Aquatic Insight
holistic water management

ANNEAR WATER RESOURCES

Dr. Lizbeth Seebacher

Wiser Lake Cyanobacteria Management Plan

Wiser Lake, Whatcom County, Washington

May 31, 2025

Prepared for:

Whatcom County Health and Community Services

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Abbreviations

APAM	Aquatic Plant Algae Management
AU	Assessment Unit
BMP	Best Management Practice
Chla	Chlorophyll *a*
DO	Dissolved Oxygen
DOE	Department of Ecology
DOH	Department of Health
EIM	Environmental Information Management
FTW	Floating Treatment Wetland
HAB	Harmful Algae Blooms
HCB	Harmful Cyanobacteria Blooms
IAVMP	Integrated Aquatic Vegetation Management Plan
KCEL	King County Environmental Lab
LA	Lake Association
LCMP	Lake Cyanobacteria Management Plan
LMD	Lake Management District
LMN	Lower Main Nooksack
MCL	Maximum Contaminant Level
NRCS	National Resource Conservation Service
Ortho-P	Ortho Phosphorous
OSS	On Site Septic
PC	Phycocyanin
PHS	Priority Habitat Species
QAPP	Quality Assurance Project Plan
SD	Secchi depth
T	Temperature
TN	Total Nitrogen
TSI	Trophic State Index
TP	Total Phosphorus
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WCCD	Whatcom County Conservation District
WDFW	Washington Department of Fish and Wildlife
WCHCS	Whatcom County Health and Community Services
WL1	Wiser Lake West Sampling Station
WL2	Wiser Lake East Sampling Station
WRIA	Water Resource Inventory Area

Definitions

Anoxic – the absence of dissolved oxygen in a lake or water body

Epliminion - the uppermost layer of water in a lake that is warmest and most mixed.

Eutrophic – having rich levels of nutrients and supporting a dense plant population, the decomposition of which kills some aquatic life due to a lack of dissolved oxygen.

Holomictic - a lakes that has uniform temperature and density from surface to bottom at a specific time during the year, which allows the lake waters to mix over depth.

Hypereutrophic - having an excessive amount of nutrients and minerals, resulting in high productivity.

Hypolimnion - the lowest layer of water in a stratified lake that is cooler than the water above and relatively stagnant.

Metalimnion - the middle layer of a thermally stratified lake, separating the epilimnion and the hypolimnion, in which the water temperature decreases rapidly with depth.

Mesotrophic - having moderate levels of nutrients in a lake or waterbody.

Oligotrophic – having relatively low levels (or deficiency) of nutrients and plants and containing abundant dissolved oxygen in the deeper parts of a lake.

Polymictic – a lake that is too shallow to develop thermal stratification

Stratification – the process by which a lake separates into distinct layers with different temperatures. Sometimes the accompanied by difference concentrations of dissolved oxygen as well.

Thalweg - a line connecting the lowest points of a series of successive cross-sections along the course of a river or stream. In a lake created from an impounded stream or river the historic river bed, or thalweg, remains visible at the lake bottom.

Thermocline – The zone between the epilimnion above and the hypolimnion below where the water temperature starts a steep decline.

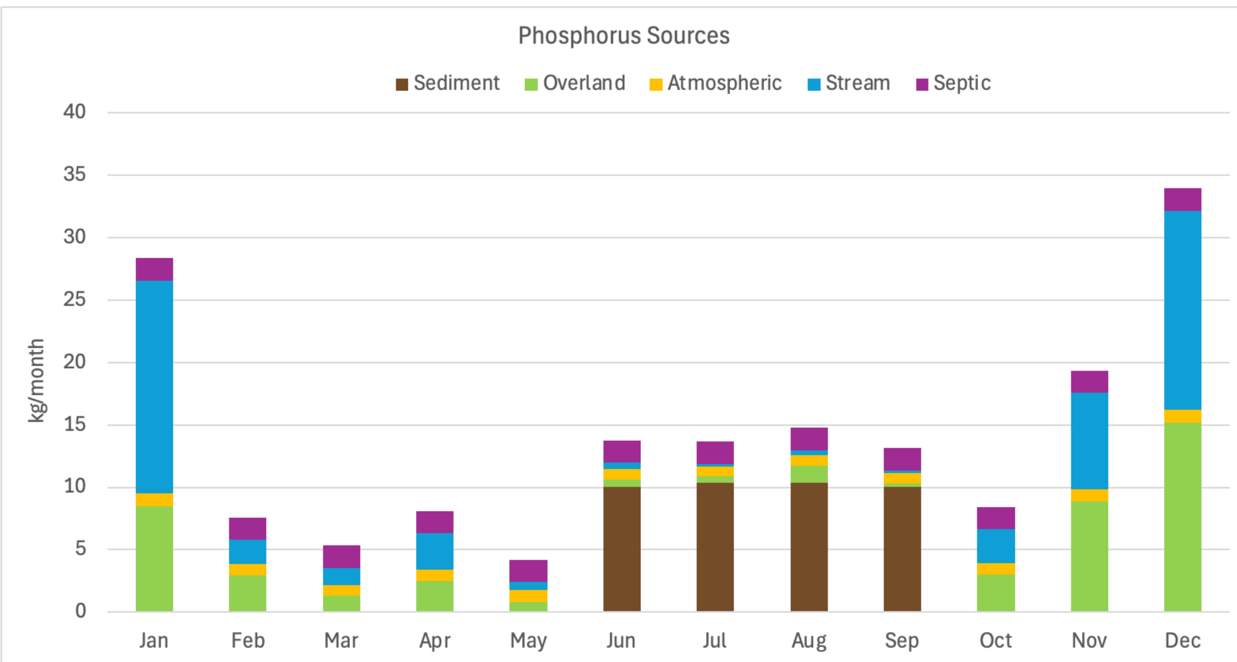
Executive Summary

This Lake Cyanobacteria Management Plan (LCMP) was developed for Wiser Lake in response to years of harmful cyanobacteria blooms. Whatcom County Health and Community Services (WCHCS) received a grant from the Washington State Department of Ecology (DOE) to collect the necessary field data, which they performed in 2023 and 2024, and an additional grant to develop the LCMP.

Water quality data were collected from Cougar Creek upstream of Wiser Lake, and from both the east and west basins of the lake proper. Data collection took place from May 2023 to April 2024 and included phosphorus and nitrogen, temperature, pH, conductivity and dissolved oxygen profiles, phytoplankton, and zooplankton. Sediment cores were taken from both basins and analyzed for phosphorus fractions. Weekly waterfowl surveys were also conducted. Analytical modeling was performed to establish the phosphorus, nitrogen, and water budgets.

Key findings from the study include:

- The dominant source of phosphorus input for Wiser Lake on an annual basis was external loading at 76%, with internal loading from sediment accounting for 24%.
- The dominant source of phosphorus input in summer (June-September) is the opposite of the annual load, with internal loading from sediment at 74% and external loading at 26% (See chart below).



- Elevated nitrogen concentration in winter, likely from agriculture and septic inputs, and groundwater.
- Secchi transparency is low during summer, limiting phytoplankton and aquatic plant growth.
- Nitrogen:phosphorus ratio is low during summer, potentially favoring nitrogen fixing cyanobacteria species.

- Dominance of cyanobacteria species such as *Anabaena circinalis* and *Aphanizomenon flos-aquae* during late summer and fall. Both are nitrogen fixing species and can produce toxins.

- Data showed Wiser Lake was well mixed over depth throughout the year, but the data were incomplete and did not reach the sediment layer. There may be times when the sediment becomes anoxic during calm summer weather conditions, or at night but that was not measured specifically in this study.
- While data showed the lake as being mixed, this may be due to lack of data near the sediment and at night (when winds are lower) so additional temperature and dissolved oxygen profiles are suggested to better define internal phosphorus loading. This will also define the spatial and temporal scale of treatments necessary to reduce internal loading.
- The Wiser Lake watershed is dominated by agriculture and field-applying manure may still be in practice. We suggest WCHCS work with the Whatcom Conservation District (WCD) and agriculture producers on implementing best management practices (BMPs) that reduce the potential for excess nitrogen and phosphorus entering Cougar Creek and groundwater.

Recommended management activities:

- Continue monitoring the lake for nutrient concentration, phytoplankton population, and temperature and dissolved oxygen parameters.
- Reduce phosphorus in summer by treating with either EutroSORB (lanthanum) to bind soluble phosphorus, or alum (aluminum) to bind soluble phosphorus and physically remove algae from the water column.
- Monitor and control invasive aquatic plants to reduce their dominance when conditions improve. Establish an aquatic vegetation management plan in anticipation of improved conditions.
- Continue conducting septic system inspections and offering support for upgrading malfunctioning systems.
- Expand support for homeowners to enhance the onsite sewage systems by incorporating nutrient treatment to reduce nitrogen and phophorus levels.
- Work with agriculture in the watershed to reduce field-applied fertilizer and manure

This is an adaptive management plan intended to be used by WCHCS for improving the health of Wiser Lake. To be successful, this plan will require the participation of lake residents, the agriculture community, Whatcom County, lake users, WCD, and future partners invested in the health of Wiser Lake. Funding for lake improvement activities could come from a Lake Management District (LMD) or Lake Association (LA), which would ensure long-term stable funding for lake improvement projects. There are state and federal programs that could also provide funding to support plan implementation.

E. Background

E.1 Study Area

E1.1 Lake and Watershed

Wiser Lake, located in Whatcom County is 116 acres in surface area and has a maximum depth of 10 feet. The east to west oriented lake is separated into two basins by State Route 539/Guide Meridian, with the West Basin at 26 acres and the east at 90 acres (Figure 1). This natural lake is fed by Cougar Creek to the east which also serves as the lake outlet, draining west of the lake. The Wiser Lake watershed is 3.3 square miles (2,112 acres) and land use consists of 69% agriculture, 21% residental, and 10% water, forest and wetland.

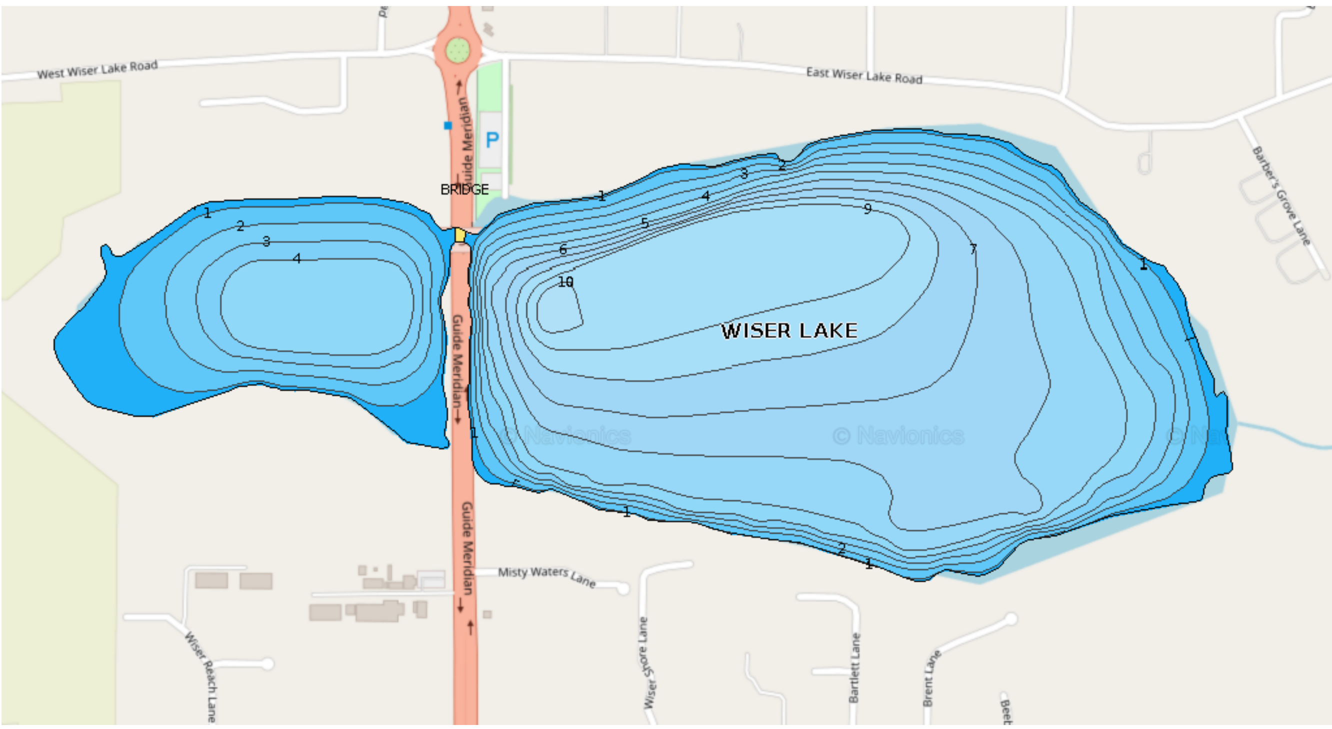


Figure 1. Bathymetric map of Wiser Lake. Data from usa.fisermap.org, by Garmin/Navionics.

Wiser Lake falls within Water Resource Inventory Area (WRIA) 1 and is part of the South Lynden Watershed Improvement District and within the floodplain of the main Nooksack River. The continuation of Cougar creek on the west side of Wiser Lake eventually flows into the Nooksack River. The watershed is primarily agricultural comprising mostly of dairy farms and fields, per the South Lynden Watershed Improvement District (WID). The soils within this WID are classified by the United States Department of Agriculture (USDA) National Resource Conservation Service (NRCS) as predominantly Agricultural Prime (94%), with over 80% of land in Wiser Lake/Cougar North classified as Ag Zoning or Rural Study Area. This watershed is designated as critical habitat for shorebird concentrations, trumpeter swan, waterfowl concentration and wetland as well as for Char, Chinook, Chum, Coho, Cutthroat, Pink, Sockeye, and Steelhead.

Sections of Cougar Creek are classified as Category 5 for dissolved oxygen (DO) impairment and Category 4a for bacterial contamination. A section of the main Nooksack River in AU1103 (west of Hannegan Road) is listed as Category 4a for bacteria. An unnamed tributary to the Nooksack River in AU1103 is classified as Category 5 for DO impairment. The 2022 Water Quality Assessment draft released by the Washington State Department of Ecology (DOE) has classified Wiser Lake as Category 5 on the 303(d) List for Harmful Cyanobacteria Blooms (HCBs).

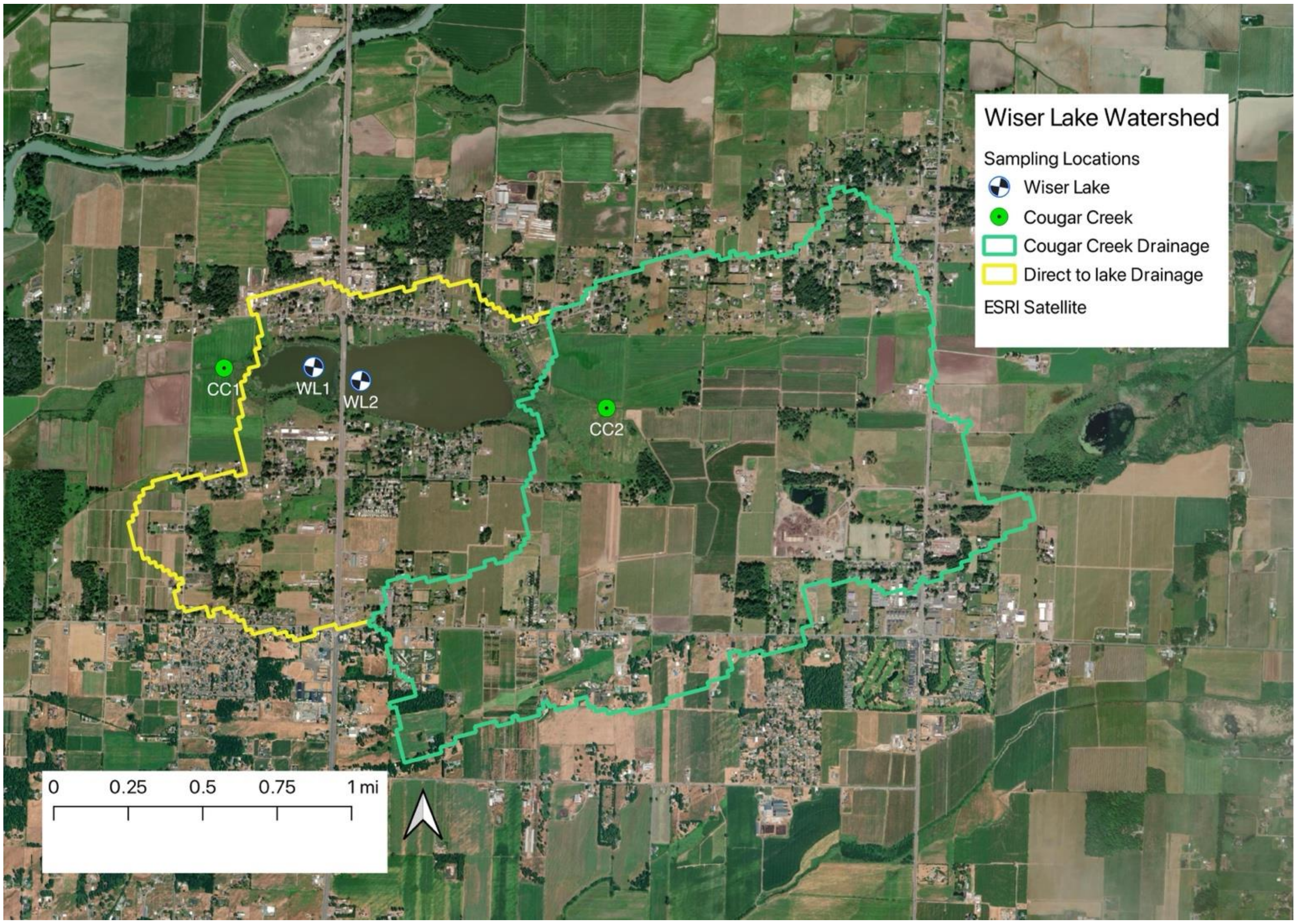


Figure 2. Wiser Lake watershed and sampling locations. Yellow outlined area directly drains to Wiser Lake. Green outlined area is input from Cougar Creek. Lake sampling locations WL1 and WL2 are represented by black and white icons. Creek monitoring locations CC2 (Inlet) and CC1 (outlet) are shown as green circles. Only CC2 was sampled but flow was measured at CC1 and CC2.

E.1.2 Beneficial uses of the lake

Wiser Lake is home to approximately 50 residents with homes directly along its shoreline, as well as another 355 residents in the watershed that drains directly to the lake. In addition to offering scenic views, Wiser Lake provides a range of recreational opportunities, including boating, kayaking, wildlife observation, and fishing. The Washington Department of Fish and Wildlife (WDFW) manages a public boat ramp located off SR 539 on the north side of the lake's East Basin.

According to the regional WDFW fish biologist, Wiser Lake supports a population of Largemouth Bass along with several non-native fish species, including Yellow Perch, Brown Bullhead, Bluegill, Pumpkinseed Sunfish, and Black Crappie (https://wdfw.wa.gov/fishing/locations/lowland-lakes/wiser-lake). The WDFW page on

Wiser Lake also highlights that Largemouth Bass, Brown Bullhead, and Pumpkinseed are among the most frequently caught fish by anglers.

E.1.3 Current and historical land uses

Whatcom County has a long-standing tradition of intensive agricultural activity, which continues to thrive today. The county ranks second in dairy production within Washington State and contributes over 59% of the nation's raspberry production (Almasri and Kaluarachchi, 2004). Although raspberries have relatively low nutrient requirements, the application of fertilizers can result in significant nitrogen accumulation in the soil.

Other major crops cultivated in WRIA 1 include strawberries, potatoes, blueberries, beans, corn, carrots, peas, and cauliflower. These agricultural activities are predominantly concentrated in the western portion of WRIA 1.

Almasri and Kaluarachchi (2004) noted that land use within WRIA 1 has remained relatively stable over the years, with intensive agricultural practices concentrated around the Sumas-Blaine aquifer, lying beneath Wiser Lake. The authors consolidated the 21 land use classes from the National Land Cover Database (U.S. Geological Survey, USGS, https://www.usgs.gov/centers/eros/science/national-land-cover-database) into four broader categories (Figure 3).

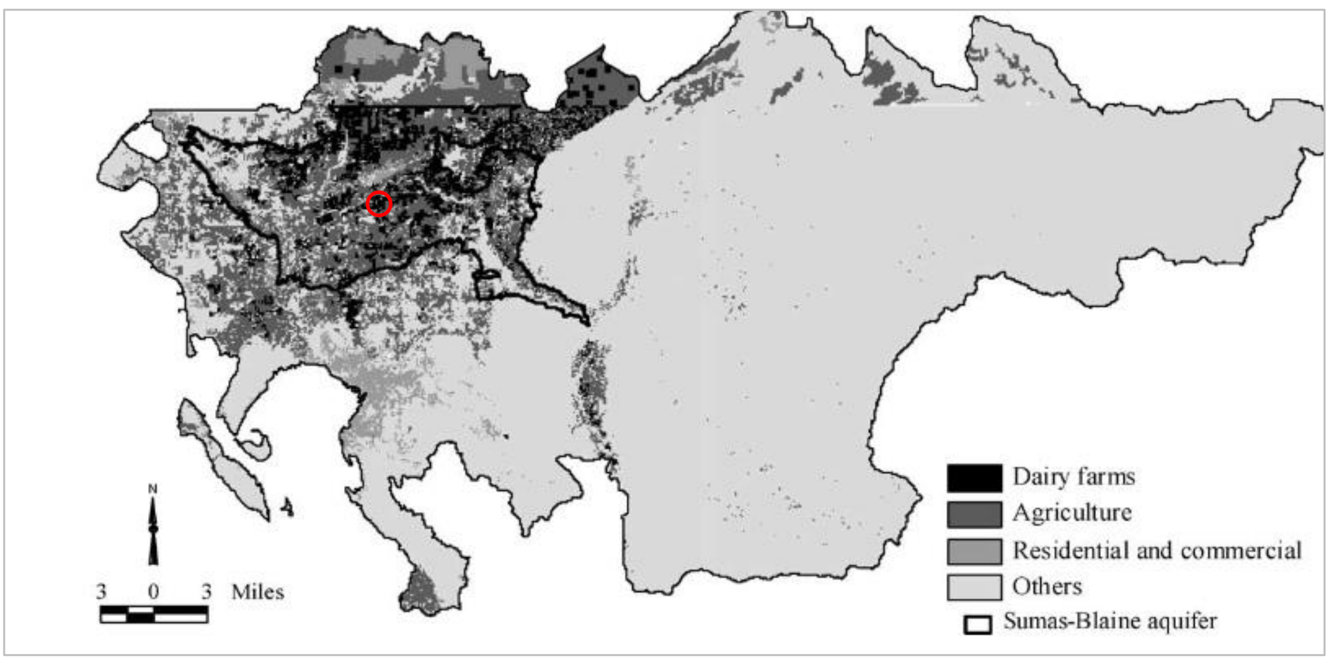


Figure 3. Land Use within the Sumas-Blaine aquifer.
Red circle indicates the location of Wiser Lake.

The Whatcom County Agriculture-Watershed Pilot Project (2016) identified that manure solids, often mixed with sawdust and applied to berry fields, gets incorporated into runoff. These solids are commonly transported to nearby streams, further impacting water quality in the region. Carey (2017) also noted that manure from dairies is commonly used as fertilizer for forage crops, with an estimated 16–18 million pounds of nitrogen applied annually to lands over the Sumas-Blaine aquifer.

Carey (2017) also highlighted a recent shift in land use, with many fields previously dedicated to dairy-related grass and corn production transitioning to berry cultivation.

E.1.4 Number and location of houses on septic

Residential homes outside the cities of Lynden, Everson, and Nooksack primarily depend on on-site sewage systems (OSS) for wastewater disposal. The Wiser Lake watershed contains 631 onsite septic systems (OSSs), according to the WCHCS (Anna Mostovetsky pers. Comm.). Of these systems:

- 63% (397) are currently in compliance.
- 35% (219) have had previous evaluations but are not up to date with recent evaluations.
- 2% (15) have never undergone an evaluation.

The types of OSS systems within the watershed and shown in Figure 4 are as follows:

- ~91% Gravity Systems: These require evaluations every three years and are eligible for homeowner evaluations.
- ~6% Pressure Distribution Systems: These require annual evaluations and are eligible for homeowner evaluations.
- ~3% Proprietary Systems: These also require annual evaluations but are not eligible for homeowner evaluations.

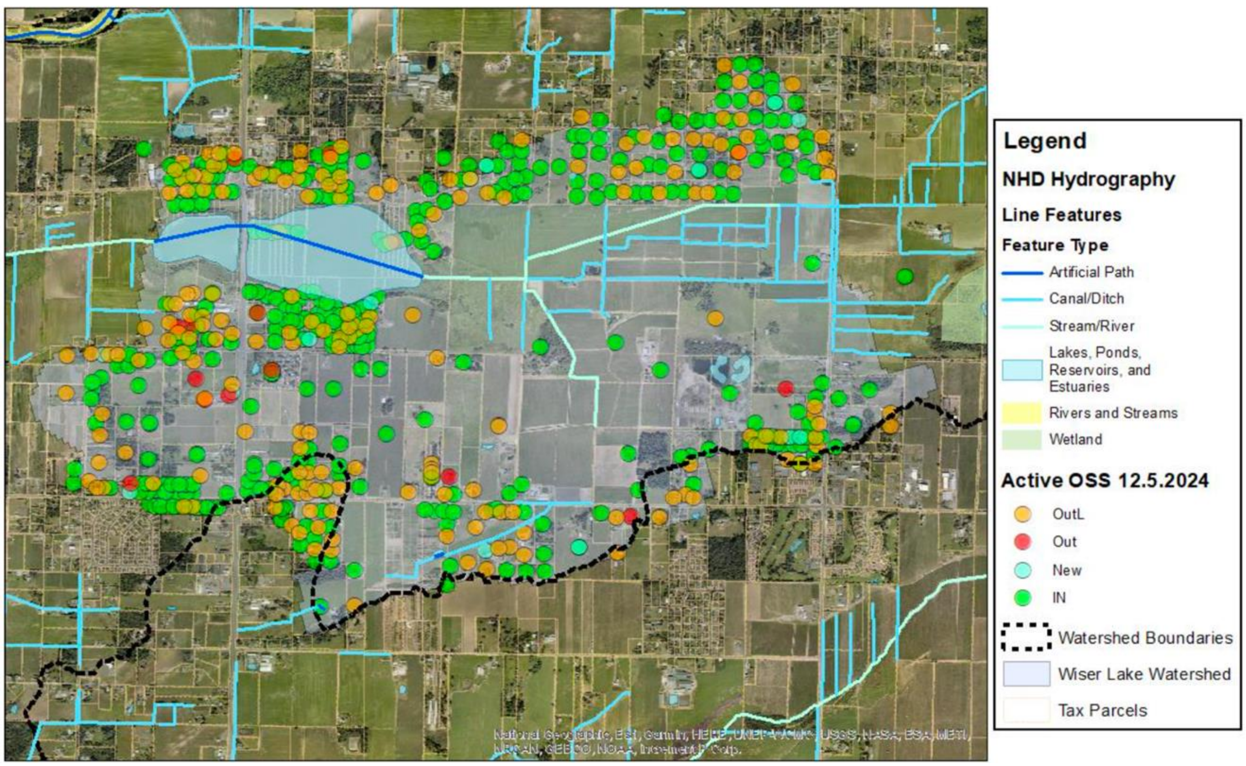


Figure 4. Active OSS systems in the Wiser Lake watershed. Graphic provided by Whatcom County.

Surface water contamination has been linked to nutrient waste from septic systems (Lusk et al., 2011; Louda and Hayford, 2023). Louda and Hayford (2023) compared two Florida communities: one with high-density onsite septic systems with drain fields and another served by a municipal vacuum sewage system (central treatment system). The septic system community had 125% (2.25 times) the total phosphorus and 20% the total nitrogen compared to the vacuum sewage system community.

Septic tank effluent typically retains 80-100% of the nutrients found in wastewater, which then enters the drain field where nutrients interact with the soil (Lusk et al., 2011). Organic phosphorus (P) from human excreta and food residues can convert to orthophosphate through microbial mineralization, a process that accelerates in warm, moist, and well-drained soils. Organic P can also adsorb onto soil surfaces, especially in high-clay soils rich in iron and aluminum oxides, such as Oxisols and Ultisols.

Inorganic P, primarily in the form of orthophosphate, can adsorb onto organic matter, calcium, iron, and aluminum or precipitate as compounds of these minerals. Acidic soils promote precipitation as iron, aluminum, and manganese compounds, while alkaline soils favor calcium and magnesium compounds. Long-term phosphorus attenuation is limited in small, unsaturated soil zones where redox conditions encourage rapid precipitation of insoluble phosphorus minerals. Phosphorus desorption can occur in older septic systems or when soils become saturated, releasing previously absorbed phosphorus (Lusk et al., 2011).

Most septic systems in the Wiser Lake watershed are located in soils 100, 103, 99, and 116 (Table 1). The latter (Pangborn muck) predominantly lies within agricultural fields. Soils like 100, 103, and 99, formed in glacial outwash and loess, are generally less effective at absorbing phosphorus due to their coarse-grained nature and hydrological characteristics (Figure 5, and Table 1).

Figure 5. Map of dominant soil types in the Wiser Lake watershed.

Table 1. Description of dominant soil types in the Wiser Lake watershed.

Soil Code	Soil Type	Soil Properties
116	Pangborn muck, drained	Very deep, poorly drained soils in depressional areas; acidic.
99	Lynden sandy loam	Well-drained soils formed in volcanic ash, loess, and glacial outwash.

72	Histosols, ponded	Organic-rich soils, common in bogs and muck areas.
103	Lynnwood sandy loam	Deep, excessively drained glacial outwash soils.
54	Fishtrap muck, drained	Deep, poorly drained organic soils in depressional areas.
62	Hale silt loam, drained	Somewhat poorly drained soils formed in aeolian and glacial outwash deposits.
100	Lynden-Urban land complex	Well-drained soils formed in volcanic ash, loess, and glacial outwash.
(Data sources: USDA Official Soil Series Descriptions and Natural Resources Conservation Service.) https://soilseries.sc.egov.usda.gov/		

According to Carey (2017), the Wiser Lake area lies amidst fine-grained and coarse-grained recessional outwash. Coarse-grained soils tend to have lower phosphorus retention due to higher permeability and reduced reactive substrate. The figure from Carey's 2017 DOE report illustrates groundwater movement in the area, emphasizing that nutrient transport in groundwater is influenced by soil characteristics and hydrology (Figure 6).

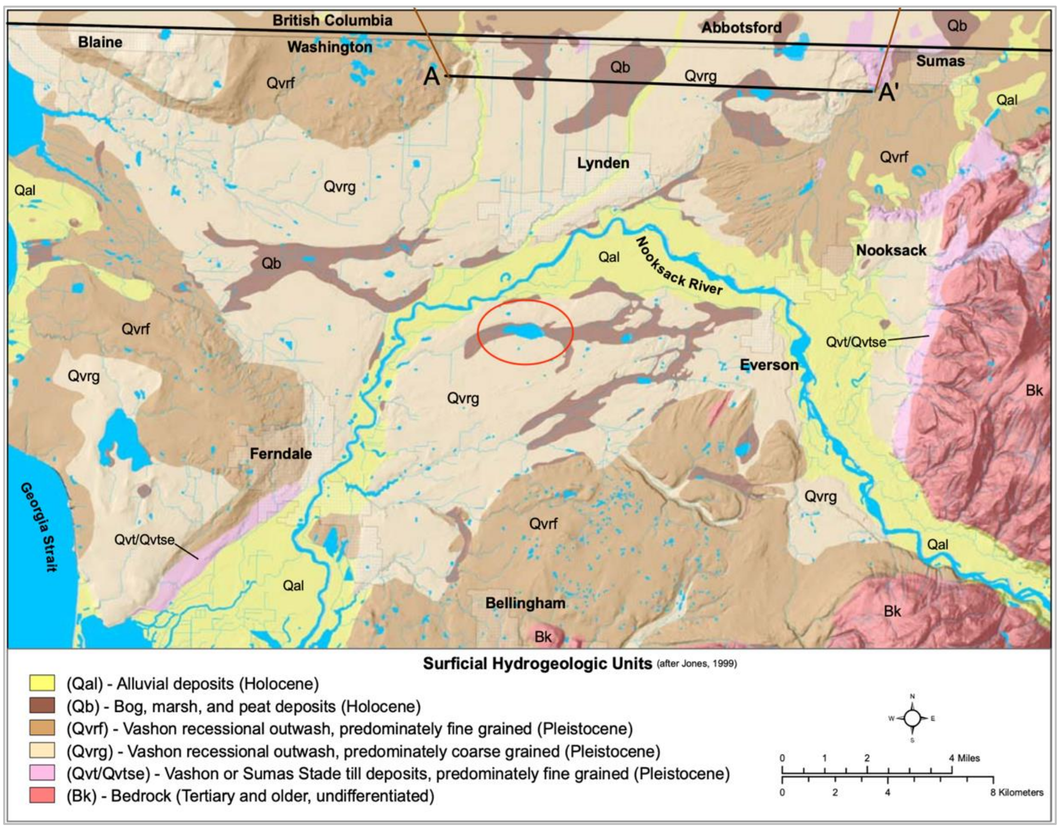


Figure 6. Groundwater flow in the Wiser Lake watershed.

Groundwater

Data compiled from 1990–2000 on nitrate concentrations in WRIA 1 groundwater identified high nitrate levels primarily associated with intensive agricultural activities (Almasri and Kaluarachchi, 2004). Elevated nitrate levels in drinking water are linked to health risks, including methemoglobinemia in infants and various cancers in adults. As a result, the EPA has established a maximum contaminant level (MCL) of 10 mg/L.

In Whatcom County, elevated nitrate concentrations in surficial aquifers have been recorded since the 1970s. Studies have attributed these excessive nitrate levels in shallow groundwater within the Sumas-Blaine aquifer to agricultural practices, dairy farming, and dairy lagoons (Liebscher et al., 1992; Erickson, 1992, 1994; Garland and Erickson, 1994; Hulsman, 1998; Hii et al., 1999; Cox and Liebscher, 1999; Carey, 2002). At the time of Almasri's research there were more than 200 dairy farms in the area, housing a total of 77,500 cows. The average nitrogen leaching from a dairy lagoon was estimated to be 852 kg (1,880 lb.). Additional nitrogen sources in the study area include: inorganic fertilizers, atmospheric deposition, irrigation with nitrogen-contaminated groundwater, and OSS.

The Sumas-Blaine aquifer consists primarily of gravel, sand, and alluvial deposits. Nitrate transport to surface water occurs mainly via groundwater discharge during baseflow conditions (Almasri, 2004). Groundwater data from the Department of Ecology's Environmental Information Management (EIM) database show consistently elevated nitrate levels, with concentrations exceeding both the EPA's maximum contaminant level (MCL) of 10 mg/L (US EPA, 2000) and the human impact level (HIL) of 3 mg/L (Madison and Burnett, 1985) in every year data were collected (Figure 7).

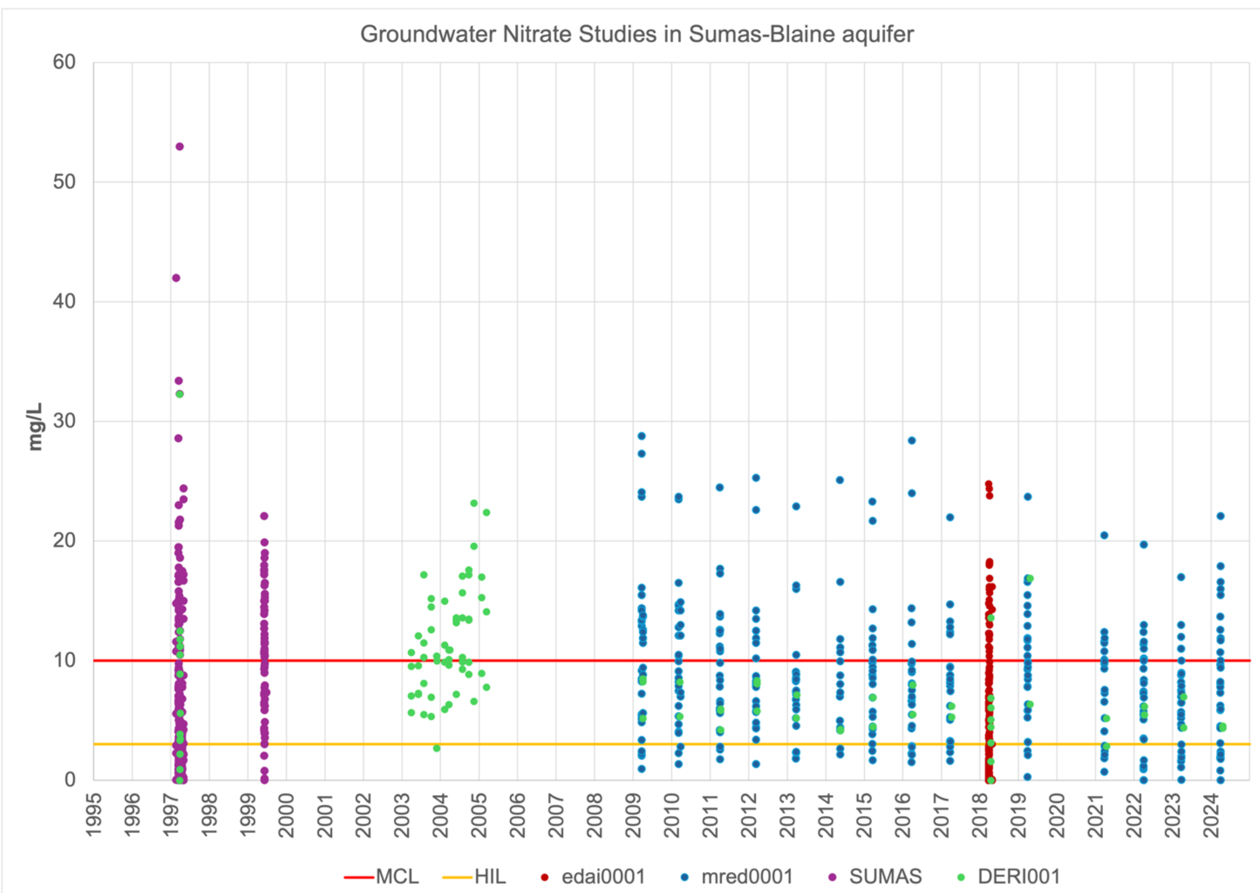


Figure 7. Groundwater nitrogen levels from four studies in the Sumas-Blaine aquifer. Red line is maximum contamination level and yellow line represents the level where human impact is possible.

