Sample Comment: unfiltered Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.041	0.010	0.0088	mg/L	1.0	350.1	a	10/9/23	MSO	350.1_231009	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	1.24	0.20	0.0585	mg/L	1.0	351.2	a	10/17/23	TJB	351.2_231017	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.21	0.01	0.0042	mg/L	1.0	SM4500-NO3 F	a	9/29/23	TJB	NO3NO2_230929	
14265-44-2	**ORTHO-PHOSPHATE**	0.06	0.01	0.0032	mg/L	1.0	SM4500-P F	a	9/29/23	TJB	OPHOS_230929	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.089	0.010	0.0021	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	10/10/23	TJB	TPHOS_231010	

Sample Description: DUPE-20230928 CS1 Matrix SW Sample Date: 9/28/23 9:39 am
Lab Number: 59228 Sample Comment: unfiltered Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.035	0.010	0.0088	mg/L	1.0	350.1	a	10/9/23	MSO	350.1_231009	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	2.15	0.20	0.0585	mg/L	1.0	351.2	a	10/17/23	TJB	351.2_231017	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.21	0.01	0.0042	mg/L	1.0	SM4500-NO3 F	a	9/29/23	TJB	NO3NO2_230929	
14265-44-2	**ORTHO-PHOSPHATE**	0.06	0.01	0.0032	mg/L	1.0	SM4500-P F	a	9/29/23	TJB	OPHOS_230929	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.096	0.010	0.0021	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	10/10/23	TJB	TPHOS_231010	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

If you have any questions concerning this report contact us at the above phone number.
Form: cRslt_2.rpt

SAMPLE INDEPENDENT
QUALITY CONTROL REPORT

Reference Number: **23-29847**
Report Date: 10/25/23

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
Calibration Check											
350.1_231009	0	AMMONIA-N	2.34	2.50	mg/L	350.1	94	90-110		CAL	
351.2_231017	0	TOTAL KJELDAHL NITROGEN as N	2.33	2.50	mg/L	351.2	93	90-110		CAL	
NO3NO2_23092	0	TOTAL NITRATE+NITRITE as N	1.01	1.00	mg/L	SM4500-NO3 F	101	90-110		CAL	
ophos_230929	0	ORTHO-PHOSPHATE	0.98	1.00	mg/L	SM4500-P F	98	85-115		CAL	
tphos_231010	0	TOTAL PHOSPHORUS-P	0.100	0.100	mg/L	SM4500-P F	100	85-115		CAL	
Laboratory Fortified Blank											
351.2_231017	0	TOTAL KJELDAHL NITROGEN as N	1.80	2.00	mg/L	351.2	90	90-110		LFB	
	0	TOTAL KJELDAHL NITROGEN as N	1.97	2.00	mg/L	351.2	99	90-110		LFB	
Laboratory Reagent Blank											
351.2_231017	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		LRB	
NO3NO2_23092	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		LRB	
ophos_230929	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		LRB	
tphos_231010	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		LRB	
Method Blank											
350.1_231009	0	AMMONIA-N	ND		mg/L	350.1		0-0		MB	
351.2_231017	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		MB	
NO3NO2_23092	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		MB	
ophos_230929	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		MB	
tphos_231010	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		MB	
Quality Control Sample											
350.1_231009	0	AMMONIA-N	3.80	3.72	mg/L	350.1	102	85-115		QCS	
351.2_231017	0	TOTAL KJELDAHL NITROGEN as N	3.50	3.26	mg/L	351.2	107	85-115		QCS	
	0	TOTAL KJELDAHL NITROGEN as N	3.59	3.26	mg/L	351.2	110	85-115		QCS	
NO3NO2_23092	0	TOTAL NITRATE+NITRITE as N	1.93	2.00	mg/L	SM4500-NO3 F	97	90-110		QCS	
ophos_230929	0	ORTHO-PHOSPHATE	0.93	1.00	mg/L	SM4500-P F	93	90-110		QCS	
tphos_231010	0	TOTAL PHOSPHORUS-P	0.189	0.195	mg/L	SM4500-P F	97	90-110		QCS	

*Notation:
% Recovery = (Result of Analysis)/(True Value) * 100
NA = Indicates % Recovery could not be calculated.
Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.
FORM: QCIndependent4.rpt

Reference Number: **23-29847**
Report Date: 10/25/2023

SAMPLE DEPENDENT
QUALITY CONTROL REPORT
Duplicate, Matrix Spike/Matrix Spike Duplicate and Confirmation Result Report

Duplicate

Batch	Sample	Analyte	Result	Duplicate Result	Units	%RPD	Limits	QC Qualifier	Type	Comments
350.1_231009										
7664-41-7	57888	AMMONIA-N	0.15	0.16	mg/L	**6.5**	0-20		DUP	
7664-41-7	58764	AMMONIA-N	0.031	0.026	mg/L	**17.5**	0-20		DUP	
7664-41-7	59046	AMMONIA-N	34.1	35.3	mg/L	**3.5**	0-20		DUP	
351.2_231017										
E-10264	58440	TOTAL KJELDAHL NITROGEN as N	ND	ND	mg/L	**NA**	0-20		DUP	
E-10264	58769	TOTAL KJELDAHL NITROGEN as N	2.20	2.29	mg/L	**4.0**	0-20		DUP	
E-10264	59316	TOTAL KJELDAHL NITROGEN as N	0.87	0.73	mg/L	**17.5**	0-20		DUP	
E-10264	59803	TOTAL KJELDAHL NITROGEN as N	0.31	0.19	mg/L	**48.0**	0-20	INH	DUP	
E-10264	60164	TOTAL KJELDAHL NITROGEN as N	75.0	76.7	mg/L	**2.2**	0-20		DUP	
NO3NO2_230929										
E-10128	59227	TOTAL NITRATE+NITRITE as N	0.21	0.21	mg/L	**0.0**	0-20		DUP	
OPHOS_230929										
14265-44-2	59227	ORTHO-PHOSPHATE	0.06	0.06	mg/L	**0.0**	0-20		DUP	
TPHOS_231010										
7723-14-0	56575	TOTAL PHOSPHORUS-P	0.028	0.029	mg/L	**3.5**	0-20		DUP	
7723-14-0	58906	TOTAL PHOSPHORUS-P	0.135	0.103	mg/L	**26.9**	0-20	IM	DUP	
7723-14-0	59228	TOTAL PHOSPHORUS-P	0.096	0.090	mg/L	**6.5**	0-20		DUP	

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

Laboratory Fortified Matrix (MS)

Batch/CAS	Sample	Analyte	Result	Spike Result	Duplicate Spike Result	Conc	Units	Percent Recovery MS	Percent Recovery MSD	Limits*	%RPD	Limits*	QC Qualifier	Type	Comments
350.1_231009															
7664-41-7	57888	AMMONIA-N	0.15	1.12	1.13	1.00	mg/L	**97**	**98**	70-130	**1.0**	0-20		LFM	
7664-41-7	58764	AMMONIA-N	0.031	1.11	1.04	1.00	mg/L	**108**	**101**	70-130	**6.7**	0-20		LFM	
7664-41-7	59046	AMMONIA-N	34.1	83.3	82.8	50.0	mg/L	**98**	**97**	70-130	**1.0**	0-20		LFM	
351.2_231017															
E-10264	58440	TOTAL KJELDAHL NITROGEN as N	ND	ND		2.00	mg/L			70-130	**NA**	0-20	IM	LFM	
E-10264	58769	TOTAL KJELDAHL NITROGEN as N	2.20	4.08		2.00	mg/L	**94**		70-130	**NA**	0-20		LFM	
E-10264	59316	TOTAL KJELDAHL NITROGEN as N	0.87	2.86		2.00	mg/L	**100**		70-130	**NA**	0-20		LFM	
E-10264	59803	TOTAL KJELDAHL NITROGEN as N	0.31	2.38		2.00	mg/L	**104**		70-130	**NA**	0-20		LFM	
E-10264	60164	TOTAL KJELDAHL NITROGEN as N	75.0	78.7		2.00	mg/L	**185**		70-130	**NA**	0-20	IS	LFM	
NO3NO2_230929															
E-10128	59227	TOTAL NITRATE+NITRITE as N	0.21	1.18	1.19	1.00	mg/L	**97**	**98**	80-120	**1.0**	0-20		LFM	
OPHOS_230929															
14265-44-2	59227	ORTHO-PHOSPHATE	0.06	0.53	0.53	0.50	mg/L	**94**	**94**	70-130	**0.0**	0-20		LFM	
TPHOS_231010															
7723-14-0	56575	TOTAL PHOSPHORUS-P	0.028	0.080	0.085	0.050	mg/L	**104**	**114**	70-130	**9.2**	0-20		LFM	
7723-14-0	58906	TOTAL PHOSPHORUS-P	0.135	0.180	0.180	0.050	mg/L	**90**	**90**	70-130	**0.0**	0-20		LFM	
7723-14-0	59228	TOTAL PHOSPHORUS-P	0.096	0.148	0.149	0.050	mg/L	**104**	**106**	70-130	**1.9**	0-20		LFM	

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

Qualifier Definitions

Reference Number: 23-29847
Report Date: 10/25/23

Qualifier	Definition
IM	Matrix induced bias assumed
INH	The sample was non-homogeneous
IS	The ratio of the spike concentration to sample background was too low to meet performance criteria

Note: Some qualifier definitions found on this page may pertain to results or QC data which are not printed with this report.

HERRERA
Science + Planning + Design

2023 LAKE CAMPBELL CMP WATERSHED MONITORING DATA SHEET

Project: Lake Campbell Cyanobacteria Management Plan Project No.: 23-08143-000
Client: Skagit County Field Personnel: Leanne, Cindy
Event Type and Number Storm (✓) Base ( )
Weather and predicted rainfall (in): Spotty rain, 1.12" rain predicted

Base flow sampling to occur every month (August 2023 through January 2024) on the day of or day before lake sampling. Six additional wet weather (storm flow) sampling events to occur during fall and winter storms September 2023 through January 2024.

Field Equipment Checklist

- ☐ Flow meter
- ☐ Tape Measure
- ☐ Chain-of-Custody
- ☐ YSI multimeter
- ☐ Hanna pH meter
- ☐ Sample bottles
- ☐ Cooler with ice

Sampling Data

All samples analyzed for total nutrients. Duplicates are to be collected monthly from September 2023 through January 2024 at a random site during a random event. If applicable, record duplicate sample information below. Do not include duplicate sample times on COCs.

Site ID	Sample ID	Sample Time	Photos Taken?	Water Description (Turbidity; Unusual color, odor, sheen)
CS1	CS1-2023 1024	13:12	Y	
CS2	CS2-2023	N/A		
CS2.5	CS2.5-2023	N/A		
CS3	CS3-2023	N/A		
DUPE	DUPE-2023 1024	13:15		

Notes & observations:

mf b2_campbell_watershedmonitoring_field form_blank.docx

Discharge Data

CS1

Monitoring Location: SR-20 inflow

Discharge measurement method: ☑ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe):

Collection Date and Time: 1:12 10/24/23

Notes & Observations dupe

Culvert diameter = 36" inches

wetted width 7"

Water depth = 0.5" feet

Water velocity (flow) = ______ f/s

Calculated Flow (cfs) = ______

27.53s
2500 mL

CS2

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe):

Collection Date and Time: 12:55 10/24/23

Notes & Observations dry, took photos

Culvert diameter = ~~36"~~ inches

Water depth = ~~0.5"~~ feet ~~wetted width 7"~~

Water velocity (flow) = ______ f/s

Calculated Flow (cfs) = ______

CS2.5

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐ Stream cross-section with flow probe ☐ Other (describe): ____

Collection Date and Time: 12:53, 10/24/23

Notes & Observations: no flow, took photos

Culvert diameter = ____ inches

Water depth = ____ feet

Water velocity (flow) = ____ f/s

Calculated Flow (cfs) = ____

CS3

Monitoring Location: Lake Erie outlet

Discharge measurement method: Stream cross-section

Collection Date and Time: ____

Notes & Observations: no movement but connected under bridge. can see cut-off point downstream water present

Total channel section width = ____ feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		–	–
1			
2			
3			
4			
5			
6			
7			
8			
Edge of Bank		–	–

Calculated Flow (cfs) = ____

CAM-OUT

Monitoring Location: Outlet for Lake Campbell

Discharge measurement method: Stream cross-section

Collection Date and Time: ______

Notes & Observations Water present – disconnected 10ft down Stream. no movement / Stagnant

Total channel section width = ______ feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		–	–
1			
2			
3			
4			
5			
6			
7			
8			
Edge of Bank		–	–

Calculated Flow (cfs) = ______

Other Observations

2023 LAKE CAMPBELL CMP MONITORING DATA SHEET

10/24/23

Field Equipment Checklist

☐ Secchi disk
☐ YSI multimeter
☐ Cooler with ice
☐ Van Dorn / Kemmerer
☐ Hanna pH meter
☐ Sample bottles
☐ Plankton net
☐ Anchor
☐ Filters & syringes

Project: Lake Campbell Cyanobacteria Management Plan   Project No.: 23-08143-000
Client: Skagit County   Field Personnel: Toni, Ben, Jim, Gabriella, +1
Weather: rainy, cold (40°)
Wind (still, windy, choppy): windy
Number of vessels on lake: 0
Number of shoreline swimmers: 0
Number of shoreline anglers: 0
Number of geese: 0   ducks: 13 47
other waterfowl

CAM-DEEP (at deepest point south of island)
Collection Date and Time: 10/24/23 12:30
Secchi Depth (m): 1.8m   Depth to Bottom (m): 17.1 to 17.8 ft
Water color: Pea Green +
Notes
Used tow ring on the Plankton net | missing secchi disk

10/24/23

Profile Readings (every monthly event):

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Specific Conductivity (µS/cm)	pH*
0.2	13.5	10.3	99.1	262.2	7.26
0.5	13.4	7.00	67.2	262.1	X
1.0	13.5	7.16	68.8	262.2	7.37
1.5	13.5	6.86	66.0	262.1	X
2.0	13.4	7.4	67.7	262.4	7.49
2.5	13.4	6.97	67.9	262.2	X
3.0	13.4	6.98	66.5	262.3	7.48
3.5	13.4	6.80	66.1	262.2	X
4.0	13.3	6.71	63.7	262.7	7.44

*pH sampling done in 1-meter increments

Notes

10/24/23

Water Quality Samples Collected* (every monthly event):

Fill in the Sample IDs and depths below. Check the box (X) for each sample bottle filled. Duplicates should be collected during each monthly event; record the same time and depth here as the depth the duplicate was collected. Do not label sample bottles with the sample time or depth.

Sample ID	Sample Time	Sample Depth (m)	Total Nutrients (500 mL HDPE with H_2SO_4)	Dissolved Nitrogen ** (500 mL HDPE with H_2SO_4)	Orthophosphate ** (250 mL HDPE)	Chlorophyll-a (125-mL dark HDPE)
CAM-DEEP-2023 1024 -S	1:10	0.5	✓	✓	✓	✓
CAM-DEEP-2023 1024 -B	1:30		✓	✓	✓	✓
CAM-DUPE-2023 1024			✓	✓	✓	

*All water quality samples must be kept on ice or refrigerated until delivered to lab.

**Dissolved nitrogen and orthophosphate samples must be field filtered into bottles using syringes.

Notes 17 1/2' (water depth)

10/24/23

Plankton Samples (monthly during August, September, and October only)

Fill in the Sample IDs and depths below. Check the box (X) for each sample bottle filled.

Sample ID	Sample Time	Sample Depth (m)	Phytoplankton Samples (125-mL dark HDPE, with Lugol's)	Zooplankton Vertical Tow (250-mL HDPE, with ethanol)
CAM-DEEP-20231024-S	1:15 PM	0.5	✓	NA
CAM-DEEP-20231024-B	↑↓		✓	NA
CAM-DEEP-2023______	1:40	From 4 m to surface	NA	✓

Note: Change sample IDs to "CAM-DEEP-2024______-__" for any 2024 events.

From Whole Water Column

METER CALIBRATION LOG

Project Number/Name:	Lake Campbell CMP (23-08143-000)
Personnel Performing Calibration:	Leanne Frangian
Meter:	YSI Pro2030 multimeter (Sp. Conductivity/DO)
	Hanna HI991003 handheld meter (pH)
Date/Time:	10/24/23 @ 10:47am

PRE-Event Calibration	Meter Reading	Buffer / Cal Std	Comments
Conductivity (µS/cm)	0	0	
	9990	1,000	
DO % Saturation	99.9	100	100.4 in Field
pH	7.01	7.01	
	4.01	4.01	

POST-Event Calibration Check	Meter Reading	Buffer / Cal Std	Comments
Conductivity (µS/cm)	10037	1,000	
DO % Saturation	99.1	100	
pH	7.05	7.01	

Calibration Procedures:

Rinse Meter Sondes Between Each Operation

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

HERRERA

YSI Multimeter 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.

YSI Multimeter 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.

Hanna Meter pH Calibration Notes:

1. Perform 2-point calibration, starting with pH 7.01 buffer, followed by 10.01 or 4.01 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".

CHAIN OF CUSTODY / ANALYSIS REQUEST (PLEASE COMPLETE ALL APPLICABLE SHADED SECTIONS)

REPORT TO: SKA02 SKAGIT CO. PUBLIC WKS	**FOR LAB USE ONLY**
ADDRESS: 1800 CONTINENTAL PLACE	REF#
CITY: MOUNT VERNON STATE: WA ZIP: 98273	**CHECK REGULATORY PROGRAM**
ATTN: LEANNE INGMAN	☐ SAFE DRINKING WATER ACT
PHONE: (360) 416-1450 FAX:	☐ CLEAN WATER ACT
EMAIL: LEANNEI@CO.SKAGIT.WA.US, MEGHANM@CO.SKAGIT.WA.US	☐ RCRA / CERCLA
PROJECT NAME: LAKE CAMPBELL CMP	☐ OTHER

EDGE ANALYTICAL

Main Lab (800-755-9295)
1620 South Walnut St. Burlington, WA 98233
Microbiology (888-725-1212)
805 W. Orchard Dr. Suite 4 Bellingham, WA 98225
Wilsonville Lab (503-682-7802)
9150 SW Pioneer Ct. Suite W Wilsonville, OR 97070
Corvallis Lab (541-753-4946)
540 SW 3rd St. Corvallis, OR 97333

	SAMPLE ID	LOCATION	SAMPLE MATRIX *	DATE	TIME	Ortho phos	AMMONIA, TKN, T. PHOS, NO2/NO3	CHLOROPHYLL	SPECIAL INSTRUCTIONS/ CONDITIONS ON RECEIPT
1	~~CSI-20230918~~	~~S CamDeep~~	SW			☐	☐	☐	
2	DUPE-20231024	CamDeep S-Dup	SW	10/24/23		☑	☑	☑ No	
3	CamDeep-20231024-B	CamDeep - B	SW	10/24/23	1330	☑	☑	☑	
4	CamDeep-20231024	S-CamDeep	SW	10/24/23	1310	☑	☑	☑	Filter ASAP
5	Dupe-20231024	Dupe	SW	10/24/23	1315	☑	☑	☐	
6	CSI-20231024	CSI	SW	10/24/23	1312	☑	☑	☐	
7			SW			☐	☐	☐	
8			SW			☐	☐	☐	
9			SW			☐	☐	☐	
10			SW			☐	☐	☐	
11			SW			☐	☐	☐	
12			SW			☐	☐	☐	
13			SW			☐	☐	☐	
14			SW			☐	☐	☐	
15			SW			☐	☐	☐	
16			SW			☐	☐	☐	
17			SW			☐	☐	☐	
18			SW			☐	☐	☐	
19			SW			☐	☐	☐	
20			SW			☐	☐	☐	
21			SW			☐	☐	☐	
22			SW			☐	☐	☐	
23			SW			☐	☐	☐	
24			SW			☐	☐	☐	
25			SW			☐	☐	☐	
26			SW			☐	☐	☐	
27			SW			☐	☐	☐	

SAMPLED BY: PHONE: EMAIL:

RELINQUISHED BY	DATE	TIME	RECEIVED BY	DATE	TIME
Leanne Ingman	10/24/23	1443	KRa (W)Rely	10-24-23	1443 9.9

EDGE ANALYTICAL

Burlington, WA *Corporate Laboratory (a)*
1620 S Walnut St - Burlington, WA 98233 - **800.755.9295** • 360.757.1400

Bellingham, WA *Microbiology (b)*
805 Orchard Dr Ste 4 - Bellingham, WA 98225 - 360.715.1212

Portland, OR *Microbiology/Chemistry (c)*
9725 SW Commerce Cr Ste A2 - Wilsonville, OR 97070 - 503.682.7802

Corvallis, OR *Microbiology/Chemistry (d)*
1100 NE Circle Blvd, Ste 130 - Corvallis, OR 97330 - 541.753.4946

Bend, OR *Microbiology (e)*
20332 Empire Blvd Ste 4 - Bend, OR 97701 - 541.639.8425

Data Report

Client Name: Skagit County Public Works
1800 Continental Place
Mount Vernon, WA 98273

Reference Number: **23-32622**
Project: Lake Campbell CMP

Report Date: 11/14/23

Date Received: 10/24/23
Approved by: bj,mcs,tjb
Authorized by: [signature]

Lawrence J Henderson, PhD
Director of Laboratories, Vice President

Sample Description: Dupe-20231024 Camdeep S-Dup — Matrix SW — Sample Date: 10/24/23 1:10 pm
Lab Number: 65018 — Sample Comment: — Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.037	0.010	0.0045	mg/L	1.0	350.1	a	11/8/23	MSO	350.1_231108	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	1.09	0.20	0.0848	mg/L	1.0	351.2	a	11/9/23	MSO	351.2_231109	
E-10128	**TOTAL NITRATE+NITRITE as N**	ND	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	11/10/23	TJL	NO3NO2_231110	
14265-44-2	**ORTHO-PHOSPHATE**	0.04	0.01	0.0032	mg/L	1.0	SM4500-P F	a	10/24/23	TJB	ophos_231024	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.034	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/13/23	TJL	TPHOS_231113	

Sample Description: Camdeep-20231024-B Camdeep-B — Matrix SW — Sample Date: 10/24/23 1:30 pm
Lab Number: 65019 — Sample Comment: — Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.028	0.010	0.0045	mg/L	1.0	350.1	a	11/8/23	MSO	350.1_231108	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	2.90	0.20	0.0848	mg/L	1.0	351.2	a	11/9/23	MSO	351.2_231109	
NA	**CHLOROPHYLL A**	39.4	0.1	0	mg/m3	1.0	SM10200-H		10/25/23	CP	WML_231025	Analyzed by WML
NA	**PHEOPHYTIN A**	14.4	0.1	0	mg/m3	1.0	SM10200-H		10/25/23	CP	WML_231025	Analyzed by WML
E-10128	**TOTAL NITRATE+NITRITE as N**	ND	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	11/10/23	TJL	NO3NO2_231110	
14265-44-2	**ORTHO-PHOSPHATE**	0.04	0.01	0.0032	mg/L	1.0	SM4500-P F	a	10/24/23	TJB	ophos_231024	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.163	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/13/23	TJL	TPHOS_231113	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

If you have any questions concerning this report contact us at the above phone number.

EDGE ANALYTICAL

Reference Number: **23-32622**
Report Date: 11/14/23

Data Report

Sample Description: Camdeep-20231024 S-Camdeep — Matrix SW — Sample Date: 10/24/23 1:10 pm
Lab Number: 65020 — Sample Comment: — Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.020	0.010	0.0045	mg/L	1.0	350.1	a	11/8/23	MSO	350.1_231108	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	1.00	0.20	0.0848	mg/L	1.0	351.2	a	11/9/23	MSO	351.2_231109	
NA	**CHLOROPHYLL A**	25.6	0.1	0	mg/m3	1.0	SM10200-H		10/25/23	CP	WML_231025	Analyzed by WML
NA	**PHEOPHYTIN A**	25.6	0.1	0	mg/m3	1.0	SM10200-H		10/25/23	CP	WML_231025	Analyzed by WML
E-10128	**TOTAL NITRATE+NITRITE as N**	ND	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	11/10/23	TJL	NO3NO2_231110	
14265-44-2	**ORTHO-PHOSPHATE**	0.04	0.01	0.0032	mg/L	1.0	SM4500-P F	a	10/24/23	TJB	ophos_231024	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.030	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/13/23	TJL	TPHOS_231113	

Sample Description: Dupe-20231024 Dupe — Matrix SW — Sample Date: 10/24/23 1:15 pm
Lab Number: 65021 — Sample Comment: — Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.058	0.010	0.0045	mg/L	1.0	350.1	a	11/8/23	MSO	350.1_231108	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	ND	0.20	0.0848	mg/L	1.0	351.2	a	11/9/23	MSO	351.2_231109	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.06	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	11/10/23	TJL	NO3NO2_231110	
14265-44-2	**ORTHO-PHOSPHATE**	0.06	0.01	0.0032	mg/L	1.0	SM4500-P F	a	10/25/23	TJL	OPHOS_231025A	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.033	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/13/23	TJL	TPHOS_231113	

Sample Description: CSI-20231024 CSI — Matrix SW — Sample Date: 10/24/23 1:12 pm
Lab Number: 65022 — Sample Comment: — Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.12	0.010	0.0045	mg/L	1.0	350.1	a	11/8/23	MSO	350.1_231108	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	ND	0.20	0.0848	mg/L	1.0	351.2	a	11/9/23	MSO	351.2_231109	
E-10128	**TOTAL NITRATE+NITRITE as N**	ND	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	11/10/23	TJL	NO3NO2_231110	
14265-44-2	**ORTHO-PHOSPHATE**	0.06	0.01	0.0032	mg/L	1.0	SM4500-P F	a	10/24/23	TJB	ophos_231024	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.033	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/13/23	TJL	TPHOS_231113	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

SAMPLE INDEPENDENT
QUALITY CONTROL REPORT

Reference Number: **23-32622**
Report Date: 11/14/23

Calibration Check

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
350.1_231108	0	AMMONIA-N	2.48	2.50	mg/L	350.1	99	90-110		CAL	
351.2_231109	0	TOTAL KJELDAHL NITROGEN as N	2.70	2.50	mg/L	351.2	108	90-110		CAL	
NO3NO2_231110	0	TOTAL NITRATE+NITRITE as N	1.03	1.00	mg/L	SM4500-NO3 F	103	90-110		CAL	
ophos_231024	0	ORTHO-PHOSPHATE	0.94	1.00	mg/L	SM4500-P F	94	85-115		CAL	
OPHOS_231025/	0	ORTHO-PHOSPHATE	0.95	1	mg/L	SM4500-P F	95	85-115		CAL	
TPHOS_231113	0	TOTAL PHOSPHORUS-P	0.099	0.100	mg/L	SM4500-P F	99	85-115		CAL	

Laboratory Fortified Blank

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
351.2_231109	0	TOTAL KJELDAHL NITROGEN as N	1.96	2.00	mg/L	351.2	98	90-110		LFB	

Laboratory Reagent Blank

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
351.2_231109	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		LRB	
NO3NO2_231110	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		LRB	
ophos_231024	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		LRB	
OPHOS_231025/	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		LRB	
TPHOS_231113	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		LRB	

Method Blank

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
350.1_231108	0	AMMONIA-N	ND		mg/L	350.1		0-0		MB	
351.2_231109	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		MB	
NO3NO2_231110	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		MB	
ophos_231024	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		MB	
OPHOS_231025/	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		MB	
TPHOS_231113	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		MB	

Quality Control Sample

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
350.1_231108	0	AMMONIA-N	3.68	3.72	mg/L	350.1	99	85-115		QCS	
351.2_231109	0	TOTAL KJELDAHL NITROGEN as N	2.26	2.33	mg/L	351.2	97	85-115		QCS	
NO3NO2_231110	0	TOTAL NITRATE+NITRITE as N	2.03	2.00	mg/L	SM4500-NO3 F	102	90-110		QCS	
ophos_231024	0	ORTHO-PHOSPHATE	0.90	1.00	mg/L	SM4500-P F	90	90-110		QCS	
OPHOS_231025/	0	ORTHO-PHOSPHATE	0.91	1	mg/L	SM4500-P F	91	90-110		QCS	
TPHOS_231113	0	TOTAL PHOSPHORUS-P	0.198	0.217	mg/L	SM4500-P F	91	90-110		QCS	

*Notation:

% Recovery = (Result of Analysis)/(True Value) * 100

NA = Indicates % Recovery could not be calculated.

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QCIndependent4.rpt

SAMPLE DEPENDENT
QUALITY CONTROL REPORT
Duplicate, Matrix Spike/Matrix Spike Duplicate and Confirmation Result Report

Duplicate

Batch	Sample	Analyte	Result	Duplicate Result	Units	%RPD	Limits	QC Qualifier	Type	Comments
350.1_231108										
7664-41-7	65018	AMMONIA-N	0.037	0.025	mg/L	**38.7**	0-20	INH	DUP	
7664-41-7	65359	AMMONIA-N	ND	ND	mg/L	**NA**	0-20		DUP	
7664-41-7	65800	AMMONIA-N	0.017	0.017	mg/L	**0.0**	0-20		DUP	
7664-41-7	66604	AMMONIA-N	0.046	0.044	mg/L	**4.4**	0-20		DUP	
351.2_231109										
E-10264	65018	TOTAL KJELDAHL NITROGEN as N	1.09	1.02	mg/L	**6.6**	0-20		DUP	
E-10264	66425	TOTAL KJELDAHL NITROGEN as N	15.4	15.2	mg/L	**1.3**	0-20		DUP	
NO3NO2_231110										
E-10128	66106	TOTAL NITRATE+NITRITE as N	3.61	3.64	mg/L	**0.8**	0-20		DUP	
E-10128	66331	TOTAL NITRATE+NITRITE as N	0.01	0.01	mg/L	**0.0**	0-20		DUP	
E-10128	68436	TOTAL NITRATE+NITRITE as N	ND	ND	mg/L	**NA**	0-20		DUP	
ophos_231024										
14265-44-2	64977	ORTHO-PHOSPHATE	0.0052	0.0049	mg/L	**5.9**	0-20		DUP	
14265-44-2	64988	ORTHO-PHOSPHATE	ND	ND	mg/L	**NA**	0-20		DUP	
OPHOS_231025A										
14265-44-2	65021	ORTHO-PHOSPHATE	0.06	0.06	mg/L	**0.0**	0-20		DUP	
TPHOS_231113										
7723-14-0	65018	TOTAL PHOSPHORUS-P	0.034	0.032	mg/L	**6.1**	0-20		DUP	
7723-14-0	66881	TOTAL PHOSPHORUS-P	ND	ND	mg/L	**NA**	0-20		DUP	
7723-14-0	67530	TOTAL PHOSPHORUS-P	0.873	0.864	mg/L	**1.0**	0-20		DUP	

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

Reference Number: 23-32622
Report Date: 11/14/2023

Laboratory Fortified Matrix (MS)

Batch/CAS	Sample	Analyte	Result	Spike Result	Duplicate Spike Result	Conc	Units	Percent Recovery MS	Percent Recovery MSD	Limits*	%RPD	Limits*	QC Qualifier	Type	Comments
350.1_231108															
7664-41-7	65018	AMMONIA-N	0.037	0.97	0.99	1.00	mg/L	**93**	**95**	70-130	**2.1**	0-20		LFM	
7664-41-7	65359	AMMONIA-N	ND	1.00	0.97	1.00	mg/L	**100**	**97**	70-130	**3.0**	0-20		LFM	
7664-41-7	65800	AMMONIA-N	0.017	1.02	1.03	1.00	mg/L	**100**	**101**	70-130	**1.0**	0-20		LFM	
7664-41-7	66604	AMMONIA-N	0.046	1.01	1.01	1.00	mg/L	**96**	**96**	70-130	**0.0**	0-20		LFM	
351.2_231109															
E-10264	65018	TOTAL KJELDAHL NITROGEN as N	1.09	3.01		2.00	mg/L	**96**		70-130	**NA**	0-20		LFM	
E-10264	66425	TOTAL KJELDAHL NITROGEN as N	15.4	16.9		2.00	mg/L	**75**		70-130	**NA**	0-20		LFM	
NO3NO2_231110															
E-10128	66106	TOTAL NITRATE+NITRITE as N	3.61	8.31	8.19	5.00	mg/L	**94**	**92**	80-120	**2.6**	0-20		LFM	
E-10128	66331	TOTAL NITRATE+NITRITE as N	0.01	1.05	1.05	1.00	mg/L	**104**	**104**	80-120	**0.0**	0-20		LFM	
E-10128	68436	TOTAL NITRATE+NITRITE as N	ND	1.05	1.04	1.00	mg/L	**105**	**104**	80-120	**1.0**	0-20		LFM	
ophos_231024															
14265-44-2	64977	ORTHO-PHOSPHATE	0.0052	0.45	0.44	0.50	mg/L	**89**	**87**	70-130	**2.3**	0-20		LFM	
14265-44-2	64988	ORTHO-PHOSPHATE	ND	0.45		0.50	mg/L	**90**		70-130	**NA**	0-20		LFM	
OPHOS_231025A															
14265-44-2	65021	ORTHO-PHOSPHATE	0.06	0.49	0.49	0.50	mg/L	**86**	**86**	70-130	**0.0**	0-20		LFM	
TPHOS_231113															
7723-14-0	65018	TOTAL PHOSPHORUS-P	0.034	0.086	0.085	0.050	mg/L	**104**	**102**	70-130	**1.9**	0-20		LFM	
7723-14-0	66881	TOTAL PHOSPHORUS-P	ND	0.041	0.040	0.050	mg/L	**82**	**80**	70-130	**2.5**	0-20		LFM	
7723-14-0	67530	TOTAL PHOSPHORUS-P	0.873	1.44	1.41	0.500	mg/L	**113**	**107**	70-130	**5.4**	0-20		LFM	

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

Qualifier Definitions

Reference Number: 23-32622
Report Date: 11/14/23

Qualifier	Definition
INH	The sample was non-homogeneous

Note: Some qualifier definitions found on this page may pertain to results or QC data which are not printed with this report.

LIMNOpro
Aquatic Science

Zooplankton Taxonomic Services
Chain of Custody

Ship To: Limnopro Aquatic Science, Inc.
C/O Dan McEwen
5 11th St SW
St. Stephen, MN 56375

General Information

Client Name: Skagit County

Project Contact: Tim Clark, Herrera Environmental Consultants, Inc.

Email: tclark@herrerainc.com

Phone: 971.361.2238

Reporting/Billing Address: Herrera Environmental Consultants, 107 SE Washington Street, Suite 140, Portland, OR 97214

Sampling Details

Sampled By: Toni hunter

Collection Date(s): 10/4/23,

Waterbody Name/County/State: Lake Campbell/Skagit/WA

Additional Notes:
labels did not make it into containers. each label is included in the individual bags for each sample.

Type: ☑ Grab
☑ Plankton Tow: Mesh Opening: 50 µm Net Opening: 30 cm Tow Length: 120 cm (Please Specify Units)
☐ Other (Please Specify) ______

30 cm
120 cm
= 84823 cm³
84.8 L

Preservative: ☑ Ethanol (_95__ %) ☐ Isopropanol (______ %) ☐ Formalin ☐ Live on ice ☐ Other (Please Specify) ______

Taxonomic Resolution: ☑ Standard: (*Ostracods/rotifers to phylum, copepods to family, cladocerans to species, and all other to lowest practicable level).*
☐ Maximum: *(All to genus or species where possible - **Additional charges may apply**)*

Data Required: ☑ Counts and ID only ☐ Counts, ID, and Biomass

Chain of Custody

Relinquished by (signature in ink): Leanne Frogman Number of Samples 2 Date/Time (AM/PM) 10/25/23 0808

Received by lab (signature in ink): [signature] Number of Samples 2 Date/Time (AM/PM) 10/31/23

Please label each bottle with the appropriate information including organization, waterbody name, and date.

PRO AQUATIC SCIENCE, INC. CHAIN OF CUSTODY ZOOPLANKTON TAXONOMY

CLIENT: Skagit County
PRESERVATIVE: Ethanol

PROJECT: Lake Campbell Cyanobacteria Management Plan (23-08143-000)
NET (MESH/OPENING): 80-µm mesh; ___ diameter opening

Client Provided Information							Laboratory Use Only			
Sample Number/ID	Date Collected	Time Collected	Site Location	Number of Containers	Length of tow (m)	Collector Initials	Lab Code	Date Logged	Initials	Remarks
	10/24/23	1340	CAM-DEEP	1	4	TH, LI				
	10/6/23	1415	Lake Campbell	1	4	TH, LI				

5mL + 4mL + 4mL

At a minimum label each container as it corresponds to the "Sample Number/ID" in the table above. Use additional sheets as needed.

30 cm × 400cm tow = 283000 cm³

Zooplankton Report

Samples: 1
Preservative: 95% ethanol
Client: Herrera
Reference Method: EPA LG403, Revision 07, July 2016
Site: Lake Campbell, Skagit County (CAM-DEEP)
Collection Dates: 10/24/2023
Processing Dates: 11/20/2023
Report Date: 1/16/2024

The calculated sampling volume was 283 L based on client-reported plankton net with an opening of 30 cm and tow length of 400 cm. Mesh opening for the net was reported as 50-microns. The sample was concentrated into 0.250 L sampling jar. A subsample of 11 ml was required to count >200 organisms. After subsampling, the entire sample was poured onto a gridded Petri dish where it scanned for large and/or rare taxa not accounted for in the subsample. All counts and identifications were done by Ethan Hosey and verified by Daniel McEwen.

Results

			Raw	Multiplier	N/Tow	**N/ L**	**%/L**
Cladocera	Bosminidae	*Bosmina longirostris*	105	22.72727	2386.4	**8**	**49.6%**
Cladocera	Daphniidae	*Ceriodaphnia reticulata*	8	22.72727	181.82	**1**	**3.8%**
Cladocera	Daphniidae	*Daphnia mendotae*	31	22.72727	704.55	**2**	**14.6%**
Copepoda	Diaptomidae	Adult	4	22.72727	90.909	**0**	**1.9%**
Copepoda	Cyclopidae	Adult	36	22.72727	818.18	**3**	**17.0%**
Copepoda	Cyclopidae	Nauplii	1	22.72727	22.727	**0**	**0.5%**
Rotifer			4	22.72727	90.909	**0**	**1.9%**
Ostracoda			20	22.72727	454.55	**2**	**9.4%**

Raw = actual counts in 11 ml subsample (or full scan for calanoids = Diaptomidae)
Multiplier = 250 ml concentrated sample / 11 ml subsample
N / Tow = estimated animals per 283 L tow (30 cm diameter net x 400 cm tow)
N / L = estimated animals per L
%/L = percent animal taxon per L

Taxonomic Keys: Haney, J.F. et al. "An-Image-based Key to the Zooplankton of North America" version 5.0 released 2013. University of New Hampshire Center for Freshwater Biology <cfb.unh.edu> 24 Jan 2018; Edmondson, W.T. ed. 1959. Ward & Whipple's Fresh-Water Biology. 2nd Edition. New York: John Wiley & Sons.; Needham, J.G. and Needham, P.R., 1962. Guide to the Study of Freshwater Biology. San Francisco: Holden-Day, Inc.; Pennak, R.W. 1978. Fresh-water Invertebrates of the United States. 2nd Edition. New York: John Wiley & Sons.; Thorp, J.H. and Covich, A.P. eds., 2009. Ecology and Classification of North American Freshwater Invertebrates. 2nd Edition. San Diego: Academic Press.

