LAKE LOMA ALGAE CONTROL PLAN

January 2020

Snohomish County

Surface Water Management Division
Public Works Department
Snohomish County
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With technical analysis assistance by

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LAKE LOMA ALGAE CONTROL PLAN

1 EXECUTIVE SUMMARY

THE PROBLEM
Lake Loma is a 23-acre lake located in the Seven Lakes area of Snohomish County. The lake provides opportunities for swimming, fishing, boating and aesthetic enjoyment. It also supports a diverse array of aquatic life. Unfortunately, the lake suffers from excessive phosphorus pollution which causes:

- Low water clarity
- Low dissolved oxygen levels that stress fish
- Chronic excessive algae growth including frequent blooms of toxin-producing blue-green algae

THE EFFECT
Toxic algae blooms make the lake unsafe for residents, anglers, swimmers. The lake has been frequently posted with recreational advisories. The liver toxin, microcystin, is the most prevalent toxins with detections of over 12 times the state’s recreational guidelines. Even when not toxic, excessive algae leads to lower water clarity and depressed dissolved oxygen. The high phosphorus pollution has led the WA State Department of Ecology (Ecology) to list the lake as “impaired”. Collectively, these factors have the potential to reduce property values.

IDENTIFYING SOLUTIONS
In 2018, Snohomish County Surface Water Management (SWM), together with the Lake Loma community, began the algae control plan project. The project goal is to determine 1) the major sources of phosphorus pollution 2) the best alternatives to reduce pollution and 3) the Lake Loma community’s preferred alternative. The project is funded by SWM and a grant from Ecology.
**PHOSPHORUS SOURCES**

An estimation of the main phosphorus sources were developed based on an analysis of historic data, year-round monitoring of the lake, and sediment cores of the lake bottom. The key sources include:

- **Stormwater Runoff** – Residential pollution from pet/animal wastes, fertilizer, and dirt is carried into the lake by runoff when it rains. Runoff accounts for 25-38% of the annual pollution.
- **Groundwater** – The lake is largely fed by groundwater which contributes from 14-42% of the total phosphorus pollution each year. The pollution coming from groundwater largely depends on the level of contamination from septic systems which is difficult to accurately measure.
- **Lake sediments** – Pollution builds up from runoff and groundwater in the lake sediments and is recycled back into the lake each year, comprising 29-43% of the annual pollution to the lake. The levels in Loma’s sediments are very high and likely stem from a 1950s fish fertilization program.

**RECOMMENDED ALGAE CONTROL PLAN**

The recommended plan includes three elements described in the table below. These three elements will meet the project goal of preventing toxic algae by addressing the main phosphorus pollution sources. The three elements were identified as the most effective and affordable methods to meet the plan goals.

<table>
<thead>
<tr>
<th>PLAN ELEMENT</th>
<th>SOURCE ADDRESSED</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element 1: LakeWise Program</td>
<td>Stormwater Runoff</td>
<td>LakeWise, County’s outreach program to help lake area residents prevent phosphorus pollution from lawns, yards and septic systems. Residents can complete a voluntary checklist of actions to have their property LakeWise certified. LakeWise supports residents through educational workshops, site visits, and technical resources.</td>
</tr>
<tr>
<td>Element 2: Septic Savings Program</td>
<td>Groundwater</td>
<td>A septic savings program is designed to help residents regularly maintain septic systems which can otherwise pollute groundwater. Lake Roesiger has a successful program with the PUD where residents pay for septic care as part of their water bill. The plan calls for exploring this program as an option for Loma or the larger 7-lakes area.</td>
</tr>
</tbody>
</table>
| Element 3: Alum Treatment | Lake Sediments | Alum is a chemical that permanently binds phosphorus in the lake water and sediments so it is no longer available to fuel algae growth. Commonly used in drinking water treatment, alum is safe for lake users and wildlife when applied properly. Options for alum timing include:  
  - **Option 1** - Large Initial Dose: Apply the full dose in one initial treatment followed by a smaller treatment every 5-10 years depending on new pollution levels. |
EXPECTED OUTCOMES

Fully implementing the plan over the long-term will benefit the health of Lake Loma. The alum treatments will significantly reduce phosphorus resulting in less frequent and intense algae blooms. Lake recreation will benefit from the reduced risk of exposure to toxic blooms. Dissolved oxygen levels will increase benefitting aquatic life. Water clarity will also improve which is typically associated with higher property values. Higher clarity may also lead to increased aquatic plant growth in deeper areas of the lake. Pollution prevention by implementing Elements 1 & 2 will increase the longevity of alum treatment and reduce the frequency and scale of any future treatments.

COSTS AND FUNDING

The estimated costs of each control plan element are outlined in the table below and is provided in a 10-year timeframe. The funding required to implement the recommended Algae Control Plan will require a long-term financial investment by the Lake Loma community. Funding assistance from grants can help alleviate this financial burden. The most promising grant is the Department of Ecology Freshwater Algae Control Program grant which provides $50,000 maximum awards with a 25% local match. Options for raising local funds include:

- Creation of a lake association with voluntary local fund collection
- Formation of a Lake Management District (RCW 36.61)
- Authorization of a lake property assessment through an extra Surface Water Service Charge designated for phosphorus reduction activities at Lake Loma

ESTIMATED COSTS OF LAKE LOMA RESTORATION IN 2019 DOLLARS

<table>
<thead>
<tr>
<th>Elements</th>
<th>Year 1</th>
<th>Years 2 - 9</th>
<th>Year 10</th>
<th>10-Year Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element 1: LakeWise</td>
<td>currently funded by Snohomish County SWM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Element 2: Septic Savings Program</td>
<td>unknown administrative costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Element 3: Alum Treatment(a, b)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 1: Large Dose(c)</td>
<td>$244,000</td>
<td>$9,500</td>
<td>$151,000</td>
<td>$471,000</td>
</tr>
<tr>
<td><strong>Cost per parcel</strong></td>
<td>$2,773</td>
<td>$108</td>
<td>$1,716</td>
<td>$5,352</td>
</tr>
<tr>
<td>Option 2: Multi-Year Dose</td>
<td>$141,000</td>
<td>$35,000</td>
<td>$45,000</td>
<td>$466,000</td>
</tr>
<tr>
<td><strong>Cost per parcel</strong></td>
<td>$1,602</td>
<td>$398</td>
<td>$511</td>
<td>$5,295</td>
</tr>
</tbody>
</table>

\(a\). Year-round lake monitoring has an estimated annual cost of $9,500. A portion of monitoring costs may be covered by County’s volunteer lake monitoring program pending annual budget approval.

\(b\). A $10,000 sediment core analysis is included for both options in year 10 (used to assess future treatment doses).

\(c\). A repeat alum treatment will likely be required in 5 to 10 years. The costs is included in year 10 and is based on applying half of the original dose. The actual dose will depend upon on the sediment core analysis.

\(d\). Estimated cost based on 88 lake shoreline parcels.
**NEXT STEPS**

The goal of this plan is to provide the community with a road map for reducing toxic algae. The lake community will now need to collectively decide if the benefits of the implementation plan are worth the required financial and time investment. The recommended next steps are for volunteers from the Lake Loma community to form a lake restoration committee. The committee could review the plan and propose a path forward to the broader community for their approval. Essential decision points to decide would include: 1) plan elements to implement 2) preferred funding alternatives 3) timeline and 4) implementation roles. While this may seem like significant effort, other local lake communities have successfully navigated this process to achieve improvements in the health of their local lake.
2 PROJECT BACKGROUND

2.1 STUDY AREA

Lake Loma is a 23-acre lake located in the seven lakes area in northwest Snohomish County. The lake is relatively shallow, with a maximum depth of 8.5 meters (28 feet) and an average depth of 3.4 meters (11 feet). The lake is fed primarily through groundwater, but several small ditches drain into the lake during the rainy season. Lake Loma is the first in a four-lake chain. A small outlet on the west side drains to Lake Crabapple, which flows to Lake Goodwin and Lake Shoecraft and ultimately into Tulalip Bay.

Lake Loma supports swimming, fishing, boating, aesthetic enjoyment and wildlife habitat. Once called Cranberry Lake, Lake Loma is naturally a small bog lake. The lake area was developed in the early 1950’s and includes residential development around the entire lake. Today there are approximately 70 single family homes on the lake shoreline. There is a Washington State Department of Fish and Wildlife public boat launch on the northeast shore. The watershed (the area draining to the lake) covers 190 acres (Figure 2-1). Rural development in the northern watershed transitions to high density residential development around the lake. Forests span the southern portion of the watershed, though some of the area has been logged in recent years.

2.2 PAST LAKE MANAGEMENT

Lake Loma has a history of being managed for rainbow trout. In 1952, the Washington Department of Game rehabilitated the lake to have more favorable stocking conditions for rainbow trout by removing undesirable fish. (Menasveta, 1961). In efforts to increase fish production and raise the pH, the Department fertilized the lake from 1955 – 1958. The lake was fertilized on 16 occasions with different materials including: oyster shells, crab meal, hydrated lime, ammonium phosphate and muriate potash. Monitoring showed that the lake’s total hardness and alkalinity temporarily increased from these efforts (Menasveta, 1961).

2.3 LAKE LOMA WATER QUALITY HISTORY

Lake Loma has been regularly monitored since 1992 by Snohomish County’s volunteer lake monitoring program. The lake has very low water clarity with a 1992-2016 summer average of 1.4 meters (4.6 feet). There was a statistically significant trend of declining water clarity over that monitoring period. One reason for the low water clarity is the naturally dark color of the lake from the dissolved humic compounds from surrounding wetlands.
The long-term average total phosphorus concentration (TP) in the epilimnion (upper waters of the lake) is 33 µg/L (Snohomish County, 2017). The values vary from year to year and there is no statistically significant trend over time (Figure 2-2). In comparison to other Snohomish County lakes, Loma has the fourth highest phosphorus concentrations in the epilimnion (Figure 2-3). The
long-term average total phosphorus concentration in the hypolimnion (bottom waters of the lake) is 68 µg/L and are somewhat variable from year to year (Snohomish County, 2017).

The high phosphorus concentrations in the lake have caused Lake Loma to be listed as impaired by the State Department of Ecology (Ecology, 2018). Developing a list of impaired waterbodies (called the 303d list) is a requirement of the Clean Water Act. The listing is based on summer epilimnetic phosphorus concentrations exceeding the action level of 20 µg/l for lakes in the Puget Sound lowlands.

**FIGURE 2-2: 1996-2017 AVERAGE TOTAL PHOSPHORUS (TP) CONCENTRATIONS IN THE EPILIMNION AND HYPOLIMNION**

![Graphs showing phosphorus concentration over time in epilimnion and hypolimnion of Lake Loma.](image)
FIGURE 2-3: EPILOMNION AND HYPOLMNION PHOSPHORUS CONCENTRATIONS FROM LAKE LOMA IN COMPARISON TO OTHER SNOHOMISH COUNTY LAKES– NOTE THE LOGARITHMIC SCALE
2.3.2 ALGAE

High levels of phosphorus in the lake can cause persistent problems with aquatic plant and algae growth including potentially toxic blooms of blue-green algae (Figure 2-4). Chlorophyll \( \alpha \) is one measurement that indicates the amount of algae in the water column. The long term (2002-2016) summer average chlorophyll \( \alpha \) concentrations is 13.2 mg/L (Figure 2-5) (Snohomish County, 2017). In comparison to other lakes, the summer average is moderate (Figure 2-6). However, individual chlorophyll \( \alpha \) results measured as high as 70 mg/L. This is one of the highest measured concentrations in area lakes and indicates an intense algal bloom.

**FIGURE 2-4: TOXIC ALGAE BLOOMS AT LAKE LOMA**

*Caution Sign at boat launch (July, 2009)*

*Thin blue-green algae scum (February, 2016)*

*Heavy blue-green algae in water (April, 2010)*

*Thick blue-green algae scum (April, 2017)*
FIGURE 2-5: AVERAGE CHLOROPHYLL A CONCENTRATIONS FROM 1996 - 2017

FIGURE 2-6: CHLOROPHYLL A CONCENTRATIONS FROM LAKE LOMA IN COMPARISON TO OTHER SNOHOMISH COUNTY LAKES – NOTE THE LOGARITHMIC SCALE
Not only does Lake Loma have high algal levels, but it also experiences blooms of toxic cyanobacteria caused by excessive phosphorus. Toxic algae presents a health risk to lake users and aquatic wildlife. When the lake experiences toxic algae blooms, advisories are posted for reducing recreational opportunities and enjoyment of the lake.

Reports of algae scums at Lake Loma go back several decades, but testing for algal toxins has not been available until the State of Washington started a free testing program in 2007. They also developed signs to be used for posting lakes that are experiencing toxic algae. Lakes are posted with a CAUTION sign if there is an algae scum present. If toxins exceed state recreational guidelines for the specific toxin.

Microcystin (MC) toxin concentrations were first detected in 2005 and have ranged from the detection limit of 0.01 to 74.1 parts per billion (ppb) (Table 2-1). Microcystin is a liver toxin and the Washington State Department of Health’s recreational guidance value for microcystin is 6 ppb. As a result, toxic algae signs have been posted at the boat launch for two to three months during the recreational season (May through October) and have prevented residents and recreationists from using the lake. No other algal toxins have been detected at Loma.

### TABLE 2-1: LAKE LOMA TOXIC ALGAE TESTING RESULTS

<table>
<thead>
<tr>
<th>Year</th>
<th>Weeks Posted CAUTION</th>
<th>Weeks Posted WARNING</th>
<th>Microcystin Range (μg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005-2008¹</td>
<td>NA</td>
<td>NA</td>
<td>0.69 to &gt;100</td>
</tr>
<tr>
<td>2009</td>
<td>4</td>
<td>2</td>
<td>0.01 to 74.1</td>
</tr>
<tr>
<td>2011</td>
<td>3</td>
<td>-</td>
<td>0 to 0.13</td>
</tr>
<tr>
<td>2012</td>
<td>-</td>
<td>-</td>
<td>0 to 4.62</td>
</tr>
<tr>
<td>2013</td>
<td>-</td>
<td>-</td>
<td>0 to &gt;6</td>
</tr>
<tr>
<td>2015</td>
<td>2</td>
<td>-</td>
<td>0 to &gt;6</td>
</tr>
<tr>
<td>2016</td>
<td>15</td>
<td>5</td>
<td>&lt;1 to 9.8</td>
</tr>
<tr>
<td>2017</td>
<td>2</td>
<td>-</td>
<td>0 to &lt;1</td>
</tr>
<tr>
<td>2018</td>
<td>-</td>
<td>-</td>
<td>0 to &lt;1</td>
</tr>
</tbody>
</table>

¹The State of WA developed signs in 2008, but postings but were not tracked until 2009
²Lakes are posted with Warning if Caution if scums are present; they are posted with Warning if toxins exceed the State recreational guideline of 6 µg/L for Microcystin

### 2.4 PREVIOUS LAKE STUDIES

In 1986, the Seven Lakes Sewer District developed the Seven Lakes Water Quality Analysis and Management Plan in order to evaluate the water quality impacts of on-site sewage or simply septic systems in the Seven Lakes area (Seven Lakes, 1986). The Seven Lakes area includes the areas around lakes Goodwin, Shoecraft, Crabapple, Loma, Ki, Martha and Howard. This plan identified current water quality status, potential sources of bacteria and nutrient loading, and offered recommended restoration and management alternatives to protect water quality for each of the lakes. This plan offers a reference for water quality in Lake Loma as well as insights into nutrient loading from groundwater inputs to the lake.
In 2013, the Washington State Department of Ecology developed a Phosphorus Screening Level Assessment to identify the relative contributions of total phosphorus sources to ensure that management activities focus on dominant sources (Ecology, 2013). This study used a spreadsheet model to estimate the phosphorus sources to Lake Loma. The study found that the major sources were septic systems OSS pet and animal wastes, and lake sediments.

3 PROJECT DESCRIPTION

3.1 PROJECT BACKGROUND

Lake Loma residents and users have been increasingly concerned about the health of Lake Loma especially with the onset of toxic algae blooms in the mid to late 2000’s. In 2017, Snohomish County Surface Water Management (SWM) worked with residents at Lake Loma to develop this project and obtain funding as a first step to improving the health of Lake Loma. SWM secured a $45,000 grant from the Washington State Department of Ecology Freshwater Algae Program to develop an algae control plan for both Lake Loma and another local lake, Sunday Lake. The total project cost for the two plans is approximately $88,000. SWM contracted with a limnology consulting firm, Tetra Tech Inc., to perform detailed analyses of Lake Loma water quality and help develop the recommendations for phosphorus reduction contained in this plan.

3.2 PROJECT GOALS, OBJECTIVES, AND TARGET

The overall goal of this project is to identify the most suitable strategies for reducing phosphorus and resultant toxic algae blooms in Lake Loma. The objectives are to:

- Monitor and report current water quality conditions to develop alternatives and establish benchmark conditions from which to track effectiveness of implemented alternatives
- Quantify the internal phosphorus loading to the lake from the lake sediments
- Estimate the external phosphorus loading to the lake and its relative contribution in comparison to the internal load
- Use the phosphorus loading data to develop an Algae Control Plan for the lake that explores all available restoration options
- Identify the most feasible restoration options with detailed cost estimates
- Work in partnership with residents at Lake Loma to select a preferred restoration alternative

Should this plan be implemented, the ecological goal for the lake is to significantly reduce the frequency and duration of potentially toxic algal blooms. For Lake Loma, this would mean having no blooms of potentially harmful cyanobacteria in the majority of years and when blooms do occur having them last for a matter of weeks rather than months. Most Algae Control Plans also include a numerical target for phosphorus reductions. Based on studies of many lakes, both in Washington and nationally, average total phosphorus (TP) concentrations of less than 30 μg/L are needed to avoid the risk of harmful algal blooms (Downing et al. 2001). The nutrient criterion for lakes in the Northern Rockies ecoregion, recommended by Washington State Department of Ecology (Ecology), is a TP average of less than 20 μg/L (Ecology 2017). For Lake Loma, the goal would be to maintain summer epilimnetic TP concentrations near 20 μg/L. Lower TP
concentrations should help to reduce the appearance and duration of HABs. Ongoing monitoring should continue to determine the success of conditions if implemented.