Wiser Lake lies within the "Lower Mainstem Nooksack" (LMN) watershed of WRIA 1. Annual maximum nitrate concentrations in LMN groundwater from 1990–2000, reported by Almasri et al. (2004), consistently exceeded the EPA's MCL, with the exception of the year 2000.

Table 2. Annual maximum nitrate levels within the lower mainstem Nooksack (LMN) watershed.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
LMN, mg/L	**22.4**	**19.0**	**17.2**	**16.0**	**10.0**	**39.5**	**17.0**	**32.3**	**16.6**	**12.2**	8.5

Nitrate concentrations in the LMN watershed continue to exceed the MCL through 2024 based on results from the mred0001 study (Figure 7). These levels are among the highest in Whatcom County, surpassed only by the Lynden North and Sumas River watersheds, making the LMN watershed a priority for management actions. Almasri and Kaluarchchi (2004) suggested the high groundwater nitrate levels in the LMN watershed are due in a large part to manure applications (Figure 8).

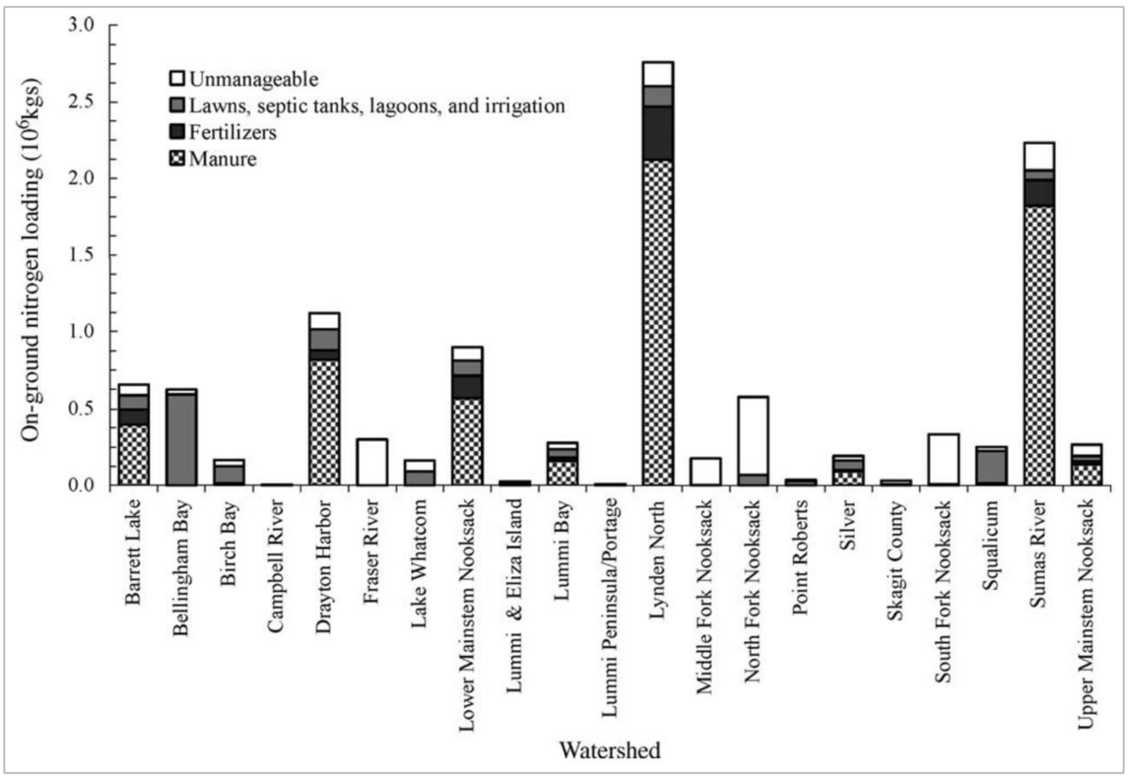


Figure 8. Nitrate sources in the LMN watershed, Almasri et al. (2004).

E.1.5 Water use

There are nine (9) water rights listed in the DOE database for Water Rights from Wiser Lake. Two (2) residences or persons have water rights for domestic use. Record number 059942CL has a water right claim for domestic general use with a surface water pump. Record number 11216CWRIS has a Certificate from 1952 for domestic single and irrigation via a surface water pump (Figure 9). The other seven (7) water rights are for stock water and irrigation.

Record Document Number	WR Doc ID	Certificate Number	Status	Phase	Priority Date Claim First Use	Purpose of Use	Qi	Units of Measure	Irrigated Acres	WRIA	Region	County	TRS	QQ	Q	First Device Type Listed	Number of Sources	First Source Name Listed
S1-*03563PWRIS	2225818		Inactive	Permit	11/25/1931	Irrigation	0.5000	CFS	25.0000	1	NWRO	Whatcom	T39.0N/R02.0E/03			Surface Water Pump	1	Wiser Lake
S1-*09058CWRIS	2276456	03701	Active	Certificate	09/08/1949	Irrigation	0.1000	CFS	10.0000	1	NWRO	Whatcom	T39.0N/R03.0E/06	SE	NW	Surface Water Pump	1	Wiser Lake
S1-*10802CWRIS	2276225	05093	Active	Certificate	10/15/1951	Irrigation	0.3000	CFS	30.0000	1	NWRO	Whatcom	T39.0N/R03.0E/06	SW	NE	Surface Water Pump	1	Wiser Lake
S1-*11128CWRIS	2275985	05148	Active	Certificate	03/10/1952	Irrigation	0.0900	CFS	9.0000	1	NWRO	Whatcom	T39.0N/R03.0E/06	SE	NW	Surface Water Pump	1	Wiser Lake
S1-*11216CWRIS	2276007	06220	Active	Certificate	04/04/1952	Domestic Single,Irrigation	0.2100	CFS	20.0000	1	NWRO	Whatcom	T39.0N/R03.0E/06			Surface Water Pump	1	Wiser Lake
S1-*11310CWRIS	2276028	05470	Active	Certificate	05/01/1952	Irrigation	0.1800	CFS	18.0000	1	NWRO	Whatcom	T39.0N/R02.0E/01	E2	NE	Surface Water Pump	1	Wiser Lake
S1-*11997CWRIS	2275836	05875	Active	Certificate	01/22/1953	Irrigation	0.5300	CFS	53.0000	1	NWRO	Whatcom	T39.0N/R02.0E/01			Surface Water Pump	1	Wiser Lake
S1-*16518AWRIS	2227388		Inactive	New Application	02/06/1961	Stockwater,Irrigation	0.2000	CFS	2.0000	1	NWRO	Whatcom	T39.0N/R03.0E/06			Surface Water Pump	1	Wiser Lake
S1-059942CL	2257027		Active	Claim Short Form		Domestic General				1	NWRO	Whatcom	T39.0N/R03.0E/06			Surface Water Pump	1	Wiser Lake
TOTAL RECORDS: 9																		

Figure 9. Water rights in the Wiser Lake basin.
(https://appswr.ecology.wa.gov/waterrighttrackingsystem/WaterRights/WaterRightSearch.aspx)

E.1.6 Water withdrawals

Given that there are nine (9) water rights for withdrawing water from Wiser Lake, if an Aquatic Plant Algae Management Permit (APAM) is needed for any restoration option selected from the recommendations below (Section L), these persons or organizations may need to be contacted per the APAM permit and WCHCS may need their approval depending on the action proposed.

Depending on the product used and existing water rights noted above, the APAM permit requires the Permittee to take specific actions, including obtaining consent, issuing notifications, and potentially providing replacement water for the period of restricted water use if the product used has such restrictions. Detailed information can be found in the APAM permit application (S. Ultican, personal communication, December 16, 2024).

E.1.7 Fisheries

The WDFW website (2024) reports that the most commonly caught fish in Wiser Lake are:

1. Brown Bullhead (*Ameiurus nebulosus*) – A species of catfish, the Brown Bullhead belongs to the Ictaluridae family. Known for tolerating high water temperatures and low DO levels, this species thrives in murky waters. Brown Bullhead is an introduced species to the Pacific Northwest and can negatively impact waterbodies through significant bioturbation and by competing with native fish for food resources.
2. Largemouth Bass (*Micropterus salmonids*) – Introduced intentionally by WDFW in the 1930s or 1940s, the Largemouth Bass is a non-native species that serves as a top predator in the ecosystem. As such, it preys on native fish populations, disrupts food webs, and significantly reduces biodiversity within waterbodies.
3. Pumpkinseed Sunfish (*Lepomis gibbosus*) – Native to eastern North America, Pumpkinseed Sunfish have been widely introduced to other areas, where they often hybridize with native and other introduced species. This species competes with native fish for food and negatively impacts zooplankton populations (Jordan et al., 2009).

According to the local WDFW Fisheries Biologist (J. Spinelli, personal communication, October 20, 2024), while Largemouth Bass were intentionally stocked it remains unclear whether the introduction of Brown Bullhead and Pumpkinseed Sunfish were authorized, illegal, or the result of natural colonization from other connected waters.

Wiser Lake was last stocked in 1940 and 1941 with a total of 3,500 Rainbow Trout and in 1987 with 4,500 Steelhead. Wiser Lake Creek was stocked with large numbers of Coho fingerlings from 1965, 1984, 1985, 1986, 1992 and 1994 (Table 3).

Table 3. Fish stocking records for Wiser Lake.

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Waterbody	Year	Fish species - fingerlings	Number
Wiser Lake	1940	Rainbow trout	2,500
Wiser Lake	1941	Rainbow trout	1,000
Wiser Lake	1987	Steelhead	4,500
Wiser Lake Creek	1965	Coho	7,584
Wiser Lake Creek	1984	Coho	92,800
Wiser Lake Creek	1985	Coho	127,400
Wiser Lake Creek	1986	Coho	45,000
Wiser Lake Creek	1986	Coho	45,000
Wiser Lake Creek	1992	Coho	57,600
Wiser Lake Creek	1994	Coho	13,800

Researchers have found significant correlations between fish stocking and eutrophic conditions in lakes. Poikane et al. (2022) observed that fish stocking was a dominant pressure in highly eutrophic shallow lakes, negatively impacting their ecological status. The stocking rates appeared to be a key factor, with lakes having low stocking rates showing low chlorophyll-a concentrations and good trophic status despite high nutrient levels. In contrast, lakes with high fish stocking displayed elevated chlorophyll-a levels and poor ecological status. Wiser Lake has not been stocked since 1994 so current water quality conditions are not being impacted by stocking activity.

According to the South Lynden Watershed Improvement District (Whatcom County Agriculture-Watershed Pilot Project, 2016) and the SalmonScape mapping system provided by the WDFW, (Washington Fish and Wildlife, https://apps.wdfw.wa.gov/salmonscape/map.html, 2024), Cougar Creek to the east of Wiser Lake is classified as "Current Presumed Salmonid Distribution." In contrast, Cougar Creek to the west of Wiser Lake is classified as "Current Known Salmonid Distribution" and is recognized as habitat for salmonids.

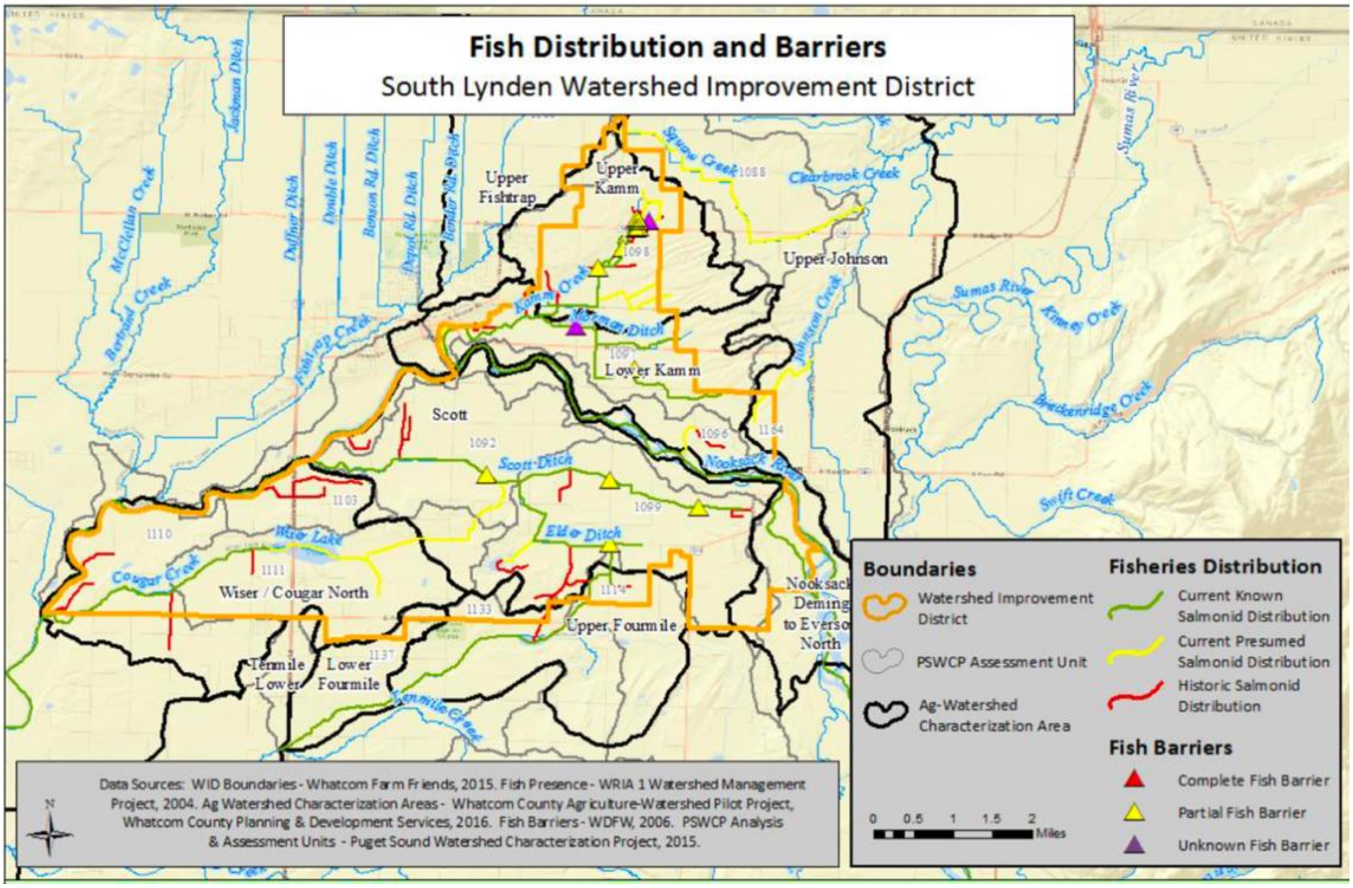


Figure 10. Salmonid habitat in the South Lynden WID.
(Whatcom County Agriculture-Watershed Pilot Project, 2016).

E.1.8 Aquatic plants

Aquatic and emergent plant data from the 2016 Integrated Aquatic Vegetation Management Plan (IAVMP) was provided by the Department of Ecology (Baldwin, L., Wiser Lake Integrated Aquatic Vegetation Management Plan, 2016) along with survey data conducted in 2018, 2021, and 2023 provided by the Whatcom County Public Works Noxious Weed Program (Table 4).

Table 4. Results from recent plant surveys in Wiser Lake.

Scientific Name	Common Name	Plant Type	Distrubution Value				Native – Introduced	Comments 2023 survey
			2016	2018	2021	2023		
Bidens cernua	Nodding beggarticks	E	1	2	2	2	N	Scattered, shoreline, both basins
Ceratophyllum demersum	Coontail	S	5	3	2	2	N	Scattered
Chara sp.	Muskwort	S	4	2			N	Scattered, both basins
Comarum palustre	Purple cinquefoil	E	1	1	1	1	N	Scattered, shoreline, both basins
Elodea canadensis	Common waterweed	S	4	3	3	3	N	Both basins
Elodea nutallii	Nuttall's waterweed	S	4				N	Not found in last 3 surveys
Epilobium hirsutum	Hairy willow-herb	E	3	2	2	2	I	Shoreline, both basins
Iris pseudacorus	Yellow flag iris	E	3	2	3	3	I	Shoreline, both basins
Najas flexilis	Slender water nymph	S	2				N	Not found in last 3 surveys
Nitella sp.	Nitella	S	2	2	2	2	N	Scattered, both basins
Nuphar polysepala	Spatterdock	F	4	3	3	3	N	Scattered, dense, nearshore
Phalaris arundinacea	Reed canarygrass	E	4	3	3	3	I	Common on shoreline
Potamogeton crispus	Curly leaf pondweed	S	5	2	1	4	I	Dominant in both basins
Potamogeton foliosus	Leafy pondweed	S	3	3	2	3	N	Becoming dominant, both basins
Potomogeton pusillus	Slender pondweed	S	2	3	2	2	N	Scattered, thin pop, both basins
Solanum dulcamara	Bittersweet nightshade	E	2	3	3	3	I	Common on shoreline
Stuckenia pectinata	Sago pondweed	S	2	3	2	3	N	More dense in west basin
Typha latifolia	Common cattail	E	3	3	3	3	N	Common on shoreline
Eleocharis sp.	Spike rush	E	2	2	2	2	N	Scattered, shoreline, both basins
Lemna minor	Lesser duckweed	F	2	2	2	2	N	Scattered
Nymphaea odorata	Fragrant waterlily	F	1				I	Not found in last 3 surveys
Potamogeton zosteriformis	Eel-grass pondweed	S		3	2	2	N	Scattered, thin pop, both basins
Schoenoplectis acutus	Hard-stem bulrush	E		2	2	2	N	Scattered patches
Stuckenia pectinata	Sago pondweed	F		3	2	3	N	More dense in west basin
E = emergent, S = submerged, F = floating								
Distribution Value is an estimate of density. 1 – few plants to 5 – thick growth covering the substrate at the exclusion of other species.								
2016 data from the Wiser Lake IAVMP submitted to the Department of Ecology by Laurel Baldwin, Program Manager of the Whatcom County Noxious Weed Board.								

According to the DOE's Lakes website (2024), Curly Leaf Pondweed (*Potamogeton crispus*) was first reported in Wiser Lake as early as 1996. It was considered a dominant species by 1997 and was still present in 2023 based on WCHCS survey data. Other invasive species identified in the 1997 DOE survey include reed canary grass, hairy willowherb, fragrant waterlily, and nightshade. It is unclear why the fragrant waterlily was recorded in both the 1997 and 2016 surveys but not in subsequent surveys.

E.1.9 Endangered/rare species

According to the WDFW threatened and endangered species within and immediately surrounding Wiser Lake include the species listed in Table 5. (WDFW, https://wdfw.wa.gov/species-habitats/at-risk/phs/maps, https://geodataservices.wdfw.wa.gov/hp/phs/, 2024)

Table 5. Threatened and endangered species in the Wiser Lake area.

Occurrence Name	Scientific Name	PHS Status	Federal	State
Trumpeter swan	*Cygnus buccinator*	Occurrence	N/A	N/A
Little brown bat	*Myotis lucifugus*	Occurrence	Sensitive	Sensitive
Yuma myotis	*Myotis yumanensis*	Occurrence	Sensitive	Sensitive
Coho	*Oncorhynchus kisutch*	Occurrence/migration	N/A	N/A
Resident coastal cutthroat	*Oncorhynchus clarki*	Occurrence	N/A	N/A

The Washington Natural Heritage Program provided data on the occurrence of Pygmy Water-lily (*Nymphaea tetragona*) at Wiser Lake (J. Holt. Personal communication, December 23, 2024). The Heritage Program states that this plant species was first found in 1966 but was not re-located in subsequent surveys conducted in 1981 or 2006. Notes from the surveyors stated that in the 1981 survey, they were unable to gain full access to that area of the lake due to vegetation and in 2006, sections of the lake west of the "road" were not surveyed. However, according to the University of Washington Herbarium's Collections Manager, Dr. David Giblin, a specimen of the Pygmy Water-lily was collected in 1939 at this location and identification confirmed in 1993. Dr. Giblin states that the "1966 occurence record is of questionable origin". Therefore, the 1966 record is described as "reported but no specimen exists". (Giblin, D. 2025. Personal communication). According to the Burke Herbarium, the species is considered "possibly extirpated" in Washington State (https://burkeherbarium.org/waflora/checklist.php?Taxon=Nymphaea%20tetragona). Additionally, the Priority Habitat and Species (PHS) database (WDFW PHS) identifies Wiser Lake and the surrounding natural areas as containing important habitat occurrences. These include: freshwater aquatic habitat, freshwater forested/shrub wetlands, and freshwater emergent wetlands, which are significant for local biodiversity and conservation efforts.

The South Lynden Watershed Improvement District concurs with the Priority Habitat and Species database referring to the abundant waterfowl populations at Wiser lake as well as with the freshwater wetlands to the east and west of the lake along Cougar Creek in Figure 11.

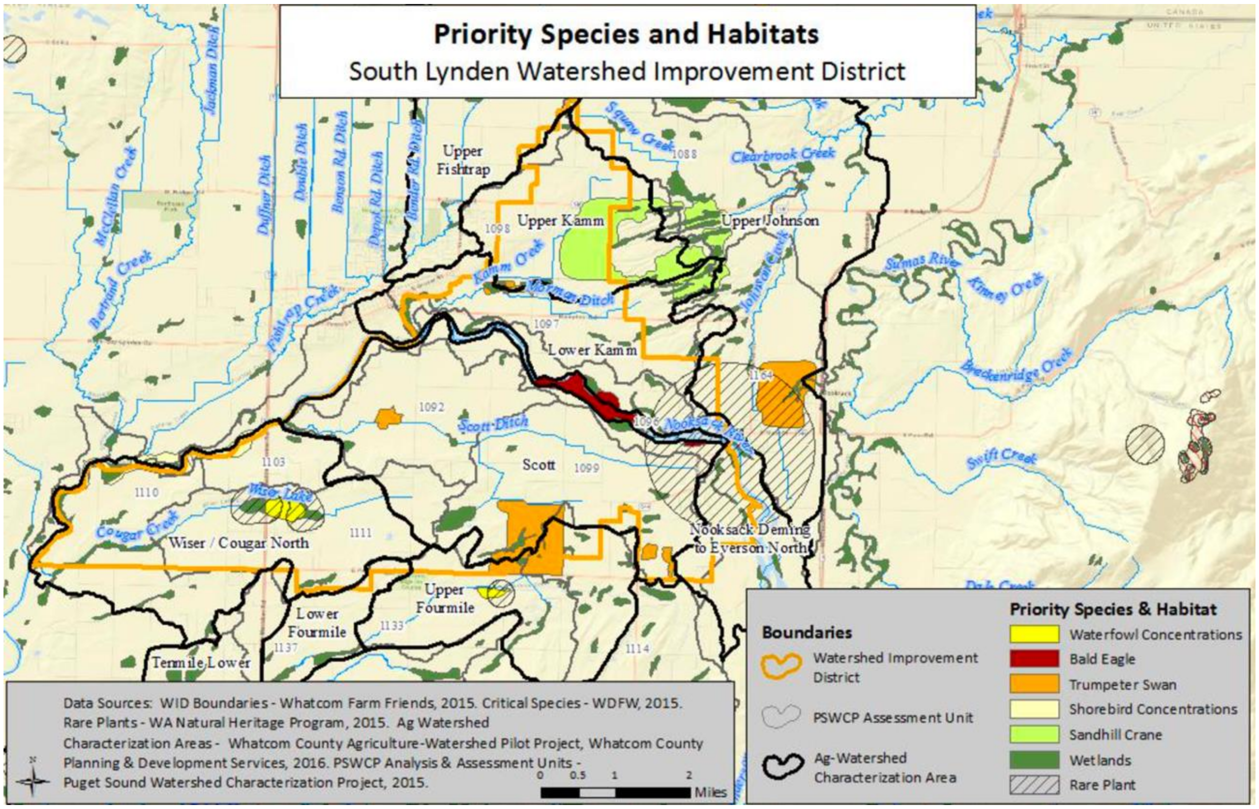


Figure 11. Priority species and habitats in the South Linden Watershed Improvement District.

E.2 Water Quality History

Historic water quality data for Wiser Lake is limited, but there is some data from past lake assessments, and recent cyanobacteria data from the DOE Cyanotoxin Program. Western Washington has collected some data from the boat ramp since 2006, but only once a year since 2013 and occasionally twice a year from 2006 to 2012 A common way to classify lake condition is to use their trophic state index (TSI), which uses Secchi depth (SD), chlorophyll (chl), and total phosphorus (TP) as variables (Carlson, 1977). The scale is from 0 to 100 with low numbers indicating less biomass and high numbers more biomass. The trophic state of Wiser Lake is mentioned several times in this report, and Table 6 identifies the range of values for each parameter and the associated trophic state.

Trophic categories range from oligotrophic (TSI<30), which indicates clear water, oxygen throughout the water column, and low chlorophyll to hypereutrophic (TSI>80), which indicates a high phosphorus concentration, resulting in dense algae and aquatic plants and poor visibility (Table 6). The trophic status could vary throughout the year depending on the season and the parameter used for measuring. For instance, chlorophyll may be low during winter when there is not enough sunlight to promote algae growth, but very high during summer. As a result, the trophic state for each parameter is averaged annually or seasonally (summer and winter) to monitor changes in lake status over time. However, this approach assumes the availability of historical data for year-to-year comparisons, which is not always the case. For Wiser Lake, data are only available for select years.

Table 6. Trophic State Indices based on Carlson (1977)

TSI	Chl (µg/L)	SD (m)	TP (µg/L)	Attributes
< 30	< 0.95	> 8	< 6	**Oligotrophy**: Clear water, oxygen throughout the year in the hypolimnion.
30 – 40	0.95 – 2.6	8 – 4	6 – 12	Hypolimnia of shallower lakes may become anoxic.
40 – 50	2.6 – 7.3	4 – 2	12 – 24	**Mesotrophy**: Water moderately clear; increasing probability of hypolimnetic anoxia during summer.
50 – 60	7.3 – 20	2 – 1	24 – 48	**Eutrophy**: Anoxic hypolimnia, macrophyte problems possible.
60 – 70	20 – 56	0.5 – 1	48 – 96	Blue-green algae dominate, algal scums and macrophyte problems.
70 – 80	56 – 155	0.25 – 0.5	96 – 192	**Hypereutrophy**: (light limited productivity). Dense algae and macrophytes.
> 80	> 155	< 0.25	192 – 384	Algal scums, few macrophytes

E.2.1 Past water quality conditions

Water quality data from the DOE dating back to as early as 1993 indicate poor water quality conditions in Wiser Lake. Secchi depth measurements were very low (ranging from 1.5 to 2 feet), and total phosphorus (TP) concentrations were high, with recorded values of 165 µg/L and 477 µg/L. While the specific date for the values is not known, the data does come from Wiser Lake and contributes to the range of phosphorus values for the lake.

A note from the 1990s mentioned mercury in fish, but no follow-up data or fish flesh analyses have been reviewed since (Ecology Environmental Information Managment (EIM) Database https://apps.ecology.wa.gov/eim/help/ValidValues/Parameters, 2024). Given that Wiser Lake was historically stocked by the WDFW and possibly by residents, any mercury contamination in fish flesh could likely be attributed to the stocking of fish from other locations or hatcheries.

From 2014, when the DOE initiated the Cyanotoxin Program, Wiser Lake has frequently exceeded the recreational guidelines set by the Department of Health (DOH) for microcystin, with occasional exceedances for anatoxin-a. Microcystin has been detected at alarmingly high levels, with the highest concentration recorded at over 400 µg/L (the DOH recreational guideline is 8 µg/L), and concentrations exceeding 100 µg/L are not uncommon (Figure 12). Additionally, although saxitoxin has been detected in the lake, it has not exceeded the recreational guidelines. It is worth noting that saxitoxin is relatively rare in Washington State, according to the King County Environmental Lab (KCEL, E. Frame, personal communication, October 25, 2024).

E.2.2 Efforts to improve water quality

Unknown, other than this LCMP and surface and groundwater monitoring.

E.3 Current Conditions

E.3.1 Water quality

Annual cyanobacteria blooms have occurred with multiple instances of cyanotoxin levels over the recreational guidelines set forth by the EPA and DOH (Figure 12). The data seem to indicate cyanobacteria blooms begin in July/August and continue into October or November in recent years. The total phosphorus, DO and chlorophyl sample data indicate that Wiser Lake is considered mesotrophic through the winter and hypereutrophic in the mid-late summer into the fall.

Total phosphorus concentrations from samples collected in 2023 and 2024 averaged 166 µg/L and 127 µg/L respectively for the west and East Basins. Ortho phosphorus was also high, comprising 22% and 36% of the total phosphorus concentration for the east and West Basins (Table 7). A high ortho phosphorus concentration indicates that algae and aquatic vegetation is not utilizing this nutrient, either due to a steady influx of additional phosphorus, or other conditions within the waterbody are limiting the ability of algae to uptake soluble phosphorus.

Table 7. Average phosphorus and nitrogen concentrations in Wiser Lake

	TP		Ortho-P		TN	
	WL2	WL1	WL2	WL1	WL2	WL1
Summer Ave.	127	166	30	81	1222	995
Annual Ave.	104	135	23	48	1759	1592
Max.	235	321	114	203	3560	3147

In order to reduce the risk of cyanobacteria blooms the total phosphorus concentration should be at or below 20 µg/L (Carvalho, et al. 2013). Although other factors can temporarily limit cyanobacteria growth, reducing phosphorus is typically the most effective long-term strategy for improving lake conditions, as it eliminates a key nutrient that supports their proliferation.

E.3.2 Contaminants of Concern

E.3.2.1 Cyanotoxins – Microcystin, Anatoxin-a and Saxitoxin

Toxin producing cyanobacteria have been recorded in Wiser Lake, with the three (3) toxin types represented (

Table 8, DOE 2024). Samples have been collected since 2014 at the public boat ramp on the north side of the East Basin, adjacent to Guide Meridian, and toxins exceeded recreational limits every year but 2019, as shown in Figure 12. No data are available for 2017 so it is not known if there were exceedances that year.

Cyanobacteria have the ability to adjust their buoyancy and can get blown to near-shore areas where they become concentrated. This seems to be the case in Wiser Lake, where surface accumulations of cyanobacteria have concentrated at the boat ramp and do not reflect the conditions in the broader lake. This is important data however, because the boat ramp is where recreational users and pets come in contact with the lake and exposure to cyanobacteria can be high.

Table 8. Toxin producing cyanobacteria in Wiser Lake. Data from DOE Toxic Algae Program (2024).

Cyanotoxin	Cyanobacteria - genera	Found in Wiser Lake?
Microcystin Recreational limit >8 µg/L	Dolichospermum (Anabaena)	Yes
	Fischerella	No
	Gleotrichia	Yes
	Microcoleus	No
	Microcystis	Yes
	Nodularia	No
	Nostoc	Yes
	Oscillatoria	Yes
	Phormidium	No
	Planktothrix	Yes
Anatoxin-a/Guanitoxins Recreational limit >1 µg/L	Chrysosporum	No
	Cuspidothrix	Yes
	Cylindrospermum	Yes
	Dolichospermum (Anabaena)	Yes
	Microcystis	Yes
	Oscillatoria	Yes
	Planktothrix	Yes
	Phormidium	No
	Raphidiopsis	No
	Tychonema	No
	Woronichinia	Yes
Saxitoxins Recreational limit >75 µg/L	Aphanizomenon	Yes
	Dolichospermum	Yes
	Microseira	No
	Planktothrix	Yes
	Raphidiopsis	No

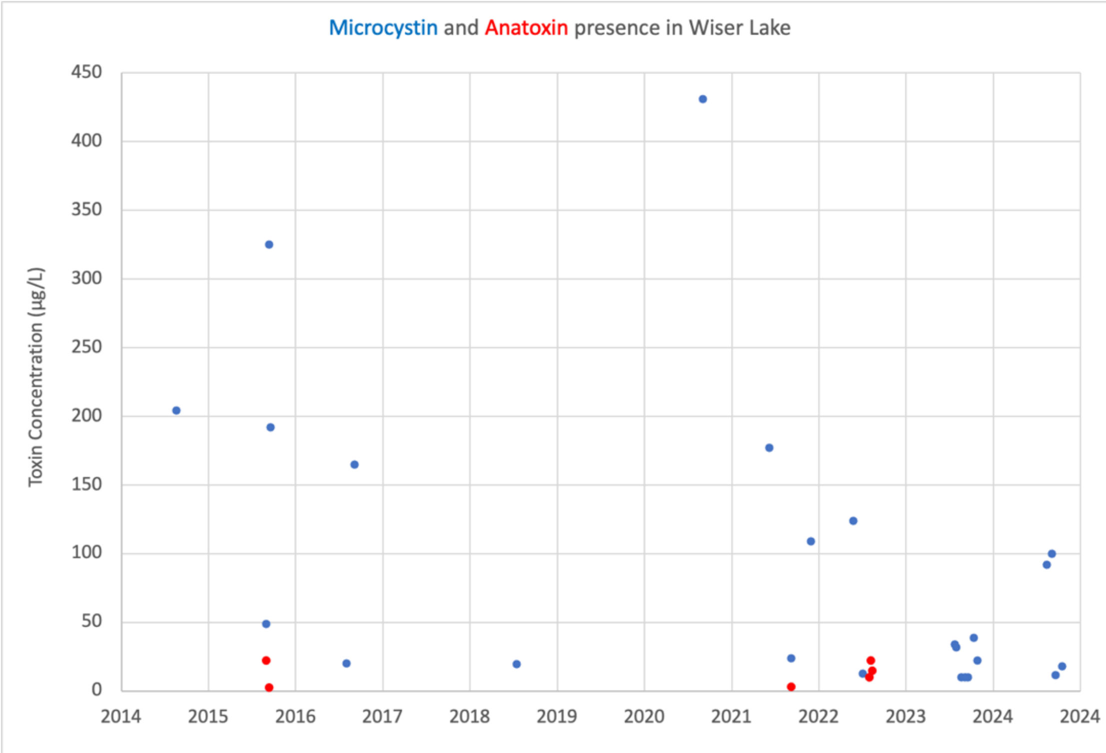


Figure 12. Toxin detections in Wiser Lake. Blue points are microcystin and red points are anatoxin. Threshold values for microcystins is 8 µg/L and anatoxins is 1 µg/L. Data from WA Ecology Toxic Algae Program

E.3.2.2 303 D LIST STATUS

The Department of Ecology's 2022 Water Quality Assessment draft was released for public comment on November 4, 2024 (DOE, 2024), which profiles an updated draft list for the 303d list (impaired waters). The corresponding document "Water Quality Program Policy 1-11, Chapter 1, Washington's Water Quality Assessment Listing Methodology to Meet Clean Water Act Requirements" was finalized in March of 2023 (Publication 18-10-035). Within this Assessment, "Harmful Algae Blooms" were included under the "Water Contact Recreation" Designated Uses for the first time in Washington State.

According to the Assessment's draft list, 36 lakes have been added to Washington's 303d list as Category 5 waterbodies, including Wiser Lake (Ecology Draft Water Quality Assessment Review Tool - https://apps.ecology.wa.gov/ApprovedWQA/CandidatePages/CandidateSearch.aspx 2024). Prior to this listing, Wiser Lake was listed as a Category 1 lake on the 303d list (Ecology Water Quality Assessment & 3030d list. https://ecology.wa.gov/water-shorelines/water-quality/water-improvement/assessment-of-state-waters-303d. 2024).

Under the framework developed by the Department of Health (DOH) for freshwater contact recreation guidance on the four most common cyanotoxins, the Department of Ecology (DOE) will use a combination of public health advisories, cyanotoxin data from the Freshwater Algae Program (Washington State Toxic Algae), and DOH recreational guidelines to assess the health of contact recreation in its Water Quality Assessments.The 303d listing identification number for Wiser Lake is: 104637 and the Assessment Unit ID is: 17110004004641_001_001 (Ecology Washington State Water Quality Assessment 303d/305b list.

https://apps.ecology.wa.gov/approvedwqa/candidatepages/viewcandidatelisting.aspx?ListingId=104637. 2024). Table 9 lists the 303(d)/305(b) draft list from the 2022 Assessment of Wiser Lake cyanotoxin results.