HERRERA
Science + Planning + Design

2023 LAKE CAMPBELL CMP
WATERSHED MONITORING DATA SHEET

Project: Lake Campbell Cyanobacteria Management Plan Project No.: 23-08143-000
Client: Skagit County Field Personnel: Victor & Cindy
Event Type and Number Storm ( ) Base (√)
Weather and predicted rainfall (in):

Base flow sampling to occur every month (August 2023 through January 2024) on the day of or day before lake sampling. Six additional wet weather (storm flow) sampling events to occur during fall and winter storms September 2023 through January 2024.

Field Equipment Checklist

- ☐ Flow meter
- ☐ Tape Measure
- ☐ Chain-of-Custody
- ☐ YSI multimeter
- ☐ Hanna pH meter
- ☐ Sample bottles
- ☐ Cooler with ice

Sampling Data

All samples analyzed for total nutrients. Duplicates are to be collected monthly from September 2023 through January 2024 at a random site during a random event. If applicable, record duplicate sample information below. Do not include duplicate sample times on COCs.

Site ID	Sample ID	Sample Time	Photos Taken?	Water Description (Turbidity; Unusual color, odor, sheen)
CS1	CS1-2023 20231026	9:41	y	yellow tinge
~~CS2~~	~~CS2-2023~~			
~~CS2.5~~	~~CS2.5-2023~~			
CAM-OUT ~~CS3~~	CAM-OUT_20231026 ~~CS3-2023 20231026~~	10:40	y	duckweed or something similar
DUPE	DUPE-2023 20231026	9:43	y	

Notes & observations:

Discharge Data

CS1

Monitoring Location: SR-20 inflow

Discharge measurement method: ☑ Timed bucket fill ☐ Stream cross-section with flow probe ☐ Other (describe):

Collection Date and Time: 10/26/23 9:41 am

Notes & Observations: foam, yellow tinge in water, 9:41 am Duplicates

Culvert diameter = ______ inches ~~9:41 am~~

Water depth = 0.7 Inches ~~feet~~

Water velocity (flow) = ______ f/s

Calculated Flow (cfs) = ______

Wetted width = 8.9 inches

Bucket Method
7.18 seconds
2900 mL

CS2

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐ Stream cross-section with flow probe ☐ Other (describe):

Collection Date and Time: 10/26/23 9:05

Notes & Observations: no water, cannot sample, took photos

Culvert diameter = ______ inches

Water depth = ______ feet

Water velocity (flow) = ______ f/s

Calculated Flow (cfs) = ______

CS2.5

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe): ____

Collection Date and Time: 10/26/23 9:10

Notes & Observations no water, cannot sample, photos taken

Culvert diameter = ____ inches

Water depth = ____ feet

Water velocity (flow) = ____ f/s

Calculated Flow (cfs) = ____

CS3

Monitoring Location: Lake Erie outlet

Discharge measurement method: Stream cross-section

Collection Date and Time: ~~10/25/23 9:59am~~

Notes & Observations ____

Total channel section width = ____ feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		–	–
1			
2			
3			
4			
5			
6			
7			
8			
Edge of Bank		–	–

Calculated Flow (cfs) = ____

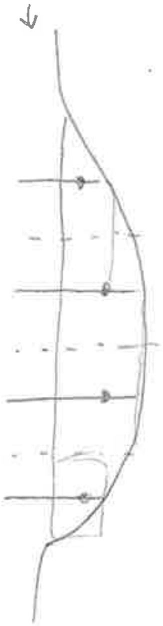
CAM-OUT

Monitoring Location: Outlet for Lake Campbell

Discharge measurement method: Stream cross-section

Collection Date and Time: 10/26/23 10:40

Notes & Observations Duckweed? or something similar



Total channel section width = 9.8 feet   2 - 11.8

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank	~~0.49~~	–	–
1	~~1.47~~ 0.61	~~0.05~~ 0.02	0.00
2	~~2.45~~ 1.84	~~0.10~~ 0.04	0.00
3	~~3.43~~ 3.06	~~0.14~~ 0.07	0.00
4	~~4.41~~ 4.29	0.10	0.00
5	~~5.39~~ 5.51	0.17	0.00
6	~~6.37~~ 6.74	0.11	0.00
7	~~7.35~~ 7.96	0.12	0.00
8	~~8.33~~ 9.19	~~0.10~~ 0.01	0.00
Edge of Bank	~~9.31~~	–	–

Calculated Flow (cfs) = 0.00

Other Observations

CHAIN OF CUSTODY / ANALYSIS REQUEST (PLEASE COMPLETE ALL APPLICABLE SHADED SECTIONS)

REPORT TO: SKA02 SKAGIT CO. PUBLIC WKS
ADDRESS: 1800 CONTINENTAL PLACE
CITY: MOUNT VERNON STATE: WA ZIP: 98273
ATTN: LEANNE INGMAN
PHONE: (360) 416-1450 FAX:
EMAIL: LEANNEI@CO.SKAGIT.WA.US, MEGHANM@CO.SKAGIT.WA.US
PROJECT NAME: LAKE CAMPBELL CMP

FOR LAB USE ONLY
REF#

CHECK REGULATORY PROGRAM
- ☐ SAFE DRINKING WATER ACT
- ☐ CLEAN WATER ACT
- ☐ RCRA / CERCLA
- ☐ OTHER

EDGE ANALYTICAL
Main Lab (800-755-9295)
1620 South Walnut St. Burlington, WA 98233
Microbiology (888-725-1212)
805 W. Orchard Dr. Suite 4 Bellingham, WA 98225
Wilsonville Lab (503-682-7802)
9150 SW Pioneer Ct. Suite W Wilsonville, OR 97070
Corvallis Lab (541-753-4946)
540 SW 3rd St. Corvallis, OR 97333

	SAMPLE ID	LOCATION	SAMPLE MATRIX *	DATE	TIME	Ortho phos	AMMONIA, TKN, T. PHOS, NO2/NO3		SPECIAL INSTRUCTIONS/ CONDITIONS ON RECEIPT
1	Cam-out_20231026	Cam-out	SW	10/26/23	10:40	☒	☒	☐	Filter ASAP
2	CS1-20231026	CS1	SW	10/26/23	9:41	☒	☒	☐	Filter ASAP
~~3~~	~~CS2-20231026~~	~~CS2~~	~~SW~~	~~10/26/23~~		☒	☒	☐	~~Filter ASAP~~
~~4~~	~~CS2.5-20231026~~	~~CS2.5~~	~~SW~~	~~10/26/23~~		☒	☒	☐	~~Filter ASAP~~
~~5~~	~~CS3-20231026~~	~~CS3~~	~~SW~~	~~10/26/23~~		☒	☒	☐	~~Filter ASAP~~
6	DUPE-20231026	Dupe	SW	10/26/23	9:43	☒	☒	☐	Filter ASAP
7			SW			☐	☐	☐	
8			SW			☐	☐	☐	
9			SW			☐	☐	☐	
10			SW			☐	☐	☐	
11			SW			☐	☐	☐	
12			SW			☐	☐	☐	
13			SW			☐	☐	☐	
14			SW			☐	☐	☐	
15			SW			☐	☐	☐	
16			SW			☐	☐	☐	
17			SW			☐	☐	☐	
18			SW			☐	☐	☐	
19			SW			☐	☐	☐	
20			SW			☐	☐	☐	
21			SW			☐	☐	☐	
22			SW			☐	☐	☐	
23			SW			☐	☐	☐	
24			SW			☐	☐	☐	
25			SW			☐	☐	☐	
26			SW			☐	☐	☐	
27			~ SW			☐	☐	☐	

SAMPLED BY: Cindy E. PHONE: 360-416-1464 EMAIL: cindye@co.skagit.wa.us

RELINQUISHED BY	DATE	TIME	RECEIVED BY	DATE	TIME
Cindy Ehr	10/26/23	11:48	KBM(W)REIS	10/26/23	1148
			7.8		

EDGE ANALYTICAL

Burlington, WA *Corporate Laboratory (a)*
1620 S Walnut St - Burlington, WA 98233 - **800.755.9295** • 360.757.1400

Bellingham, WA *Microbiology (b)*
805 Orchard Dr Ste 4 - Bellingham, WA 98225 - 360.715.1212

Portland, OR *Microbiology/Chemistry (c)*
9725 SW Commerce Cr Ste A2 - Wilsonville, OR 97070 - 503.682.7802

Corvallis, OR *Microbiology/Chemistry (d)*
1100 NE Circle Blvd, Ste 130 - Corvallis, OR 97330 - 541.753.4946

Bend, OR *Microbiology (e)*
20332 Empire Blvd Ste 4 - Bend, OR 97701 - 541.639.8425

Data Report

Client Name: Skagit County Public Works
1800 Continental Place
Mount Vernon, WA 98273

Reference Number: **23-32956**
Project: Lake Campbell CMP

Report Date: 11/14/23

Date Received: 10/26/23
Approved by: bj,tjb
Authorized by:

Lawrence J Henderson, PhD
Director of Laboratories, Vice President

Sample Description: Cam-Out_20231026 Cam-Out | Matrix SW | Sample Date: 10/26/23 10:40 am
Lab Number: 65798 | Sample Comment: Filter ASAP | Collected By: Cindy E

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.62	0.010	0.0045	mg/L	1.0	350.1	a	11/8/23	MSO	350.1_231108	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	4.18	0.20	0.0848	mg/L	1.0	351.2	a	11/7/23	MSO	351.2_231107	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.70	0.01	0.0042	mg/L	1.0	SM4500-NO3 F	a	10/26/23	TJL	NO3NO2_231026A	
14265-44-2	**ORTHO-PHOSPHATE**	0.08 H1	0.01	0.0032	mg/L	1.0	SM4500-P F	a	10/31/23	TJB	OPHOS_231031	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.317	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/8/23	TJL	TPHOS_231108	

Sample Description: CS1-20231026 CS1 | Matrix SW | Sample Date: 10/26/23 9:41 am
Lab Number: 65799 | Sample Comment: Filter ASAP | Collected By: Cindy E

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.020	0.010	0.0045	mg/L	1.0	350.1	a	11/8/23	MSO	350.1_231108	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.99	0.20	0.0848	mg/L	1.0	351.2	a	11/7/23	MSO	351.2_231107	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.72	0.01	0.0042	mg/L	1.0	SM4500-NO3 F	a	10/26/23	TJL	NO3NO2_231026A	
14265-44-2	**ORTHO-PHOSPHATE**	0.05 H1	0.01	0.0032	mg/L	1.0	SM4500-P F	a	10/31/23	TJB	OPHOS_231031	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.076	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/8/23	TJL	TPHOS_231108	

Notes:
ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

If you have any questions concerning this report contact us at the above phone number.

EDGE ANALYTICAL

Reference Number: 23-32956
Report Date: 11/14/23

Data Report

Sample Description: DUPE-20231026 Dupe | Matrix SW | Sample Date: 10/26/23 9:43 am
Lab Number: 65800 | Sample Comment: Filter ASAP | Collected By: Cindy E

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.017	0.010	0.0045	mg/L	1.0	350.1	a	11/8/23	MSO	350.1_231108	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.96	0.20	0.0848	mg/L	1.0	351.2	a	11/7/23	MSO	351.2_231107	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.78	0.01	0.0042	mg/L	1.0	SM4500-NO3 F	a	10/26/23	TJL	NO3NO2_231026A	
14265-44-2	**ORTHO-PHOSPHATE**	0.05 H1	0.01	0.0032	mg/L	1.0	SM4500-P F	a	10/31/23	TJB	OPHOS_231031	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.078	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/8/23	TJL	TPHOS_231108	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

SAMPLE INDEPENDENT
QUALITY CONTROL REPORT

Reference Number: **23-32956**
Report Date: 11/14/23

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
Calibration Check											
350.1_231108	0	AMMONIA-N	2.48	2.50	mg/L	350.1	99	90-110		CAL	
351.2_231107	0	TOTAL KJELDAHL NITROGEN as N	2.67	2.50	mg/L	351.2	107	90-110		CAL	
NO3NO2_23102(	0	TOTAL NITRATE+NITRITE as N	1.00	1.00	mg/L	SM4500-NO3 F	100	90-110		CAL	
ophos_231031	0	ORTHO-PHOSPHATE	1.01	1.00	mg/L	SM4500-P F	101	85-115		CAL	
TPHOS_231108	0	TOTAL PHOSPHORUS-P	0.101	0.100	mg/L	SM4500-P F	101	85-115		CAL	
Laboratory Fortified Blank											
351.2_231107	0	TOTAL KJELDAHL NITROGEN as N	1.96	2.00	mg/L	351.2	98	90-110		LFB	
Laboratory Reagent Blank											
351.2_231107	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		LRB	
NO3NO2_23102(	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		LRB	
ophos_231031	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		LRB	
TPHOS_231108	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		LRB	
Method Blank											
350.1_231108	0	AMMONIA-N	ND		mg/L	350.1		0-0		MB	
351.2_231107	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		MB	
NO3NO2_23102(	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		MB	
ophos_231031	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		MB	
TPHOS_231108	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		MB	
Quality Control Sample											
350.1_231108	0	AMMONIA-N	3.68	3.72	mg/L	350.1	99	85-115		QCS	
351.2_231107	0	TOTAL KJELDAHL NITROGEN as N	2.40	2.33	mg/L	351.2	103	85-115		QCS	
NO3NO2_23102(	0	TOTAL NITRATE+NITRITE as N	1.90	2.00	mg/L	SM4500-NO3 F	95	90-110		QCS	
ophos_231031	0	ORTHO-PHOSPHATE	0.95	1.00	mg/L	SM4500-P F	95	90-110		QCS	
TPHOS_231108	0	TOTAL PHOSPHORUS-P	0.211	0.217	mg/L	SM4500-P F	97	90-110		QCS	

*Notation:

% Recovery = (Result of Analysis)/(True Value) * 100

NA = Indicates % Recovery could not be calculated.

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QCIndependent4.rpt

SAMPLE DEPENDENT
QUALITY CONTROL REPORT
Duplicate, Matrix Spike/Matrix Spike Duplicate and Confirmation Result Report

Duplicate

Batch	Sample	Analyte	Result	Duplicate Result	Units	%RPD	Limits	QC Qualifier	Type	Comments
350.1_231108										
7664-41-7	65018	AMMONIA-N	0.037	0.025	mg/L	**38.7**	0-20	INH	DUP	
7664-41-7	65359	AMMONIA-N	ND	ND	mg/L	**NA**	0-20		DUP	
7664-41-7	65800	AMMONIA-N	0.017	0.017	mg/L	**0.0**	0-20		DUP	
7664-41-7	66604	AMMONIA-N	0.046	0.044	mg/L	**4.4**	0-20		DUP	
351.2_231107										
E-10264	65347	TOTAL KJELDAHL NITROGEN as N	ND	ND	mg/L	**NA**	0-20		DUP	
E-10264	65798	TOTAL KJELDAHL NITROGEN as N	4.18	4.37	mg/L	**4.4**	0-20		DUP	
E-10264	66707	TOTAL KJELDAHL NITROGEN as N	1.28	1.21	mg/L	**5.6**	0-20		DUP	
OPHOS_231031										
14265-44-2	65810	ORTHO-PHOSPHATE	ND	ND	mg/L	**NA**	0-20		DUP	
TPHOS_231108										
7723-14-0	63494	TOTAL PHOSPHORUS-P	0.038	0.038	mg/L	**0.0**	0-20		DUP	
7723-14-0	65798	TOTAL PHOSPHORUS-P	0.317	0.329	mg/L	**3.7**	0-20		DUP	
7723-14-0	66717	TOTAL PHOSPHORUS-P	ND	ND	mg/L	**NA**	0-20		DUP	

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

Reference Number: 23-32956
Report Date: 11/14/2023

Laboratory Fortified Matrix (MS)

Batch/CAS	Sample	Analyte	Result	Spike Result	Duplicate Spike Result	Conc	Units	Percent Recovery MS	Percent Recovery MSD	Limits*	%RPD	Limits*	QC Qualifier	Type	Comments
350.1_231108															
7664-41-7	65018	AMMONIA-N	0.037	0.97	0.99	1.00	mg/L	**93**	**95**	70-130	**2.1**	0-20		LFM	
7664-41-7	65359	AMMONIA-N	ND	1.00	0.97	1.00	mg/L	**100**	**97**	70-130	**3.0**	0-20		LFM	
7664-41-7	65800	AMMONIA-N	0.017	1.02	1.03	1.00	mg/L	**100**	**101**	70-130	**1.0**	0-20		LFM	
7664-41-7	66604	AMMONIA-N	0.046	1.01	1.01	1.00	mg/L	**96**	**96**	70-130	**0.0**	0-20		LFM	
351.2_231107															
E-10264	65347	TOTAL KJELDAHL NITROGEN as N	ND	0.12		2.00	mg/L	**6**		70-130	**NA**	0-20	IM	LFM	
E-10264	65798	TOTAL KJELDAHL NITROGEN as N	4.18	4.72		2.00	mg/L	**27**		70-130	**NA**	0-20	IM	LFM	
E-10264	66707	TOTAL KJELDAHL NITROGEN as N	1.28	3.25		2.00	mg/L	**99**		70-130	**NA**	0-20		LFM	
OPHOS_231031															
14265-44-2	65810	ORTHO-PHOSPHATE	ND	0.48	0.49	0.50	mg/L	**96**	**98**	70-130	**2.1**	0-20		LFM	
TPHOS_231108															
7723-14-0	63494	TOTAL PHOSPHORUS-P	0.038	0.089	0.090	0.050	mg/L	**102**	**104**	70-130	**1.9**	0-20		LFM	
7723-14-0	65798	TOTAL PHOSPHORUS-P	0.317	0.359	0.397	0.050	mg/L	**84**	**160**	70-130	**62.3**	0-20	IS	LFM	
7723-14-0	66717	TOTAL PHOSPHORUS-P	ND	0.049	0.052	0.050	mg/L	**98**	**104**	70-130	**5.9**	0-20		LFM	

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QC Dependent2.rpt

EDGE ANALYTICAL

Qualifier Definitions

Reference Number: 23-32956
Report Date: 11/14/23

Qualifier	Definition
H1	Sample analysis performed past holding time.
IM	Matrix induced bias assumed
INH	The sample was non-homogeneous
IS	The ratio of the spike concentration to sample background was too low to meet performance criteria

Note: Some qualifier definitions found on this page may pertain to results or QC data which are not printed with this report.

2023 LAKE CAMPBELL CMP MONITORING DATA SHEET

Field Equipment Checklist

- ☑ Secchi disk
- ☑ YSI multimeter
- ☐ Cooler with ice
- ☐ Van Dorn / Kemmerer
- ☑ Hanna pH meter
- ☑ Sample bottles
- NA ☐ Plankton net
- ☐ Anchor
- NA ☐ Filters & syringes

Project: Lake Campbell Cyanobacteria Management Plan Project No.: 23-08143-000

Client: Skagit County Field Personnel:

Weather: CALM, OVERCAST, 2mph WIND

Wind (still, windy, choppy): 2mph

Number of vessels on lake: 2 boats

Number of shoreline swimmers: ~~-0-~~ 1

Number of shoreline anglers: -0-

Number of geese: ducks:

other waterfowl blue heron

CAM-DEEP (at deepest point south of island)

Collection Date and Time: 11/15/2023 1:30 Pm

Secchi Depth (m): ~~FEET~~ 1.15M Depth to Bottom (m): ~~17 FEET~~ 3.5 m

Water color: PEA GREEN, HEAVY ALGAE CLUMPS.

Notes

Profile Readings (every monthly event):

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Specific Conductivity (µS/cm)	pH*
0.2	8.7	9.81	84.2	257.8	7.75
0.5	8.7	9.68	83.1	257.9	x
1.0	8.7	9.67	83.9	258.0	7.78
1.5	8.7	9.72	83.3	257.9	x
2.0	8.7	9.63	82.4	257.9	7.81
2.5	8.7	9.45	80.9	257.8	x
3.0	8.6	9.20	78.8	257.7	7.82
3.5	8.6	9.19	78.7	257.9	x
4.0	8.6	9.09	77.7	257.8	7.78

*pH sampling done in 1-meter increments

Notes

Water Quality Samples Collected* (every monthly event):

Fill in the Sample IDs and depths below. Check the box (X) for each sample bottle filled. Duplicates should be collected during each monthly event; record the same time and depth here as the depth the duplicate was collected. Do not label sample bottles with the sample time or depth.

Sample ID	Sample Time	Sample Depth (m)	Total Nutrients (500 mL HDPE with H_2SO_4)	Dissolved Nitrogen ** (500 mL HDPE with H_2SO_4)	Orthophosphate ** (250 mL HDPE)	Chlorophyll-a (125-mL dark HDPE)
CAM-DEEP-2023 1115 -S	1300	0.5	✓	✓	✓	✓
CAM-DEEP-2023 1115 -B	}	4.0	✓	✓	✓	✓
CAM-DUPE-2023 1115 -D		4.0	✓	✓	✓	N/A

*All water quality samples must be kept on ice or refrigerated until delivered to lab.

**Dissolved nitrogen and orthophosphate samples must be field filtered into bottles using syringes.

Notes

Plankton Samples (monthly during August, September, and October only)

Fill in the Sample IDs and depths below. Check the box (X) for each sample bottle filled.

Sample ID	Sample Time	Sample Depth (m)	Phytoplankton Samples (125-mL dark HDPE, with Lugol's)	Zooplankton Vertical Tow (250-mL HDPE, with ethanol)
CAM-DEEP-2023_____________-S	N/A	0.5		NA
CAM-DEEP-2023_____________-B	N/A			NA
CAM-DEEP-2023_____________	N/A	From _____ m to surface	NA	

Note: Change sample IDs to "CAM-DEEP-2024______-__" for any 2024 events.

HERRERA
Science + Planning + Design

2023 LAKE CAMPBELL CMP WATERSHED MONITORING DATA SHEET

Project: Lake Campbell Cyanobacteria Management Plan Project No.: 23-08143-000
Client: Skagit County Field Personnel: Mary Brady, Rob Lawson
Event Type and Number Storm ( ) Base (✓)
Weather and predicted rainfall (in): 40°F partly cloudy, no rain

Base flow sampling to occur every month (August 2023 through January 2024) on the day of or day before lake sampling. Six additional wet weather (storm flow) sampling events to occur during fall and winter storms September 2023 through January 2024.

Field Equipment Checklist

- ☑ Flow meter
- N/A YSI multimeter
- ☑ Cooler with ice
- ☑ Tape Measure
- N/A Hanna pH meter
- ☑ Chain-of-Custody
- ☑ Sample bottles

Sampling Data

All samples analyzed for total nutrients. Duplicates are to be collected monthly from September 2023 through January 2024 at a random site during a random event. If applicable, record duplicate sample information below. Do not include duplicate sample times on COCs.

Site ID	Sample ID	Sample Time	Photos Taken?	Water Description (Turbidity; Unusual color, odor, sheen)
CS1	CS1-2023 11 15	1421	Y	
CS2	CS2-2023 11-15	~~13:20~~ 14:08	Y	fairly clear tannish color
CS2.5	CS2.5-2023	N/A		
CS3	CS3-2023	13:20	Y	
DUPE	DUPE-2023	1423		

Notes & observations:

mf b2_campbell_watershedmonitoring_field form_blank.docx

Discharge Data

CS1

Monitoring Location: SR-20 inflow

Discharge measurement method: ☒ Timed bucket fill ☐ Stream cross-section with flow probe
☐ Other (describe): 1.8 sec. 2,365 mL / 80 oz

Collection Date and Time: 11-15-23 14:21

Notes & Observations: tannish water color

Culvert diameter = 36 inches Bucket Fill

Water depth = 1.5" ~~feet~~

Water velocity (flow) = ________ f/s

Calculated Flow (cfs) = ________

CS2

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☒ Timed bucket fill ☐ Stream cross-section with flow probe
☐ Other (describe): 7.5 sec. 700 ml. / 24 oz

Collection Date and Time: 11-15-23 14:08

Notes & Observations:
little flow in culvert
not enough to flow outlet

Culvert diameter = 36 inches Bucket Fill 24

Water depth = 0.5" ~~feet~~

Water velocity (flow) = ________ f/s

Calculated Flow (cfs) = ________

CS2.5

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe):

Collection Date and Time: 11/15/23 1358

Notes & Observations: Some water/squishy - no flow

Culvert diameter = ________ inches

Water depth = ___________ feet

Water velocity (flow) = ___________ f/s

Calculated Flow (cfs) = __________________

CS3

Monitoring Location: Lake Erie outlet

Discharge measurement method: Stream cross-section

Collection Date and Time: 11-15-23 13:20

Notes & Observations:

Visible flow not readable to meter

Total channel section width = 2 feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank	1' 9"	–	–
1	2' 3"	Ø	
2	3' 2"	.23'	0
3	4' 1"	Ø	
4			
5			
6			
7			
8			
Edge of Bank		–	–

Calculated Flow (cfs) = __________________

CAM-OUT

Monitoring Location: Outlet for Lake Campbell
Discharge measurement method: Stream cross-section
Collection Date and Time: 11-15-23 14:45 -
Notes & Observations
floating algae

Total channel section width = ________ feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft) Meters	Velocity (f/s)
Edge of Bank	1' 6"	0 -	–
1	2' 5"	.602	0 too much debris
2	3' 4"	.423	.0014
3	4' 2"	.425	.0090
4	5' 1"	.450	.0125
5	5' 11"	.450	.0157
6	6' 10"	.423	.0186
7	7' 9"	.40	.0207
8	8' 8"	.28	too much debris
Edge of Bank	9' 7"	- 0.225	– " "

Calculated Flow (cfs) = ____________

Other Observations

METER CALIBRATION LOG

Project Number/Name:	Lake Campbell CMP (23-08143-000)
Personnel Performing Calibration:	Leanne Trueman
Meter:	YSI Pro2030 multimeter (Sp. Conductivity/DO)
	Hanna HI991003 handheld meter (pH)
Date/Time:	11/15/23 1122

PRE-Event Calibration		Meter Reading	Buffer / Cal Std	Comments
Conductivity (µS/cm)		0	0	
		9998	1,000	
DO % Saturation		98.4	100	
pH		7.01	7.01	
		4.01	4.01	

11/15/23 4:42

POST-Event Calibration Check	Meter Reading	Buffer / Cal Std	Comments
Conductivity (µS/cm)	9995	1,000	
DO % Saturation	100.1	100	
pH	7.05	7.01	
	3.99	4.01	

Calibration Procedures:

Rinse Meter Sondes Between Each Operation

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

HERRERA

YSI Multimeter 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.

YSI Multimeter 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.

Hanna Meter pH Calibration Notes:

1. Perform 2-point calibration, starting with pH 7.01 buffer, followed by 10.01 or 4.01 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".

CHAIN OF CUSTODY / ANALYSIS REQUEST (PLEASE COMPLETE ALL APPLI

23-35130
70179 - 70185

EDGE ANALYTICAL

Main Lab (800-755-9295)
1620 South Walnut St. Burlington, WA 98233
Microbiology (888-725-1212)
805 W. Orchard Dr. Suite 4 Bellingham, WA 98225
Wilsonville Lab (503-682-7802)
9150 SW Pioneer Ct. Suite W Wilsonville, OR 97070
Corvallis Lab (541-753-4946)
540 SW 3rd St. Corvallis, OR 97333

REPORT TO: SKA02 SKAGIT CO. PUBLIC WKS
ADDRESS: 1800 CONTINENTAL PLACE
CITY: MOUNT VERNON STATE: WA ZIP: 98273
ATTN: LEANNE INGMAN
PHONE: (360) 416-1450 FAX:
EMAIL: LEANNEI@CO.SKAGIT.WA.US, MEGHANM@CO.SKAGIT.WA.US
PROJECT NAME: LAKE CAMPBELL CMP-11/15/23

FOR LAB USE ONLY
REF#

CHECK REGULATORY PROGRAM
- ☐ SAFE DRINKING WATER ACT
- ☐ CLEAN WATER ACT
- ☐ RCRA / CERCLA
- ☐ OTHER

	SAMPLE ID	LOCATION	SAMPLE MATRIX *	DATE	TIME	Ortho Phos	AMMONIA, TKN, T. PHOS, NO2/NO3	CHLOROPHYL	SPECIAL INSTRUCTIONS/ CONDITIONS ON RECEIPT
1	CS1-20231115	CS1	SW	11/15/23	1421	☒	☒	☐	Filter ASAP
2	~~CS2-20231115~~	~~CS2~~	~~SW~~	~~11/15/23~~		☒	☒	☐	~~Filter ASAP~~
3	CS2.5-20231115	CS2.5	SW	11/15/23	1358	☒	☒	☐	Filter ASAP
4	CS3-20231115	CS3	SW	11/15/23	1320	☒	☒	☐	Filter ASAP
5	DUPE-20231115		SW	11/15/23	1423	☒	☒	☐	Filter ASAP
6	Cam-Deep-20231115-S	Surface	SW	11/15/23	1300	☒	☒	☒	Filter ASAP
7	Cam-deep-20231115-B	Bottom	SW	11/15/23	1300	☒	☒	☒	Filter ASAP
8	Cam-dupe-20231115		SW	11/15/23	1300	☒	☒	☐	Filter ASAP
9			SW			☐	☐	☐	
10			SW			☐	☐	☐	
11			SW			☐	☐	☐	
12			SW			☐	☐	☐	
13			SW			☐	☐	☐	
14			SW			☐	☐	☐	
15			SW			☐	☐	☐	
16			SW			☐	☐	☐	
17			SW			☐	☐	☐	
18			SW			☐	☐	☐	
19			SW			☐	☐	☐	
20			SW			☐	☐	☐	
21			SW			☐	☐	☐	
22			SW			☐	☐	☐	
23			SW			☐	☐	☐	
24			SW			☐	☐	☐	
25			SW			☐	☐	☐	
26			SW			☐	☐	☐	

SAMPLED BY: PHONE: EMAIL:

RELINQUISHED BY	DATE	TIME	RECEIVED BY	DATE	TIME
Leanne Ingman	11/15/23	1617	R Ravel Keir	11-15-23	1617
					7.7

Burlington, WA *Corporate Laboratory (a)*
1620 S Walnut St - Burlington, WA 98233 - **800.755.9295** • 360.757.1400
Bellingham, WA *Microbiology (b)*
805 Orchard Dr Ste 4 - Bellingham, WA 98225 - 360.715.1212
Portland, OR *Microbiology/Chemistry (c)*
9725 SW Commerce Cr Ste A2 - Wilsonville, OR 97070 - 503.682.7802
Corvallis, OR *Microbiology/Chemistry (d)*
1100 NE Circle Blvd, Ste 130 - Corvallis, OR 97330 - 541.753.4946
Bend, OR *Microbiology (e)*
20332 Empire Blvd Ste 4 - Bend, OR 97701 - 541.639.8425

Data Report

Client Name: Skagit County Public Works
1800 Continental Place
Mount Vernon, WA 98273

Reference Number: **23-35130**
Project: Lake Campbell CMP 11/15/23
Report Date: 12/14/23
Date Received: 11/15/23
Approved by: mcs,tjb
Authorized by:

Lawrence J Henderson, PhD
Director of Laboratories, Vice President

Sample Description: CS1-20231115 CS1 — Matrix SW — Sample Date: 11/15/23 2:21 pm
Lab Number: 70179 — Sample Comment: — Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.016	0.010	0.0045	mg/L	1.0	350.1	a	11/29/23	MSO	350.1_231129	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.62	0.20	0.0848	mg/L	1.0	351.2	a	11/30/23	MSO	351.2_231130	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.16	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	11/27/23	TJL	NO3NO2_231127	
14265-44-2	**ORTHO-PHOSPHATE**	0.04	0.01	0.0027	mg/L	1.0	SM4500-P F	a	11/16/23	TJL	OPHOS_231116	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.066	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/21/23	TJL	TPHOS_231121	

Sample Description: CS2.5-20231115 CS2.5 — Matrix SW — Sample Date: 11/15/23 1:58 pm
Lab Number: 70180 — Sample Comment: — Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.0091 J	0.010	0.0045	mg/L	1.0	350.1	a	11/29/23	MSO	350.1_231129	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.62	0.20	0.0848	mg/L	1.0	351.2	a	11/30/23	MSO	351.2_231130	
E-10128	**TOTAL NITRATE+NITRITE as N**	1.09	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	11/27/23	TJL	NO3NO2_231127	
14265-44-2	**ORTHO-PHOSPHATE**	0.03	0.01	0.0027	mg/L	1.0	SM4500-P F	a	11/16/23	TJL	OPHOS_231116	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.056	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/21/23	TJL	TPHOS_231121	

Notes:
ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

If you have any questions concerning this report contact us at the above phone number.

EDGE ANALYTICAL

Reference Number: **23-35130**
Report Date: 12/14/23

Data Report

Sample Description: CS3-20231115 CS3 | Matrix SW | Sample Date: 11/15/23 1:20 pm
Lab Number: 70181 | Sample Comment: | Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.010	0.010	0.0045	mg/L	1.0	350.1	a	11/29/23	MSO	350.1_231129	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.68	0.20	0.0848	mg/L	1.0	351.2	a	11/30/23	MSO	351.2_231130	
E-10128	**TOTAL NITRATE+NITRITE as N**	ND	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	11/27/23	TJL	NO3NO2_231127	
14265-44-2	**ORTHO-PHOSPHATE**	0.06	0.01	0.0027	mg/L	1.0	SM4500-P F	a	11/16/23	TJL	OPHOS_231116	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.067	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/21/23	TJL	TPHOS_231121	

Sample Description: Dupe-20231115 | Matrix SW | Sample Date: 11/15/23 2:23 pm
Lab Number: 70182 | Sample Comment: | Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.013	0.010	0.0045	mg/L	1.0	350.1	a	11/29/23	MSO	350.1_231129	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.56	0.20	0.0848	mg/L	1.0	351.2	a	11/30/23	MSO	351.2_231130	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.16	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	11/27/23	TJL	NO3NO2_231127	
14265-44-2	**ORTHO-PHOSPHATE**	0.04	0.01	0.0027	mg/L	1.0	SM4500-P F	a	11/16/23	TJL	OPHOS_231116	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.049	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/21/23	TJL	TPHOS_231121	

Sample Description: Cam Deep 20231115-S Surface | Matrix SW | Sample Date: 11/15/23 1:00 pm
Lab Number: 70183 | Sample Comment: | Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.011	0.010	0.0045	mg/L	1.0	350.1	a	11/29/23	MSO	350.1_231129	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	1.14	0.20	0.0848	mg/L	1.0	351.2	a	11/30/23	MSO	351.2_231130	
NA	**CHLOROPHYLL A**	37.4	0.1	0	mg/m3	1.0	SM10200-H		11/30/23	CP	WML_231130	Analyzed by WML
NA	**PHEOPHYTIN A**	ND	0.1	0	mg/m3	1.0	SM10200-H		11/30/23	CP	WML_231130	Analyzed by WML
E-10128	**TOTAL NITRATE+NITRITE as N**	ND	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	11/22/23	TJL	NO3NO2_231122	
14265-44-2	**ORTHO-PHOSPHATE**	0.03	0.01	0.0027	mg/L	1.0	SM4500-P F	a	11/16/23	TJL	OPHOS_231116	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.040	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/29/23	TJL	TPHOS_231129	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

Reference Number: **23-35130**
Report Date: 12/14/23

Data Report

Sample Description: Cam-Deep-20231115-B Bottom — Matrix SW — Sample Date: 11/15/23 1:00 pm
Lab Number: 70184 — Sample Comment: — Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.011	0.010	0.0045	mg/L	1.0	350.1	a	11/29/23	MSO	350.1_231129	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	1.00	0.20	0.0848	mg/L	1.0	351.2	a	11/30/23	MSO	351.2_231130	
NA	**CHLOROPHYLL A**	39.5	0.1	0	mg/m3	1.0	SM10200-H		11/30/23	CP	WML_231130	Analyzed by WML
NA	**PHEOPHYTIN A**	ND	0.1	0	mg/m3	1.0	SM10200-H		11/30/23	CP	WML_231130	Analyzed by WML
E-10128	**TOTAL NITRATE+NITRITE as N**	ND	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	11/22/23	TJL	NO3NO2_231122	
14265-44-2	**ORTHO-PHOSPHATE**	0.03	0.01	0.0027	mg/L	1.0	SM4500-P F	a	11/16/23	TJL	OPHOS_231116	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.021	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/29/23	TJL	TPHOS_231129	

Sample Description: Cam-Dupe-20231115 — Matrix SW — Sample Date: 11/15/23 1:00 pm
Lab Number: 70185 — Sample Comment: — Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.013	0.010	0.0045	mg/L	1.0	350.1	a	11/29/23	MSO	350.1_231129	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.96	0.20	0.0848	mg/L	1.0	351.2	a	11/30/23	MSO	351.2_231130	
E-10128	**TOTAL NITRATE+NITRITE as N**	ND	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	11/22/23	TJL	NO3NO2_231122	
14265-44-2	**ORTHO-PHOSPHATE**	0.03	0.01	0.0027	mg/L	1.0	SM4500-P F	a	11/16/23	TJL	OPHOS_231116	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.031	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	11/29/23	TJL	TPHOS_231129	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

SAMPLE INDEPENDENT
QUALITY CONTROL REPORT

Reference Number: **23-35130**
Report Date: 12/14/23

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
Calibration Check											
350.1_231129	0	AMMONIA-N	2.49	2.50	mg/L	350.1	100	90-110		CAL	
351.2_231130	0	TOTAL KJELDAHL NITROGEN as N	2.62	2.50	mg/L	351.2	105	90-110		CAL	
NO3NO2_23112	0	TOTAL NITRATE+NITRITE as N	0.99	1.00	mg/L	SM4500-NO3 F	99	90-110		CAL	
NO3NO2_23112	0	TOTAL NITRATE+NITRITE as N	0.98	1.00	mg/L	SM4500-NO3 F	98	90-110		CAL	
OPHOS_231116	0	ORTHO-PHOSPHATE			mg/L	SM4500-P F		85-115		CAL	
	0	ORTHO-PHOSPHATE	1.00	1.00	mg/L	SM4500-P F	100	85-115		CAL	
TPHOS_231121	0	TOTAL PHOSPHORUS-P	0.101	0.100	mg/L	SM4500-P F	101	85-115		CAL	
TPHOS_231129	0	TOTAL PHOSPHORUS-P	0.097	0.100	mg/L	SM4500-P F	97	85-115		CAL	
Laboratory Fortified Blank											
351.2_231130	0	TOTAL KJELDAHL NITROGEN as N	1.89	2.00	mg/L	351.2	95	90-110		LFB	
Laboratory Reagent Blank											
351.2_231130	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		LRB	
NO3NO2_23112	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		LRB	
NO3NO2_23112	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		LRB	
OPHOS_231116	0	ORTHO-PHOSPHATE			mg/L	SM4500-P F		0-0		LRB	
	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		LRB	
TPHOS_231121	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		LRB	
TPHOS_231129	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		LRB	
Method Blank											
350.1_231129	0	AMMONIA-N	ND		mg/L	350.1		0-0		MB	
351.2_231130	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		MB	
NO3NO2_23112	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		MB	
NO3NO2_23112	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		MB	
OPHOS_231116	0	ORTHO-PHOSPHATE			mg/L	SM4500-P F		0-0		MB	
	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		MB	
TPHOS_231121	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		MB	
TPHOS_231129	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		MB	

*Notation:

% Recovery = (Result of Analysis)/(True Value) * 100

NA = Indicates % Recovery could not be calculated.