3.3 PROJECT APPROACH

The project was designed to use a cost-effective approach to develop planning-level estimates for lake restoration options. The study relies on using a combination of historic data as well as recent detailed studies of in-lake water quality and sediment monitoring. It does not include a full hydrologic model and associated nutrient budget. The latter approach would provide more accurate estimates of nutrient loading and anticipated effectiveness from restoration actions. It would require gaging of the lake inlets and outlets, lake levels, and the local precipitation. Groundwater inputs could be calculated as a residual in the hydrologic model, or alternatively, additional groundwater monitoring could be used to quantify phosphorus inputs.

Ultimately, it was determined that obtaining funding for such a detailed study would be another $80-$150,000 beyond the budget for this project. Obtaining funding for such a project would be highly unlikely. Furthermore, the cost of conducting a full study might be greater than potential restoration options given the lake’s small size. Therefore, a higher degree of uncertainty in the findings was accepted in order to develop a practical plan to proceed with lake restoration.

4 MONITORING METHODS AND RESULTS

4.1 LAKE WATER QUALITY MONITORING

SWM staff conducted water quality monitoring of the lake for one full year from April 2016 to March 2017. This monitoring documented the concentrations of phosphorus in the lake as well as changes in temperature, dissolved oxygen and water clarity through the seasons. These data reveal the patterns of phosphorus moving within the lake during the year. Additional data collected in 2012 and 2013 and 2019 as part of SWM’s monitoring program was also included in the analysis to supplement the study year data.

Lake monitoring involved collection of water samples for laboratory analysis and field measurements of physical and chemical parameters. Monitoring took place every month from April 2016 through March 2017. Water samples were collected from two stations, Loma and Loma-East (Figure 4-1) that represent the two deep portions of the lake. Samples were taken from 1 meter for total phosphorus (TP), soluble reactive phosphorus (SRP), total nitrogen (TN) and chlorophyll a. Samples of TP and SRP were also collected at 7 meters in the Loma sampling station and 6.5 meters at Loma East station. In addition, SWM staff took field measurements at both stations of temperature and dissolved oxygen at every meter depth from the lake surface to the lake bottom. Water clarity was also measured using a Secchi disk at the Loma station.

Lake Loma does not have a defined inlet stream. There a few small intermittent ditches or channels that flow into the lake (Cedarhouse, Firetruck, Boat Launch and 150th St) (Figure 4-1). For the seasonal inlets to the lake, SWM staff took grab samples of water at the road access points when the water was flowing in January and February 2013. These water samples were analyzed for TP and SRP.
Lake level data helps determine the changes in total volume of water over time. Volunteers and SWM staff recorded measurements of the height of the water (lake level) taken from a staff plate installed near the shoreline at the public boat launch (Figure 4-1). Lake levels were read at least once a month from April 2016 to March 2017 during monthly lake monitoring events. Additional lake level readings were taken by a volunteer when possible. Lake levels are read as one-hundredths of a foot at the water surface. Precipitation was measured 0.66 miles from Lake Loma using a Snohomish County rain gage located on neighboring Lake Crabapple. The rain gage measured every 0.01 inch of rain that fell during the monitoring period. The water quality monitoring methods are described in more detail in the Quality Assurance Monitoring Plan - Appendix F (Snohomish County, 2019).

FIGURE 4-1: LAKE LOMA WATER QUALITY MONITORING LOCATIONS

4.2 LAKE AND STREAM WATER QUALITY MONITORING RESULTS

4.2.1 WATER TEMPERATURE AND DISSOLVED OXYGEN

The temperature of lake water changes with the seasons and varies with depth. During spring and summer, the sun warms the upper waters. Because warmer water is less dense, it floats above the cooler, denser water below. The temperature and density differences create distinct layers of water in the lake and these layers do not easily mix. This process is called stratification and generally starts in April and continues through the early fall. The warm upper water layer is called the epilimnion and the colder bottom zone is called the hypolimnion. These layers will stay separated until the fall when the epilimnion cools. When the temperature difference between the two layers decreases, the entire lake mixes, or turns over. Lake Loma typically turns over in
October and the turnover is sometimes accompanied by changes in water color, lake odor and/or blooms of algae.

Figure 4-3 shows the profiles of water temperatures in Lake Loma from April 2016 through March 2017. Each line indicates the water temperatures in Celsius from the surface of the lake (at the top) to the lake bottom near seven meters. In April, the lake was already stratified with the surface waters warming to around 16°C (59°F) while the bottom remained colder near 8°C (46°F). The stratification grew stronger in the summer, peaking in late August where the surface temperatures reached 23.2°C (73°F) while the bottom remained at 9°C (48°F) into September. This difference in temperature created a physical and chemical separation between the upper waters and the bottom waters. By October 2016 the entire lake was cooling off, with turnover likely occurring early in the month. From November through March, the temperature was uniform from top to bottom. From Dec – March the lake was significantly colder with temperatures ranging between 3° and 6°C (38 – 42°F). The lake surface was mostly frozen in portions of January (Figure 3-2) which occasionally occurs in winter when there are sustained freezing temperatures. Freezing temperatures are not common for the Puget Sound lowlands region.

FIGURE 4-3: WATER TEMPERATURE PORFILES DRUING STUDY PERIOD

FIGURE 4-2: ICE FORMING ON LAKE LOMA’S SURFACE ON JANUARY 26, 2016
Dissolved oxygen in the lake is closely related to temperature. Most of the dissolved oxygen in the lake comes from the atmosphere. During the warm months, the epilimnion receives oxygen from the atmosphere and via photosynthesis by algae. In contrast, the hypolimnion cannot be replenished with oxygen because of the separation between water layers and because there is little algal growth in the lower waters where sunlight is limited. Meanwhile, bacteria at the lake bottom are consuming oxygen as they decompose organic matter. Eventually, oxygen is depleted in the hypolimnion.

The profiles of dissolved oxygen in Lake Loma show seasonal and depth changes that correspond to the changes in water temperature (Figure 4-4). When monitoring first began in April, the lake surface was fully saturated with oxygen with levels around 9.6 mg/L. The oxygen levels near the bottom were lower (6.9 mg/L) indicating that oxygen depletion in the hypolimnion had begun as a result of the lake stratification. By May, the entire lake below two meters was anoxic or had oxygen levels below 0.2 mg/L. These conditions persisted at the lake bottom through September. By mid-October, the lake was fully mixed with oxygen levels between 8 and 9 mg/L throughout the water column.

The dissolved oxygen levels in the lake are connected to the phosphorus cycling in the lake. Phosphorus is stored in lake sediments and is chemically bound to a variety of elements or is found as part of organic matter. However, when oxygen is depleted in the hypolimnion, phosphorus can be released from some of those bonds. This process is called internal loading. In Lake Loma, it appears that internal loading could have been occurring during from May through later September/early October.

**FIGURE 4-4: DISSOLVED OXYGEN PROFILES DURING STUDY PERIOD**
Both temperature and dissolved oxygen are also connected to aquatic life. Fish such as trout, require colder, oxygen-rich waters while other species such as bass tolerate warmer, low-oxygen waters. Temperatures that are warmer than 17.5°C (63.5°F) for salmonid rearing and migration and 20 °C (68°F)¹ for indigenous warmwater fishes (WAC 173-201A-210). Similarly, oxygen levels that are lower than 6.5 mg/L² also exceed the criteria for aquatic life for both salmonids and indigenous warmwater species.

In Lake Loma there is not a suitable region in the water column with both low temperatures and high dissolved oxygen concentrations during July and August. August conditions could be particularly stressful for fish as water temperatures exceeded 20°C above 4 meters in the lake, yet oxygen levels were only 2.2 mg/L at 4 meters and drop to 0.4 mg/L at 5 meters. This condition is alleviated with the return of cooler temperatures in the fall. After lake turnover in October, oxygen is replenished throughout the entire water column.

### 4.2.2 Conductivity

Conductivity measures the ability of water to conduct an electrical current and provides a measure of the dissolved salts or ions in the water. Lake Loma has relatively low conductivity with surface values ranging from 36.4 to 49.1 umhos/cm. Of the 36 monitored lakes in Snohomish County, conductivity ranges from 20.2 to 227 with an all lakes averaging 66 umhos/cm.

During the stratified period, conductivity did increase in the hypolimnion reaching a maximum of 69.9 umhos/cm at 7 meters in September. The hypolimnetic increase is due to mineralization of organics into ionic materials. It could also be a result of additional groundwater influence in the summer months. The relatively low conductivity reflects the chemical interactivity of organics within the water column to absorb ions and points to the complex ecological balance that exists in Loma.

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¹ This is based on a 7-day average of the daily maximum temperatures
² Lowest 1-day minimum
Alkalinity is a measure of the buffering capacity of a lake, which is the ability of the lake to maintain a relatively stable pH with the addition of acids. Lakes in the Pacific Northwester are typically considered softwater lakes (<50 mg CaCO₃/L). Few measurements of alkalinity have been taken on Lake Loma. Results from 1994-1995 range from 5.5-9.4 mg CaCO₃/L and one result from September 2019 with a value of 10.2 mg CaCO₃/L at 1 meter. The values suggest that Loma has extremely low buffering capacity though additional data collection is recommended to confirm this assumption.

### Table 2: Alkalinity Concentrations in Lake Loma 1994 - 2019

<table>
<thead>
<tr>
<th>Date</th>
<th>Alkalinity (mg CaCO₃/L)</th>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loma</td>
</tr>
<tr>
<td></td>
<td>1 m</td>
</tr>
<tr>
<td></td>
<td>7 m</td>
</tr>
<tr>
<td>6/22/1994</td>
<td>7.2</td>
</tr>
<tr>
<td>8/18/1994</td>
<td>7.6</td>
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<td>5.5</td>
</tr>
<tr>
<td>9/19/2019</td>
<td>10.2</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The pH of a lake is a measure of the acidity or alkalinity, expressed in terms of its concentration of hydrogen ions. The pH in Lake Loma is generally low with small increases due to algal photosynthetic activity in the spring and summer months (Figure 4-6). The relatively low pH at Lake Loma is the result of the low alkalinity combined with the relatively high concentrations of...
dissolved and particulate refractory organics referred to as humic acids. Without the high to excessive phytoplankton photosynthesis the lake would be acidic year round.

**FIGURE 4-6: PH PROFILES DURING STUDY PERIOD**

![PH Profiles during study period](image)

### 4.2.4 Phosphorus

Phosphorus is the main nutrient of concern as it is directly related to the growth of algae including potentially toxic cyanobacteria. In most Washington lakes, phosphorus is the “limiting nutrient” meaning that it controls the primary productivity in the lake, especially in highly productive lakes (Welch and Jacoby, 2001). Phosphorus was measured as total phosphorus (TP) and soluble reactive phosphorus (SRP). SRP is the dissolved inorganic phosphorus component that is found as phosphate in the water. This type of phosphorus is bioavailable for plant and algae growth. TP includes SRP as well as particulate and other phosphorus forms. Particulate and other phosphorus forms (i.e. organic) are not immediately available for algal growth but over time can be released into the lake in more readily available forms.

The TP concentrations in the epilimnion at both stations were fairly consistent throughout the year with a range 25 to 51 µg/l at both the Loma and Loma East stations. The summer average (May – Oct) was 30.7 µg/l at the Loma station and 38.8 µg/l at the Loma East station. These values are typical for Lake Loma as the long term summer average for Loma is 33 µg/l.

Figure 4-7 illustrates the seasonal patterns of TP and SRP at 1-meter (epilimnion) and 7-meter (hypolimnion) depths at the Loma and Loma East stations. During the stratified period when the lake was divided into two layers (April through September), the 1-meter TP concentrations were relatively stable ranging between 25-38 µg/l and the SRP concentrations were very low (2-6 µg/l).
The low SRP values indicate that the algae were growing vigorously and using up nearly all of the available phosphorus in the epilimnion. In contrast, during the same stratified period, the 7-meter TP concentrations climbed steadily with a TP maximum of 171 µg/l in September, 91% of which was in the form of SRP. At least a portion of the build-up is stemming from phosphorus released from the lake sediments. As discussed in Section 4.2.1, this is known as internal loading and occurs during the warm months when the lake is stratified into two separate layers and the bottom becomes anoxic. When the lake began mixing again in late September, the phosphorus spreads throughout the rest of the lake and will become available for algal growth.

FIGURE 4-7: 2016-17 LOMA & LOMA EAST TOTAL PHOSPHORUS & SOLUBLE REACTIVE PHOSPHORUS CONCENTRATIONS
The Loma East station showed a different seasonal TP and SRP pattern between the two layers (Figure 4-7). In April, the epilimnion had a TP concentration of 33 µg/l while the hypolimnion TP was very high at 95 µg/l. Such a large difference in concentrations would not be expected in April as the lake had just begun to stratify. In March, a local resident had installed three aerator units on the bottom of the east basin of the lake in an attempt to improve lake health. While they were turned off a few weeks prior to the sampling, it is likely that the aerators stirred up the phosphorus-containing lake bottom sediments. In addition, only 17% of the hypolimnetic TP was comprised of SRP which indicates that phosphorus was found in particulate matter or other forms which would be indicative of disturbed lake bottom sediments. Unexpectedly, Loma East showed little hypolimnetic phosphorus build-up in the summer months. Phosphorus levels peaked in the hypolimnion in August at 56 µg/l and then actually decreased to 33 µg/l September prior to turnover (Figure 4-7).

To ensure that the aerator was not confounding results in 2016, TP/SRP monitoring of the Loma and Loma East was repeated from May through October in 2019 (Figure 4-8). Results from the Loma station show a similar pattern to 2016, with a hypolimnetic build-up of phosphorus with a September maximum of 105 µg/l which was 63% SRP. The Loma East station also shows that phosphorus concentrations increased in the hypolimnion over the summer months with a maximum 96 µg/l in October, 60% of which was SRP. As expected, the 2019 Loma East pattern closely matched the Loma station and showed a hypolimnetic build-up of phosphorus throughout the summer. Given the unique circumstances that could have impacted the Loma East station in 2016, it is assumed that the 2019 data is more representative of a typical year at Loma East. Only data from 2019 was used from the Loma East station to calculate alternatives.
Nitrogen is the other primary nutrient that determines plant and algal growth in lake systems. Similar to phosphorus, it can be found in several forms in lakes. Total nitrogen is the sum of the organic and inorganic nitrogen. Inorganic nitrogen includes ammonia and nitrate-nitrite and is the portion that is available for plant and algal growth. Organic nitrogen is the fraction that is bound up in algal or plant biomass.

The main purpose of collecting nitrogen data for this study was to confirm that phosphorus and not nitrogen is the limiting nutrient. Nitrogen is not typically the limiting nutrient in highly productive systems like Lake Loma that are dominated by cyanobacteria. Cyanobacteria have a competitive advantage over other types of algae as they have the ability to fix nitrogen from the atmosphere. In these systems, it was found that phosphorus reduction was a successful method for reducing the frequency and intensity of potentially toxic blooms (Jeppesen et al., 2005).

The epilimnion total nitrogen concentrations ranged from 0.510 to 1.07 mg/l with an annual average of 0.81 mg/l. The summer (Jun – Sep) average was 0.738 mg/l. Loma has the second highest total nitrogen levels of 36 lakes monitored lakes in the county with a 3-year summer average of 0.81 mg/l (Snohomish County, 2017). This is almost twice as high as the countywide average of 0.43 mg/l.
The 2019 results confirm that nitrogen is not the limiting nutrient in Lake Loma. When nitrogen concentration exceeds 0.2 to 0.3 mg/l in the water column it is considered to be in excess supply (Gibbons, 2020). Furthermore, the low levels of available epilimnetic SRP in the summer months confirm that the lake algal production is limited by phosphorus and not nitrogen. However, even with phosphorus control efforts, nitrogen will still be available in high concentrations to support aquatic plant growth.

The high levels of nitrogen coupled with the extremely low levels of available epilimnetic SRP in the summer months indicate that the lake algal production is limited by phosphorus and not nitrogen. Phosphorus should therefore be the focus of control efforts. However, even with phosphorus control efforts, nitrogen will still be available in high concentrations to support aquatic plant (macrophyte).

FIGURE 4-9: LAKE LOMA LAKE TOTAL NITROGEN CONCENTRATIONS IN COMPARISON TO OTHER SNOHOMISH COUNTY LAKES

![Graph showing nitrogen concentrations in Lake Loma compared to other Snohomish County lakes.](image)

FIGURE 4-10: LOMA TOTAL NITROGEN CONCENTRATIONS
4.2.6 Iron

Lake Loma total iron concentrations were measured in the epilimnion and hypolimnion at both monitoring stations in April, August, and November. Iron was measured as it affects the internal loading of phosphorus to the lake from the sediments. Iron-bound phosphorus in lake sediments is sensitive to dissolved oxygen concentrations. During anoxic periods, iron changes from its oxidized form (Fe$^{3+}$) to its reduced form (Fe$^{2+}$) and both the iron and the phosphorus are released into the water column.