Table 9. Washington State Water Quality Assessment 303(d)/305(b) Draft List – Wiser Lake Assessment Year 2022 – Basis Table. Red years are those that put Wiser Lake in Category 5 based on the DOE Assessment Report

Sampling Year	Sample Count	Microcystin Calculated value (µg/L)	Microcystin Threshold (µg/L)	Anatoxin-a (µg/L)	Anatoxin-a Threshold (µg/L)	Cylindrospermopsin (ug/L)	Cylindrospermopsin Threshold (µg/L)	Saxitoxin (µg/L)	Saxitoxin Threshold (µg/L)
2021	3	177	8	2.9	1	0.025	15	0.037	75
2020	1	431	8	0.01	1	0.025	15	0.064	75
2019	1	.299	8	0.01	1	0.025	15	0.033	75
2018	2	19.4	8	0.025	1		15		75
2016	3	165	8	0.032	1		15		75
2015	5	325	8	22	1		15		75
2014	1	204	8	0.01	1		15		75

The terms *Harmful Algal Blooms (HABs)* and *Harmful Cyanobacteria Blooms (HCBs)* are often used interchangeably, although HABs can refer to blooms caused by various types of algae, while HCBs specifically refer to those caused by cyanobacteria.

From the HABs (Harmful Algae Bloom) section of the DOE Assessment Report (2024): Category determinations for waterbodies with HABs incidents:

Category 5

DOE will place an AU (Assessment Unit) in Category 5 when:

1. Two cyanotoxin sampling events meet DOH recommendations for a WARNING or DANGER public health advisory in each of two or more years. Samples should be collected a minimum of one week apart. The years do not need to be consecutive.

OR

2. A WARNING or DANGER public health advisory for potentially toxin-producing cyanobacteria or algae has been issued by a local or state health jurisdiction in two or more years. Each advisory must be in place for a minimum of three weeks and supported by cyanotoxin or other toxicity data. The years do not need to be consecutive.

OR

3. DOH public health assessment has identified one or more probable or confirmed human or animal HABs exposure events resulting in illness or death.

Category 4

DOE will place an AU in Category 4A when EPA has approved a TMDL that addresses HABs.

DOE will place an AU in Category 4B when an alternative pollution control program (meeting the requirements in Section 1F) is actively addressing the HABs problem.

Category 3

DOE will place an AU in Category 3 when the available data are insufficient for another category determination. This information will be maintained in Ecology's WQA database for future use. As additional data and information become available in future listing cycles, Ecology will again assess all available data to update the category determination according to this policy.

Category 2

DOE will place an AU in Category 2 when:

1. At least one cyanobacteria sampling event meets DOH recommendations for a WARNING or DANGER public health advisory, but the listing does not qualify for Category 5.

OR

2. A WARNING or DANGER public health advisory for potentially toxin-producing cyanobacteria or algae is issued by a local or state health jurisdiction, but the listing does not qualify for Category 5.

Category 1

DOE will place an AU in Category 1 when:

The waterbody is free of public health advisories for three consecutive years and has supplemental data (photos, algae cell counts, cyanotoxin or other toxin levels) in each year consistent with DOH advisory removal procedures.

E.3.2.3 Total Maximum Daily Loads

There are no Total Maximum Daily Loads (TMDLs) in place at this time (Ecology Draft 2022 Water Quality Assessment. https://apps.ecology.wa.gov/waterqualityatlas/wqa/proposedassessment?lstid=104637. 2024). Section 303(d) of the Clean Water Act (1972) mandates that each state identifies water bodies that do not meet water quality standards and develop TMDLs for these waters. A TMDL specifies the maximum allowable pollutant load for a waterbody, serving as a key tool for improving water quality. In Washington State, the DOE is responsible for implementing the TMDL process. However, this process can be both costly and time-consuming. To expedite water quality improvements, the state and counties may implement a Pollution Control Plan or go straight to an Implementation Plan. These approaches allow for watershed cleanup before formal TMDLs are established, especially when the sources of pollution are already known. BMPs are identified to target the specific pollutants and their sources. The Lake Cyanobacteria Management Plan (LCMP) also addresses similar pollutant concerns and recommends corresponding BMPs.

E.3.2.4 Regulatory criteria of contaminants and cyanotoxins

Washington DOH provides recreational guideline values for microcystin, anatoxin-a, cylindrospermopsin, and saxitoxin (Table 10). The DOH incorporated EPA's recreational guidance values for microcystins and cylindrospermopsin into Washington's Lake Management Protocol, but the EPA has not adopted guidance values for Anatoxin-a and saxitoxon. Provisional guidance for these toxins were developed by DOH (Hardy, 2021)

Table 10. Regulatory criteria for cyanotoxins (WA DOH)

Cyanotoxin	Recreational Guidance	Water body Guidance
Microcystin	8 µ/L	Tier 1. Caution: when a bloom is forming or a scum is visible (toxic algae may be present) Tier 2. Warning: Toxic algae present Tier 3. Danger: Lake Closed
Anatoxin-a	1 µ/L	
Cylindrospermopsin	15 µ/L	
Saxitoxin	75 µ/L	

Cyanotoxin	Bottle-fed infants and pre-school children	School-age children and adults
Microcystin	0.3 µ/L	1.6 µ/L
Cylindrospermopsin	0.7 µ/L	3 µ/L

E.3.3 Community Involvement

E.3.4.1 Public participation

The WCHCS held one in-person outreach event for the community in September 2023, with over 40 people attending (Anna Mostovetsky pers. Comm.). This was a combination of lake-side residents, water recreation enthusiasts and representatives from professional organizations. This served as a general HCB overview and informed the public about Whatcom County's work on Wiser Lake. Whatcom County also created a general HAB and Wiser Lake project page on their website (https://www.whatcomcounty.us/4236/Wiser-Lake-HAB-Project). The County has also been sending bi-annual email/web project updates to their listserv.

Local partner groups and agencies who have participated in this project include:

- Whatcom County Public Works
- Re-Sources
- Washington State Department of Health
- Washington State Department of Ecology
- Washington Department of Fish and Wildlife
- Audubon Society
- Western Washington University, Institute of Watershed Studies

E.3.4.2 Public support

There is broad support for improving water quality in Wiser Lake to address public health concerns and support recreational and aesthetic uses.

F. Project Description

F.1 Project goals and objectives

Wiser Lake routinely experiences harmful cyanobacteria blooms with anatoxin and microcystin exceeding DOH recreational criteria. These toxins can be harmful to human and animal health and limit both residential and recreational use. There is little historical data available and no formal studies on Wiser Lake so this LCMP was proposed in order to understand the cause of these blooms. Nutrient and water budgets developed as part of the LCMP will be used to inform an action plan for reducing nutrient levels and bloom intensity.

F.2 Project schedule

Lake data was collected from May 2023 to April 2024 by WCHCS. Data were collected every two weeks during the summer (May-October) and monthly during the remaining months. Sediment samples were collected September 12, 2023 from both basins.

G. Monitoring Methods and Results

Specific monitoring methods used for data collection are described in the quality assurance project plan (WCHCS, 2023). A summary of monitoring methods and data sources are provided at the start of each section below.

G.1 Hydrology

The hydrology data collection and review involved lake level, stream inflows and outflows, groundwater assessment, and precipitation data and evaporation calculations.

G.1.1 Monitoring Methods

Flow was monitored at the Cougar Creek lake outlet (CC1) and as close as logistically possible to the lake inlet (CC2) (Figure 2). These sites were selected based on physical characteristics and permission to access private property. A stage sensor was installed at both locations in May 2023 to collect continuous water level data. However technical issues led to difficulty in accessing and downloading the outlet data.

Meteorological data was downloaded from internet archives of measurements at Bellingham International Airport (BLI, https://mrcc.purdue.edu/CLIMATE/welcome.jsp).

Groundwater was calculated as the remaining unknown portion of the water budget as discussed below in Section H.2.5 Net Groundwater.

Evaporation was estimated employing the Hamon Method (Hamon, 1961), which incorporates monthly air temperature and daylight hours to quantify seasonal variability in water loss from the lake's surface, as discussed below in Section H.3.2 Evaporation.

Creek and lake water sampling occurred monthly starting in Spring of 2023 and continued for twelve months. Twice monthly samples were taken from May to October, when HCBs are most common, during the first and third weeks of the month. From November to April, sampling took place in the first week of the month.

Cougar Creek is a perennial stream that flows year-round, therefore stream sampling occurred during all field sampling events. Additional grab samples were collected during high flow storm events. Phytoplankton and zooplankton samples were collected monthly from May through December in both basins.

G.1.2 Monitoring Results

RAINFALL DATA

The Bellingham International Airport, located seven (7) miles SW of Wiser Lake was used for weather data due to its proximity. The airport received 31.27 inches of rain over the study period, with significant rain events on 10/24/23 that produced 1.58 inches and on 11/2/23 where 1.46 inches fell. Air temperature ranged from a freezing period where it got down to 10° F on January 12, 2024 to a high temperature of 87° F on August 14, 2023 (Figure 13).

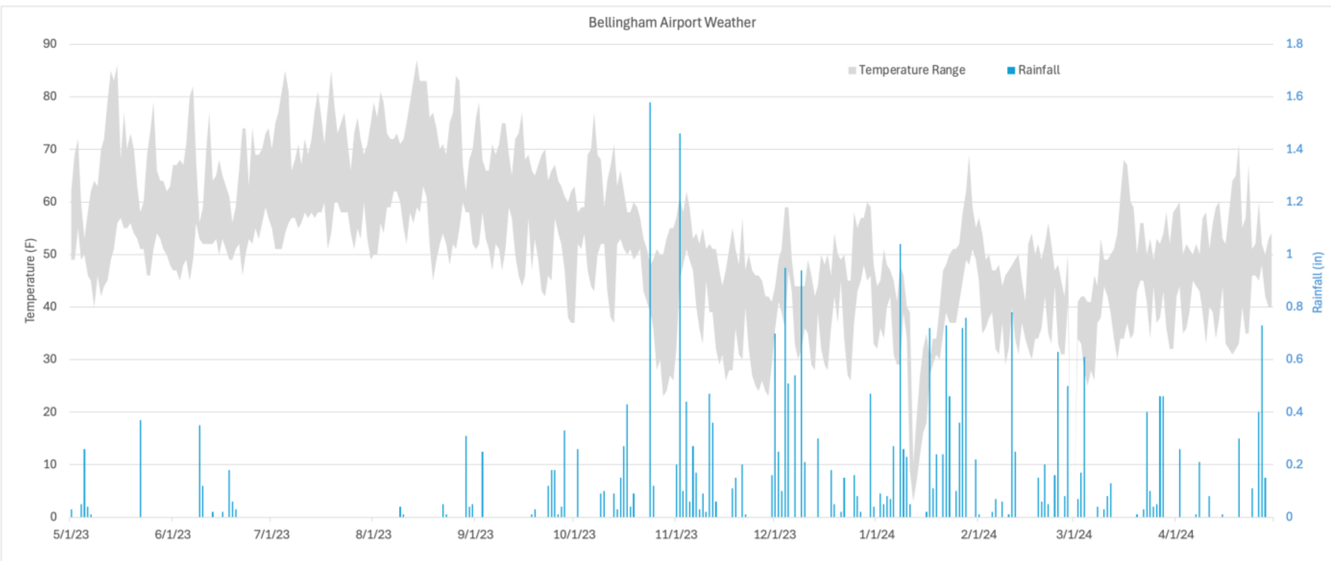


Figure 13. Air Temperature and Rainfall Data at Bellingham International Airport.

Wind speed at Bellingham International Airport was steady, with sustained velocities rarely above 15mph, but gusts occasionally exceeded 30 mph. There were periods of calm wind from August to October, and if there were sustained calm winds at night it may have led to brief periods of thermal and DO stratification (Figure 14). As will be discussed in Section G.3.2 this could lead to internal phosphorus releases from the sediment.

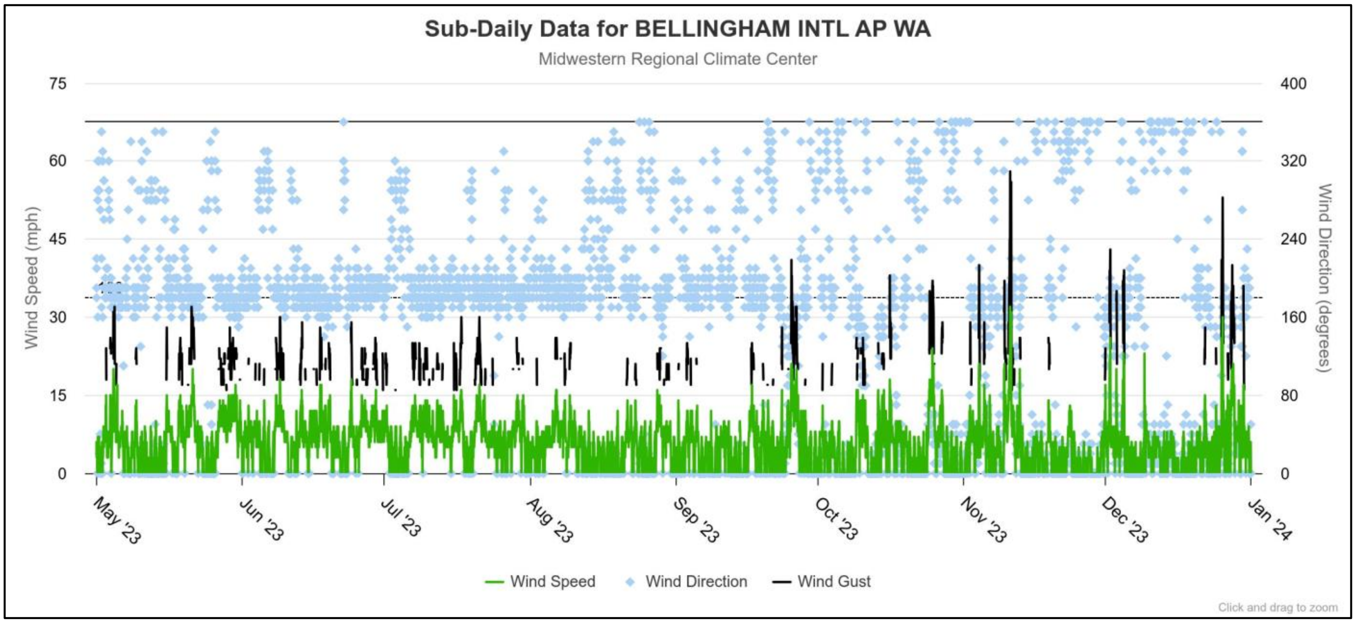


Figure 14. Wind speed and direction at Bellingham International Airport.

Lake stage data

Lake stage level was measured using a weighted line from the sample boat during monitoring trips. There was some variability in stage measurement between visits due to bottom contours if the boat was not anchored at exactly the same location every time. If the same location was sampled every time the difference between the depths at WL1 and WL2 would be exactly the same for every visit, which is not the case (Figure 15). It would be beneficial to install a stage indicator on the bridge abutment to allow more accurate readings.

The lake stage level at WL1 ranged from 1.4 to 2.32 meters deep, a 0.92-meter fluctuation over the study period, while WL2 ranged from 2.4 to 3.15 meters deep at WL2, a 0.75 meter fluctuation (Figure 15). The lake is held at the desired level with an outlet structure, but it tends to become blocked with vegetation and debris and it is difficult to access for clearing, which leads to more variability in the lake stage level data even during the dry summer periods.

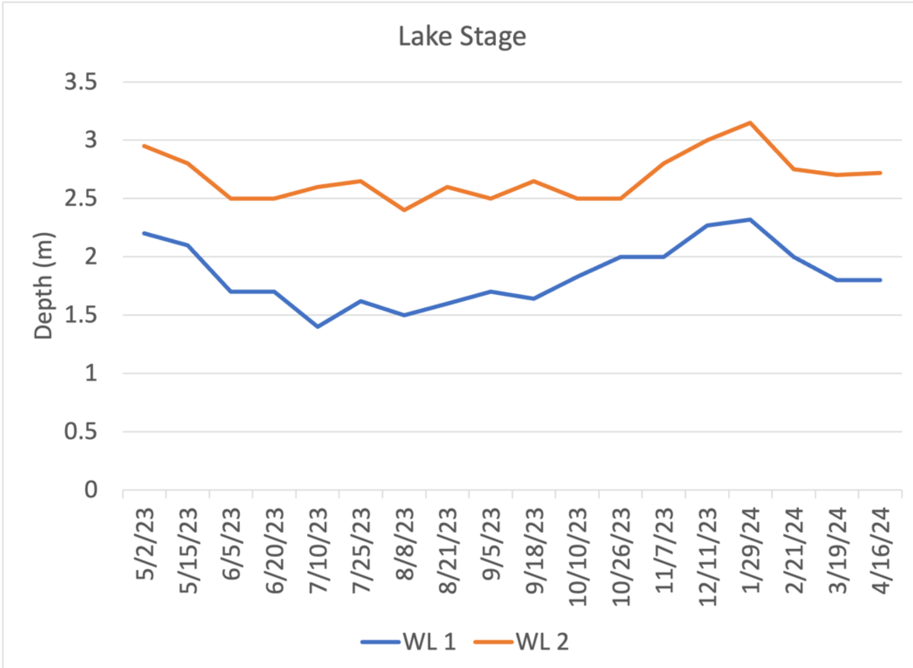


Figure 15. Lake stage data for West Basin (WL1) and East Basin (WL2), 2023 – 2024.

CREEK FLOW DATA

Flow measurements on Cougar Creek were very difficult to obtain due to the amount of vegetation in the channel both upstream and downstream of the lake. Instruments would become fouled by vegetation which would render the readings meaningless. In addition, the sediment layer in the canals was very loose which made finding the bottom with the wading wand challenging, and loose sediment would foul the propellor. During high flow periods in winter, the water in the creek was so deep it was not possible to wade to get flow readings. An alternate approach was used where a ball was placed on the surface and its movement was timed over a set distance. Unfortunately some of the sampling days were windy, which led to the ball being blown upstream.

Future measurements could be improved by clearing vegetation from within the canal during the summer season, and maintaining a vegetation-free zone to facilitate accurate flow readings, but that would not solve the issue of loose sediment. While WCHCS did manually clear vegetation from the sample area, upstream and downstream growth still impeded readings. If flow measurements are deemed important for future lake projects a 50 foot section of the canal could be cleared of aquatic vegetation, possibly using herbicides, in order to maintain a vegetation-free monitoring location. Due to the challenges of measuring flow with a wading wand, an acoustic doppler current profiler could be floated across the surface to characterize flow. These could be rented or maybe borrowed from USGS during the project.

G.1.3 Discussion

Creek flow and stage data were difficult to capture during the field study. Wiser Lake and the watershed are very flat so water from the lake backs up into Cougar Creek upstream of the lake, and the drainage downstream of the lake holds water throughout the summer. This makes it very difficult to achieve an accurate flow reading, compounded by the amount of vegetation in the channel that interferes with instrumentation.

Having accurate flow and stage readings is important for making sure the water and nutrient budget calculations are accurate.

G.2 Lake water quality profile monitoring – Field measurements

G.2.1 Monitoring Methods

Water quality field parameters were collected from WL1 and WL2 stations (Figure 16) by lowering a water quality sonde and recording measurements at discrete intervals. Readings were recorded just below the surface, then at 0.5 meter intervals down through the water column until 0.5 meters above the sediment. Temperature (T), specific conductivity (SC), pH and DO data were collected with the sonde and Secchi depth was measured at every sampling event.

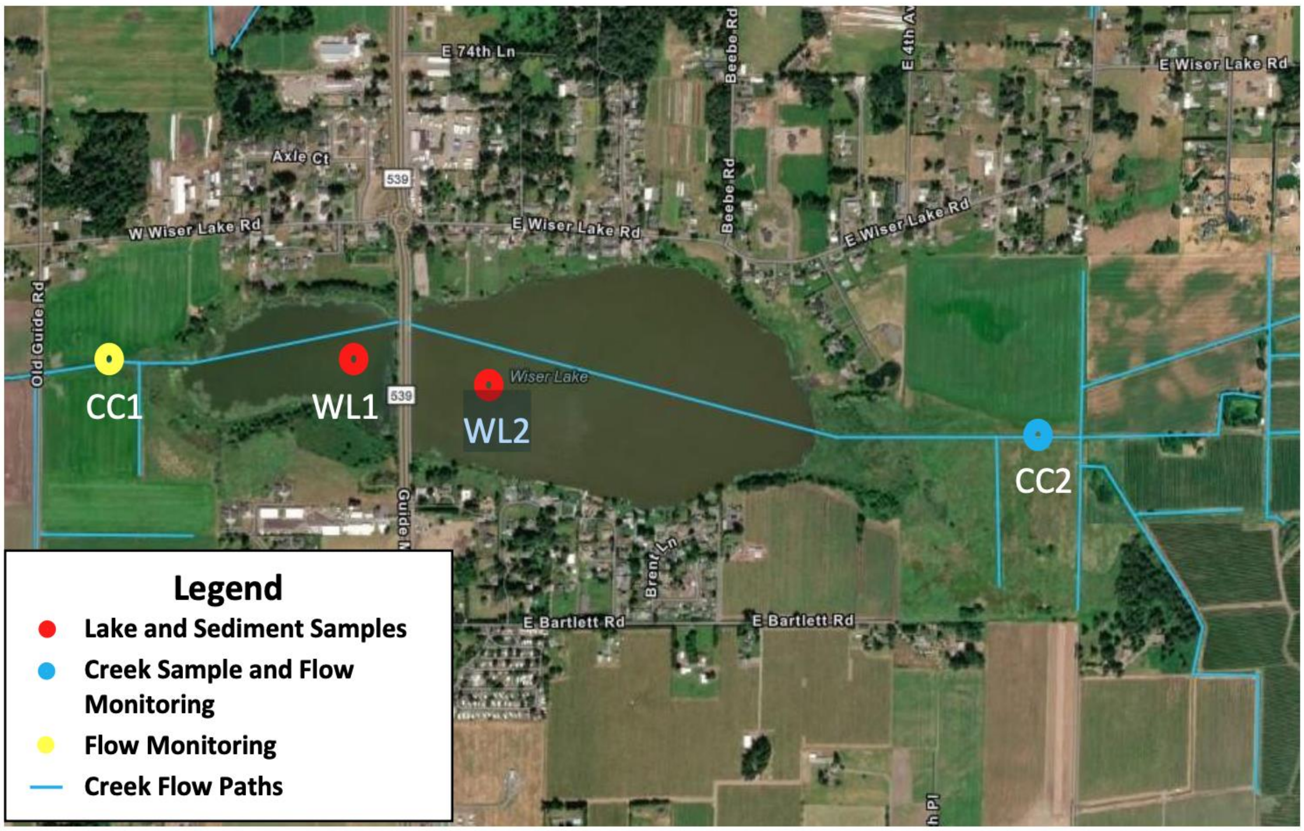


Figure 16. Sampling stations in Wiser Lake and Cougar Creek.

G.2.2 Monitoring Results

Sonde profile data for Wiser Lake at station WL1 showed a mixed water column condition for most of the summer season, with a brief period of thermal stratification in July and August. The DO remained at or above 4 mg/L with the exception of the August 21, 2023 profile. The deeper East Basin WL2 showed similar results, with DO remaining above 4 mg/L throughout the summer with the exception of the May 2, 2023 profile (Figure 18).

Aquatic Insight

Dissolved Oxygen

The DO trend for both stations was similar, with a slight reduction in DO near the bottom during July and August (blue line in Figure 18). Note the minimum DO concentrations in Figure 17 drops below 4mg/L in WL1 and just above 2 mg/L in WL2, which is not reflected in the DO time series shown in Figure 18. This is because the time series used depths that had data throughout most of the sample period whereas the profiles in figure Figure 17 reflected changes in lake depth, with sample profiles during the wet season reaching deeper than profiles in the dry season.

It is also important to note that while dissolved oxygen (DO) levels never dropped below 2 mg/L, the sonde was positioned 0.5 meters above the lake bottom. As a result, DO levels may have declined to near-anoxic conditions within that final half meter. This is a critical consideration for the phosphorus budget, as anoxic conditions at the sediment-water interface can trigger the release of phosphorus from the sediments into the water column. This will be discussed later in section G3.

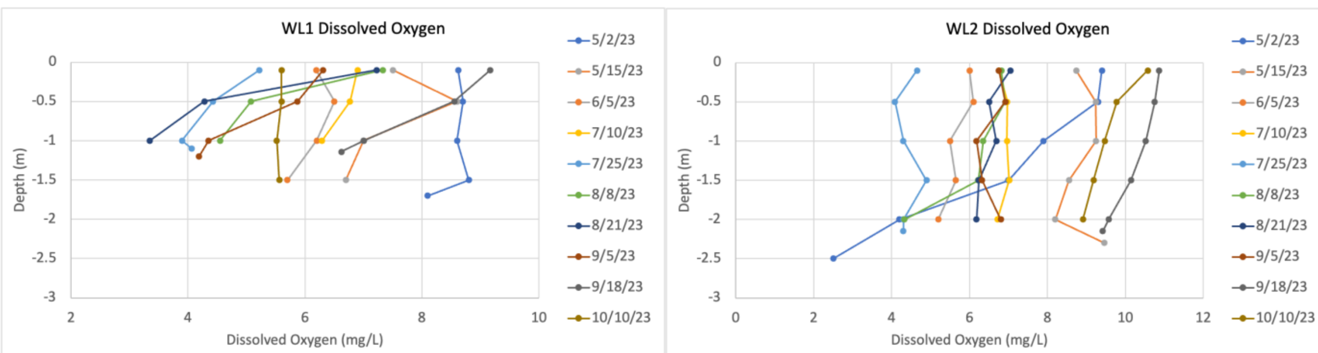


Figure 17. Dissolved oxygen profiles for Wiser Lake station WL1 (left) and WL2 (right).

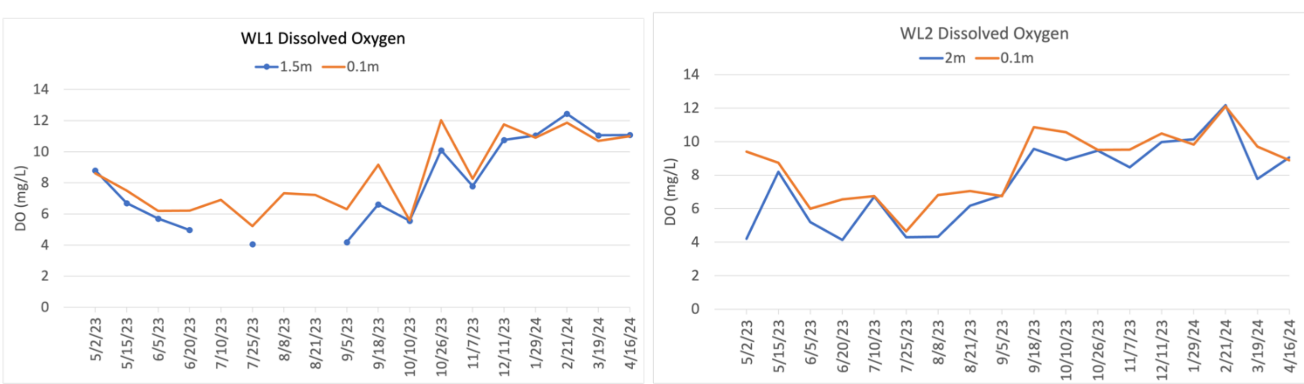
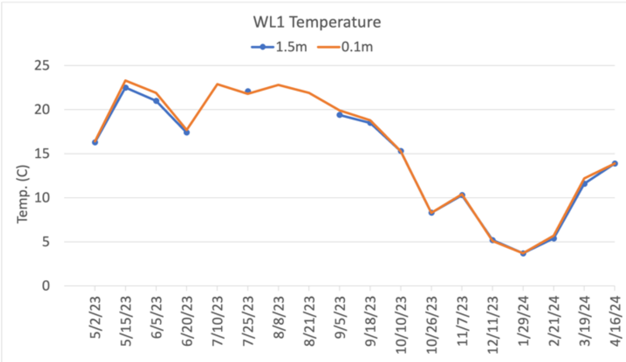


Figure 18. Dissolved oxygen concentration trend in Wiser Lake station WL1 (left) and WL2 (right).

Temperature

The water temperature profiles confirm the vertically mixed status of Wiser Lake, with the temperature between the surface and bottom staying nearly equal throughout the sampling period. Surface water temperature ranged from 23° C (73° F) on August 8, 2023 to 3.6° C (39° F) on January 29, 2024 (Figure 19).



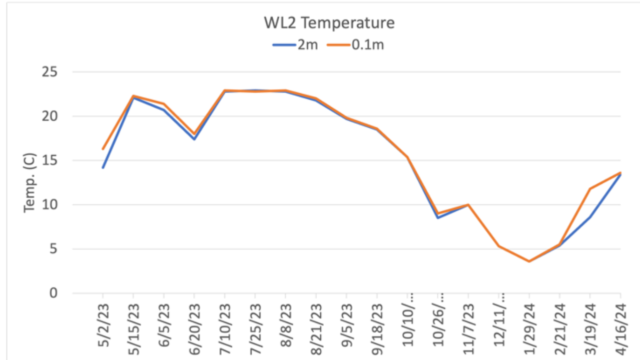


Figure 19. Temperature in Wiser Lake station WL1 (left) and WL2 (right).

PH

The pH in lakes typically averages around 7.0 throughout the year, the pH in Wiser Lake at 1 meter depth averaged 7.93 for WL1 and 7.84 for WL2 during the summer months of June to September. The highest pH levels were recorded on September 18 with WL1 reaching 9.14 and WL2 measuring 8.78 (Figure 20). The pH readings in Cougar Creek upstream of the lake were lower, averaging 7.39 for the summer months. The elevated pH in in both lake basins corresponded to cyanobacteria activity, with the photosynthetic activity related to the bloom increasing pH. While phytoplankton was not sampled on September 18, a sample collected October 10 revealed very large numbers of *Aphanizomenon flos-aquae.*

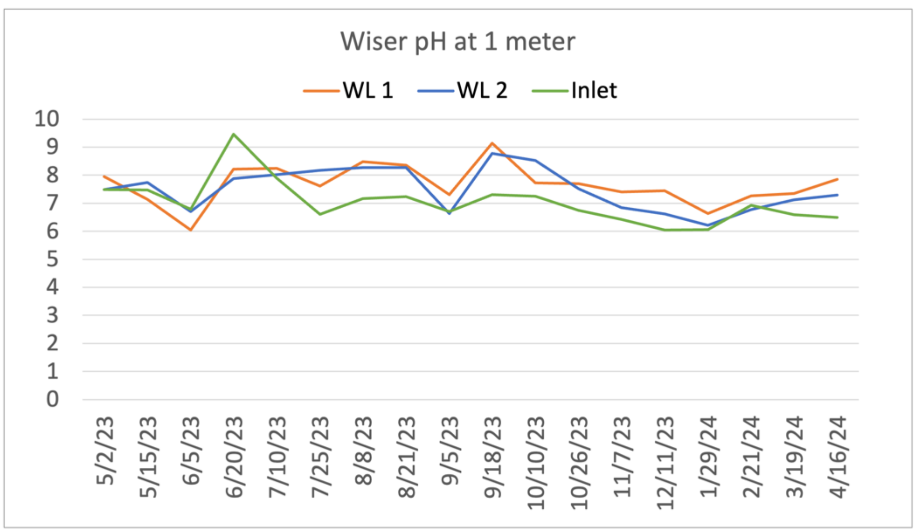


Figure 20. pH in Wiser Lake during 2023-2024 study period.

CONDUCTIVITY

Conductivity in Wiser Lake and the inlet was very high compared to other lakes in Washington (Ecology EIM database). Average conductivity at 1 meter in WL1 was 425 µS/cm and at WL2 was 439 µS/cm. Most lakes in the Ecology EIM database had conductivity levels around 100 µS/cm, and rarely went above 200 µS/cm. Conductivity in Cougar creek was lower than conductivity in the lake during the summer months but exceeded conductivity in the lake during the rainy season (Figure 21). Average conductivity in Cougar Creek was 427 µS/cm over the study period.

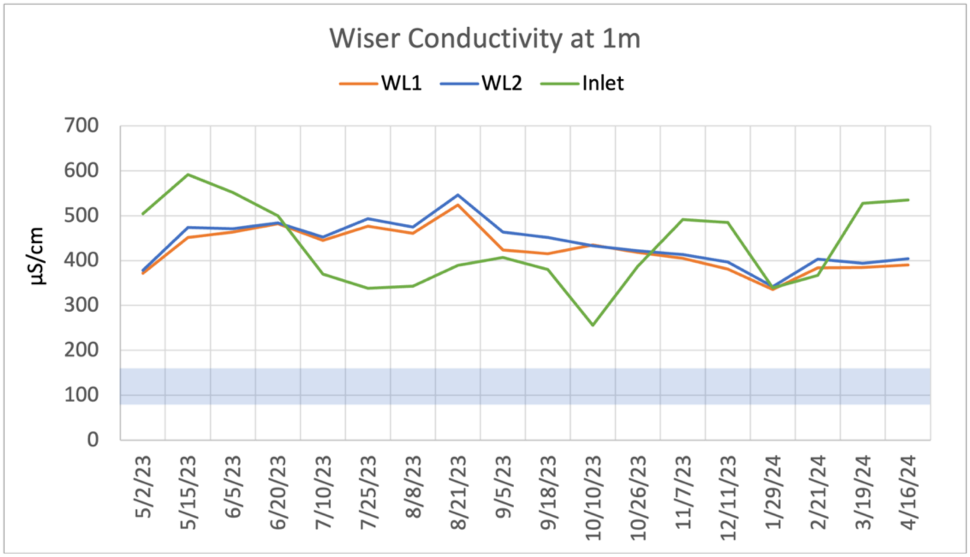


Figure 21. Conductivity in Wiser Lake. Light blue bar is typical conductivity readings in Washington Lakes (Source: Ecology EIM Database)

G.2.3 Discussion

Sonde profiles provide valuable insight into lake conditions from the surface to the bottom, particularly regarding thermal stratification, which can lead to oxygen depletion near the sediment. In deep lakes during summer, the water column often separates into layers—warmer water remains at the surface while cooler water settles at the bottom. This thermal stratification reduces vertical mixing, causing oxygen to decline near the sediment, where sunlight cannot penetrate to support photosynthesis.

Oxygen is produced near the surface through photosynthesis, but deeper layers receive no sunlight, halting oxygen generation. Meanwhile, dead algae and organic matter sink to the bottom, where oxygen is consumed during decomposition. Without mixing between layers, oxygen near the sediment is depleted, potentially triggering the release of phosphorus from the sediment into the water column.

In contrast, shallow lakes like Wiser may remain well-mixed if wind is consistent, as suggested by the DO and temperature profiles and wind data shown in Figure 14. However, this data may not capture the full picture. While wind is the primary driver of lake mixing, calm nighttime conditions can allow short-term stratification, potentially leading to nutrient release from the sediment. These nutrients may then be mixed into the upper water column during daytime wind-driven mixing.

Wiser Lake also exhibited elevated conductivity, averaging 425 µS/cm in the West Basin and 440 µS/cm in the East Basin—significantly higher than typical values for Washington lakes. This is likely due to wind-induced disturbance, which suspends ions from the sediment into the water column. Elevated conductivity highlights the role of sediment resuspension in nutrient dynamics, pointing to sediment as a key source of nutrient inputs.

The pH readings were also high and could be contributing to internal phosphorus release. Typically lakes are near neutral (pH~7) except for periods when algae density is very high. The pH in Wiser Lake averaged above 7.5 during the entire study duration, with the average summer (June-September) concentration above 7.8. During periods of high phytoplankton growth the pH regularly exceeded 8.0 in both basins while WL1 saw pH above 9 in September. Under these alkaline conditions (pH>8), phosphorus is released from aluminum into the overlying water column (Reitzel, 2013).

The profile data show a lake that does not stratify (at least not during the daytime), experiences sediment resuspension and high pH and conductivty. Deep lakes that experience temperature stratification often have high levels of phosphorus in the deeper layers due to anoxic conditions, but that does not seem to be occurring in Wiser Lake during the daytime due to wind mixing. While brief periods of stratification may occur at night during calm conditions, further monitoring would be necessary to verify this. Both basins experience pH conditions high enough to trigger phosphorus release from the sediment, further contributing to internal phosphrous loading. Elevated conductivity is likely a result of suspended sediment in the main lake but high conductivity in Cougar Creek could be due to ions from groundwater and high nutrient runoff.

G.3 Lake water quality sampling – Lab samples

G.3.1 Monitoring Methods

Two lake samples were collected for laboratory analysis at every sampling event in the East Basin (WL2). The epilimnion sample was collected at 0.5 m below the surface and the hypolimnion sample was collected 0.5 m above the apparent bottom. During periods of lake stratification (observed as a change of ≥1 °C per meter of depth), an additional sample was taken from the metalimnion. One sample per sampling event was deemed sufficient for the West Basin (WL1) due to it's shallow depth. These samples were analyzed for: Total P (TP), Ortho-phosphorus, Total Nitrogen (TN), Nitrate + Nitrite, Ammonia, Chlorophyll-a (chl-*a*) and Phycocyanin. Due to the shallow nature of the lake, chl-*a* and Phycocyanin samples were only collected from the 0.5 m surface depth.