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QCIndependent4.rpt

SAMPLE INDEPENDENT QUALITY CONTROL REPORT

Reference Number: **23-35130**
Report Date: 12/14/23

Quality Control Sample

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
350.1_231129	0	AMMONIA-N	3.68	3.72	mg/L	350.1	99	85-115		QCS	
351.2_231130	0	TOTAL KJELDAHL NITROGEN as N	2.31	2.33	mg/L	351.2	99	85-115		QCS	
NO3NO2_23112	0	TOTAL NITRATE+NITRITE as N	1.94	2.00	mg/L	SM4500-NO3 F	97	90-110		QCS	
NO3NO2_23112	0	TOTAL NITRATE+NITRITE as N	1.92	2.00	mg/L	SM4500-NO3 F	96	90-110		QCS	
OPHOS_231116	0	ORTHO-PHOSPHATE			mg/L	SM4500-P F		90-110		QCS	
	0	ORTHO-PHOSPHATE	0.93	1.00	mg/L	SM4500-P F	93	90-110		QCS	
TPHOS_231121	0	TOTAL PHOSPHORUS-P	0.205	0.217	mg/L	SM4500-P F	94	90-110		QCS	
TPHOS_231129	0	TOTAL PHOSPHORUS-P	0.199	0.217	mg/L	SM4500-P F	92	90-110		QCS	

*Notation:

% Recovery = (Result of Analysis)/(True Value) * 100

NA = Indicates % Recovery could not be calculated.

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QCIndependent4.rpt

SAMPLE DEPENDENT
QUALITY CONTROL REPORT

Duplicate, Matrix Spike/Matrix Spike Duplicate and Confirmation Result Report

Reference Number: **23-35130**
Report Date: 12/14/2023

Duplicate

Batch/CAS	Sample	Analyte	Result	Duplicate Result	Units	%RPD	Limits	QC Qualifier	Comments
350.1_231129									
7664-41-7	69198	AMMONIA-N	0.018	0.016	mg/L	**11.8**	0-20		
7664-41-7	69501	AMMONIA-N	ND	ND	mg/L	**NA**	0-20		
7664-41-7	70584	AMMONIA-N	0.010	0.012	mg/L	**18.2**	0-20		
7664-41-7	70675	AMMONIA-N	0.010	0.0082	mg/L	**19.8**	0-20	IEV	
7664-41-7	71283	AMMONIA-N	0.032	0.027	mg/L	**16.9**	0-20		
351.2_231130									
E-10264	70185	TOTAL KJELDAHL NITROGEN as N	0.96	0.94	mg/L	**2.1**	0-20		
E-10264	71518	TOTAL KJELDAHL NITROGEN as N	1.60	1.58	mg/L	**1.3**	0-20		
NO3NO2_231122									
E-10128	69333	TOTAL NITRATE+NITRITE as N	5.30	5.34	mg/L	**0.8**	0-20		
E-10128	70183	TOTAL NITRATE+NITRITE as N	ND	ND	mg/L	**NA**	0-20		
NO3NO2_231127									
E-10128	68216	TOTAL NITRATE+NITRITE as N	0.26	0.26	mg/L	**0.0**	0-20		
E-10128	68228	TOTAL NITRATE+NITRITE as N	0.02	0.01	mg/L	**66.7**	0-20	INH	
E-10128	68311	TOTAL NITRATE+NITRITE as N	37.3	38.0	mg/L	**1.9**	0-20		
E-10128	69061	TOTAL NITRATE+NITRITE as N	7.29	7.20	mg/L	**1.2**	0-20		
OPHOS_231116									
14265-44-2	70179	ORTHO-PHOSPHATE	0.04	0.04	mg/L	**0.0**	0-20		
TPHOS_231121									
7723-14-0	68554	TOTAL PHOSPHORUS-P	3.04	3.14	mg/L	**3.2**	0-20		
7723-14-0	69495	TOTAL PHOSPHORUS-P	0.039	0.038	mg/L	**2.6**	0-20		
TPHOS_231129									
7723-14-0	70183	TOTAL PHOSPHORUS-P	0.040	0.042	mg/L	**4.9**	0-20		
7723-14-0	70678	TOTAL PHOSPHORUS-P	0.082	0.081	mg/L	**1.2**	0-20		

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QC Dependent_Port.rpt

EDGE ANALYTICAL

SAMPLE DEPENDENT
QUALITY CONTROL REPORT

Duplicate, Matrix Spike/Matrix Spike Duplicate
and Confirmation Result Report

Reference Number: **23-35130**
Report Date: 12/14/2023

Laboratory Fortified Matrix (MS)

Batch/CAS	Sample	Analyte	Result	Spike Result	Duplicate Spike Result	Conc	Units	Percent Recovery MS	Percent Recovery MSD	Limits*	%RPD	Limits*	QC Qualifier	Comments
350.1_231129														
7664-41-7	69198	AMMONIA-N	0.018	0.96	0.97	1.00	mg/L	**94**	**95**	70-130	**1.1**	0-20		
7664-41-7	69501	AMMONIA-N	ND	0.93	0.97	1.00	mg/L	**93**	**97**	70-130	**4.2**	0-20		
7664-41-7	70584	AMMONIA-N	0.010	0.98	0.99	1.00	mg/L	**97**	**98**	70-130	**1.0**	0-20		
7664-41-7	70675	AMMONIA-N	0.010	0.96	1.00	1.00	mg/L	**95**	**99**	70-130	**4.1**	0-20		
7664-41-7	71283	AMMONIA-N	0.032	0.96	1.01	1.00	mg/L	**93**	**98**	70-130	**5.2**	0-20		
351.2_231130														
E-10264	70185	TOTAL KJELDAHL NITROGEN as N	0.96	2.92		2.00	mg/L	**98**		70-130	**NA**	0-20		
E-10264	71518	TOTAL KJELDAHL NITROGEN as N	1.60	3.50		2.00	mg/L	**95**		70-130	**NA**	0-20		
NO3NO2_231122														
E-10128	69333	TOTAL NITRATE+NITRITE as N	5.30	15.4	15.4	10.0	mg/L	**101**	**101**	80-120	**0.0**	0-20		
E-10128	70183	TOTAL NITRATE+NITRITE as N	ND	0.93	0.92	1.00	mg/L	**93**	**92**	80-120	**1.1**	0-20		
NO3NO2_231127														
E-10128	68216	TOTAL NITRATE+NITRITE as N	0.26	1.25	1.26	1.00	mg/L	**99**	**100**	80-120	**1.0**	0-20		
E-10128	68228	TOTAL NITRATE+NITRITE as N	0.02	0.96	0.99	1.00	mg/L	**94**	**97**	80-120	**3.1**	0-20		
E-10128	68311	TOTAL NITRATE+NITRITE as N	37.3	136	136	100	mg/L	**99**	**99**	80-120	**0.0**	0-20		
E-10128	69061	TOTAL NITRATE+NITRITE as N	7.29	31.8	31.7	25.0	mg/L	**98**	**98**	80-120	**0.4**	0-20		
OPHOS_231116														
14265-44-2	70179	ORTHO-PHOSPHATE	0.04	0.51	0.50	0.50	mg/L	**94**	**92**	70-130	**2.2**	0-20		
TPHOS_231121														
7723-14-0	68554	TOTAL PHOSPHORUS-P	3.04	3.64	3.60	0.500	mg/L	**120**	**112**	70-130	**6.9**	0-20		
7723-14-0	69495	TOTAL PHOSPHORUS-P	0.039	0.090	0.084	0.050	mg/L	**102**	**90**	70-130	**12.5**	0-20		
TPHOS_231129														
7723-14-0	70183	TOTAL PHOSPHORUS-P	0.040	0.087	0.091	0.050	mg/L	**94**	**102**	70-130	**8.2**	0-20		
7723-14-0	70678	TOTAL PHOSPHORUS-P	0.082	0.130	0.129	0.050	mg/L	**96**	**94**	70-130	**2.1**	0-20		

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QC Dependent_Port.rpt

Qualifier Definitions

Reference Number: 23-35130
Report Date: 12/14/23

Qualifier	Definition
IEV	Acceptance criteria do not apply to estimated values
INH	The sample was non-homogeneous
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

Note: Some qualifier definitions found on this page may pertain to results or QC data which are not printed with this report.

HERRERA
Science + Planning + Design

2023 LAKE CAMPBELL CMP WATERSHED MONITORING DATA SHEET

Project: Lake Campbell Cyanobacteria Management Plan Project No.: 23-08143-000
Client: Skagit County Field Personnel: Ingman, Edmonds
Event Type and Number Storm (✓) Base ( )
Weather and predicted rainfall (in): 41°F & drizzling predicted rain 0.07

Base flow sampling to occur every month (August 2023 through January 2024) on the day of or day before lake sampling. Six additional wet weather (storm flow) sampling events to occur during fall and winter storms September 2023 through January 2024.

Field Equipment Checklist

- ☑ Flow meter
- ☑ Tape Measure
- ☑ Chain-of-Custody
- ☐ ~~YSI multimeter~~
- ☐ ~~Hanna pH meter~~
- ☑ Sample bottles
- ☑ Cooler with ice

Sampling Data

All samples analyzed for total nutrients. Duplicates are to be collected monthly from September 2023 through January 2024 at a random site during a random event. If applicable, record duplicate sample information below. Do not include duplicate sample times on COCs.

Site ID	Sample ID	Sample Time	Photos Taken?	Water Description (Turbidity; Unusual color, odor, sheen)
CS1	CS1-2023 1201	0858	✓	Clear, some bubbles (Natural)
X CS2	CS2-2023 1201	X	✓	no sample taken, dry
CS2.5	CS2.5-2023 1201	0938	✓	
CS3	CS3-2023 1201	0951		clear, flowing
DUPE	DUPE-2023 1201	0946		clear, flowing

Notes & observations:

mf b2_campbell_watershedmonitoring_field form_blank.docx

Discharge Data

CS1

The readings for flow at CS1 and CS3 were recorded with the meter reporting Velocity not count. -LI

Monitoring Location: SR-20 inflow

Discharge measurement method: ☐ Timed bucket fill ☑ Stream cross-section with flow probe ☐ Other (describe):

Collection Date and Time: 0858

Notes & Observations: outflow from perched culvert = level with flow beyond cul. stream width [illegible] 3ft 4in

Culvert diameter = _______ inches

Water depth = _______ feet

Water velocity (flow) = _______ f/s

Calculated Flow (cfs) = _______

	point	Depth	velocity
Edge	~~0~~ 0"	0	0
	6"	0.025	0.008
	~~0~~ 1Ft 7"	0.05	0.28
	2Ft 3in	0.0	No Flow (rocky)
Edge	3ft 4in	0.0	no Flow (rocky)

X

CS2

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐ Stream cross-section with flow probe ☐ Other (describe):

Collection Date and Time: ~~0924~~

Notes & Observations: water in channel connecting to outflowing culvert, not deep enough for flow measurement, too wide for bucket, too much debris for timed object

↓ notes for CS2.5

Culvert diameter = _______ inches

Water depth = _______ feet

Water velocity (flow) = _______ f/s

Calculated Flow (cfs) = _______

CS2 - No flow from incoming culvert

CS2.5

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐ Stream cross-section with flow probe ☐ Other (describe):

Collection Date and Time: 0938

Notes & Observations: Notes in CS2

CS2.5 flow was not very negligible so considerable slower than CS1.-LI

Culvert diameter = ________ inches

Water depth = ___________ feet

Water velocity (flow) = ___________ f/s

Calculated Flow (cfs) = __________________

CS3

Monitoring Location: Lake Erie outlet

Discharge measurement method: Stream cross-section

Collection Date and Time: 0951

Notes & Observations: clear flow - deeper than last time

Channel Width at CS3 is 2Ft 6in. The bank is a straight drop.-LI

The readings for flow at CS1 and CS3 were recorded with the meter reporting Velocity not count.-LI

Total channel section width = _______ feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank	0	–	–
1	6"	0.075	0.030
2	2ft"	0.2	0.048
3	2ft 6"	0.255	0.126
4			
5			
6			
7			
8			
Edge of Bank	0	–	–

Calculated Flow (cfs) = __________________

mf b2_campbell_watershedmonitoring_field form_blank.docx

CAM-OUT

Monitoring Location: Outlet for Lake Campbell

Discharge measurement method: Stream cross-section

Collection Date and Time: 0833

Notes & Observations Shallower but faster flow

Total channel section width = 7Ft 3" feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank	0	0.475	0034
1	65"	0.225	0142
2	1F7"	0.475	0185
3	2Ft 8"	0.450	0201
4	3Ft 9"	0.420	0215
5	4Ft 10"	0.460	0221
6	5Ft 11"	0.270	0236
7	~~10 Ft~~ 7 Ft	0.21	0267
8			
Edge of Bank	7Ft 3"	-	-

read count #'s not calculated velocity I think

Calculated Flow (cfs) = ____________

Other Observations

Chain of Custody / Analysis Request (Please complete all applicable shaded sections)

Report to: SKA02 Skagit Co. Public WKS	**23-36228**
Address: 1800 Continental Place	72538 - 72541
City: Mount Vernon State: WA Zip: 98273	**Check Regulatory Program**
Attn: Leanne Ingman	☐ Safe Drinking Water Act
Phone: (360) 416-1450 Fax:	☐ Clean Water Act
Email: .leannei@co.skagit.wa.us, meghanm@co.skagit.wa.us	☐ RCRA / CERCLA
Project Name: Lake Campbell CMP_12/01/23	☐ Other

EDGE ANALYTICAL

Main Lab (800-755-9295)
1620 South Walnut St. Burlington, WA 98233
Microbiology (888-725-1212)
805 W. Orchard Dr. Suite 4 Bellingham, WA 98225
Wilsonville Lab (503-682-7802)
9150 SW Pioneer Ct. Suite W Wilsonville, OR 97070
Corvallis Lab (541-753-4946)
540 SW 3rd St. Corvallis, OR 97333

O

	Sample ID	Location	Sample Matrix *	Date	Time	Ortho phos	Ammonia, TKN, T. Phos, NO2/NO3		Special Instructions/ Conditions on Receipt
1	DUPE-20231201		SW	12/01/23	0946	☒	☒	☐	Filter ASAP
2	CS1-20231201	CS1	SW	12/01/23	0858	☒	☒	☐	Filter ASAP
3	~~CS2-20231201~~	~~CS2~~	~~SW~~	~~12/01/23~~		☒	☒	☐	~~Filter ASAP~~
4	CS2.5-20231201	CS2.5	SW	12/01/23	0938	☒	☒	☐	Filter ASAP
5	CS3-20231201	CS3	SW	12/01/23	0951	☒	☒	☐	Filter ASAP
6			SW			☐	☐	☐	
7			SW			☐	☐	☐	
8			SW			☐	☐	☐	
9			SW			☐	☐	☐	
10			SW			☐	☐	☐	
11			SW			☐	☐	☐	
12			SW			☐	☐	☐	
13			SW			☐	☐	☐	
14			SW			☐	☐	☐	
15			SW			☐	☐	☐	
16			SW			☐	☐	☐	
17			SW			☐	☐	☐	
18			SW			☐	☐	☐	
19			SW			☐	☐	☐	
20			SW			☐	☐	☐	
21			SW			☐	☐	☐	
22			SW			☐	☐	☐	
23			SW			☐	☐	☐	
24			SW			☐	☐	☐	
25			SW			☐	☐	☐	
26			SW			☐	☐	☐	
27			SW			☐	☐	☐	

Sampled by: Phone: Email:

Relinquished by	Date	Time	Received by	Date	Time
Leanne Ingman	12/1/23	1035	KBM(W)HE18	12/1/23	1035

5.3

EDGE ANALYTICAL

Burlington, WA *Corporate Laboratory (a)*
1620 S Walnut St - Burlington, WA 98233 - **800.755.9295** • 360.757.1400

Bellingham, WA *Microbiology (b)*
805 Orchard Dr Ste 4 - Bellingham, WA 98225 - 360.715.1212

Portland, OR *Microbiology/Chemistry (c)*
9725 SW Commerce Cr Ste A2 - Wilsonville, OR 97070 - 503.682.7802

Corvallis, OR *Microbiology/Chemistry (d)*
1100 NE Circle Blvd, Ste 130 - Corvallis, OR 97330 - 541.753.4946

Bend, OR *Microbiology (e)*
20332 Empire Blvd Ste 4 - Bend, OR 97701 - 541.639.8425

Data Report

Client Name: Skagit County Public Works
1800 Continental Place
Mount Vernon, WA 98273

Reference Number: **23-36228**
Project: Lake Campbell
CMP_12/01/23
Report Date: 12/18/23
Date Received: 12/1/23
Approved by: bj,tjb
Authorized by:

Lawrence J Henderson, PhD
Director of Laboratories, Vice President

Sample Description: DUPE-20231201 Dupe — Matrix SW — Sample Date: 12/1/23 9:46 am
Lab Number: 72538 — Sample Comment: — Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.0082 J	0.010	0.0045	mg/L	1.0	350.1	a	12/7/23	MSO	350.1_231207	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.60	0.20	0.0848	mg/L	1.0	351.2	a	12/12/23	MSO	351.2_231212	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.0055 J	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	12/1/23	TJL	NO3NO2_231201	
14265-44-2	**ORTHO-PHOSPHATE**	0.09	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/1/23	TJL	OPHOS_231201	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.109	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/6/23	TJL	TPHOS_231206	

Sample Description: CS1-20231201 CS1 — Matrix SW — Sample Date: 12/1/23 8:58 am
Lab Number: 72539 — Sample Comment: — Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.022	0.010	0.0045	mg/L	1.0	350.1	a	12/7/23	MSO	350.1_231207	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.57	0.20	0.0848	mg/L	1.0	351.2	a	12/12/23	MSO	351.2_231212	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.22	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	12/1/23	TJL	NO3NO2_231201	
14265-44-2	**ORTHO-PHOSPHATE**	0.05	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/1/23	TJL	OPHOS_231201	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.069	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/6/23	TJL	TPHOS_231206	

Notes:
ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

If you have any questions concerning this report contact us at the above phone number.

Reference Number: **23-36228**
Report Date: 12/18/23

Data Report

Sample Description: CS2.5-20231201 CS2.5 | Matrix SW | Sample Date: 12/1/23 9:38 am
Lab Number: 72540 | Sample Comment: | Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	ND	0.010	0.0045	mg/L	1.0	350.1	a	12/7/23	MSO	350.1_231207	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	6.01	1	0.424	mg/L	5.0	351.2	a	12/12/23	MSO	351.2_231212	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.09	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	12/1/23	TJL	NO3NO2_231201	
14265-44-2	**ORTHO-PHOSPHATE**	0.04	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/1/23	TJL	OPHOS_231201	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.971	0.050	0.0095	mg/L	5.0	SM4500-P F/SM4500-P B(5)	a	12/6/23	TJL	TPHOS_231206	

Sample Description: CS3-20231201 CS3 | Matrix SW | Sample Date: 12/1/23 9:51 am
Lab Number: 72541 | Sample Comment: | Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.0068 J	0.010	0.0045	mg/L	1.0	350.1	a	12/7/23	MSO	350.1_231207	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.64	0.20	0.0848	mg/L	1.0	351.2	a	12/12/23	MSO	351.2_231212	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.0065 J	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	12/1/23	TJL	NO3NO2_231201	
14265-44-2	**ORTHO-PHOSPHATE**	0.09	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/1/23	TJL	OPHOS_231201	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.108	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/6/23	TJL	TPHOS_231206	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

SAMPLE INDEPENDENT QUALITY CONTROL REPORT

Reference Number: **23-36228**
Report Date: 12/18/23

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
Calibration Check											
350.1_231207	0	AMMONIA-N	2.73	2.50	mg/L	350.1	109	90-110		CAL	
NO3NO2_231201	0	TOTAL NITRATE+NITRITE as N	0.99	1.00	mg/L	SM4500-NO3 F	99	90-110		CAL	
OPHOS_231201	0	ORTHO-PHOSPHATE	0.99	1.00	mg/L	SM4500-P F	99	85-115		CAL	
tphos_231206	0	TOTAL PHOSPHORUS-P	0.100	0.100	mg/L	SM4500-P F	100	85-115		CAL	
Laboratory Reagent Blank											
NO3NO2_231201	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		LRB	
OPHOS_231201	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		LRB	
tphos_231206	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		LRB	
Method Blank											
350.1_231207	0	AMMONIA-N	ND		mg/L	350.1		0-0		MB	
NO3NO2_231201	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		MB	
OPHOS_231201	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		MB	
tphos_231206	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		MB	
Quality Control Sample											
350.1_231207	0	AMMONIA-N	2.35	2.15	mg/L	350.1	109	85-115		QCS	
NO3NO2_231201	0	TOTAL NITRATE+NITRITE as N	1.95	2.00	mg/L	SM4500-NO3 F	98	90-110		QCS	
OPHOS_231201	0	ORTHO-PHOSPHATE	0.93	1.00	mg/L	SM4500-P F	93	90-110		QCS	
tphos_231206	0	TOTAL PHOSPHORUS-P	0.206	0.217	mg/L	SM4500-P F	95	90-110		QCS	

*Notation:

% Recovery = (Result of Analysis)/(True Value) * 100

NA = Indicates % Recovery could not be calculated.

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QCIndependent4.rpt

SAMPLE DEPENDENT QUALITY CONTROL REPORT

Duplicate, Matrix Spike/Matrix Spike Duplicate and Confirmation Result Report

Reference Number: **23-36228**
Report Date: 12/18/2023

Duplicate

Batch/CAS	Sample	Analyte	Result	Duplicate Result	Units	%RPD	Limits	QC Qualifier	Comments
350.1_231207									
7664-41-7	71474	AMMONIA-N	0.083	0.067	mg/L	**21.3**	0-20	INH	
7664-41-7	72443	AMMONIA-N	0.13	0.0086	mg/L	**175.2**	0-20	IEV	
7664-41-7	73341	AMMONIA-N	21.8	22.9	mg/L	**4.9**	0-20		
7664-41-7	73640	AMMONIA-N	0.28	0.29	mg/L	**3.5**	0-20		
351.2_231212									
E-10264	71830	TOTAL KJELDAHL NITROGEN as N	0.25	0.21	mg/L	**17.4**	0-20		
E-10264	72518	TOTAL KJELDAHL NITROGEN as N	0.12	0.31	mg/L	**88.4**	0-20	INH	
NO3NO2_231201									
E-10128	72538	TOTAL NITRATE+NITRITE as N	0.0055	0.0066	mg/L	**18.2**	0-20		
OPHOS_231201									
14265-44-2	72538	ORTHO-PHOSPHATE	0.09	0.09	mg/L	**0.0**	0-20		
TPHOS_231206									
7723-14-0	72307	TOTAL PHOSPHORUS-P	6.32	6.39	mg/L	**1.1**	0-20		
7723-14-0	72433	TOTAL PHOSPHORUS-P	0.0032	0.0033	mg/L	**3.1**	0-20		
7723-14-0	72443	TOTAL PHOSPHORUS-P	0.0024	0.0048	mg/L	**66.7**	0-20	INH	

Laboratory Fortified Matrix (MS)

Batch/CAS	Sample	Analyte	Result	Spike Result	Duplicate Spike Result	Conc	Units	Percent Recovery MS	Percent Recovery MSD	Limits*	%RPD	Limits*	QC Qualifier	Comments
350.1_231207														
7664-41-7	72443	AMMONIA-N	0.13	0.98	0.92	1.00	mg/L	**85**	**79**	70-130	**7.3**	0-20		
7664-41-7	73341	AMMONIA-N	21.8	73.5	76.2	50.0	mg/L	**103**	**109**	70-130	**5.1**	0-20		
7664-41-7	73640	AMMONIA-N	0.28	1.38	1.33	1.00	mg/L	**110**	**105**	70-130	**4.7**	0-20		
351.2_231212														
E-10264	71830	TOTAL KJELDAHL NITROGEN as N	0.25	2.38		2.00	mg/L	**107**		70-130	**NA**	0-20		
E-10264	72518	TOTAL KJELDAHL NITROGEN as N	0.12	1.74		2.00	mg/L	**81**		70-130	**NA**	0-20		
NO3NO2_231201														
E-10128	72538	TOTAL NITRATE+NITRITE as N	0.0055	0.94	0.93	1.00	mg/L	**93**	**92**	80-120	**1.1**	0-20		
OPHOS_231201														
14265-44-2	72538	ORTHO-PHOSPHATE	0.09	0.56	0.56	0.50	mg/L	**94**	**94**	70-130	**0.0**	0-20		
TPHOS_231206														
7723-14-0	72307	TOTAL PHOSPHORUS-P	6.32	8.83	9.01	2.5	mg/L	**100**	**108**	70-130	**6.9**	0-20		
7723-14-0	72433	TOTAL PHOSPHORUS-P	0.0032	0.050	0.051	0.050	mg/L	**94**	**96**	70-130	**2.1**	0-20		
7723-14-0	72443	TOTAL PHOSPHORUS-P	0.0024	0.055	0.055	0.050	mg/L	**105**	**105**	70-130	**0.0**	0-20		

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

Qualifier Definitions

Reference Number: 23-36228
Report Date: 12/18/23

Qualifier	Definition
IEV	Acceptance criteria do not apply to estimated values
INH	The sample was non-homogeneous
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

Note: Some qualifier definitions found on this page may pertain to results or QC data which are not printed with this report.

HERRERA
Science + Planning + Design

2023 LAKE CAMPBELL CMP WATERSHED MONITORING DATA SHEET

Project: Lake Campbell Cyanobacteria Management Plan   Project No.: 23-08143-000
Client: Skagit County   Field Personnel: Bob Edmonds, Leanne Fugman
Event Type and Number Storm ( )   Base (✓)
Weather and predicted rainfall (in): 46°F Cloudy w/ occasional light rain 0.00"

Base flow sampling to occur every month (August 2023 through January 2024) on the day of or day before lake sampling. Six additional wet weather (storm flow) sampling events to occur during fall and winter storms September 2023 through January 2024.

Field Equipment Checklist

- ☑ Flow meter
- ~~☐ YSI multimeter~~
- ☑ Cooler with ice
- ☑ Tape Measure
- ~~☐ Hanna pH meter~~
- ☑ Chain-of-Custody
- ☑ Sample bottles

Sampling Data

All samples analyzed for total nutrients. Duplicates are to be collected monthly from September 2023 through January 2024 at a random site during a random event. If applicable, record duplicate sample information below. Do not include duplicate sample times on COCs.

Site ID	Sample ID	Sample Time	Photos Taken?	Water Description (Turbidity; Unusual color, odor, sheen)
CS1	CS1-2023________			
CS2	CS2-2023________			
CS2.5	CS2.5-2023________			
CS3	CS3-2023________			
DUPE	DUPE-2023________			

Notes & observations:

Discharge Data

CS1

Monitoring Location: SR-20 inflow 1352

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe):

Collection Date and Time: 12/13/23 – 1352

Notes & Observations

Culvert diameter = ______ inches Channel Width 5' 5"

Water depth = ________ feet Edge of Bank

Water velocity (flow) = ________ f/s 0 & 0 Velocity

Calculated Flow (cfs) = __________

		Depth	Vel
①	6	0.05	Not Readable
②	1.5"	0.10	0.02
③	2.4"	0.15	0.17
④	3.3"	0.1	0.03
⑤	4'2"	0.07	0.00
6	5'1" Bank	0	0
7		0	0

CS2

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe):

Collection Date and Time: 12/13/23 – 1407

Notes & Observations Width = 5'4"

Culvert diameter = ______ inches

Water depth = ________ feet

Water velocity (flow) = ________ f/s

Calculated Flow (cfs) = __________

Edge	Point	Depth	Velocity
1	6"	0.1	.10
2	1'5"	0.13	0.29
3	2'4"	0.11	0.91
4	3'3"	0.05	0.11
5	4'2"	0.05	NM
6	Bank	0	0	0
7			

CS2.5

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe):

Collection Date and Time: 12/13/23

Notes & Observations

Channel width 2'1" 2 feet 1 inch

	Depth	Velocity
Bank 0		
① 6"	0.1	0.12
② 1 ft	0.11	0.08
③ 1.5 ft	0.09	0.0
Bank	0	0

Culvert diameter = ________ inches

Water depth = __________ feet

Water velocity (flow) = __________ f/s

Calculated Flow (cfs) = ________________

CS3

Monitoring Location: Lake Erie outlet

Discharge measurement method: Stream cross-section

Collection Date and Time: 12/13/23

Notes & Observations Channel Width = 11'1"

Total channel section width = ________ feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		0.25	0
1	6" ~~1'3" = 1'1"~~	0.052	0
2	2' 8"	0.12	0
3	3' 10"	0.34	0.03
4	5'	0.45	0.04
5	6' 2"	0.45	0.44
6	7' 4"	0.15	0.01
7	8' 6"	0.08	0
8	9' 8"	0.15	0
Edge of Bank	—	0.05	0 -

Calculated Flow (cfs) = ________________

CAM-OUT

Monitoring Location: Outlet for Lake Campbell

Discharge measurement method: Stream cross-section

Collection Date and Time: 12/13/23 1327

Notes & Observations

Outlet was reportedly flowing back into the lake as of 12/10. Flowing out normally today.

a lot of Brush for these 3

Total channel section width = 8-3" feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank	~~83~~"	0.25	0
1	6" inches	0.4	0
2	1.5" 5 inches	0.425	0
3	2 ft 4" inches	0.44	0
4	2ft 3 inches	0.44	0
5	5ft 2 inches	0.41	0
6	5ft 1 inch	0.42	0
7	6ft 0 inch	0.28	0
8	6 ft 11 inches	0.25	0
Edge of Bank	7ft 10 inches	0.35	0 -

Calculated Flow (cfs) =

Edge of Bank

Other Observations

The outlet was reportedly moving back into the lake as noted on the field sheet. I did see a video and it seemed to be significant flow. I do not have permission at this time to share the video. The landowners downstream notched a beaver dam on 12/12. The water from the lake was trickling over the beaver dam on the north side of the bridge in the outflow direction but the water at our sample point to the south was still (as you can see with the flow measurements).

2023 LAKE CAMPBELL CMP
MONITORING DATA SHEET

Field Equipment Checklist

- ☑ Secchi disk
- ☑ YSI multimeter
- ☑ Cooler with ice
- ☐ Van Dorn / Kemmerer
- ☑ Hanna pH meter
- ☑ Sample bottles
- ~~☐ Plankton net~~
- ☐ Anchor
- ~~☐ Filters & syringes~~

Project: Lake Campbell Cyanobacteria Management Plan Project No.: 23-08143-000

Client: Skagit County Field Personnel: ______

Weather: calm, partly cloudy

Wind (still, windy, choppy): still

Number of vessels on lake: 0

Number of shoreline swimmers: 0

Number of shoreline anglers: 0

Number of geese: ______ ducks: ______

other waterfowl ______

CAM-DEEP (at deepest point south of island)

Collection Date and Time: ______

Secchi Depth (m): 1.5 Depth to Bottom (m): ______

Water color: ______

Notes ______

Profile Readings (every monthly event):

Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Specific Conductivity (µS/cm)	pH*
0.2	6.2	9.49	76.0	253.3	7.49
0.5	6.2	9.44	76.1	253.3	x
1.0	6.2	9.49	74.8	253.5	7.52
1.5	6.2	9.38	75.5	253.3	x
2.0	6.2	9.29	74.9	253.1	7.56
2.5	6.2	9.35	75.4	253.1	x
3.0	6.2	9.33	75.3	253.1	7.58
3.5	6.1	9.35	75.4	253.2	x
4.0	6.1	9.28	74.4	253.3	7.52

*pH sampling done in 1-meter increments

Notes

Water Quality Samples Collected* (every monthly event):

Fill in the Sample IDs and depths below. Check the box (X) for each sample bottle filled. Duplicates should be collected during each monthly event; record the same time and depth here as the depth the duplicate was collected. Do not label sample bottles with the sample time or depth.

→ record at *each* sample

Sample ID	Sample Time	Sample Depth (m)	Total Nutrients (500 mL HDPE with H_2SO_4)	Dissolved Nitrogen ** (500 mL HDPE with H_2SO_4)	Orthophosphate ** (250 mL HDPE)	Chlorophyll-a (125-mL dark HDPE)
CAM-DEEP-2023 1213 -S	13:30	0.5	✓	–	–	–
CAM-DEEP-2023 1213 -B	13:40	4.5	✓	–	–	–
CAM-DUPE-2023 1213	13:50	4,5	✓	–	✓	

*All water quality samples must be kept on ice or refrigerated until delivered to lab.

**Dissolved nitrogen and orthophosphate samples must be field filtered into bottles using syringes.

Notes ____________________

Plankton Samples (monthly during August, September, and October only)

Fill in the Sample IDs and depths below. Check the box (X) for each sample bottle filled.

N/A

Sample ID	Sample Time	Sample Depth (m)	Phytoplankton Samples (125-mL dark HDPE, with Lugol's)	Zooplankton Vertical Tow (250-mL HDPE, with ethanol)
CAM-DEEP-2023_____________-S		0.5		NA
CAM-DEEP-2023_____________-B				NA
CAM-DEEP-2023_____________		From _____ m to surface	NA	

Note: Change sample IDs to "CAM-DEEP-2024______-__" for any 2024 events.

METER CALIBRATION LOG

Project Number/Name:	Lake Campbell CMP (23-08143-000)
Personnel Performing Calibration:	
Meter:	YSI Pro2030 multimeter (Sp. Conductivity/DO)
	Hanna HI991003 handheld meter (pH)
Date/Time:	12/13/23 1138

PRE-Event Calibration	Meter Reading	Buffer / Cal Std	Comments
Conductivity (µS/cm)		0	unstable reading
	9999	1,000	
DO % Saturation	99.6	100	
pH	7.01	7.01	
	4.01	4.01	

1604

POST-Event Calibration Check	Meter Reading	Buffer / Cal Std	Comments
Conductivity (µS/cm)	9995	1,000	
DO % Saturation	91.3	100	
pH	7.00	7.01	
	3.98	4.01	

Calibration Procedures:

Rinse Meter Sondes Between Each Operation

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

HERRERA

YSI Multimeter 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.

YSI Multimeter 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.

Hanna Meter pH Calibration Notes:

1. Perform 2-point calibration, starting with pH 7.01 buffer, followed by 10.01 or 4.01 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".

CHAIN OF CUSTODY / ANALYSIS REQUEST (PLEASE COMPLETE ALL APPLICABLE SHADED SECTIONS)

REPORT TO: SKA02 SKAGIT CO. PUBLIC WKS	**FOR LAB USE ONLY**
ADDRESS: 1800 CONTINENTAL PLACE	REF#
CITY: MOUNT VERNON STATE: WA ZIP: 98273	**CHECK REGULATORY PROGRAM**
ATTN: LEANNE INGMAN	☐ SAFE DRINKING WATER ACT
PHONE: (360) 416-1450 FAX:	☐ CLEAN WATER ACT
EMAIL: LEANNEI@CO.SKAGIT.WA.US, MEGHANM@CO.SKAGIT.WA.US	☐ RCRA / CERCLA
PROJECT NAME: LAKE CAMPBELL CMP-12/13/23	☐ OTHER

EDGE ANALYTICAL

Main Lab (800-755-9295)
1620 South Walnut St. Burlington, WA 98233
Microbiology (888-725-1212)
805 W. Orchard Dr. Suite 4 Bellingham, WA 98225
Wilsonville Lab (503-682-7802)
9150 SW Pioneer Ct. Suite W Wilsonville, OR 97070
Corvallis Lab (541-753-4946)
540 SW 3rd St. Corvallis, OR 97333

#	SAMPLE ID	LOCATION	SAMPLE MATRIX *	DATE	TIME	Ortho Phos	AMMONIA, TKN, T. PHOS, NO2/NO3	CHLOROPHYL	SPECIAL INSTRUCTIONS/ CONDITIONS ON RECEIPT
1	CS1-20231115	CS1	SW	12/13/23	1353	☒	☒	☐	Filter ASAP
2	CS2-20231115	CS2	SW	12/13/23	1407	☒	☒	☐	Filter ASAP
3	CS2.5-20231115	CS2.5	SW	12/13/23	1423	☒	☒	☐	Filter ASAP
4	CS3-20231115	CS3	SW	12/13/23	1441	☒	☒	☐	Filter ASAP
5	DUPE-20231115		SW	12/13/23	1407	☒	☒	☐	Filter ASAP
6	Cam-Deep-20231115-S	Surface	SW	12/13/23	1330	☒	☒	☒	Filter ASAP
7	Cam-deep-20231115-B	Bottom	SW	12/13/23	1340	☒	☒	☒	Filter ASAP
8	Cam-dupe-20231115		SW	12/13/23	1350	☒	☒	☐	Filter ASAP
9			SW			☐	☐	☐	
10			SW			☐	☐	☐	
11			SW			☐	☐	☐	
12			SW			☐	☐	☐	
13			SW			☐	☐	☐	
14			SW			☐	☐	☐	
15			SW			☐	☐	☐	
16			SW			☐	☐	☐	
17			SW			☐	☐	☐	
18			SW			☐	☐	☐	
19			SW			☐	☐	☐	
20			SW			☐	☐	☐	
21			SW			☐	☐	☐	
22			SW			☐	☐	☐	
23			SW			☐	☐	☐	
24			SW			☐	☐	☐	
25			SW			☐	☐	☐	
26			SW			☐	☐	☐	

SAMPLED BY: **Leanne Ingman** PHONE: **360-416-1450** EMAIL: LEANNEI@CO.SKAGIT.WA.US

RELINQUISHED BY	DATE	TIME	RECEIVED BY	DATE	TIME
Leanne Ingman	12/13/23	1535	JBL(WI) REC 8	12-13	1535

Burlington, WA *Corporate Laboratory (a)*
1620 S Walnut St - Burlington, WA 98233 - **800.755.9295** • 360.757.1400

Bellingham, WA *Microbiology (b)*
805 Orchard Dr Ste 4 - Bellingham, WA 98225 - 360.715.1212

Portland, OR *Microbiology/Chemistry (c)*
9725 SW Commerce Cr Ste A2 - Wilsonville, OR 97070 - 503.682.7802

Corvallis, OR *Microbiology/Chemistry (d)*
1100 NE Circle Blvd, Ste 130 - Corvallis, OR 97330 - 541.753.4946

Bend, OR *Microbiology (e)*
20332 Empire Blvd Ste 4 - Bend, OR 97701 - 541.639.8425

January 10, 2024

Leanne ingman
Skagit County Public Works
1800 Continental Place
Mount Vernon, WA 98273

RE: 23-37686 - Lake Campbell CMP - 12/13/23

Dear Leanne ingman,

Your project: Lake Campbell CMP - 12/13/23, was received on Wednesday December 13, 2023.