In Lake Loma, total iron at 1 meter ranged from 250 – 478 µg/L and was very similar between the Loma and Loma East stations (Table 4-3). The hypolimnetic iron was significantly higher at the Loma station during the stratified period reaching 2080 µg/L in September. This indicates iron release by the lake sediments. An increase in Loma East was also seen during the stratified period but was much lower at 980 µg/L.

**TABLE 4-3: TOTAL IRON CONCENTRATIONS IN LAKE LOMA 2016 - 2017**

<table>
<thead>
<tr>
<th>Date</th>
<th>Total Iron (µg/L)</th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Loma</td>
<td>Loma E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4/11/2016</td>
<td>250</td>
<td>261</td>
<td>259</td>
<td>256</td>
</tr>
<tr>
<td>8/17/2016</td>
<td>478</td>
<td>2080</td>
<td>437</td>
<td>980</td>
</tr>
<tr>
<td>11/14/2016</td>
<td>326</td>
<td>324</td>
<td>322</td>
<td>323</td>
</tr>
</tbody>
</table>

4.2.7 Algae

Lake Loma suffers from nuisance production of algae that can impair the use and enjoyment of the lake. Algal blooms are typical from late spring through mid-fall. Figure 4-11 illustrates the pattern of algal growth in 2016 measured by chlorophyll a concentrations. Algal production was higher from May through October with a summer average of 9.6 µg/l. There were two small
blooms observed in May and August with chlorophyll $a$ concentrations of 15 µg/l. Given that sampling only occurred once per month during that period, it is likely that there were additional peaks that were not observed. Algae production sharply dropped in November through March with a winter average of 1.34 µg/l during these months.

The types of algae in Lake Loma are also a concern. Cyanobacteria are especially concerning as they are known for causing nuisance blooms and scums. Some cyanobacteria can also produce toxins that are threats to human and pet health. A previous study showed consistent dominance of cyanobacteria in Lake Loma, ranging from 40-70% of the total algal population in the summer months (Jacoby et al, 2015). When the 2016 monitoring began, the lake was posted with a CAUTION sign because of the presence of a cyanobacteria bloom and associated algal scums. The signs were posted from 2/16/2016 through 4/19/2019. Fortunately, no toxins were detected during that time. However, during the fall of 2016, the liver toxin, microcystin, was detected. The peak toxin concentration occurred in September when microcystin levels reached 9.8 parts per billion (ppb) on 9/15/2016. The Washington State recreational guideline for microcystin is 6 ppb. The lake was posted with either a WARNING or a CAUTION sign from mid-September through the end of November of 2016 based on the presence of toxins (WARNING) or algal scum (CAUTION).

**FIGURE 4-11: LAKE LOMA CHLOROPHYLL a CONCENTRATIONS**

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### 4.2.8 WATER CLARITY

Lake water clarity is measured by how far down in the water column you can see a black and white-patterned secchi disk. Clarity can be affected by water color (the darkness of the water), sediment in the water column, and the amount of algae in the water.
Water clarity in Lake Loma is low, ranging from 1.1 to 2.1 meters. The lake’s darkly colored water is a major factor in the low water clarity. The dark color comes from dissolved organic matter such as humic acids from decaying plant matter. Snohomish County has taken past measurements of true water color which is a measure of the color of the dissolved compounds in the water after the sample has filtered to remove sediments and algae. True water color measurements in 2010-2011 showed Loma had an average reading of 116 platinum-cobalt color units (PCU). Of the 33 lakes monitored in the County, Lake Loma was the second darkest lake and its water color is over five times darker than the median water color of 33 PCU. Furthermore, it appears that lake has darkened from previous true color measurements taken in 1994-1995 which averaged 77 PCU (Snohomish County, 2016).

The amount of algae in the water also appears to influence water clarity at Loma. The seasonal pattern of water clarity and chlorophyll $a$ closely align (Figure 4-12). Generally, when chlorophyll $a$ levels rose, water clarity declined meaning the Secchi disk was less visible in the water. Clarity was much lower in the summer season with a May through October average of 1.3 meters as compared to the winter season average (Nov – Mar) of 2.0 meters. While the pattern typically held, the water clarity was not sensitive to peaks in chlorophyll $a$ levels that exceeded 10 ug/L. This can be seen in May and August of 2016 and June 2017 when secchi depths stayed just over 1 meter despite higher chlorophyll $a$ concentrations.

**FIGURE 4-12: LAKE LOMA WATER CLARITY AND CHLOROPHYLL A CONCENTRATIONS**
5 LAKE SEDIMENT SAMPLING

Understanding the quantity and types of phosphorus in the lake sediment is critical to understanding the overall lake phosphorus cycling. Phosphorus can initially enter the lake from various sources such as runoff, groundwater, and precipitation. Once phosphorus enters a lake system, only a small portion leaves the lake through the lake outlet. The remainder settles out and is incorporated in the lake sediments. The sediments provide a record of phosphorus inputs through the years. The lake sediment also becomes a phosphorus source. Certain types of phosphorus can be recycled back into the lake each year which contributes to the growth of nuisance algae. A sediment core study was completed at Lake Loma to quantify the phosphorus present in the sediments and identify the portion of that phosphorus available to be released into the water column.

5.1.1 SEDIMENT SAMPLING METHODS

Sediment core samples were collected from Lake Loma from three locations to represent both shallow and deep locations within the lake (Figure 4-1). The stations are as follows:

- West Deep – Approximately 8 meter deep (16 feet)
- East Deep – Approximately 7.5 meters deep (24.5 feet)
- Mid Station: Approximately 3 meters deep (10 feet)

The West Deep and Mid Station cores were both 30 cm deep and the East deep station was 35 cm deep. Cores were sectioned every 5 cm and each section was analyzed for the following 10 parameters.

- Total phosphorus
- Loosely sorbed phosphorus
- Organic Phosphorus
- Fe-P (iron-bound phosphorus)
- Al-P (aluminum-bound phosphorus)
- Ca-P (calcium-bound phosphorus)
- Iron
- Aluminum
- Calcium
- % Water
- % Solids
- % Volatile solids (organic content)

A full description of the parameters above and how they are determined as well as results are included in Section B of the Technical Appendix. The sediment sampling and analysis methods are also fully described in the quality assurance project plan for the Lake Loma sediment study (Snohomish County, 2011c).
5.1.2 SEDIMENT SAMPLING RESULTS

The results of the sediment analysis revealed that phosphorus levels are high in the Lake Loma sediments, especially in the upper sediments from 0 to 10 cm (Figure 5-2). Upper sediment total phosphorus concentrations ranged from 2098 to 3619 mg/kg (mg of phosphorus/kg of soil) with an average of 2,766 mg/kg. The levels were highest in the two deep portions of the lake (West Deep and East Deep) which makes sense as the finest, phosphorus-rich sediments tend to settle or slide to the deepest portion of the lake.

The total phosphorus levels in the upper Loma sediments are higher than total phosphorus levels in several other Washington lakes (Figure 5-2) (Snohomish County, 2009 & 2012; LLSWD, 2018). With the exception of Liberty Lake, these comparison lakes were all experiencing significant internal loading at the time the sediment cores were taken and are undergoing subsequent lake restoration to alleviate the internal loading. For example, Lake Loma has approximately 2-3 times higher sediment phosphorus levels than Lake Ketchum which had extremely high internal loading and chronic toxic algal blooms. Lake Washington, which was previously receiving wastewater effluent had 4000 mg/kg of phosphorus in the lake sediment (Shapiro et al. 1971). The highest cited in literature is between 10,000 and 12,000 mg/kg based on sediment cores from a central location that were composited into one sample in a heavily waste loaded Danish lake (Cooke et al., 2005).
FIGURE 5-2: LAKE LOMA SEDIMENT PHOSPHORUS CONCENTRATIONS

FIGURE 5-3: LAKE LOMA SEDIMENT PHOSPHORUS COMPARED TO OTHER WASHINGTON LAKES
In addition to analyzing the total phosphorus in the lake sediments, it is also important to identify the different fractions of phosphorus in the lake sediments. Technical Appendix C has a full description of each fraction and how it relates to the analysis procedures.

One of the most important fractions of the sediment phosphorus is the available phosphorus (available-P). Available-P is the portion of the sediment phosphorus that is available to be recycled back into the lake as internal loading. It is comprised of mobile phosphorus (mobile-P) and biogenic phosphorus (biogenic-P). The remaining phosphorus found in lake sediments (e.g. calcium-bound phosphorus and aluminum-bound phosphorus) is stable and will remain in the sediments in standard lake conditions.

Mobile-P is made up of loosely-sorbed and iron-bound phosphorus. Loosely-sorbed is phosphorus that is not chemically bound but physically attracted to other particles like organics and clay. It can be released when sediment is re-suspended and is not dependent upon oxygen conditions. It is typically only a small portion of the mobile phosphorus.

The other portion of mobile phosphorus is iron-bound phosphorus. It can be released or mobilized during anoxic (i.e. lack of DO) conditions. Under oxic conditions (i.e. presence of DO), iron exists in the ferric form to which phosphorus chemically binds. In anoxic conditions, iron is reduced, and phosphorus is released. This results in an upward diffusion of phosphorus through the sediments to the overlying water, contributing to internal loading.

Biogenic-P is largely composed of organic material which has not completely decayed to refractory (stable) organic material. This material may also include some bacteria, fungus, and algal cells that have recently died or are still viable. It also consists of some labile-phosphorus which is already soluble. Unlike mobile-P, biogenic-P can become available in both anoxic and oxic conditions and is released at a higher rate in oxic conditions. This is because aerobic metabolism is generally faster than anaerobic metabolism. A portion of biogenic-P can become available in any given year and contribute to internal loading. However, the specific mechanisms that drive biogenic-P release are not fully understood and are still being explored. Recent studies have found that 8-30% of total biogenic-P can mobilize and become soluble (NALMS, 2019). It is anticipated that Loma would be on the higher end in that range give its high humic concentration compared to lakes that are more dominated by the reducing conditions that occur during summer anoxia.

Overall, Lake Loma has a high amount of available-P as it makes up 42% of the total phosphorus on average across all locations and depths (Figure 5-4). Within the upper 20 cm of Loma’s sediment, available-P ranged from 838 to 1725 mg/kg averaging of 1152 mg/kg. A good comparison lake is the previously referenced Lake Ketchum. It is a similarly sized lake also located in northern Snohomish County. The available-P in the top 20 cm of Lake Ketchum ranged from 289 to 830 mg/kg averaging 495 mg/kg across all sites.

Loma also has high levels of biogenic-P which makes up 90% of the available with mobile-P making up the remaining 10%. The low proportion of mobile-P may indicate that iron redox reactions may not be as dominant in sediment phosphorus recycling as in other lakes, but it is still a factor to be taken into account. The ratio of iron to phosphorus (Fe:TP) in sediment, and in the water column, usually determines if iron is controlling the release of phosphorus. The average Fe:TP ratio across the three sampling sites was 1.8 (1.7 in West Deep, 2.6 in East Deep, and 1.0 in Mid). These ratios
are substantially below 15:1, which is the ratio above which phosphorus is controlled by iron (Cooke et al. 2005; Jensen et al. 1992). Below this ratio, iron control over phosphorus and subsequent internal phosphorus loading is reduced. For comparison, Fe:TP ratios for Liberty Lake, with a low rate of internal loading averaged 27 and in Lake Ketchum, with a very high rate of internal loading (prior to alum), Fe:TP ratios averaged only 6.8.

High amounts of organic matter are typically associated in bog like systems. The low pH and high humic acid content lead to slow rates of decomposition. However, the extremely high total and biogenic phosphorus levels are also likely a side-effect of the lake fertilization activities that occurred in the 1950’s (Menasveta, 1961). In 1955 the lake was fertilized with 4,400 pounds of oyster shell in an attempt to increase the yield of rainbow trout in the lake. When that was determined to be ineffective at raising the pH of the water, the Department of Game added several thousand pounds of crab meal/waste and hydrated lime from October 1955 through April 1958. The efforts did at least temporarily increase the lake pH, however, the longer-term impact appears to be a buildup of organic matter in the lake sediments. Unfortunately, it is not possible to better estimate the impacts of the WDFW fertilization program as no other lakes in the same program have sediment core data available for comparison.

Regardless of the original source, the high levels of total phosphorus in the lake bottom is likely a long-term driver of eutrophication within the lake and a significant potential source for phosphorus cycling and bioavailability in Lake Loma in the future. Given the magnitude of the sediment phosphorus levels, Loma will likely face worsening conditions with limited dissolved oxygen, higher total phosphorus release from the sediments, and more frequent and severe harmful algal blooms within twenty to fifty years without actions to limit phosphorus.

**FIGURE 5-4: STABLE AND AVAILABLE PHOSPHORUS CONCENTRATIONS IN LAKE LOMA SEDIMENTS**

![Graph showing stable and available phosphorus concentrations in Lake Loma sediments]
6 HYDROLOGY

The primary sources of water to the lake and leaving the lake informs the primary sources of lake phosphorus to the lake. Due to the high cost of conducting a full hydrologic study, it was determined to instead use only the existing hydrologic data and accept a higher degree of uncertainty in the related phosphorus loading analysis.

A conceptual model of Lake Loma’s hydrology is presented in Figure 6-1. The potential sources of water flowing into the lake include: 1) precipitation on the lake surface, 2) surface runoff from the rest of the watershed, 3) seasonal creeks/ditches and 4) shallow groundwater inputs. The outflows of water from the lake include: 1) outlet flow, 2) evaporation, and 3) shallow groundwater losses. Lake Loma has a relatively small watershed and lacks a defined inlet. While there are a few seasonal creeks/ditches that flow to the lake during heavy rains, it is assumed to be mostly groundwater fed. Lake Loma has an outlet on the west end that flows to Lake Crabapple.

FIGURE 6-1: CONCEPTUAL HYDROLOGIC MODEL FOR LAKE LOMA

6.1 PRECIPITATION

The annual precipitation to the lake can be estimated based on a Snohomish County precipitation gage station (Marysville @ 2824 S. Lake Crabapple Road). The average annual precipitation to the lake was 38.2 inches from 2008 to 2018. Over that time period, the monthly precipitation is highest October through April with July and August having very little precipitation (Figure 6-4).
6.2 SEASONAL FLOWS AND LAKE LEVELS

Since quantitative data is lacking for all other sources and outflows, only the seasonal patterns of hydrologic cycling could be characterized for Lake Loma. In 2011, Snohomish County completed a hydrologic model of Lake Crabapple (Snohomish County, 2011). Because Loma flows to Lake Crabapple, this study provides some insight into the hydrologic patterns and water movement into and out of the lake for the water years 2005-2006 and 2005-2007.

Based on the estimates from the Lake Crabapple model, the majority of the runoff into Lake Loma (both surface and groundwater) occurs between mid-November and early April. Outflow from Lake Loma to Lake Crabapple only occurs from mid-December to early April. Most of the precipitation that falls on the lake also occurs during this time and in May and October. Only 12 to 14% of the annual precipitation fell on the lake during the summer (June-September) during the two water years that were modeled.

This pattern of inflow and outflow align with observed lake water levels. Limited lake level data is available for portions of 2008, 2009, 2016, 2017, and 2018 (Figure 6-3 and Figure 6-4). Lake level data was collected by volunteers who took readings at a staff plate installed at the boat launch. Lake water levels consistently declined during the summer months with no outflow which is indicative of very limited to no inflow. The lake water level increases in late fall following an increase in precipitation.
FIGURE 6-3: LAKE LOMA WATER LEVELS AND PRECIPITATION  OCTOBER 2007 – DECEMBER 2009

FIGURE 6-4: LAKE LOMA WATER LEVELS AND PRECIPITATION 2016 – 2018
7 PHOSPHORUS DYNAMICS

A conceptual diagram of the inflows and outflows of phosphorus for Lake Loma are presented in Figure 7-1. Phosphorus estimates were developed for each of the sources to understand the primary drivers for phosphorus loading to the lake. The primary external sources of phosphorus to the lake are 1) precipitation on the lake surface, 2) surface runoff (including the small ditches/creeks) and 3) shallow groundwater flow. Phosphorus can also enter the lake from the sediments at the bottom of the lake. This is known as internal loading. Internal loading primarily occurs during the stratified period when oxygen is depleted in the bottom waters, or hypolimnion. As discussed above, this occurs because the phosphorus, which is normally bound to iron or organic materials in the sediments, is released during low oxygen conditions.

FIGURE 7-1: CONCEPTUAL PHOSPHORUS MODEL FOR LAKE LOMA

7.1 EXTERNAL LOADING

7.1.1 DIRECT PRECIPITATION

Precipitation contains a small amount of naturally-occurring phosphorus. Lake Loma’s annual phosphorus load from precipitation directly to the lake was estimated to be 2.1 kg/year. The estimate was created by multiplying the annual precipitation by the lake surface area by the TP concentration of precipitation. The amount of annual precipitation was estimated to be 38.2 inches per year as described in Section 6.1. The average phosphorus concentration of local precipitation was estimated to be 24 µg/L based on the Washington Department of Ecology’s 2013 study. This estimate does not include dry atmospheric loading (via dust) to the lake that would occur during the summer months as this was considered negligible.
7.1.2 RUNOFF FROM SEASONAL CREEKS AND DITCHES

Nutrient loading data is limited for the seasonal creeks and ditches that flow into the lake during heavy rain events. In May 1983 and June 1984, one inlet into Lake Loma (LS1) was sampled 5 times during the wet season between May 1983 and June 1984. The TP concentrations ranged from 15 to 101 µg/L with an average of 27 µg/L (Entranco Engineers, Inc. 1986). Flow measurements on this inlet were also taken as part of the study allowing for an estimation of the total phosphorus loading to the lake. The annual contribution of the one seasonal inlet from that study was estimated to be 1 kg/year.