A grab sample method was used for the 0.5 m depths and a 4- to 6-Liter (L) vertical Kemmerer bottle was used at depths greater than 0.5 m. Gradations of 0.5 m were marked on the rope used to suspend the Kemmerer bottle, and this determined the precision of the depth at which samples are collected. The sampling boat was anchored prior to deployment of the Kemmerer bottle. When the Kemmerer bottle was retrieved, it was used to fill individual sample bottles. Sample bottles were handled only with gloved hands, and stored in resealable plastic bags in coolers on ice before and after sampling. Sample bottles were supplied by the analytical laboratory and were not cleaned by WCHCS; the Kemmerer bottle was rinsed 3-5 times with distilled water prior to each sampling day.

G.3.2 Monitoring Results

G.3.2.1 Phosphorus

Phosphorus is the most important nutrient to measure for lake health. This is a primary food source for plants, algae and cyanobacteria. A phosphorus concentration above 20 µg/L will often lead to cyanobacteria dominance. The two forms of phosphorus measured: total phosphorus and soluble phosphorus. Soluble phosphorus is immediately available to support the growth of alge and cyanobacteria, while total phosphorus includes both the soluble form and phosphorus bound to sediment and organic matter. Wiser Lake had a very high phosphorus concentrations throughout the sampling period. At station WL2 TP and Ortho-P near the surface averaged 127 µg/L and 30 µg/L, respectively during the summer months. For station WL1 TP and Ortho-P averaged 166 µg/L and 81 µg/L, respectively during the same time period (

Table 11).

Table 11. Total phosphorus (TP), Ortho-P, and total nitrogen (TN) concentration, ug/L, near the surface at the two lake sampling locations.

	TP (µg/L)		**Ortho-P** (µg/L)		**TN** (µg/L)	
	WL2 (top)	WL1	WL2 (top)	WL1	WL2 (top)	WL1
Summer Ave.	127	166	30	81	1222	995
Annual Ave.	104	135	23	48	1759	1592
Max.	235	321	114	203	3560	3147

The phosphorus concentration increased during the summer, topping out on September 1, 2023 at WL1 and August 8, 2023 at WL2 (Figure 22). A summer peak in phosphorus levels in this region typically indicates internal loading from sediments, as external loads from runoff are minimal during the dry season. But as shown in the previous discussion, the lake was fairly well mixed vertically throughout the year with DO at the bottom (0.5 meters above sediment) staying above 2 mg/L throughout the summer. The phosphorus concentration at WL1 was 37% higher than at WL2 and this may have been the result of wind concentrating algae and plant debris near the sampling site. The prevailing west wind during summer would stack cyanobacteria, filamentous algae, and plant material near the causeway where it could have been picked up in sampling.

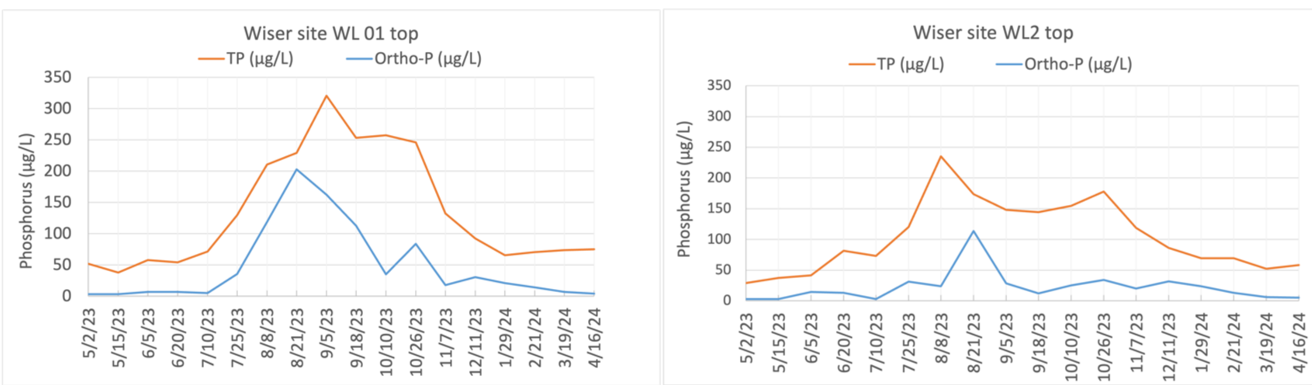


Figure 22. Total phosphorous (TP) and Ortho-P near the surface at station WL1 (left) and WL2 (right).

If the water column stratifies during summer there would be a gradual increase in phosphorus near the bottom as anoxic conditions lead to phosphorus release from the sediment. As shown in Figure 18 for site WL1 there is a period from July to October, 2023 where DO near the bottom was less than the concentration near the surface, but the data did not show anoxia near the bottom. However, there was a steady increase in TP at both WL1 and WL2 starting in July that seems to indicate internal phosphorus releases.

At WL2, it was deep enough to warrant collecting a phosphorus sample from both the surface and near the bottom. The TP concentration near the surface was greater than the concentration near the bottom, which is opposite what is typically seen in a stratified system. Ortho-P was very similar between the top and bottom samples though, barely diverging throughout the sample periods (Figure 23).

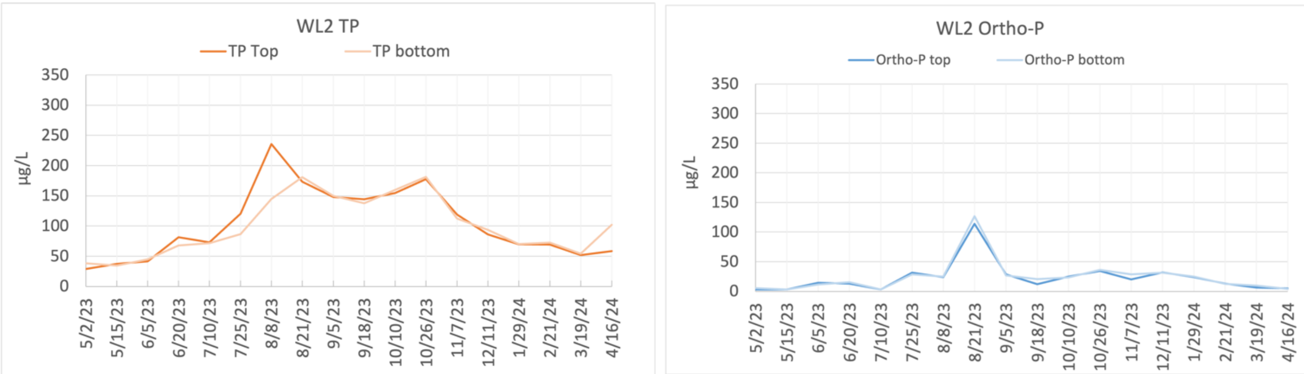


Figure 23. Total phosphorus (TP) and Ortho-P at station WL2. Solid lines represent data near the top and shaded lines represent data near the bottom.

G.3.2.2 Nitrogen

Along with phosphorus, nitrogen is a vital nutrient for algae and plant growth. Nitrogen forms analyzed for this project were ammonium (NH4), nitrate (NO3-NO2), and total nitrogen. Ammonium and nitrate are inorganic, bioavailable forms of nitrogen that support plant and algal growth. They are important to monitor because they indicate inputs from agricultural runoff, septic effluent, groundwater and fertilizers. Total nitrogen represents all forms of nitrogen, including ammonia, nitrate, and organic nitrogen contained in organic matter.

Table 12. Nitrogen species in Wiser Lake

	Ammonium (µg/L)		**Nitrate** (µg/L)		**TN** (µg/L)	
	WL2 (top)	WL1	WL2 (top)	WL1	WL2 (top)	WL1
Summer Ave.	62	42	30	25	1222	995
Annual Ave.	139	163	588	432	1759	1592
Max.	537	100	2383	2348	3560	3147

Nitrogen concentrations in Wiser Lake were significantly higher during the winter months, with fall levels likely reflecting inputs from Cougar Creek and possibly groundwater. At WL2, total nitrogen from June to September averaged 1,222 µg/L, with nitrate comprising only about 3% of the total (Table 12). In contrast, during the rainy season (October to May), nitrate accounted for 40% of total nitrogen. A similar pattern was observed at WL1, where nitrate made up just 3% of total nitrogen in summer but increased to 32% in winter.

These results indicate a seasonal shift in dominant nitrogen forms. During the wet season, nitrate and ammonium concentrations were higher, consistent with increased runoff and groundwater influence. In summer, nitrogen was primarily in organic forms, likely tied up in algal and plant biomass, while concentrations of nitrate and ammonium were much lower.

During summer, nitrogen levels were relatively low compared to available phosphorus, which may limit algal growth (see Section G.5.3). However, this would not constrain nitrogen-fixing cyanobacteria, which can supplement their nitrogen needs from atmospheric sources.

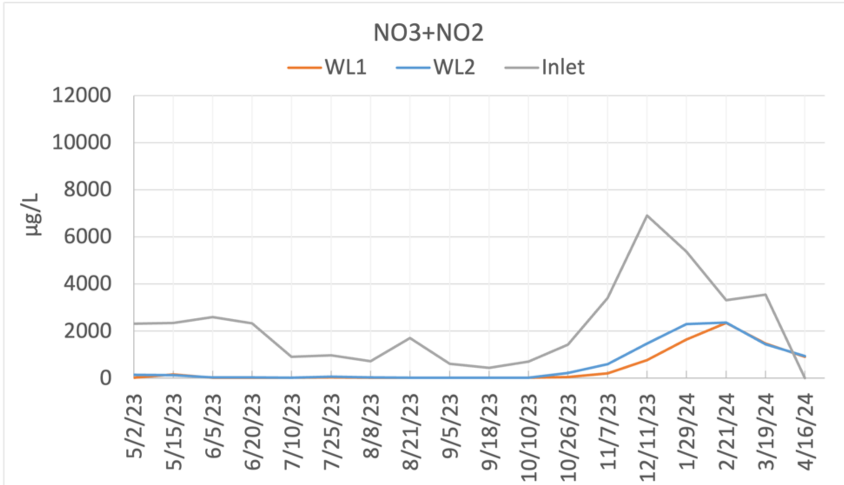


Figure 24. Nitrate+Nitrite concentration in Wiser Lake. Values for WL2 represent samples collected near the surface. Samples collected near the bottom are very similar.

Nitrate made up a majority of the total nitrogen concentration in Cougar Creek, even exceeding total nitrogen on three occasions. Cougar Creek is a major source of nitrogen to Wiser Lake during the rainy season, and the concentration remains high during the summer months, but since there is little flow entering the lake the impact is not as great as during the wet season.

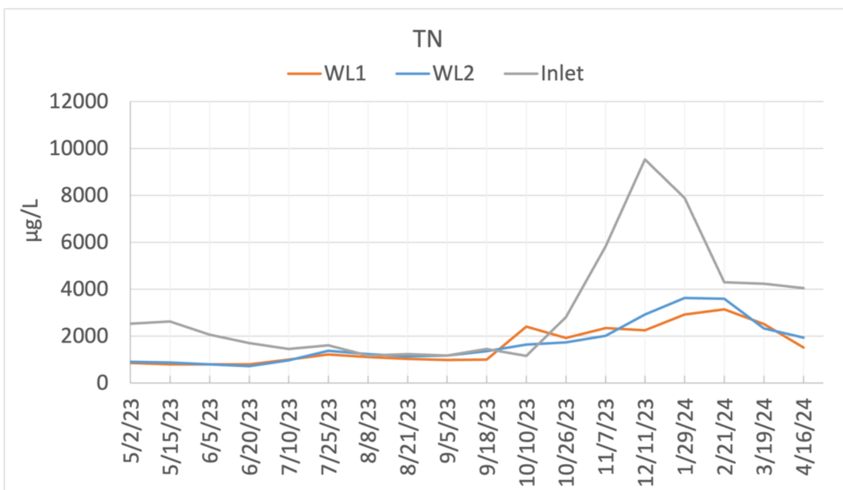


Figure 25. Total nitrogen concentration in Wiser Lake. Values for WL2 represent samples collected near the surface. Samples collected near the bottom are very similar.

G.3.2.3 Chlorophyll and Phycocyanin

Chlorophyll *a* (chl-a) is produced by plants, algae and cyanobacteria, and phycocyanin (PC) is an accessory pigment produced by cyanobacteria. While chl-a indicates the concentration of algae, and potentially cyanobacteria in a lake, the PC concentration shows how much of the chl-a concentration may be due to cyanobacteria. Monitoring chlorophyll a is a good indicator of the overall algae population, and therefore nutrient loading to the lake, but it may not capture the extent of a cyanobacteria bloom if they are concentrated at depths that were not sampled. For instance, there was a very high concentration of chlorophyll shown in samples collected from the boat ramp by Western Washington, but the concentration in the lake at the time was much lower. This discrepancy is because samples collected at the boat ramp represent a concentration of buoyant cyanobacteria, but the water column sample reflects what is distributed in the water column.

The chl-*a* concentration in Wiser Lake followed the phytoplankton population (Section G.5) with spikes in WL1 and WL2 in July and October. The phytoplankton population in WL2 was less than in WL1 and the chl-*a* concentration reflected that. Chl-*a* in both locations spiked on October 10 due to a cyanobacteria bloom, and as a result the PC concentration was high on those two days. Interestingly the PC concentration in WL2 was high on November 7 as well, exceeding the chl-a concentration even though the algal population was low and cyanobacteria was less than one percent of the biovolume. However, this could have been due to instrument error because this condition was not repeated in any other sample event.

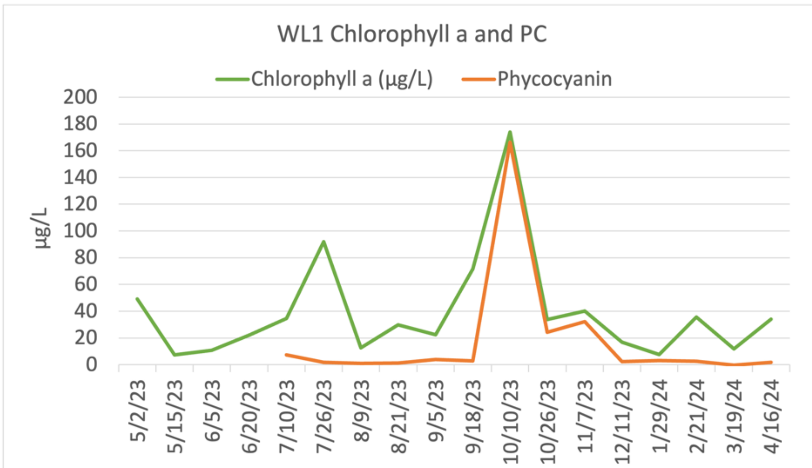


Figure 26. Chlorophyll a and phycocyanin in WL1

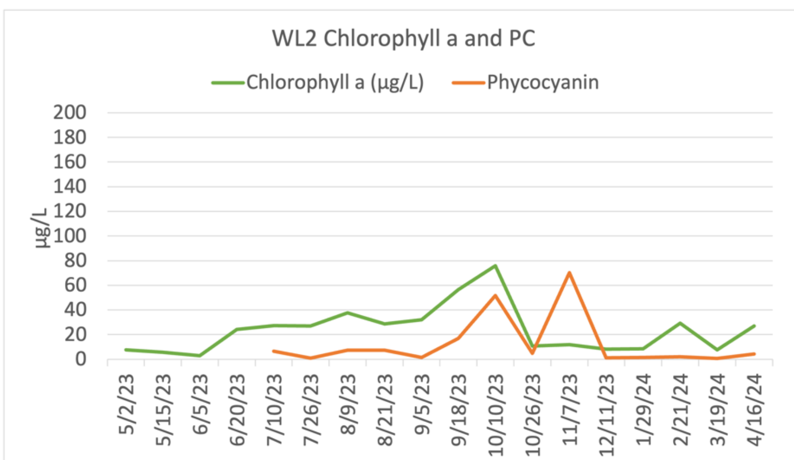


Figure 27. Chlorophyll a and phycocyanin in WL2 (top).

G.3.3 Discussion

Wiser Lake experiences high phosphorus levels in the summer, likely due to internal loading, and elevated nitrogen levels in the winter, primarily from groundwater input and surface runoff. Nitrogen forms shift seasonally, with lower concentrations of nitrate and ammonium during the summer growing season as these forms are absorbed by plants and algae. In contrast, these forms are more concentrated during the winter months, suggesting that runoff from agriculture, septic systems, and groundwater is contributing significant nutrients. This seasonal shift appears to create a nitrogen-limited system during the summer, which favors nitrogen-fixing cyanobacteria. During the rainy season, nitrogen levels rise significantly due to inputs from the watershed and groundwater.

Phytoplankton biovolume was comprised mostly of diatoms in the spring, followed by cyanobacteria becoming dominant when the weather warmed and nitrogen became limiting. Light penetration into the water column was very low during summer, which limited algae and cyanobacteria growth, but in October the wind velocity slowed and could have allowed cyanobacteria to regain the competitive advantage provided by buoyancy regulation. During the windy summer weather the lake was turbulent enough that cyanobacteria were forced to circulate out of depths that were optimal for growth. Turbulence also mixed sediment in the water column which reduced transparency, further limiting growth.

Chlorophyll *a* tracked with the phytoplankton population and phycocyanin (PC) tracked with cyanobacteria. During the summer months PC was low compared to chloroplyll *a*, due to low cyanobacteria concentrations, but in October the PC concentration spiked with cylorophyll *a*, which indicated most of the species were cyanobacteria. This is useful for future monitoring. Using a fluorometer for rapid assessments can provide insight about the phytoplankton population, which can be followed by lab analysis to quantify species when PC becomes elevated.

As discussed in Section G.2.3 Discussionthere is a potential for internal loading from the sediment in Wiser Lake due to stratification, but sonde data show oxygenated conditions to the bottom of the profile, which was 0.5 meters above the sediment. If the sonde were lowered to the sediment surface it could show further declines in DO and potentially reduced conditions that would lead to internal loading. Internal loading could be enhanced at night when the wind is calm, strengthening thermal stratification and leading to greater reductions in DO.

The concern with lowering a sonde to the sediment surface is the potential to stir up material that could be captured during water collection for other samples. A solution is to perform tasks that have a potential to stir sediment (Secchi reading and sonde profile) as a last step after all other samples have been collected. This is also why setting a permanent anchor at the sample location is advised so the exact same spot is sampled every time and the sediment is not disturbed by dropping an anchor before sampling.

Wiser Lake appears to be mixed lake system where the water column is homogenous from top to bottom. While showing the characteristics of a mixed lake it may be polymictic, meaning it mixes several times throughout the year. This could be caused by stratification at night during calm weather and then mixing during the day. While water near the surface would typically cool at night, increasing the potential for water column mixing, aquatic vegetation may reduce circulation and enhance DO depletion through respiration. This would lead to a phosphorus pumping effect where the nutrient is released from the sediment at night and mixed to the surface by wind during the day. Later in Section I2 there is a discussion phosphorus loading from internal and external sources.

While the exact processes happening in the water column are not known at this time, it is possible to fill in some of the data gaps and understand with some limited additional sampling. Section M lists suggestions for additional monitoring and adaptive management strategies.

G.4 Stream water quality sampling – Lab samples and field measurements

G.4.1 Monitoring Methods

Water quality grab samples were collected from Cougar Creek upstream of Wiser Lake. The grab samples were taken from the center of the stream at wrist depth, as close as possible to the thalweg. The samples were analyzed for TP, Ortho-P, NO3+NO2, NH4, and TN. For grab samples, laboratory-provided bottles were obtained and filled with sample. Samples were stored on ice in a cooler until delivery to the lab.

G.4.2 Monitoring Results

The phosphorus concentration at the inlet to Wiser Lake (CC2) averaged 50.2 µg/L over the study period, with an average concentration of 37.6 µg/L during the summer months of June to September, 2023. Ortho-P averaged 18.1 µg/L over the study period and 16 µg/L during the summer. Nitrate+nitrite concentrations averaged 2,366 µg/L during the study period and 1,284 µg/L during summer (Table 13).

Table 13. Nutrient data from the inlet to Wiser Lake (CC2), ug/L.

	TP	Ortho-P	TN	NO3+NO2
Summer Average	37.6	16	1,489	1,284
Annual Average	50.2	18.1	3,160	2,366
High summer (6/5/23)	54.3	23.3	2,066	2,597
High Annual (12/11/23)	124.5	67	9,525	6,911

The phosphorus concentration increased steadily starting in early November, with the highest concentration on the January 29 sample event, likely due to heavy rain where 3.15 inches of rain fell in the week prior to sampling (Figure 28). Heavy rain would have washed manure and soils from pastures and avian waste from the watershed into Cougar Creek. This surface runoff would have been added to what was coming to the lake via groundwater flow.

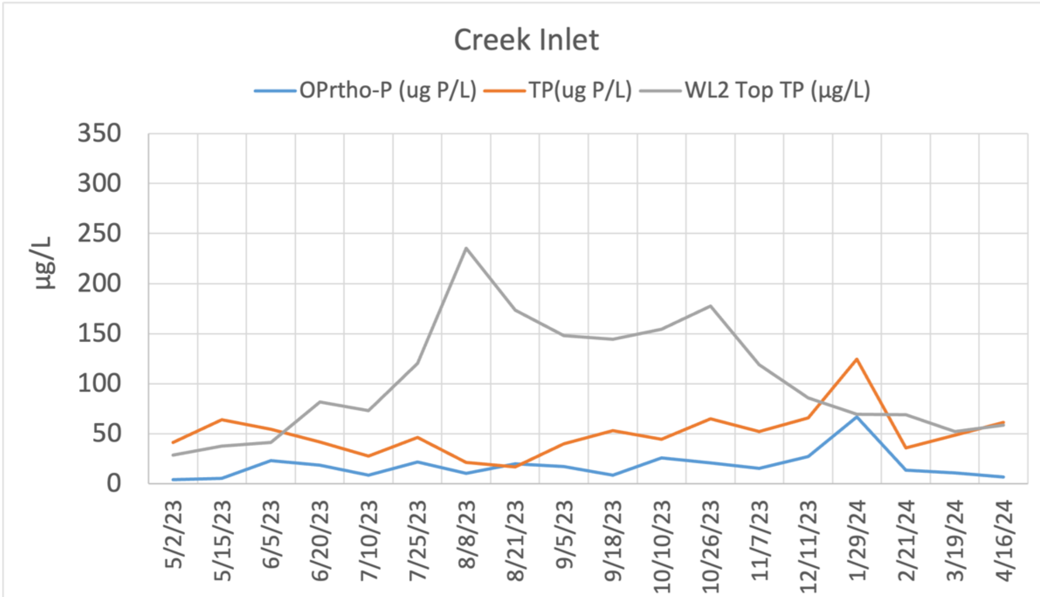


Figure 28. TP and Ortho-P concentration in Cougar Creek at station CC2. Grey line is lake station WL2 for reference. Phosphorus goal is 20 µg/L

G.4.3 Discussion

The phosphorus concentration in Cougar Creek was lower than the concentration in the lake from mid June to mid December, but the creek concentration started to increase in early January when fall rains started. The phosphorus concentration peaked on January 29 but quickly fell by the next sampling date of February 21. Even though the summer concentration of phosphorus in Cougar Creek was lower than the lake it did provide a steady source of phosphorus to the east lake basin and accounts for 30% of the phosphorus budget (Figure 52). While heavy rainfall increases the phosphorus concentration in Cougar Creek it also increases nitrogen. Analytical modeling has shown that Cougar Creek contributes almost 5,000 kg/year of nitrogen and 52 kg/year of phosphorus to Wiser Lake (see Section I.1.1).

Nitrogen from Cougar Creek was dominated by nitrates, which is an inorganic form of nitrogen and bioavailable for aquatic plant and algae growth. The primary source of nitrates to surface water is agricultural and urban runoff, particularly from manure runoff and septic systems. The nitrogen concentration during summer was relatively low compared to the phosphorus concentration, which may lead to nitrogen limits to algae growth. A response to this limitation could be why the lake was dominated by the nitrogen fixing species *Anabaena flos-aquae* (discussed in section G.5.3)

G.5 Phytoplankton sampling

G.5.1 Monitoring Methods

Due to the shallow nature of the lake, one phytoplankton sample was collected from each basin at each sampling event. Each sample was collected from a 0.5 m depth.

G.5.2 Monitoring Results

Phytoplankton in both basins was dominated by cyanobacteria in July and October 2023. In the West Basin (WL1) cyanobacteria made up 71% of the biovolume in the July 10, 2023 sample and 78% of the biovolume in the October 10, 2023 sample. Diatoms were dominant in June, 2023, representing 93% of the biovolume and in September, 2023 with 98% of the biovolume (Figure 29).

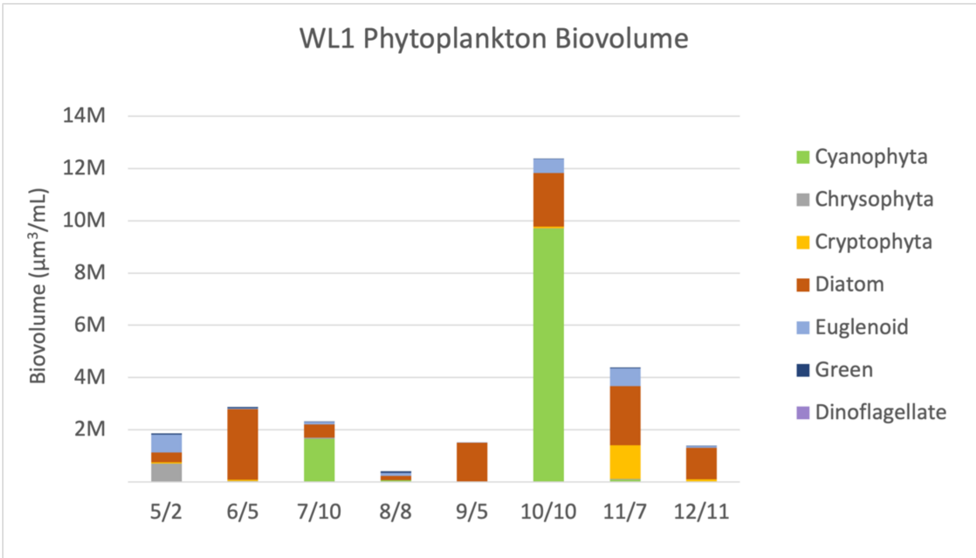


Figure 29. Phytoplankton Biovolume at WL1 (West Basin), 2023

Cyanobacteria species during the summer at station WL1 were dominated by *Anabaena circinalis* on July 10 and *Anabaena flos-aquae* on October 10. Cyanobacteria were present in August and September, but their biovolume was very low compared to diatoms. The species observed were *Aphanizomenon flos-aquae* in August, 2023 and *Anabaena flos-aquae* in September, 2023 (Figure 30).

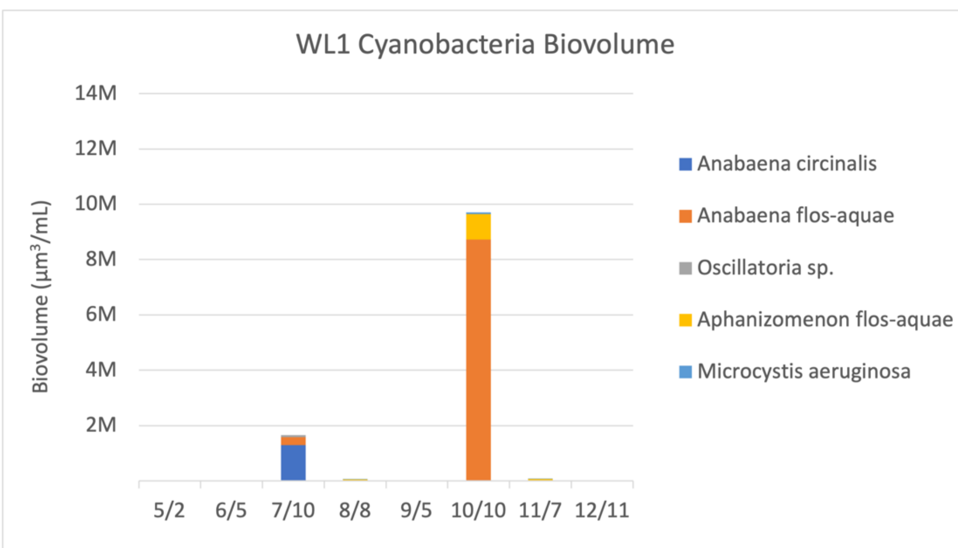


Figure 30. Cyanobacteria Species Dominance at WL1 (West Basin), 2023.

The phytoplankton population in the East Basin (WL2) was similarly dominated by cyanobacteria during the July and October, 2023 samples, but the biovolume in October, 2023 was less than in the West Basin (Figure 31). Cyanobacteria species in the East Basin consisted of primarily *Dolichospermum flos-aquae* (Formerly *Anabaena flos-aquae*) during both the July and October, 2023 sample periods (Figure 32).

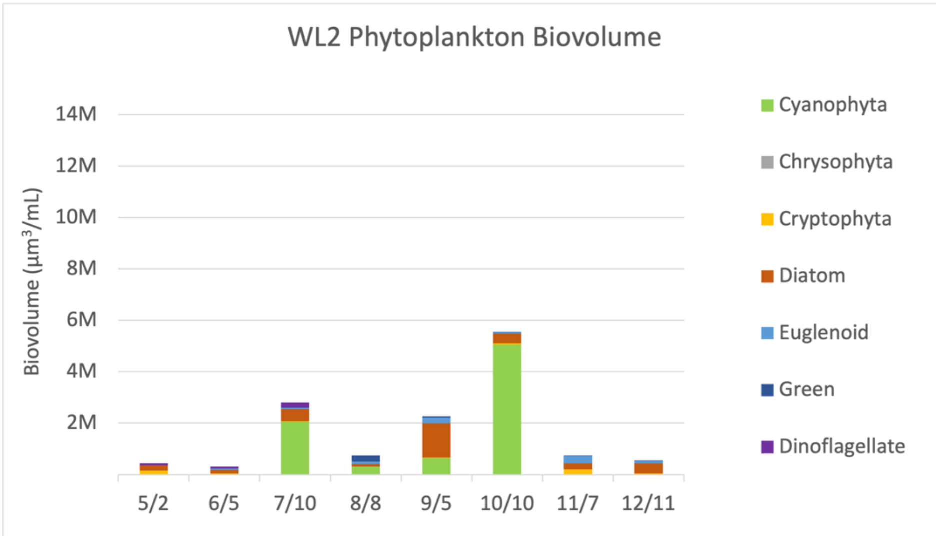


Figure 31. Phytoplankton Biovolume at WL2 (East Basin), 2023.

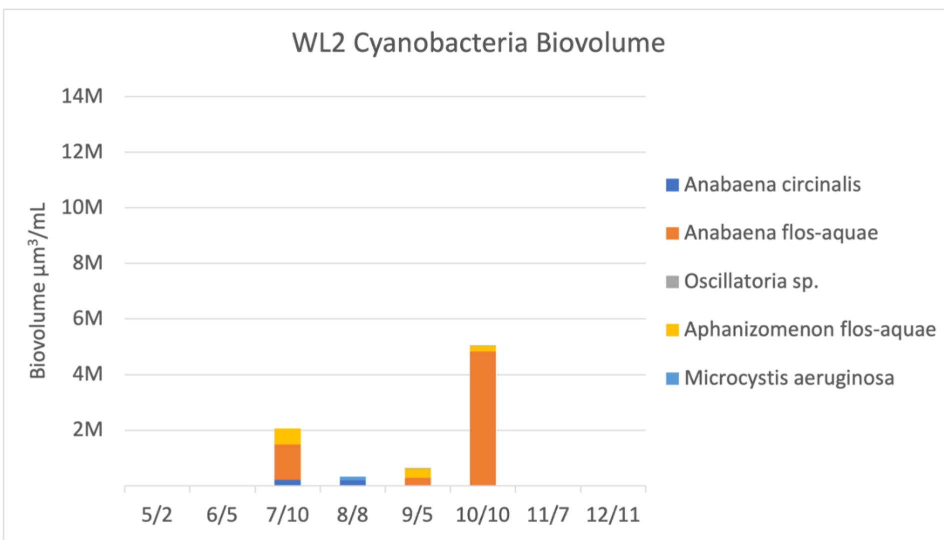


Figure 32. Cyanobacteria Species Dominance at WL2 (East Basin), 2023.

G.5.3 Discussion

Cyanobacteria and algae are among a group of microscopic aquatic organisms known as phytoplankton. Even though both are considered phytoplankton, they are distinct because cyanobacteria have prokaryotic cells associated with bacteria instead of eukaryotic cells associated with algae. The exact definition is not as important as the fact that algae are beneficial organisms at the base of the aquatic food chain, whereas cyanobacteria have little food value and tend to become harmful when in high concentrations.

Phytoplankton refrences in this report include both cyanobacteria and algae, but cyanobacteria and algae are used separately when appropriate. This distinction will become important when discussing specific steps to reduce cyanobacteria, while allowing beneficial algae to grow. For instance, BMPs that reduce nutrients will affect all phytoplankton, but those that counter the unique advantages of cyanobacteria would be more targeted.

Phytoplankton are a natural part of aquatic systems and grow in waterbodies of all sizes from the ocean to a roadside ditch. Whereas many algal species are key members of the aquatic food chain, cyanobacteria have physiological characteristics that make them a less desirable food source, leading to limited predation. Cyanobacteria also have unique qualities that allow them to outcompete algae to quickly become the dominant phytoplankton species.

Cyanobacteria possess several adaptations that give them a competitive advantage in freshwater ecosystems. They use gas vesicles to regulate buoyancy, allowing them to position themselves optimally within the water column. This enables them to access and store phosphorus from deeper waters, then return to the surface where sunlight drives photosynthesis and energy production. Many cyanobacteria can also fix atmospheric nitrogen, allowing them to thrive even when nitrogen levels are too low to support other algal species.

Their ability to capture light across a wide range of wavelengths—and at low intensities—enables photosynthesis under conditions that are often unfavorable for other algae. Additionally, cyanobacteria often form colonies that are resistant to grazing by predators and produce akinetes, specialized cells that store nutrients and facilitate rapid growth when environmental conditions improve (Paerl et al. 2001). As discussed earlier, some cyanobacterial species are also capable of producing liver or neurotoxins, posing risks to ecosystem and human health.

Cyanobacteria in Wiser Lake are dominated by the species *Anabaena circinalis* and *Aphanizomenon flos-aquae*, both of which have the ability to produce toxins. A cyanotoxin sample from the West Basin exceeded the World Health Organization (WHO) standard of 100,000 cells/ml on October 10, 2023. While the Washington Department of Health (DOH) has recreational guidelines for specific toxin levels, the WHO standard can provide an initial assessment of toxin risk based on cyanobacteria density. However, collecting a sample in the water column often does not represent the concentration at the surface due to buoyancy regulation by cyanobacteria. Since cyanobacteria have the ability to regulate their buoyancy, they often collect at the surface, particularly when they are stressed or dying. This is apparent when referencing toxin samples collected near the boat ramp, which regularly exceeded recreational limits (Figure 12).

It was surprising that phytoplankton concentrations were not higher, given the elevated phosphorus levels. If Wiser Lake remains well mixed for most of the year, this circulation could disrupt the buoyancy advantage of cyanobacteria, allowing diatoms and other non-buoyant phytoplankton to dominate near the surface. Phytoplankton cells typically follow a nitrogen-to-phosphorus (N:P) ratio of 16:1, known as the Redfield Ratio (Redfield, 1958), which reflects the optimal nutrient balance for growth across many species. While not absolute, this ratio serves as a useful benchmark for assessing nutrient limitation.

In Wiser Lake, the N:P ratio was below 16 for much of the growing season (Figure 33), suggesting nitrogen limitation during summer months. This nutrient imbalance may explain the late-summer dominance of *Aphanizomenon flos-aquae*, a cyanobacteria species capable of fixing atmospheric nitrogen and thriving under low nitrogen conditions.

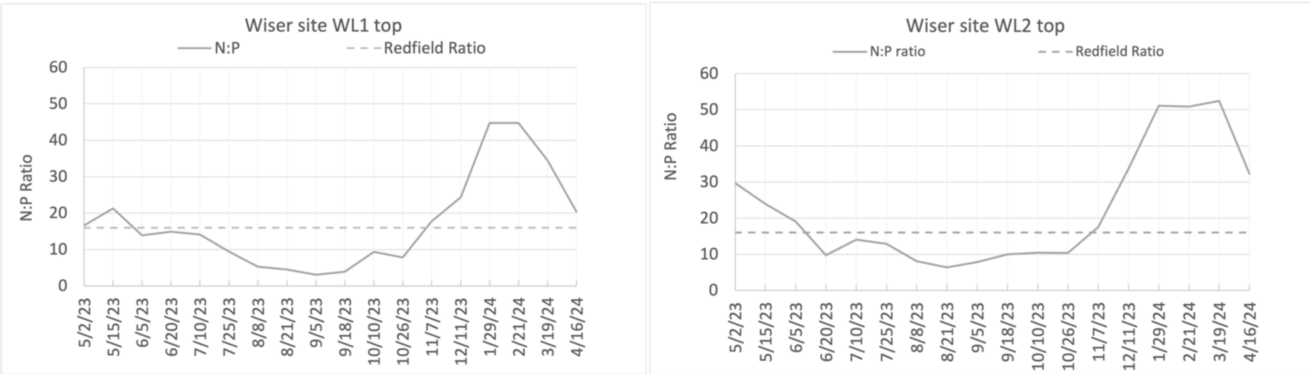


Figure 33. Nitrogen to Phosphorus Ratio for WL1 and WL2, 2023-2024.