All samples were analyzed within the accepted holding times and were appropriately preserved and analyzed according to approved analytical protocols, unless noted in the data or QC reports. The quality control data was within laboratory acceptance limits, unless specified in the data or QC reports.

If you have questions phone us at 800 755-9295.

Respectfully

Lawrence J Henderson, PhD
Director of Laboratories, Vice President

Enclosures: Data Report
QC Reports
Chain of Custody

Burlington, WA *Corporate Laboratory (a)*
1620 S Walnut St - Burlington, WA 98233 - **800.755.9295** • 360.757.1400
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Bend, OR *Microbiology (e)*
20332 Empire Blvd Ste 4 - Bend, OR 97701 - 541.639.8425

Data Report

Client Name: Skagit County Public Works
1800 Continental Place
Mount Vernon, WA 98273

Reference Number: **23-37686**
Project: Lake Campbell CMP - 12/13/23
Report Date: 1/10/24
Date Received: 12/13/23
Approved by: bj,mcs,tjb
Authorized by:

Lawrence J Henderson, PhD
Director of Laboratories, Vice President

Sample Description: CS1-20231213 CS1 — Matrix SW — Sample Date: 12/13/23 1:53 pm
Lab Number: 75902 — Sample Comment: Filter ASAP — Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.035	0.010	0.0045	mg/L	1.0	350.1	a	12/29/23	MSO	350.1_231229	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.68	0.20	0.0267	mg/L	1.0	351.2	a	1/3/24	MSO	351.2_240103	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.60	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/5/24	TJL	NO3NO2_240105	
14265-44-2	**ORTHO-PHOSPHATE**	0.05	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/14/23	TJL	OPHOS_231214	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.069	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/21/23	TJL	TPHOS_231221	

Sample Description: CS2-20231213 CS2 — Matrix SW — Sample Date: 12/13/23 2:07 pm
Lab Number: 75903 — Sample Comment: Filter ASAP — Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.015	0.010	0.0045	mg/L	1.0	350.1	a	12/29/23	MSO	350.1_231229	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.40	0.20	0.0267	mg/L	1.0	351.2	a	1/3/24	MSO	351.2_240103	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.17	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/5/24	TJL	NO3NO2_240105	
14265-44-2	**ORTHO-PHOSPHATE**	0.02	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/14/23	TJL	OPHOS_231214	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.024	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/21/23	TJL	TPHOS_231221	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

If you have any questions concerning this report contact us at the above phone number.

EDGE ANALYTICAL

Reference Number: **23-37686**
Report Date: 1/10/24

Data Report

Sample Description: CS2.5-20231213 CS2.5 — Matrix SW — Sample Date: 12/13/23 2:23 pm
Lab Number: 75904 — Sample Comment: Filter ASAP — Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.017	0.010	0.0045	mg/L	1.0	350.1	a	12/29/23	MSO	350.1_231229	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.38	0.20	0.0267	mg/L	1.0	351.2	a	1/3/24	MSO	351.2_240103	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.29	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/5/24	TJL	NO3NO2_240105	
14265-44-2	**ORTHO-PHOSPHATE**	0.03	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/14/23	TJL	OPHOS_231214	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.018	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/21/23	TJL	TPHOS_231221	

Sample Description: CS3-20231213 CS3 — Matrix SW — Sample Date: 12/13/23 2:41 pm
Lab Number: 75905 — Sample Comment: Filter ASAP — Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.043	0.010	0.0045	mg/L	1.0	350.1	a	12/29/23	MSO	350.1_231229	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.81	0.20	0.0267	mg/L	1.0	351.2	a	1/3/24	MSO	351.2_240103	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.14	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/5/24	TJL	NO3NO2_240105	
14265-44-2	**ORTHO-PHOSPHATE**	0.01	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/14/23	TJL	OPHOS_231214	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.046	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/21/23	TJL	TPHOS_231221	

Sample Description: DUPE-20231213 Dupe — Matrix SW — Sample Date: 12/13/23 2:07 pm
Lab Number: 75906 — Sample Comment: Filter ASAP — Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.18	0.010	0.0045	mg/L	1.0	350.1	a	12/29/23	MSO	350.1_231229	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.37	0.20	0.0267	mg/L	1.0	351.2	a	1/3/24	MSO	351.2_240103	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.17	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/5/24	TJL	NO3NO2_240105	
14265-44-2	**ORTHO-PHOSPHATE**	0.02	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/14/23	TJL	OPHOS_231214	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.020	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/21/23	TJL	TPHOS_231221	

Sample Description: Cam-Deep-20231213-S Surface — Matrix SW — Sample Date: 12/13/23 1:30 pm
Lab Number: 75907 — Sample Comment: Filter ASAP — Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.036	0.010	0.0045	mg/L	1.0	350.1	a	12/29/23	MSO	350.1_231229	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.90	0.20	0.0267	mg/L	1.0	351.2	a	1/3/24	MSO	351.2_240103	
NA	**CHLOROPHYLL A**	29.9	0.1	0	mg/m3	1.0	SM10200-H		12/14/23	TA	WML_231214	Analyzed by WML
NA	**PHEOPHYTIN A**	ND	0.1	0	mg/m3	1.0	SM10200-H		12/14/23	TA	WML_231214	Analyzed by WML
E-10128	**TOTAL NITRATE+NITRITE as N**	0.0089 J	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/5/24	TJL	NO3NO2_240105	
14265-44-2	**ORTHO-PHOSPHATE**	0.04	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/14/23	TJL	OPHOS_231214	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.036	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/21/23	TJL	TPHOS_231221	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

Reference Number: **23-37686**
Report Date: 1/10/24

Data Report

Sample Description: Cam-Deep-20231213-B Bottom   Matrix SW   Sample Date: 12/13/23 1:40 pm
Lab Number: 75908   Sample Comment: Filter ASAP   Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.022	0.010	0.0045	mg/L	1.0	350.1	a	12/29/23	MSO	350.1_231229	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.91	0.20	0.0267	mg/L	1.0	351.2	a	1/3/24	MSO	351.2_240103	
NA	**CHLOROPHYLL A**	20.8	0.1	0	mg/m3	1.0	SM10200-H		12/14/23	TA	WML_231214	Analyzed by WML
NA	**PHEOPHYTIN A**	ND	0.1	0	mg/m3	1.0	SM10200-H		12/14/23	TA	WML_231214	Analyzed by WML
E-10128	**TOTAL NITRATE+NITRITE as N**	0.0071 J	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/5/24	TJL	NO3NO2_240105	
14265-44-2	**ORTHO-PHOSPHATE**	0.04	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/14/23	TJL	OPHOS_231214	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.036	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/21/23	TJL	TPHOS_231221	

Sample Description: Cam-Dupe-20231213 Cam Dupe   Matrix SW   Sample Date: 12/13/23 1:50 pm
Lab Number: 75909   Sample Comment: Filter ASAP   Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.024	0.010	0.0045	mg/L	1.0	350.1	a	12/29/23	MSO	350.1_231229	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.90	0.20	0.0267	mg/L	1.0	351.2	a	1/3/24	MSO	351.2_240103	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.0071 J	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/5/24	TJL	NO3NO2_240105	
14265-44-2	**ORTHO-PHOSPHATE**	0.04	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/14/23	TJL	OPHOS_231214	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.037	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/21/23	TJL	TPHOS_231221	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

SAMPLE INDEPENDENT QUALITY CONTROL REPORT

Reference Number: **23-37686**
Report Date: 01/10/24

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
Calibration Check											
350.1_231229	0	AMMONIA-N	2.27	2.50	mg/L	350.1	91	90-110		CAL	
351.2_240103	0	TOTAL KJELDAHL NITROGEN as N	2.43	2.50	mg/L	351.2	97	90-110		CAL	
	0	TOTAL KJELDAHL NITROGEN as N	2.46	2.50	mg/L	351.2	98	90-110		CAL	
NO3NO2_24010!	0	TOTAL NITRATE+NITRITE as N	1.00	1.00	mg/L	SM4500-NO3 F	100	90-110		CAL	
OPHOS_231214	0	ORTHO-PHOSPHATE	0.99	1.00	mg/L	SM4500-P F	99	85-115		CAL	
TPHOS_231221	0	TOTAL PHOSPHORUS-P	0.094	0.100	mg/L	SM4500-P F	94	85-115		CAL	
Laboratory Fortified Blank											
351.2_240103	0	TOTAL KJELDAHL NITROGEN as N	1.86	2.00	mg/L	351.2	93	90-110		LFB	
	0	TOTAL KJELDAHL NITROGEN as N	1.97	2.00	mg/L	351.2	99	90-110		LFB	
Laboratory Reagent Blank											
351.2_240103	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		LRB	
NO3NO2_24010!	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		LRB	
OPHOS_231214	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		LRB	
TPHOS_231221	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		LRB	
Method Blank											
350.1_231229	0	AMMONIA-N	ND		mg/L	350.1		0-0		MB	
351.2_240103	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		MB	
	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		MB	
NO3NO2_24010!	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		MB	
OPHOS_231214	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		MB	
TPHOS_231221	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		MB	
Quality Control Sample											
350.1_231229	0	AMMONIA-N	2.05	2.15	mg/L	350.1	95	85-115		QCS	
351.2_240103	0	TOTAL KJELDAHL NITROGEN as N	2.18	2.33	mg/L	351.2	94	85-115		QCS	
	0	TOTAL KJELDAHL NITROGEN as N	2.20	2.33	mg/L	351.2	94	85-115		QCS	
NO3NO2_24010!	0	TOTAL NITRATE+NITRITE as N	1.99	2.00	mg/L	SM4500-NO3 F	100	90-110		QCS	
OPHOS_231214	0	ORTHO-PHOSPHATE	0.93	1.00	mg/L	SM4500-P F	93	90-110		QCS	
TPHOS_231221	0	TOTAL PHOSPHORUS-P	0.210	0.217	mg/L	SM4500-P F	97	90-110		QCS	

*Notation:

% Recovery = (Result of Analysis)/(True Value) * 100

NA = Indicates % Recovery could not be calculated.

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QCIndependent4.rpt

ANALYTICAL

SAMPLE DEPENDENT
QUALITY CONTROL REPORT

Duplicate, Matrix Spike/Matrix Spike Duplicate and Confirmation Result Report

Reference Number: **23-37686**
Report Date: 1/10/2024

Duplicate

Batch/CAS	Sample	Analyte	Result	Duplicate Result	Units	%RPD	Limits	QC Qualifier	Comments
350.1_231229									
7664-41-7	75902	AMMONIA-N	0.035	0.035	mg/L	**0.0**	0-20		
7664-41-7	77781	AMMONIA-N	0.024	0.026	mg/L	**8.0**	0-20		
7664-41-7	78731	AMMONIA-N	26.0	26.2	mg/L	**0.8**	0-20		
351.2_240103									
E-10264	75902	TOTAL KJELDAHL NITROGEN as N	0.68	0.70	mg/L	**2.9**	0-20		
E-10264	76238	TOTAL KJELDAHL NITROGEN as N	48.4	41.9	mg/L	**14.4**	0-20		
E-10264	76688	TOTAL KJELDAHL NITROGEN as N	34.1	33.9	mg/L	**0.6**	0-20		
E-10264	76895	TOTAL KJELDAHL NITROGEN as N	1.84	1.86	mg/L	**1.1**	0-20		
E-10264	78405	TOTAL KJELDAHL NITROGEN as N	2.04	2.03	mg/L	**0.5**	0-20		
NO3NO2_240105									
E-10128	75902	TOTAL NITRATE+NITRITE as N	0.60	0.60	mg/L	**0.0**	0-20		
E-10128	77498	TOTAL NITRATE+NITRITE as N	0.08	0.09	mg/L	**11.8**	0-20		
E-10128	77974	TOTAL NITRATE+NITRITE as N	0.02	0.02	mg/L	**0.0**	0-20		
E-10128	78145	TOTAL NITRATE+NITRITE as N	1.29	1.29	mg/L	**0.0**	0-20		
E-10128	78287	TOTAL NITRATE+NITRITE as N	ND	ND	mg/L	**NA**	0-20		
OPHOS_231214									
14265-44-2	75803	ORTHO-PHOSPHATE	1.14	1.11	mg/L	**2.7**	0-20		
14265-44-2	75906	ORTHO-PHOSPHATE	0.02	0.02	mg/L	**0.0**	0-20		
TPHOS_231221									
7723-14-0	74677	TOTAL PHOSPHORUS-P	0.038	0.043	mg/L	**12.3**	0-20		
7723-14-0	74773	TOTAL PHOSPHORUS-P	0.017	0.020	mg/L	**16.2**	0-20		
7723-14-0	75251	TOTAL PHOSPHORUS-P	0.021	0.023	mg/L	**9.1**	0-20		
7723-14-0	75261	TOTAL PHOSPHORUS-P	0.402	0.403	mg/L	**0.2**	0-20		
7723-14-0	75903	TOTAL PHOSPHORUS-P	0.024	0.031	mg/L	**25.5**	0-20	INH	
7723-14-0	76174	TOTAL PHOSPHORUS-P	0.110	0.110	mg/L	**0.0**	0-20		

%RPD = Relative Percent Difference
NA = Indicates %RPD could not be calculated
Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.
Only Duplicate sample with detections are listed in this report
Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

EDGE ANALYTICAL

SAMPLE DEPENDENT
QUALITY CONTROL REPORT

Duplicate, Matrix Spike/Matrix Spike Duplicate
and Confirmation Result Report

Reference Number: **23-37686**
Report Date: 1/10/2024

Laboratory Fortified Matrix (MS)

Batch/CAS	Sample	Analyte	Result	Spike Result	Duplicate Spike Result	Conc	Units	Percent Recovery MS	Percent Recovery MSD	Limits*	%RPD	Limits*	QC Qualifier	Comments
350.1_231229														
7664-41-7	75902	AMMONIA-N	0.035	0.96	1.06	1.00	mg/L	**93**	**103**	70-130	**10.3**	0-20		
7664-41-7	77781	AMMONIA-N	0.024	0.92	0.92	1.00	mg/L	**90**	**90**	70-130	**0.0**	0-20		
7664-41-7	78731	AMMONIA-N	26.0	80.6	71.4	50.0	mg/L	**109**	**91**	70-130	**18.4**	0-20		
351.2_240103														
E-10264	75902	TOTAL KJELDAHL NITROGEN as N	0.68	2.58		2.00	mg/L	**95**		70-130	**NA**	0-20		
E-10264	76238	TOTAL KJELDAHL NITROGEN as N	48.4	135		100	mg/L	**87**		70-130	**NA**	0-20		
E-10264	76688	TOTAL KJELDAHL NITROGEN as N	34.1	71.6		40.0	mg/L	**94**		70-130	**NA**	0-20		
E-10264	76895	TOTAL KJELDAHL NITROGEN as N	1.84	3.80		2.00	mg/L	**98**		70-130	**NA**	0-20		
E-10264	78405	TOTAL KJELDAHL NITROGEN as N	2.04	3.92		2.00	mg/L	**94**		70-130	**NA**	0-20		
NO3NO2_240105														
E-10128	75902	TOTAL NITRATE+NITRITE as N	0.60	1.53	1.53	1.00	mg/L	**93**	**93**	80-120	**0.0**	0-20		
E-10128	77498	TOTAL NITRATE+NITRITE as N	0.08	0.32	0.33	1.00	mg/L	**24**	**25**	80-120	**4.1**	0-20	IM	
E-10128	77974	TOTAL NITRATE+NITRITE as N	0.02	0.58	0.59	1.00	mg/L	**56**	**57**	80-120	**1.8**	0-20	IM	
E-10128	78145	TOTAL NITRATE+NITRITE as N	1.29	2.19	2.19	1.00	mg/L	**90**	**90**	80-120	**0.0**	0-20		
E-10128	78287	TOTAL NITRATE+NITRITE as N	ND	0.95	0.95	1.00	mg/L	**95**	**95**	80-120	**0.0**	0-20		
OPHOS_231214														
14265-44-2	75803	ORTHO-PHOSPHATE	1.14	5.78	5.78	5.00	mg/L	**93**	**93**	70-130	**0.0**	0-20		
14265-44-2	75906	ORTHO-PHOSPHATE	0.02	0.47	0.47	0.50	mg/L	**90**	**90**	70-130	**0.0**	0-20		
TPHOS_231221														
7723-14-0	74677	TOTAL PHOSPHORUS-P	0.038	0.096	0.091	0.050	mg/L	**116**	**106**	70-130	**9.0**	0-20		
7723-14-0	74773	TOTAL PHOSPHORUS-P	0.017	0.063	0.071	0.050	mg/L	**92**	**108**	70-130	**16.0**	0-20		
7723-14-0	75251	TOTAL PHOSPHORUS-P	0.021	0.076	0.074	0.050	mg/L	**110**	**106**	70-130	**3.7**	0-20		
7723-14-0	75261	TOTAL PHOSPHORUS-P	0.402	0.509	0.517	0.050	mg/L	**214**	**230**	70-130	**7.2**	0-20	IM	
7723-14-0	75903	TOTAL PHOSPHORUS-P	0.024	0.083	0.086	0.050	mg/L	**118**	**124**	70-130	**5.0**	0-20		
7723-14-0	76174	TOTAL PHOSPHORUS-P	0.110	0.178	0.180	0.050	mg/L	**136**	**140**	70-130	**2.9**	0-20	IM	

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

EDGE ANALYTICAL

Qualifier Definitions

Reference Number: 23-37686
Report Date: 01/10/24

Qualifier	Definition
IM	Matrix induced bias assumed
INH	The sample was non-homogeneous
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

Note: Some qualifier definitions found on this page may pertain to results or QC data which are not printed with this report.

HERRERA
Science + Planning + Design

2023 LAKE CAMPBELL CMP WATERSHED MONITORING DATA SHEET

Project: Lake Campbell Cyanobacteria Management Plan Project No.: 23-08143-000
Client: Skagit County Field Personnel: Rob Lawson, Leanne Ingman
Event Type and Number Storm (✓) Base ( )
Weather and predicted rainfall (in): predicted rainfall 0.06" 43, Cloudy sprinkle

Base flow sampling to occur every month (August 2023 through January 2024) on the day of or day before lake sampling. Six additional wet weather (storm flow) sampling events to occur during fall and winter storms September 2023 through January 2024.

Field Equipment Checklist

- ☐ Flow meter
- ☐ Tape Measure
- ☐ Chain-of-Custody
- ☐ YSI multimeter
- ☐ Hanna pH meter
- ☐ Sample bottles
- ☐ Cooler with ice

Sampling Data

All samples analyzed for total nutrients. Duplicates are to be collected monthly from September 2023 through January 2024 at a random site during a random event. If applicable, record duplicate sample information below. Do not include duplicate sample times on COCs.

Site ID	Sample ID	Sample Time	Photos Taken?	Water Description (Turbidity; Unusual color, odor, sheen)
CS1	CS1-2023_1222	1033		
CS2	CS2-2023_1222	1050		
CS2.5	CS2.5-2023_1222	1100		
* CS3	CS3-2023_1222	1115		
DUPE	DUPE-2023_1222	1115		

Notes & observations:
water at all sites was very clear

mf b2_campbell_watershedmonitoring_field form_blank.docx

Discharge Data

CS1

Monitoring Location: SR-20 inflow

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe):

Collection Date and Time: 10:33 12/22/23

Notes & Observations WATER TINTED BROWN But Clear

Culvert diameter = _______ inches

Water depth = __________ feet

Water velocity (flow) = __________ f/s

Calculated Flow (cfs) = ______________

SEE Spreadsheet

CS2

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe):

Collection Date and Time: 10:50 12/22/23

Notes & Observations BUBBLES/OTHERWISE CLEAR

Culvert diameter = _______ inches

Water depth = __________ feet

Water velocity (flow) = __________ f/s

Calculated Flow (cfs) = ______________

SEE SPREADSHEET

CS2.5

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe): ____

Collection Date and Time: 11:00 12/22/23

Notes & Observations ____

Culvert diameter = ____ inches

Water depth = ____ feet

Water velocity (flow) = ____ f/s

Calculated Flow (cfs) = ____

CS3

Monitoring Location: Lake Erie outlet

Discharge measurement method: Stream cross-section

Collection Date and Time: 11:15 12/22/23

Notes & Observations ____

Total channel section width = ____ feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		–	–
1			
2			
3			
4			
5			
6			
7			
8			
Edge of Bank		–	–

Calculated Flow (cfs) = ____

CAM-OUT

Monitoring Location: Outlet for Lake Campbell

Discharge measurement method: Stream cross-section

Collection Date and Time: ______________________

Notes & Observations ______________________

Total channel section width = 8'6" feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		0.22	0 -
1	6"	0.40	0
2	1'7"	0.52	0
3	2'5"	0.55	0
4	3'4"	0.57	0
5	4'3"	0.6	0.01
6	5'2"	0.57	0
7	6'1"	0.48	0 SURFACE 0.05
8	7'	0.37	0 0.03
Edge of Bank	7'11"	0.25 -	0.01 -
	8'6"	0	0

SLIGHTLY FASTER AT SURFACE

Calculated Flow (cfs) = ______________________

Other Observations

3'3"

CS1			
Point	Distance (Ft)	Depth(m)	Velocity(m/s)
Edge of Bank 0	~~3'3"~~ 0	0	0
1	6'	0.05	0.20
2	1'5"	0.12	0.33
3	2'4"	0.1	0.33
BANK 4	3'3"	0.05	0
5			
6			
7			
8			
9			
Edge of Bank 10			

CS2.5 16"

CS2.5			
Point	Distance (Ft)	Depth(m)	Velocity(m/s)
BANK 0	0	0	0
1	8"	0.06	*0.13 AT SURFACE
BANK 2	0	0	0
3			
4			
5			
6			
7			
8			
9			
10			

CS2 4'10"

~~CS2.5~~			
Point	Distance (Ft)	Depth(m)	Velocity(m/s)
BANK 0	0	0.05	0
1	6"	0.07	0.01
2	1'3"	0.12	0.03
3	2'4"	0.14	0.85
4	3'3"	0.07	0
5	4'2"	0.02	0
BANK 6		0.01	0
7			
8			
9			
10			

8'7"

CS3			
Point	Distance (Ft)	Depth(m)	Velocity(m/s)
BANK 0	0	0	0
1	6"	0.02	0
2	1'5"	0.24	0.01
3	2'4"	0.34	0.07
4	3'3"	0.35	0.24
5	4'2"	0.23	0.02
6	5'1"	0.06	0 DEBRI
7	6'0"	0.02	0
8	6'11"	0.01	0
9	7'10"	0.	0
BANK 10	0	0	0

Chain of Custody / Analysis Request (Please complete all applicable shaded sections)

Report to: SKA02 Skagit Co. Public WKS	**For Lab Use Only**
Address: 1800 Continental Place	Ref#
City: Mount Vernon State: WA Zip: 98273	**Check Regulatory Program**
Attn: Leanne Ingman	☐ Safe Drinking Water Act
Phone: (360) 416-1450 Fax:	☐ Clean Water Act
Email: .leannei@co.skagit.wa.us, meghanm@co.skagit.wa.us	☐ RCRA / CERCLA
Project Name: Lake Campbell CMP_12/22/23	☐ Other

EDGE ANALYTICAL

Main Lab (800-755-9295)
1620 South Walnut St. Burlington, WA 98233
Microbiology (888-725-1212)
805 W. Orchard Dr. Suite 4 Bellingham, WA 98225

Wilsonville Lab (503-682-7802)
9150 SW Pioneer Ct. Suite W Wilsonville, OR 97070
Corvallis Lab (541-753-4946)
540 SW 3rd St. Corvallis, OR 97333

	Sample ID	Location	Sample Matrix *	Date	Time	Ortho phos	Ammonia, TKN, T. Phos, NO2/NO3		Special Instructions/ Conditions on Receipt
1	DUPE-20231222		SW	12/22/23	1115	☒	☒	☐	Filter ASAP
2	CS1-20231222	CS1	SW	12/22/23	1033	☒	☒	☐	Filter ASAP
3	CS2-20231222	CS2	SW	12/22/23	1050	☒	☒	☐	Filter ASAP
4	CS2.5-20231222	CS2.5	SW	12/22/23	1100	☒	☒	☐	Filter ASAP
5	CS3-20231222	CS3	SW	12/22/23	1115	☒	☒	☐	Filter ASAP
6			SW			☐	☐	☐	
7			SW			☐	☐	☐	
8			SW			☐	☐	☐	
9			SW			☐	☐	☐	
10			SW			☐	☐	☐	
11			SW			☐	☐	☐	
12			SW			☐	☐	☐	
13			SW			☐	☐	☐	
14			SW			☐	☐	☐	
15			SW			☐	☐	☐	
16			SW			☐	☐	☐	
17			SW			☐	☐	☐	
18			SW			☐	☐	☐	
19			SW			☐	☐	☐	
20			SW			☐	☐	☐	
21			SW			☐	☐	☐	
22			SW			☐	☐	☐	
23			SW			☐	☐	☐	
24			SW			☐	☐	☐	
25			SW			☐	☐	☐	
26			SW			☐	☐	☐	
27			SW			☐	☐	☐	

Sampled by: Leanne Ingman | Phone: 360 416 1450 | Email: Leannei@co.skagit.wa.us

Relinquished by	Date	Time	Received by	Date	Time
Leanne Ingman	12/22/23	1213	JDS (WI) REC8	12-22-23	1212

Temp: 7.7

EDGE ANALYTICAL

Burlington, WA *Corporate Laboratory (a)*
1620 S Walnut St - Burlington, WA 98233 - **800.755.9295** • 360.757.1400

Bellingham, WA *Microbiology (b)*
805 Orchard Dr Ste 4 - Bellingham, WA 98225 - 360.715.1212

Portland, OR *Microbiology/Chemistry (c)*
9725 SW Commerce Cr Ste A2 - Wilsonville, OR 97070 - 503.682.7802

Corvallis, OR *Microbiology/Chemistry (d)*
1100 NE Circle Blvd, Ste 130 - Corvallis, OR 97330 - 541.753.4946

Bend, OR *Microbiology (e)*
20332 Empire Blvd Ste 4 - Bend, OR 97701 - 541.639.8425

Data Report

Client Name: Skagit County Public Works
1800 Continental Place
Mount Vernon, WA 98273

Reference Number: **23-38618**
Project: Lake Campbell
CMP_12/22/23

Report Date: 1/16/24

Date Received: 12/22/23
Approved by: bj,tjb
Authorized by: [signature]

Lawrence J Henderson, PhD
Director of Laboratories, Vice President

Sample Description: DUPE-20231222 — Matrix SW — Sample Date: 12/22/23 11:15 am
Lab Number: 78102 — Sample Comment: Filter ASAP — Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.0078 J	0.010	0.0066	mg/L	1.0	350.1	a	1/4/24	MSO	350.1_240104	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.87	0.20	0.0848	mg/L	1.0	351.2	a	1/4/24	MSO	351.2_240104	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.10	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/5/24	TJL	NO3NO2_240105	
14265-44-2	**ORTHO-PHOSPHATE**	0.007 J	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/22/23	TJL	ophos_231222	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.033	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/28/23	TJL	TPHOS_231228	

Sample Description: CS1-20231222 CS1 — Matrix SW — Sample Date: 12/22/23 10:33 am
Lab Number: 78103 — Sample Comment: Filter ASAP — Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.012	0.010	0.0066	mg/L	1.0	350.1	a	1/4/24	MSO	350.1_240104	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.76	0.20	0.0848	mg/L	1.0	351.2	a	1/4/24	MSO	351.2_240104	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.28	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/5/24	TJL	NO3NO2_240105	
14265-44-2	**ORTHO-PHOSPHATE**	0.05	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/22/23	TJL	ophos_231222	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.087	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/28/23	TJL	TPHOS_231228	

Notes:
ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

If you have any questions concerning this report contact us at the above phone number.

Reference Number: **23-38618**
Report Date: 1/16/24

Data Report

Sample Description: CS2-20231222 CS2 — Matrix SW — Sample Date: 12/22/23 10:50 am
Lab Number: 78104 — Sample Comment: Filter ASAP — Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.021	0.010	0.0066	mg/L	1.0	350.1	a	1/4/24	MSO	350.1_240104	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.49	0.20	0.0848	mg/L	1.0	351.2	a	1/8/24	TJB	351.2_240108	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.09	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/5/24	TJL	NO3NO2_240105	
14265-44-2	**ORTHO-PHOSPHATE**	0.01	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/22/23	TJL	ophos_231222	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.012	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/28/23	TJL	TPHOS_231228	

Sample Description: CS2.5-20231222 CS2.5 — Matrix SW — Sample Date: 12/22/23 11:00 am
Lab Number: 78105 — Sample Comment: Filter ASAP — Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	ND	0.010	0.0066	mg/L	1.0	350.1	a	1/4/24	MSO	350.1_240104	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.47	0.20	0.0848	mg/L	1.0	351.2	a	1/8/24	TJB	351.2_240108	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.10	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/5/24	TJL	NO3NO2_240105	
14265-44-2	**ORTHO-PHOSPHATE**	0.02	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/22/23	TJL	ophos_231222	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.047	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/28/23	TJL	TPHOS_231228	

Sample Description: CS3-20231222 CS3 — Matrix SW — Sample Date: 12/22/23 11:15 am
Lab Number: 78106 — Sample Comment: Filter ASAP — Collected By: Leanne Ingman

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	ND	0.010	0.0066	mg/L	1.0	350.1	a	1/4/24	MSO	350.1_240104	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	1.11	0.20	0.0848	mg/L	1.0	351.2	a	1/8/24	TJB	351.2_240108	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.10	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/5/24	TJL	NO3NO2_240105	
14265-44-2	**ORTHO-PHOSPHATE**	0.007 J	0.01	0.0027	mg/L	1.0	SM4500-P F	a	12/22/23	TJL	ophos_231222	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.036	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	12/28/23	TJL	TPHOS_231228	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

SAMPLE INDEPENDENT
QUALITY CONTROL REPORT

Reference Number: **23-38618**
Report Date: 01/16/24

Calibration Check

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
350.1_240104	0	AMMONIA-N	2.54	2.50	mg/L	350.1	102	90-110		CAL	
351.2_240104	0	TOTAL KJELDAHL NITROGEN as N	2.44	2.50	mg/L	351.2	98	90-110		CAL	
351.2_240108	0	TOTAL KJELDAHL NITROGEN as N	2.58	2.50	mg/L	351.2	103	90-110		CAL	
NO3NO2_240105	0	TOTAL NITRATE+NITRITE as N	1.00	1.00	mg/L	SM4500-NO3 F	100	90-110		CAL	
OPHOS_231222	0	ORTHO-PHOSPHATE	0.99	1.00	mg/L	SM4500-P F	99	85-115		CAL	
TPHOS_231228	0	TOTAL PHOSPHORUS-P	0.099	0.100	mg/L	SM4500-P F	99	85-115		CAL	

Laboratory Fortified Blank

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
351.2_240104	0	TOTAL KJELDAHL NITROGEN as N	1.89	2.00	mg/L	351.2	95	90-110		LFB	
351.2_240108	0	TOTAL KJELDAHL NITROGEN as N	2.11	2.00	mg/L	351.2	106	90-110		LFB	

Laboratory Reagent Blank

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
351.2_240104	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		LRB	
351.2_240108	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		LRB	
NO3NO2_240105	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		LRB	
OPHOS_231222	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		LRB	
TPHOS_231228	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		LRB	

Method Blank

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
350.1_240104	0	AMMONIA-N	ND		mg/L	350.1		0-0		MB	
351.2_240104	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		MB	
351.2_240108	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		MB	
NO3NO2_240105	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		MB	
OPHOS_231222	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		MB	
TPHOS_231228	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		MB	

Quality Control Sample

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
350.1_240104	0	AMMONIA-N	2.10	2.15	mg/L	350.1	98	85-115		QCS	
351.2_240104	0	TOTAL KJELDAHL NITROGEN as N	2.25	2.33	mg/L	351.2	97	85-115		QCS	
351.2_240108	0	TOTAL KJELDAHL NITROGEN as N	2.55	2.33	mg/L	351.2	109	85-115		QCS	
NO3NO2_240105	0	TOTAL NITRATE+NITRITE as N	1.99	2.00	mg/L	SM4500-NO3 F	100	90-110		QCS	
OPHOS_231222	0	ORTHO-PHOSPHATE	0.94	1.00	mg/L	SM4500-P F	94	90-110		QCS	
TPHOS_231228	0	TOTAL PHOSPHORUS-P	0.202	0.217	mg/L	SM4500-P F	93	90-110		QCS	

*Notation:

% Recovery = (Result of Analysis)/(True Value) * 100

NA = Indicates % Recovery could not be calculated.

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QCIndependent4.rpt

EDGE ANALYTICAL

SAMPLE DEPENDENT QUALITY CONTROL REPORT

Duplicate, Matrix Spike/Matrix Spike Duplicate and Confirmation Result Report

Reference Number: **23-38618**
Report Date: 1/16/2024

Duplicate

Batch/CAS	Sample	Analyte	Result	Duplicate Result	Units	%RPD	Limits	QC Qualifier	Comments
350.1_240104									
7664-41-7	77338	AMMONIA-N	20.7	20.8	mg/L	**0.5**	0-20		
7664-41-7	77923	AMMONIA-N	0.029	0.025	mg/L	**14.8**	0-20		
7664-41-7	78771	AMMONIA-N	0.052	0.050	mg/L	**3.9**	0-20		
351.2_240104									
E-10264	76860	TOTAL KJELDAHL NITROGEN as N	44.6	45.9	mg/L	**2.9**	0-20		
E-10264	77497	TOTAL KJELDAHL NITROGEN as N	18.0	18.2	mg/L	**1.1**	0-20		
351.2_240108									
E-10264	78104	TOTAL KJELDAHL NITROGEN as N	0.49	0.39	mg/L	**22.7**	0-20	INH	
E-10264	78415	TOTAL KJELDAHL NITROGEN as N	0.58	0.66	mg/L	**12.9**	0-20		
E-10264	78712	TOTAL KJELDAHL NITROGEN as N	244	244	mg/L	**0.0**	0-20		
NO3NO2_240105									
E-10128	75902	TOTAL NITRATE+NITRITE as N	0.60	0.60	mg/L	**0.0**	0-20		
E-10128	77498	TOTAL NITRATE+NITRITE as N	0.08	0.09	mg/L	**11.8**	0-20		
E-10128	77974	TOTAL NITRATE+NITRITE as N	0.02	0.02	mg/L	**0.0**	0-20		
E-10128	78145	TOTAL NITRATE+NITRITE as N	1.29	1.29	mg/L	**0.0**	0-20		
E-10128	78287	TOTAL NITRATE+NITRITE as N	ND	ND	mg/L	**NA**	0-20		
OPHOS_231222									
14265-44-2	77918	ORTHO-PHOSPHATE	0.03	0.03	mg/L	**0.0**	0-20		
14265-44-2	78102	ORTHO-PHOSPHATE	0.007	0.007	mg/L	**0.0**	0-20		
TPHOS_231228									
7723-14-0	77484	TOTAL PHOSPHORUS-P	3.68	3.65	mg/L	**0.8**	0-20		
7723-14-0	77965	TOTAL PHOSPHORUS-P	0.040	0.040	mg/L	**0.0**	0-20		
7723-14-0	78230	TOTAL PHOSPHORUS-P	0.0051	0.0052	mg/L	**1.9**	0-20		

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QC Dependent_Port.rpt

EDGE ANALYTICAL

SAMPLE DEPENDENT
QUALITY CONTROL REPORT

Duplicate, Matrix Spike/Matrix Spike Duplicate and Confirmation Result Report

Reference Number: **23-38618**
Report Date: 1/16/2024

Laboratory Fortified Matrix (MS)

Batch/CAS	Sample	Analyte	Result	Spike Result	Duplicate Spike Result	Conc	Units	Percent Recovery MS	Percent Recovery MSD	Limits*	%RPD	Limits*	QC Qualifier	Comments
350.1_240104														
7664-41-7	77338	AMMONIA-N	20.7	71.5	71.0	50.0	mg/L	**102**	**101**	70-130	**1.0**	0-20		
7664-41-7	77923	AMMONIA-N	0.029	1.04	1.03	1.00	mg/L	**101**	**100**	70-130	**1.0**	0-20		
7664-41-7	78771	AMMONIA-N	0.052	1.05	1.07	1.00	mg/L	**100**	**102**	70-130	**2.0**	0-20		
351.2_240104														
E-10264	76860	TOTAL KJELDAHL NITROGEN as N	44.6	137		100	mg/L	**92**		70-130	**NA**	0-20		
E-10264	77497	TOTAL KJELDAHL NITROGEN as N	18.0	19.9		2.00	mg/L	**95**		70-130	**NA**	0-20		
351.2_240108														
E-10264	78104	TOTAL KJELDAHL NITROGEN as N	0.49	2.45		2.00	mg/L	**98**		70-130	**NA**	0-20		
E-10264	78415	TOTAL KJELDAHL NITROGEN as N	0.58	2.41		2.00	mg/L	**92**		70-130	**NA**	0-20		
E-10264	78712	TOTAL KJELDAHL NITROGEN as N	244	350		100	mg/L	**106**		70-130	**NA**	0-20		
NO3NO2_240105														
E-10128	75902	TOTAL NITRATE+NITRITE as N	0.60	1.53	1.53	1.00	mg/L	**93**	**93**	80-120	**0.0**	0-20		
E-10128	77498	TOTAL NITRATE+NITRITE as N	0.08	0.32	0.33	1.00	mg/L	**24**	**25**	80-120	**4.1**	0-20	IM	
E-10128	77974	TOTAL NITRATE+NITRITE as N	0.02	0.58	0.59	1.00	mg/L	**56**	**57**	80-120	**1.8**	0-20	IM	
E-10128	78145	TOTAL NITRATE+NITRITE as N	1.29	2.19	2.19	1.00	mg/L	**90**	**90**	80-120	**0.0**	0-20		
E-10128	78287	TOTAL NITRATE+NITRITE as N	ND	0.95	0.95	1.00	mg/L	**95**	**95**	80-120	**0.0**	0-20		
OPHOS_231222														
14265-44-2	77918	ORTHO-PHOSPHATE	0.03	0.50	0.50	0.50	mg/L	**94**	**94**	70-130	**0.0**	0-20		
14265-44-2	78102	ORTHO-PHOSPHATE	0.007	0.48	0.48	0.50	mg/L	**95**	**95**	70-130	**0.0**	0-20		
TPHOS_231228														
7723-14-0	77484	TOTAL PHOSPHORUS-P	3.68	4.38	4.31	0.500	mg/L	**140**	**126**	70-130	**10.5**	0-20	IM	
7723-14-0	77965	TOTAL PHOSPHORUS-P	0.040	0.092	0.087	0.050	mg/L	**104**	**94**	70-130	**10.1**	0-20		
7723-14-0	78230	TOTAL PHOSPHORUS-P	0.0051	0.051	0.057	0.050	mg/L	**92**	**104**	70-130	**12.3**	0-20		

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

1/19/24

HERRERA
Science + Planning + Design

2023 LAKE CAMPBELL CMP
WATERSHED MONITORING DATA SHEET

Project: Lake Campbell Cyanobacteria Management Plan Project No.: 23-08143-000
Client: Skagit County Field Personnel: Rob Lawson, Leanne
Event Type and Number Storm (✓) ~~Base (✓)~~
Weather and predicted rainfall (in): raining, 37°

Base flow sampling to occur every month (August 2023 through January 2024) on the day of or day before lake sampling. Six additional wet weather (storm flow) sampling events to occur during fall and winter storms September 2023 through January 2024.