In January and February 2013, samples for TP and SRP were collected from all four seasonal inlet sites (Figure 4-1). Note that the “Cedar House” inlet sampled in 2013 corresponds with the LS1 site from the 1980’s. Concentrations of TP and SRP were similar between the two sampling events and ranged from 16 to 74 µg/L TP and 1 to 24 µg/L SRP (Table 4-1). Soluble reactive phosphorus concentrations in the lake during the same time period (Dec 11, 2012, Jan 28 and Feb 19, 2013) were 12 µg/L, similar to those measured in the seasonal inlets. Total phosphorus in December 2012 was 35 µg/L which was very similar to the TP concentrations measured in three of the four seasonal creeks and ditches in January 2013 (Table 4-1). No samples for TP were collected in the lake in January or February 2013. No flow data was collected during the sampling events so phosphorus loads from these seasonal inlets cannot be determined.

The only other winter (January through March) phosphorus data available for Lake Loma, which may provide insight regarding watershed seasonal inputs, was collected in 2017. Epilimnion TP ranged from 23 to 51 µg/L and SRP ranged from 13 to 17 µg/L, which are similar to seasonal inlet concentrations collected in 2013.

**TABLE 7-1: TP AND SRP CONCENTRATIONS IN SEASONAL INLETS TO LAKE LOMA IN JANUARY AND FEBRUARY 2013.**

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Total Phosphorus (µg/L)</th>
<th>Soluble Reactive Phosphorus (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/28/2013</td>
<td>S 150TH PL</td>
<td>35</td>
<td>5</td>
</tr>
<tr>
<td>1/28/2013</td>
<td>BOAT LAUNCH</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>1/28/2013</td>
<td>FIRE TRUCK</td>
<td>34</td>
<td>14</td>
</tr>
<tr>
<td>1/28/2013</td>
<td>CEDAR HOUSE</td>
<td>55</td>
<td>16</td>
</tr>
<tr>
<td>2/25/2013</td>
<td>S 150TH PL</td>
<td>44</td>
<td>1</td>
</tr>
<tr>
<td>2/25/2013</td>
<td>FIRE TRUCK</td>
<td>49</td>
<td>24</td>
</tr>
<tr>
<td>2/25/2013</td>
<td>CEDAR HOUSE</td>
<td>74</td>
<td>10</td>
</tr>
</tbody>
</table>

7.1.3 SURFACE WATER RUNOFF

External phosphorus loading to Lake Loma was further estimated by using a surface water runoff modeling approach. First, the lake’s watershed was categorized into seven land use classifications (Table 4.2). The classifications were based on the Snohomish County’s Drainage Needs Report protocols, which classifies county tax parcels by the underlying majority land use as visible in the latest aerial imagery and land cover GIS data. For Lake Loma, each parcel’s land cover was
determined manually using 2018 aerial imagery together with 2015 high-resolution land cover data from the National Oceanic and Atmospheric Administration.

Next, phosphorus contributions were assigned to each land use. Phosphorus contributions were determined by multiplying the surface area for each land use by a runoff coefficient for that land use. The runoff coefficient is the mass of total phosphorus that would be expected to runoff in one year and has the units kg/ha-year. The estimated TP loading from this method only includes surface water runoff and does not include any phosphorus loading from groundwater (including septic system effluent) or direct loading via precipitation.

Runoff coefficients for this study were based on published values for TP in King County (Herrera 2006) as shown in Table 7-2. The values were adapted as follows:

- **Forested** - The average of all reported coefficients in the Sammamish-Lake Washington Watershed and the Green Duwamish Watershed.
- **Light rural residential, light urban residential, and medium urban residential** – These values were determined by using the coefficients for the maximum dwelling density for each land-use area from Herrera (2006). For example, light urban residential land-use around Lake Loma was defined as 0.2 to 2 dwelling units per acre, so the coefficient for 1 to 4 dwelling units per acre was used from the published values for King County.
- **Pasture** - the King County runoff coefficient for Park/Open Space was used to represent pasture.

**TABLE 7-2: ANNUAL TP LOADING RUNOFF COEFFICIENTS USED TO ESTIMATE EXTERNAL LOADING TO SUNDAY LAKE**

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>King County Published Loading Coefficients (kg/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>0.45</td>
</tr>
<tr>
<td>Park / Open Space</td>
<td>0.10</td>
</tr>
<tr>
<td>Forested</td>
<td>0.12</td>
</tr>
<tr>
<td>Light Rural Residential (&lt; 1 Dwelling/Ac)</td>
<td>0.16</td>
</tr>
<tr>
<td>Light Urban Residential (1-4 Dwellings/Ac)</td>
<td>0.26</td>
</tr>
<tr>
<td>Medium Urban Residential (4-6 Dwellings/Ac)</td>
<td>0.43</td>
</tr>
<tr>
<td>Streets / ROW</td>
<td>0.34</td>
</tr>
</tbody>
</table>
Lake Loma’s watershed is just under half (45%) forested (Table 7-3). The majority of the residential is light urban making up 36% of the watershed. There is some (5%) medium urban residential around the lake. Roads and other right of ways account for another 4% of the watershed. Finally
the lake itself comprises 10% of the watershed, but the lake itself is excluded for external loading estimates.

Based on current watershed land uses, estimated annual surface water runoff TP loading to Lake Loma is 16.2 kg per year. Light and medium residential contribute about 63% of the annual surface water runoff total. Forest naturally contribute some phosphorus comprising 29% of the annual total. The remainder largely comes from roads/right-of-way areas (7%) and commercial (1%). The annual value is in line with the 2013 study where a similar modeling analysis was completed (Ecology 2013). That study estimated the external load from surface water runoff to be between 9 and 25 kg per year, with a best estimate of 14 kg per year.

The timing of phosphorus inputs from surface water runoff are also critical to understanding the lake’s phosphorus cycling. Most of that external load would occur during late fall and early spring given the hydrologic patterns observed at Lake Loma. Rainfall records from 2008 – 2018 indicate that 14% of the total annual precipitation falls during the summer (June – September) (Section 6.1). Therefore, summer external TP loading from surface water runoff is estimated to be much lower at just 2.3 kg per year.

**TABLE 7-3: LAKE LOMA LAND USE AND EXTERNAL TP LOADING TO LAKE PER LAND USE AREA.**

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>Land Use Area (acres)</th>
<th>Land Use Area %</th>
<th>Annual TP Load (kg/yr)</th>
<th>Annual TP Load (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>0.48</td>
<td>0.22%</td>
<td>0.09</td>
<td>0.6%</td>
</tr>
<tr>
<td>Park / Open Space</td>
<td>0.06</td>
<td>0.03%</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>Forested</td>
<td>97.1</td>
<td>44.46%</td>
<td>4.72</td>
<td>29.1%</td>
</tr>
<tr>
<td>Light Rural Residential (&lt; 1 Dwelling/Ac)</td>
<td>0.03</td>
<td>0.01%</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>Light Urban Residential (1-4 Dwellings/Ac)</td>
<td>78.1</td>
<td>35.76%</td>
<td>8.21</td>
<td>50.7%</td>
</tr>
<tr>
<td>Medium Urban Residential (4-6 Dwellings/Ac)</td>
<td>11.6</td>
<td>5.31%</td>
<td>2.02</td>
<td>12.5%</td>
</tr>
<tr>
<td>Streets / ROW</td>
<td>8.4</td>
<td>3.85%</td>
<td>1.15</td>
<td>7.1%</td>
</tr>
<tr>
<td>Lake Surface Area</td>
<td>22.6</td>
<td>10.35%</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>218.4</strong></td>
<td><strong>100%</strong></td>
<td><strong>16.2</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

---

### 7.1.4 GROUNDWATER

Since shallow groundwater is an important factor in the hydrologic cycling of Lake Loma, it is also an important factor in phosphorus loading to the lake. Groundwater phosphorus concentrations are primarily affected by the local soils and the aquifer sediments. Typically groundwater concentrations are low because soils have a high potential to adsorb phosphorus (Holman at al. 2008). For example, a study of 300 shallow wells found in the US found that average...
orthophosphate concentrations of 3 µg/L (Dubrovsky et al. 2010). However, if local soils become saturated with phosphorus and no longer have the ability to adsorb new phosphorus, transport of phosphorus in groundwater is more likely. Potential anthropogenic sources contributing to higher phosphorus in groundwater include septic systems, animals waste and agricultural fertilizers (Dubrovsky et al. 2010). Of these, on-site sewage systems (septic systems) or and pet and animal waste are potential contributors in the Lake Loma watershed. Since pet waste was also factored into the surface runoff calculations, only septic systems were assessed in this study as an additional contributor to groundwater.

Septic systems can have a direct impact on phosphorus concentrations in the groundwater as the wastewater as septic system effluent is designed to be infiltrated into groundwater. In systems are well-designed, properly site, and functioning, then phosphorus can effectively be attenuated by the soils via either precipitation or adsorption in the soils. In addition to failing systems, the circumstances where septic effluent is more likely to contribute phosphorus pollution include the following (NESC, 2013):

- Calcareous (or alkaline) soils
- Coarse-grained soils such as sandy and gravelly soils that allow rapid flow rates;
- Households that generate more wastewater than their septic systems were designed to handle;
- Drainfields with thin soils, shallow bedrock, or high water tables;
- Systems with drainfields close to lakes or streams;
- Areas where onsite systems are densely sited;
- Systems where the septic tank effluent is not uniformly distributed across the drainfield
- Older or substandard systems such as cesspools, which may be in direct contact with groundwater during part of the year.

Lake Loma Septic Systems

An analysis of Lake Loma septic systems was completed using best available data from the Snohomish Health District’s online database of septic system which includes system types and mean age (Table 7-4, Figure 7-3). The systems listed as unknown consist of 1) alternative system types 2) new homes that are not yet reflected in the database and 3) old homes that never had records filed with the health district. The age of the house was used as a surrogate for the system age.

Lake Loma has 106 septic systems in the lake watershed, 69 of which are located on lake shoreline parcels. Gravity systems are the most common system representing over half of all system in the watershed and at least 70% of the lakeshore systems. Gravity systems are also older with a mean age of over 40 years. The unknown systems are also likely older gravity systems given the age of the houses. The remaining systems represent newer systems that are more commonly permitted to ensure proper treatment depending on the ability of the local soils to treat the wastewater. Low pressure distribution systems allow septic system effluent to be more evenly spread across the entire drainfield. Sand filters, aerobic treatment units and mound systems provide for additional treatment of the effluent prior to being released into the drainfield.
At Lake Loma, it is most likely that the older gravity systems located closest to the lake are the most likely contributors of phosphorus pollution to the lake. A septic effluent study conducted at Pine Lake, WA found that septic system phosphorus loading stemmed mostly from older systems with saturated soils which is often the case of lakeshore properties in winter months. (Gilliom and Patmont, 1983). Pine Lake provides a good comparison to Lake Loma as it geologically similar lake to Loma located in King County, WA. Groundwater monitoring found that septic systems located close to the lake with inappropriate soils may be larger contributors of phosphorus to groundwater than other sources. Older systems were not designed to ensure the soils could adequately treat the effluent. Furthermore, the soils can become saturated with phosphorus over time making its transport to groundwater more likely.

**TABLE 7-4: LAKE LOMA SEPTIC SYSTEM TYPES AND MEAN AGES - 2019**

<table>
<thead>
<tr>
<th>System Type</th>
<th>Lake Shoreline</th>
<th></th>
<th>Watershed</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Mean Age</td>
<td>Number</td>
<td>Mean Age</td>
</tr>
<tr>
<td>Gravity</td>
<td>40</td>
<td>42.4</td>
<td>60</td>
<td>40.3</td>
</tr>
<tr>
<td>Low Pressure Distribution</td>
<td>13</td>
<td>19.2</td>
<td>21</td>
<td>19.2</td>
</tr>
<tr>
<td>Sand Filter / Low Pressure Distribution</td>
<td>5</td>
<td>20.4</td>
<td>10</td>
<td>21.9</td>
</tr>
<tr>
<td>Aerobic Treatment Unit</td>
<td>5</td>
<td>11.4</td>
<td>6</td>
<td>12.3</td>
</tr>
<tr>
<td>Mound</td>
<td>1</td>
<td>28.0</td>
<td>2</td>
<td>24.0</td>
</tr>
<tr>
<td>Drip</td>
<td>0</td>
<td>NA</td>
<td>1</td>
<td>7.0</td>
</tr>
<tr>
<td>Sand Filter</td>
<td>1</td>
<td>21.0</td>
<td>1</td>
<td>21.0</td>
</tr>
<tr>
<td>Other/Unknown</td>
<td>4</td>
<td>48.8</td>
<td>5</td>
<td>43.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>69</strong></td>
<td><strong>-</strong></td>
<td><strong>106</strong></td>
<td><strong>-</strong></td>
</tr>
</tbody>
</table>
Two Approaches to Estimating Groundwater Contributions

Groundwater contributions are typically estimated as part of developing a full hydrologic budget for the lake. If all other hydrological inputs can be measured, the residual losses or gains can be
attributed to groundwater. In addition, groundwater well monitoring can be completed to understand the background concentrations of groundwater as well as potential inputs from septic systems. When initially developing the project, SWM obtained cost estimates to complete a full hydrologic budget for the lake with groundwater monitoring. An additional $80,000 - $120,000 was required to for a more robust study that accurately modeled groundwater inputs. Therefore, SWM instead opted to accept a higher degree of uncertainty for groundwater contributions. SWM used data from two previous studies that have different approaches to estimating groundwater loading including the impact of septic system effluent.

The first study had more robust monitoring including development of a basic hydrologic budget as well as shallow groundwater well monitoring (Entranco, 1986). Three monitoring wells were established within five feet of the lake shoreline, each with water tables 1-3 feet below the ground surface. In June and October of 1983, the SRP concentrations were all non-detectable (5 µg/L detection limit) except for one value of 9 µg/L. In February (1984) the SRP concentrations were 5 µg/L, 16 µg/L, and 148 µg/L. The average concentration of 22 µg/L was used in the development of a phosphorus budget for the Entranco study. Using this estimate, it was determined that groundwater was responsible for contributing 6 kg of phosphorus per year to the lake.

This study also included some limited monitoring for potential septic system failures via a septic leachate survey. A portable fluorometer was used to conduct shoreline surveys looking for septic leachate plumes. If plumes were detected, additional groundwater surveys and dye testing was conducted. At the time of the study, there were 49 shoreline residences around Lake Loma. The septic leachate survey did not detect any suspect or confirmed on-site septic system failures. Therefore, the septic contribution to groundwater was considered to be zero.

While this study provides a good baseline of background phosphorus concentrations of groundwater to the lake, it is over twenty-three years old. The study likely underestimates the current role of septic system effluent on the lake for the following reasons:

- The original methodology used to detect septic failures is highly prone to false negatives meaning failing system could have been present but were not leaching effluent into the lake at the time of the survey.
- There has been significant development around the lake and in the watershed since the study with 20 additional homes on the lake shoreline and more in the lake watershed.
- Septic systems have a limited life span. As they age they are more likely to encounter failures. At least three systems at Lake Loma have been replaced in the last two years based on SWM staff communication with lake residents.
- Even if older systems are not failing, the older systems in the original study were not designed to modern standards. This means they were more likely to be permitted in soils that were not able to fully infiltrate and clean the effluent water. They were also not subject to protective setbacks from susceptible waterbodies.

The second method for estimating groundwater contributions was completed by the Department of Ecology in 2013. This study estimated the contribution of septic systems effluent to lake phosphorus loading. Load estimates were calculated based on an occupancy rate of 2.2 people per dwelling (76 dwelling units total) and a per-capita phosphorus contribution rate of 1 kg P/person per year. The attenuation rate of phosphorus (meaning how much was retained in the
soils) was presumed to be 90% for functioning systems and 50% for failing systems. A failure rate of 15% was assumed. The total annual estimated TP load from septic systems to Lake Loma was 27 kg per year.

The Ecology study has limitations that may overestimates the impact of on-site septic systems. Specifically, a constant attenuation rate was applied to all septic systems and was not adjusted to be specific to local soils or proximity to waterbodies. The study indicates: “. . . several factors influence the amount of attenuation that occurs before the phosphorus reaches the lake, including distance from the shoreline, the flow path, height above groundwater table, plant uptake, and soil sorption and precipitation processes that vary with soil type. Attenuation is likely quite variable” (Ecology, 2013).

On the other hand, the Ecology study used 76 dwelling units for the study. There are approximately 106 in the watershed in 2019 indicating that the load may be higher. However, these newer homes are mostly located further from the lake and have been permitted with newer design standards.

Since both methods have pros and cons for calculating contributions, a range of 6-27 kg per year was used to reflect the phosphorus loading from groundwater for this study. The range was used to exhibit the uncertainty and ensure it is considered when evaluating and selecting restoration options. The actual value likely falls somewhere in the middle of the range. The main impact of the uncertainty is determining the longevity of potential restoration alternatives.

Seasonality of Groundwater Contributions

While the total input of groundwater contributions to the lake cannot be accurately estimated, the seasonality of the phosphorus loading from groundwater and septic systems is more certain based on the known hydrologic information. Loading would primarily occur during the late fall, winter and spring months when soils become saturated with water and phosphorus transport is more likely to occur. Very little phosphorus loading from septic systems occurs during the summer when phytoplankton production is high. The seasonality is confirmed by the groundwater monitoring studies conducted in 1986.

7.2 INTERNAL LOADING

Internal phosphorus loading to Lake Loma is the release of phosphorus from the lake sediments. Sediment release primarily occurs when the bottom of the lake becomes anoxic during the summer stratified period as described in Section 5.1.2. Some sediment release can also occur in aerobic conditions especially in shallow areas of the lake. Aerobic release mostly occurs from the sediment being disrupted allowing for sediment to be re-suspended in the water. For example, carp have been known to cause bioturbation of sediments resulting in aerobic release of phosphorus from the lake sediments (Huser et al., 2016a).