G.6 Zooplankton Data

G.6.1 Monitoring Methods

One vertical zooplankton sample was collected in each basin using an 80 µm Wisconsin net with a collection bucket attached at the cod end. The depth and number of tows was documented for each sample. The objective was to sample a sufficient volume of water to obtain at least 300 organisms per sample. Once the net was lifted out of the water it was rinsed from the outside to free organisms from the side of the net and to concentrate them in the collection bucket. Organisms in the sample were narcotized with an effervescent sodium bicarbonate tablet (e.g., Alka-Seltzer® tablet). The sample were transferred to a 500 ml container and preserved with 95% ethanol.

G.7.2 Monitoring Results

The zooplankton population varied between the two basins with WL1 dominated by rotifers, particularly on June 1, 2023 and WL2 dominated by cladocera, with the largest population on November 1(Figure 35 and Figure 35).

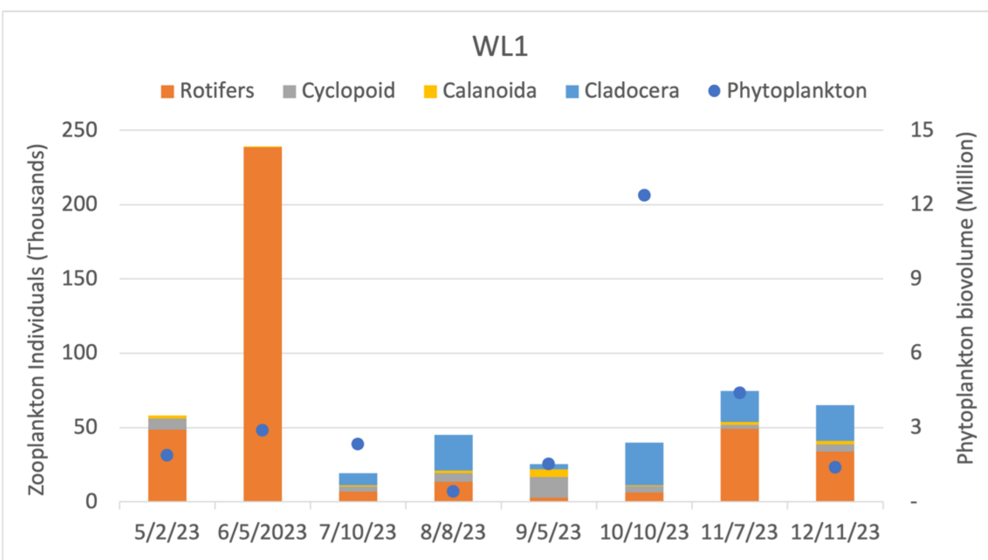


Figure 34. Zooplankton population (number of organisms) in WL1. Phytoplankton biomass shown as blue dots.

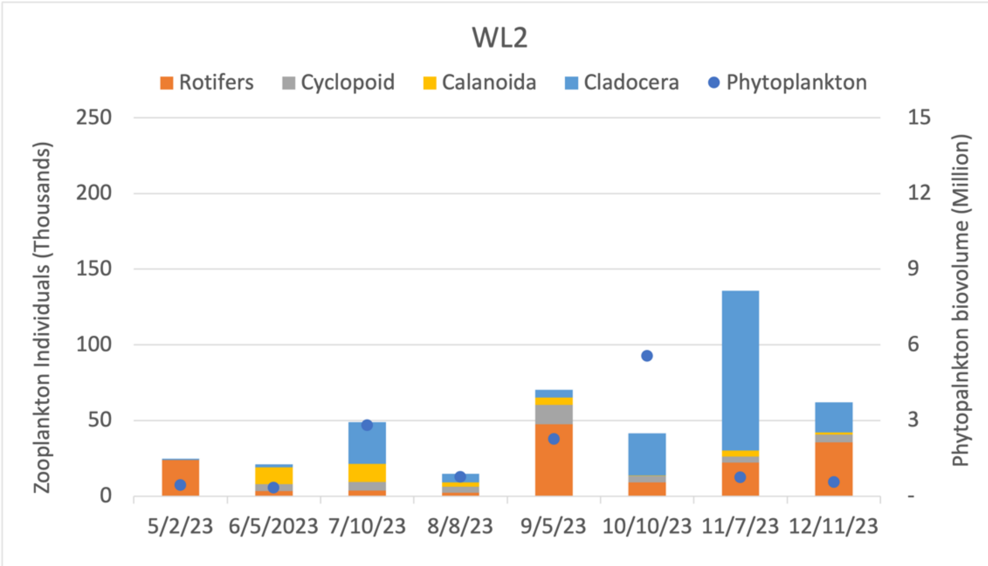


Figure 35. Zooplankton population (number of organisms) in WL2. Phytoplankton biomass shown as blue dots.

F.7.2 Discussion

The zooplankton community in Wiser Lake showed distinct differences between the two basins. The West Basin (WL1) had a consistently higher population of rotifers throughout the year, while the East Basin (WL2) was dominated by cladocerans. Following the cyanobacteria bloom on October 10, a typical delayed response was observed in the zooplankton population, which increased in the following weeks, likely taking advantage of the increased food availability. This rise in grazers may have contributed to a reduction in phytoplankton biomass the following month.

Although zooplankton generally do not prefer cyanobacteria as a food source, studies have shown that they tend to consume more cyanobacteria in the fall, possibly due to the fragmentation of colonies, which makes them easier to ingest (Sweeney, 2022).

G.7 Waterfowl Survey

G.7.1 Monitoring Methods

Waterfowl surveys were conducted weekly from May 2023 through April 2024 (Figure 5) by a former WDFW Wildlife Biologist with previous experience conducting waterfowl surveys on Wiser Lake. In addition, the biologist has established relationships with landowners allowing the biologist access to private property.

The following information were recorded:

- Date, start and end time
- Weather, including temperature, visibility, approximate cloud cover, approximate wind speed
- Observer name
- Number of waterfowl and species. Identification will be limited to duck, goose and swan.

Information on location of waterfowl (in lake, or on/near shore) was not collected. This limited how nutrient loading from waterfowl could be quantified as discussed in section I1.

G.7.2 Monitoring Results

The fall waterfowl population at Wiser Lake in 2023 was unusually high, with estimates ranging from 8,000 to 10,000 geese and swans observed throughout October and into late November during the migration period. In addition to geese and swans, various species of ducks were present throughout the year, and their numbers also rose during the migratory season. However, their numbers were small compared to the numbers of geese and swans (Figure 36). The population of waterfowl other than geese, swans, and ducks was very small, even during migration.

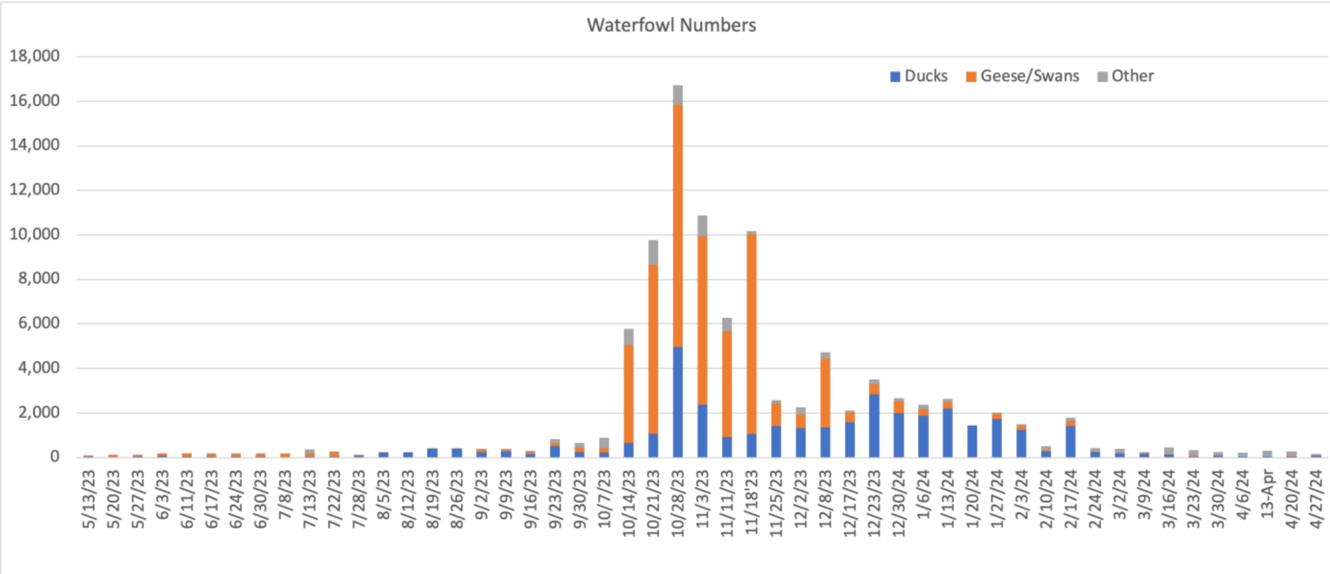


Figure 36. Waterfowl survey data for Wiser Lake, 2023-2024.

G.7.3 Discussion

Given that each adult goose excretes approximately 0.23 kg of phosphorus per year, the total phosphorus contribution from geese and ducks at the lake could reach up to 2,300 kg. Goose droppings are particularly rich in phosphorus, a nutrient that can fuel excessive algal growth in lakes. Large concentrations of waterfowl, like those at Wiser Lake during the fall, can significantly elevate phosphorus levels, exacerbating the risk of water quality degradation.

A study by Manny et al. (1994) created a model to assess whether waterfowl contribute to water quality decline based on their time spent on the lake and their species type. The study found that waterfowl introduced 4,462 kg of carbon, 280 kg of nitrogen, and 88 kg of phosphorus into the lake annually. It was concluded that waterfowl were responsible for 69% of the lake's carbon, 27% of its nitrogen, and 70% of its phosphorus from external sources, directly contributing to the lake's water quality deterioration. Additional discussion of waterfowl contributions to Wiser Lake nutrients is included in section I.1.4.

G.8 Vegetation survey

G.8.1 Monitoring Methods

Plant surveys were conducted on Wiser Lake in 2013, 2014, 2018, 2021, and 2023 by the Whatcom County Public Works' Noxious Weed Program. No additional survey work was conducted during the 2023-2024 field season.

G.8.2 Monitoring Results

Aquatic vegetation monitoring included submersed, emergent, and floating leaved plants. Survey results of those three categories are included below.

G.8.2.1 Submersed Plants

From the 2023 vegetation survey completed by Whatcom County, submersed plant species in Wiser Lake include the following species as shown in Table 14. Curly leaf pondweed has become more dominant over the survey years of 2016 to 2023 and should be a priority for control.

Table 14. Submersed plant population in Wiser Lake.

Scientific Name	Common Name	Status	Population
Ceratophyllum demersum	Coontail	Native	Few plants, patchy distribution
Elodea canadensis	waterweed	Native	Large patches, co-dominant
Nitella sp.	Nitella	Native	Scattered, few plants
Potamogeton crispus	Curly leaf pondweed	Invasive	Dominant, mono-specific patches
Potamogeton foliosus	Leafy pondweed	Native	Large patches, co-dominant
Potamogeton pusillus	Slenderleaf pondweed	Native	Scattered, few plants
Stuckenia pectinata	Sago pondweed	Native	Large patches, co-dominant, primarily West Basin
Potamogeton zosteriformis	Eel-grass pondweed	Native	Scattered, few plants

G.8.2.2 Emergent Plants

Four invasive emergent/shoreline species were consistently found on Wiser Lake during all survey years, with no noticeable increase in their distribution, as shown in Table 15. Hairy willow herb spreads via wind-dispersed seeds, while yellow flag iris propagates through floating seed pods. Controlling and preventing the further spread of all these species can be challenging but should be a priority.

Table 15. Emergent plant population in Wiser Lake.

Scientific Name	Common Name	Status	Population
Bidens cernua	Nodding beggarticks	Native	Scattered, few plants
Comarum palustre	Purple cinquefoil	Native	Few plants, few locations
Epilobium hirsutum	Hairy willow herb	Invasive	Scattered, few plants
Iris pseudacorus	Yellow flag iris	Invasive	Large patches, co-dominant
Phalaris arundinacea	Reed canary grass	Invasive	Large patches, co-dominant
Solanum dulcamara	Bittersweet nightshade	Invasive	Common on shoreline
Typha latifolia	Common cattail	Native	Common on shoreline
Eleocharis sp.	Spike rush	Native	Scattered on shoreline, both basins
Schoenoplectis acutus	Hard-stem bulrush	Native	Scattered patches on shoreline

G.8.2.3 Floating Plants

Floating vegetation noted in the surveys were both native species, including the water lily Spatterdock, and duckweed, a very small floating plant (Table 16).

Table 16. Floating plant population in Wiser Lake

Scientific Name	Common Name	Status	Population
Nuphar polysepala	Spatterdock	Native	Scattered but dense
Lemna minor	Lesser duckweed	Native	Scattered

G.8.3 Discussion

Discussion about past vegetation surveys was covered in Section E.1.8 and includes several mentions of non-native species, including Curly Leaf Pondweed (*Potamogeton crispus*), reed canary grass (*Phalaris arundinacea*), yellow flag iris (*Iris pseudacorus*), and hairy willow-herb (*Epilobium hirsutum*). There should be active and ongoing efforts to control these species in anticipation of water clarity due to lake restoration efforts. Refer to Section L – Recommended Management / Lake Restoration Plan, for recommendations for aquatic vegetation control.

G.9 Shoreline modification survey

Shoreline modification data was not collected as part of this study.

G.10 Lake Sediment Sampling

G.10.1 Monitoring Methods

One sediment core was collected from each sampling location using a piston interface corer (Aquatic Research Instruments, 2011). The core samples were kept cool until delivered to the lab. Polycarbonate tubes were transported from the field in an upright position to the laboratory so that sediment cores remain intact and representative of the sediment matrix. Sediment samples were photographed prior to sectioning in 5-cm core sections. Sediment sections were homogenized and analyzed for the parameters using methods shown in Table 17. Sediment Sample Analytical Methods

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Table 17. Sediment Sample Analytical Methods

Parameter	Method
Total Phosphorus	SM18 4500PF
Loosely sorbed Phosphorous	Rydin & Welch (NH4Cl)
Iron-bound Phosphorous	a) EAP038 (Sectioning sediment cores)
	b) Rydin & Welch (dithionate) (fractionates Fe-P)
	c) SM18 2540B or EPA160.3 (water content in soils)
	d) EPA 365.1 or SM4500PF (Soil Phosphorus content)

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<table>
<tr><th>Parameter</th><th>Method</th></tr>
<tr><td rowspan="4">Aluminum-bound Phosphorous</td><td>a) EAP038 (Sectioning sediment cores)</td></tr>
<tr><td>b) Rydin & Welch (NAOH) (fractionates Al-P)</td></tr>
<tr><td>c) SM2540B or EPA160.3 (water content in soils)</td></tr>
<tr><td>d) EPA 365.1 or SM4500PF (Soil Phosphorus content)</td></tr>
<tr><td rowspan="4">Calcium-bound Phosphorous</td><td>a) EAP038 (Sectioning sediment cores)</td></tr>
<tr><td>b) Rydin & Welch (HCl) (fractionates Ca-P)</td></tr>
<tr><td>c) SM18 2540B or EPA160.3 (water content in soils)</td></tr>
<tr><td>d) EPA365.1 or SM18 4500PF (Soil Phosphorus content)</td></tr>
<tr><td>Organic Phosphorous</td><td>Rydin & Welch (NAOH)</td></tr>
<tr><td>Biogenic Phosphorous</td><td></td></tr>
<tr><td>Total Calcium</td><td>EPA 6010</td></tr>
<tr><td>Total Iron</td><td>EPA 6010D</td></tr>
<tr><td>Total Aluminum</td><td>EPA 6010</td></tr>
<tr><td>% Water</td><td>SM18 2540B or EPA160.3</td></tr>
<tr><td>% Solids</td><td>SM18 2540B or EPA160.3</td></tr>
</table>

G.10.2 Monitoring Results

Sample WL1 recovered a 30 cm core of soft black mud similar to what was seen in the WL2 core. Aquatic vegetation was present as well as *Aphanizomenon, Nostoc,* and filamentous algae.

Sediment TP in the WL1 sample was 1,419 mg/kg in the upper five cm of the sample and ranged from 912 to 962 mg/kg from 5-25 cm before dropping to 793 mg/kg from 25 to 30 cm (Figure 37). The bioavailable Iron bound and organic fractions made up 59% of TP in the upper 5 cm.

Sample WL2 recovered a 32 cm core of soft black mud with an anaerobic odor. Water depth in this location was 2.5 meters and it took two attempts to recover an intact core. There was some *Aphanizomenon* algae noted on the core.

Sediment TP in the WL2 sample was 2,591 mg/kg in the upper five cm of the sample core, dropping to 1,315 mg/kg in the 5-10 cm section, and hovering around 1,000 mg/kg for the remaining sections (Figure 38). Iron-bound and organic phosphorus combined made up 69% of the TP in the upper 5 cm.

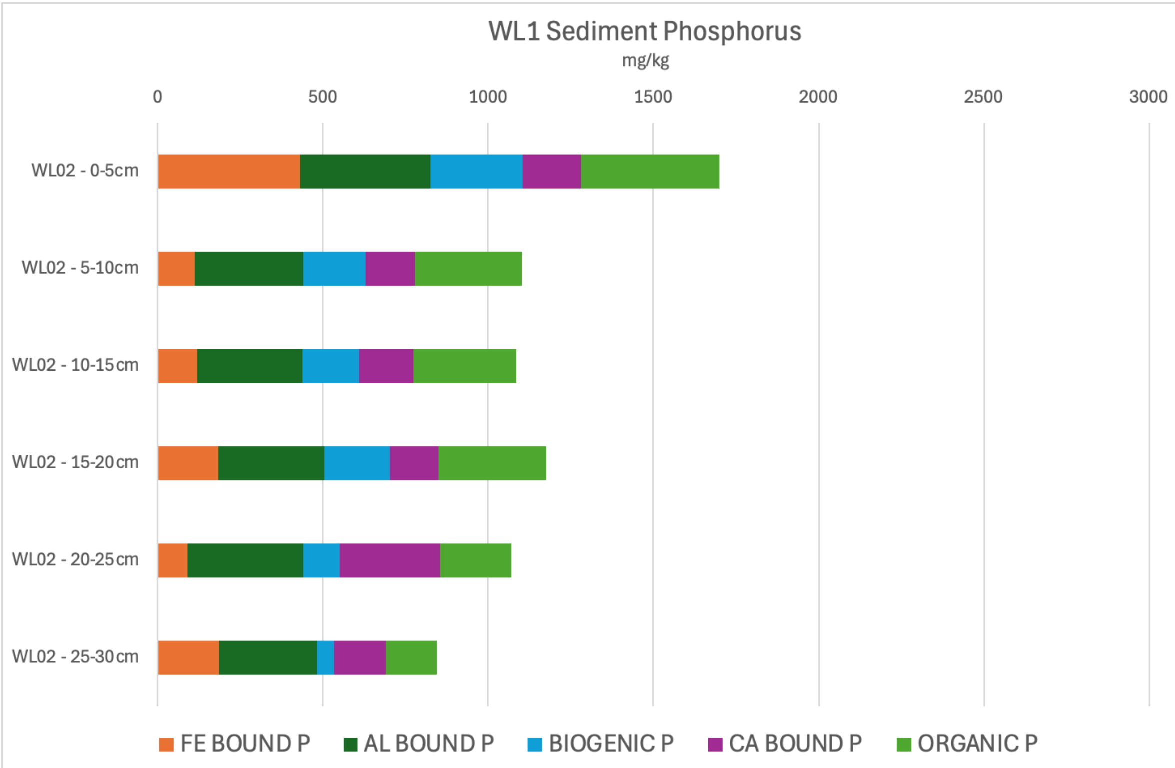

Figure 37. Sediment phosphorus fractions at WL1.

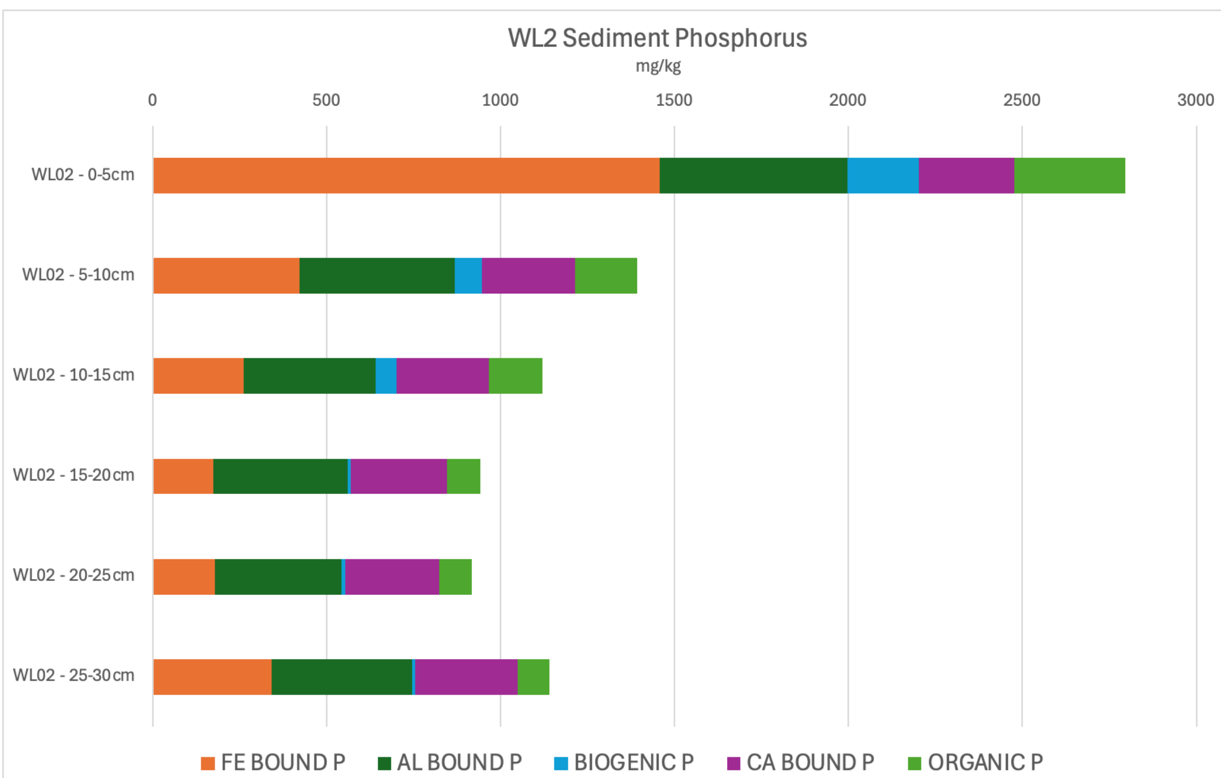

Figure 38. Sediment phosphorus fractions at WL2.

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G.10.3 Discussion

Iron bound and organic fractions are the least effective at holding onto phosphorus. The organic fraction is loosely bound and can readily release phosphorus into the water column. The iron bound fraction holds on to phosphorus under oxygenated conditions, but if the water column becomes stratified and oxygen is depleted at the sediment/water interface, the iron will release phosphorus into the water column. Aluminum and calcium bound phosphorus fractions are considered to be more permanent under anoxic conditions, but pH conditions above 8 can lead to phosphorus release from aluminum and pH above 10 can lead to phosphorus release from calcium.

Results of sediment testing and the phosphorus analytical models discussed in Section I.3 indicate that internal loading may account for a sizable portion of the phosphorus budget. The iron bound phosphorus fraction is high at both of these sample sites so anoxic conditions could lead to releases into the water column. However, sonde profiles collected during this project indicated a mixed lake, as discussed in section G.2.2 above.

H. Hydrologic Budget

The water budget for Wiser Lake was developed based on an analysis of multiple inflow and outflow components, utilizing available data and established methodologies to ensure accuracy. This section outlines the key components, calculations, and assumptions used to estimate the water budget, providing a foundation for understanding the lake’s hydrologic balance and guiding subsequent nutrient budget assessments.

H.1 Description of water budget components

The water budget for Wiser Lake was formulated through an analysis of key inflow and outflow components to quantify the lake hydrologic balance. Inflows to the lake consist of surface water contributions from the upstream watershed, direct precipitation on the lake surface, overland flow originating from the surrounding drainage area to the lake, and groundwater inputs. Surface water inflow was estimated utilizing the Soil Conservation Service Curve Number (SCS CN) method (SCS, 1985), which integrates precipitation data and land use characteristics to calculate runoff. Direct precipitation was assessed based on PRISM climate data (PRISM Climate Group, 2024), with an average of 2023 and 2024 data used for months where measurements were available in both years. Overland flow calculations assumed that 80% of runoff entered the lake directly, supported by observations and discussions with Whatcom County about the lack of stormwater diversion infrastructure in the area. Groundwater contributions were estimated through low-flow measurements conducted during dry periods, providing a baseline for net groundwater exchange with the lake.

Outflows from the lake include water discharged through the lake outlet, groundwater loss, and water lost due to evaporation. Observations during specific months indicated consistent inflow and outflow rates. To ensure the overall water balance aligned with these observations and inflows, the lake outflow was adjusted by incorporating the difference between the calculated inflows and water balance estimates. Evaporation was estimated employing the Hamon Method (Hamon, 1961), which incorporates monthly air temperature and daylight hours to quantify seasonal variability in water loss from the lake's surface. Changes in lake storage were also taken into account, with the stage-volume relationship derived from bathymetric data serving as the foundation for estimating fluctuations in storage volumes over time. Collectively, these components provide a comprehensive understanding of Wiser Lake's hydrologic balance, forming the basis for subsequent nutrient assessments.

H.2 Inflows

H.2.1 Surface Water Inflow (Stream Inflow)

Surface water inflow to Wiser Lake was estimated using calculated flow derived from the Soil Conservation Service Curve Number (SCS CN) method (SCS, 1985). The drainage area contributing to the lake inlet is shown in Figure 39 below. Monthly inflows were determined by incorporating total monthly precipitation data, obtained from PRISM Precipitation Data (PRISM Climate Group, 2024), which synthesizes observations from over 8,000 NOAA and 600 NRCS meteorological stations. The analysis spanned from January 2023 through September 2024, ensuring seasonal and interannual variability was captured.

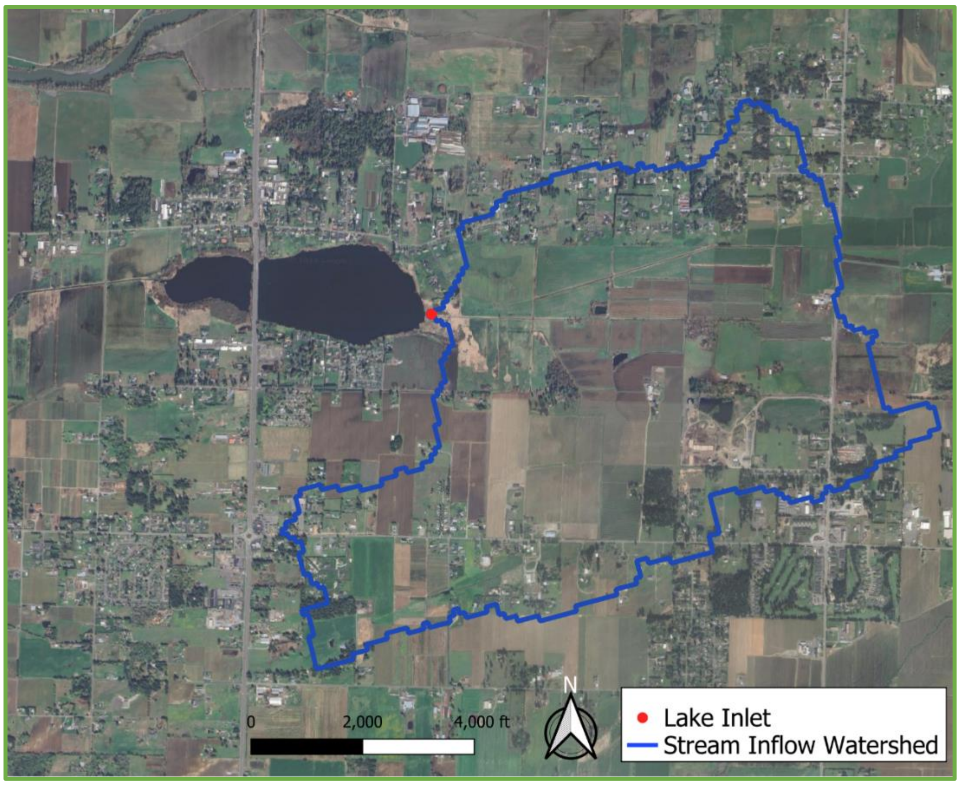

Figure 39. Wiser Lake upstream drainage area.

The following equation was used to estimate runoff from the watershed to the lake inlet:

$$Q = \frac{(P - I_a)^2}{P - I_a + S}$$

where,

P is the precipitation (in inches),

I_a is the initial abstraction, often calculated as 0.2 × S, and

S is the potential maximum retention after runoff begins, which depends on the Curve Number (CN), where

$$S = \frac{1000}{CN} - 10$$

The Curve Number (CN) was derived using the 2023 National Land Cover Dataset (USGS, 2024) land use classifications and 2024 SSURGO soil type data (NRCS, 2024). Area-weighted averages for CN and hydrologic group classifications were applied to refine these calculations. Table 17 and Table 18 list the land use and soil hydrologic groups for the drainage area upstream of the lake, respectively.

Table 17. Wiser Lake Upstream Watershed Land Use.

Land Use Name	Area (sq meter)	Area (% of total)
Open Water	10,900	0.19%
Developed - Open Space	487,800	8.81%
Developed - Low Intensity	630,900	11.39%
Developed - Medium Intensity	133,200	2.40%
Developed - High Intensity	11,700	0.21%
Evergreen Forest	114,300	2.06%
Mixed Forest	4,500	0.08%
Pasture/Hay	3,064,500	55.33%
Cultivated Crops	1,034,100	18.67%
Woody Wetlands	25,200	0.45%
Emergent Herbaceous Wetlands	21,600	0.39%

Table 18. Wiser Lake Upstream Watershed Soil Hydrologic Groups.

Soil Hyd. Group	Area (% of total)	Weighted CN	S
A	61%	53	8.7
B	0.11%	70	4.3
C	38.77%	80	2.5
D	0.11%	85	1.8
Area Weighted Soil Hyd. Groups and CN Area Weighted	**100%**	**64**	**5.7**

To validate the estimated inflow time series pattern, flow measurements collected periodically in 2023 and 2024 were compared against the estimated inflows. Figure 40 illustrates the monthly precipitation, estimated lake inflow, and periodically measured flows showed a consistent pattern, lending confidence to the methodology. The data points in Figure 40 (red dots) represent single-point in time measurements taken on one specific day with their respective month. As a result, they do not always align with estimated monthly inflows using the SCS method.

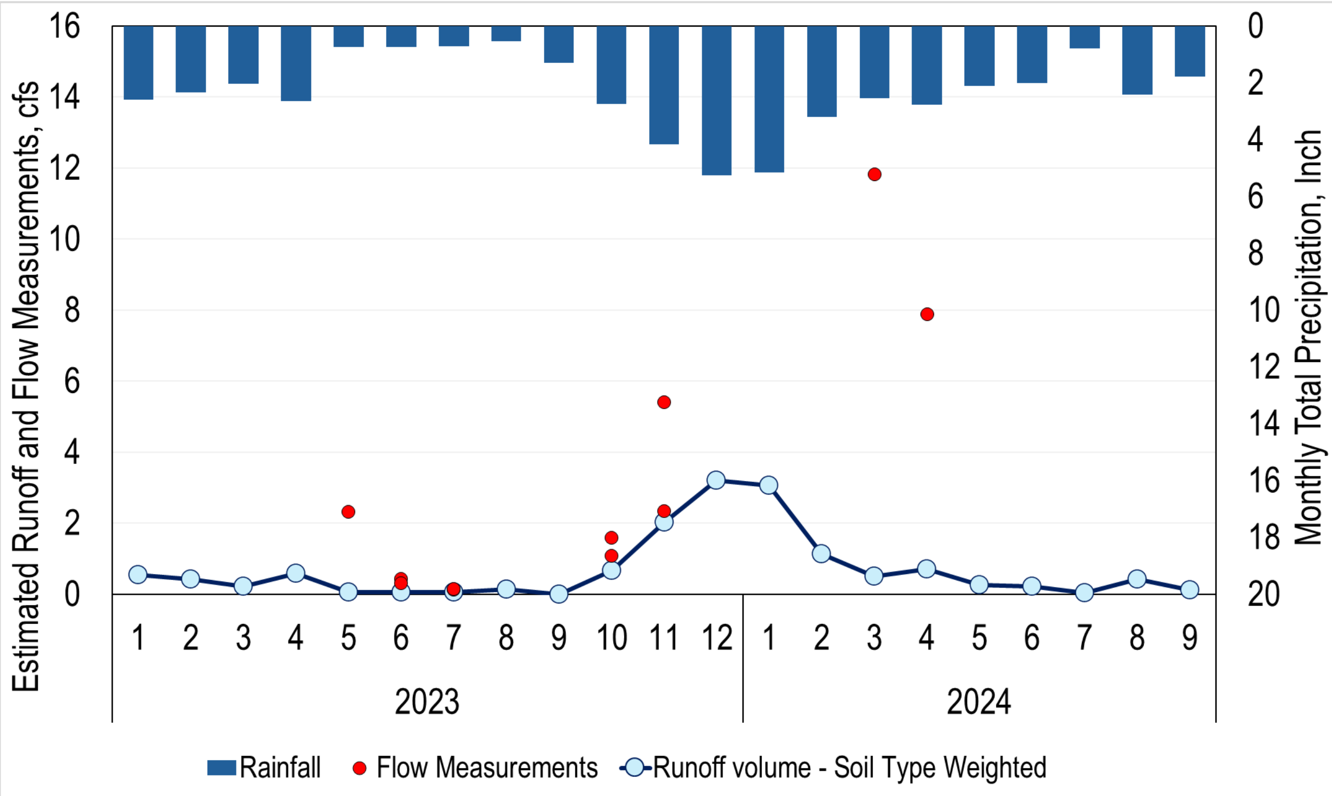

Figure 40. Wiser Lake Hydrology, 2023 – 2024.

Based on the discrepancies between flow measuremetns in Figure 40 and the monthly flow estimates additional investigation was undertaken.

The estimated inflows at Wiser Lake were derived using the SCS rainfall-runoff method, were compared with the gage-height data from the nearby USGS gage on the Nooksack River near Lynden, WA (12211500) just north of Wiser Lake (Figure 41). While the USGS gage did not measure flow, the seasonal pattern gage height was compared with the seasonal pattern of the flow estimates for Waiser Lake, as shown in Figure 42. The analysis showed a strong correlation (Pearson coefficient of 0.91) between the estimated inflows to the Lake and gage-height trends during the same time period. This level agreement suggests the SCS rainfall-runoff method reflects regional hydrologic patterns and provides a reasonable estimation of monthly inflows to Wiser Lake.

Figure 41. USGS gage on the Nooksack River near Lynden, WA (12211500).

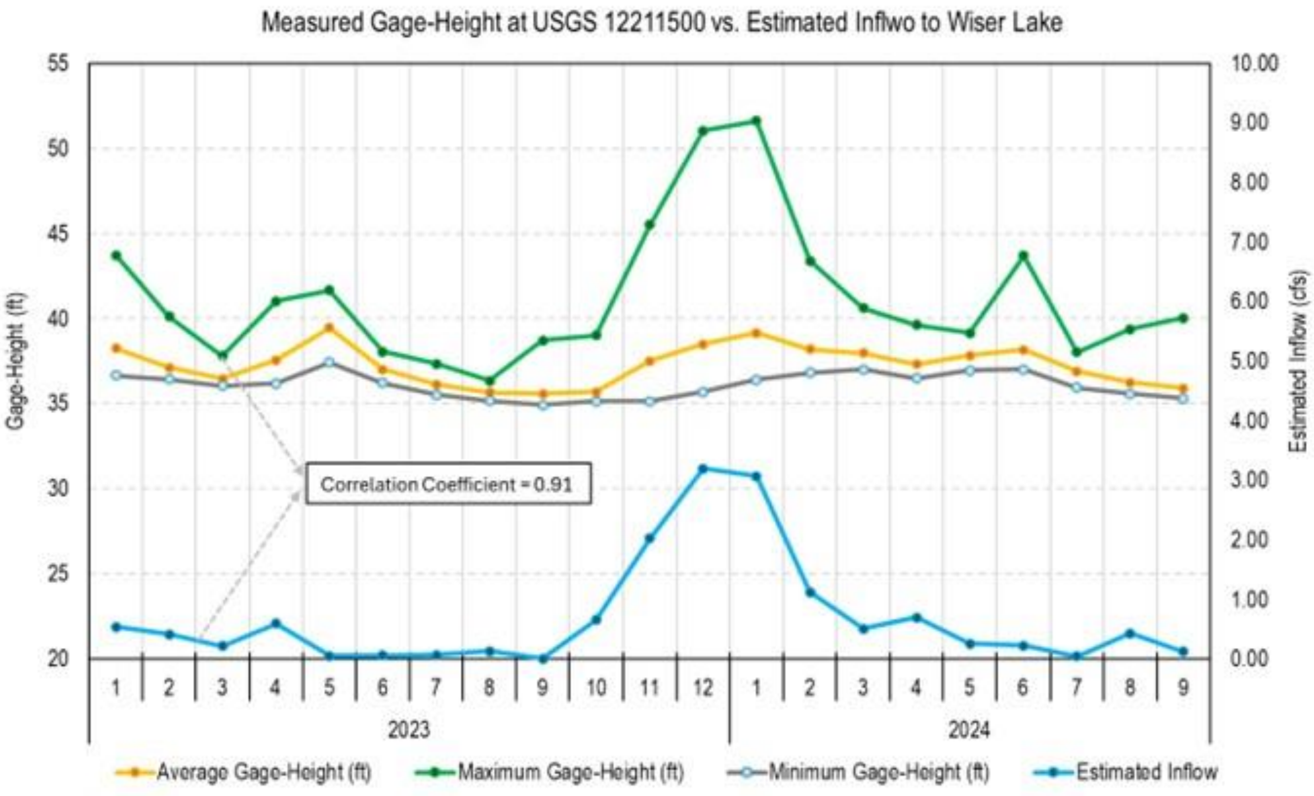

Figure 42. Comparison of maximum, average, and minimum Gage-Height measured at USGS 12211500 with estimated inflow to Wiser Lake from January 2023 to September 2024.