Field Equipment Checklist

- ☐ Flow meter
- ☐ YSI multimeter
- ☐ Cooler with ice
- ☐ Tape Measure
- ☐ Hanna pH meter
- ☐ Chain-of-Custody
- ☐ Sample bottles

Sampling Data

All samples analyzed for total nutrients. Duplicates are to be collected monthly from September 2023 through January 2024 at a random site during a random event. If applicable, record duplicate sample information below. Do not include duplicate sample times on COCs.

Site ID	Sample ID	Sample Time	Photos Taken?	Water Description (Turbidity; Unusual color, odor, sheen)
CS1	CS1-20240119			
CS2	CS2-20240119			
CS2.5	CS2.5-20240119			
CS3	CS3-20240119			
DUPE	DUPE-20240119			

Notes & observations:

mf b2_campbell_watershedmonitoring_field form_blank.docx

Discharge Data

CS1

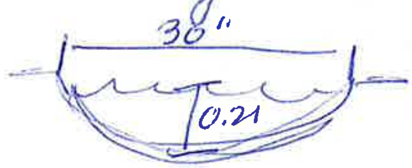
Monitoring Location: SR-20 inflow

Discharge measurement method: ☐ Timed bucket fill ☐ Stream cross-section with flow probe ☐ Other (describe):

Collection Date and Time: 13:34

Notes & Observations muddy/turbid flow measured on culvert, usual spot was flooded too far into blackberry shrubs.

Culvert diameter = 36 inches



Water depth = ________ feet

Water velocity (flow) = ________ f/s

Calculated Flow (cfs) = ____________

CS2

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐ Stream cross-section with flow probe ☐ Other (describe):

Collection Date and Time: 13:48

Notes & Observations Clear flow

Culvert diameter = ______ inches

Water depth = ________ feet

Water velocity (flow) = ________ f/s

Calculated Flow (cfs) = ____________

CS2.5

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe): ____

Collection Date and Time: ____

Notes & Observations ~~Clear Flow~~ appeared water coming from west ~~had~~ more turbid than water coming from the west

Culvert diameter = ____ inches

Water depth = ____ feet

Water velocity (flow) = ____ f/s

Calculated Flow (cfs) = ____

CS3

Monitoring Location: Lake Erie outlet

Discharge measurement method: Stream cross-section

Collection Date and Time: ____

Notes & Observations Clear Flow

Total channel section width = ____ feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		–	–
1			
2			
3			
4			
5			
6			
7			
8			
Edge of Bank		–	–

Calculated Flow (cfs) = ____

CAM-OUT

Monitoring Location: Outlet for Lake Campbell

Discharge measurement method: Stream cross-section

Collection Date and Time: 13010

Notes & Observations: Clear & moving, Floody side water

Total channel section width = 11'5" feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		TOO MUCH DEBRIS ——	-
1	6"	TOO MUCH DEBRIS ——	
2	1'5"	0.82	0.01
3	2'4"	0.825	0.09
4	3'3"	0.925	0.04
5	~~4'2"~~ ~~5'1"~~	~~0.925~~ ~~1.05~~	~~0.03~~ ~~0.02~~
6	6'0" 6'11"	.97 1.0	0.03 0.06
7	7'10" 8'9"	1.0 0.59	0.06 0.06
8	9'8" 10'7"	0.275 0.23	0.06 TOO MUCH DEBRIS
Edge of Bank	0.20	TOO MUCH DEBRIS ——	-

Calculated Flow (cfs) = __________

Other Observations

mf_b2_campbell_watershedmonitoring_field form_blank.docx

* WATER IS BROWN / 2'6" WIDTH

CS1			
Point	Distance (Ft)	Depth(m)	Velocity(m/s)
0	0	0	0
1	6"	0.16	0.50
2	1.0"	0.21	0.58
3	1'6"	0.2	0.64
4	2'0"	0.15	0.52
5	0	0	0
6			
7			
8			
9			
10			

TOTAL WIDTH 3'6"

CS2			
Point	Distance (Ft)	Depth(m)	Velocity(m/s)
0	0	0	0
1	6"	0.05	TOO SHALLOW
2	1'5"	0.07	0.02
3	2'4"	0.17	0
4	3'3"	0.2	0.69
5	4'2"	0.2	0.73
6	5'1"	0.15	0.16
7	0	0	0
8			
9			
10			

14:02 2'2" TOTAL WIDTH

CS2.5			
Point	Distance (Ft)	Depth(m)	Velocity(m/s)
0	0	0	0
1	6"	0.15	0.23
2	1'	0.17	0.47
3	1'6"	0.15	0.30
4	2'	0.13	0.34 - AT SURFACE BOTTOM VEGETATION
5	2'6"	0.1	0.17
6	3'	0.05	0
7			
8			
9			
10			

11'2" TOTAL WIDTH

CS3			
Point	Distance (Ft)	Depth(m)	Velocity(m/s)
0	0	0	0
1	6"	0.8	TOO MUCH DEBRIS
2	1'5"	0.1	0
3	2'4"	0.22	0
4	3'3"	0.39	0.04
5	4'2"	0.45	0.64
6	5'1"	0.44	0.44
7	6'0"	0.27	0.09
8	6'11"	0.15	TOO MUCH DEBRIS
9	7'10"	0.15	"
10	8'9"	0.16	0.01
11	9'8"	0.18	T.M.D.
12	10'7"	0.03	T.M.D.

Chain of Custody / Analysis Request (Please complete all applicable shaded sections)

Report to: SKA02 Skagit Co. Public WKS	**For Lab Use Only**
Address: 1800 Continental Place	Ref#
City: Mount Vernon State: WA Zip: 98273	**Check Regulatory Program**
Attn: Leanne Ingman	☐ Safe Drinking Water Act
Phone: (360) 416-1450 Fax:	☐ Clean Water Act
Email: leannei@co.skagit.wa.us, meghanm@co.skagit.wa.us	☐ RCRA / CERCLA
Project Name: Lake Campbell CMP_01/19/24	☐ Other

EDGE ANALYTICAL

Main Lab (800-755-9295)
1620 South Walnut St. Burlington, WA 98233
Microbiology (888-725-1212)
805 W. Orchard Dr. Suite 4 Bellingham, WA 98225
Wilsonville Lab (503-682-7802)
9150 SW Pioneer Ct. Suite W Wilsonville, OR 97070
Corvallis Lab (541-753-4946)
540 SW 3rd St. Corvallis, OR 97333

	Sample ID	Location	Sample Matrix *	Date	Time	Ortho phos	Ammonia, TKN, T. Phos, NO2/NO3		Special Instructions/ Conditions on Receipt
1	DUPE-20240119		SW		1402	☒	☒	☐	Filter ASAP
2	CS1-20240119	CS1	SW	01/19/24	1340	☒	☒	☐	Filter ASAP
3	CS2-20240119	CS2	SW	01/19/24	1348	☒	☒	☐	Filter ASAP
4	CS2.5-20240119	CS2.5	SW	01/19/24	1402	☒	☒	☐	Filter ASAP
5	CS3-20240119	CS3	SW	01/19/24	1420	☒	☒	☐	Filter ASAP
6			SW			☐	☐	☐	
7			SW			☐	☐	☐	
8			SW			☐	☐	☐	
9			SW			☐	☐	☐	
10			SW			☐	☐	☐	
11			SW			☐	☐	☐	
12			SW			☐	☐	☐	
13			SW			☐	☐	☐	
14			SW			☐	☐	☐	
15			SW			☐	☐	☐	
16			SW			☐	☐	☐	
17			SW			☐	☐	☐	
18			SW			☐	☐	☐	
19			SW			☐	☐	☐	
20			SW			☐	☐	☐	
21			SW			☐	☐	☐	
22			SW			☐	☐	☐	
23			SW			☐	☐	☐	
24			SW			☐	☐	☐	
25			SW			☐	☐	☐	
26			SW			☐	☐	☐	
27			SW			☐	☐	☐	

Sampled by: Phone: Email:

Relinquished by	Date	Time	Received by	Date	Time
Leanne Ingman	1/19/24	1518	HBm (WI) REL8	1/19/24	1516

3.2

Burlington, WA *Corporate Laboratory (a)*
1620 S Walnut St - Burlington, WA 98233 - **800.755.9295** • 360.757.1400
Bellingham, WA *Microbiology (b)*
805 Orchard Dr Ste 4 - Bellingham, WA 98225 - 360.715.1212
Portland, OR *Microbiology/Chemistry (c)*
9725 SW Commerce Cr Ste A2 - Wilsonville, OR 97070 - 503.682.7802
Corvallis, OR *Microbiology/Chemistry (d)*
1100 NE Circle Blvd, Ste 130 - Corvallis, OR 97330 - 541.753.4946
Bend, OR *Microbiology (e)*
20332 Empire Blvd Ste 4 - Bend, OR 97701 - 541.639.8425

Data Report

Client Name: Skagit County Public Works
1800 Continental Place
Mount Vernon, WA 98273

Reference Number: **24-01575**
Project: Lake Campbell CMP_01/19/24
Report Date: 2/2/24
Date Received: 1/19/24
Approved by: bj,tjb
Authorized by:

Lawrence J Henderson, PhD
Director of Laboratories, Vice President

Sample Description: DUPE-20240119 | Matrix SW | Sample Date: 1/19/24 2:02 pm
Lab Number: 3019 | Sample Comment: Filter ASAP | Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.018	0.010	0.0045	mg/L	1.0	350.1	a	1/26/24	TJB	350.1_240126	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.60	0.20	0.0267	mg/L	1.0	351.2	a	1/25/24	MSO	351.2_240125	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.40	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/29/24	TJL	NO3NO2_240129	
14265-44-2	**ORTHO-PHOSPHATE**	0.02	0.01	0.0027	mg/L	1.0	SM4500-P F	a	1/19/24	TJL	OPHOS_240119	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.042	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	1/22/24	TJL	TPHOS_240122	

Sample Description: CS1-20240119 CS1 | Matrix SW | Sample Date: 1/19/24 1:40 pm
Lab Number: 3020 | Sample Comment: Filter ASAP | Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.13	0.010	0.0045	mg/L	1.0	350.1	a	1/26/24	TJB	350.1_240126	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.97	0.20	0.0267	mg/L	1.0	351.2	a	1/25/24	MSO	351.2_240125	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.63	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/29/24	TJL	NO3NO2_240129	
14265-44-2	**ORTHO-PHOSPHATE**	0.10	0.01	0.0027	mg/L	1.0	SM4500-P F	a	1/19/24	TJL	OPHOS_240119	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.173	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	1/22/24	TJL	TPHOS_240122	

Notes:
ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

If you have any questions concerning this report contact us at the above phone number.

Reference Number: **24-01575**
Report Date: 2/2/24

Data Report

Sample Description: CS2-20240119 CS2 | Matrix SW | Sample Date: 1/19/24 1:48 pm
Lab Number: 3021 | Sample Comment: Filter ASAP | Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.011	0.010	0.0045	mg/L	1.0	350.1	a	1/26/24	TJB	350.1_240126	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.76	0.20	0.0267	mg/L	1.0	351.2	a	1/25/24	MSO	351.2_240125	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.21	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/29/24	TJL	NO3NO2_240129	
14265-44-2	**ORTHO-PHOSPHATE**	0.01	0.01	0.0027	mg/L	1.0	SM4500-P F	a	1/19/24	TJL	OPHOS_240119	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.042	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	1/22/24	TJL	TPHOS_240122	

Sample Description: CS2.5-20240119 CS2.5 | Matrix SW | Sample Date: 1/19/24 2:02 pm
Lab Number: 3022 | Sample Comment: Filter ASAP | Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.019	0.010	0.0045	mg/L	1.0	350.1	a	1/26/24	TJB	350.1_240126	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.46	0.20	0.0267	mg/L	1.0	351.2	a	1/25/24	MSO	351.2_240125	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.40	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/29/24	TJL	NO3NO2_240129	
14265-44-2	**ORTHO-PHOSPHATE**	0.02	0.01	0.0027	mg/L	1.0	SM4500-P F	a	1/19/24	TJL	OPHOS_240119	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.036	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	1/22/24	TJL	TPHOS_240122	

Sample Description: CS3-20240119 CS3 | Matrix SW | Sample Date: 1/19/24 2:20 pm
Lab Number: 3023 | Sample Comment: Filter ASAP | Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.042	0.010	0.0045	mg/L	1.0	350.1	a	1/26/24	TJB	350.1_240126	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.92	0.20	0.0267	mg/L	1.0	351.2	a	1/25/24	MSO	351.2_240125	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.31	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/29/24	TJL	NO3NO2_240129	
14265-44-2	**ORTHO-PHOSPHATE**	0.03	0.01	0.0027	mg/L	1.0	SM4500-P F	a	1/19/24	TJL	OPHOS_240119	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.072	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	1/22/24	TJL	TPHOS_240122	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

EDGE ANALYTICAL

SAMPLE INDEPENDENT QUALITY CONTROL REPORT

Reference Number: **24-01575**
Report Date: 02/02/24

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
Calibration Check											
350.1_240126	0	AMMONIA-N	2.54	2.50	mg/L	350.1	102	90-110		CAL	
351.2_240125	0	TOTAL KJELDAHL NITROGEN as N	2.50	2.50	mg/L	351.2	100	90-110		CAL	
NO3NO2_24012ɛ	0	TOTAL NITRATE+NITRITE as N	1.02	1.00	mg/L	SM4500-NO3 F	102	90-110		CAL	
ophos_240119	0	ORTHO-PHOSPHATE	1.01	1.00	mg/L	SM4500-P F	101	85-115		CAL	
TPHOS_240122	0	TOTAL PHOSPHORUS-P	0.101	0.100	mg/L	SM4500-P F	101	85-115		CAL	
Laboratory Fortified Blank											
351.2_240125	0	TOTAL KJELDAHL NITROGEN as N	2.01	2.00	mg/L	351.2	101	90-110		LFB	
Laboratory Reagent Blank											
350.1_240126	0	AMMONIA-N	ND		mg/L	350.1		0-0		LRB	
351.2_240125	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		LRB	
NO3NO2_24012ɛ	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		LRB	
ophos_240119	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		LRB	
TPHOS_240122	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		LRB	
Method Blank											
351.2_240125	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		MB	
NO3NO2_24012ɛ	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		MB	
ophos_240119	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		MB	
TPHOS_240122	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		MB	
Quality Control Sample											
350.1_240126	0	AMMONIA-N	2.12	2.15	mg/L	350.1	99	85-115		QCS	
351.2_240125	0	TOTAL KJELDAHL NITROGEN as N	2.40	2.33	mg/L	351.2	103	85-115		QCS	
NO3NO2_24012ɛ	0	TOTAL NITRATE+NITRITE as N	1.94	2.00	mg/L	SM4500-NO3 F	97	90-110		QCS	
ophos_240119	0	ORTHO-PHOSPHATE	0.94	1.00	mg/L	SM4500-P F	94	90-110		QCS	
TPHOS_240122	0	TOTAL PHOSPHORUS-P	0.197	0.217	mg/L	SM4500-P F	91	90-110		QCS	

*Notation:

% Recovery = (Result of Analysis)/(True Value) * 100

NA = Indicates % Recovery could not be calculated.

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QCIndependent4.rpt

EDGE ANALYTICAL

SAMPLE DEPENDENT
QUALITY CONTROL REPORT

Duplicate, Matrix Spike/Matrix Spike Duplicate
and Confirmation Result Report

Reference Number: **24-01575**
Report Date: 2/2/2024

Duplicate

Batch/CAS	Sample	Analyte	Result	Duplicate Result	Units	%RPD	Limits	QC Qualifier	Comments
350.1_240126									
7664-41-7	2747	AMMONIA-N	13.2	13.3	mg/L	**0.8**	0-20		
7664-41-7	2810	AMMONIA-N	12.5	12.3	mg/L	**1.6**	0-20		
7664-41-7	3166	AMMONIA-N	1.44	1.61	mg/L	**11.1**	0-20		
7664-41-7	3426	AMMONIA-N	4.59	4.49	mg/L	**2.2**	0-20		
351.2_240125									
E-10264	1907	TOTAL KJELDAHL NITROGEN as N	82.4	85.1	mg/L	**3.2**	0-20		
E-10264	2917	TOTAL KJELDAHL NITROGEN as N	1.29	1.13	mg/L	**13.2**	0-20		
NO3NO2_240129									
E-10128	2606	TOTAL NITRATE+NITRITE as N	5.25	5.25	mg/L	**0.0**	0-20		
E-10128	2739	TOTAL NITRATE+NITRITE as N	0.10	0.10	mg/L	**0.0**	0-20		
E-10128	2773	TOTAL NITRATE+NITRITE as N	ND	ND	mg/L	**NA**	0-20		
E-10128	3021	TOTAL NITRATE+NITRITE as N	0.21	0.22	mg/L	**4.7**	0-20		
E-10128	3323	TOTAL NITRATE+NITRITE as N	0.01	0.01	mg/L	**0.0**	0-20		
E-10128	4244	TOTAL NITRATE+NITRITE as N	0.05	0.05	mg/L	**0.0**	0-20		
OPHOS_240119									
14265-44-2	3023	ORTHO-PHOSPHATE	0.03	0.03	mg/L	**0.0**	0-20		
TPHOS_240122									
7723-14-0	3019	TOTAL PHOSPHORUS-P	0.042	0.043	mg/L	**2.4**	0-20		

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

SAMPLE DEPENDENT
QUALITY CONTROL REPORT

Duplicate, Matrix Spike/Matrix Spike Duplicate
and Confirmation Result Report

Reference Number: **24-01575**
Report Date: 2/2/2024

Laboratory Fortified Matrix (MS)

Batch/CAS	Sample	Analyte	Result	Spike Result	Duplicate Spike Result	Conc	Units	Percent Recovery MS	Percent Recovery MSD	Limits*	%RPD	Limits*	QC Qualifier	Comments
350.1_240126														
7664-41-7	2747	AMMONIA-N	13.2	22.2	22.5	10.0	mg/L	**90**	**93**	70-130	**3.3**	0-20		
7664-41-7	2810	AMMONIA-N	12.5	20.4	20.4	10.0	mg/L	**79**	**79**	70-130	**0.0**	0-20		
7664-41-7	3166	AMMONIA-N	1.44	2.37	2.37	1.00	mg/L	**93**	**93**	70-130	**0.0**	0-20		
7664-41-7	3426	AMMONIA-N	4.59	6.02	6.28	2.00	mg/L	**72**	**85**	70-130	**16.7**	0-20		
351.2_240125														
E-10264	1907	TOTAL KJELDAHL NITROGEN as N	82.4	183		100	mg/L	**101**		70-130	**NA**	0-20		
E-10264	2917	TOTAL KJELDAHL NITROGEN as N	1.29	3.13		2.00	mg/L	**92**		70-130	**NA**	0-20		
NO3NO2_240129														
E-10128	2606	TOTAL NITRATE+NITRITE as N	5.25	15.9	14.6	10.0	mg/L	**107**	**94**	80-120	**13.0**	0-20		
E-10128	2739	TOTAL NITRATE+NITRITE as N	0.10	1.10	1.05	1.00	mg/L	**100**	**95**	80-120	**5.1**	0-20		
E-10128	2773	TOTAL NITRATE+NITRITE as N	ND	1.01	1.01	1.00	mg/L	**101**	**101**	80-120	**0.0**	0-20		
E-10128	3021	TOTAL NITRATE+NITRITE as N	0.21	1.21	1.21	1.00	mg/L	**100**	**100**	80-120	**0.0**	0-20		
E-10128	3323	TOTAL NITRATE+NITRITE as N	0.01	1.06	1.04	1.00	mg/L	**105**	**103**	80-120	**1.9**	0-20		
E-10128	4244	TOTAL NITRATE+NITRITE as N	0.05	1.10	1.10	1.00	mg/L	**105**	**105**	80-120	**0.0**	0-20		
OPHOS_240119														
14265-44-2	3023	ORTHO-PHOSPHATE	0.03	0.51	0.51	0.50	mg/L	**96**	**96**	70-130	**0.0**	0-20		
TPHOS_240122														
7723-14-0	3019	TOTAL PHOSPHORUS-P	0.042	0.094	0.101	0.050	mg/L	**104**	**118**	70-130	**12.6**	0-20		

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

HERRERA
Science + Planning + Design

Lake Still Frozen

2023 LAKE CAMPBELL CMP WATERSHED MONITORING DATA SHEET

Project: Lake Campbell Cyanobacteria Management Plan Project No.: 23-08143-000
Client: Skagit County Field Personnel: Mary Brady, Leanne Ingman
Event Type and Number Storm Base (√)
Weather and predicted rainfall (in): cloudy occasional drizzle 41° 0.29" predicted

Base flow sampling to occur every month (August 2023 through January 2024) on the day of or day before lake sampling. Six additional wet weather (storm flow) sampling events to occur during fall and winter storms September 2023 through January 2024.

Field Equipment Checklist

- ☑ Flow meter
- ☒ YSI multimeter
- ☑ Cooler with ice
- ☑ Tape Measure
- ☒ Hanna pH meter
- ☑ Chain-of-Custody
- ☑ Sample bottles

Sampling Data

All samples analyzed for total nutrients. Duplicates are to be collected monthly from September 2023 through January 2024 at a random site during a random event. If applicable, record duplicate sample information below. Do not include duplicate sample times on COCs.

Site ID	Sample ID	Sample Time	Photos Taken?	Water Description (Turbidity; Unusual color, odor, sheen)
CS1	CS1-20240122			
CS2	CS2-20240122			
CS2.5	CS2.5-20240122			
CS3	CS3-20240122			
DUPE	DUPE-20240122			

Notes & observations:

mf b2_campbell_watershedmonitoring_field form_blank.docx

Discharge Data

CS1

Monitoring Location: SR-20 inflow

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe):

Collection Date and Time: 1-22-24 13:48

Notes & Observations

total width = 35 inches

Culvert diameter = ______ inches

Water depth = ______ feet

Water velocity (flow) = ______ f/s

Calculated Flow (cfs) = ______

SEE SPREADSHEET

CS2

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe):

Collection Date and Time: 1-22-24 14:03

Notes & Observations

6" total width

Culvert diameter = ______ inches

Water depth = ______ feet

Water velocity (flow) = ______ f/s

Calculated Flow (cfs) = ______

SEE SPREADSHEET

CS2.5

Monitoring Location: Inflow from Mount Erie and/or Whistle Lake

Discharge measurement method: ☐ Timed bucket fill ☐Stream cross-section with flow probe ☐Other (describe): ________

Collection Date and Time: 1-22-24 14:20

Notes & Observations ________

Culvert diameter = ________ inches

Water depth = ________ feet

Water velocity (flow) = ________ f/s

Calculated Flow (cfs) = ________

SEE SPREADSHEET

CS3

Monitoring Location: Lake Erie outlet

Discharge measurement method: Stream cross-section

Collection Date and Time: 1-22-24 14:30

Notes & Observations

9'8" total width

Total channel section width = ________ feet

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		–	–
1			
2			
3			
4			
5			
6			
7			
8			
Edge of Bank		–	–

Calculated Flow (cfs) = ________

CAM-OUT

Monitoring Location: Outlet for Lake Campbell
Discharge measurement method: Stream cross-section
Collection Date and Time: 1-22-24 13:20
Notes & Observations

Total channel section width = 9 feet 11"

**skip point measurements as necessary depending on stream width:

Point	Point Location (feet)	Depth* (ft)	Velocity (f/s)
Edge of Bank		- 0.22	too much debris
1	6"	0.30	
2	20" 1 ft 8"	0.90	0.0
3	2 ft 10"	1.04	0.0
4	44 4 ft	0.81	0.0
5	5 ft 2"	0.83	0.17
6	6' 4"	0.86	0.16
7	7' 6"	0.74	0.12
8	8' 8"	0.67	0.07
Edge of Bank	9'	- 0.34	- too much debris

Calculated Flow (cfs) = ________

Other Observations

Measured established channel
Water extended beyond Bank.
Saturated reed canary grass

36" total width

CS1			
Point	Distance (Ft)	Depth(m)	Velocity(m/s)
edge 0			
1	6 in	0.15	0.5[illegible] .53
2	1 ft	0.25	0.00
3	1' 6"	0.29	0.57
4	2'	0.25	0.58
5	2' 6"	0.14	0.56
6			
7			
8			
9			
10			

6' total width

CS2			
Point	Distance (Ft)	Depth(m)	Velocity(m/s)
edge 0		0	0
1	6"	0.15	0.02
2	1' 2"	0.15	0.33
3	1' 10"	0.16	0.67
4	2' 6"	0.15	0.24
5	3' 2"	0.14	0.88
6	3' 10"	0.13	0.37
7	4' 6"	0.4	1.06
8	5'	0.05	0.54
edge 9			
10			

2' 9" total width

CS2.5			
Point	Distance (Ft)	Depth(m)	Velocity(m/s)
edge 0		0	0
1	6"	0.16	0.08
2	1'	0.22	0.20
3	1' 6"	0.23	0.73
4	2'	0.20	0.34
5	2' 6"	0.15	0.00
edge 6	—	—	—
7			
8			
9			
10			

9' 8" total width

CS3			
Point	Distance (Ft)	Depth(m)	Velocity(m/s)
edge 0		0.1	0.0
1	16"	0.15	0.0
2	1' 8"	0.25	0.0
3	2' 10"	0.46	0.04
4	4'	0.50	0.74
5	5' 2"	0.29	0.35
6	6' 4"	0.19	0.05
7	7' 6"	0.17	0.0
8	8' 8"	0.16	0.0
edge 9	9' 8"	0.08	0.0
10			

CHAIN OF CUSTODY / ANALYSIS REQUEST (PLEASE COMPLETE ALL APPLICABLE SHADED SECTIONS)

REPORT TO: SKA02 SKAGIT CO. PUBLIC WKS	**FOR LAB USE ONLY**
ADDRESS: 1800 CONTINENTAL PLACE	REF#
CITY: MOUNT VERNON STATE: WA ZIP: 98273	**CHECK REGULATORY PROGRAM**
ATTN: LEANNE INGMAN	☐ SAFE DRINKING WATER ACT
PHONE: (360) 416-1450 FAX:	☐ CLEAN WATER ACT
EMAIL: .LEANNEI@CO.SKAGIT.WA.US, MEGHANM@CO.SKAGIT.WA.US	☐ RCRA / CERCLA
PROJECT NAME: LAKE CAMPBELL CMP_1/22/24	☐ OTHER

EDGE ANALYTICAL

Main Lab (800-755-9295)
1620 South Walnut St. Burlington, WA 98233
Microbiology (888-725-1212)
805 W. Orchard Dr. Suite 4 Bellingham, WA 98225
Wilsonville Lab (503-682-7802)
9150 SW Pioneer Ct. Suite W Wilsonville, OR 97070
Corvallis Lab (541-753-4946)
540 SW 3rd St. Corvallis, OR 97333

	SAMPLE ID	LOCATION	SAMPLE MATRIX *	DATE	TIME	Ortho phos	AMMONIA, TKN, T. PHOS, NO2/NO3		SPECIAL INSTRUCTIONS/ CONDITIONS ON RECEIPT
1	DUPE-20240122		SW		1920	☒	☒	☐	Filter ASAP
2	CS1-20240122	CS1	SW	1/22/24	1348	☒	☒	☐	Filter ASAP
3	CS2-20240122	CS2	SW	1/22/24	1403	☒	☒	☐	Filter ASAP
4	CS2.5-20240122	CS2.5	SW	1/22/24	1420	☒	☒	☐	Filter ASAP
5	CS3-20240122	CS3	SW	1/22/24	1430	☒	☒	☐	Filter ASAP
6			SW			☐	☐	☐	
7			SW			☐	☐	☐	
8			SW			☐	☐	☐	
9			SW			☐	☐	☐	
10			SW			☐	☐	☐	
11			SW			☐	☐	☐	
12			SW			☐	☐	☐	
13			SW			☐	☐	☐	
14			SW			☐	☐	☐	
15			SW			☐	☐	☐	
16			SW			☐	☐	☐	
17			SW			☐	☐	☐	
18			SW			☐	☐	☐	
19			SW			☐	☐	☐	
20			SW			☐	☐	☐	
21			SW			☐	☐	☐	
22			SW			☐	☐	☐	
23			SW			☐	☐	☐	
24			SW			☐	☐	☐	
25			SW			☐	☐	☐	
26			SW			☐	☐	☐	
27			SW			☐	☐	☐	

SAMPLED BY:	PHONE:	EMAIL:

RELINQUISHED BY	DATE	TIME	RECEIVED BY	DATE	TIME
Leanne Ingman	1/22/24	1528	KRawReiv	1-22-24	1527

EDGE ANALYTICAL

Burlington, WA *Corporate Laboratory (a)*
1620 S Walnut St - Burlington, WA 98233 - **800.755.9295** • 360.757.1400

Bellingham, WA *Microbiology (b)*
805 Orchard Dr Ste 4 - Bellingham, WA 98225 - 360.715.1212

Portland, OR *Microbiology/Chemistry (c)*
9725 SW Commerce Cr Ste A2 - Wilsonville, OR 97070 - 503.682.7802

Corvallis, OR *Microbiology/Chemistry (d)*
1100 NE Circle Blvd, Ste 130 - Corvallis, OR 97330 - 541.753.4946

Bend, OR *Microbiology (e)*
20332 Empire Blvd Ste 4 - Bend, OR 97701 - 541.639.8425

February 7, 2024

Leanne Ingman
Skagit County Public Works
1800 Continental Place
Mount Vernon, WA 98273

RE: 24-01689 - Lake Campbell CMP_1/22/24

Dear Leanne Ingman,

Your project: Lake Campbell CMP_1/22/24, was received on Monday January 22, 2024.

All samples were analyzed within the accepted holding times and were appropriately preserved and analyzed according to approved analytical protocols, unless noted in the data or QC reports. The quality control data was within laboratory acceptance limits, unless specified in the data or QC reports.

If you have questions phone us at 800 755-9295.

Respectfully

Lawrence J Henderson, PhD
Director of Laboratories, Vice President

Enclosures: Data Report
QC Reports
Chain of Custody

Burlington, WA *Corporate Laboratory (a)*
1620 S Walnut St - Burlington, WA 98233 - **800.755.9295** • 360.757.1400
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1100 NE Circle Blvd, Ste 130 - Corvallis, OR 97330 - 541.753.4946
Bend, OR *Microbiology (e)*
20332 Empire Blvd Ste 4 - Bend, OR 97701 - 541.639.8425

Data Report

Client Name: Skagit County Public Works
1800 Continental Place
Mount Vernon, WA 98273

Reference Number: **24-01689**
Project: Lake Campbell
CMP_1/22/24

Report Date: 2/7/24

Date Received: 1/22/24
Approved by: tjb
Authorized by:

Lawrence J Henderson, PhD
Director of Laboratories, Vice President

Sample Description: Dupe-20240122 | Matrix SW | Sample Date: 1/22/24 2:20 pm
Lab Number: 3263 | Sample Comment: | Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.0071 J	0.010	0.0066	mg/L	1.0	350.1	a	2/2/24	MSO	350.1_240202	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.37	0.20	0.0267	mg/L	1.0	351.2	a	1/25/24	MSO	351.2_240125	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.33	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/23/24	TJL	NO3NO2_240123	
14265-44-2	**ORTHO-PHOSPHATE**	0.01	0.01	0.0027	mg/L	1.0	SM4500-P F	a	1/23/24	TJL	OPHOS_240123	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.020	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	2/6/24	TJL	TPHOS_240205	

Sample Description: CSI-20240122 CS1 | Matrix SW | Sample Date: 1/22/24 1:48 pm
Lab Number: 3264 | Sample Comment: | Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.040	0.010	0.0066	mg/L	1.0	350.1	a	2/2/24	MSO	350.1_240202	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	1.05	0.20	0.0267	mg/L	1.0	351.2	a	1/25/24	MSO	351.2_240125	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.80	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/23/24	TJL	NO3NO2_240123	
14265-44-2	**ORTHO-PHOSPHATE**	0.08	0.01	0.0027	mg/L	1.0	SM4500-P F	a	1/23/24	TJL	OPHOS_240123	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.119	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	1/30/24	TJL	TPHOS_240130	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

If you have any questions concerning this report contact us at the above phone number.

Reference Number: **24-01689**
Report Date: 2/7/24

Data Report

Sample Description: CS2-20240122 CS2 — Matrix SW — Sample Date: 1/22/24 2:03 pm
Lab Number: 3265 — Sample Comment: — Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.012	0.010	0.0066	mg/L	1.0	350.1	a	2/2/24	MSO	350.1_240202	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.51	0.20	0.0267	mg/L	1.0	351.2	a	1/25/24	MSO	351.2_240125	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.27	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/23/24	TJL	NO3NO2_240123	
14265-44-2	**ORTHO-PHOSPHATE**	0.01	0.01	0.0027	mg/L	1.0	SM4500-P F	a	1/23/24	TJL	OPHOS_240123	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.031	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	1/30/24	TJL	TPHOS_240130	

Sample Description: CS2.5-20240122 CS2.5 — Matrix SW — Sample Date: 1/22/24 2:20 pm
Lab Number: 3266 — Sample Comment: — Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.010	0.010	0.0066	mg/L	1.0	350.1	a	2/2/24	MSO	350.1_240202	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	0.56	0.20	0.0267	mg/L	1.0	351.2	a	1/25/24	MSO	351.2_240125	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.31	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/23/24	TJL	NO3NO2_240123	
14265-44-2	**ORTHO-PHOSPHATE**	0.01	0.01	0.0027	mg/L	1.0	SM4500-P F	a	1/23/24	TJL	OPHOS_240123	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.018	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	1/30/24	TJL	TPHOS_240130	

Sample Description: CS3-20240122 CS3 — Matrix SW — Sample Date: 1/22/24 2:30 pm
Lab Number: 3267 — Sample Comment: — Collected By:

CAS ID#	Parameter	Result	PQL	MDL	Units	DF	Method	Lab	Analyzed	Analyst	Batch	Comment
7664-41-7	**AMMONIA-N**	0.022	0.010	0.0066	mg/L	1.0	350.1	a	2/2/24	MSO	350.1_240202	
E-10264	**TOTAL KJELDAHL NITROGEN as N**	1.24	0.20	0.0267	mg/L	1.0	351.2	a	1/25/24	MSO	351.2_240125	
E-10128	**TOTAL NITRATE+NITRITE as N**	0.27	0.01	0.0047	mg/L	1.0	SM4500-NO3 F	a	1/23/24	TJL	NO3NO2_240123	
14265-44-2	**ORTHO-PHOSPHATE**	0.02	0.01	0.0027	mg/L	1.0	SM4500-P F	a	1/23/24	TJL	OPHOS_240123	
7723-14-0	**TOTAL PHOSPHORUS-P**	0.050	0.010	0.0019	mg/L	1.0	SM4500-P F/SM4500-P B(5)	a	1/30/24	TJL	TPHOS_240130	

Notes:

ND = Not detected above the listed practical quantitation limit (PQL) or not above the Method Detection Limit (MDL), if requested.
PQL = Practical Quantitation Limit is the lowest level that can be achieved within specified limits of precision and accuracy during routine laboratory operating conditions.
D.F. - Dilution Factor

SAMPLE INDEPENDENT
QUALITY CONTROL REPORT

Reference Number: **24-01689**
Report Date: 02/07/24

Batch		Analyte	Result	True Value	Units	Method	% Recovery	Limits*	QC Qualifier	QC Type	Comment
Calibration Check											
350.1_240202	0	AMMONIA-N	2.44	2.50	mg/L	350.1	98	90-110		CAL	
351.2_240125	0	TOTAL KJELDAHL NITROGEN as N	2.50	2.50	mg/L	351.2	100	90-110		CAL	
NO3NO2_24012:	0	TOTAL NITRATE+NITRITE as N	1.02	1.00	mg/L	SM4500-NO3 F	102	90-110		CAL	
OPHOS_240123	0	ORTHO-PHOSPHATE	1.00	1.00	mg/L	SM4500-P F	100	85-115		CAL	
TPHOS_240130	0	TOTAL PHOSPHORUS-P	0.097	0.100	mg/L	SM4500-P F	97	85-115		CAL	
TPHOS_240205	0	TOTAL PHOSPHORUS-P	0.096	0.100	mg/L	SM4500-P F	96	85-115		CAL	
Laboratory Fortified Blank											
351.2_240125	0	TOTAL KJELDAHL NITROGEN as N	2.01	2.00	mg/L	351.2	101	90-110		LFB	
Laboratory Reagent Blank											
351.2_240125	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		LRB	
NO3NO2_24012:	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		LRB	
OPHOS_240123	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		LRB	
TPHOS_240130	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		LRB	
TPHOS_240205	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		LRB	
Method Blank											
350.1_240202	0	AMMONIA-N	ND		mg/L	350.1		0-0		MB	
351.2_240125	0	TOTAL KJELDAHL NITROGEN as N	ND		mg/L	351.2		0-0		MB	
NO3NO2_24012:	0	TOTAL NITRATE+NITRITE as N	ND		mg/L	SM4500-NO3 F		0-0		MB	
OPHOS_240123	0	ORTHO-PHOSPHATE	ND		mg/L	SM4500-P F		0-0		MB	
TPHOS_240130	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		MB	
TPHOS_240205	0	TOTAL PHOSPHORUS-P	ND		mg/L	SM4500-P F		0-0		MB	
Quality Control Sample											
350.1_240202	0	AMMONIA-N	2.02	2.15	mg/L	350.1	94	85-115		QCS	
351.2_240125	0	TOTAL KJELDAHL NITROGEN as N	2.40	2.33	mg/L	351.2	103	85-115		QCS	
NO3NO2_24012:	0	TOTAL NITRATE+NITRITE as N	1.98	2.00	mg/L	SM4500-NO3 F	99	90-110		QCS	
OPHOS_240123	0	ORTHO-PHOSPHATE	0.95	1.00	mg/L	SM4500-P F	95	90-110		QCS	
TPHOS_240130	0	TOTAL PHOSPHORUS-P	0.212	0.217	mg/L	SM4500-P F	98	90-110		QCS	
TPHOS_240205	0	TOTAL PHOSPHORUS-P	0.229	0.217	mg/L	SM4500-P F	106	90-110		QCS	

*Notation:

% Recovery = (Result of Analysis)/(True Value) * 100

NA = Indicates % Recovery could not be calculated.