To identify the total amount of loading, it is necessary to establish a sediment release rate (SRR). Because sediment release is difficult to physically measure, especially in aerobic conditions, it is estimated using several approaches which are compared and aggregated to develop the best estimate. As an additional check, sediment release rates can be evaluated in multiple years. There
was sufficient data for Loma to calculate sediment release in both 2012 and 2016. The average and maximum sediment release rates were calculated each year by the following two methods:

- **Method 1**: Examine observed increases in hypolimnetic TP concentrations during the period when the lake was thermally stratified (April/May - October).
- **Method 2**: Use the relationships between sediment mobile phosphorus concentrations and phosphorus release rates (Nurnberg 1988)

The area of sediment that is potentially releasing phosphorus was estimated as the full hypolimnetic surface area, as delineated by the thermocline. In both years the hypolimnion was estimated based on the 4 meter depth contour.

When using the hypolimnetic area, sediment release rates across the whole stratified period in 2012 and 2016 were very close at 2.3 and 2.2 mg/m²/day (Table 7-5). Release rates were also calculated for each time step between. In 2012, the maximum rate was 8.5 mg/m²/day which occurred between Aug. 6 and 20th. In 2016, the highest rate was 2.5 mg/m²-day and was between June 16 and Sept 15. The large difference in release rates was likely because samples were taken every two weeks in 2012 allowing for finer resolution of the high release period in late summer.

A final estimated sediment release rate of 3.9 mg/m²/day was determined for the lake by averaging all of the sediment release rates (maximum and average) for the hypolimnetic area. The maximums were included in the average as the infrequency of sampling will likely fail to capture the higher release days as shown by the large difference in the sampling years.

**TABLE 7-5: ESTIMATED SEDIMENT RELEASE RATES CALCULATED FROM HYPOLIMENTIC INCREASE IN TOTAL PHOSPHORUS (METHOD 1)**

<table>
<thead>
<tr>
<th>Surface Area</th>
<th>Sediment Release Rates (mg/m²/day)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2012</td>
</tr>
<tr>
<td>Hypolimnetic – Average*</td>
<td>2.3</td>
</tr>
<tr>
<td>Hypolimnetic - Maximum</td>
<td>8.5</td>
</tr>
</tbody>
</table>

*Average based on July 23 - Oct 22 (91 days) in 2012 and May 16 - Sept 15 in 2016 (122 days)

Method 2 used was used to calculate sediment release rates from each of the sediment core sampling cores locations as described in Section 5. The release rates were 2.3 mg/m²-day for both west and east sediment core locations and 0.6 mg/m²-day for sediments located at the mid-station. The SRR calculated from the west and east sediment core are relatively close to the release rates calculated through Method 1 confirming their validity.

Using the average SRR, 3.9 mg/m²-day, the hypolimnetic surface area and an average anoxic period of June through September (122 days), the average internal phosphorus loading to Lake Loma from anoxic release was estimated to be 14 kg a year.

Some aerobic (with oxygen) sediment release has the potential to occur in the shallow areas of the lake. For example, in shallow, unstratified aerobic lakes there has been summer internal phosphorus loading and sediment release, e.g. 6 mg/m²-day in Upper Klamath, OR and 2.6 mg/m²-day in Long Lake (Kitsap), WA (Welch and Cooke 1995). Aerobic release is especially likely if iron
to phosphorus ratios (Fe:TP) in surficial sediments are less than 15:1 (Jensen et al. 1992). Loma has a Fe:TP ratio of 1.0 to 2.6 increasing the potential for aerobic release. Aerobic sediment release rate for Loma was estimated to be 10% of the anoxic rate or 0.4 mg/m² per day. When applied to the epilimnetic sediments during the stratified period (April – September) there is a total aerobic internal load of 4.4 kg. Therefore, the total internal load to Lake Loma is 18.4 kg/year.

The sediment release rate does appear to have increased since the 1980’s (Entranco, 1986). In this study, release rates were calculated by Method 1 with a hypolimnetic surface area of 10 acres (roughly equivalent to the 3 meter contour). The estimated SRR ranged from 0.49 to 0.62 mg/m²-day depending on the length of stratification. The lower SRR in 1983 corresponds to lower hypolimnmonic TP concentrations with a summer hypolimnmonic increase from 20 µg/L to 40 µg/L. Recent hypolimnmonic TP concentrations are much higher, increasing from around 40 µg/L to maximums of 144 and 171 µg/L in 2012 and 2016, respectively. The increase over the past few decades coupled with the high phosphorus in the sediments is one indicator that internal loading will continue to increase in the future.

In comparison to other area lakes, Loma has a moderate sediment release rate despite its much higher phosphorus levels in the lake sediments. As discussed in Section 5.1.2, Loma had much higher phosphorus in the lake sediments than Lake Ketchum. However, unlike Loma, Lake Ketchum experienced extremely high internal loading in the summer with 2-3 times the sediment release rate of Loma (Brattebo et al. 2017). The difference can be seen the summer hypolimnmonic phosphorus concentrations. Ketchum’s long-term average is 1,746 µg/L in the summer compared to Loma’s 68 µg/L. The lower sediment release and overall internal load is likely due to differences in the sediment between the two lakes. Loma has a much higher fraction of biogenic-P. Furthermore the acidic conditions of the lake change the metabolic reactions in the lake which could also suppress sediment release. While these conditions are helping to protect the lake currently, Ketchum demonstrates that Loma has the potential to have much higher sediment release rates in the future.

<table>
<thead>
<tr>
<th>Lake</th>
<th>Sediment Release Rate Annual Average (mg/m²/day)</th>
<th>Average TP in top 20 cm of sediment (mg/kg)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Loma</td>
<td>3.9</td>
<td>2600</td>
</tr>
<tr>
<td>Liberty Lake</td>
<td>1.06 – 1.2</td>
<td>569</td>
</tr>
<tr>
<td>Lake Ketchum</td>
<td>32</td>
<td>975</td>
</tr>
<tr>
<td>Lake Stevens</td>
<td>1.13</td>
<td>1,297</td>
</tr>
</tbody>
</table>

*Total phosphorus provided as available phosphorus data not collected for all lakes

7.3 PHOSPHORUS LOADING SUMMARY

The contributions of all external and internal loading to Lake Loma are shown in Table 4-4. The annual contributions of 2.1 kg of phosphorus from precipitation and 18.4 kg from internal loading are the sources with the highest degree of certainty. While data was not specifically collected to track surface water loading, the estimated load of 16.2 kg/year estimate is derived from a widely accepted method of identifying runoff based on land use type. The total load from these three sources is 36.7 kg/year.
The loading contribution of groundwater contribution which includes impacts from on-site septic systems (OSS) is largely unknown at this time. As discussed previously, the groundwater is the factor with the highest degree of uncertainty, and for this reason, it is presented as a range (7.1.4 Groundwater). Using the low estimate, groundwater contributes 14% and using the high estimate it contributes 42%.

The summer inputs to the lake were also calculated as phosphorus inputs during the June-September period are likely driving high phytoplankton productivity and nuisance blooms of potentially toxic algae. During the summer, internal loading is the dominant source accounting for 72-83% of the inputs with some contributions from groundwater (4-17%) and runoff (10-11%).

**TABLE 4-4: SUMMARY OF AVERAGE TP LOADS TO LAKE LOMA. SUMMER INCLUDES JUNE – SEPT.**

<table>
<thead>
<tr>
<th>Source</th>
<th>Low Groundwater Contribution</th>
<th>High Groundwater Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual (kg)</td>
<td>Annual (%)</td>
</tr>
<tr>
<td>External - Surface Runoff</td>
<td>16.2</td>
<td>38%</td>
</tr>
<tr>
<td>External - Groundwater,</td>
<td>6</td>
<td>14%</td>
</tr>
<tr>
<td>including OSS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct Precipitation</td>
<td>2.1</td>
<td>5%</td>
</tr>
<tr>
<td>Internal - Sediments</td>
<td>18.4</td>
<td>43%</td>
</tr>
<tr>
<td>Total</td>
<td>42.7</td>
<td>100%</td>
</tr>
</tbody>
</table>

**8 DIRECT ALGAE CONTROL METHODS**

There are several possible methods for directly controlling algal growth rate and quantity. These methods were briefly evaluated to determine if any might be appropriate for long-term algae control at Lake Loma. However, none of these methods address the underlying phosphorus that feeds algae and typically only provide temporary relief. Therefore, these options were not included in the final plan recommendations.

**8.1 Algaecides/Chemicals**

There are several commercially available products that will kill or inhibit algae growth when applied to a waterbody including:
8.1.1 Copper sulfate

Copper sulfate is a well-known algaecide that has been used historically and successfully on many lakes in Washington and across the US. However, copper sulfate use as an algaecide was banned in Washington State during the mid-1990s due to its adverse effects on other species.

8.1.2 Sodium carbonate peroxyhydrate

This product is a fast-acting compound that, in some cases, can inhibit algal growth or prevent the formation of algal blooms. However, there is limited evidence that products containing this compound can control algal growth in a lake system. The compound is 100% soluble in water and the short life span of the active ingredient requires the use of quick and efficient application for maximum effectiveness. There is also the possibility of untreated algae moving back into a treatment area after the active ingredient is no longer at a concentration high enough for effective control. If there was a drifting algae bloom at the time of treatment, it would likely re-infest areas of the lake not treated, as well as already treated areas.

8.1.3 Hydrothol 191 (endothall-amine)

This is a salt of endothall, and is a contact algaecide that attacks the algal cell wall. This chemical kills algae; however, it has a high toxicity to fish and aquatic invertebrates and must be applied at low concentrations. According to the label, fish may be killed by dosages in excess of 0.3 parts per million (ppm). It would take repeated applications of endothall-amine at Lake Loma at an appropriate low dose, and the algae would keep returning because of the high phosphorus concentrations in the lake.

8.1.4 Barley Straw

Bales of have been used in the mid-west (Minnesota) and England to limit algal growth in ponds and some lakes. Barley straw, when exposed to sunlight and in the presence of oxygen, produces an inhibiting substance. Experience in the US has not shown any consistent benefits from the use of barely straw, especially at a larger scale.

8.2 PHYSICAL INHIBITORS

8.2.1 Shade Products

Algae can sometimes be controlled by adding shading products (dyes) to the water. The dyes make the water dark and limit the amount of light available for algae. Swimming is permitted immediately after application, but the material cannot be used in a potable water source. Shading products may be successful in controlling algae in small ponds that do not experience harmful algae blooms, but have not proven sustainable in algal management once cyanobacteria have become a dominate phytoplankton component. However, they are not as effective in a large lake system and would likely not be permitted.
8.2.2 Ultrasonic devices

Ultrasonic devices have been used to disrupt algal cells and control algal growth. The citizens at Lake Ketchum in Snohomish County deployed a number of the SonicSolution® brand of these devices in an attempt to control chronic blooms of cyanobacteria. Weekly testing in 2008 and 2009 did not find any statistical evidence that the units reduced algal growth in Lake Ketchum (Snohomish County, 2010). The community later removed the units.

9 INTERNAL PHOSPHORUS CONTROL METHODS

9.1 METHODS CONSIDERED AND REJECTED

There are several methods that could be implemented to control internal loading from lake sediments. Of these, the following options were evaluated but were eliminated from detailed consideration because of their high cost or predicted ineffectiveness for Lake Loma.

9.1.1 Dredging

Dredging could be used to remove the most phosphorus-rich sediments from the lake bottom, thus reducing internal loading and improving water quality. However, the cost of dredging is extremely high. The estimated cost to remove three feet of sediment from Lake Loma (over 110,000 cubic yards) would exceed $14.8 million. This cost estimate is based on costs for comparable recent dredging projects within Washington State. Also, any dredging project would have to be followed by an aluminum sulfate treatment to clear the water of suspended particles. Additional characterization of the lake sediments would also be necessary to refine dredging depth and determine disposal requirements.

9.1.2 Hypolimnetic Aeration

Adding oxygen to the bottom waters of the lake could be used to promote binding of some of the phosphorus in the bottom sediments and prevent it from releasing and becoming available for algal growth. Aeration is a potentially expensive technique and depends on ongoing management and maintenance. This technique was effectively used in Lake Stevens, WA from 1994 to 2012. However, hypolimnetic aeration will only be effective if there is adequate iron in the sediments to bind all the phosphorus. The recommended iron to phosphorus ratio for successful aeration in a lake is 15:1. Lake Loma has very low iron in the sediments with iron to phosphorus averaging only 1.7 to 2.6. Therefore, even if anoxic conditions were maintained in the lake bottom, there would not be adequate iron to successfully bind additional phosphorus inputs. In fact, one of the reasons the aerator in Lake Stevens was removed was that it was no longer effectively controlling phosphorus due to a lack of iron in the sediments (Snohomish County, 2012b). At Loma, the increase in hypolimnetic oxygen could also increase the rate of metabolic degradation of biogenic phosphorous to soluble reactive phosphorus. This would accelerate internal loading rates to the lake increasing overall phosphorus concentrations.
9.1.3 Hypolimnetic Withdrawal

This technique involves withdrawing phosphorus-rich water from the bottom of the lake and sending it downstream through the lake outlet. This removes phosphorus from the lake, but requires a supply of low-phosphorus water to offset all or part of the lost water. However, there is no available supply of low-phosphorus water for Lake Loma to offset the loss of water volume during summer withdrawal. Also, moving phosphorus rich water downstream would negatively impact water quality conditions in Lake Crabapple which currently is in a healthy condition with low phosphorus loading to the lake.

9.1.4 Chemical Addition of Iron

Chemical formulations of iron could be applied to the lake sediments to bind with phosphorus and make it unavailable for algal growth. The addition of iron is not appropriate at Lake Loma, however, because iron requires adequate dissolved oxygen levels at the sediment surface to maintain the bond with phosphorus. Through much of the year, dissolved oxygen levels are near zero in the lower waters of Lake Loma. Therefore, iron addition would not effectively bind the phosphorus without aeration. In addition, an increase in iron concentration in the lake could result in an increase in color intensity and decrease in water clarity as it can turn the lake orange or black.

9.1.5 Lanthanum Treatment

Lanthanum (sold commercially as Phoslock®) can be applied to a lake to bind soluble phosphorus in the water column and sediments, with minimal impacts to lake chemistry and biology. However, Phoslock, which is lanthanum embedded clay, would most likely not settle due to the high humic concentration within the water column. It would most likely require polyaluminum chloride to promote sedimentation and provide additional phosphorus absorption by aluminum. Also, Phoslock has been shown to perform poorly in lakes with low alkalinity and/or high dissolved organic carbon (Lurling et al. 2014, Reitzel et al. 2017, van Oosterhout et al. 2014). Lanthanum treatments have been used more recently with some success, especially outside the United States (Epe et al. 2017 and Nurnberg 2017). However, the long-term effectiveness of these treatments is unknown. Phoslock is several times more expensive than alum relative to equivalent effective dose. While other metal chemicals are necessary in states or provinces where alum is prohibited or strictly limited, that is not the case in Washington State, where several whole-lake alum treatments were successfully implemented in recent years; e.g., Green Lake (King County), Long Lake (Kitsap County), Wapato Lake (Pierce County), and Lake Ketchum and Lake Stevens (Snohomish County). Also, there has been no demonstrated advantage of using lanthanum (Phoslock) over the buffered alum treatments discussed in the next section.
9.2 METHODS SELECTED FOR CONTROL OF INTERNAL LOADING

The only method determined to be appropriate for controlling internal loading in Lake Loma is the use of aluminum sulfate (alum) either with or without aeration. Below is a review of alum and two different methods that were considered for treatment at Lake Loma including: 1) Whole-lake alum treatments and 2) Continuous alum injection coupled with hypolimnetic lake aeration.

9.2.1 ALUM OVERVIEW

Alum is a safe and widely used chemical for clarifying or removing impurities from drinking water. In lakes, Alum can effectively inactive phosphorus in lake sediments, reducing internal loading, and mitigate associated algal problems. Alum is the most commonly used lake restoration tool and has been for over 40 years in over 250 lakes worldwide (Cooke et al. 2005, Brattebo et al. 2015, Huser et al. 2016b).

Alum works by permanently binding phosphorus from the water column and sediments. Alum is applied as a slurry. When it mixed with the lake water it hydrolyzes and forms a white flocculent which resembles snowflakes in the water. The floc quickly settles to the lake bottom binding the phosphorus and other particles as it settles (also referred to as water stripping). The floc then condenses and settles into the sediments. Over time it further binds phosphorus in the sediments until all binding sites are full. The bond created by the floc is insensitive to anoxic conditions. That is, phosphorus remains bound with aluminum even in low or zero dissolved oxygen, contrary to iron bound phosphorus.

EFFECTIVENESS

Alum has been shown to be highly effective at reducing internal loading in both shallow (unstratified), as well as deep (stratified) lakes (Welch and Cooke 1999, Cooke et al. 2005, Huser et al. 2016b). The effectiveness at reducing algae and internal loading is often greater in shallow lakes because the phosphorus released from sediment is immediately available in the photic zone or easily enters the photic zone with mixing. In contrast, internally loaded phosphorus is largely locked in the hypolimnion of deep lakes, or gradually diffused into the epilimnion, and is not readily available until fall mixing of the water column.

A whole-lake alum treatment to inactivate phosphorus in lake sediments can be a very effective management tool. In one analysis, over 80% of the projects proved successful, reducing internal loading by an average of 54% (Welch and Jacoby, 2001). However, these earlier projects typically did not supply a high enough dose of alum to fully inactivate the available phosphorus. Another analysis of four lakes showed an average of 90% reduction in internal loading (Cooke, et. al., 2005). For the purposes of the Lake Loma plan, the assumption is that when a full dose has been applied internal loading will be reduced by 85%.