A second analysis was undertaken to compare the measured flows with the precipitation data from Bellingham International Airport to assess whether high flow measurements in 2024 aligned with rainfall events (Figure 43). The comparison analysis shows that some measured flows did not follow precipitation trends, with delays of five (5) or more days from the earliest storm events, suggesting that certain measurements may not accurately reflect runoff response from precipitation events. These inconsistencies raise the possibility of inaccuracy or anomalies in the measured flow data or the precipitation data is not accurate for the Wiser Lake area.

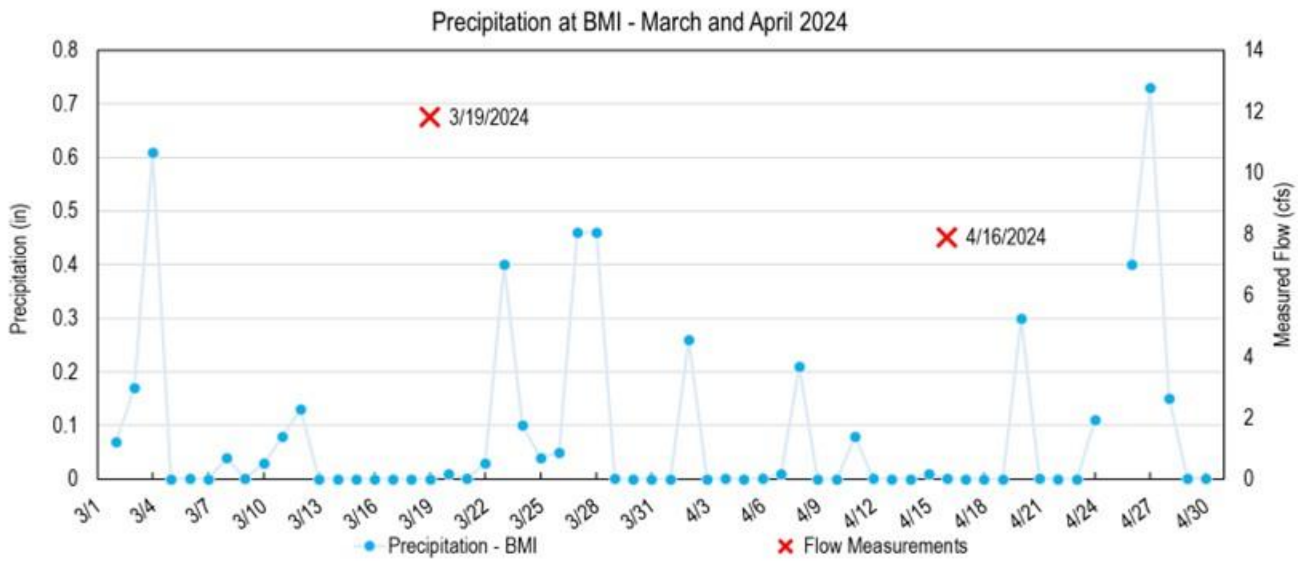

Figure 43. Rainfall events at Bellingham International Airport and the measured flow upstream of Wiser Lake.

H.2.2 Lake Stage and Volume Storage

The stage-volume storage relationship for Wiser Lake was developed using bathymetric data from Fishermap (2024). Bathymetric lines were digitized to estimate the lake's surface area at various stages. The volume for each depth interval was calculated using the following equation:

$$Volume = \frac{(A_1 - A_2)}{2} \times \Delta depth$$

where,

A_1 is the area at the top depth (sq. ft),

A_2 is the area at the bottom depth (sq. ft), and

Δ*depth* is the difference in depth between the bathymetry lines (ft).

To extend the data below the lowest recorded depth, three additional 1-ft intervals were estimated based on the reduction in area observed in the lower contours. This was necessary because field measurements taken in 2023 and 2024 indicated that the lake depth extended beyond the maximum depth available in the bathymetry data from Fishermap. For months where measurements were available in both 2023 and 2024, an average of the data from these two years was calculated and used to represent the values for those months. Monthly lake levels from nutrient sampling events in 2023 and 2024 were used to estimate corresponding surface areas and storage volumes, as shown in Figure 44. These monthly values were critical for subsequent water budget calculations.

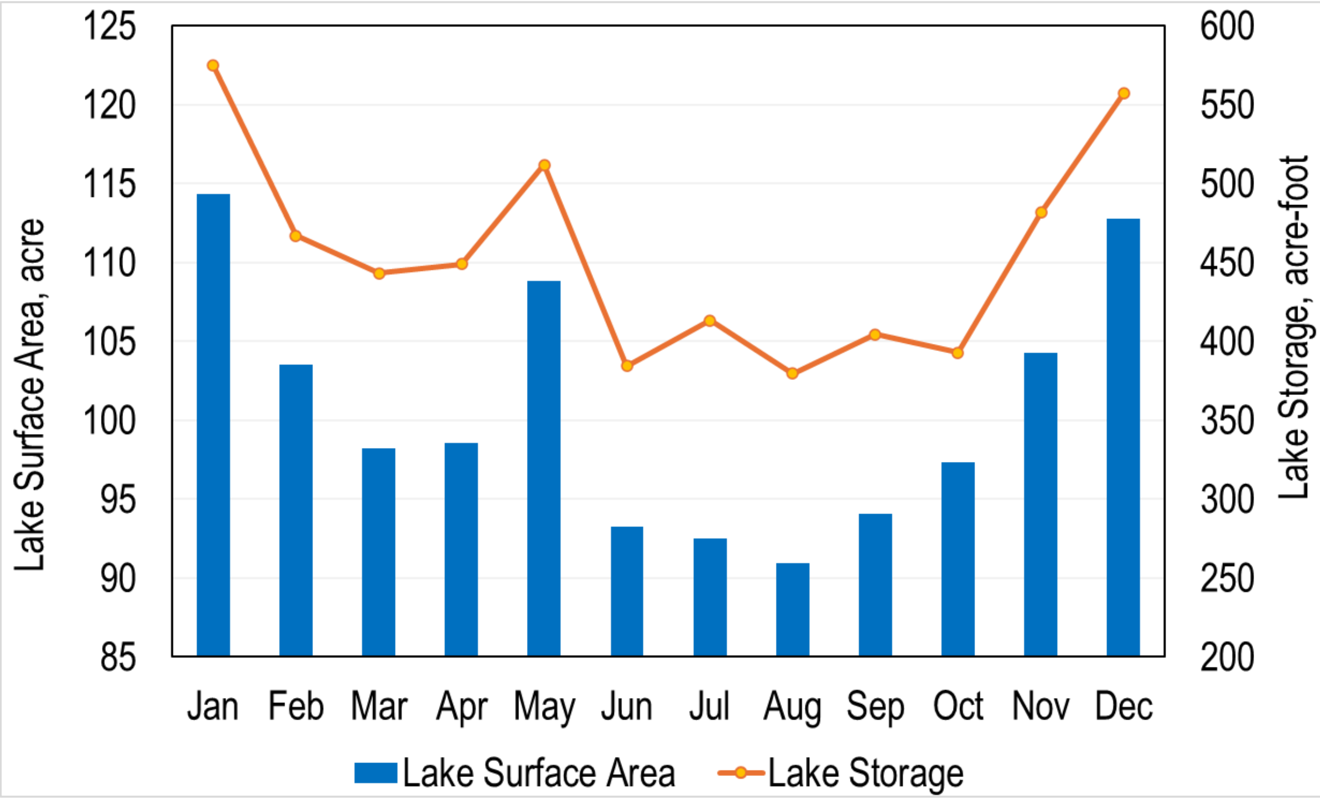

Figure 44. Wiser Lake Surface Area and Volume, 2023 – 2024.

H.2.3 Precipitation

Monthly precipitation directly falling on Wiser Lake's surface was calculated using the lake's surface area (as determined in the previous section) and PRISM-derived monthly precipitation totals. For months where measurements were available in both 2023 and 2024, an average of the data from these two years was calculated and used to represent the values for those months. The resulting monthly precipitation volumes provided a key inflow component, summarized graphically to show temporal variability in Figure 45 below.

Since the nutrient data collected was in both 2023 and 2024, the precipitation data in Figure 45 is from January 2023 to September 2024, averaging monthly values when multiple data points exist. Therefore, the values for January through September are the average from 2023 and 2024, while October, November, and December are from 2023 only. This approach provides a better perspective of the overall condition for this management plan since we are looking at annual water budget conditions.

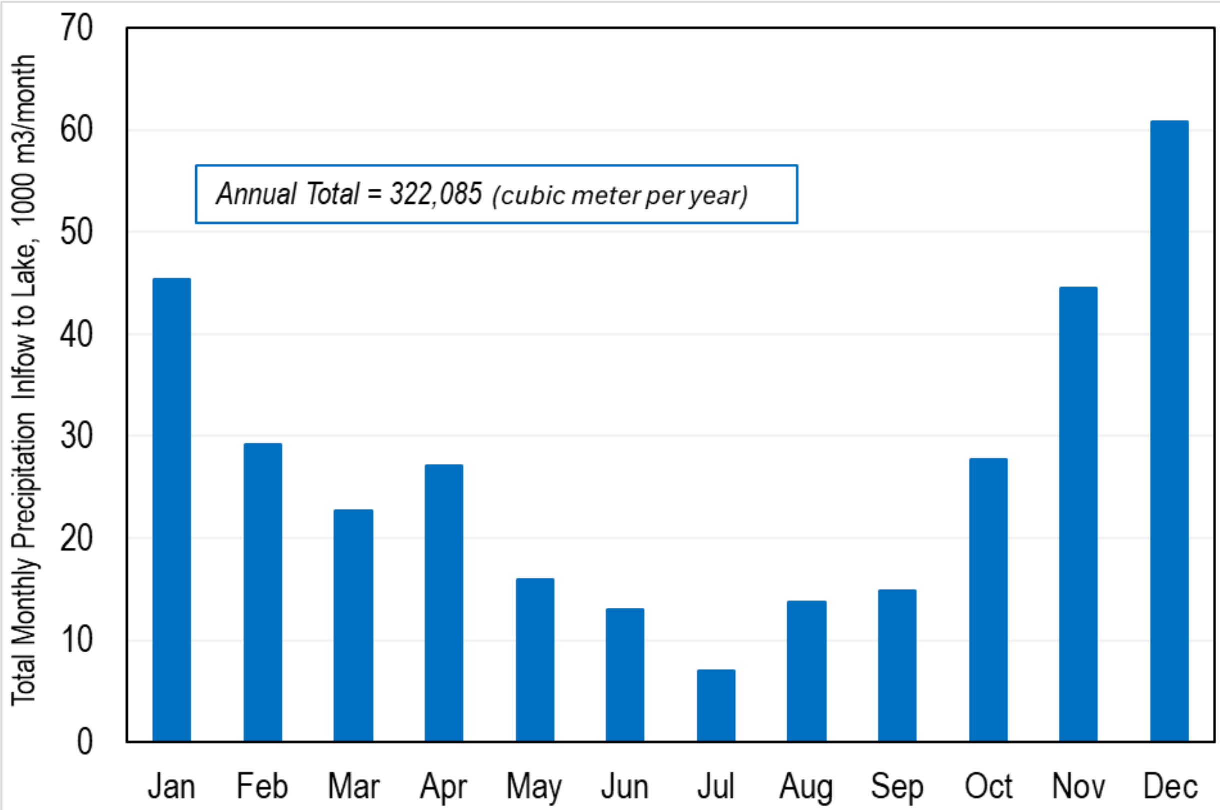

Figure 45. Monthly Precipitation on the Wiser Lake surface, 2023 - 2024.

H.2.4 Overland Flow

Overland flow contributions from the land surrounding the lake were calculated using the SCS CN Method, as described earlier. Monthly runoff flows were adjusted to account for 80% of the runoff entering the lake, with the remaining 20% bypassing the lake. For precipitation data used in the calculation, an average of measurements from 2023 and 2024 was used for months where data was available in both years. The 20-80 partitioning was informed by input from Whatcom County, which confirmed that there is limited to no stormwater infrastructure in this drainage area. This lack of drainage systems supports the assumption that the majority of runoff flows directly into the lake through natural pathways.

A portion of the 20% bypassed runoff is considered to flow into the lake indirectly, as discussed in detail in the groundwater section, contributing to the net groundwater exchange. Figure 46 shows the overland flow drainage area surrounding the lake.

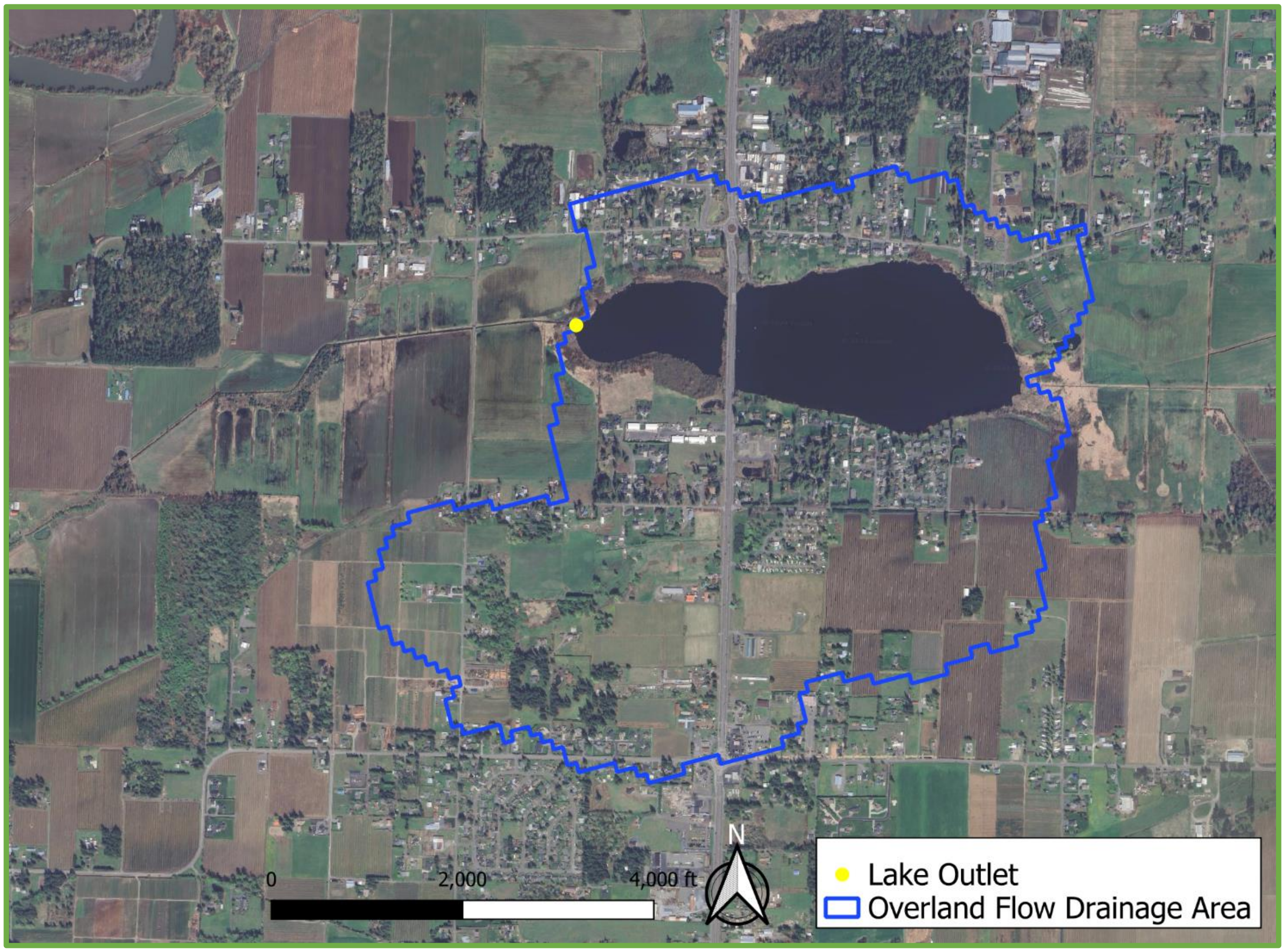

Figure 46. Wiser Lake Overland Flow Drainage Area.

This adjustment reflects the hydrologic routing within the watershed and aligns with observed land-use characteristics.

$$Q = \frac{(P - I_a)^{2}}{P - I_a + S}$$

where,

> P is the precipitation (in inches),
>
> I_a is the initial abstraction, often calculated as 0.2 × S, and
>
> S is the potential maximum retention after runoff begins, which depends on the Curve Number (CN), where

$$S = \frac{1000}{CN} - 10$$

Table 19 and Table 20 list the land use and soil hydrologic groups for the drainage area surrounding the lake. Figure 47 shows the monthly overland flow to the lake.

Table 19. Wiser Lake Overland Flow Drainage Area Land Use.

Land Use Name	Area (sq. meter)	Area (% of total)
Open Water	447,358	15.19%
Developed - Open Space	472,562	18.93%
Developed - Low Intensity	625,582	25.05%
Developed - Medium Intensity	159,321	6.38%
Developed - High Intensity	16,202	0.65%
Deciduous Forest	2,700	0.11%
Evergreen Forest	16,202	0.65%
Mixed Forest	900	0.04%
Pasture/Hay	716,495	28.70%
Cultivated Crops	319,542	12.80%
Woody Wetlands	9,901	0.40%
Emergent Herbaceous Wetlands	157,520	6.31%

Table 20. Wiser Lake Overland Flow Drainage Area Soil Hydrologic Groups.

Soil Hyd. Group	Area (% of total)	Weighted CN	S
A	73.73%	56	8.0
B	5.40%	70	4.3
C	15.48%	80	2.6
D	5.40%	84	1.8
Area Weighted Soil Hyd. Groups and CN Area Weighted	**100%**	**62**	**6.2**

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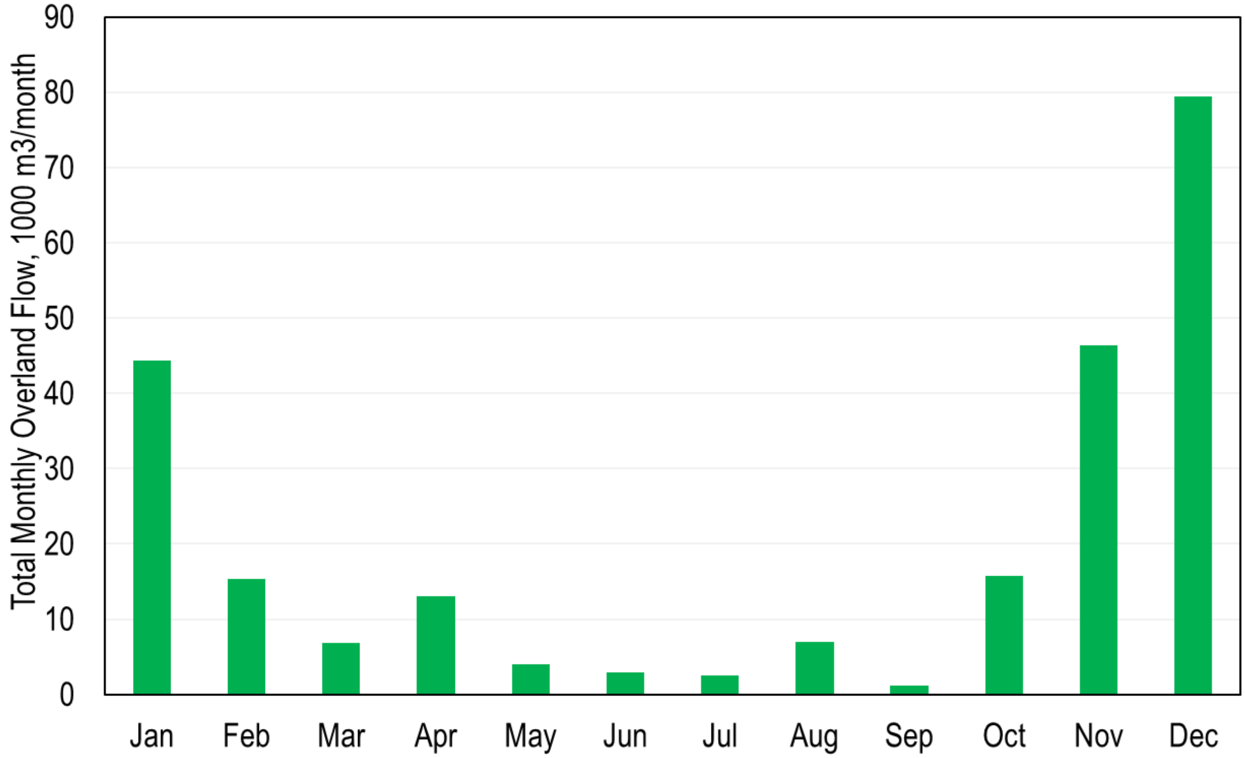

Figure 47. Monthly Overland Flow to Wiser Lake, 2023 – 2024.

H.2.5 Net Groundwater

The net groundwater contribution to Wiser Lake was estimated using low-flow measurements at the lake's inlet during July 2023, a period of minimal rainfall. The July measurement (0.142 cfs/0.004 m^3/s) was assumed to represent groundwater inflow, with 70% of this value attributed to net groundwater exchange with the lake (gains and losses). The annual contribution was distributed evenly across all months, resulting in a total annual groundwater inflow of approximately 40,050 cubic meters.

H.3 Outflows

H.3.1 Lake Outflow

The outflow from the lake was estimated based on limited field measurements. Specifically, during April and May, when both inflow and outflow measurements were collected, the data showed nearly identical rates. Given this consistency, it was assumed for the purposes of the water budget analysis that the lake's inflow and outflow were relatively equal. However, to ensure the overall water balance, the outflow was adjusted by adding the difference between the calculated inflows and the estimated outflows. This adjustment ensured that the water budget remained consistent and provided a more accurate representation of lake outflow. The water budget summary below provides an annual estimate of these outflows.

H.3.2 Evaporation

Evaporation was estimated using the Hamon Method (Hamon 1961), which relies on average monthly air temperature, which was obtained from PRISM, and daylight hours, which were calculated using NOAA's Solar Calculator (NOAA, 2024) for Wiser Lake's coordinates (48° 53' N, 122° 27' W) and shown below in Table 21. For months with available data in both 2023 and 2024, average monthly air temperatures were calculated and used in the analysis.

Table 21. Monthly Average Daylight Duration.

Month	Monthly Average Daylight Duration, hrs.	Month	Monthly Average Daylight Duration, hrs.
Jan	9	Jul	17
Feb	10.5	Aug	16
Mar	12.5	Sep	14.5
Apr	14	Oct	12.5
May	15.5	Nov	10
Jun	16.5	Dec	8.5

The estimated evaporation rate was multiplied by the corresponding surface area to estimate total water loss. The results showed seasonal trends, with higher evaporation rates during warmer months, as expected, and shown in Figure 48.

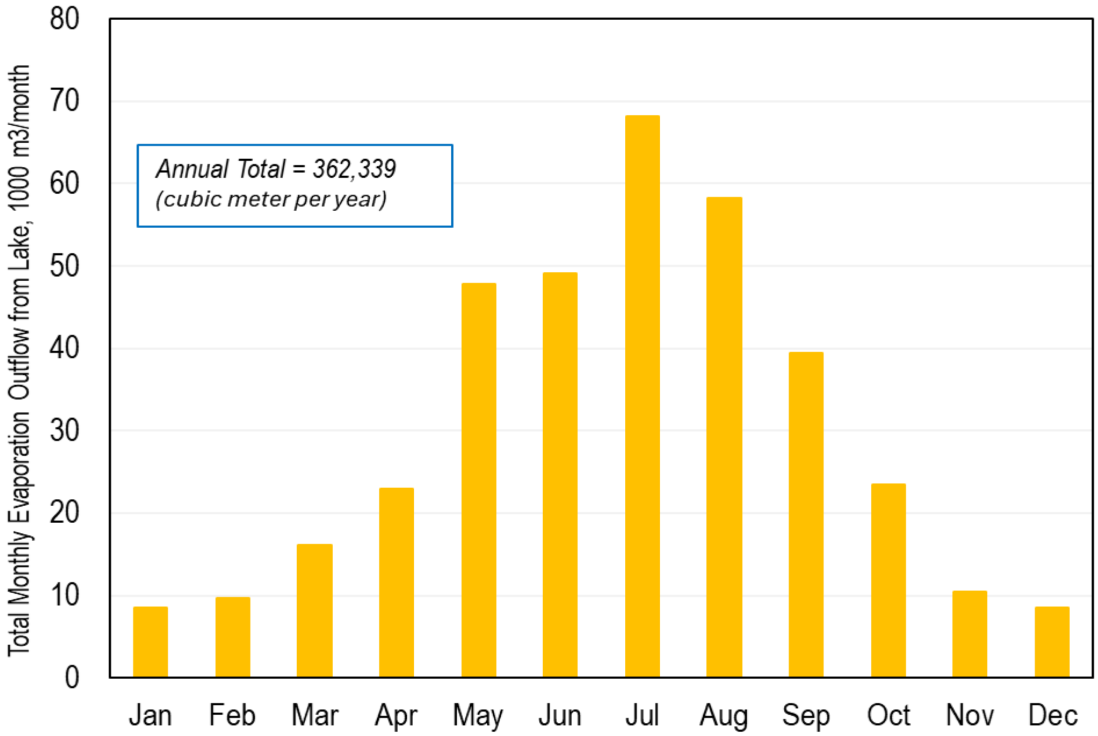

Figure 48. Monthly Evaporation from Wiser Lake, 2023 - 2024.

H.3.3 Groundwater Loss

Groundwater losses were not able to be estimated based on the lack of data and local information, but an estimate of the groundwater gains and losses was developed and documented in the Section Net Groundwater.

H.4 Water Budget Summary

The water budget for Wiser Lake incorporates the inflow and outflow components described above. The updated analysis indicates that the lake experienced a net balance during the analysis period (2023–2024), with inflows and outflows closely aligned to ensure water balance consistency. Total annual inflows, including streamflow, precipitation, groundwater, and overland flow, amounted to 1,103 acre-feet (1,360,764 m³). Total annual outflows, including lake outlet discharge and evaporation, were also calculated as 1,103 acre-feet (1,360,002 m³). The water budget reflects the refined assumptions and calculations, providing a breakdown of the lake's hydrologic conditions. The revised water budget is summarized in Table 22 below.

Table 22. Wiser Lake Water Budget Summary.

<table>
<tr><th colspan="6">Annual Water Budget Summary from 2023 - 2024 data</th></tr>
<tr><th></th><th>Component</th><th>Ac-ft</th><th>m^3</th><th>Ac-ft</th><th>m^3</th></tr>
<tr><td rowspan="4">Total Inflow</td><td>Lake Inlet (streamflow)</td><td>616</td><td>759,601</td><td rowspan="4">1,103</td><td rowspan="4">1,360,764</td></tr>
<tr><td>Precipitation</td><td>261</td><td>322,085</td></tr>
<tr><td>Groundwater</td><td>32</td><td>40,050</td></tr>
<tr><td>Overland Flow</td><td>194</td><td>239,028</td></tr>
<tr><td rowspan="2">Total Outflow</td><td>Lake Outlet</td><td>809</td><td>997,663</td><td rowspan="2">1,103</td><td rowspan="2">1,360,002</td></tr>
<tr><td>Evaporation</td><td>294</td><td>362,339</td></tr>
</table>

I. Nutrient Budget and Phosphorus Model

The nutrient budget for Wiser Lake evaluates the contributions of TP and TN from various inflows and internal sources. This section integrates measured data, established methods, and assumptions to estimate nutrient inputs, providing critical insights into the lake's trophic dynamics.

I.1 Waterfowl Nutrient Load

I.1.1 Data Collection

Bird observations at the lake were conducted from May 2023 to April 2024 (former WDFW Wildlife Biologist). Data were collected for 3 to 5 days each month, categorizing the birds into three groups:

- Geese and Swans: Included species such as White-Fronted Goose, Ross' Goose, Snow Goose, Canada Goose (Adult and Young), Cackling Geese, Tundra Swan, and Trumpeter Swan.
- Ducks: Included species like Mallard (Adult and Young), Domestic Duck, Hooded Merganser, Red-Breasted Merganser, Common Merganser, Bufflehead, Scaup, Teal, Canvasback, Pintail, Ruddy Duck, Eurasian Wigeon, American Wigeon, Wood Duck (Adult and Young), Common Goldeneye, Redhead, Ring-Necked Duck, Gadwall, Shoveler, and unidentified ducks.
- Others: Included Great Blue Heron, Coot, Common Loon, Western Grebe, Pied-billed Grebe, Horned Grebe, Double-Crested Cormorant, Red-necked Grebe, Bald Eagle, and various Gull species.

Figure 49 illustrates the percentage distribution of bird categories observed over time from May 2023 to April 2024. The data reveal distinct seasonal patterns in bird presence and composition.

During the early summer months (May to July), Geese and Swans were predominant, contributing over 60% of total bird observations, while Ducks accounted for between 30% and 40%. As summer progressed into August, there was a significant increase in Duck populations, peaking in August with Ducks comprising over 95% of total observations, while Geese and Swan numbers declined sharply.

In the fall months (September to November), Geese and Swan populations surged again, reaching their peak in October and November, contributing to more than 70% of the total bird observations, with over 5,500 individuals observed in both months. Ducks remained consistently present but in lower numbers compared to Geese and Swans.

During the Winter months (December to February), there was a shift in trends, with Ducks dominating the bird population. January recorded the highest number of Ducks (over 1,800), while Geese and Swan numbers significantly declined to less than 300 by February. The "Other" bird category remained relatively low throughout the year but showed slight increases during transitional months like September and March.

In early spring (March and April), there was a general decline in bird populations across all categories, with Ducks and Others making up most observations. Geese and Swan numbers remained minimal during this period.

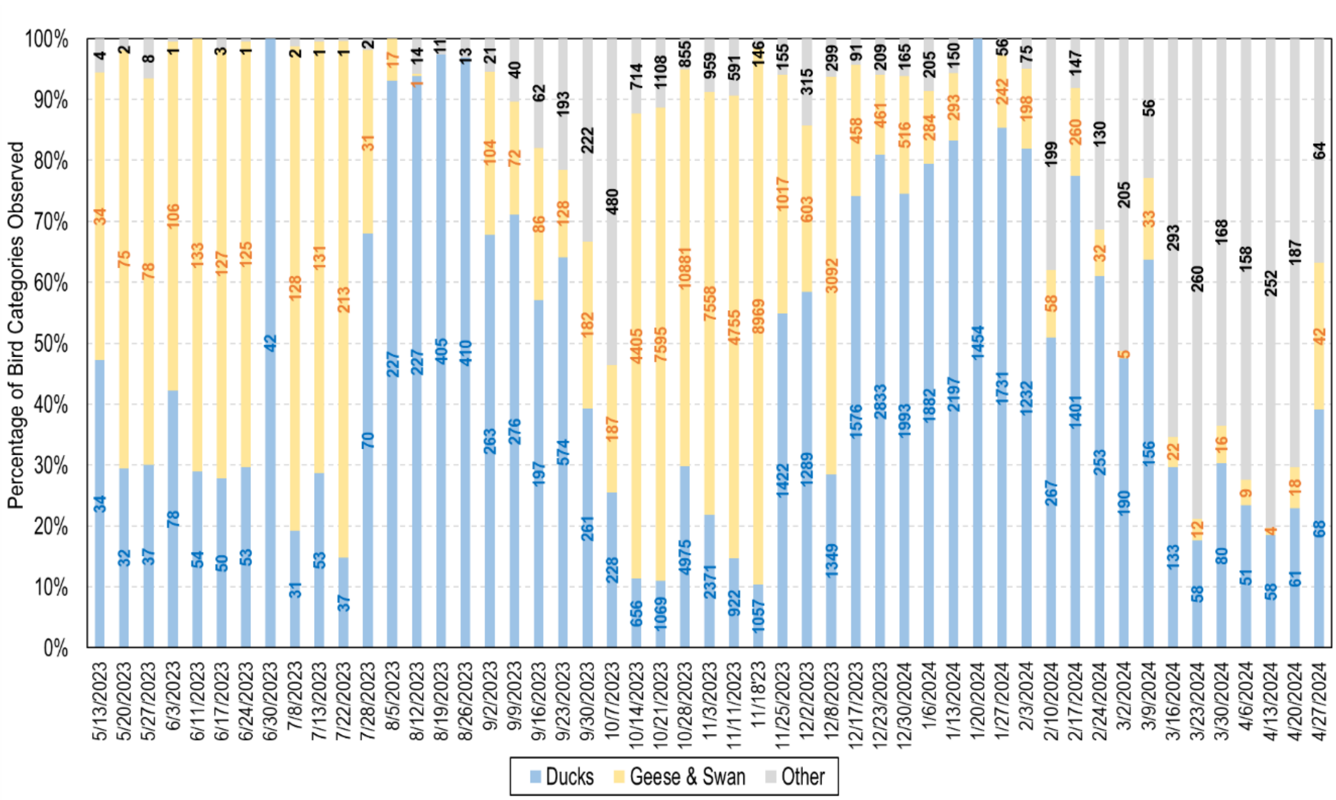

Figure 49. Percentage of Bird Categories Observed Over Time.

I.1.2 Methodologies

Two methodologies were employed to estimate phosphorus loading from waterfowl into the lake. These methods differ in their approaches, assumptions, and calculations. The first method follows Manny et al. (1994), and the second is based on Scherer et al. (1995).

Manny et al. (1994) estimated nutrient loading by waterfowl to Wintergreen Lake, MI through a detailed process that integrated bird behavior observations with defecation rates and nutrient content analysis, as follows:

- The process began with monitoring birds, where daily records of waterfowl presence were maintained using binoculars, and the weekly counts of geese, dabbling ducks, and diving ducks from a fixed observation point. These counts were conducted under consistent conditions—on clear, calm, sunny days between 10:00 AM and 3:00 PM—using a variable power telescope. Over the span from 1969 to 1972, a total of 208 such counts were made.
- From these observations, the number of days each type of waterfowl spent on the lake was estimated every month. This involved multiplying the average number of birds observed by the estimated days they were present, resulting in “effective use days” for each waterfowl group. Adding these monthly values provided the annual effective use days, and averaging across the four years yielded the mean annual waterfowl use of the lake.
- The next step was estimating defecation rates, as an important factor for nutrient loading calculations. Instead of direct observation, defecation rates were estimated from measurements of bird density, dropping density, and the time geese occupied specific areas of the lake. For example, in January 1970,

when a large flock of migrant Canada geese gathered on the frozen lake, over 500 droppings were collected from the freshly fallen snow using randomized sampling, providing data on day and night defecation rates.

- Laboratory analyses were conducted on the collected droppings to determine their nutrient content. The mean daily loading rates of nitrogen and phosphorus were estimated by multiplying the average defecation rate by the mean dry weight of a dropping and the nutrient concentration in the feces. These values were used as the baseline for nutrient load calculations.
- To account for duck nutrient loading, which were not directly measured, Manny et al. (1994) assumed the nutrient contributions were proportional to their body weight relative to geese. This standardization allowed for a unified approach to estimating total nutrient loads from diverse waterfowl species.
- Additionally, a correction factor to account for the time waterfowl actually spent off the lake, such as feeding and nesting. They applied an annual mean correction of 32% for geese and 31% for ducks. Finally, the nutrient load was calculated by multiplying the corrected effective use days by the daily nutrient loading rates for each bird group.