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

FORM: QCIndependent4.rpt

SAMPLE DEPENDENT
QUALITY CONTROL REPORT

Duplicate, Matrix Spike/Matrix Spike Duplicate and Confirmation Result Report

Reference Number: **24-01689**
Report Date: 2/7/2024

Duplicate

Batch/CAS	Sample	Analyte	Result	Duplicate Result	Units	%RPD	Limits	QC Qualifier	Comments
350.1_240202									
7664-41-7	3250	AMMONIA-N	0.025	0.025	mg/L	**0.0**	0-20		
7664-41-7	3793	AMMONIA-N	0.15	0.15	mg/L	**0.0**	0-20		
7664-41-7	3902	AMMONIA-N	26.3	25.5	mg/L	**3.1**	0-20		
7664-41-7	4247	AMMONIA-N	0.032	0.029	mg/L	**9.8**	0-20		
351.2_240125									
E-10264	1907	TOTAL KJELDAHL NITROGEN as N	82.4	85.1	mg/L	**3.2**	0-20		
E-10264	2917	TOTAL KJELDAHL NITROGEN as N	1.29	1.13	mg/L	**13.2**	0-20		
NO3NO2_240123									
E-10128	3166	TOTAL NITRATE+NITRITE as N	1.11	1.11	mg/L	**0.0**	0-20		
OPHOS_240123									
14265-44-2	3166	ORTHO-PHOSPHATE	1.03	1.02	mg/L	**1.0**	0-20		
TPHOS_240130									
7723-14-0	4026	TOTAL PHOSPHORUS-P	0.028	0.029	mg/L	**3.5**	0-20		
7723-14-0	4032	TOTAL PHOSPHORUS-P	0.268	0.267	mg/L	**0.4**	0-20		
7723-14-0	4230	TOTAL PHOSPHORUS-P	0.029	0.029	mg/L	**0.0**	0-20		
TPHOS_240205									
7723-14-0	3263	TOTAL PHOSPHORUS-P	0.020	0.019	mg/L	**5.1**	0-20		
7723-14-0	4249	TOTAL PHOSPHORUS-P	0.034	0.034	mg/L	**0.0**	0-20		
7723-14-0	4920	TOTAL PHOSPHORUS-P	2.19	2.24	mg/L	**2.3**	0-20		

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

SAMPLE DEPENDENT
QUALITY CONTROL REPORT

Duplicate, Matrix Spike/Matrix Spike Duplicate and Confirmation Result Report

Reference Number: **24-01689**
Report Date: 2/7/2024

Laboratory Fortified Matrix (MS)

Batch/CAS	Sample	Analyte	Result	Spike Result	Duplicate Spike Result	Conc	Units	Percent Recovery MS	Percent Recovery MSD	Limits*	%RPD	Limits*	QC Qualifier	Comments
350.1_240202														
7664-41-7	3250	AMMONIA-N	0.025	0.97	0.98	1.00	mg/L	**95**	**96**	70-130	**1.1**	0-20		
7664-41-7	3793	AMMONIA-N	0.15	1.16	1.18	1.00	mg/L	**101**	**103**	70-130	**2.0**	0-20		
7664-41-7	3902	AMMONIA-N	26.3	73.4	73.5	50.0	mg/L	**94**	**94**	70-130	**0.2**	0-20		
7664-41-7	4247	AMMONIA-N	0.032	0.99	0.96	1.00	mg/L	**96**	**93**	70-130	**3.2**	0-20		
351.2_240125														
E-10264	1907	TOTAL KJELDAHL NITROGEN as N	82.4	183		100	mg/L	**101**		70-130	**NA**	0-20		
E-10264	2917	TOTAL KJELDAHL NITROGEN as N	1.29	3.13		2.00	mg/L	**92**		70-130	**NA**	0-20		
NO3NO2_240123														
E-10128	3166	TOTAL NITRATE+NITRITE as N	1.11	11.8	11.2	10.0	mg/L	**107**	**101**	80-120	**5.8**	0-20		
OPHOS_240123														
14265-44-2	3166	ORTHO-PHOSPHATE	1.03	5.83	5.85	5.00	mg/L	**96**	**96**	70-130	**0.4**	0-20		
TPHOS_240130														
7723-14-0	4026	TOTAL PHOSPHORUS-P	0.028	0.078	0.082	0.050	mg/L	**100**	**108**	70-130	**7.7**	0-20		
7723-14-0	4032	TOTAL PHOSPHORUS-P	0.268	0.313	0.317	0.050	mg/L	**90**	**98**	70-130	**8.5**	0-20		
7723-14-0	4230	TOTAL PHOSPHORUS-P	0.029	0.075	0.078	0.050	mg/L	**92**	**98**	70-130	**6.3**	0-20		
TPHOS_240205														
7723-14-0	3263	TOTAL PHOSPHORUS-P	0.020	0.079	0.074	0.050	mg/L	**118**	**108**	70-130	**8.8**	0-20		
7723-14-0	4249	TOTAL PHOSPHORUS-P	0.034	0.088	0.090	0.050	mg/L	**108**	**112**	70-130	**3.6**	0-20		
7723-14-0	4920	TOTAL PHOSPHORUS-P	2.19	2.74	2.70	0.50	mg/L	**110**	**102**	70-130	**7.5**	0-20		

%RPD = Relative Percent Difference

NA = Indicates %RPD could not be calculated

Matrix Spike (MS)/Matrix Spike Duplicate (MSD) analyses are used to determine the accuracy (MS) and precision (MSD) of a analytical method in a given sample matrix. Therefore, the usefulness of this report is limited to samples of similar matrices analyzed in the same analytical batch.

Only Duplicate sample with detections are listed in this report

Limits are intended for water matrices only. These criteria are for guidance only when reported with soils/solids.

Qualifier Definitions

Reference Number: 24-01689
Report Date: 02/07/24

Qualifier	Definition
IE	An estimated concentration exceeding the calibration range.
INH	The sample was non-homogeneous
J	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.

Note: Some qualifier definitions found on this page may pertain to results or QC data which are not printed with this report.

Appendix C

Cyanobacteria Management Methods

HERRERA
Science + Planning + Design

Appendix C: Cyanobacteria Management Methods

This appendix summarizes external and internal lake management methods for cyanobacteria control, their advantages and disadvantages, and their suitability for implementation at Lake Campbell. Actions assessed as suitable for implementation at Lake Campbell are highlighted in green in Table 1 and further described in the sections below. Actions determined not feasible for implementation in Lake Campbell and rationale are detailed in the *Methods Rejected* section.

Table 1. Cyanobacteria Management Feasibility Screening for Lake Campbell.

Method	Effectiveness	Cost	Impact Risk	Feasibility	Suitability
Watershed (External Nutrient Loading Control) Methods					
Septic System Management	Low-Moderate	High	Low	Moderate	Yes
Stormwater Management	Low-Moderate	Moderate	Low	Moderate	Yes
Stream Phosphorus Inactivation	Low-Moderate	Moderate	Moderate	Low	No
Waterfowl Management	Low-Moderate	Moderate	Low	Moderate	Yes
Shoreline Management	Low-Moderate	Moderate	Low	Moderate	Yes
Lake Physical Methods					
Lake Mixing – Surface Mixing by SolarBees	Low-Moderate	Low-Moderate	Low	Moderate-High	No – uncertain effectiveness
Lake Mixing – Whole-lake Mixing by Aeration	Low-Moderate	Moderate	Low	Moderate	No – uncertain effectiveness
Sonication	Low-Moderate	Moderate	Low-Moderate	Low	No – uncertain effectiveness
Lake dilution	Moderate	High	Low	Low	No – high cost
Hypolimnetic Oxygenation/ Aeration	Low-Moderate	Moderate-High	Low-fish benefits	Moderate	No – lake too shallow
Ozone/ Microbubbles/ Nanobubbles	Low	Moderate	Low	Low	No – not effective, experimental
Hypolimnetic Withdrawal	Low	Moderate	High	Low	No – insufficient inflow, downstream impacts
Beaver Dam / Lake Level Management	Moderate	Low	Low-Moderate	Moderate	Yes
Dredging	Low-Moderate	Very High	Moderate	Low	No – high cost/benefit
Shading (Dyes)	Moderate	Moderate	High	Low	No – not feasible
Lake Chemical Methods					
Algaecide treatment	Moderate	Low-Moderate	Low-Moderate	Moderate	No –not a long-term solution
Sediment Phosphorus Inactivation with Alum or Lanthanum)	High	Moderate	Low-Moderate	Moderate	Yes
Calcium treatment	Low	Low-Moderate	Low	Low	No – not effective with low hardness
Iron treatment	Low	Low	Low	Low-Moderate	No – not effective with sediment layer anoxia

Table 1 (continued). Cyanobacteria Management Feasibility Screening for Lake Campbell.					
Method	**Effectiveness**	**Cost**	**Impact Risk**	**Feasibility**	**Suitability**
Lake Biological Methods					
Carp removal	Low	Moderate-High	Low-Moderate	Low	No – high cost/ benefit
Biomanipulation (Zooplankton planting; Piscivore stocking)	Low	Low-Moderate	Low-Moderate	Low	No – not feasible, low effectiveness
Aquatic Weed Harvesting	Low-Moderate	Moderate	Low	Moderate	No – high cost/benefit
Macrophyte plantings	Low	Moderate	Low	Low	No – high cost/benefit
Barley Straw	Low	Low	Low-Moderate	Low	No – uncertain benefit

In-Lake Techniques

The following sections summarize the most feasible lake management techniques that may be used to improve the algae community and meet the water quality objectives. These techniques are considered feasible for reducing the magnitude and frequency of toxic cyanobacteria blooms. There are advantages and disadvantages to each management technique; some are more experimental, with limited scientific studies of effectiveness, and there are wide differences in initial and long-term costs. Table 1 provides a comparative summary of these techniques.

It is important to recognize that any lake management technique aimed at controlling algae, if successful, is likely to impact aquatic macrophyte populations. The clearer water means more sunlight for plant growth. Since most plants obtain their nutrients from the sediments rather than the water, lake nutrient reduction techniques typically do not impact them. Although phosphorus inactivation methods reduce nutrient availability in sediments where most aquatic macrophytes obtain nutrients, macrophyte roots typically penetrate below the inactivation zone (upper 10 centimeters) and are not affected by inactivation treatments. Lake management should focus on achieving the appropriate ecological balance between algae and plants, since too much of either can be problematic.

Lake Phosphorus Inactivation

Alum Treatment

Applications of aluminum sulfate (alum), in a sufficient dose to inactivate all mobile sediment phosphorus, have been shown to be effective for at least 10 years in lakes with low watershed inputs (Cooke et al. 2005). When alum is added to water it forms a floc that grows in size and weight as it settles through the water column, sorbing inorganic phosphorus and incorporating particulate organic phosphorus through entrapment (Burrows 1977, Driscoll and Schecher 1990). The alum floc settles to the sediments, where it continues to control phosphorus by sorbing additional phosphorus that is present in the sediments. This forms a barrier to future phosphorus release from sediments into the water column. The resultant phosphorus that is bound to aluminum in the lake sediments is very stable and is thought to be permanently bound (Rydin and Welch 1998).

Alum treatments have been used successfully in many lakes in Washington (Table 2). Several strategies have been implemented in Washington and around the world to inactivate phosphorus in sediments and lakes and to form watershed inputs, including the following:

- Whole lake alum dose
- Multiple small alum doses
- Microfloc alum injection
- Inflow stream alum injection

Multiple small alum doses typically cost more than a whole lake alum dose, due to higher mobilization costs. However, costs can be similar if an expensive buffer (sodium aluminate) is not needed to neutralize small alum doses but is needed for large alum doses. Multiple small alum doses are more appropriate for lakes with high external loading, which would reduce the longevity of a whole lake alum dose. Multiple small alum doses are sometimes preferred over a large long-term dose for financial reasons or to reduce potential impacts of aluminum toxicity to aquatic organisms. Multiple small alum doses can be used to strip phosphorus from the water column and to inactivate sediment phosphorus.

Because of the acute toxicity concerns of aluminum under acidic conditions, sodium aluminate (a base) and alum (an acid) are added as a buffer to soft water lakes. This prevents the pH from dropping below the lower end of the acceptable range (i.e., 6.0), which can result in widespread fish kills. The ratio typically used for alum and sodium aluminate is 2:1 by volume. This ratio is appropriate for Lake Campbell because it is a soft water lake. Sodium aluminate is expensive and adds a lot to the cost of an alum treatment. Sodium aluminate is usually not needed, even in soft water lakes, for low dose (less than 5 mg Al/L) water column stripping applications that do not include sediment inactivation.

Under the Aquatic Plant and Algae Management General Permit, a jar test must be completed prior to whole lake treatments only if a buffer other than sodium aluminate is used or if a ratio of liquid alum to liquid sodium aluminate differs from 2:1 by volume. Furthermore, monitoring under S6.B of the permit is required. This includes the following:

- One surface water pH measurement must be taken in the morning, prior to any alum addition, and one surface water pH measurement 1 hour after alum addition has stopped for that day. These measurements may partially fulfill the permit conditions in S6.B.1.c.
- The Permittee must monitor pH for the duration of the treatment and for 24 hours following treatment completion. For continuous monitoring, measurements must be taken at intervals no longer than 15 minutes. The monitoring location must be representative of waterbody-wide conditions. If the pH decreases to less than 6.2, the Permittee must stop the treatment, analyze for alkalinity, and take immediate steps to increase the pH.
- For continuous injection treatments, the Permittee must measure pH at a minimum once every 2 weeks during the first month of continuous injection and thereafter once a month for the duration of the injection process. The Permittee must ensure that pH measurements represent waterbody-wide conditions, unless the injection system is in an isolated area in relation to the main waterbody

(e.g., in a bay with a narrow channel to the main waterbody). For isolated areas of waterbodies, the Permittee must measure pH at the end of the bay and in the main waterbody.

- When performing any treatment using alum, the permittee must monitor for aluminum in the waterbody according to the following procedures:
- Before the alum treatment, permittees must take water samples to establish a baseline for the following metrics:
  - pH
  - Dissolved organic carbon (DOC)
  - Total hardness (as $CaCO_3$)
- Water samples must be representative of the treatment area, with at least one shoreline sample and one open water sample.
- The latitude and longitude coordinates of water sample locations must be recorded in decimal degrees. Pre- and post-treatment water samples must be taken from the same locations.
- During the alum treatment, pH must be monitored continuously.
- Immediately after the alum treatment, the permittee must take water samples and test them for aluminum concentration. This measurement must include both total recoverable aluminum and dissolved aluminum.
- The permittee must take water samples to test for total recoverable aluminum, pH, DOC, and hardness 2 weeks after the treatment.
- The permittee must take water samples to test for total recoverable aluminum, pH, DOC, and hardness once per month for the 2 months following the alum treatment.
- The permittee must take water samples to test for total recoverable aluminum, pH, DOC, and hardness quarterly until one year after the alum treatment date.
- Reporting Aluminum Monitoring Data: The permittee will send all aluminum monitoring data to the Department of Ecology within 30 days of each sampling event. Permittees do not need to take any further action after measuring and reporting the results of these water samples.

Additionally, under the permit, an onsite storage facility is required for any treatment requiring 9,000 gallons of alum or more, or the project proponent must have a plan to store any unused alum or buffering products.

Table 2. Comparison of Alum Treatment Doses in Washington.					
Lake (County)	**Treatment Date**	**Volumetric Dose (mg Al/L)**	**Aerial Dose (g Al/m^2)**	**Longevity (years)[a]**	**Reference**
Heart Lake (Skagit)	April 2018	12.9	32.1	>5	Herrera 2019
Lake Campbell (Skagit)	October 1985	10.9	26	>8	Cooke et al. 2005
Lake Erie (Skagit)	September 1985	10.9	20	>8	Cooke et al. 2005
Lake Ketchum (Snohomish)	May 2014 March 2015 Annual 2016-2023	19 19 NP	66.5 66.5 NP	NA unknown --	G. Williams/M. Burghdoff (pers. comm.)
Lake Stevens (Snohomish)	Annual 2013-2020	0.15 per year	NP	unknown	Tetra Tech 2022
Long Lake (Kitsap)	September 1980 September 1991 August 2006 April 2007 April 2019	5.5 5.5 2.5 17.5 NP	10.7 10.7 4.6 36.2 NP	>11 >11 <1 NP TBD	Rydin et al. 2000 Rydin et al. 2000 Tetra Tech 2010 Tetra Tech 2010 S. Brattebo (pers. comm.)
Lake Ballinger (King)	June 1990	5.0	6.5	unknown	Rydin et al. 2000
Phantom Lake (King)	September 1990	4.2	9.5	unknown	Rydin et al. 2000
Hicklin Lake (King)	April 2005	22	NP	3	King County 2006
Lake Fenwick (King)	October 2023 (planned)	11.7	NP	unknown	S. Brattebo (pers. comm.)
Long Lake (Thurston)	September 1983 2008 (planned)	7.7 15.2	27.7 54.9	5 unknown	Cooke et al. 2005 Tetra Tech 2006
Green Lake (King)	October 1991 April 2004 April 2016	8.6 24 8.2	34 94 32	3 >10 >8	Herrera 2003 Herrera 2004 Herrera 2016
Pattison Lake (Thurston)	September 1983	7.7	30.8	7	Cooke et al. 2005
Black Lake (Thurston)	April 2016 May 2021	1.9 54.5	13 317	>5 unknown	Herrera 2017a Herrera 2021
Wapato Lake (Pierce)	July 1984 July 2008 April 2017	7.8 67.7 56.3	11.7 108 90	<1 5 >6	Cooke et al. 2005 Herrera 2017b Herrera 2018
Waughop Lake (Pierce)	March 2020 July 2020 July 2023	40 40 20	NP NP NP	unknown	Tetra Tech 2023
Liberty Lake (Spokane)	1980-1981	NP	NP	NP	B. Adams (pers. comm.)
Medical Lake (Spokane)	Aug.-Sept. 1977	12.2	83.5	unknown	Rydin et al. 2000
Newman Lake (Spokane)	May 2021	NP	NP	NP	S. Brattebo (pers. comm.)

[a] Longevity reported by reference or observed through 2023.

mg Al/L = milligrams of aluminum per liter

g Al/m^2 = grams of aluminum per square meter

NA = not applicable

NP = Not provided

Advantages

- Instantaneous water column phosphorus control
- Long-term, stable sediment phosphorus control
- Floc rapidly settled to bottom
- Promotion of water clarity
- Cost-effective and widely successful

Disadvantages

- Potential impacts of aluminum toxicity to aquatic organisms (however, extensive use of a buffer and monitoring in our region has minimized this risk)
- Sediment phosphorus monitoring required for accurate dosage calculations
- Limited effectiveness when watershed load is dominant

Suitability for Lake Campbell

Alum treatment would be a suitable management method to inactivate available phosphorus in Lake Campbell because of the high internal loading rate throughout the season. Alum is comparable in cost to lanthanum-modified clay but typically has greater longevity because it is applied at rates with a higher phosphorus binding capacity than lanthanum-modified clay. The 1985 alum treatment of Lake Campbell (and Lake Erie) showed long-lasting control of phosphorus algae blooms in the lake, lasting through at least the mid-2000s.

Planning Level Costs

Planning level costs for water column stripping and sediment inactivation with alum are provided in the *Planning Level Comparison for Phosphorus Inactivation* subsection at the end of this section.

Lanthanum Treatment

Lanthanum (La^{3+}) has a strong affinity for phosphate (PO_4^{3-}), such that it chemically inactivates phosphate through precipitation and forms a mineral of extremely low solubility. Therefore, similar to alum, it permanently binds the phosphorus. Lanthanum is available for application in lakes as lanthanum-modified bentonite (LMB), which is applied as a slurry using either Phoslock or EutroSORB. Bentonite is an adsorbent swelling clay commonly used as drilling mud. Unlike alum, however, LMB is not a coagulant and therefore does not trap and remove particles in the water column. Rather, LMB works mainly in the sediment to bind phosphate that would normally be released to the water through decomposition or changes in sediment chemistry. The lanthanum in LMB binds only to inorganic phosphate (soluble reactive phosphorus or orthophosphate) and does not address organic phosphorus until it degrades to phosphate. LMB can be applied in frequent small does to 'strip' the water column of inorganic phosphorus. Although alum treatment effectiveness and duration has been much better studied (see Cooke et al. 2005), there are many Phoslock and a few EutroSORB studies published to date worldwide (see Copetti et al. 2016). Kitsap Lake, in Bremerton, Washington, has undergone annual lanthanum treatments with notable improvements in water quality and no closures during the high lake use periods of June through August.

Lanthanum concentrations immediately following application may exceed estimated toxicity thresholds, particularly for zooplankton, and little study has been done for impacts on benthic organisms (Copetti et al. 2016). Generally, because lanthanum is applied in phosphorus-rich waters, the amount of free lanthanum ions is low as they bind to phosphate. Jar tests prior to application can be used to ensure proper dosage.

Phoslock® is the tradename of the original commercially available LMB product that was developed in Australia in the 1990s. EutroSORB® is an LMB product developed over the past few years by SeaPRO®, a major manufacturer of lake management chemicals. Currently, there are three formulas of EutroSORB® used for sediment inactivation (EutroSORB® G), water column stripping (EutroSORB® G), and filtration of flowing waters (EutroSORB F). EutraSORB® WC has an undisclosed ingredient(s) to flocculate particulate phosphorus that is evaluated in the next section on *Proprietary Product Treatment*.

Advantages

- Permanently inactivates phosphorus water column and/or sediment
- Remains effective and non-toxic under all pH and oxygen conditions

Disadvantages

- Temporarily increases turbidity from clay
- Requires monitoring for accurate dosage calculations
- Has fewer case studies to evaluate effectiveness and duration of treatments compared to alum
- Has limited effectiveness when watershed load is dominant

Suitability for Lake Campbell

Lanthanum treatment would be a suitable management method to remove available phosphorus in Lake Campbell. Phoslock and EutroSORB G are currently permitted for use in Washington and are best used for sediment inactivation lasting one to several years. However, either of these products could be applied to strip phosphate from the water column with some additional product to inactivate phosphate released from recent sediments over a 1-year period.

In waterbodies with low alkalinity (< 20 mg $CaCO_3$/L), a jar test must be completed prior to treatment to identify proper dosing levels. Data from the mid-1980s indicate that Lake Campbell is likely sufficiently alkaline with measured in-lake alkalinity ranging from 38 to 94 mg $CaCO_3$/L, but additional sampling is recommended to confirm.

Planning Level Costs

Planning level costs for Phoslock and EutroSORB G are provided in the *Planning Level Comparison for Phosphorus Inactivation* subsection at the end of this section.

Proprietary Product Treatment

There are several proprietary formulations available on the market that provide binding sites for dissolved phosphorus in the water column and produce floccules that will pull particulates, including algae and sediment, from the water column. In this way, the products act similarly to alum.

Currently available products include EutroSORB WC, produced by SePRO, and MetaFloc, produced by Naturalake Biosciences. Both manufacturers claim that their products do not impact water chemistry (including pH) and have low toxicity to aquatic life and humans, but no case studies are as-of-yet available to support these claims.

Advantages

- Permanently inactivates phosphorus in the water column and/or sediment

Disadvantages

- Monitoring required for accurate dosage calculations
- Few case studies to evaluate effectiveness and duration of treatments
- Limited effectiveness when watershed load is dominant
- Uncertain stability and toxicity impacts, assumed to be similar to alum and lanthanum

Suitability for Lake Campbell

There is no available information to support the claims of the manufacturers, regarding the effectiveness and low ecological impacts. However, if the claims hold true, these products could be effective alternatives to alum (which as toxicity and pH concerns) and LMB (which does not remove particulate phosphorus).

The above-described proprietary products are not currently approved in the Washington State Department of Ecology's Aquatic Plant and Algae Management Permit. As such, an experimental application permit would need to be obtained for treatment in Lake Campbell. This would likely entail thorough monitoring before, during, and after application.

Planning Level Costs

Planning level costs for MetaFloc and EutroSORB WC are provided in the *Planning Level Comparison for Phosphorus Inactivation* subsection at the end of this section.

Calcium Application

Calcium is applied to lakes in the form of lime (CaO, $CaCO_3$, $Ca(OH)_2$) or calcite ($CaCO_3$). Lime addition mimics natural calcite ($CaCO_3$) precipitation in hard water lakes that strips phosphorus from the water column. CaO and $Ca(OH)_2$ addition in water increases aqueous pH and facilitates the formation of $CaCO_3$. Direct addition of $CaCO_3$ is deemed beneficial because it precipitates and then reacts with dissolved orthophosphate in the water column. Calcium applications are generally not effective in soft water lakes present in western Washington. There is so little background calcium that the applied amount is not sufficient to precipitate phosphorus as was demonstrated in Lake Steilacoom (Herrera 2009).

Under the Aquatic Plant and Algae Management General Permit, a jar test must be completed prior to treatment to identify proper dosing levels. This jar test needs to be conducted at least over a 24-hour period to ensure that the pH response is at equilibrium with water chemistry. Furthermore, monitoring under S6.B of the permit is required. This includes the following:

1. The Permittee must measure pH once on the day before treatment, once in the morning prior to treatment and once in the afternoon after treatment has stopped for the day, for the duration of the treatment and for 24 hours following treatment. If the pH is above 9.0 due to the effects of the treatment (rather than through photosynthesis), the Permittee must stop treatment.
2. For continuous injection systems, the Permittee must measure pH at a minimum once every 2 weeks during the first month of continuous injection and thereafter once a month for the duration of the injection process. The Permittee must ensure that pH measurements represent waterbody-wide conditions, unless the injection system is in an isolated area in relation to the main waterbody (e.g., in a bay with a narrow channel to the main waterbody). For isolated areas of waterbodies, the Permittee must measure pH at the end of the bay and in the main waterbody.

Advantages

- Short-term removal of available phosphorus from water column

Disadvantages

- Possible limitation to provide only short-term improvements due to the redissolution of precipitating $CaCO_3$ as it settles in deep waters
- Potential to cause high pH in the water column
- Limited effectiveness in soft water lakes
- Limited effectiveness when watershed load is dominant

Suitability for Lake Campbell

Alternative phosphorus inactivation treatments are expected to be more effective due to the lake's frequent elevated pH, which can allow dissolution of bound phosphorus.

Iron Application

Iron treatment is a relatively inexpensive control strategy (Matthijs et al., 2016) added to aquatic systems within the water column or sediment surface in the form of chloride and sulfate salts, such as $FeCl_3$, $FeCl_2$, and $Fe(SO_4)_3$, or as zero valent iron (ZVI). Iron used to coagulate dissolved phosphorus is sensitive to potential redox changes, in that ferric iron (Fe^{3+}) freely precipitates phosphorus in oxygenated conditions. In anoxic conditions, however, ferric iron is reduced to ferrous iron (Fe^{2+}), and the binding capacity with orthophosphate declines. This results in release into the aqueous phase. As a result, iron applications are often done in combination with hypolimnetic oxygenation methods.

ZVI is a form of iron typically used in soil and groundwater remediation efforts to bind chemical contaminants by transferring an electron to a contaminant compound. Contaminants in groundwater that have been inactivated by ZVI include petroleum hydrocarbons, pesticides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and nitrates.

ZVI has also been added experimentally to rural wastewater treatment systems where sewage strength was low. In these systems, ZVI additions helped enrich bacteria biofilms and prevent blooms of filamentous cyanobacteria, even under conditions without additional aeration treatments (Wang and Li 2022). However, primary sewage treatment requires at least basic oxygenation. This suggests that ZVI is ineffective under anoxic conditions. ZVI could become effective, if applied in combination with hypolimnetic oxygenation methods, or if ZVI was applied as a modified clay composite like bentonite (Sarkar et al. 2019). Lake Lorene in Federal Way, Washington, is frequently treated with algaecide followed by ZVI applications to inactivate soluble phosphorus released by dead algae.

Under the Aquatic Plant and Algae Management General Permit, a jar test must be completed prior to treatment to identify proper dosing levels.

Advantages

- Removes soluble reactive phosphorus from water column and from shallow sediments in the epilimnion (and deep sediments if hypolimnion remains oxygenated)
- Not expected to have environmental impacts at anticipated dosage

Disadvantages

- Phosphorus bound to iron in lakes and reservoirs can be resuspended due to dissolution in anoxic conditions
- Limited effectiveness when watershed load is dominant

Suitability for Lake Campbell

Lake Campbell's sediments become anoxic during the summer. The application of iron to sequester water column phosphorus is therefore not expected to be effective, because much of the phosphorus bound to iron would settle and be released while there is heightened oxygen demand at the lake sediments. Furthermore, the iron-phosphate bonds are weakened during high pH, and the phosphorus may be released. Such anoxic conditions develop by microbial decomposition of high organic matter content or under dense aquatic plant canopies.

The Aquatic Pesticide and Algae Management Permit issued by the Washington Statement Department of Ecology specifically states the following, regarding iron:

> *Do not apply where anoxic conditions (zero percent dissolved oxygen) may occur, including anoxic conditions created by applications of herbicide and algaecide.*

Planning Level Comparison for Phosphorus Inactivation with Alum, Lanthanum, and Proprietary Products

Approximate dose and cost estimates were prepared for the inactivation of phosphorus for water column stripping and sediment inactivation, using alum, lanthanum, and proprietary blends under current conditions with an anoxic hypolimnion for comparison to the cost for hypolimnetic oxygenation. These doses are based on available data for phosphorus in the water column and sediments. They are expected to last approximately 5 years based on continued moderate amounts of watershed and groundwater phosphorus loading. Table 3 provides the dosing and cost assumptions used for developing estimates.

Table 3. Assumptions for Dose and Cost Estimates for Phosphorus Inactivation Chemicals.

Approach	Ratio to Phosphorus	Cost per Unit
Alum (Buffered with Sodium Aluminate)	20 Al : 1 P (by mass)	Alum: $2.00/gal; Buffer: $5.10/gal
Alum (Unbuffered)	20 Al : 1 P (by mass)	$2.00/gal
Lanthanum (EutraSorb G; 10% La))	50 product: 1 P or 5 La : 1 P (by mass)	$3/kg
Lanthanum (Phoslock; 5% La)	100 product: 1 P or 5 La : 1 P (by mass)	$6.6/kg
Proprietary Blend – MetaFloc	1.3 gallons : 1 kg	$75/gal
Proprietary Blend – EutroSORB WC	1.28 gallons : 1 kg	$200/gal

Water stripping doses were developed assuming (1) that 159 kg of phosphorus in the water column would inactivate in the first year of treatment (2025) and (2) that subsequent phosphorus levels for treatment would be 25 percent lower (119 kg). Table 4 provides cost estimates for water stripping using unbuffered alum, lanthanum modified bentonite (Phoslock and EutroSORB G), and proprietary products (MetaFloc and EutroSORB WC). An unbuffered dose of alum is appropriate due to the low alum dose required for only water column stripping (dose of 0.9 mg/L Al; 2.1 g Al/m^2). The assumptions include a contractor fee of $50,000 for mobilization and application, and a consultant fee of $50,000 for monitoring and oversight. A 15 percent contingency is included.

Table 4. Water Phosphorus Stripping Cost Estimates.

Phosphorous Inactivation Product	Application Dose	Materials Cost	Mob/ Application	Tax (9.25%)	Oversight, Monitoring	Contingency (+15%)	Total Year 1 Cost	Total Year 2 Cost
Unbuffered Alum	14,446 gal	$30,337	$50,000	$7,712	$50,000	$13,207	**$151,257**	**$141,698**
PhosLock	15,891 kg	$104,880.26	$50,000	$14,869	$50,000	$25,462	**$245,211**	**$212,163**
Eutrosorb G	7,945 kg	$23,836.42	$50,000	$7,088	$50,000	$12,139	**$143,063**	**$135,553**
MetaFloc	454 gal	$34,086.09	$50,000	$8,072	$50,000	$13,824	**$155,982**	**$145,242**
Eutrosorb WC	447 gal	$89,497.82	$50,000	$13,392	$50,000	$22,933	**$225,823**	**$197,622**

Sediment inactivation doses were estimated based on an average sediment mobile phosphorus concentration of 474 mg/kg-DW and a treatment area of 1,550,000 m^2 (the entire lake area) to inactivate 1,037 kg of phosphorus in sediments to a depth of 10 centimeters. The sediment inactivation doses include water column stripping of 159 kg. The alum should be buffered due to the higher aluminum dose (7.9 mg/L Al; 18.0 g Al/m^2). The estimated cost of sediment inactivation ranged from $667,281 for EutroSORB G to $2.5 million for Phoslock (Table 5).

Table 5. Sediment Phosphorus Inactivation and Water Column Stripping Cost Estimates.

Phosphorus Inactivation Product	Application Dose	Materials Cost	Mobilization + Application	Tax (9.25%)	Oversight, Monitoring	Contingency (+15%)	Total
Buffered Alum	55,773 gal alum 27,886 gal buffer	$256,556	$50,000	$29,429	$50,000	$50,398	$436,383
PhosLock	293,167 kg	$1,934,900	$50,000	$190,550	$50,000	$326,318	$2,551,768
EutroSORB G	146,583 kg	$439,750	$50,000	$47,016	$50,000	$80,515	$667,281
MetaFloc	8,385 gal	$628,843	$50,000	$65,169	$50,000	$111,602	$905,613
EutroSORB WC	8,256 gal	$1,651,115	$50,000	$163,307	$50,000	$279,663	$2,194,085

The longevity of sediment inactivation treatments is dependent on the control of external loading and stability of the bonds between the inactivation chemical and sediment phosphorus. We have developed ranges of costs for a 20-year period assuming a longevity of 5, 10, and 20 years including a 3.5 percent escalation per year (Table 6). Sediment inactivation treatments are expected to last longer for alum than lanthanum because the phosphorus binding capacity is four times greater for alum (20 Al: 1 P) than lanthanum (5 La; 1P) (see Table 3). We have also estimated the cost of annual water stripping.

Table 7 provides a high-level summary and comparison of the evaluated water column inactivation chemicals suitable for Lake Campbell.

Table 6. Estimated Long-Term Cost of Phosphorus Inactivation through Water Stripping or Sediment Inactivation.

Phosphorus Inactivation Chemical	Annual Water Stripping	Single Sediment Inactivation Treatment (20-year Longevity)	Two Sediment Inactivation Treatments (10-year Longevity)	Three Sediment Inactivation Treatments (5-year Longevity)
Buffered Alum	–	$436,000	$1,050,000	$2,300,000
Unbuffered Alum	$3,890,000	–	–	
PhosLock	$5,840,000	$2,550,000	$6,150,000	$13,460,000
EutroSORB G	$3,720,000	$670,000	$1,610,000	$3,520,000
MetaFloc	$3,980,000	$910,000	$2,180,000	$4,780,000
EutroSORB WC	$5,430,000	$2,190,000	$5,290,000	$11,570,000

Table 7. Comparison of Water Column Phosphorus Inactivation Chemicals.