BUFFERING REQUIREMENTS

Alum is an acidic compound meaning it has the potential to lower the pH of the treatment lake. Loma is a low-alkalinity lake meaning it has little ability to buffer against or prevent changes in pH. Therefore, it requires an additional buffer that is applied simultaneously to the lake. Sodium
aluminate is the preferred buffer for alum treatments. Sodium aluminate also helps with floc formation and creates additional opportunities for phosphorus binding, which could save cost.

**POTENTIAL ADVERSE IMPACTS**

The most potentially harmful impact of an alum treatment is a temporary decrease in lake pH that could adversely affect aquatic life. Low pH problems are avoided with the added buffer, sodium aluminate, as well as using the proper application equipment and technique. Jar tests would performed on lake water with the prescribed dose prior to the actual treatment to assure an acceptable pH is maintained.

Alum applications either via boat or injection do not have any water use or recreational restrictions. Once alum is applied, a hydroxide floc is instantaneously formed and settles out of the water column within 10 minutes to 2 hours. Direct contact with the floc is not a safety concern, because the alum dose is based in part on pH stability (including the use of a buffer). Also, the floc’s presence is so short-lived that direct contact is highly unlikely. However, if applied by barge, other boaters or lake recreationists should stay away from the treatment barge to avoid physical contact hazards or interference with the alum applicator.

Alum is sometimes perceived as a threat to human health because of the aluminum. However, alum is safe. It is used extensively in treatment of drinking water supply systems. Even if people drank water from Lake Loma, the levels of aluminum after an alum treatment would be within drinking water standards. The form of aluminum in alum is also the same as in over-the-counter antacids. And, contrary to past suspicions, recent studies have not found links between aluminum and Alzheimer’s disease. In summary, alum is safe for the lake and for humans. For a detailed review of alum safety, see the Washington State Department of Ecology’s environmental assessment (Ecology, 2017).

An alum treatment will increase water transparency which will allow more light into the water column. Additional light availability could lead to increased growth of aquatic plants in deeper water. An increase in aquatic plant biomass is not ecologically harmful if the increase is in native species. Native species provide important refuge for fish, food source for fish and wildlife, and help to compete with algae for the available nutrients. The increase in plants may actually be a return to more natural conditions for the lake. However, lake residents may dislike an increase in aquatic plant growth required education on options for removal of small areas of native plants that allows for beach and boat access.

**9.2.2 ALUM DOSING FOR LAKE LOMA**

Appropriate dosing is essential to the success of any alum application. A dose must be calculated for the phosphorus both in the sediment and in the phosphorus. Dosing for Lake Loma was determined using the sediment core results coupled with the most recent scientific guidelines.

The dose for the sediment phosphorus was calculated based on the available phosphorus in top 20 cm of the lake sediments. Available phosphorus consists of mobile and biogenic phosphorus which are dosed differently based on their bioavailability. The full amount of mobile phosphorus is used for dose calculations. However, biogenic phosphorus is less bioavailable and only 1/3 of
the total amount is used for calculations. For Loma this means that the total amount of phosphorus for dose calculations was 468 mg/kg. The other key aspect of dosing is to select a ratio of aluminum added to available phosphorus. A ratio of 20:1 was selected for sediment neutralization based on past successful alum treatments. Therefore a dose of 41.3 mg Al/L is required to neutralize the phosphorus. A detailed explanation of the dosing calculations can be found in Section D of the Technical Appendix.

The dose for the water column was then calculated for Lake Loma using the average lake total phosphorus concentration in April of 31 µg/L. In most lakes, the same 20:1 ratio of aluminum added to the available phosphorus would be used to calculate the water column dose. However, Lake Loma has darkly colored water stemming from the dissolved humic acid. When the alum is applied, the flocculent will also bind these dissolved compounds. To ensure there are adequate binding sites to also bind the phosphorus, a much higher ratio of 100:1 was applied. The water column dose was calculated to be 3.05 mg/L. However, should implementation of this plan proceed, a jar test should be conducted using several ratios. The dose can then be adjusted up or down slightly to ensure the 85% effectiveness at the lowest cost possible.

In total, the whole-lake alum treatment dose for Lake Loma is 41.3 mg Al/L. This dose is relatively high compared to other lakes in the Pacific Northwest. Lake Ketchum, which had slightly lower sediment total phosphorus but similar mobile-P concentrations, was treated with alum at a total dose of 28 mg Al/L. This dose, however, was calculated based on the top 10 cm of sediment because mobile-P concentrations at Ketchum declined below 10 cm. In Lake Loma, mobile-P concentrations do not appear to reach a background level until 20 cm. The higher concentrations deeper in the sediments at Loma are a concern as the sediments also have a low bulk density (6.5%) meaning they are loosely consolidated. Since they are not tightly packed, the diffusional rate of phosphorus up through the sediments is likely to be high. Therefore, the 20 cm depth was selected in order to reduce any potential release of phosphorus from deeper sediments.

9.2.3 Whole Lake Alum Treatment Options

A standard alum treatment is applying alum and any required buffer to the lake surface where it binds water in the water column and then settles out and binds phosphorus in the sediments. Ultimately, the goal is to treat all of the historic pollution in the lake sediments along with phosphorus in the water column. If appropriately dosed, the alum treatment will essentially “reset” the system by neutralizing past pollution to the lake.

Application Procedures

Surface alum treatments are applied from a boat or barge equipped with nozzles or small hoses. It is important to have the chemicals applied separately so they do not mix before reaching the water but are also applied simultaneously to ensure mixing as soon as it is released in the water. To achieve this, alum and the buffer are applied from separate nozzles or hoses which are paired or connected so that they immediately mix in the water column. When applied at the appropriate ratio and with the appropriate equipment, major changes in lake pH can be prevented. Distribution systems on the application vessels are continuously monitored and rates of injecting
alum and buffer are adjusted during application according to boat speed, lake position and water depth.

TREATMENT EFFECTIVENESS AND LONGEVITY

If properly dosed to inactivate the sediment phosphorus, the longevity of the alum treatment success becomes largely dependent upon the amount of external loading that continues to flow in from the lake watershed. Over time, ongoing external loading will again build-up in lakes and overcome the benefit of a single alum treatment. The longevity can also be affected if the alum floc layer gradually sinks deeper into the sediment and is no longer able to bind new phosphorus.

While the longevity is highly dependent on the lake, one time whole-lake alum treatments can typically be effective for 10 to 15 years (Welch and Cooke, 1999) if properly designed and dosed. For example, Green Lake, a highly urbanized lake in Seattle, WA, was treated with alum in 2004. The Al:P ratio continued to decrease for 12 years after treatment (Welch et al. 2017). Other lake communities have opted to treat the lake with a full dose in a single year and also treat the lake with annual small treatments. For example, Lake Ketchum was planned to be treated with the whole-lake alum dose in one year followed by annual small alum treatments conducted each year. Unfortunately, equipment issues prohibited the full-dose application in the first year and only half of the dose was applied. The remainder of the full-dose was applied in the second year. Total phosphorus and chlorophyll $a$ results from year-round monitoring indicate that the full-dose applied over two years was effective at neutralizing phosphorus in the water column and lake sediments (Snohomish County, 2019). Additionally small alum treatments have been applied in subsequent years to remove phosphorus from the water column. The small annual alum treatments have also been effective at neutralizing phosphorus in the water column.

In Lake Loma, it is anticipated that alum should generally have long-lasting benefits in Lake Loma as the internal loading would be significantly decreased. The system would have some resilience to continued inputs from surface water runoff and groundwater. The longevity could be further increased by any efforts to prevent and reduce pollution coming. Options to reduce external loads are discussed further in Section 10. The treatment effectiveness will also depend upon the way in which the alum treatment dose is distributed. A whole-lake alum approach could be achieved in a single treatment to neutralize all phosphorus or could be spread out over a number of years. There are several combinations to achieve the full goal, two of which were explored for this project.

The treatment effectiveness will also depend upon the way in which the alum treatment dose is distributed. A whole-lake alum approach could be achieved in a single treatment to neutralize all phosphorus or could be spread out over a number of years. There are several combinations to achieve the full goal, two of which were explored for this project.

TREATMENT OPTION 1: INITIAL LARGE-DOSE

In a single dose treatment the full dose of 41.3 mg Al/L is applied to the lake at one time. The dose would account for both the phosphorus in the two 20 cm of sediments as well as the water column. The treatment would require a buffer to ensure no changes in lake pH. A dose of 41.3 mg Al/L would require 23,640 gallons of liquid alum and 11,820 gallons of liquid sodium aluminate.
A single full-dose alum treatment would be expected to reduce internal loading and water column phosphorus by about 80-85% and maintain that control for 5 to 10 years. There is a high degree of uncertainty about the timing with the second treatment and the exact dose that would be needed. For the purposes of this plan, it was estimated that another treatment would need to be performed around year 10 and that the dose would be equivalent to half of the original dose. If groundwater contributions are in the smaller range, the treatment could last longer and vice versa. Monitoring will be essential to assess the treatment effectiveness and the need to conduct further treatments.

TREATMENT OPTION 2: MULTI-YEAR DOSE

The second treatment option is a multi-year approach. In this approach, there would be a large treatment in Year 1 which accounts for ½ of the total dose or 23.1 mg Al/L. This would require 13,230 gallons of alum and 6,620 gallons of sodium aluminate. The remainder of the dose would be applied through annual treatments spread over ten years with a dose each year of 4.5 mg Al/L. This approach would provide immediate benefits to the lake but would allow for the remainder to be spread out and adjusted as needed depending on the lake response. Monitoring of lake conditions would also be essential to this option.

A multiple-dose approach has significant benefits for longevity. Each year the dose will be adequate to bind an estimated 85% of the phosphorus in the water column for the year effectively neutralizing any incoming pollution. Each year, a small portion of the dose would also work to neutralize the phosphorus in the sediments. Also, multiple smaller treatments would produce less alum floc that was less dense and more diffuse than a full dose treatment. It is anticipated that a less dense floc would settle slower through the very fluid top 20 cm of sediment, allowing for more contact time within the active phosphorus release zone.

Most importantly, the effects of a multi-year dose can be continually evaluated and treatments can be fine-tuned based on results. For example, if the treatment dose appears to be neutralizing the sediment phosphorus faster than expected, the annual dose may be decreased or years may be skipped. Similarly, if there is a winter with higher than normal rainfall, the dose could be increased slightly to account for higher pollution levels in the runoff. This is a strong benefit given the uncertainty with the groundwater contributions in the Lake Loma system.

COSTS

The cost for Option 1 with a whole lake sediment inactivation alum treatment is approximately $235,000 using an aluminum dose of 41.3 mg Al/L. A repeated treatment in year ten with half of the dose is approximately $131,000 in 2019 dollars for a 10-year cost of $365,000.

The cost of Option 2 is $131,000 for the first-year dose of 23.1 mg Al/L. The annual cost for years 2-10 will be $26,000 for a dose of 4.5 mg Al/L. This annual dose may be changed slightly based on jar test. Adjustments to the aluminum dose may result in increased or decreased costs.

These costs include an estimate for alum at $2.10 per gallon and the estimated cost of sodium aluminate at $5.00 per gallon. The estimates also includes costs for treatment design, pre-treatment testing, chemical delivery, application, and permitting. Note that all costs are
presented in 2019 dollars. More details on the alum dosing and cost assumptions for each option can be found in Technical Appendix Section D.
9.2.4 Continuous Alum Injection with Whole-Lake Aeration

In this option, alum is continuously injected in conjunction with an artificial whole-lake aeration system. The system would use compressed air delivered to the lake bottom to continuously mix the water column and oxygenate bottom sediments. Continuous mixing would prevent the natural stratification of the lake system and the associated low dissolved oxygen conditions near the sediment-water interface. However, as discussed in, Section 9.1.2, aeration of the bottom sediments also has the potential to significantly increase phosphorus availability in the lake. Coupling aeration with injection can prevent the increase in phosphorus so creating a highly effective mechanism for reducing phosphorus pollution and preventing subsequent toxic algae blooms. Aeration has the additional potential benefits for increasing aquatic habitat for fish.

APPLICATION METHOD

Whole lake circulation/aeration would be accomplished with the placement of diffusers in the lake. The amount of aeration applied to a lake is typically measured in an air-flow rate per lake surface area. The recommended flow rate for achieving complete circulation or de-stratification of a waterbody is 9.2 m$^3$/km$^2$ per minute (1.33 ft$^3$/acre per minute) (Lorenzen & Fast, 1977). Small aeration units, which have been used successfully in small ponds and lagoons would not be appropriate for a waterbody as large as Lake Loma. Instead a minimum of three large diffusers would be installed. At the diffuser sites, alum injection portals would be placed to deliver alum (potentially with a buffer [sodium aluminate]). The aeration and alum injection would start each year in April when stratification typically begins and run through mid-October.

During the period of operation, a total dose 4.0 mg Al/L would be injected into the lake. This dose should be sufficient to overcome the assumed water column demand and provide at least 1 mg Al/L to the sediment for inactivation. It is assumed that over time the water column demand would decrease, and more aluminum would be delivered to the sediment to inactivate sediment phosphorus. At the proposed delivery rate, it would take approximately 20 years of operation to bind all sediment phosphorus. However, on-going monitoring of phosphorus (total and soluble reactive) and sediment phosphorus would identify the treatment effectiveness such that the alum injection rate could be adaptively managed and potentially reduced as sediment phosphorus and ground phosphorus/on-site septic control is achieved.

EFFECTIVENESS AND LONGEVITY

Similar to the whole-lake alum treatments, the combination of alum injection and aeration will reduce the phosphorus loading to Lake Loma. The aeration would prevent low oxygen conditions and the subsequent release of mobile phosphorus from the water column. The alum would further reduce water column phosphorus and over time would reduce the release of biogenic phosphorus from the lake sediments. If properly dosed, the water column phosphorus reduction is assumed to be 80 to 85%. The water column dose would include neutralizing any ongoing phosphorus inputs entering the lake through including groundwater and on-site septic systems. Once injected, the alum floc will also settle to the bottom of the lake with slowly binding the available phosphorus in the sediments. It is estimated that with using a low-dose continuous injection, it would take approximately 20 years to achieve the goal of 85% reduction of the internal phosphorus load.
The continuous aeration does provide additional benefits to the lake over the whole-lake alum treatment. Aeration could improve aquatic habitat by increasing water column dissolved oxygen. It would also reduce the water column humic acids thus improving lake water clarity. The continuous mixing of the water column may also decrease the incidence of potentially harmful cyanobacteria. Cyanobacteria have a competitive advantage over other algae in that it can regulate its buoyancy to change its position in the water column. This means it can physically descend in the water column to reach nutrient-rich waters and then move closer to the surface to increase exposure to light. The continuous mixing could disrupt this ability making it more physically limit its growth due to lower light ability.

**POTENTIAL ADVERSE IMPACTS**

A whole-lake circulation/aeration system will disrupt the stratification of Lake Loma. This will lead to temperature increases in the bottom waters. This could potentially limit the cold-water fishery due to temperature increases in the bottom waters of the lake. Currently, water quality conditions (lack of dissolved oxygen and high nutrient and algal levels) already limit a successful cold-water fishery in Lake Loma. Additional potential impacts related to the use of alum are discussed in detail in the whole-lake alum treatment in Section 9.2.1.

**TREATMENT DOSE AND APPLICATION PROCEDURE**

A whole-lake circulation/aeration system with alum injection would consist of no less than 3 diffusers in the lake delivering at least 9.2 cubic meter per minute per kilometer of air. Air supply lines would connect to an on-shore compressor. Alum injection units would be located at each diffuser. For planning purposes, there would be a diffuser and injection unit located in both deep areas of the lake and in the lake middle. They would be placed near the bottom of the lake. Alum injection meters and pumps, as well as alum storage tanks would be located on-shore in an alum storage building or vault. Alum would be metered at a dose rate of at least 4.0 mg Al/L over the operational period of April through October.

**COSTS**

Initial capital cost for air compressor, alum injection pumps and storage tanks, on-shore storage building, or vault is estimated to range between $150,000 to $300,000. The actual installation of the air supply lines, air diffusers and alum injection units would range from $150,000 to $400,000. The whole-lake circulation/aerations system would need to be further designed beyond the conceptual phase and an engineer’s cost estimate completed. The range of costs provided are based on professional experience and recent projects.

Operation costs are anticipated to include:

- $15,000 to $25,000 per year for lake circulation system (electrical, mechanical and diffuser maintenance)
- $8,000 to $18,000 per year for alum/buffer injection system (electrical, mechanical and injection line/portal maintenance)

Alum/buffer cost would be approximately 12 to 20 percent of the one-year sediment inactivation treatment, $45,000 to $65,000 per year.
This alternative would need to be further refined and designed beyond the conceptual phase to determine the correct number of diffusers and alum injection units, as well as, placement of each diffuser and injection unit, sizing of air supply hoses and location of on-shore compressors and alum storage tanks.

9.3 MONITORING FOR ADAPTIVE MANAGEMENT

Monitoring will be necessary to track conditions as the lake responds to restoration, enable proper dosing of the future treatments and help determine effectiveness of each year’s treatment.

If any of the methods for controlling internal release are implemented, monitoring will allow for adaptive management and effective use of resources. Price estimates provided in Section 11.2 are based on year-round (12 months) monitoring to overcome the unknowns of phosphorus inputs, longevity of results, and variation in individual lake response. It is possible that monitoring could be reduced after several years of alum treatments or if alum treatments do not occur every year.