Scherer et al. (1995) estimated phosphorus loading in Green Lake from bird droppings by integrating multiple observational and analytical steps, as follows:

- The process began with weekly bird counts from January 1992 to December 1994 by an experienced ornithologist using binoculars and a high-powered spotting scope. Bird counts were conducted weekly along the 2.8-mile lake perimeter during early morning hours. Then, the number of individuals recorded for each species was multiplied by the number of days in the month and averaged to calculate monthly bird days. Then, monthly bird days were summed up to determine the annual bird days for each species. The Scherer et al. (1995) methodology expanded beyond geese and ducks to include more species, including but not limited to coots, cormorants, gulls, and other non-waterbirds.
- Based on prior research, the dry weight of droppings was estimated as 2.25% of body weight per day for most waterfowl. These production rates were paired with published body weight data to estimate the mass of the daily dropping per bird.
- The phosphorus concentration in the droppings was assumed to average 1.87% of the dry weight, based on previous published studies on ducks, gulls, and geese. Then, the 1.87% fraction was applied to body weight across bird categories.
- To account for the likelihood of droppings entering the lake, a probability factor was incorporated. This factor reflected observed bird behavior and habitat use, assigning probabilities based on how much time each bird species spent on or over the water. For example, cormorants and grebes, which are almost exclusively aquatic, were assigned a probability of 1.0, meaning all their droppings were assumed to enter the lake. In contrast, Canada geese and wigeons were assigned a probability of 0.5. Non-waterbirds, such as rock doves, had a much lower probability (0.125), considering their limited interaction with the lake surface.
- The phosphorus loading was the calculated using the following equation:

P = (bird-days) × (droppings dry weight per day) × (1.87% P content) × (entry probability)

Both methods were applied to Wiser Lake while making necessary modifications to ensure consistency and relevance. A primary adjustment was expanding species categorization beyond Scherer et al. (1995) to reflect species-specific variations observed at Wiser Lake. The categories used include Gadwall, American & European Wigeon, Other Ducks, American Coot, Canada and Domestic Goose, Snow Goose, Swan (Trumpeter), Cormorants, Gulls, Other Waterbirds, and Other Non-Waterbirds.

I.1.3 Results

The total phosphorus load estimated using the two methodologies varied significantly, with the Manny et al. (1994) method yielding 93.5 kg P/yr. and the Scherer et al. (1995) method estimating 362.5 kg P/yr.

Figure 50 shows the total monthly phosphorus load estimates across the bird species. As shown in this figure, the total monthly estimates followed a distinct seasonal pattern, with both methodologies showing the highest values in October and November. However, the Scherer et al. (1995) method consistently produced higher estimates across the months, with peak loads reaching over 140 kg P in November compared to 34.8 kg P under Manny et al. (1994). Winter months, particularly January and December, also showed notable differences, with Scherer's estimates more than four times higher than Manny’s.

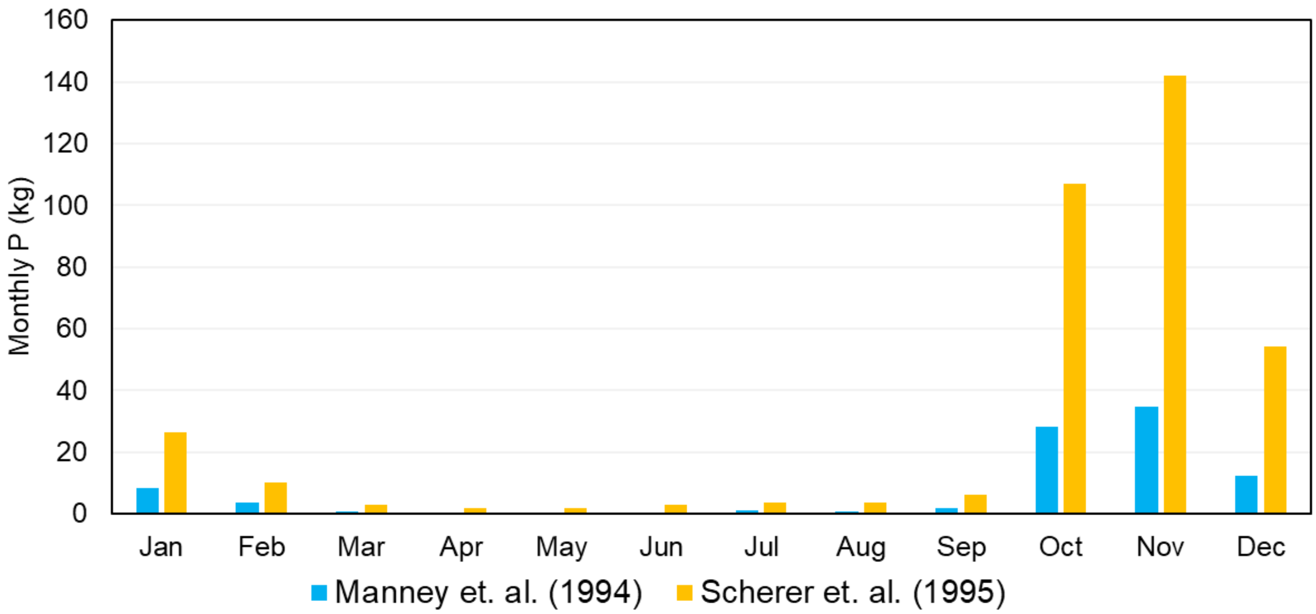

Figure 50. Estimated Monthly phosphorus loading estimates for Wiser Lake based on Manny et al. (1994) and Scherer et al. (1995) methods.

Figure 51 illustrates the annual phosphorus contribution by bird species. The Scherer et al. (1995) method estimated higher phosphorus loads across all bird categories, particularly for Snow Goose, Swan (Trumpeter), and Canada and Domestic Goose. For example, Snow Geese contributed 134.1 kg P under Scherer’s method, compared to 37.4 kg P under Manny’s approach. Similarly, Swans and Canada Geese showed significantly larger phosphorus contributions under Scherer’s estimates.

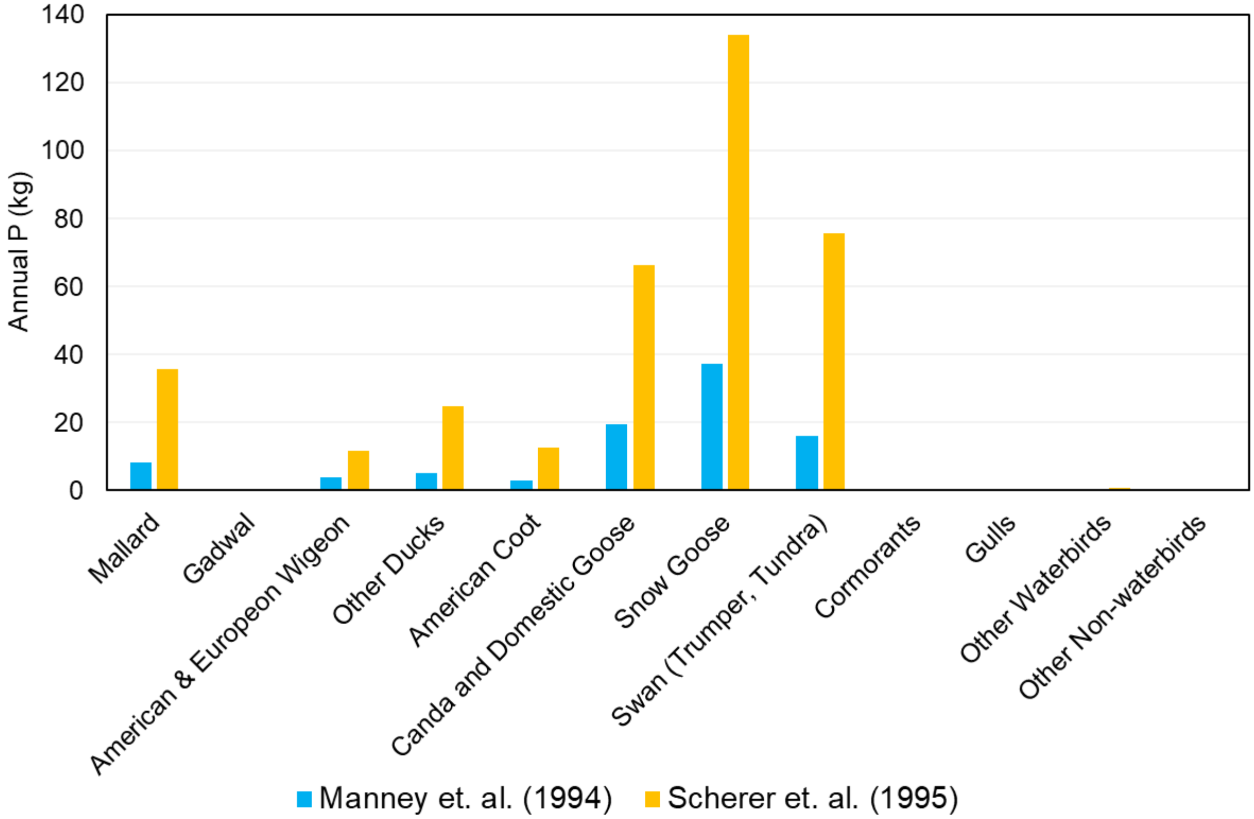

Figure 51. Estimated Annual phosphorus contribution by bird species using Manny et al. (1994) and Scherer et al. (1995) methods.

These discrepancies are due to different methods and assumptions used in calculating total bird-days, defecation rates, and probability factors used in each method. For example, Scherer et al. (1995) applied a P rate per day based on a percentage of bird species, while Manny et al. (1994) used a ratio of species to goose to estimate the P rates.

I.1.4 Discussion and Argument

While the estimates from both methodologies provide insight into the potential phosphorus contributions from waterfowl, a more thorough analysis, an extended observation period, and additional data collection would be necessary to refine these estimates and determine their true impact on nutrient dynamics for Wiser Lake. A few of these refinements are discussed below.

Scherer et al. (1995) reported that 87% of phosphorus in bird droppings was internally cycled, meaning that most of the phosphorus excreted by birds originated from food sources within the lake rather than external inputs. Additionally, their study found there was no correlation between phosphorus loading from birds and total phosphorus, chlorophyll-a concentrations, or Secchi depth in the water column. This may suggest that most phosphorus from droppings rapidly settles into the sediment, limiting its short-term impact on water quality and raising questions about whether it should be considered as an internal or external load. Without accounting for sediment interactions or internal cycling processes, directly including bird phosphorus contributions in the lake nutrient budget may overestimate their role in lake productivity.

Prior studies show significant variation in the estimated contribution of waterfowl phosphorus to total lake nutrient budgets. At Wintergreen Lake, Michigan, Manny et al. (1994) estimated waterfowl accounted for 70% of phosphorus loading. In contrast, Scherer et al. (1995) estimated contributions ranging from 27% to 34% in Green Lake, Washington. Scherer et al. (1995) summarized the reported contribution from other studies showing lower values, with estimates between 2% and 10% in lakes across Hungary, Washington, and Florida. Some research even suggests that birds are not a major external nutrient source but instead respond to existing eutrophic conditions, as observed in lakes in Alaska, Minnesota, and the Netherlands. This wide variability underscores the need for a site-specific, process-based evaluation of waterfowl contributions before integrating them into the nutrient budget for Wiser Lake.

Unlike previous studies such as Manny et al. (1994) and Scherer et al. (1995), which incorporated long-term multi-year observations (i.e., three years), detailed daily/weekly bird counts, and habitat-specific defecation rates, our dataset was limited to a single year (May 2023–April 2024), with only three to five observations per month. This limited frequency restricts the ability to capture fluctuations in bird populations, particularly seasonal migrations, diurnal variations, habitat preferences and fraction of the population on the lake. Without a more robust dataset, the estimated phosphorus loads may not fully represent the actual contributions from waterfowl.

To refine waterfowl phosphorus loading estimates and improve understanding of their role in Wiser Lake's nutrient dynamics, future studies may benefit from:

- Extending the observation period to multiple years to capture interannual variability,
- Including in the observation studies data on waterfowl lake usage,
- Conducting species-specific behavioral studies on Wiser Lake to refine defecation rates and phosphorus deposition estimates,
- Comparing short-term water quality parameters (such as chlorophyll-a, Secchi depth, phosphorus) with waterfowl presence to explore potential correlations,
- Collect targeted sediment samples to assess phosphorus accumulation from bird droppings and better understand nutrient cycling specific to Wiser Lake, and
- Reviewing recent literature and regional data from the Pacific Northwest to assess findings from similar lake systems and improve contextual understanding.

I.2 External phosphorus loading

I.2.1 Inlet Stream

Nutrient loads from surface water inflow were calculated using monthly flow estimates (as determined in the water budget) and measured nutrient concentrations. Nutrient sampling was conducted monthly during 2023 and 2024, capturing seasonal variability in TP and TN concentrations. These concentrations were multiplied by the estimated monthly inflows to quantify the monthly nutrient load entering the lake from streamflow, as shown in Table 23.

Table 23. Total Phosphorus and Nitrogen Monthly Loads to Wiser Lake at Inlet.

Month	TP (kg/year)	TN (kg/year)
Jan	17.06	1,081.78
Feb	1.90	227.56
Mar	1.35	118.01
Apr	2.92	192.19
May	0.64	31.41
Jun	0.50	19.76
Jul	0.16	6.46
Aug	0.41	26.04
Sep	0.22	6.30
Oct	2.74	99.62
Nov	7.75	867.97
Dec	15.94	2,310.56
Annual Total (Kg/year)	***51.59***	***4,987.66***

I.2.2 Atmospheric Deposition (Precipitation)

Atmospheric deposition of nutrients was calculated based on lake surface area and deposition rates from established literature. The annual atmospheric deposition rates used were 0.24 lb. TP/ac/yr for TP (Reckhow et. al., 1980) and 0.1 g N/m²/yr for TN (Wetzel,1983). These rates were applied to the lake's monthly surface area to estimate nutrient inputs from precipitation. Table 24 shows the results and illustrates the significance of atmospheric deposition as a consistent nutrient source over the year.

Table 24. Monthly Atmospheric Deposition to Wiser Lake.

Month	TP (kg/year)	TN (kg/year)
Jan	1.04	46.27
Feb	0.94	41.89
Mar	0.89	39.75
Apr	0.89	39.89
May	0.99	44.05
Jun	0.85	37.75
Jul	0.84	37.44
Aug	0.82	36.80
Sep	0.85	38.07
Oct	0.88	39.39
Nov	0.95	42.20
Dec	1.02	45.63
Annual Total (Kg/year)	***10.96***	***489.13***

I.2.3 Overland Flow

Nutrient contributions from overland flow, from the land surrounding the lake, were calculated using the event mean concentrations (EMCs) for TP and TN derived from the literature (Lusk et. al., 2019; Lang et. al., 2013; Kedlec & Wallace, 2009) and shown in Table 25 and Table 26. The EMC for TP was 0.19 mg/L, and for TN, it was 3.35 mg/L. These values were adjusted for land use and weighted based on the fraction of the overland drainage area surrounding the lake contributing to runoff.

Table 25. Land Use Total Phosphorous Event Mean Concentrations.

Land use	Average TP EMCs (mg/l)
Residential	0.22
Commercial	0.21
Industrial	0.25
Open Space	0.11
Land Use Weighted Average	0.19

Table 26. Land Use Total Nitrogen Event Mean Concentrations.

Land use	Average TN EMCs (mg/l)
Residential	1.6
Agricultural	6.2
Open Space	1
Land Use Weighted Average	3.35

Monthly overland flow estimates (from the water budget) were multiplied with the EMCs to determine nutrient loads entering the lake from the surrounding land, as shown in

Table 27. The results highlight the variability of nutrient contributions across different seasons and land uses.

Table 27. Monthly Total Phosphorous and Nitrogen Loading from Overland Flow to Wiser Lake.

Month	TP (kg/year)	TN (kg/year)
Jan	8.48	148.73
Feb	2.94	51.56
Mar	1.30	22.83
Apr	2.50	43.82
May	0.77	13.56
Jun	0.57	9.99
Jul	0.47	8.30
Aug	1.34	23.50
Sep	0.23	4.11
Oct	3.01	52.79
Nov	8.86	155.32
Dec	15.18	266.27
Annual Total (Kg/year)	***45.65***	***800.77***

I.2.4 Septic

Nutrient inflows from septic systems were estimated based on groundwater inflow values (calculated in the water budget), a retention factor of 0.70, and effluent concentrations from literature (Whelan & Titamnis,1982; Robertson et al., 2019; Magdoff et al., 1974; Withers et al., 2011; Gobler et al., 2021). The septic tank effluent concentration for TP was 1.18 mg/L, and for TN, it was 4.3 mg/L. Using these values, the annual septic nutrient load to the lake was estimated, as shown in Table 28. This estimate assumes the septic system contributions are transported via groundwater to the lake, representing a significant portion of the overall nutrient budget.

Table 28. Septic System Nutrient Loading to Wiser Lake.

	TP (kg/year)	TN (kg/year)
Annual Total	22	52

I.3 Internal phosphorus loading

Internal phosphorus loading was estimated based on sediment TP release rates associated with the lake's trophic status. Given Wiser Lake's classification near the eutrophic-hypereutrophic threshold (100 µg P/L), a TP release rate of 5 mg/m²/day was applied (Welch and Cooke, 2005; Nürnberg, 1988), as shown in Table 29.

Table 29. Phosphorous Loading Rate to Wiser Lake from the Sediments.

	Release Rate (mg/m²/day)		
	Lower	Average	Upper
Eutrophic Status	2	3.5	**5**

DO data indicated the potential for anoxic conditions in the deeper sections of the lake during the months of June to September. Based on this observation, internal phosphorus release calculations were focused on these months. An estimate of the lake bottom area for sediment release was developed by using the bottom most depth contours of up to 2 ft (0.61 m) above the bottom. This area was assumed to represent the deepest portion of the lake (east and west), where anoxic conditions are most likely to occur, as suggested by the DO data.

Monthly sediment releases were calculated using this sediment surface area and the duration of anoxic conditions. The total annual internal TP load was estimated to be 40.85 kg, as shown in Table 30, emphasizing the role of internal cycling in sustaining elevated TP concentrations.

Table 30. Monthly Total Phosphorous Loading from the Sediments.

Month	TP (kg/year)
Jun	10.04
Jul	10.38
Aug	10.38
Sep	10.04
Annual Total (kg/year)	40.85

I.4 Nutrient Budget Summary

The nutrient budget for Wiser Lake integrates the inflow components (stream inflow, atmospheric deposition, overland flow, and septic contributions) and internal loads to estimate annual TP and TN inputs. The results are presented in Table 31 below, accompanied by pie charts illustrating the relative contributions of each source. These findings provide a foundation for evaluating potential management strategies and their implications for nutrient load reductions.

Table 31. Wiser Lake Nutrient Budgets.

Component	TP (kg/year)	TN (kg/year)
Streamflow Lake Inflow	51.89	4,987.66
Overland Flow Contribution	45.65	800.77
Internal Load sediment release)	40.85	-
Septic System	21.63	51.66
Atmospheric Deposition (Precipitation)	10.96	489.13
Total Budget	170.7	6,329

The TP Annual Budget Summary (Figure 52) below shows the largest contribution of phosphorous to the lake inflow from the upstream watershed, with overland lake contribution as the second largest source. The TN Annual Budget Summary (Figure 53), shows the largest source of nitrogen to the lake is the inflow from the upstream watershed.

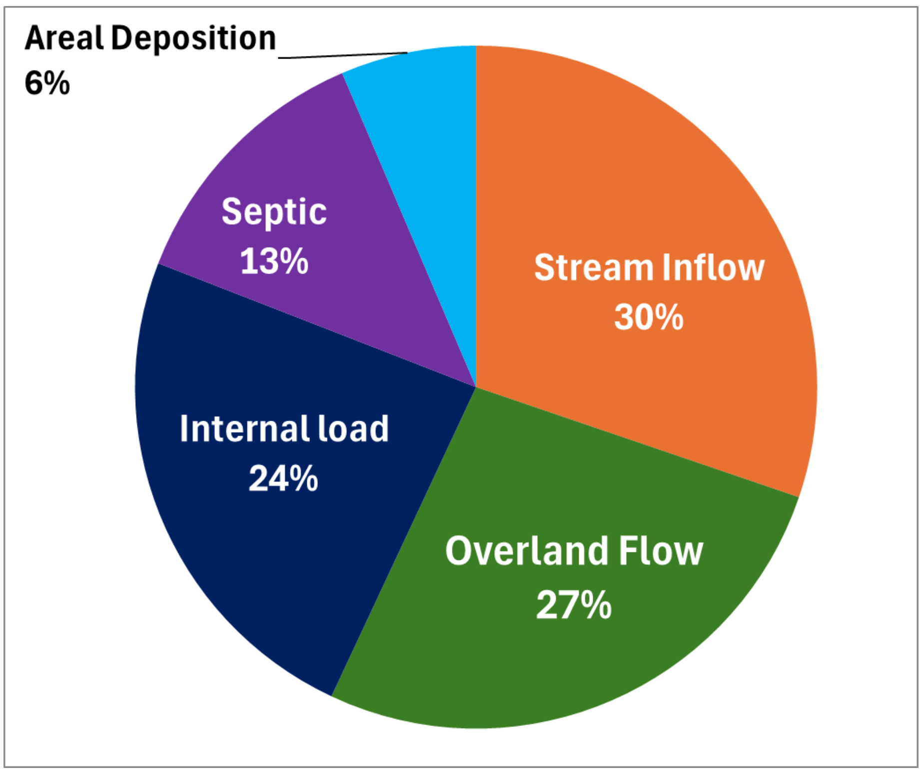

Figure 52. TP Annual Budget Percentage Summary.

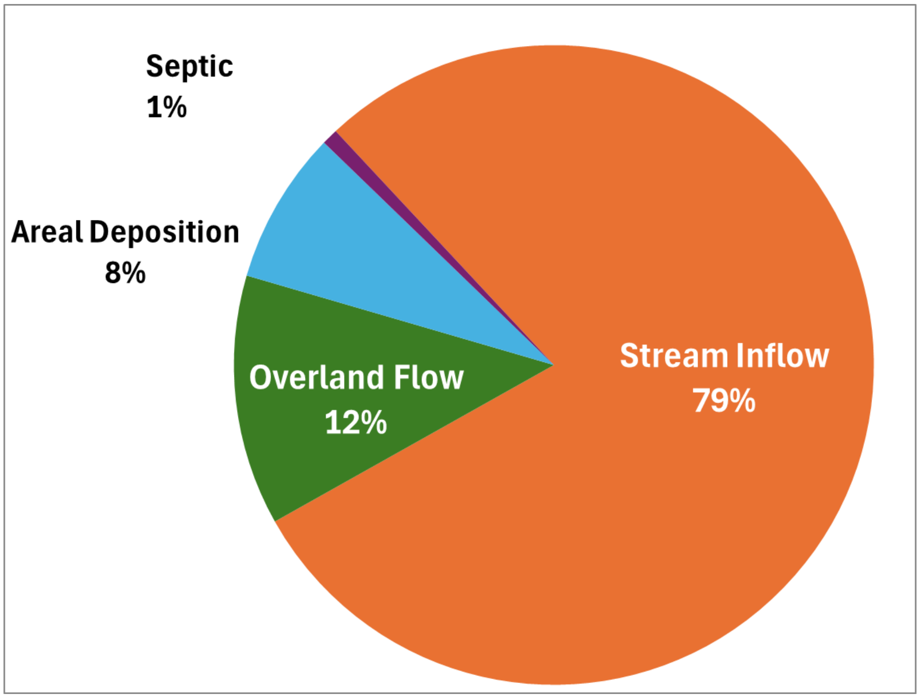

Figure 53. TN Annual Budget Percentage Summary.

I.5 In-Lake Phosphorus Analytical Modeling

In-lake phosphorus analytical modeling provides valuable insights into nutrient dynamics and their implications for lake water quality and trophic status. Two widely recognized models, the Vollenweider Model and the Nürnberg Model, were applied to estimate phosphorus concentrations in Wiser Lake, evaluate trophic conditions, and guide nutrient management strategies.

I.5.1 Vollenweider Model

The Vollenweider Model (Vollenweider, 1976) predicts mean in-lake phosphorus concentration (*pv*) based on annual phosphorus loading, mean lake depth, and hydraulic residence time. Developed from a study of 200 waterbodies worldwide, the model assumes uniform mixing and offers a widely validated approach for nutrient management. The equation is expressed as:

$$P_v = \frac{L_p}{(q_s(1 + \sqrt{\tau_w}))}$$

where,

- *pv* is the Mean in-lake phosphorus concentration,
- *Lp* is the Annual Phosphorus load/lake area,
- *τw* is the Hydraulic Residence Time,
- *qs* is the Hydraulic Overflow Rate- z/τw, and
- *z* is the Average Depth

Table 32 below summarizes the input and output of the Vollenweider model.

Table 32. Vollenweider model input and output.

Vollenweider Model Parameter	Value
Annual External TP Load (kg/year)	129.8
Average Lake Volume (m^3)	561,268
Average Lake Surface Area (m^2)	407,608
Average Depth (m)	2.3
Annual TP Loading Rate ($kg/m^2/year$)	0.00032
Hydraulic Residence Time (year)	0.56
Hydraulic Overflow Rate (m/year)	2.45
P estimated concentration in the lake - p_v (ug/L)	***74.4***

The results of the Vollenweider Model indicate a modeled mean in-lake phosphorus concentration of 74.4 µg/L, reflecting the lake's eutrophic to hypereutrophic conditions. This concentration aligns with measured values, which vary spatially and seasonally across the lake. For example, measurements from the East side of the lake show annual average TP concentrations of 96.2 µg/L, while the West side exhibits a higher annual average of 122.3 µg/L. Seasonal variations are notable, with peak concentrations observed during late summer and fall (August and September), emphasizing the role of external loading and internal cycling in driving these dynamics.

Achieving mesotrophic conditions, corresponding to a mean total phosphorus concentration of 12.1 to 24 µg/L, would require substantial reductions in external phosphorus loading. Based on the Vollenweider Model parameters, including an annual external TP load of 130 kg/year and a hydraulic residence time of 0.56 years, a reduction of approximately 68% to 84% in phosphorus loading would be required, depending on the specific target within the mesotrophic range. These reductions highlight the need for management strategies, such as stormwater runoff controls, agricultural best management practices (BMPs), and watershed restoration efforts, to improve water quality effectively.

The Vollenweider Model results also underscore the sensitivity of phosphorus concentrations to changes in external loading. For example, a hypothetical 10% reduction in external loading resulted in a corresponding decrease in modeled phosphorus concentration. These findings provide a quantitative framework for assessing the effectiveness of management actions, such as stormwater runoff controls and watershed BMPs.

I.5.2 Nürnberg Model

The Nürnberg Model offers a more nuanced approach by incorporating internal phosphorus loading and seasonal variability. This dynamic model calculates annual, summer epilimnion, and fall phosphorus concentrations, making it particularly suitable for lakes like Wiser, which experience significant internal cycling of nutrients. The model equations include:

Annual Average P:

$$P_{ann} = \left[\frac{(L_{ext} + L_{int})}{q_s}\right](1 - R)$$

Summer Epilimnion P:

$$P_{epi} = \left[\frac{(L_{ext})}{q_s}\right](1 - R) + \frac{L_{int}}{q_s}$$

Fall P Concentration:

$$P_{fall} < \left[\frac{(L_{ext})}{q_s}\right](1 - R) + \frac{L_{int}}{q_s}$$

where,

> L_{ext} is the Annual External TP phosphorus Load (kg/m2/year),
> L_{int} is the Annual Internal TP phosphorus Load (kg/m2/year),
> q_s is the Hydraulic Overflow Rate (m/year), and
> R is the Retention Factor [unitless].

Table 33 below summarizes the input parameters and model results.

Table 33. Nürnberg Model inputs and output.

Nürnberg Model Parameter	Value
Annual External TP Load (kg/year) =	129.8
Annual External TP Load (kg/year) =	40.6
Average Lake Volume (m^3) =	561,268
Average Lake Surface Area (m^2) =	407,608
Average Depth (m) =	2.3
Annual External TP Loading Rate (kg/m^2/year) =	0.00032
Annual Internal TP Loading Rate (kg/m^2/year) =	0.00010
Hydraulic Residence Time (year) =	0.56
Hydraulic Overflow Rate (m/year) =	2.45
Retention Factor [-] =	0.73
Annual Average P concentration (p_{ann}) (ug/L) =	***45.6***
Summer Epilimnion P concentration (p_{epi}) (ug/L) =	***34.7***
Fall P concentration (p_{fall}) (ug/L) =	***75.6***

The Nürnberg model results provide valuable insights into the phosphorus dynamics of Wiser Lake, capturing the interplay between external and internal loading:

- Annual Average Phosphorus Concentration (p_{ann}): The modeled value of 45.6 µg/L indicates a eutrophic condition, which is lower than the concentration estimated by the Vollenweider Model and measured data. This suggests that the Nürnberg model accounts for retention and internal cycling processes differently.
- Summer Epilimnion Phosphorus Concentration (P_{epi}): A summer concentration of 34.7 µg/L reflects stratified conditions, where phosphorus released from the sediment during stratification is temporarily sequestered in the hypolimnion, reducing its influence on surface layers during this period. This estimated value is less important since the current understanding is the water column can be well mixed during the summer due to winds.
- Fall Phosphorus Concentration (P_{fall}): The modeled fall concentration of 75.6 µg/L highlights the role of internal phosphorus release during turnover events, as accumulated phosphorus from the hypolimnion mixes throughout the water column. Fall turnover may be less significant at Wiser Lake since winds tend to result in a well-mixed water column.

These results emphasize the importance of both external and internal phosphorus sources in driving seasonal nutrient dynamics in Wiser Lake. While external loading remains a primary driver of annual phosphorus levels, the impact of internal loading becomes pronounced during late summer and fall, underscoring the need to address both sources in management strategies. These results also underscore the need to better understand the anoxic sediment conditions in summer via DO measurements closer to the sediments and the extent of the sediment where these releases would occur.

Furthermore, the Vollenweider and Nürnberg models provide complementary insights into the nutrient dynamics of the lake, with each emphasizing different processes and assumptions. The Vollenweider Model focuses on the relationship between external phosphorus loading and in-lake concentrations, producing higher annual average estimates (74.4 µg/L) that highlight the importance of managing watershed inputs. In contrast, the Nürnberg Model incorporates internal loading, stratification effects, and phosphorus retention, resulting in lower annual average predictions (45.6 µg/L). These differences are expected, as the models address distinct aspects of phosphorus dynamics. The Vollenweider Model is particularly suited for evaluating the impact of external loading, while the Nürnberg Model provides a detailed perspective on seasonal and internal processes, including sediment phosphorus release. Together, these models highlight different aspects of nutrient dynamics and indicate that both external and internal phosphorus sources play a role in influencing Wiser Lake water quality.

J. Management Methods for Cyanobacteria

Cyanobacteria growth is fueled by excess nutrients and warm water. As discussed in Section G.5.3, Wiser Lake contains abundant phosphorus and experiences sufficiently warm temperatures to support excessive cyanobacterial growth. While reducing phosphorus inputs should be a long-term goal to limit cyanobacteria, short-term management actions may be needed to improve water quality conditions in the interim—especially before watershed best management practices (BMPs) become effective at reducing external phosphorus loading.

Management strategies for controlling cyanobacteria include direct algae control, internal load reduction, and external load reduction. Direct algae control is a short-term approach focused on disrupting and removing existing blooms. Internal load reduction targets the longer-term goal of minimizing phosphorus release from lake sediments, thereby limiting a key nutrient that fuels cyanobacterial growth. External load reduction addresses phosphorus inputs entering the lake from the watershed, including runoff from streams, overland flow, and groundwater sources.

J.1 Direct algae control methods

Direct algae control methods are those that quickly remove algae and cyanobacteria from the water column. Copper sulfate-based algaecides are not permitted in Washington but endothall and sodium carbonate peroxyhydrate are permitted per the Aquatic Plant and Algae Management (APAM) permit system (DOE, 2021). Aluminum sulfate (alum) can also be considered a direct algae control method because it physically removes algal cells from the water column while simultaneously sequestering phosphorus. Control methods such as alum treatments will be discussed in Section J2.

Table 34. Direct Algae Control Products Allowed in Washington.

Product	Timing	Restrictions	Limitations	Restrictions
Endothall (mono salt)	Subject to timing window for salmon, steelhead, bull trout[1]	24 hr. swimming advisory after application to the entire waterbody	Use for control of filamentous algae, cyanobacteria, or harmful algae only. Limit concentration to 0.2 mg/L of active ingredient	Must treat from shoreline outward. Consult label for use restrictions
Sodium carbonate peroxyhydrate	None for fish. Possibly for other priority species	None	Do not treat plants growing onshore	None
[1]–Timing window restrictions for priority fish species apply in addition to timing windows identified for other priority non-fish species, (WDFW Timing Window Map)				

The APAM states that any use of algaecide cannot result in further impairment of any 303(d) listed parameter in the waterbody. Algaecide use can decrease the dissolved oxygen in the water column, and can release cyano-toxins into the waterbody if the algal species are producing toxins at the time of treatment.

Algaecides should be used sparingly and only as part of a comprehensive management plan focused on achieving long-term nutrient reduction. Any application should take into account the presence of toxin producing cyanobacteria species and take steps to protect the public from the potential release of toxins.

J.2 Internal loading control methods

Internal loading controls target phosphorus released from lake sediments during the summer. Analytical modeling indicates that internal loading accounts for approximately 24% of Wiser Lake's phosphorus budget (Section I.3). Phosphorus release typically occurs during summer stratification when oxygen is depleted at the sediment-water interface and under extreme pH conditions. While low pH events are rare in lakes, high productivity can raise pH levels to 9 or above, and when combined with sediment resuspension, this can enhance phosphorus mobilization (Koski-Vahala, 2001).

Although preliminary data suggest Wiser Lake was not thermally stratified during sampling (as discussed in Section G.3.3), periods of anoxia at the sediment-water interface may still occur. Calm wind conditions can also induce temporary stratification by reducing mixing. To address this, artificial circulation can be used to mix the water column and prevent stratification. Alternatively, minerals that better retain phosphorus under anoxic conditions can be applied. Another related approach is to remove phosphorus from the water column to mitigate ongoing blooms.

J.2.1 Circulation

If internal loading under anoxic conditions is a large source of phosphorus loading, an aeration system can be installed to increase oxygen at the sediment layer. While Wiser Lake seems to be mixed during the day , there may be conditions when it becomes stratified and anoxic at the bottom during calm nights. Adding artificial circulation can provide mixing during those periods when wind is not adequate.

Aeration systems consist of a compressor, weighted air lines, and diffusers installed in the lake to circulate and oxygenate the water. Additional monitoring is needed to determine whether Wiser Lake experiences anoxia during certain periods and to assess its extent. If anoxia is confined to a small area at the deepest part of the lake, a relatively small aeration system may suffice. However, if anoxic conditions occur in shallower areas as well, the system would need to be expanded to cover those zones.

Initial costs would include a building to house the on-shore equipment, installation of an electrical service for the building, compressor, weighted hoses and air diffusers. More information would be required before a recommendation can be made for aeration due to data gaps related to the spatial extent of any anoxic zones.

J.2.2 Phosphorus Sequestration

Phosphorus is the primary nutrient fueling algae blooms in the Northwest. A common method to reduce phosphorus concentrations in lakes involves applying minerals that bind phosphorus and remove it from the water column. This approach is used both to strip phosphorus directly from the water and to treat sediments, intercepting phosphorus before it can enter the water column.

Several minerals can bind phosphorus; however, some may release it again under certain environmental conditions. For example, iron binds phosphorus effectively but can release it back into the water under anoxic (oxygen-depleted) conditions. The most commonly used minerals for phosphorus sequestration are aluminum and lanthanum. While aluminum has been widely used for many years, lanthanum is a relatively new option that can offer additional benefits in specific situations. The different approaches to phosphorus sequestration are described below.

Water Column Stripping

The goal of water column stripping is to remove soluble phosphorus from the water column and make it unavailable to feed cyanobacteria. This works best when there is a high percentage of soluble phosphrous in the water column since both aluminum and lanthanum will bind to phosphorus and make it unavailable to feed algae and cyanobacteria. In addition, once aluminum and lanthanum fall to the sediment they continue to bind phosphorus, even in anoxic conditions.

Aluminum sulfate (alum) is the most widely used product for treating internal phosphorus loading in lakes. Its phosphorus-binding effect is generally considered permanent under most environmental conditions (Rydin and Welch, 1998). Alum is typically applied in liquid form to the lake surface, where it forms a “floc” that strips algae from the water column, sequesters soluble phosphorus, and then settles to the lake bottom. There, it intercepts phosphorus migrating upward through the sediment.

Because alum applications can lower pH, potentially causing aluminum toxicity if pH falls below 6, high-dose treatments require buffering. Sodium aluminate is commonly added during alum application to maintain pH within a safe range.

However, during high pH conditions (>8.0), the aluminum-phosphorus complex can break down, releasing phosphorus back into the water column. Wiser Lake experienced pH levels above 8.5 in August and September, which likely increased internal phosphorus loading. Persistent high pH conditions may reduce alum's effectiveness in controlling internal loading. Nonetheless, applying alum as pH begins to rise could help reduce water column phosphorus and lower pH, mitigating internal loading.

Lanthanum is a rare earth mineral used in phosphorus sequestration products produced by companies like SePRO. Two such products are **EutroSORB WC** and **EutroSORB G**:

- **EutroSORB WC** is a liquid formulation designed to strip soluble phosphorus from the water column.
- **EutroSORB G** consists of lanthanum embedded in a clay matrix. While it removes some soluble phosphorus from the water column, its primary role is to settle on the lake bottom, forming a capping layer that intercepts phosphorus before it can enter the water column.

Lanthanum products are more pH-neutral than alum, presenting a lower risk of environmental toxicity. In Washington, EutroSORB G is approved for use, while EutroSORB WC remains under experimental review.