Water Column Inactivation Method	Alum	Lanthanum	Proprietary Blend
Commercial Products	Available from general chemical suppliers	Phoslock EutroSORB G	MetaFloc EutroSORB WC
Mode of Inactivation	Forms stable complexes with dissolved phosphorus. Forms floccules that pull particulate phosphorus (i.e., algae and sediment from the water column. Stable at pH 6 to 9.	Forms stable complexes with dissolved phosphorus. Binding efficiency is highest between pH 5 and 7. Dissolution may occur at elevated pH levels (>9).	Form complexes with dissolved phosphorus. Most blends include a floccule agent that, like alum, will pull particulate phosphorus (i.e., algae and sediment from the water column.
Application Approach	Applied at water surface and settled to the sediment. Alum is expected to sink and incorporate into the lake sediments.	Applied as lanthanum modified bentonite or as lanthanum salt across the waters surface. Expected to incorporate into the lake's sediments.	Applied at water surface and settled to the sediment.
Potential Negative Consequences	Aluminum toxicity to aquatic life may occur if inadequate buffer is applied and the pH is outside permitted range of 6-8.5. This can be prevented through rigorous planning and monitoring as required by the permit.	Lanthanum concentration immediately following application may exceed estimated toxicity thresholds, particularly for zooplankton, and little study has been done for impacts on benthic organisms. Generally, because lanthanum is applied in phosphorus-rich waters, the amount of free lanthanum ions is low as they bind to phosphate. Jar tests prior to application can be used to ensure proper dosage.	The specific make-up of the blends is proprietary. If alum and lanthanum blend, then the same potential impacts and toxicity prevention approaches.
Permitting	Alum is an approved phosphorus inactivation chemical in the APAM permit.	Lanthanum is an approved phosphorus inactivation chemical in the APAM permit.	Ecology must be allowed to confirm that the chemicals in the product are already approved or an experimental application permit must be obtained.
Water Stripping Estimated Cost for 2025	$151,000 (unbuffered alum)	$143,000 (EutroSORB G) $245,000 (Phoslock) (note these will only strip *dissolved* phosphorus)	$156,000 (MetaFloc) $226,000 (EutroSORB WC)
Long-term 20-year Water Stripping Cost	$3.9 million	$3.7 million (EutroSORB G) $5.8 million (PhosLock)	$4.0 million (MetaFloc) $5.4 million (EutroSORB WC)
Sediment Inactivation Estimated Cost for 2025	$436,000 (buffered alum)	$667,000 (EutroSORB G) $2,550,000 (Phoslock)	$906,000 (MetaFloc) $2,194,000 (EutroSORB WC)
Long-term 20-year Sediment Inactivation Cost	$0.4 to $1.1 million	$0.7 to $1.6 million (EutroSORB G) $2.6 to $6.2 million (PhosLock)	$0.9 to $2.2 million (MetaFloc) $2.2 to $5.3 million (EutroSORB WC)
Recent Past Applications	Black Lake, Tumwater, Washington (2021) Waughop Lake, Lakewood, Washington (2020) Heart Lake, Anacortes, Washington (2018) Wapato Lake, Tacoma, Washington (2017) Green Lake, Seattle, Washington (2016)	Kitsap Lake, Bremerton, Washington (2020 – [annually]) Lake Lorene, Federal Way, Washington (2012)	No published case studies or management plans

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Beaver Dam / Lake Level Management

Beaver dams play important ecological roles in shaping freshwater ecosystems. Beaver activity may conflict with human interests in some locations. Their presence at the outlet of a lake, such as Lake Campbell can have significant implications for water quality, particularly in terms of phosphorus accumulation and algae blooms. The presence of a beaver dam at the lake's outlet may have the following impacts:

- Reduction of lake surface outflow and increase in lake level
- Potential increase of subsurface water (groundwater) level around the lake increasing hydraulic connectivity from septic system drain fields (if present)
- Increase in lake nutrient retention due to decrease in lake outflow
- Flooding of the nearshore of the lake
- Downstream flooding impacts in the case of dam failure

Beavers provide ecological benefits by storing water and creating unique wetland habitats. Stored water may filter down into the water table and recharge groundwater. This stored water can also support summer stream flows, preventing streams from going dry. Beaver ponds are habitat for many insect, bird, amphibian, mammal, and fish species. Beavers are ecosystem engineers because they create, modify, and maintain habitat and ecosystems. They consequently have a large impact on the biodiversity of an area. They bring wood into the water, and that wood provides food and shelter for insects. Those insects become food for other species, including salmon. The insides of beaver lodges provide homes for other animals such as muskrats, mink, and even river otters. Some birds nest on top of their lodges. And fish take cover in the woody parts of the lodges that are in the water. Beaver dams slow down water, and the water and wood in the ponds provide different habitat types all in one place.

King County (2017) identified a suite of beaver management tools and developed a summary matrix.[1]

Acceptance

Acceptance is defined as "is simply to appreciate the beavers for all the benefits they provide, and leave them alone if they are not causing problems" (King County 2017)

Advantages

- Continued ecological benefit
- "Natural" solution
- No management costs (onsite)

[1] https://kingcounty.gov/en/legacy/services/environment/animals-and-plants/beavers/-/media/services/environment/animals-and-plants/beavers/Beaver_management_matrix_KingCount_9-6-19.ashx?la=en&hash=8ADBDB87C58162C34785AB99F5BABAF8

Disadvantages

- Issues may continue to persist.
- Risk of downstream flooding impacts if dam failure

Tree Protection

Beavers use as trees as a food source and for dam and lodge building materials. Restricting access to trees can reduce the suitability of the dam location for beavers and support relocation. Methods include:

- Fencing/barriers
- Tree painting
- Intentional tree planting with non-desirable trees shrubs (for restoration projects)

Advantages

- Relatively low cost

Disadvantages

- Will not cause immediate relocation
- May not be effective if suitable food and wood source alternative are nearby
- Relocation may shift impacts further downstream and shift the location of property conflicts.

Dam Manipulation / Removal

For both beaver dam notching (removing the top layers of the dam) and complete removal, the effective lifetime before the beaver repair or rebuild the dam is expected to be brief, on the order of 0.5 to 4 days. As such these are short-term solutions that will result in increased vegetation removal from the riparian area. Tree and shrub protection measures may be employed to deter harvest and potentially prevent reconstruction.

Advantages

- May be done in conjunction with beaver removal
- May be done with hand tools alone

Disadvantages

- In older, established ponds, dam removal can result in sediment behind the dam moving downstream, which can result in fish kills.
- Removing dams results in loss of habitat for many fish and wildlife species.

Level Management Devices

Pond levelers are used to control the height of water behind a beaver dam to prevent flooding (King County 2017). Levelers are designed to transport water through a dam in such a way that the beaver does not detect the flow of water through the dam and therefore does not instinctively do all it can to block the flow. Flows from storm events flow over the top of the dam, so the pipes do not need to be sized like road culverts, and after the storm, water levels return to normal via the pond leveler. Some pond levelers have been trademarked. Pond levelers are generally installed in ponded locations where water depth is sufficient to submerge the upstream end of the pipe along the pond bottom beyond the depth of most normal beaver activity (Figure 1).

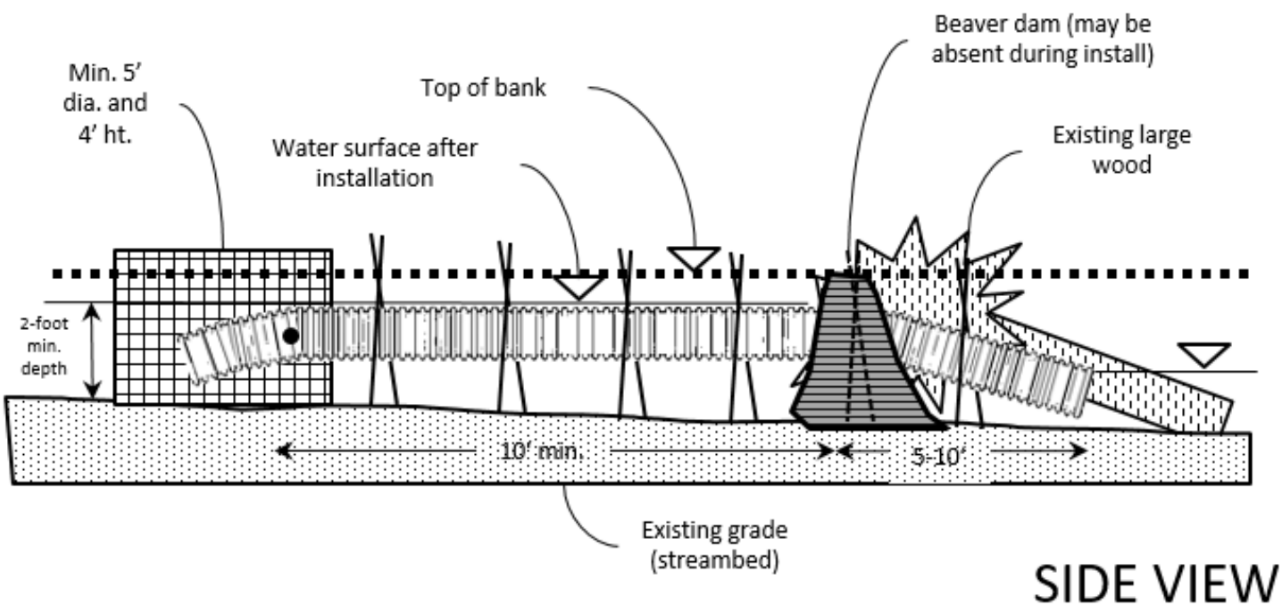
Advantages

- When properly designed and functioning, they can support long-term co-existence.

Disadvantages

- Levelers are only effective if the reduced upstream water level is acceptable to the beaver. If too low, the beaver may go up or downstream and rebuild a new dam.

Figure 1. Schematic of a Flexible Pond Leveler™.



Beaver Removal

Beaver removal (trapping) may be done by a licensed trapper, and the beavers may be relocated or euthanized. Eventually, beavers will recolonize the location. The beaver is classified as a furbearer (WAC 232-12-007). A trapping license and open season are required to trap or shoot a beaver recreationally. When combined with dam removal, beaver removal can reestablish previous water levels and provide an opportunity to establish level management devices (King County 2017).

Advantages

- Provides a period of time (2 to 18 months) to install lake level management devices and adjust the habitat area to prepare for new beaver arrivals

Disadvantages

- Hiring a trapper can be expensive.
- Must also remove dam

Suitability for Lake Campbell

Beaver management is a suitable management approach in Lake Campbell to maintain desirable lake levels and reduce nutrient retention in the lake. Jen Vanderhoof (beaver expert at King County Water and Land Resources Division) recommended the following management options: (1) Acceptance; or (2) Fence off high-quality shrubs and trees at the outlet and do either of the following: remove dam or install leveling device (J. Vanderhoof, pers. comms.).

External Loading Control Methods

The annual phosphorus budget for Lake Campbell indicates that watershed sources of phosphorus primarily are primarily via the Erie Lake outlet and groundwater inflow.

Septic System Management

Conventional septic systems offer little treatment or reduction of phosphorus, except the settling of solid-bound phosphorus to the bottom the septic tank. Concentrations in effluent range from 1 to 26 mg/L (1,000 to 26,000 µg/L) (McCray et al. 2005). Phosphorus is treated or removed by soils in the drain field after leaving septic tank as effluent. Within a properly sized drain field, phosphorus will undergo mineralization, bind (adsorb) to soil particles, and be taken up by plants. A particular issue for lakes is the presence of septic systems, along the immediate perimeter, which may have critically undersized drain fields in shallow, pervious soils that do not offer the binding sites and residence time necessary for phosphorus removal. For this reason, septic systems are not allowed to be installed within 100 feet of a lake in Washington and within up to 300 feet in other states.

The effectiveness of soils and underlying aquifer materials in attenuating P movement to subsurface and surface water depends upon a number of factors including: the soil chemical and physical properties, the chemical properties and loading rate of the wastewater, site hydrology, proximity of the site to surface water, and the design and management of the onsite sewage disposal system (McCray et al. 2005).

Advanced septic system technology has shown promise for removing phosphorus in areas with limited drain field area or highly pervious soils. A pilot study at Newman Lake in Spokane County, Washington, installed membrane bioreactor treatment systems and measured the ability to reduce phosphorus, nitrogen, and other wastewater constituents. These systems can treat up to 97.9 percent nitrogen, 98.1 percent phosphorus, and 99.99 percent fecal coliform bacteria (Morrison Maierle 2022).

The cost of the membrane bioreactor systems is not trivial. In the Newman Lake pilot study, two models were installed (Morrison Maierle 2022). For a single residence, initial equipment costs ranged from $27,500 to $44,000, with an annual maintenance contract of $500. Cost can vary substantially based on existing site conditions and electrical capacity. The lifespan of the installed systems is estimated at 25 to 35 years. The average cost to install a conventional septic system in Washington State is $15,500, but this also varies widely and depending on many factors (https://www.nexgenseptics.com/).

Failing septic systems farther away from the lake and streams may also contribute substantial phosphorus to the lake via stream base flow and groundwater. Because proximity is the greatest factor, we recommend that inspections for failing or inadequate systems prioritize residences located adjacent to the lake and streams.

Techniques such as septic system function assessment, microbial source tracking, and nutrient source tracing should be used to assess cost-effective source-control actions, regardless of their immediate impact to lake phosphorus loading by septic systems in the watershed.

Advantages

- Reduces phosphorus loading to the lake in the long term
- Maintains and upgrades critical individual wastewater infrastructure

Disadvantages

- Costly
- Will not provide immediate relief

Suitability for Lake Campbell

We recommend taking actions to identify existing septic systems that may be contributing disproportionate loads of phosphorus to Lake Campbell. These include failing systems that are no longer functioning per their initial design and systems that do not have adequate local conditions to remove phosphorus. Systems that appear to be working can still be contributing phosphorus loading to the lake. Failing systems may be identified via operation and maintenance inspections by certified professionals. Important factors for improperly sited systems and drain fields are distance to a nearby lake or stream, depth to the water table, and soil chemistry.

We recommend encouraging septic system owners throughout the watershed to complete routine inspections, as required by state law. Additionally, we recommend evaluating higher risk systems that are located around the lake or along streams to evaluate if adequate treatment is provided. In locations where the systems are not adequate, advanced treatment systems (ATUs) may be necessary. For instance, membrane bioreactor systems treat wastewater before discharge to the drain field and therefore do not necessitate the full drain field treatment area. The installation of such technology must be permitted by Skagit County Health Department, per WAC 246-272A. We recommend coordination with Skagit County Health Department and the State Department of Health, to develop a pathway for upgrading septic systems that do not have adequate drain field areas or soil treatment.

Replacing septic systems can be very expensive (up to $20,000 to $40,000), depending on the location and installation constraints. However, there are numerous grants and low-interest loans available that may ease the upfront investment. This includes Craft3 Clean Water Loans, a low-interest loan program.

Planning Level Costs

Septic system inspections and enforcement should be performed by Skagit County at an enhanced rate, as time and funding allow. Skagit County Health Department should also identify how to allow and promote upgrading of septic systems that do not have adequate drain field areas or soil treatment. Funding of County Health Department activities and new septic systems are not included in this LCMP.

Stormwater Management

Stormwater runoff can also be an important pathway of nutrients to surface water and groundwater. Fertilized areas, domestic animals, wildlife, and erosion of soils and organic matter contribute phosphorus to stormwater runoff. Stormwater management seeks to treat or infiltrate runoff from impervious and pollutant-generating surfaces prior to discharge to lake. External phosphorus reductions may be achieved through source control and stormwater treatment. Source control can include reduction in phosphorus-containing fertilizer use, identification and removal of illicit sewage connections, pet waste management, and erosion control. Stormwater treatment can include detention facilities, rain gardens, and regional treatment facilities. Stormwater management that reduces peak flows entering streams will also reduce streambank erosion. Lake management plans can be used to declare a lake as sensitive to phosphorus inputs and require new developments to install stormwater treatment systems that are designed to remove phosphorus not just suspended solids.

Advantages

- Reduces phosphorus loading to the lake in the long term
- Reduces other pollutants (e.g., metals)

Disadvantages

- Expensive, low cost-effectiveness
- Does not address immediate bloom issues

Suitability for Lake Campbell

The Lake Campbell watershed has a modest level of residential and roadway development. Opportunities to install small phosphorus treatment systems in areas currently without stormwater treatment and to retrofit existing facilities to provide treatment could be explored.

Lake Erie Management

Outflows from Lake Erie are an important source of phosphorus to Lake Campbell. Efforts to reduce nutrient inputs to Lake Erie (both internal and external loading) will benefit both lakes. Development of recommendations for Lake Erie management is beyond the scope of this project.

Advantages

- Reduces phosphorus loading to the lake in the long term
- Improves water quality in Lake Erie

Disadvantages

- Expensive, low cost-effectiveness on a large scale
- Does not address immediate algae bloom issues

Shoreline Management

Over the years, people altered the lakeshore by removing trees and dead wood from the shorelines and by building bulkheads. Concrete or rock wall bulkheads negatively impact fish and wildlife habitat. They can accelerate erosion of shallow lake sediments by increasing wave energy, which can fuel cyanobacteria growth by suspending sediment nutrients.

Best management practices for lake shorelines include healthy shoreline alternatives that use native plants, beaches, and wood to protect houses while improving habitat for fish and wildlife, views, and recreational opportunities. Healthy shoreline alternatives are designed to create a more gradual sloping shoreline and overhanging vegetation to provide protected, shallow water habitat needed by fish and a food source for native birds and wildlife. Healthy shorelines are simply lake edges planted with shrubs, trees, or perennials instead of lawn to the water's edge (Snohomish County 2023; see example planting plan). These plants have lots of benefits over lawn, including the following:

- Have deeper roots that trap and filter up to nine times more phosphorus
- Stabilize the shoreline, preventing erosion
- Provide great habitat and food for birds, turtles, frogs and other beneficial aquatic life
- Can add beauty to your shoreline and potentially increase property values
- Need little maintenance once established

Benefits of healthy shorelines for property owners include the following:

- Reduced lake sediment erosion
- Reduced wave-induced sediment nutrient recycling and cyanobacteria growth
- Reduced Canada geese activity and droppings on property
- Easier access to beach and water
- Shallow gradient shorelines are often favored over steeper designs, especially if you have small children
- More usable shoreline with beach and cove
- Reduced maintenance
- Potential for increased property values
- Many shoreline management actions may also reduce attractiveness to waterfowl, described in the previous section.

Advantages

- Reduces phosphorus loading to the lake in the long term
- Improves lake habitat quality

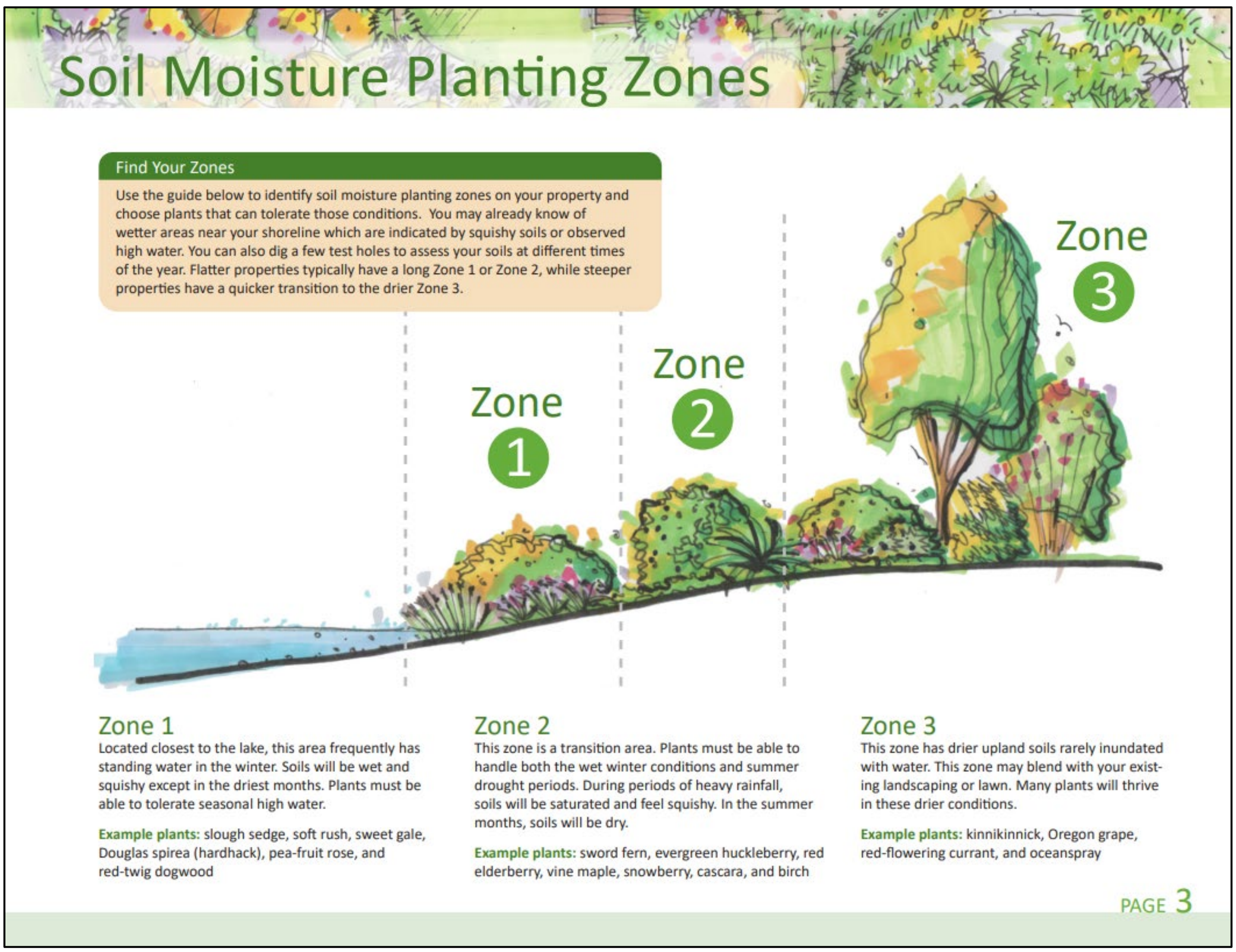
Disadvantages

- Expensive, low cost-effectiveness on a large scale
- Does not address immediate algae bloom issues

Suitability for Lake Campbell

Developing a healthy shoreline program to promote and fund replacement of bulkheads and lawns with native plants is a suitable management action to reduce nutrient inputs and cyanobacteria growth in Lake Campbell. Snohomish County Surface Water Management runs a program, LakeWise, to encourage lake stewardship through lawn and yard care, septic system care, and healthy shorelines. The program provides online outreach materials (see example in Figure 2). Lake Campbell manager may take advantage of these material, adapting them for use in Lake Campbell.

Figure 2. LakeWise Shoreline Planting Guide Excerpt.



Methods Rejected

We rejected several management and restoration methods for Lake Campbell due to high cost and/or low certainty in success. Rejected methods and rationale for rejection are described in the sections below and summarized below in Table 8.

Table 8. Rejected Management/Restoration Methods for Lake Campbell.

Management Method	Rationale for Rejection
Aquatic Plant Harvesting	Risk of spreading Eurasian milfoil infestation. Diver assisted removal is cost-prohibitive.
Hypolimnetic Oxygenation and Aeration	Lake weakly stratifies. Sediment release appears to primarily driven by elevated pH rather than low dissolved oxygen
Stream Phosphorus Inactivation	Expensive; risk of toxicity; relative watershed contribution is low.
Sonification	Low confidence in success
Ozone/Microbubble/Nanobubbles	Low confidence in success
Dredging	Very expensive, difficult to permit
Lake Mixing	Expensive, low confidence in success
Biological Control (biomanipulation, barley straw, macrophytes)	Potential for unintended ecological consequences. Low confidence in success.
Calcium or Iron Application	Less effective than other phosphorus inactivation methods.

Aquatic Plant Harvesting

Aquatic plants take up nutrients from the sediments and water within a lake. Mechanical harvesting of aquatic plants involves the removal of excessive plant biomass from lakes using specialized equipment such as harvesters and cutters. Aquatic plants store significant amounts of nutrients in their tissues. By removing excess plant biomass, mechanical harvesting helps to remove these nutrients from the lake.

Mechanical Harvester

A mechanical harvester is similar to a lawn mower positioned on a barge. This machine can mow aquatic plants and bring them onto the boat. This method will not remove plant roots but will harvest a large amount of plants in a small amount of time. These plants can grow back within a few weeks, thus requiring multiple harvesting events over the course of a growing season. Harvesters must be cleaned before entering the lake, as they are often hired to mow lakes with invasive populations, and fragments of these plants can cause infestations in other lakes.

Suction Harvesting

A dredging device or suction harvester will suck up plants, ensuring removal of root fragments. Divers operate a hose attached to a dredge to suck up the entire plant from the sediment. The suction hose dredges up the plant, as well as sediment and water. The contents of the hose are deposited onto a fine screen that holds the plants while filtering out the water and sediment. Usually, the sediment and water is returned to the lake, behind an area sectioned off from the rest of the lake by a sediment curtain. After the sediment behind the curtain settles, the curtain is removed. Plant material remains in the screen and is not returned to the water. Dredging or suction harvesting will require permits, including an HPA from WDFW, a Section 404 permit from the US Army Corps of Engineers, and additional local permits.

Advantages

- This method quickly removes large amounts of plants from the lake.
- Habitat for fish can be maintained if plants are not cut too short.
- Harvesting can target areas of the lake.

Disadvantages

- Mechanical harvesting of some aquatic plants, like Eurasian milfoil, can result in fragmentation and spread of the infestation. Diver dredging is expensive.
- Requires continual monitoring and management
- Plants grow back and may need to be harvested multiple times within a season.
- A large amount of plant material will be generated, and it will need a place to dry out on shore or be hauled away to a disposal facility.

Suitability for Lake Campbell

In 1986, 581 tons (wet) of aquatic plants were harvested from 58 acres of Lake Campbell's nearshore. The primary target of harvest was *Ceratophyllum* (coontail). They used an Aquamarine harvester and shore conveyer. It was estimated that aquatic plants contribute about 11 percent of the phosphorus budget to the lake (for WY1982). The removal was estimated have removed 60 kg of phosphorus.

Currently, under the IAVMP, submerged aquatic plants (i.e., Eurasian milfoil (*Myriophyllum spicatum*)) are treated with triclopyr or diquat and emergent plants (i.e., water lily and spatterdock) are treated with a 1% solution of imazapyr. Following treatment, the decaying plant material may release nutrients into the water column.

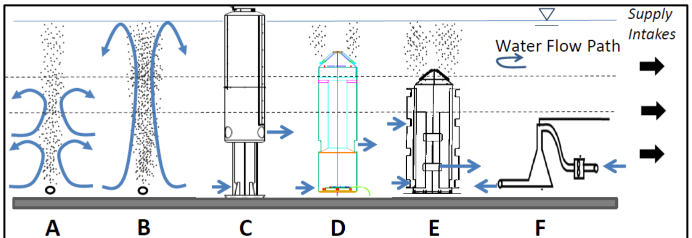
Physical removal of Eurasian milfoil is challenging, because Eurasian milfoil may spread through fragmentation. Mechanical harvesting may actually spread and worsen the infestation. Diver assisted suction harvesting has successfully been used to remove the plant with fragmentation. However, this management approach is time-intensive and expensive, and low water clarity in the lake increases the difficulty.

Efficient cost-effective removal of aquatic plants from Lake Campbell is not feasible in consideration of the risk of spreading milfoil and the high cost of diver assisted removal.

Hypolimnetic Oxygenation and Aeration

Hypolimnetic oxygenation or aeration techniques are implemented to combat hypolimnetic anoxia by maintaining or increasing DO levels in the hypolimnion while preserving thermal stratification. Hypolimnetic oxygenation uses pure oxygen, whereas hypolimnetic aeration uses air to maintain oxygen levels. Maintaining oxygenated conditions in the hypolimnion transfers oxygen into the underlying surficial sediments to suppress the release of phosphorus and nitrogen from sediments, settled particulate matter, and groundwater inflow. Maintaining stratification reduces the mixing of nutrient-rich hypolimnion water to the epilimnion.

Hypolimnetic aeration/oxygenation systems typically involves the installation of diffuser tubes or plates on the lake bottom to inject air or oxygen into the bottom of the hypolimnion. A vertical structure is needed to carry the released bubbles and associated water up to the top of the hypolimnion (partial lift) or epilimnion (full lift). Once there, bubbles are released at the lake surface and the aerated water is discharged near the lake sediments. A summary of lakes where hypolimnetic oxygenation or aeration have been deployed is provided in Table 9.



Schematic Diagrams of Aeration and Oxygenation Techniques

A variety of apparatus is available for managing thermal stratification and respiration in water supply reservoir systems. Some prevent stratification. Some adjust the location of the thermocline to expand epilimnetic mixing depth or establish high quality layers at the elevation of a raw water intake. Some add oxygen to the hypolimnion without changing stratification.

A. Line Diffuser with Low Enough Gas Flow to Maintain Stratification
B. Line Diffuser with High Enough Gas Flow to Prevent Stratification
C. Traditional Full-Lift Hypolimnetic Aeration
D. Submerged Partial-Lift Hypolimnetic Aeration
E. Depth-Selective Layer Aeration
F. Conical Oxygen Contactor, A.K.A. "Speece Cone".

Modified from: Moore, et.al, 2015

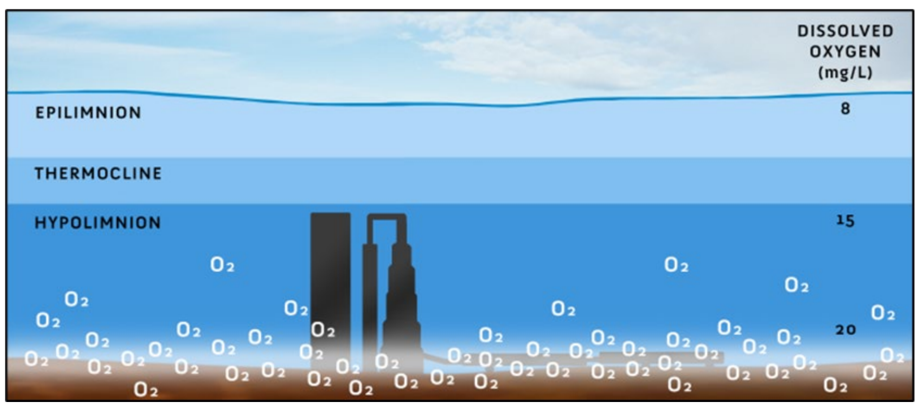
Table 9. Hypolimnetic Oxygenation and Aeration System Examples.

Lake, Location	Install Year	Lake Characteristics	System	Effect on Phosphorus Release	Source
Newman Lake Spokane County, Washington	1992 (renovation planned as of 2022)	Mean depth = 5.8 m Max depth = 9.1 m Area = 490 ha	Hypolimnetic oxygenation with Speece Cone and alum emitter	Decrease in lake phosphorus concentrations	Moore et al. 2012
Stevens Lake Snohomish County, Washington	1994 (retired in 2012)	Mean depth = 20.5 m Max depth = 46 m Area = 421 ha	Hypolimnetic aeration	Reduced sediment phosphorus. Decrease in effectiveness in final years attributed to saturation of iron-binding sites for phosphorus	Snohomish County and TetraTech 2012
Lake Fenwick Kent, Washington	1994 (renovated in 2020)	Mean depth = 4.0 m Max depth = 9.4 m Area = 9 ha	Hypolimnetic aeration	Not evaluated.	Ecology 2002
Falling Creek Reservoir Vinton, Virginia	2013	Mean depth = 4.0 m Max depth = 9.3 m Area = 11.9 ha	Hypolimnetic oxygenation with Oxygen Saturation Technology	Increased DO and maintained thermal stratification. Decrease in hypolimnion TP and SRP during operation	Gerling et al. 2014
Sarah's Pond Orleans, Massachusetts	2021	Mean depth = 3 m Max depth = 5.3 m Area = 2.3 ha	Hypolimnetic oxygenation with Oxygen Saturation Technology	Reduction in sediment phosphorus release. Decreased effectiveness due to electrical service shutdown and expanded anoxic area due to hot weather.	Wagner 2022

See Preece et al. 2019 for an expanded list of hypolimnetic oxygenation systems.

Generally, the cost of installing a hypolimnetic aeration system can range from hundreds of thousands to millions of dollars. Importantly, the cost of the system is not a one-time expense. It requires ongoing maintenance to ensure it operates efficiently. The maintenance cost can include electricity bills for running the system, periodic cleaning and replacement of diffuser membranes, and inspection of the system components. For example, the hypolimnetic aeration system installed in Lake Stevens in Snohomish County in the 1990s ultimately failed. Now algae blooms in that lake are being controlled by alum treatments. Installation and operating costs for that system over a 10-year period was $1,240/hectare/year (Cooke et al. 2005), or about $5 million for 10 years in a 421-hectare lake. A hypolimnetic aeration system was installed in Lake Fenwick, a 22-acre lake in King County, and recently this system was upgraded at a cost of $900,000.

Oxygen Saturation Technology (OST) is a relatively new, patent-pending innovation used to administer precise concentrations of oxygen at strategic depths in a waterbody, also known as side-stream supersaturation (SSS). The OST's design eliminates bubbles, which eliminates turbulence, sediment resuspension, and undesirable mixing. These systems can maintain dissolved oxygen (DO) levels as high as 20 mg/L directly over and into the sediments, where oxygen is needed most. They may also help prevent oxygen-related fish mortality. These high dissolved oxygen levels (exceeding those from simple saturation with the air) are important to overcome the high oxygen demand of organic-rich sediments in eutrophic lakes. Traditional hypolimnetic aeration systems can fail because they do not meet the sediment oxygen demand.



An OST system functions by transporting approximately 95 percent pure oxygen from an onshore facility to an in-lake device where the water is supersaturated with oxygen. The water is then injected back into deep areas of the lake where it disperses over the sediment surface. The oxygenated water can coat and penetrate the sediments, preventing the release of phosphorus from iron-phosphate complexes and allowing the oxidized iron to bind to phosphate released by microbial decay of organic matter. The onshore facility consists of a compressor and an oxygen generator. There is no storage of oxygen on premises.

Advantages

An oxygenation system would have the following advantages:

- Reduces phosphorus release from anoxic sediments
- Increases deep water oxygen, improves fish habitat and aquatic life uses
- Degrades organic matter and cyanotoxins faster by using aerobic microbes
- Is a non-chemical alternative

In addition to these advantages, new oxygen saturation technology (OST) pumping oxygenated water to and from hypolimnion is very promising for small lakes and is cheaper than traditional oxygenation systems.

Disadvantages

An oxygenation system would have the following disadvantages:

- May potentially resuspend sediment layer nutrients/ions in the water column
- Causes sedimentation of organic matter
- Requires installation and operational cost (electricity)
- Is ineffective in shallow lakes/ reservoirs with a large surface area (i.e., weak to no stratification)
- May require continuous operation
- Can be ineffective when external nutrients are not controlled

Suitability for Lake Campbell

Hypolimnetic oxygenation is a not suitable management technique for Lake Campbell because (1) pH is believed to be the primary driver of sediment nutrient release and (2) the lake is too shallow and does not support strong thermal stratification.

Algaecides

Algaecides provide short-term algae control by killing the algae and cyanobacteria in the water column. However, algaecides may affect other aquatic biota to varying degrees and accelerate recycling of nutrients. Algaecides are effective only while the active ingredient is in the water column and available for uptake by the algae (Cooke et al. 2005). Typically, two or more applications must occur within the same season to provide effective control of algae and cyanobacteria throughout the season. Algaecides do not reduce phosphorus or nitrogen concentrations and do not provide long-term control. In fact, they increase recycling of phosphorus and decrease dissolved oxygen from algae decay.

Currently, endothall (e.g., Hydrothol® 191) and sodium carbonate peroxyhydrate (e.g., PAK 27 or Phycomycin) are the only algaecides permitted for use in the State of Washington. The primary algaecide utilized in Washington State is sodium carbonate peroxyhydrate. When applied to the lake, this compound breaks down into hydrogen peroxide and sodium carbonate. The hydrogen peroxide oxidizes and thus kills the target algae. After contact, the hydrogen peroxide breaks down harmlessly into water and oxygen. When properly applied at a low rate, this algaecide is selective for cyanobacteria, which are lacking a cell wall, and does not harm many of the more beneficial green algae that are protected by a cell wall. When sodium carbonate peroxyhydrate is applied in accordance with directions on the label, no harm is expected to birds, other terrestrial animals, freshwater fish, or freshwater invertebrates (EPA 2011).

Sodium carbonate peroxyhydrate can also be used to kill *E. coli* and other fecal coliform bacteria that often cause beach closures due to waterfowl droppings and other fecal sources. Small peroxyhydrate treatments limited to the waters in the vicinity of a closed beach can be used to reduce *E. coli* counts to levels below the threshold for public safety closures.

Advantages

- Rapid water quality improvement
- Inexpensive management option
- Sodium carbonate peroxyhydrate algaecides:
  - Have no use restrictions and are non-toxic to wildlife.
  - Oxidize intra-cellular cyanobacteria toxins and also kill fecal bacteria.
  - Can be applied at low rates to not impact most beneficial green algae.
  - Rapidly degrade into water and oxygen.
  - Do not accumulate in the environment.

Disadvantages

- Sodium carbonate peroxyhydrate algaecides:
  - Are effective short-term only, while the active ingredient is in the water.
  - May affect non-target plants or other aquatic organisms, if not applied according to the label.
  - Do not reduce nutrients and can accelerate recycling of nutrients.
  - Typically require more than one application within the same season for effective control.
  - May require a 24-hour swimming restriction (for Hydrothol 191 but not sodium carbonate peroxyhydrate) and can have possible toxic effects to fish.
  - Require a permit and licensed applicator.

Suitability for Lake Campbell

Algaecides are not a cost-effective tool for cyanobacteria management, because they only work for a short time. Since blooms are difficult to predict, there may be logistical challenges in mobilizing a contractor rapidly enough to provide treatment. An algaecide treatment may only lessen a bloom for as little as 2 days. In addition to the higher costs, relying on algaecides as a sole management strategy would have negative ecological consequences.

Under certain situations, sodium carbonate peroxyhydrate treatments may be suitable for short-term treatment of the entire lake or for impacted swim beaches and isolated areas of scum accumulation. Lake residents are accustomed to using herbicides for aquatic plant control, and they are not likely to object to the use of algaecides. Sodium carbonate peroxyhydrate has no use restrictions or aquatic toxicity. When applied at a low rate, it primarily oxidizes cyanobacteria and cyanotoxins rather than beneficial green algae.

Planning Level Costs

The cost for the material and application of sodium carbonate peroxyhydrate treatment is approximately $250 per acre. A single whole-lake treatments would cost approximately $97,500. However, multiple treatments may be required in a single year. Assuming two to four treatments per year, the cost of algaecide-only management would be $200,000 to $400,000 per year.