Total monitoring costs are estimated to be $9,580 per year. The cost estimate assumptions for monitoring are fully outlined in the Technical Appendix Section D.

### TABLE 9-1: RECOMMENDED MONITORING PLAN FOR LAKE LOMA STATION IF IMPLEMENTING METHOD FOR CONTROLLING INTERNAL LOADING.

<table>
<thead>
<tr>
<th>Monitoring Activity</th>
<th>Location</th>
<th>Profile Depth</th>
<th>Time Period</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Loma Station</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Observations</td>
<td>Lake Center</td>
<td>NA</td>
<td>Year-round</td>
<td>Monthly</td>
</tr>
<tr>
<td>Secchi Disk Depth</td>
<td>Lake Center</td>
<td>NA</td>
<td>Year-round</td>
<td>Monthly</td>
</tr>
<tr>
<td>In-situ Temperature</td>
<td>Lake Center</td>
<td>every meter</td>
<td>Year-round</td>
<td>Monthly</td>
</tr>
<tr>
<td>In-situ Dissolved Oxygen</td>
<td>Lake Center</td>
<td>every meter</td>
<td>Year-round</td>
<td>Monthly</td>
</tr>
<tr>
<td>In-situ Conductivity</td>
<td>Lake Center</td>
<td>every meter</td>
<td>Year-round</td>
<td>Monthly</td>
</tr>
<tr>
<td>In-situ pH</td>
<td>Lake Center</td>
<td>every meter</td>
<td>Year-round</td>
<td>Monthly</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>Lake Center</td>
<td>1 meter</td>
<td>Year-round</td>
<td>Monthly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 meters</td>
<td>Mar – Oct</td>
<td>Monthly</td>
</tr>
<tr>
<td>Soluble Reactive Phosphorus</td>
<td>Lake Center</td>
<td>1 meter</td>
<td>Year-round</td>
<td>Monthly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 meters</td>
<td>Mar – Oct</td>
<td>Monthly</td>
</tr>
<tr>
<td>Total Persulfate Nitrogen</td>
<td>Lake Center</td>
<td>1 meter</td>
<td>Year-round</td>
<td>Monthly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 meters</td>
<td>Mar – Oct</td>
<td>Monthly</td>
</tr>
<tr>
<td>Chlorophyll a</td>
<td>Lake Center</td>
<td>1 meter</td>
<td>Year-round</td>
<td>Monthly</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>Lake Center</td>
<td>1 meter</td>
<td>Year-round</td>
<td>Every Other Month</td>
</tr>
<tr>
<td><strong>Loma East Station</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>Lake Center</td>
<td>6.5 meters</td>
<td>Mar – Oct</td>
<td>Monthly</td>
</tr>
<tr>
<td>Soluble Reactive Phosphorus</td>
<td>Lake Center</td>
<td>6.5 meters</td>
<td>Mar – Oct</td>
<td>Monthly</td>
</tr>
</tbody>
</table>
10 EXTERNAL LOADING PREVENTION/REDUCTION

Preventing or reducing new phosphorus inputs into Lake Loma are not only important for protecting the lake but will also prolong the effectiveness of any actions to reduce internal loading. In Lake Loma, the external phosphorus that enters the lake directly via stormwater runoff account for 25-38% of the total annual phosphorus load. There could be an additional 14-42% entering the lake via groundwater that can be influenced by septic system effluent.

Lake Loma’s sources of external phosphorus pollution are nearly all residential including pet and animal wastes, runoff from roofs and driveways, and erosion from shorelines and bare soils. Phosphorus loading to the lake can also be impacted by the removal of natural vegetation in the watershed or the areas that drain to the lake. Trees and other deeply rooted plants slow water and then act as a sponge absorbing the water and filtering out pollution. When replaced by hard surfaces water can no longer infiltrated and instead contributes to pollution. When replaced by lawns, there is some infiltration of water, but they only filter out 10% of the pollution compared to more deeply rooted plants. Removal of lake shoreline vegetation, in particular, is harmful as shoreline plants are the last line of defense to prevent polluted runoff from reaching the lake.

Reducing residential phosphorus pollution is challenging. Most residents do not know their actions can cause pollution or do not see think that their actions can make a difference for water quality. Even if they are aware, there may be barriers to changing behaviors such as not having enough knowledge, time or financial ability to make changes. Options for most sources include regulations, public outreach, and incentive programs. Since regulation is likely not possible for most sources, the main alternative is public outreach.

For the purposes of this study, the existing Snohomish County LakeWise program was the primary alternative explored for reducing residential pollution. In addition, several alternatives were also explored to specifically address septic system loading given the high potential contribution of these systems to the groundwater.

10.1 LAKEWISE OUTREACH PROGRAM

In response to declining water quality at many local lakes including Loma, Snohomish County developed the LakeWise outreach program. LakeWise aims to build awareness of water quality impacts that residents have on their lakes and effect behavior changes through incentives and partnerships to implement changes (best practices or BMP’s) to reduce phosphorus.

The program is focused on nine actions landowners can take to reduce pollution in their lawns and yard care and septic system care (Figure 10-1: LakeWise Program Checklist). The program invites residents to attend septic system and natural lawn care workshops; have a site visit to their home to learn how they can protect lake health; and become LakeWise-certified by completing items on the Clear Choices checklist of nine best management practices (BMPs). Shoreline landowners can also receive an optional Healthy Shores certification by protecting or restoring their shoreline vegetation which acts as a filter for phosphorus pollution and provide valuable habitat.
FIGURE 10-1: LAKEWISE PROGRAM CHECKLIST

Clear Choices Checklist

By taking these voluntary actions, you can protect the health of your lake and have your property LakeWise certified.

Lawns and yards

☐ Avoid fertilizer. If you do fertilize, apply phosphorus-free products.
   By initialing, I agree to perform this practice. _____

☐ Attend a FREE natural lawn care workshop. Date attended: ________________

☐ Scoop pet waste, bag it and place it in the trash.
   By initialing, I agree to perform this practice. _____

☐ Divert roof and driveway runoff into stable, vegetated areas.
   No downspouts or drains directly into lake, stream or ditch.

☐ Cover bare soil areas with mulch or plants.

☐ Fix eroding areas in yard, driveway and parking areas.

Septic systems

☐ Have inspection by licensed provider within the past three years.
   Documentation showing date of inspection/pumping is required. Date inspected: ________________

☐ Have inspections at least every three years (system type determines frequency).
   By initialing, I agree to perform this practice. _____

☐ Attend a FREE septic system care workshop. Date attended: ________________

Healthy Shore Checklist

Shoreline properties can also obtain a healthy shore certification.

☐ Maintain existing non-lawn shoreline vegetation.
   By initialing, I agree to perform this practice. _____

☐ Re-establish shoreline vegetation by replacing some lawn with other plants
   such as shrubs, perennials and trees.

Congratulations! The following property has met the Snohomish County LakeWise certification requirements:

<table>
<thead>
<tr>
<th>Property Address</th>
<th>LakeWise Reviewer’s Signature</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Property Owner’s Name: ____________________________

Snohomish County

SHR 2.1.X.2019
10.1.2 LAKEWISE - SEPTIC SYSTEM CARE AND MAINTENANCE

Septic systems that are failing can be a source of phosphorus pollution, as well as bacteria and pathogens that can threaten the lake’s and residents’ health. However, even septic systems that are not failing but are poorly maintained can have higher phosphorus loading. This is especially true for older systems that are located close to the lake or were approved prior to stricter design requirements based on soil types as discussed in Section 7.1.4. Employing the following set septic system practices will help to minimize the amount of phosphorus coming from septic systems and protect the health of Lake Loma:

- Attend a septic system care workshop which encourages practices to prevent failures and keep systems working longer such as:
  - Know the location of your system
  - Protect the septic system drainfield and reserve areas
  - Avoid putting food or anything else down the drain
  - Reduce or space out water use
  - Repair septic system promptly when failures occur
- Regularly inspect septic system (3 years for gravity; increased frequency for advanced systems depending on type).

10.1.3 LAKEWISE - LAWNS AND YARDS

LAWN CARE

Lawn care practices can have a large impact on both the amount of runoff and the concentration of phosphorus in the runoff that enters a lake. The use of fertilizers, in particular, can contribute significant amounts of phosphorus that is easily washed into the lake. Fortunately, the State of Washington banned the use of phosphorus in synthetic fertilizers for turf grass in 2013. Because the majority of soils in this region have more than ample phosphorus required for a healthy lawn, there are virtually no negative impacts from using phosphorus-free products. The law does allow for exceptions when establishing a new lawn or if soil tests show the soil is deficient. While the ban significantly helps with phosphorus runoff, there is still phosphorus in pasture fertilizers, manure products, and garden fertilizers. Furthermore, lawns that have compacted soils can prevent water from infiltrating and increase the overall quantity of runoff.

As an alternative, residents can employ natural lawn care practices to eliminate the need for fertilizers. Natural lawn care practices also have the benefit of reducing pesticides and other harmful chemicals from reaching our waterways. The LakeWise practices include: Recommended practices include:

- Attend a workshop on natural lawn care to learn practices which include:
  - Mow high and leave the clippings.
  - Do not use weed-n-feed products; instead spot treat weed problem areas.
  - Water deeply and less frequently.
  - Improve poor lawns with aeration.
  - Use lawn alternatives for slopes, shady areas, or near streams and lakes.
- If fertilizer is used – use only phosphorus-free products.
PET AND ANIMAL WASTE

Many people do not consider the impacts of pet waste on water quality. Not only does animal waste have a high load of phosphorus that can be washed into the lake, it also can transmit harmful microorganisms, such as roundworms, *E. coli*, and *Giardia*. Even though it may seem like a small factor, pet waste adds up. On average, 37.4 percent of Washington State households own dogs, with an average of 1.5 dogs per dog-owning household. With approximately 106 households in the Lake Loma watershed there would be roughly 60 dogs. It is estimated that 1/3 pound of solid waste is produced daily per dog. Therefore, about 18 pounds per day or over 6,500 pounds of fecal matter that would be deposited in the Lake Loma watershed. The LakeWise practice to prevent pet waste from polluting local stream and lakes and protect the health of family members playing in the year is to:

- Pick up pet waste, bag it, put it in the trash.
- Do not bury or compost dog waste on your property — this doesn’t kill bacteria and phosphorus still ends up in the lake via groundwater.

ROOF AND DRIVEWAY RUNOFF

Reducing and slowing runoff from rain can help prevent phosphorus and other pollutants from entering the lake. As land around Lake Loma has been developed, hard surfaces such as driveways, houses, patios, and walkways (also known as impervious surfaces) prevent rain water from infiltrating into the ground. Instead, the rain runs off these surfaces and picks up phosphorus that is washed directly into the lake. Even worse, runoff from driveways and roofs is sometimes piped directly into the lake instead of being directed away from the lake. Any actions that can be taken to slow the water runoff will help reduce the amount of phosphorus going to the lake. LakeWise practices include:

- Disconnect pipes from downspouts or driveway runoff that run to the lake and re-route water into vegetated areas or dry wells (but not on to septic drain fields).
- Minimize the amount of paved or concrete services for driveways and patios.
- Preserve trees and other vegetation on your property that helps to capture and clean runoff (not required for LakeWise certification, but an important practice).

EROSION FROM BARE SOILS AND SHORELINES

One of the ways that phosphorus washes into a lake is through soil erosion. Soils in our region are rich in soils (one of the reasons you don’t need phosphorus in your fertilizer). If rainfall erodes bare soils, the soil particles that are picked up by the water bring the phosphorus along. Preventing erosion and covering bare soils helps stop this pollution pathway. LakeWise practices include:

- Covering all bare soils with mulch or plants
- Fixing eroding slopes
- Using effective erosion control measures during construction and landscaping projects.
10.1.4 LAKEWISE - SHORELINE LANDSCAPING

The last line of defense for preventing phosphorus from reaching lake waters is the zone of vegetation along the shoreline. These vegetated buffer zones stabilize the lake shore, intercept stormwater runoff, and remove phosphorus from water before it reaches the lake. Without shoreline vegetation, there is little or no filtering and removal of phosphorus flowing toward the lake. Furthermore, lake shorelines without a zone of native vegetation also frequently suffer from erosion. Eroding shorelines can serve as additional sources of sediment and phosphorus. Since shoreline vegetation buffers capture the phosphorus that run off from other sources, providing intact shoreline vegetation may be the most important step that lakeshore property owners can take to protect lake water quality. LakeWise practices include:

- Leave existing shoreline vegetation intact.
- Re-establish shoreline vegetation by replacing some shoreline lawn with other plants such as trees, shrubs or perennials. Plantings can be designed to preserve lake access and view corridors.

10.1.5 LAKEWISE – EFFECTIVENESS

The LakeWise actions that were selected for the program are considered “best management practices” for creating on-the-ground reductions in pollution. If implemented there will be a reduction of phosphorus pollution to the lake. In addition, per a 2017 evaluation of the program, LakeWise has been a successful model for increasing awareness of phosphorus pollution and resulting in sustained behavior changes especially for lawn care practices, pet waste management and septic system care.

While LakeWise can work to make meaningful changes for lake health the impact will be increased with increased level of participation in a lake watershed. Lake Loma has had one of the higher participation rates in the County with roughly 1 in 3 households in the Lake Loma watershed participating from 2013-2019. Participation means either attending a natural lawn care or septic system care workshop. Thirty-three households have attended workshops. Twelve properties have had a LakeWise site visit and completed some actions on the checklist. Of those eight properties have become fully LakeWise certified. In addition, five properties have planted their shorelines resulting in 264 linear feet (0.11) acres of new shorelines planted to protect and buffer the lake from stormwater pollution. Unfortunately, in that same time period there was also clearing of vegetation along shorelines in other areas of the lake.

While the initial response by the community has been high, it will become more effective if additional community members also participate in the LakeWise program. Efforts to increase community involvement in the program by neighbors could increase the overall pollution reduction impact of the program. In addition, success relies on residents continuing LakeWise commitments such as picking up pet waste and having regular septic system care.
10.1.6 LAKEWISE COSTS

The LakeWise program is currently funded through Snohomish County Surface Water Management’s utility charge paid by all residents in unincorporated Snohomish County. The program is open to all Snohomish County residents living in lake watersheds (areas that drain to lakes). The funding for this program is subject to approval through the County’s annual budget process.

10.2 Additional On-Site Septic System Control Measures

Septic systems are of particular concern at Lake Loma because of the large influence of groundwater on the lake hydrology. Septic system regulations have already been put in place that are helping lakes such as requiring advanced treatment for poor soils and requiring setbacks from sensitive waterbodies. While these are helping with newer systems, several additional approaches were explored to reduce the impact of phosphorus pollution in septic system effluent.

10.2.1 ALTERNATIVES CONSIDERED AND REJECTED

SEWERING

Conversion of the 7-lakes area from septic systems to a municipal sewer has been extensively explored in the past. In 1971, the Seven Lakes Sewer District was established in response to community concerns to increasing development and potential failures of existing septic systems. In 1972, a comprehensive sewerage plan was completed and recommended a central wastewater treatment plant and sewage collection system for the. Initial designs included 6,000 residents around Goodwin and Shoecraft with a cost estimate of $4.7 million in 1972 dollars (Entranco, 1986). Projected costs of the design and construction of sewer treatment facilities in the region have been as high as $142 million dollars. Ultimately, the project was never moved forward given the prohibitive cost. While this is a potential phosphorus reduction option that may be possible in the future, this alternative was not considered viable for Loma restoration at this time.

PHOSPHORUS CONTROL RETROFITS

New technologies are being developed to treat septic system effluent to remove phosphorus prior to it reaching the drain field. As discussed in Section 7.1.4, the septic systems that are most likely contributing to the Lake Loma phosphorus load are older gravity systems, especially those close to the lake. The septic systems on the Lake Loma shoreline at around 60% gravity systems that are older than 20 years. In fact the mean age of the shoreline gravity systems is 42.4 years. Retrofitting these systems with advanced treatment capabilities would reduce the amount of phosphorus leaving the system. Retrofits might include the additions to the existing OSS. The following retrofits are an example of what is now available on the market.

- Busse MBR unit - an aboveground holding tank with media that is designed to capture 98% of phosphorus before it is released. The estimated cost for installation per household was approximately $74,000 (Belsby, 2018)
• BioBarrier system – two underground tanks, the first tank is utilized to settle solids and the second tank contains media to capture 75-90% of phosphorus before it is released. The estimated cost for installation per household is approximately $42,000 (Belsby, 2018).

If all 40 systems were retrofitted, it would cost approximately $1.68 million. While these systems would be highly effective at phosphorus prevention from the individual household, the current technology is cost prohibitive for an individual landowner. In the future, the technology may improve and decrease in cost. In the interim, systems near the lake that fail should be replaced by systems far away from the lake as possible that adhere to current permitting standards.

10.2.2 ALTERNATIVES CONSIDERED - SEPTIC SAVINGS PROGRAM

DESCRIPTION

While the LakeWise program addresses septic system care through workshops and the property certification program, its scope is limited to those individuals who volunteer to participate. An additional option to help residents conduct regular septic system care is a septic care savings program conducted in coordination with the local water purveyor. The concept is that landowners pay a small amount each month on their water bill that is determined based on their water usage and septic system type. Once a homeowner has reached the required interval for inspection or has consumed a set amount of water, they would be reminded to schedule a septic inspection and pumping that is paid for by their monthly contributions.

This concept is based on a successful program established between Lake Roesiger residents and the Snohomish County Public Utility District (PUD). At Roesiger, residents pay an additional rate of about $0.0084/ft³ of water consumed on their monthly water bill. Once the household has consumed 48,000 cubic feet of water, they qualify for a free septic pumping through a contracted provider (or the equivalent dollar amount if choosing a different provider).