Comparing Alum and Lanthanum

Both alum and lanthanum effectively bind phosphorus, but their application methods present distinct advantages and limitations:

- **Alum** requires careful buffering to avoid toxicity but has the added benefit of physically removing phytoplankton from the water column along with soluble phosphorus. This dual action can reduce phosphorus bound in algal cells as well as the soluble form, resulting in a more significant overall reduction.
- **Lanthanum** products have minimal impact on pH and do not require buffering. However, they primarily target soluble phosphorus and are less effective at removing phytoplankton biomass. While EutroSORB G's clay matrix may remove some material as it settles, this amount is much less than that removed by alum.

Given Wiser Lake's high soluble phosphorus concentrations, EutroSORB G would be an effective treatment. Additionally, EutroSORB G maintains sustained phosphorus-binding capacity at the elevated pH levels observed in Wiser Lake.

Water column stripping with alum

Water column stripping with alum could be effective in Wiser Lake; however, the lake's history of high pH (above 8) can break the aluminum-phosphorus bond, reducing treatment effectiveness. The goal of this approach is to lower algal productivity by removing phosphorus, which in turn would decrease photosynthesis and help bring pH closer to neutral (around 7). Nonetheless, this pH reduction may be temporary and may not persist throughout the summer, indicating that more detailed analysis is needed to fully evaluate this method. Due to ongoing external phosphorus loading and sediment disturbance, annual treatments may be necessary.

Cost estimation for alum application is based on the average summer phosphorus concentration of 119 µg/L and the lake's total water volume, resulting in approximately 59 kg of phosphorus present. Alum application rates generally range from 10:1 to 100:1 (aluminum to phosphorus) depending on water conditions (Natarajan and Gulliver, 2020). Given Wiser Lake's turbid conditions and the need to physically remove algae and sediment-bound phosphorus, a 60:1 ratio was selected. This equates to 3,523 kg of aluminum per treatment. Since alum contains about 0.22 kg of aluminum per gallon, the total alum dose needed to strip phosphorus from the water column is approximately 16,013 gallons.

This aluminum will accumulate in the sediment over time, potentially reducing internal phosphorus releases after several years. However, depending on how quickly phosphorus levels recover due to external and internal inputs, multiple applications in a single year may be required.

Sediment treatment with alum

When treating sediment with alum you typically target the areas that become anoxic during summer stratification. But with Wiser Lake not only is there internal release from anoxic sediment, but sediment resuspension from wind, and groundwater intrusion all contributing phosphorus to the lake. As a result it is suggested the entire lake be treated. Using iron bound and biogenic P as sediment sources it is estimated there is 7,390 kg of phosphorus that needs to be inactivated. Using a ratio of 50:1 for the iron bound P and 30:1 for the biogenic P the total mass of aluminum required is 342,600 kg. Multiplying the Al required by a ratio of .22 kg of Al per gallon results in 1.56 million gallons of alum. If that were spread over 20 annual treatments it would require dosing the lake with 78,000 gallons of alum per year.

Sediment treatment with EutroSORB

An alternate to using alum would be Eutrosorb, and as discussed previously there are some benefits to this product over aluminum sulfate. It does not reduce pH so there is no impact to alkalinity; it has a wider pH tolerance and maintains its phosphrous bond up to pH 9.5; and It does not require pre and post treatment monitoring for pH and dissolved aluminum. However, it is more expensive than an alum application so all factors will have to be weighed.

An estimate for treating the lake with EutroSORB G was based on the same sediment phosphorus concentration as used in the alum calculations. The east basin (WL2) which would require 189,980 kg (417,950 pounds) of EutroSORB G to bind sediment phosphorus. For the west basin (WL1) an estimated 22,840 kg (50,250 pounds) of EutroSORB G would be required. The total amount of the two applications was divided into 20 treatments which led to an annual target of 10,118 klg (22,260 pounds) of EutroSORB G.

Summary

Table 36 presents a cost breakdown by basin and phosphorus reduction target. Both alum and lanthanum products can be used to strip soluble phosphorus from the water column and treat the sediment; however, alum is more effective at removing phosphorus overall due to its additional ability to remove phytoplankton. These treatment approaches are not mutually exclusive—treating the sediment also strips phosphorus from the water column but involves applying an excess amount of material that forms a layer over the sediment to intercept phosphorus before it re-enters the water column. The table provides separate dosing recommendations for stripping the water column and for sediment treatment for both products, organized by basin.

Table 35. Alum and EutroSORB treatment costs per basin and per treatment goal.

Product	Treatment	Location	Total Cost
Alum	Stripping	WL1	18,200
Alum	Stripping	WL2	151,000
Alum	Sediment Treatment	WL1	$311,000
Alum	Sediment Treatment	WL2	$2.6 million
EutroSORB G	Stripping	WL1	$14,700
EutroSORB G	Stripping	WL2	$107,500
EutroSORB G	Sediment Treatment	WL1	$271,000 million
EutroSORB G	Sediment Treatment	WL2	$1.9 million

Table 36 includes both stripping and sediment treatment doses, with the goal of having the annual stripping doses add up to a sediment treatment over the course of 20 years of annual applications. These are planning level calculations and more information will be required to establish a firm application cost. Material prices may increase, and permitting requirements would add additional expense.

Table 36. Phosphorus sequestration costs

Product	Advantages	Disadvantages
Alum	-Can be less expensive -Physically removes algae from water column -Reduces pH	-Can reduce pH excessively* -Aluminum releases phosphorus when pH > 8.5 -Will need monitoring before, during, and after treatment
EutroSORB G	-Maintains phosphorus bond at higher pH conditions -Does not require testing -Can use less product -Does not reduce pH during application*	-Typically more expensive than alum -Does not strip algae from water column -Does not decrease pH during application*
	*It may be desirable to decrease pH during an application, but if pH is already low a buffer may be required to balance pH during an alum application. EutroSORB has no impact on pH so if pH is too high it will not reduce it.	

J.2.3 Permits for phosphorus sequestration

If Wiser Lake requires an algae control or internal loading management method, an Aquatic Plant and Algae Management (APAM) permit from the DOE will be necessary. Instructions for applying for the permit are on the DOE's website (Ecology APAM Permit Information).

Prior to receiving a DOE permit, the applicant will need to post a Notice in a local newspaper two (2) times, at least seven (7) days apart to allow the local community to comment on the potential application. A template for the Notice can be found on DOE's website as cited above.

The DOE requires public notification as part of the permit conditions. Prior to treatment, signs will need to be posted around treated areas to inform the public that treatment will occur or has occurred. These signs include water use restriction details, enabling individuals to decide whether they wish to enter the treated area. The intent is to encourage users to avoid the area for a specified period, depending on the type of treatment applied. The template for the signage with the required information is below and is available on DOE's website as cited above.

Phosphorus inactivation products typically do not have water use restrictions or health advisories; however, the permittee and contractor must check the product label for any restrictions. There are treatment limitations and other restrictions listed in Table 3 of the APAM permit found on the DOE's website as cited above.

The APAM general permit fact document states that a permit for phosphorus reduction treatment will mandate that Permittees monitor water conditions when applying phosphorus sequestration products such as aluminum sulfate (alum), sodium aluminate, or calcium hydroxide with carbon dioxide. Since alum lowers the pH of receiving waters and calcium hydroxide raises it, the DOE requires permittees to monitor pH levels both before and during treatment.

J.3 External loading control methods

External loading refers to programmatic, physical, or chemical means of reducing the amount of watershed-generated phosphorus that makes it to the lake. These are often long-term projects since they may involve capital expenditures to upgrade septic systems, a modification to agricultural practices, restoration projects, or behavioral changes by residents. However, these are the BMPs for long-term lake health and will reduce the reliance of short-term treatments.

Results from the annual nutrient budget (Section I.3) showed the watershed contributing 30% of the TP and 79% of the TN load to the lake. Historical agricultural land use and residential OSS systems in the watershed could be contributing to the high nutrient inputs (Section E.1.4).

J.3.1 Septic

As discussed in Section E.1.4, septic systems can contribute significantly to nutrient pollution in both groundwater and surface waters. It is recommended that Whatcom County take proactive steps to address septic systems that are either non-compliant or failing, as well as those that no longer function as originally designed, especially when they are situated in soil or climate conditions that do not effectively remove phosphorus. Additionally, septic systems located near high-risk areas, such as those close to the lake, along Cougar Creek, or in regions with high water tables or improper soil conditions, should be evaluated for potential nutrient leaching.

The county should prioritize the replacement of failing systems, particularly those near Wiser Lake and Cougar Creek. A possible solution is to replace these outdated systems with a newer advanced treatment design, recently tested at Newman Lake with funding from the Department of Ecology. The project, which focuses on reducing nutrients from septic systems, tested the following two advanced treatment models:

Biomicrobics Biobarrier System (in-ground)

Busse GT 500 System (above-ground)

Unlike conventional septic systems, these advanced systems do not require a drain field for treatment, offering enhanced nutrient and bacteria removal. The pilot project at Newman Lake demonstrated that these systems successfully eliminated over 97% of phosphorus and nitrogen from effluent (Reducing nutrients from septic systems in Newman Lake: https://tinyurl.com/NewmanBioreactor 2024).

Both models are listed on the Washington State Department of Health's (DOH) approved technology list for pre-treatment. The Department of Ecology (DOE) is currently collaborating with DOH to expand their use as primary treatment systems, eliminating the need for a soil treatment component (S. Elsen, personal communication, 2024).

While the cost of these systems can range from $40,000 to $45,000 depending on location and installation factors, funding may be available through the DOE's Combined Funding Program. Eligible entities, such as local agencies, conservation districts, and tribes, can apply for grants of up to $500,000, with loans available for amounts exceeding this limit. The DOE also offers funding for watershed repair/replacement programs, sanitary surveys, and rebates for septic system pumping and maintenance.

For urgent repairs or loans for property owners, the OSS Regional Loan Program, managed by Craft3 (a nonprofit third-party lender), may provide financial assistance. More information is available at Ecology: On-site sewage system projects (https://ecology.wa.gov/water-shorelines/water-quality/water-quality-grants-and-loans/on-site-sewage-projects. 2025).

J.3.2 Shoreline restoration

Shorelines that are developed up to the lake edge do not provide buffering capacity to treat runoff from urban lawns before it reaches the lake. This leads to fertilizers, animal waste, and chemicals applied to lawns washing into the lake. Buffers of at least 30 feet that include native vegetation provide this separation and an area where nutrients are taken up before reaching the waterbody. A buffer strip that includes taller vegetation provides a secondary benefit of discouraging geese from moving between the lake and lawns.

DOE grants from the Water Quality Combined Program (https://ecology.wa.gov/about-us/payments-contracts-grants/grants-loans/find-a-grant-or-loan/water-quality-combined)may be available for those residences that are interested in restoring native shoreline and emergent vegetation to create a more natural shoreline which can compete with cyanobacteria for nutrients and provide shade for cooling. The landscape can be designed so vegetation not impact views but provides shade and habitat for aquatic and amphibian wildlife.

J.3.3 Fish stocking

Fish stocking – according to WDFW, fish were last stocked in Wiser Lake in 1987. Stocking in Cougar Creek continued every 3-4 years until 1994. It is unclear if the fingerlings stocked in Cougar Creek would migrate upstream to the lake. However, due to the eutrophic conditions of Wiser Lake and the nutrient input from fish stocking as noted above (Section E.1.7), it is recommended that WDFW and the WCHCS do not reinstate fish stocking of Wiser Lake in the future.

J.3.4 Agriculture Best Management Practices

According to the "Voluntary Clean Water Guidance for Agriculture", animal agriculture plays a vital role in Washington's economy and food supply. To support environmentally responsible practices, the Department of Ecology outlines several BMPs particularly relevant to the Wiser Lake immediate watershed area.

For Livestock Management

- **Site confinement areas responsibly**: Locate animal confinement areas at least 215 feet away from surface waters and outside of designated Riparian Management Zones (RMZs). Prefer elevated ground over depressional or low-lying areas.
- **Avoid surface water conduits**: Do not place confinement areas near swales, tile drains, or other direct drainage pathways.
- **Consider groundwater depth**: Select sites with deeper groundwater, as most areas in the watershed are characterized by shallow water tables.

For Manure Management

Manure spreading is permitted in WRIA 1; however, farmers are strongly encouraged to follow these BMPs to minimize water quality impacts.

- **Proper storage**: Follow guidelines from the Department of Ecology's *Livestock Management: Animal Confinement, Manure Handling & Storage* (June 2023).
- **Application timing**: Apply manure in sync with crop nutrient needs and favorable weather to ensure optimal uptake and minimize runoff.
- **Field conditions**: Assess field saturation and water table levels before spreading to avoid leaching and runoff.
- **Application methods**: Use equipment and techniques that incorporate manure into the soil to reduce surface runoff and nutrient loss.

For Nutrient Management

Additional BMPs from the EPA and North Carolina State Extension.

- **Soil testing**: Analyze soil to determine existing nutrient levels and the need for supplemental nitrogen (N) and phosphorus (P).
- **Appropriate phosphorus use**: Apply phosphorus carefully, as surface-applied phosphorus is more prone to runoff and less likely to be absorbed by plants.
- **Apply nutrients when needed**: Apply only in necessary quantities and at times aligned with crop demand—especially for nitrogen, which is highly mobile in the environment.
- **Erosion control practices**: Implement windbreaks, buffer strips, vegetative buffers, and year-round ground cover to protect soil and water quality.

Protecting Riparian Areas and Surface Water

- **Establish Riparian Management Zones (RMZs)**: Maintain RMZs at a minimum width of 215 feet.
- **Use native vegetation**: Plant RMZs with native species to restore natural habitat functions, including:
  - Filtering and dispersing surface runoff
  - Promoting water infiltration and sediment trapping
  - Preventing streambank erosion
  - Shading streams and maintaining water temperature
  - Contributing large woody debris to aquatic systems
- **Wetland-adjacent streams**: Where riparian forest restoration is not feasible (e.g., due to wetlands), adhere to the Department of Ecology's wetland buffer guidance.

J.3.5 Waterfowl Management

Waterfowl are a significant source of nutrient addition to Wiser Lake, primarily due to their fecal matter. To improve water quality and maintain a healthier shoreline, Whatcom County should consider promoting practices that reduce waterfowl presence and encourage natural shoreline vegetation. Key strategies could include:

Discouraging Artificial Armoring: Residents should be encouraged not to implement artificial armoring on their shorelines, as it can disrupt natural habitats and encourage waterfowl congregation.

Replacing Lawns with Native Plants: By replacing grass lawns with native plants, residents can create a more natural, waterfowl-deterrent environment. Tall, dense shrubs and grasses, especially along the shoreline, can provide habitat for wildlife while also competing with cyanobacteria for essential nutrients.

Residents can use resources like the King County Native Plant Guide (available at https://green2.kingcounty.gov/gonative/Plan.aspx?Act=view&PlanID=20 to plan landscaping based on their specific site conditions.

Additionally, effective waterfowl management should be prioritized to reduce nutrient loading from large quantities of fecal matter in the lake, on the shoreline, and from agricultural runoff in the Cougar Creek watershed. These combined actions will contribute to a healthier lake ecosystem.

Table 37. Waterfowl management strategies.

Management Strategy	Description	Advantages and Disadvantages
Discourage feeding of all wildlife	Resident and public education, signage	Removes the encouragement that feeding waterfowl provides.
Shoreline vegetation restoration	Remove grass lawns and restore with tall, dense shrubs and grasses, restore emergent species along lake shore	Discourages waterfowl from using parcels along the lakeshore. Vegetation can compete with cyanobacteria for nutrients. Reduces shoreline erosion.
Predators for chasing	Trained dogs are hired to chase the geese from the site.	Discourages waterfowl from remaining on site and nesting. Can be expensive and intrusive on private property
Predator decoys and other	Realistic decoys - coyotes or owls Reflective streamers and/or flags Fences along the shoreline Motion activated sprinklers Chemical repellants	Relatively inexpensive One method may not work for long, multiple methods tend to work better
Lethal control	Capturing and culling the geese population Addling eggs of geese via shaking vigorously, pierce eggshell, apply thin coating of corn oil	USFWS permits are required WDFW permits are required Adult geese are very protective and addling eggs may cause them to charge

K. Management / Restoration Methods Rejected

Not every management method will work for every lake. The methods below were considered for Wiser Lake but were considered inappropriate at this time.

K.1 Dredge

Dredging can be an effective means of removing high-nutrient sediment from the lake, particularly when the lake has sustained stratification and anoxic sediment that contributes a major portion of the phosphorus load. While internal loading is a factor in Wiser Lake it is not the most cost-effective means of addressing internal phosphorus loads considering the expense of permitting and implementation. In addition, due to the amount of external loading there will still be significant nutrient inputs to the lake after sediment removal.

K.2 Ultrasonic algae treatment

There are several companies that market products that produce ultrasonic waves as algae control methods. The devices emit tuned frequencies to target specific algae groups, with the goal of disrupting algae cells and reducing the population. While there has been some evidence of ultrasonic algae control in laboratory settings, the results have been less positive in mixed cultures (Lüring and Toman, 2014, Tekile et al., 2017).

K.3 Floating treatment wetlands

Floating treatment wetlands (FTW) are artificial islands of specific vegetation where the plant roots hang down to extract nutrients from the water. In addition to extracting nutrients the islands shade the water column to reduce light available for phytoplankton growth, and can help cool the water column. Phosphorus uptake is enhanced by biofilm made up of non-photosynthetic bacterial communities that forms on the plant roots (Floating Island International).

While FTW's can be successful in certain applications, for larger lakes the coverage area necessary to provide beneficial phosphorus uptake could be large. One application in Montana covered 2.7% of the lake surface with a floating wetland, which in the case of Wiser Lake would require 4.3 acres of floating wetland. At a cost of approximately $40 per square foot this requires $1.7 million dollars per acre for the islands, or almost $7 million for the entire project. This does not include annual costs for harvesting vegetation and maintaining the islands.

While not appropriate for the entire lake, installing FTW's opportunistically in areas where windblown cyanobacteria tend to accumulate could be a way of providing a physical barrier to improve condtions. This is discussed further in section L.

K.4 Alum Injection

If a significant source of phosphorus comes from a point source like Cougar Creek there is an option to treat water in the creek with phosphorus sequestration products. This continuous injection system would be used to bind with the Ortho-P component coming into the lake from Cougar Creek, with the alum/phosphorus complex settling onto the sediment layer.

An alum injection system requires accurate flow monitoring to ensure the proper dose is applied, and Cougar Creek is very slow-moving during summer, acting more as an extension of Wiser Lake than a flowing stream. This would make it difficult to inject alum without running the risk of over or under-dosing. In addition, permitting and infrastructure costs for an injection system can be quite costly.

K.5 Oxygenation

Oxygenation or nanobubblers use a system where oxygen is introduced into the water column to increase oxygen transfer efficiency. These are often used in lakes where stratification has reduced oxygen at the bottom of the lake. The benefit of using oxygenation over aeration is thermal stratification is maintained, with oxygenation providing a cool water refuge for fish at the lake bottom. Wiser Lake does not seem to be stratified, and if further testing shows it does stratify at night or during brief periods oxygenation would not be the best approach. These systems are very costly and require high electricity demands, much more than an aeration system.

L. Recommended Management / Lake Restoration Plan

L.1 Long-term Strategies

Wiser Lake is approaching hypereutrophic status based on total phosphorus levels, with approximately 70% of the phosphorus load originating from external sources. Of this, about 30% comes from stream inflow, 27% from overland flow, and 13% from septic systems (Section I.3). Addressing these external inputs is essential for achieving long-term improvements in lake water quality.

The Sumas aquifer in Whatcom County, characterized by coarse glacial outwash and a very shallow water table, is part of the DOE nitrate prioritization project (DOE, 2016). Historical land use in the watershed includes manure fertilizer application to fields, and there are hundreds of septic systems. Given the shallow groundwater, nutrients from both legacy and current sources are likely reaching the lake.

To achieve lasting water quality improvements, a comprehensive review of these external phosphorus sources is necessary. The goal should be to initiate programs aimed at reducing nutrient export to the lake, such as septic system inspections and upgrades, agricultural best management practices (BMPs) to minimize fertilizer and manure applications, and a phosphorus-free lawn fertilizer program for local residents. While the benefits of these long-term initiatives may take years to materialize, short-term treatments might be needed to improve water quality more immediately.

Successful implementation of these strategies will depend on strong partnerships among agencies and landowners.

L.2 Long-term Strategies

While a reduction in external loading will be necessary for long-term lake health, there are actions that can be taken to improve the lake while those broader programs are initiated. If it is determined the lake becomes anoxic at the sediment/water interface an aeration system may be adequate to keep the lake mixed. While more information is required to determine the extent of anoxia, this is an approach that should be considered.

While aeration can control internal phosphorus loading it may be necessary to apply a phosphorus stripping dose of alum or lanthanum. This could be applied in early summer after input from Cougar Creek has slowed. The alum application could be focused on the East Basin, which is directly impacted from creek flow but will provide water quality benefits to the whole lake. Cost estimates for a whole-lake treatment are included in section J.2.2 and assumes the treatment boat can fit under the bridge to access the West Basin.

A phosphorus sequestration application that clears the water column may encourage more aquatic plant growth. This may impede recreational activities and could cause downward pressure on DO at the end of the growing season when the vegetation dies back. A phosphorus stripping program should be coupled with an aquatic vegetation monitoring and control program to ensure non-native species do not eliminate the beneficial native plant community. Due to the large percentage of phosphorus coming to the lake from external sources an annual phosphrus sequestration treatment may be required.

Residents located on the windward side of Wiser Lake have frequently experienced the accumulation of cyanobacterial surface scums during bloom events. The deployment of Floating Treatment Wetlands (FTWs) may offer a practical solution for mitigating the transport of surface scum to shoreline areas by serving as a physical barrier. Similar in function to deflector logs or booms—commonly employed to prevent surface debris and scum from encroaching on designated lake zones such as recreational beaches—FTWs can be strategically positioned to perform a comparable role.

In contrast to conventional deflection methods, FTWs provide an aesthetically pleasing alternative due to their vegetative composition, typically featuring native wetland plant species. Beyond their physical barrier function, FTWs have also demonstrated potential for improving water quality by facilitating the removal of total nitrogen (TN) and total phosphorus (TP) from the water column, as supported by multiple studies (Lynch et al., 2014; Chang et al., 2012; Wang and Sample, 2013; Wang and Sample, 2014; Stewart et al., 2008; White and Cousins, 2013; Zhao et al., 2012; Van de Moortel et al., 2010).

A configuration involving multiple FTW units arranged in a large "C" shape in front of residential properties may help intercept and block surface scum before it reaches the immediate shoreline. However, it is important to note that this approach may not prevent cyanobacterial blooms from developing inshore of the FTW barrier.

LCMP Recommendations in order of priority

The following figures provide a quick graphical reference for the water quality improvement steps recommended in this LCMP.

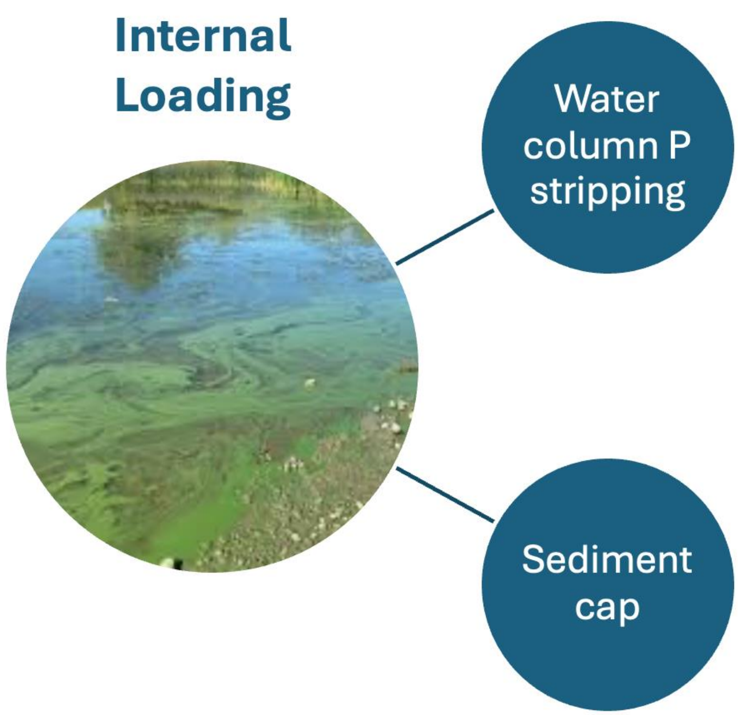

Figure 54. Internal Loading Recommendations

Figure 55. External Loading Recommendations

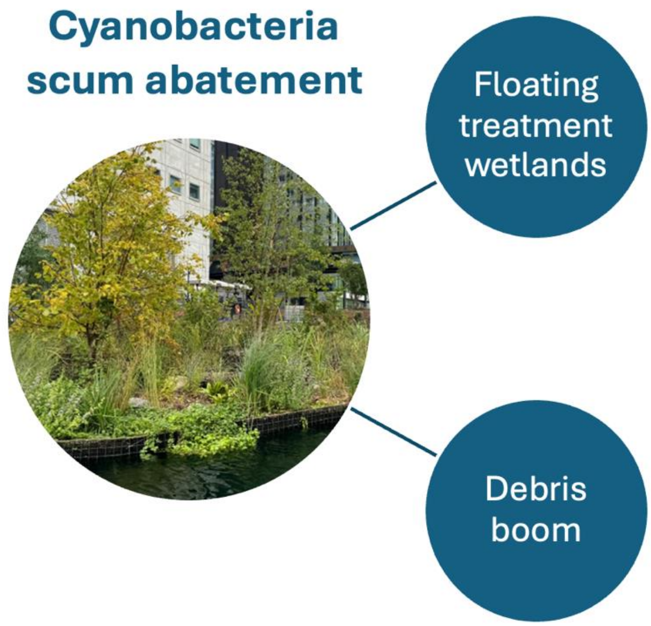

Figure 56. Cyanobacteria Scum Abatement

L.3 Aquatic Vegetation Control

This can start with an Integrated Aquatic Vegetation Management Plan (IAVMP) to determine priorities for aquatic vegetation control.

Curly leaf pondweed may continue to spread once the cyanobacteria blooms subside following potential treatment. Future control efforts should focus on Curly leaf pondweed as well as yellow flag iris (*Iris pseudacorus*), hairy willow-herb (*Epilobium hirsutum*), and reed canary grass (*Phalaris arundinacea*), as these species are likely to continue spreading and could potentially enter the Nooksack River.

L.3.1 Control measures

Curly leaf pondweed - Herbicide control is recommended as mechanical or manual removal may allow stem fragments to escape and establish new plants elsewhere. Endothall and fluridone are excellent at controlling Curly leaf pondweed and diquat is slightly less so. Treatment should occur early in the season before turions form via a licensed herbicide applicator and with a permit from the DOE.

Yellow flag iris – This species can be toxic to livestock if ingested and can cause skin irritation in humans. As it spreads by seeds and rhizomes, all fragments must be removed if manual control is chosen. Manual control is possible if the population is small but herbicide control may be needed if populations are large. Removing the stems via cutting (wear gloves) and applying herbicides to the stump works best using glyphosate or imazapyr.

Hairy willow herb – This species can be controlled via manual removal of the entire plant and root system if the populations are small. For larger populations, the herbicides listed as being effective include: Clearcast; Renovate; Milestone; Rodeo (pre-flowering); Arsenal (pre-flowering); Habitat (pre-flowering).

The DOE's Aquatic Invasive Plant Managemet Program (https://tinyurl.com/Ecology-AIPMP) may provide funding to update the IAVMP and assist with controlling these invasive species.

No other species of concern are present in Wiser Lake at this time. However, once the cyanobacteria blooms subside due to potential treatment, it will be important to monitor the aquatic plant species in Wiser Lake, as both native and invasive species may begin to spread due to the increased clarity of the water and the shallowness of the lake.

M. Future Monitoring and Adaptive Management

M.1 Monitoring

Monitoring should continue for Wiser Lake to gauge the effectiveness of improvement projects. This will be important as external loading from the watershed is reduced and to refine short-term improvement goals. Ongoing monitoring should include sonde profiles for temperature, pH, conductivity, and DO to assess the extent and timing of any sediment anoxia. A temperature and oxygen logger should be installed for a month or two during the summer season to measure these parameters near the surface and near the bottom. The additional measurements closer to the sediment/water interface will help identify if anoxic conditions occur in the bottom 0.0 to 0.5 meter depth and additional vertical profiles could help establish the spatial extent of any internal loading.

Phosphorus and nitrogen samples should be collected near the surface and just above the bottom to monitor internal loading. However, care should be taken to not disturb the bottom with the sample bottle. Phosphorus and nitrogen should be collected from Cougar Creek both upstream and downstream of the lake to refine the nutrient budget. Creek flow coming into and leaving the lake should be continued, with modifications to the sample area to make it easier to record data.

An updated bathymetric survey would be helpful in the coming years to better define the deepest areas of the two lake basins, where internal phosphorus loading may be occurring.

The goal of management actions is to shift the phytoplankton community from cyanobacteria to beneficial algae. Continuing to collect phytoplankton samples will be necessary to quantify population dynamics in response to treatments.

M.2 Adaptive Management

As more is learned about the lake during ongoing treatments it will be necessary to adjust the approach based on ongoing monitoring and results. This will be necessary to fine tune any treatments in response to ongoing monitoring data in order to produce desirable results. Ongoing monitoring will be used to adjust the chemical dose for phosphorus sequestration to maximize phosphorus reduction while staying within the proper pH range. If the treatment strategy does not result in adequate phosphorus reductions within four (4) years other strategies should be revisited.

N. Funding Strategy

Potential funding strategies for the following lake restoration management methods: Algaecide; Aeration System; Phosphorus sequestration; Septic System replacement; Shoreline restoration; Agricultral BMP implementation; Cougar creek riparian and wetland restoration are outlined Table 38 below.

Table 38. Potential Funding Sources to Support LCMP Implementation.

Grant Agency	Grant Program	Restoration Method	Entities Eligible
United States Department of Agriculture	NRCS – Regional Conservation Partnership Program	Agricultural BMPs, Creek restoration, Wetland restoration	Any
United State Department of Agriculture	NRCS – Conservation Innovation Grants	Agricultural BMPs	State and Local Governments, Tribes, Non-profit organizations, Individuals
Environmental Protection Agency	Water Pollution Control (Section 106) Grants	Agricultural BMPs, Creek restoration, Wetland restoration	State agency and Tribes
Environmental Protection Agency	Pollution Prevention Grant	Agricultural BMPs, Creek restoration, Wetland restoration	State agency, Educational Institutions, Tribes
Environmental Protection Agency and National Fish and Wildlife Foundation	Five Star and Urban Waters Restoration Grants Program	Shoreline restoration, Agricultural BMPs, Creek restoration, Wetland restoration	Non-profit organizations, State agencies, Local governments, municipal governments, Tribes, Educational institutions
Environmental Protection Agency	Wetland Program Development Grants	Shoreline restoration, Agricultural BMPs, Creek restoration, Wetland restoration	Tribes, Local governments, State agencies, Interstate entities
Department of Ecology and Puget Sound Partnership	National Estuary Program - Habitat SIL	Shoreline restoration, Cougar Creek restoration, Wetland restoration	Federal and State agencies, Local governments, Non-profit organizations, Tribes, Educational institutions
Department of Ecology	Freshwater Algae Control Program	Algaecide application, Aeration System, Phosphorus sequestration	State agencies, Local governments, Special Purpose Districts, Tribes
Department of Ecology	Aquatic Invasive Plant Program	Aquatic and emergent invasive plant control	State agencies, Local governments, Special Purpose Districts, Tribes

Grant Agency	Grant Program	Restoration Method	Entities Eligible
Department of Ecology	Water Quality Combined Funding Program	All non-point activities - Aeration, Phosphorus sequestration, Shoreline restoration, Agricultural BMPs, Riparian and wetland restoration, Onsite Septic System replacement	Tribes, State and Local governments, Non-profit organizations, Special purpose districts, Conservation districts
Department of Ecology	Floodplain by Design	Shoreline restoration, Agricultural BMPs, Creek restoration, Wetland restoration	Conservation Districts, Local governments, Tribes, Ports, Non-profit organizations
Department of Ecology	Streamflow and Restoration Program	Shoreline restoration, Agricultural BMPs, Creek restoration, Wetland restoration	Tribes, Federal, State and Local governments, Non-profit organizations
Department of Ecology	National Coastal Wetlands Conservation Grant Program	Shoreline restoration, Agricultural BMPs, Creek restoration, Wetland restoration	State agencies only - partnerships recommended
Recreation and Conservation Office	Salmon Recovery and Puget Sound Acquisition and Restoration	Creek restoration, wetland restoration	Local governments, Non-profit organizations, Special purpose districts, State agencies, Tribes, Private landowners, Fisheries enhancement groups
Recreation and Conservation Office	Farmland Preservation - WA Wildlife and Recreation Program	Agricultural BMPs	Local governments, Non-profit organizations, State Conservation Commission
Recreation and Conservation Office	Estuary and Salmon Restoration Program	Shoreline restoration, Cougar Creek restoration, Wetland restoration	Federal and State agencies, Local governments, Non-profit organizations, Tribes, Educational institutions, Private institutions

Lake Management District

The WCHCS may want to explore the option of involving local residents in the creation of a Lake Management District (LMD) for Wiser Lake. A "Lake Management District" is a government-established entity with the authority to collect taxes from property owners within its boundaries to fund lake management efforts. These districts typically have more regulatory power than lake associations.

Under Chapter 36.61 RCW, cities, towns, and counties are authorized to establish local improvement districts focused on lake water quality improvements. The goal of this legislation is to "*create a governmental framework through which property owners can implement lake or beach improvement and maintenance programs for the benefit, health, and welfare of both residents and the public*" (Washington Code 36.61).

An LMD can address various lake-related issues, including property assessments, bond issuance, control or removal of aquatic plants, water quality improvements, management of water levels, treatment and diversion of stormwater, control of agricultural runoff, research on water quality concerns, and maintenance of ditches and streams feeding into the lake (MRSC LMD).

Many counties have established advisory committees to guide the formation of LMDs, with each taking a slightly different approach. For instance, Whatcom County has established the Lake Whatcom Watershed Advisory Committee, formalized under Whatcom County Code Ch. 2.96, which oversees the Lake Whatcom Management District No. 1 (Whatcom County Code 2.96).

It is recommended that WCHCS consider a similar approach in developing an LMD for Wiser Lake and its surrounding areas.

Lake Associations

Lake Associations, commonly found in the Midwest (Minnesota and Wisconsin) and New England (primarily New York and New Hampshire), are voluntary groups formed by individuals who share a lake. These associations pool their resources to maintain the lake, with officers setting policies and budgets. Fund collection tends to be informal, often dependent on the level of support and cooperation from residents who own land near the lake. The primary goal of a lake association is to maintain, protect, and enhance the lake's quality, its fisheries, and its watershed (https://allaboutlakes.org/lake-associations/).

Membership in a Lake Association is typically voluntary, with members including both lakefront residents and others who may not live directly on the lake. Participation is not mandatory, and meetings are usually governed by Robert's Rules of Order. Many associations also adopt bylaws to guide their operations. To fund their activities, associations rely on various fundraising methods and voluntary membership dues. However, these associations would not be eligible for the Department of Ecology's Freshwater Algae Control Program or the Aquatic Invasive Plant Program grants.

Lake associations are typically led by officers elected by the membership, and daily activities are carried out by these officers or by committees. The strength of a lake association lies in its membership, as it fosters a sense of community and can create a network for sharing information. Associations often collaborate with state and local government agencies to implement lake management practices. With the appropriate permits, they can carry out projects such as aquatic plant management, fish stocking, boating safety programs, and educational initiatives. Additionally, they may lobby government bodies to address issues that affect the lake and its community.

There is no legal requirement for a voluntary lake association to remain active, and it can be dissolved by the members if they choose (https://www.thurstoncountywa.gov/departments/public-health-and-social-services/environmental-health/water/lake-management).

O. Roles and Responsibilities

For projects to succeed, it is crucial that all participants clearly understand their roles and responsibilities. Clearly defining these roles offers several benefits, including enhanced clarity, greater accountability, improved efficiency, faster achievement of project goals, better collaboration, and a reduction in misunderstandings, conflicts, and duplication of efforts. It also leads to more effective resource allocation and strengthens communication and shared ownership of both project successes and challenges.

The key entities responsible for coordinating and implementing the recommended management options for Wiser Lake are detailed in Table 39 below.

Table 39. Roles and Responsibilities

Entity	Roles	Responsibilities
Whatcom County Health and Community Services	Lead	Review and select Management Plan recommendations Procure funding mechanisms for chosen management plan Manage contracts for implementing recommendations from the LCMP Educate the public, residents, and LMD participants on BMPs for phosphorus reduction and lake management Lead for water quality monitoring
Whatcom Conservation District	Support agriculture BMPs	Educate the public and agriculture community on nutrient reduction and impacts of nutrients on surface and ground water quality Lead for supporting agriculture BMPs
Lake Management District and Lake Association	Support and Community engagement	Assist the county with grant and funding procurement Educate lake residents and users on BMPs Assist with water quality monitoring Engage the lake residents and users to become lake stewards
Dept. Of Ecology	Monitoring support	Assist with water quality monitoring Assist with ground water monitoring Provide funding for OSS replacement, wetland and shoreline vegetation restoration Continue to provide cyanotoxin testing and reporting
Dept. of Agriculture	Monitoring support and support for agriculture BMPs	Assist with ground water quality monitoring Assist with agriculture BMP implementation and monitoring
Dept. of Heath	Monitoring support	Assist with surface and groundwater monitoring and support Assist with cyanotoxin monitoring and support

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