Stream Phosphorus Inactivation

Phosphorus inactivation products can be applied at the mouth of streams or stormwater outfalls entering a lake to inactivate phosphorus prior to it becoming available for lake algae. Systems that pump aluminum-based inactivating compounds into an inflow pipe, ditch, or stream have become more widespread (Pilgrim and Brezonik 2005, Wagner et al. 2017). In some cases, a retention pond is provided to capture aluminum floc before it enters the lake, whereas in others the floc is allowed to enter the lake and settle onto target sediments where further P inactivation can occur. Due to high installation and operating costs, alum injection is most effective for large volumes of water that a system either conveys from a large drainage area or stores in a large basin (EPA 2021).

An alum injection system could be designed for lake inlet(s) that injects low doses of alum through tubing from onshore storage tanks to an aeration or circulator system mounted in the stream bed for through mixing of the alum with stream waters. A flow-weighted dosing system would be used that adjusts the dose with stream flow and may be integrated with a water quality monitoring system to measure pH or other parameters to terminate treatment exceeded programmed thresholds. A buffer such as sodium hydroxide or aluminate can be added but is not likely needed for low doses, mixed systems, and pH feedback mechanisms.

Alternatively, lanthanum-modified clay or zero valent iron can be used to inactivate stream phosphorus in lake inlet(s). Porous bags can be filled with either product and placed in the bottom of the stream channel and may require installation of a hard substrate to prevent them from sinking in soft stream sediment. The bags are turned on one occasion before they are replaced when they are expected to become ineffective based on the phosphorus loading rate relative to the amount of inactivation product.

Advantages

- Reduces phosphorus loading to the lake long-term

Disadvantages

- Alum could impact aquatic biota from aluminum toxicity if the pH is outside 6.5-8.5.
- Ecology may not permit alum injection in a stream without containment and removal of the alum floc.
- It requires routine O&M and has an annual operating cost.

Suitability for Lake Campbell

Stream phosphorus inactivation with an alum injection system is not suitable for Lake Campbell because placement and operation at any of the lake inlets would be difficult, presents a risk for aluminum toxicity to aquatic organisms under extreme pH conditions (less than 6 or greater than 8.5), may not be allowed by Ecology without a floc retention system, and the relative contribution of stream phosphorus input to the lake is low. Stream phosphorus inactivation with filter bags of lanthanum-modified clay or zero valent iron is not suitable for Lake Campbell because the bag replacement would be labor intensive and difficult to predict, and the relative contribution of stream phosphorus input to the lake is low.

Sonification

Sonication treatment implements high frequency (>20 Khz) ultrasound for the control of cyanobacterial blooms. The ultrasonic waves act as a barrier to upward movement of algal cells into the photic zone. The waves also reduce cyanobacterial growth by causing structural and functional cellular damage. The LG Sonic system continuously monitors cyanobacteria pigments and water quality parameters to systematically transmit ultrasonic waves when conditions warrant. There are few well-studied implementations of sonication systems and reports are largely anecdotal with highly variable results. In a recent review, Luring and Mucci (2020) concluded that low-frequency ultrasound should be avoided, as it is ineffective; high-frequency treatment is more effective, but it is costly due to energy demand, and its effective range is limited.

Advantages

- Permanent control
- Some devices provide real-time data on lake quality.

Disadvantages

- Few lake case studies to confirm effectiveness; results have been variable
- May cause cell lysis, and increase extracellular cyanotoxin levels
- Benthic blooms may still occur.
- Limited by the effective treatment radius
- Requires a permanent contract for monitoring

Suitability for Lake Campbell

Sonification treatment in Lake Campbell is not recommended due to the low certainty of success.

Ozone, Microbubbles, and Nanobubbles

Ozone is a strong oxidant that is majorly employed in water treatment for pre-oxidation to control natural organic matter to minimize the formation of disinfection by-products. Studies have shown its ability to damage cyanobacteria cells (Coral et al., 2013; Fan et al., 2013; Wert and Rosario-Ortiz 2013) while simultaneously oxidizing cyanotoxins and taste and odor compounds (Meriluoto et al., 2017; Wert et al., 2014). Ozone application for managing blooms at the source may be promising but is limited by structural and safety requirements that make for a complex application. Furthermore, the efficiency of aqueous ozone oxidation is restricted by rapid decay rates.

Microbubbles (diameter 10–50 µm) and nanobubbles (<200 nm) have attracted increasing scientific attention in recent years. Due to their small diameters, these tiny bubbles have low rising velocities in the aqueous phase, high internal pressures, and rapid mass transfer rates that can significantly improve gas solubility (Atkinson et al., 2019; Hu and Xia, 2018; Li et al., 2014).

Nanobubble aeration uses compressed gas (e.g., air, ozone, carbon dioxide) to produce nanobubbles (bubbles 2,000 times smaller than a grain of salt) to aerate the water column. The key advantage of using nanobubbles versus traditional aeration technologies is that the very small bubbles move both vertically and horizontally, spreading out evenly and remaining in the water column for long periods of time (versus floating to the surface and dispersing), and therefore this technology greatly increases oxygen transfer. Another advantage is that the bubbles are too small to cause water currents and disrupt a stable thermocline. Bubbles are typically injected near the sediment surface, thus reducing phosphorus release from the sediments without physically disturbing the sediments, which can occur from traditional aeration systems. The high oxygen transfer rate and resultant oxidation (through creation of ozone and other oxidative compounds) has been shown to breakdown algae cells and degrade toxins.

Advantages

- Very small bubbles spread out evenly and remain in the water column for long periods of time (versus floating to the surface and mixing water column).
- Greatly increases oxygen transfer and benefits aquatic life uses
- Reduces phosphorus release from sediments
- Breaks down algae cells and degrades toxins
- Easily scalable modular units
- Low/no design costs

Disadvantages

- Requires supply of compressed gas (e.g., air, ozone, carbon dioxide)
- Few case studies to evaluate effectiveness and duration of treatments with some recent reports of ineffective systems
- New technology with many companies; specifications and costs vary

Suitability for Lake Campbell

Ozone, microbubbles, or nanobubble are not recommended for Lake Campbell due to the limited information on effectiveness and the initial investment cost.

Dredging

Dredging is a technique that can be used to control phosphorus levels in lakes. The process involves removing sediment and organic material from the bottom of the lake, which can contain significant amounts of phosphorus that have accumulated over time. By removing this material, the amount of phosphorus in the lake can be reduced, which can help to prevent the growth of harmful algal blooms and promote better water quality.

Dredging can be a complex and costly process that requires specialized equipment and expertise. The process typically involves the use of a dredge, which is a machine that is designed to scoop up sediment and other material from the bottom of the lake. The material is then transported to a dewatering site to remove excess water and then to a disposal site, where it can be treated or stored for later use. Dredging is very expensive primarily due to costs associated with dewatering and disposal of the material. Alum may be used to settle suspended sediment and associated phosphorus suspended by dredging and to inactivate phosphorus in remaining sediments.

Advantages

- Removal of sediment as a phosphorus source
- Increased lake depth, causing reduced aquatic weed entanglement risk and improving recreational uses

Disadvantages

- Difficulty to permit
- Prohibitive expense ($ millions)
- Impacts to aquatic life
- Temporary increased turbidity
- Temporary public use disturbance

Suitability for Lake Campbell

Dredging is not suitable for Lake Campbell due to its high cost.

Lake Mixing

The key objective of lake aeration or mixing technologies is that the circulating or mixing motion of the water is also circulating and mixing algae cells. Most bloom-forming cyanobacteria can regulate their buoyancy to optimize their position in the water column and float to the surface. Mixing promotes growth of preferred algae such as green algae and diatoms because under natural conditions their time in the sunlit photic zone is determined by their sinking rate, so mixing increases their time in the photic zone. Cyanobacteria have air vacuoles that provide buoyancy and allow them to remain within the photic zone for longer periods of time. Aeration or mixing reduces this advantage, although to do so requires that mixing velocities need to be high enough to overcome cyanobacteria buoyancy, which can vary and be difficult to predict.

While cyanobacteria concentrations may be reduced, total algal biomass and chlorophyll-a concentrations may increase and green the water from the decreased settling rates. Whole-lake mixing by aeration disrupts the thermocline and increases nutrient availability by mixing deep waters to the surface. These technologies also introduce oxygen either passively through increased mixing and turbulence of surface waters or more actively through pumping air through the water. These changes in algal community populations and oxygen levels result in other changes in the lake food web.

Surface Mixing (SolarBees)

The SolarBee is a solar-energy–driven, mixing device that is used to mix either the epilimnion or the entire lake volume. Like other mixing devices it controls algae through mixing them throughout the water column (Hudnell et al. 2010). Although no air is pumped into the water, additional oxygen is added through turbulence and increased contact with air above the lake surface. Surface mixing is theorized to combat cyanobacteria dominance by (1) increasing contact with cyanobacteria pathogens, predators, and bacteria that lyse cyanobacteria; (2) promoting competitor algae; and (3) interfering with the advantages of buoyancy-regulating cyanobacteria (Hudnell et al. 2010).

There are no significant design costs or issues associated with these; they are modular units that are easily scalable depending upon lake surface area. While SolarBees appear to primarily be used in small lakes and ponds, there have been successful applications in larger lakes, reservoirs, and drinking water supplies.

Advantages

- SolarBees have no long-term energy costs because they are solar-powered.
- Can sink algae to below the photic zone, decreasing productivity
- Mixing systems can mix either epilimnion or entire water column.
- Can give advantage to diatoms and other beneficial algae that can't control their buoyancy
- Easily scalable modular units
- Low/no design costs

Disadvantages

- Epilimnetic mixing does not address sediment-derived phosphorus.
- Few case studies for epilimnion mixing
- Can increase algae biomass and decrease water clarity by reducing settling rate of non-buoyant algae
- Often insufficient oxidation of sediments to reduce sediment phosphorus release

Suitability for Lake Campbell

Surface mixing with a SolarBee unit is not expected be an effective tool to manage cyanobacteria in Lake Campbell.

Whole-Lake Mixing

Artificial circulation and mechanical mixers have been successfully used in lakes and reservoirs as physical controls to increase oxygen concentrations in bottom waters and to destratify the water column to remove the optimal habitat for buoyant cyanobacteria.

The two most common types of destratification are air injection and mechanical mixing (Hudson and Kirschner 1997). Air injection is a “bottom-up” approach that quickly pumps air to the bottom of the lake so that it will rise and carry the water from the hypolimnetic layers to the top layer. Mechanical mixing uses a “top-down” approach wherein a rotating propeller in the surface layers pushes the water downward, displacing bottom waters to the surface, where they are reoxygenated by the atmosphere. Popular commercially available models are powered by solar panels. Although artificial circulation is beneficial for oxygen and nutrient redistribution, the ecological effects on plant and animal life of destratifying a lake are not always predictable and could potentially be harmful (Hudson and Kirschner 1997).

Advantages

- Permanent control by both mixing and oxygenation
- Depending upon design may also target sediment derived phosphorus
- Many lake applications for case studies for whole-lake mixing

Disadvantages

- Resuspension of sediment layer nutrients in the water column
- Sedimentation of organic matter
- Installation and operational cost
- Ineffective in shallow lakes/ reservoirs with a large surface area
- May require continuous operation

- Can be ineffective when external nutrients are not controlled
- These need to be carefully designed and engineered. Poorly sized or designed applications can worsen problems.
- Larger mixing systems require shore based electrical supply and long, air supply line.

Suitability for Lake Campbell

Whole-lake mixing is not recommended for Lake Campbell because of its high cost and high uncertainty in its ability control the internal phosphorus load.

Biomanipulation

This method involves increasing the pressure on phytoplankton communities by reducing or removing planktivorous fish (Shapiro, 1990; Shapiro and Wright, 1984) or by increasing grazers and zooplankton populations (Ger et al., 2014; Kâ et al., 2012). By increasing pressure on phytoplankton, the goal is to reduce their populations through increased consumption by other feeders. Biomanipulation can also involve removal of common carp or other benthivorous fish to reduce phosphorus loading from sediment disturbance and fish excretion. Removal of zooplanktivorous and benthivorous fish and the addition of piscivores are the most frequently applied biomanipulation methods.

Some species of cyanobacteria are more resistant to grazing pressures from zooplankton. Cell/colony/filament size, toxicity, and poor nutritional value are defense mechanisms against grazing (Moustaka-Gouni and Sommer 2020). Grazers may fail to feed if cyanobacterial species, especially filamentous species, can surpass the optimal size range for food based on grazer body size.

Advantages

- Potential for long-term benefits
- No chemical residuals

Disadvantages

- Uncertainty of success
- Does not address nutrient issues
- May remove desirable fish species (e.g., trout)

Suitability for Lake Campbell

Biomanipulation is not recommended for Lake Campbell because of the uncertainty of success.

Macrophytes

Submerged macrophytes can control cyanobacteria through three main processes: (1 macrophytes compete with phytoplankton for nutrients, taking up nutrients from the sediments, and can prevent resuspension of sediments during rainfall and wind events; (2) macrophyte coverage provides habitat for zooplankton grazers of cyanobacteria; and (3) some macrophytes secrete allelochemicals that are inhibitory to phytoplankton.

Advantages

- Potential for long-term benefits
- No chemical residuals
- Increased fish habitat

Disadvantages

- Uncertainty in ideal macrophyte coverage
- Relatively minor nutrient control
- Does not address external nutrient loads
- Macrophytes may not be desired by shoreline homeowners

Suitability for Lake Campbell

Aquatic plant management is an ongoing effort in Lake Campbell with a history of herbicide treatment. Mapping efforts have shown substantial macrophyte coverage in the shallow areas of the lake, and despite this, cyanobacteria blooms have occurred. Based on this observation, it is not anticipated that increasing macrophyte growth in the lake would be an adequate management method for cyanobacteria in Lake Campbell. However, developing an IAVMP is an important tool for managing aquatic plants, especially following control of phosphorus and cyanobacteria, which will likely benefit macrophytes and can lead to their excess growth.

Straw

Applying straws such as barley and rice straws in lake systems is considered an alternative cyanobacterial control strategy. The mode of action of barley straws for cyanobacteria control is not entirely understood and has been a subject of much debate. However, various researchers have indicated that the release of allelopathic compounds during the aerobic decay of straws is a potential mechanism for controlling algae. Barley straws do not provide immediate improvements in water quality. The decomposition of straws may create an oxygen demand in the water column. Therefore, successful application may require oxygen-rich systems as low oxygen levels can slow or hinder the straws from releasing algal inhibitory substances.

Advantages

- No chemical residuals
- Rotting straw may provide habitat for invertebrates
- Low cost

Disadvantages

- Do not provide immediate relief
- Inhibitory action is not understood
- May reduce lake oxygen levels due to decomposition
- May be a visual or boating nuisance
- Does not address nutrient issues

Suitability for Lake Campbell

The use of straws is not recommended for Lake Campbell due to the low certainty in success.

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Appendix D

Supplementary Funding Options

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Table D-1. Lake Campbell Cyanobacteria Management Plan – Potential Supplementary Funding Options.							
Name	**Funder or Administrative Agency**	**Award Range**	**Target Purpose**	**Required Applicants or Lead Entities**	**Match Requirement**	**Notes**	**Resource URL**
National Estuary Program's Coastal Watersheds Grant Program	Restore America's Estuaries, US EPA	$75K–$250K	Protect/restore water quality or ecological integrity coastal or estuarine habitat	Public agencies (federal, state, tribal, intertribal, regional water pollution control, etc.), non-profits, local governments, academic institutions, for-profit organizations.	33% (25% total cost), but ability to request full or partial waiver	Projects within specific geographic areas (including Lower Columbia River and floodplains) following Congressionally set priorities (see list online; includes recurring HABs). Awarded annually to 3 to 10 awardees.	https://estuaries.org/coastal-watershed-grants/
Aquatic Invasive Plants Management Grants	WA Ecology	Depends on project: up to $30K–$75K	Aquatic invasive plants management activities (e.g., mapping/inventory, IAVMP development, public education, plant control activities, pilot projects, evaluation of implementation, and follow-up monitoring)	State agencies, counties, cities, special purpose districts, tribes	25%, or 12.5% if early infestation grant	Funds originate from boat trailer registration fees. Lower match % and higher grant total for early Infestation grants.	https://ecology.wa.gov/About-us/Payments-contracts-grants/Grants-loans/Find-a-grant-or-loan/Aquatic-Invasive-Plants-Management-Grants
Stormwater Capacity Grants Program	WA Ecology	Set biennially based on state budget	Stormwater projects	Phase I and Phase II NPDES municipal permittees	None	Noncompetitive; activities and equipment necessary for permit installation	https://ecology.wa.gov/About-us/Payments-contracts-grants/Grants-loans/Find-a-grant-or-loan/Stormwater-capacity-grants
Stormwater Grants of Regional or Statewide Significance (GROSS)	WA Ecology	≤$300K	Stormwater projects	Phase I and Phase II NPDES municipal permittees	None	Competitive; assist permittees in completing projects that will benefit multiple permittees	https://ecology.wa.gov/About-us/Payments-contracts-grants/Grants-loans/Find-a-grant-or-loan/Grants-of-regional-or-statewide-significance
Water Quality Combined Funding Program	WA Ecology	Varies	Single-application process for all funding sources at once- eligible projects benefit water quality	Varies	Varies	Funds from: CWA Section 319 grants, Centennial Clean Water Program grants, Clean Water Act State Revolving fund (CWSRF), stormwater financial assistance program (SFAP)	https://ecology.wa.gov/About-us/Payments-contracts-grants/Grants-loans/Find-a-grant-or-loan/Water-Quality-grants-and-loans
Salmon Recovery Funding Program	WA State Conservation Commission, funded by state legislature	Unclear	Protect/restore riparian habitats and streams for salmon while maintaining agricultural viability	conservation districts (can be partnered with other entities, and/or landowners for cost-share)	NA	New in 2022, encourages incentive programs with landowners' involvement in riparian restoration projects; projects must be in riparian areas, instream projects must support riparian projects.	https://www.scc.wa.gov/salmon-recovery-program
Land and Water Conservation Fund-State Program	WA Recreation and Conservation Office	$200K–$2M	Develop outdoor recreation resources (parks, trails, wildlife lands) – available to all communities	local agencies, special purpose districts, tribes, state agencies	50%	Eligible projects: certain types of land acquisition, development/renovation of parks; applicants MUST have a comprehensive recreation or conservation plan.	https://rco.wa.gov/grant/land-and-water-conservation-fund/
Land and Water Conservation Fund-Legacy Program	WA Recreation and Conservation Office	$300K–$9.85M	For urban communities to buy/develop land for parks/recreation; priority to disadvantaged areas	local agencies, special purpose districts, tribes, state agencies	50%	Eligible projects: certain types of land acquisition, development/renovation of parks; applicants MUST have a comprehensive recreation or conservation plan.	https://rco.wa.gov/grant/land-and-water-conservation-fund/
Salmon Recovery & Puget Sound Acquisition and Restoration (PSAR) Grants	WA Recreation and Conservation Office	No maximum	Restore degraded salmon habitat and protect existing, high-quality habitat (including actual habitat used by salmon and land/water supporting salmon processes);	Local agencies, special purpose districts (port, park, conservation, school), tribes, state agencies, private landowners, nonprofits, regional fisheries enhancement groups	15%	The grant program for both salmon recovery and PSAR grants are run together and generally have the same requirements. PSAR program is to help implement habitat protection/restoration in the Puget Sound only, co-managed by the Partnership.	https://rco.wa.gov/grant/salmon-recovery/

Table D-1 (continued). Lake Campbell Cyanobacteria Management Plan – Potential Supplementary Funding Options.							
Name	**Funder or Administrative Agency**	**Award Range**	**Target Purpose**	**Required Applicants or Lead Entities**	**Match Requirement**	**Notes**	**Resource URL**
Pacific Coastal Salmon Recovery Fund	NOAA	≤$25M	Salmon recovery	Western US states, federally recognized tribes of the Columbia River and Pacific Coast	Yes (amount unclear)	Funds many other grants	https://www.fisheries.noaa.gov/grant/pacific-coastal-salmon-recovery-fund
Aquatic Lands Enhancement Account	WA Recreation and Conservation Office	≤$1M	Aquatic lands improvement	WA agencies or tribes may apply	50%	Usually awarded at $500k for acquisition, improvement, or protection of aquatic lands for public purposes; or to provide or improve public access to the waterfront.	https://rco.wa.gov/grant/aquatic-lands-enhancement-account/
WWRP – Farmland Preservation	WA Recreation and Conservation Office	No maximum (*but see note)	To buy development rights on farmlands to ensure they remain available for farming, and restore natural functions to improve land's viability for farming	Cities, counties, nonprofit nature conservancies, State Conservation Commission	50%	*Stewardship plans not to exceed $10k; restoration elements may not exceed half of total land acquisition costs	https://rco.wa.gov/grant/washington-wildlife-and-recreation-program-farmland-preservation/
WWRP – Forestland Preservation	WA Recreation and Conservation Office	≤$500K	Conserve land for timber, wildlife, public access. Used to lease or buy voluntary land preservation/conservation agreements to restore forests and/or ensure they remain available for timber production in the future.	Cities, counties, nonprofit nature conservancies, State Conservation Commission	50%	Commonly used with conservation easement/lease to restore stream corridors to support clean water/fish habitat. Eligible forests: industrial, private, community, tribal, publicly owned forests of contiguous 5+ acres devoted primarily to timber production and enrolled in a county's open space or forestland property tax program.	https://rco.wa.gov/grant/washington-wildlife-and-recreation-program-forestland-preservation/
WWRP – Habitat Conservation (includes 3 categories)	WA Recreation and Conservation Office	Varies by category (e.g., no cap, ≥$25k request, and/or ≤$1M)	Conserve natural areas/wildlife habitat, improve/acquire recreation areas	Cities, counties, towns, tribes, nonprofit nature conservancies, special purpose districts, port districts (and other political subdivisions), state agencies	50%	For a broad range of land conservation efforts, from conserving natural areas near big cities to protecting the most pristine and unique collections of plants in the state. Typically used to buy land to conserve wildlife habitat and to restore state lands	https://rco.wa.gov/grant/washington-wildlife-and-recreation-program-habitat/
WWRP – Recreation Projects	WA Recreation and Conservation Office	Varies by category (e.g., no cap, ≥$25k request, and/or ≤$1M)	Land protection and outdoor recreation (parks, trails, water access)	Cities, counties, towns, tribes, nonprofit nature conservancies, special purpose districts, port districts (and other political subdivisions), state agencies	Varies by applicant	For a broad range of land protection and outdoor recreation including for local and state parks, trails, water access, and the conservation and restoration of state land. Typically used to buy land for a park, building athletic facilities, building/renovating parks, developing regional trails, developing state lands. Applicants must have a comprehensive recreation or conservation plan.	https://rco.wa.gov/grant/washington-wildlife-and-recreation-program-recreation/

Note that this is a starting point and a non-exhaustive list that can and should be continuously updated as project needs and funding options change.

Table D-2. Lake Campbell Cyanobacteria Management Plan – Other Potentially Useful Programs.					
Name	**Funder or Administrative Agency**	**Target Purpose**	**Required Applicants or Lead Entities**	**Notes**	**Resource URL**
Forest Legacy Program	US Forest Service	Encourage the protection of privately owned forest lands through conservation easements or land purchases.	States and tribes		https://www.fs.usda.gov/managing-land/private-land/forest-legacy
Family Forest Fish Passage Program	WA DNR	Assist private forestland owners in activities to improve fish passage to upstream habitat (e.g., removing culverts, stream crossing structures, and replacement of other eligible barriers with new structures).	Private or small forest landowner (timber harvest restrictions) with fish-bearing stream		https://www.dnr.wa.gov/fffpp
Healthy Forests Reserve Program	USDA NRCS	Protect and restore forest on private land with 10-year restoration agreements and 30-year or permanent easements for specific conservation actions.	Private owners, or owned by tribes	For acreage owned by an American Indian tribe, there is an additional enrollment option of a 30-year contract. Some landowners may avoid regulatory restrictions under the Endangered Species Act by restoring or improving habitat on their land for a specified period of time.	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/forests/
Rivers and Habitat Open Space Program (WAC 222-23)	WA DNR	Easement to protect forestland with at-risk species (critical habitat), or CMZ river habitat	WA landowners of forestland, free of hazardous substances or other jeopardizing conditions to conservation	Program is funded by a grant and requires submission of an application	https://www.dnr.wa.gov/programs-and-services/forest-practices/small-forest-landowners/rivers-and-habitat-open-space
Forestry Riparian Easement Program	WA DNR	Easement to protect fish habitat	Landowners with >20 acres of contiguous forest, or >80 acres forest in WA, with other timber harvest specs	Reimburses landowners for the value of the trees they are required to leave to protect fish habitat. The program provides compensation for a minimum of 50 percent of the timber value and applies to trees adjacent to streams, wetlands, seeps, or unstable slopes.	https://www.dnr.wa.gov/programs-and-services/forest-practices/small-forest-landowners/forestry-riparian-easement-program
Conservation Reserve Enhancement Program (CREP)	WA State Conservation Commission, Farm Service Agency, local conservation districts	Restore streams along farmland by planting native vegetation	Farmers/landowners	Farmers are paid directly by program for planting native vegetation as a buffer, project costs/maintenance for 5 years covered by program, and landowners paid rent for acreage restored and receive enrollment bonus, renewable for 10–15 year contracts.	https://www.scc.wa.gov/conservation-reserve-enhancement-program

Note that this is a non-exhaustive list that can and should be continuously updated as project needs and program options change.

Appendix E

Glossary of Lake Terms

Herrera
Science + Planning + Design

Glossary of Lake Terms

Source: King County Lakes webpage:
https://kingcounty.gov/en/legacy/services/environment/water-and-land/lakes/glossary

Aerobic: Living in the presence of oxygen. Most organisms are aerobic and must have oxygen available in order to survive.

Algae: Single celled nonvascular plants occurring singly or in groups (colonies). They contain chlorophyll-*a*, used to produce their own food by means of photosynthesis. Algae form the base of the food chain in aquatic environments.

Algal bloom: Heavy growth of algae in and on a body of water, often a result of high nutrient concentrations.

Alkalinity: The acid neutralizing capacity of a solution, usually related to the amount of carbonates present; buffering capacity.

Allochthonous. Arising in another biotope, from outside of the lake basin.

Anaerobic: Living in the absence of oxygen. Some bacteria can survive and grow without oxygen present.

Anoxic: No oxygen present in the system; see anaerobic.

Average: The sum of a group of numbers divided by the total number of values in the group. (see "Mean")

Bathymetric map: A map showing the bottom contours and depth of a lake.

Benthic: Bottom area of the lake which hosts the community of organisms (benthos) that live in or on the sediment.

Biochemical oxygen demand (BOD). The decrease in oxygen content in milligrams per liter of a sample of water in the dark at a certain temperature over a certain period of time due to microbial respiration.

Biogenic. Arising as a result of life processes of organisms

Biomass. The total organic matter present.

Biovolume: Space occupied by organic matter.

Bluegreen algae: See cyanobacteria.

Buffer. A mixture of weak acids and their salts which (in solution) is able to greatly minimize changes in the hydrogen-ion concentration.

Catchment basin: See "Watershed."

Chlorophyll-a: A green pigment in plants which is used to capture light energy and convert it, along with water and carbon dioxide, into food or organic material.

Chlorophyte algae: Bright green algae that occur in lakes as plankton, as well as forming tangled masses of filaments coming up from the lake bottom or near shorelines. This group does especially well in warm water and bright light and is usually abundant in summer. The species are very diverse, including several that look more like grassy aquatic plants than algae. Another species, Botryococcus, turns bright orange under certain conditions, but is not toxic like the marine red tides.

Chrysophyte algae: Golden algae that are common members of the plankton in small lakes. They can be solitary or make colonies with large numbers of individuals. Some species make a protective silica sheath around the cells or have a covering of siliceous scales that preserve in lake sediments and have been used for reconstruction studies of past lake environments.

Concentration: The amount of one substance in a given amount of another substance, such as the weight of a chemical in a liter of water.

Conductivity: The measure of water's capacity to convey an electric current. Increasing the numbers of dissolved ions also increases the conductivity.

Core. Sample of soil or sediment taken in such a way as to keep the vertical characteristic of the sediment undisturbed.

Cryptophyte algae: Algae with a characteristic brown color, which are solitary and mobile, with two whip-like appendages ("flagella"). They are common residents of the plankton in lakes and are known as excellent food items for planktonic animals, thus supporting healthy food chains.

Cyanobacteria: Bacteria living in lakes and streams that make their own food instead of decomposing dead organisms and are very similar to freshwater algae in lake ecosystems. Many cyanobacteria grow especially well in lakes with high phosphorus content and are sometimes used as indicators of change due to human impacts through watershed development. Several species can make toxins dangerous to humans and other mammals if ingested. High concentrations of these cells in the water can result in closure of lakes to recreation or domestic use of water, although this has been relatively rare in occurrence historically.

Decomposers. Organisms, mostly bacteria or fungi, that break down complex organic material into its inorganic constituents.

Detritus. Settleable material suspended in the water: organic detritus, from the decomposition of the broken down remains of organisms; inorganic detritus, settleable mineral materials.

Dimictic lake. A lake which circulates twice a year.

Drainage basin. The area drained by, or contributing to, a stream, lake, or other water body.

Ecosystems. Any complex of living organisms together with all the other biotic and abiotic (non-living) factors which affect them.

Diatoms: Golden-brown algae that make intricate siliceous shells, which are found in lake plankton and attached to wood and rocks along shorelines. Many diatoms grow in cool water and low light, and are often abundant in winter and early spring in temperate lakes. Diatoms are nutritious food for planktonic animals and are important components of a healthy food chain in lakes. The shells preserve well in sediments and can be used in studies of lake history.

Dissolved oxygen: The oxygen gas that is dissolved in water as O_2

Ecosystem: Any complex of living organisms along with all other factors that affect them and are affected by them.

Epilimnion: The warmer, less dense, upper layer of a lake lying above cooler water (metalimnion and hypolimnion) in some seasons of the year.

Euglenophyte algae: Algae often found in ponds and smaller water bodies, particularly in the warm seasons of the year. They may be bright green, orange or brown. Euglenoid algae are mobile, using a whip-like appendage ("flagellum") to move through the water. Some make an organic shell that encloses the cell, with the flagellum inserted through a pore.

Euphotic zone. That part of a water body where light penetration is sufficient to maintain photosynthesis.

Eutrophic: Waters in which algae grow into large populations and biovolumes, generally related to nutrient supply. Trophic state indicators above 50 are classified as eutrophic.

Eutrophication: The physical, chemical, and biological changes associated with enrichment of a body of freshwater due to increases in nutrients and sedimentation.

Fecal coliform bacteria. A group of organisms common to the intestinal tract of vertebrates.

Fall Turnover: The mixing of thermally stratified waters that commonly occurs during early autumn. The sequence of events leading to a turnover includes: cooling of surface waters leading to a density change in surface water that produces convection currents from top to bottom, and circulation of the total water volume by wind action. Turnover generally results in uniformity of the physical and chemical properties of the water.

Green algae: See chlorophyte algae.

Holomictic. Lakes that are completely circulated to the bottom at the time of winter cooling.

Humic substances: Organic substances incompletely broken down by decomposers such as bacteria. Humic acids are large molecular organic acids that are present in water, often giving the water a yellow or brown color.

Hydrogen sulfide gas. A gas resulting from the reduction of sulfate containing organic matter under anaerobic conditions which is frequently found in the hypolimnion of eutrophic lakes.

Hypolimnion: The colder, dense, deep water layer in a thermally stratified lake, lying below the metalimnion and removed from surface influences.

Isopleth. A line for the same numerical value of a given quantity.

Lake level. Water level of a lake in centimeters relative to a given point established when the first King County lake level gauge was installed at the lake.

Lentic. slowly flowing.

Limiting nutrient: Essential nutrient for algae that is available in the smallest amount in the environment, relative to the needs of the organisms.

Limnology: The study of lakes and inland waters as ecosystems.

Littoral: The shallow region in a body of water which can be inhabited by rooted aquatic plants. This is somewhat dependent on the ability of light to penetrate the water. Specific animal groups also inhabit this zone.

Loading: The total amount of material (sediment or nutrients) entering a water body via streams, overland flow, precipitation, direct discharge, or other means over time (usually considered annually). Recycling of nutrients among sediment, organisms and water is sometimes referred to as "internal loading."

Mean: (see "Average") The sum of a group of numbers divided by the total number of values in the group.

Median: The datum in a set of numbers that represents the exact center of the group: half of the numbers are smaller and the other half are larger.

Mesotrophic: Waters that promote algae growth at rates intermediate between eutrophy and oligotrophy. Trophic state indicators between 40 and 50 are classified as mesotrophic.

Metalimnion: The layer of water in a lake between the epilimnion and hypolimnion in which the temperature, and thus density, change rapidly over a short distance. (see Thermocline).

Monomictic: A water pattern of lakes in which thermal mixing and stable stratification alternate once per year.

Morphology. Study of configuration or form.

Nannoplankton. Those organisms suspended in open water which because of their small size cannot be collected by most nets. They can be recovered by sedimentation or centrifugation.

NH3-N. The ammonia nitrogen portion of total nitrogen in a sample. Increases in the absence of oxygen.

NO2+3-N. Nitrite and nitrate nitrogen portions of total nitrogen in a sample.

Nitrogen: One of the elements essential for the growth of organisms. Nitrogen is most abundant on the earth in the form of N2, comprising 80% of the atmosphere, but is usually taken up by plants in the forms NO_3, NO_2 and NH_3.

Nonpoint source pollution: Pollution from diverse sources difficult to pinpoint as separate entities and thus more complicated to control or manage. Examples of "nonpoint sources" include area-wide erosion (as opposed to landslides or mass wasting), widespread failure of septic systems, certain farming practices or forestry practices, and residential/urban land uses (such as fertilizing or landscaping).

Noxious weeds: A legal definition of by the State of Washington that lists specific non-native, invasive plants known to destroy habitat for other plants or animals, or documented as having caused serious agricultural problems. A list of names is published each year by the Department of Ecology which lists the level of threat posed by the plants and the legal responsibilities of owners who find them growing on their properties. Individual counties may modify the list to fit specific distributions within the county.

Nutrient: Any chemical element, ion, or compound required by an organism for growth and reproduction.

Oligotrophic: Waters that are nutrient poor and which, as a result, have little algal production. Trophic state indicators below 40 are classified as oligotrophic.

Orthophosphate (PO4). The dissolved portion of phosphorus that is available for biological uptake. Also called soluble reactive phosphorus based on the analytical method.

Oxidation. A chemical process that can occur in the uptake of oxygen.

Periphyton. The biological community attached to substrate (such as rocks, sediments, aquatic plants) that is primarily composed of algae.

pH: The negative logarithm of the hydrogen ion concentration in a solution. This is a measure of acidity. pH decreases as acidity increases. Values below 7 are considered acidic.

Precipitation. Rain or snow. Volunteer lake monitors record daily rain in millimeters (or snow measured in millimeters of water equivalent).

Pheophytin: A pigment compound resulting from the degradation of chlorophyll a, usually found in algal remains, suspended organic matter, or bottom sediments.

Phosphorus: One of the elements essential for growth and reproduction. Phosphorus is often the limiting or least available nutrient for plant growth in temperate freshwater ecosystems. The primary original source of phosphorus is from the earth in the form of phosphate rocks.

Photic Zone: The upper water in a lake in which light penetrates enough to enable plants to carry out photosynthesis.

Photosynthesis: The production of organic matter (carbohydrates) from inorganic carbon and water, utilizing the energy of light.

Phytoplankton: Free floating microscopic organisms that photosynthesize (algae and cyanobacteria).

Productivity: The production and accumulation of organic matter, usually measured over a certain period of time.

Pyrrhophyte algae: These algae, also called dinoflagellates, are solitary and mobile, with two appendages ("flagella") that move the cell through water using whiplike motions. In marine waters, certain species are known for making toxic "red tides" that can render shellfish poisonous for humans. Freshwater dinoflagellates are not known to produce toxins and, while they may color the water brown or red when abundant, have never been considered dangerous.

Residence time: The average length of time that water or a chemical within the water, such as phosphate, remains in a lake.

Secchi disk: A 20-cm (8-inch) diameter disk painted white and black in alternating quadrants. It is used to measure Secchi depth, which is the transparency of the water in lakes.

Sediment: Solid material deposited in the bottom of a lake over time.

Stratification: The separation of water into nearly discrete layers caused by differences in temperature and subsequent water density differences.

Stagnation period. The period of time in which through warming (or cooling) from above a density stratification is formed that prevents a mixing of the water mass.

Stratification stability. The work that must be done to destroy or equalize the density stratification existing in a lake.

Standing crop. The biomass present in a body of water at a particular time.

Suspension. Very finely divided particles of an insoluble solid material dispersed in a liquid.

Thermocline: The zone of rapid temperature decrease in a vertical section of lake water. Typically, the temperature decrease reaches 1°C or more for each meter of descent. (See metalimnion.)

Transparency: Water clarity of a lake as measured with a Secchi disk.

Trophic State: A term used to describe the productivity of a lake ecosystem classifying it as one of three increasing categories based on algal biomass: oligotrophic, mesotrophic, or eutrophic. Trophic state indicators are calculated on the basis of total phosphorus, chlorophyll-*a* and Secchi transparency measurements.

Turbidity: Cloudiness in water caused by the suspension of tiny particles (algae or detritus).

Turnover: The mixing of lake water from top to bottom after a period of stable stratification. This typically occurs in fall and is caused by wind and seasonal cooling of surface waters.

UV254. A measure of water color; measures water sample's absorbance of ultra violet rays at a wavelength of 254 nanometers.

Van Dorn Sampler: A water sampling device that allows collection of a water sample from a desired depth without contaminating the sample with water from other depths.

Watershed. The geographical area that contributes surface and groundwater flow to a stream, lake, or other body of water. This can also be referred to as the "catchment basin" or "drainage basin."

Watershed Management: The planning and carrying out of actions, legal requirements and protective measures taken by agencies and citizens to preserve and enhance the natural resources of a drainage basin for the production and protection of water supplies and water-based resources.

Water Year (WY): A division of the earth year based on the general pattern of annual wet and dry periods rather than by calendar months. The U.S. Geological Survey uses the water year of October 1 through September 30 for data analysis.

Zooplankton: Small animals found in the water of lakes that possess limited powers of locomotion, and which feed on bacteria, algae, smaller animals, and organic detritus present in the water.