While the Roesiger program provides a good start for a model for such a program, there would likely need to be some adaptations for a successful program. Primarily, the Roesiger model is focused on pumping and not inspection. Washington State law already requires regular septic system inspections that are established based on the type of system (Chapter 246-272A-0270). A new program would want to incorporate the requirement for regular inspections in addition to the need for pumping when needed.

EFFECTIVENESS

Since options to remove or retrofit systems are cost-prohibitive, regular septic system maintenance is the best option to reduce phosphorus loading to the lake. Regular inspections are critical to preventing failures which causes large influxes of phosphorus to the lake as well as harmful bacteria. Regular pumping could also have a marginal reduction in the phosphorus concentration of the effluent. While most landowners agree with the need for regular septic system care, it is often out-of-site out of mind with care not occurring until there is a problem.
A septic system care savings program has several benefits to homeowners beyond improving water quality:

- Creates a built-in prompt for residents to care for septic systems
- Reduces the hassle of remembering septic care and finding a qualified provider
- Spreads the financial burden of septic repairs over a longer time-span alleviating the financial barrier to maintenance
- Prevents failures that protects water quality and saves landowners from the hassle of dealing with a failed system as well as preventing costly repairs

**PROCESS**

The septic savings program is only in a conceptual stage. There has been no communication with the local water purveyor, the 7-lakes Water Association or members of Lake Loma or the greater 7-lakes area. There would need to be a significant amount of time and effort to explore this option to lay the groundwork for this program. As mentioned previously, this type of program could help to protect the water quality in the entirety of the 7 lakes area including nearby lakes such as Goodwin, Shoecraft, Crapapple, and Ki. Community members from the larger group could be recruited for such an effort that may include the following steps:

- Further investigate the current program with the PUD and Lake Roesiger residents
- Explore feasibility with the local water purveyor
- Identify potential options for program to meet local needs
- Conduct outreach to obtain feedback from local residents

If there is community support for this project, there may be opportunities to obtain grant funding to initiate and implement the project.

**COSTS**

The costs for this program would include the following:

- The time and effort of community members to explore this option with the 7 Lakes Water Association. If coordination is requested and staff available there would also be costs for staff time for technical assistance.
- If implemented
  - 7 lakes water association – there would be an administrative cost to implement the program, track the payments, and setup the process for septic care provides. These costs would likely be reflected in the monthly water bills
  - Landowners – additional monthly cost on the water bill depending on septic type that would be recuperated when septic care was implemented. The landowners would also likely pay some of the administrative overhead costs of the water provider.
11 RECOMMENDED ALGAE CONTROL PLAN

11.1 PLAN ELEMENTS

After researching many options, three elements were found to be the most effective and affordable methods to meet the plan goal of reducing phosphorus and resultant toxic algae blooms in Lake Loma (Figure 11-1). Implementing these elements will comprehensively address the main phosphorus sources.

The first two elements of the plan, LakeWise and the Septic Savings Program, are focused on preventing new pollution to the lake. The expected result will be lower levels of phosphorus loading to the lake each year via surface water runoff and potentially groundwater. The magnitude of these changes will depend on the level of participation by the community. The septic savings program has a higher potential to positively impact the lake because the program would increase the number of residents maintaining their septic system to most of the watershed households. While these two elements are important for preventing conditions from worsening in the lake, they will not improve conditions without implementation of Element 3.

The third element of the plan is focused on neutralizing the historic pollution built up in the lake bottom using alum treatments. The alum treatments will also neutralize new phosphorus pollution and will provide immediate improvements in lake water quality conditions.

FIGURE 11-1: RECOMMENDED ALGAE CONTROL PLAN ELEMENTS

<table>
<thead>
<tr>
<th>Plan Element</th>
<th>Source Addressed</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Element 1:</strong> LakeWise Program</td>
<td>Stormwater Runoff</td>
<td>LakeWise, County’s outreach program to help lake area residents prevent phosphorus pollution from lawns, yards and septic systems. Residents can complete a voluntary checklist of actions to have their property LakeWise certified. LakeWise supports residents through educational workshops, site visits, and technical resources.</td>
</tr>
<tr>
<td><strong>Element 2:</strong> Septic Savings Program</td>
<td>Groundwater</td>
<td>A septic savings program is designed to help residents regularly maintain septic systems which can otherwise pollute groundwater. Lake Roesiger has a successful program with the PUD where residents pay for septic care as part of their water bill. The plan calls for exploring this program as an option for Loma or the larger 7-lakes area.</td>
</tr>
</tbody>
</table>
EXPECTED OUTCOMES

Fully implementing the plan over the long-term will benefit the health of Lake Loma. The alum treatments will significantly reduce phosphorus, resulting in less frequent and intense algae blooms. Lake recreation will benefit from the reduced risk of exposure to toxic blooms. Dissolved oxygen levels will increase benefitting aquatic life. Water clarity will also improve which is typically associated with higher property values. Higher clarity may also lead to increased aquatic plant growth in deeper areas of the lake. Pollution prevention by implementing Elements 1 & 2 will increase the longevity of alum treatment and reduce the frequency, scale and cost of any future treatments.

11.2 IMPLEMENTATION COSTS

The total cost for implementing the plan over 10 years is between $466,000 and $471,000 in 2019 dollars (Table 11-1). These costs are based on the following assumptions:

- Element 1 will be funded through Snohomish County Surface Water Management pending annual budget approval.
- Element 2 costs are unknown at this time though there would be administrative costs should the program be developed.
- Element 3 costs were estimated based on current costs of alum and sodium aluminate, tax, mobilization, permitting, and contingency costs in case of price increases. A full explanation of cost estimates can be found in Appendix E3.

To help the landowners plan, Table 11-1 also provides an approximation of total cost by household. This cost is a rough estimation calculated by dividing the total by the 88 parcels that are located on the Lake Loma shoreline. The actual cost to a resident will vary greatly depending on the ability to obtain grants for funding and the funding structure that is selected by the community. These options are further discussed in the following Section 12.
Cost estimates include year-round lake monitoring and one sediment core analysis during the 10 year period as discussed in Section 9.

**TABLE 11-1: ESTIMATED COSTS FOR LAKE LOMA RESTORATION IN 2019 DOLLARS**

<table>
<thead>
<tr>
<th>Elements</th>
<th>Year 1</th>
<th>Years 2 - 9</th>
<th>Year 10</th>
<th>10-Year Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element 1: LakeWise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Element 2: Septic Savings Program</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Element 3: Alum Treatment(^a,b)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Option 1: Large Dose(^c)</td>
<td>$244,000</td>
<td>$9,500</td>
<td>$151,000</td>
<td>$471,000</td>
</tr>
<tr>
<td>(\text{Cost per parcel}^d)</td>
<td>$2,773</td>
<td>$108</td>
<td>$1,716</td>
<td>$5,352</td>
</tr>
<tr>
<td>Option 2: Multi-Year Dose</td>
<td>$141,000</td>
<td>$35,000</td>
<td>$45,000</td>
<td>$466,000</td>
</tr>
<tr>
<td>(\text{Cost per parcel}^d)</td>
<td>$1,602</td>
<td>$398</td>
<td>$511</td>
<td>$5,295</td>
</tr>
</tbody>
</table>

\(^a\) Year-round lake monitoring has an estimated annual cost of $9,500. A portion of monitoring costs may be covered by County’s volunteer lake monitoring program pending annual budget approval.  
\(^b\) A $10,000 sediment core analysis is included for both options in year 10 (used to assess future treatment doses).  
\(^c\) A repeat alum treatment will likely be required in 5 to 10 years. The costs is included in year 10 and is based on applying half of the original dose. The actual dose will depend upon the sediment core analysis.  
\(^d\) Estimated cost based on 88 lake shoreline parcels.

12 FUNDING OPTIONS FOR PLAN IMPLEMENTATION

Implementation of the restoration plan for Lake Loma will require a long-term financial investment by the Lake Loma community. There are a variety of mechanisms by which residents can raise funds for local lake management. In addition, there may be state or local grants that could help reduce the financial burden on local residents.

12.1 LOCAL PROPERTY OWNER FUNDING

Three options are presented below that the Lake Loma community could use to collect funds from local residents. Each of these options has been successfully implemented by lake groups in Snohomish County.

12.1.1 LOCAL FUNDING – LAKE ASSOCIATION COLLECTION

Collecting funds via a lake association is a common method for funding lake-related activities. Fund collection can take many forms and may be a combination of efforts such as annual dues, one-time collections, or even fundraisers. The manner and timing in which lake communities collect funds varies widely and is at the discretion of the membership.

Lake associations typically incorporate as a non-profit organization when they decide to take on financial responsibilities or commit to long-term lake management activities. For example, Lake Roesiger, Lake Ketchum, and Sunday Lake have incorporated as non-profit organizations. Formalizing a lake association provides several benefits including the ability to open a bank account, to apply for some grants, and it provides a structure for better lake advocacy. While non-
profits are the most common structure, other structures might work depending on the goals and structure of the organization.

The Secretary of State’s office for Washington has a full list of considerations and steps when deciding to incorporate as a non-profit or other organization (see resources below). Some considerations include filing for tax exempt status with the IRS or registering as a charitable organization. Additional helpful resources may be found in an internet search about starting a non-profit in WA state.

- Starting a nonprofit – Published by Washington Nonprofits
- WA state non-profit handbook – Published by Wayfind in partnership with Washington Nonprofits and Washington State Office of the Secretary of State
- Non-profit online registration - Washington Secretary of State

### 12.1.2 LOCAL FUNDING – LAKE MANAGEMENT DISTRICT

Another option available for local funding is formation of a Lake Management District (LMD) as laid out in Washington State administrative code - RCW 36.61. An LMD could be formed for the specific purpose of funding Lake Loma restoration. It could potentially include properties around the lakeshore and within the larger watershed. An LMD is established to collect fees for a specific length of time. In Snohomish County, LMD’s had been established for Lake Roesiger and Lake Goodwin/Lake Shoecraft. However, both of these groups have since moved to alternative funding options.

The LMD must be formed through the county legislative authority. It is initiated through “either the adoption of a resolution of intention by a county legislative authority or the filing of a petition signed by ten landowners or the owners of at least twenty percent of the acreage contained within the proposed lake or beach management district, whichever is greater” (RCW 36.61.030). The County may require a bond of $5,000 if it is initiated by landowners to pay for some of the administrative costs with establishing the LMD.

There are numerous procedural steps in forming a LMD including at least two public hearings. The owners of every property included within a proposed LMD will then have the opportunity to vote to approve or not approve the LMD. Each owner gets one vote for every dollar they would be assessed. A majority of votes is required to establish the LMD. If passed, there are additional steps regarding the assessment role for taxing or for bonding if desired.

There are several benefits of a LMD. It ensures everyone has a clear vote in the process. It also allows bonding of large upfront costs that could be paid back over several years by annual assessments. However, there are also significant drawbacks to the LMD. The LMD creation process is long (12 to 18 months) and very costly. The administrative costs to set up a LMD in 2000 for Lake Goodwin/Lake Shoecraft was approximately $30,000 in addition to the annual administrative costs. Once established it is very rigid with significant changes requiring the same process as the initial setup.
Another potential option for local funding is for Snohomish County to establish a surcharge in addition to the current SWM fees to be paid by all developed shoreline properties. The surcharge is established as part of County Code and requires the approval of the Snohomish County Council. The surcharge would be for a specific length of time and would be collected with property taxes. Funds collected could only be used for the purposes designated by the community and adopted in County Code. A SWM fee surcharge has been established for lake-related projects at Lake Ketchum, Lake Serene, Lake Goodwin and Lake Shoecraft.

Similarly to forming a LMD, establishing a SWM fee surcharge would require numerous procedural steps. In order to implement a surcharge, it would first require support from SWM and would be contingent upon staff availability to assist in the setup and administration of this fee. It would also require a clear definition of roles for fund administration. A County Council person would need to introduce an ordinance that would then be supported by a majority of the County Council. The lake group would need to meet with their Council representative and show community support, likely by organizing a community meeting and public hearing. While this option would not require a vote of affected property owners, it would require strong support from property owners for the County Council to approve such a surcharge as the County Council would not likely pass surcharge with strong backlash from the majority of property owners.

A significant drawback to a surcharge is that Surface Water Management must support all surcharge spending. This may be in conflict with lake organization desires as Surface Water Management will not support native plant removal and does not have the capacity to oversee plant management or lake level adjudication. Once established it is also very rigid, with significant changes requiring the same process as the initial setup.

Grants can help stretch local dollars and provide funding for larger cost items such as the initial alum treatment. However, grants are not a reliable source of funding for long-term or ongoing lake management activities. There are limited grant opportunities for funding the Plan’s recommended actions.

The most promising and closely aligned grant-funding program for Lake Loma restoration is the WA Department of Ecology’s Freshwater Algae Control Grant Program. At this time, grants of up to $50,000 are possible for algae control projects. These grants require a 25% local match and are typically offered every year or every other year pending funding availability. According to current guidelines, all three elements of the recommended plan would be eligible. It may even be possible to obtain separate grants for the alum treatment and the outreach activities. Eligible public bodies that may apply include state agencies, counties, special purpose districts (including LMD’s) and tribes.
Another potential source of grant or loan funds is the Centennial Clean Water Fund and EPA 319 funds managed by the Washington State Department of Ecology. These funds support a wide variety of water quality improvement projects. Elements one and two of the plan could potentially be funded by this source. However, indications from the Department of Ecology are that alum treatments are considered “short-term” and “palliative” rather than providing long-term pollution source control. Therefore, alum treatments may be ineligible for grants unless Ecology can be convinced that the alum treatments in Lake Loma are not palliative and that every effort is being made to reduce shoreline/watershed phosphorus sources. The eligibility of alum treatments for State loans is not clear.

The two grant opportunities provided above are the most likely funding opportunities for implementation of this plan. However, there may be other sources that have not been identified or may become available in the future. Residents are encouraged to seek opportunities from other local or national funding sources. Examples may include opportunities from non-profits, tribes, or charitable foundations.

Snohomish County Surface Water Management (SWM) funding comes from utility charges that are currently paid by all developed properties within unincorporated Snohomish County (SCC § 25.20). SWM utility charges have paid for a large portion of the development of this plan. In addition, SWM utility charges are used to fund technical assistance to Lake Loma residents, the LakeWise outreach program, and lake water quality monitoring through the County’s Volunteer Lake Monitoring program. Funding and staff for these programs are subject to the County’s annual budget process.

At this time, SWM cannot commit any additional funding for the implementation of the recommended plan for Lake Loma. If implementation of the plan requires additional SWM involvement (e.g. applying for a toxic algae grant), SWM’s ability to provide services will be subject to availability of staff and financial resources.

The primary responsibilities for plan implementation will lie with lake residents. The lake community will need to decide if the benefits of the implementation plan are worth the required financial and time investment. The proposed plan was presented and approved by the community on October 10th, 2019 when SWM hosted a public meeting. However, less than 10% of the landowners were in attendance. Attendees and the County recognize the strong need for feedback from the broader community and participation of more community members should implementation be desired. Below is a list of potential steps that the Lake Loma community could
take to achieve lake restoration. These are only suggestions and are based upon successful approaches taken by other lake organizations.

13.1 STEP 1: CREATE A LAKE RESTORATION COMMITTEE

Implementation of this plan will require the efforts and support of the Loma community. A voluntary committee of seven or more residents could be formed to review plan findings and develop a plan of action to share with the broader community. Potential initial decisions by the committee may include:

- **Specific actions or scope of work**: The committee will need to decide which plan elements, LakeWise, Septic Saving and/or Alum treatment to implement. If an alum treatment is desired, the committee will need to decide between the two options on treatment dose and timing or develop their own option.

- **Funding alternatives**: The community will need to establish a funding plan to achieve the funding necessary for implementation. This may include the creation of a lake association as described in Section 12.

- **Timeline**: It will likely take several years to develop support for restoration and secure funding. Laying out a timeline will help when communicating expectations to the broader community.

- **Implementation roles**: The committee will be responsible for implementing and funding alternatives. However, roles such as planning and application of alum treatments can be fulfilled by environmental consulting firms or professional applicators. As funding allows, SWM will continue to fund the LakeWise program for Lake Loma residents and basic summer volunteer monitoring (May – Oct). SWM’s ability to help with other aspects of implementation will be subject to availability of staff and financial resources.

13.2 STEP 2: ENGAGE COMMUNITY

Successful restoration will require buy-in and support of the larger lake community. It will be a critical first step to ensuring everyone has had an opportunity to provide feedback especially if being asked to provide financial contribution to the plan. It will be important to develop a plan to reach out and include the larger community.

13.3 STEP 3: FORMALIZE LAKE ORGANIZATION & IMPLEMENT

If the larger community is in favor of the committee’s plan, it is a logical progression for the lake community to establish a formal lake association as discussed in Section 12. The committee would then transition into a more formal board with bylaws etc. that lay out the rules for making decisions for the group. It will also be a necessary step for many of the funding options. With this structure in place, the community will be poised to make decisions for the broader community and pursue the implementation plan laid out by the community.

While the steps laid out above may seem daunting, lake groups here in Snohomish County and across the state have successfully navigated this process to implement similar restoration that have protected and improved their lake.
14 CITED REFERENCES


16. Liberty Lake Sewer and Water District (LLSWD). 2018. Liberty Lake Algae Control Plan


28. Snohomish County Surface Water Management. 2010. Cyanobacteria Prevention and Early Detection – Project Completion Report for Grant #GO800483 – Section D.


32. Snohomish County Surface Water Management 2012b. Lake Stevens Hypolimnetic Aeration and Alum Treatments Analysis Technical Memorandum.


